

## Quantification of Heavy Metals and Metalloid in Cassava Roots (manihotesculentacrantz; Family: Euphorbiaceae) grown in Oil Bearing Communities of the Niger Delta

<sup>1</sup>Ogwu, C, <sup>2</sup>Ukpene, A. O., <sup>3</sup>Ekpe, I. N. & <sup>4</sup>Umukoro B. O. J., <sup>5</sup>Onuelu J. E.

<sup>1,3&4</sup>Department of Environmental Management & Toxicology, Delta State University of Science & Technology, Ozoro

<sup>2</sup>Department of Biological Sciences, University of Delta, Agbor

<sup>5</sup>Department of Pharmacology, Delta State University, Abraka

Corresponding author: **Ogwu, C,**

---

---

### Abstract

*This study is an ex-port facto research that investigated the heavy metals concentrations in cassava roots harvested in the Niger Delta oil bearing communities. The study answered 4 research questions and tested a hypothesis. To accomplish these, 5 states out of 9 Niger Delta states were randomly selected and an oil producing community also randomly selected from each state. Cassava roots samples were randomly collected from 5 farms in 5 villages/quarters of the oil producing communities. The analytical standard adopted for this study is EPA 201650 and the instrument of determination deployed is Analytic Jena's NOVAA 800AAS. The grand mean results of the metals investigated were: Cd;  $0.06 \pm 0.00$ , Cr,  $0.06 \pm 0.01$  mg/kg, As,  $0.06 \pm 0.01$  mg/kg, and Co,  $0.07 \pm 0.01$  mg/kg, and Pb  $0.06 \pm 0.01$  mg/kg. The grand mean result of the metals determined were subjected to test of significance deploying ANOVA using SPSS model 29 at 0.05 level of significance. The p-value was 0.48 thus rejecting  $H_0$ . The study concludes that the heavy metals in the cassava tubers are higher than the critical threshold recommended by WHO thus the cassava roots and products are not healthy for human consumption. They are also not fit for export. It recommends that the impacted areas should be remediated and the monitoring agencies advised to increase their surveillance for the oil extracting companies to comply and adopt world best practices in their activities.*

**Keywords:** Oil exploitation, heavy metals, cassava roots, bioaccumulation, human health

---

---

### Introduction

Cassava has its origin in America and was brought into Africa by the Portuguese in 1558 where it has become staple food and mainstay economic source of the rural economies. Cassava is a traditional food in Nigeria, Ghana, Togo, Republic of Benin and Central Africa Republic (Ogwu, 2021, Singh *et al.*, 2012, Singh *et al.*, 2015). It is also consumed as staple food in Thailand, China, Indonesia and Panama (Shah *et al.*, 2013; Ogwuet *al.*, 2022b, Sangwanet *al.*, 2014). Cassava is very rich in vitamin and low in sugar (Rasaqet *al.*, 2015, Ogwuet *al.*, 2021b, Panda *et al.*, 2013). It repairs damaged kidneys and protects the liver against cancer

(Ogunlesiet *et al.*, 2017, Ogwuet *al.*, 2021a, Nwinnewii and Neeka, 2017). Cassava is used as composite in bread and cakes in confectionary and as a sweetener in drug manufacturing (Ogwuet *al.*, 2020, Moradiet *all.*, 2013, Mee-Young *et al.*, 2013). It also found use as glue, in plyboards manufacturing and in alcohol production (Ogwuet *al.*, 2021a, Luoet *al.*, 2012, Khan *et al.*, 2008). Cassava is useful in making of wall paper, starch production and in canned fruits (Kacholi&Sabu, 2018, Ogwuet *al.*, 2022a, Idodo-Umeh&Ogbeibu, 2010). The peelingsand pellets are valuable in livestock nutrition (Ogwuet *al.*,2023c, Hind *et al.*, 2014, Foju-Mensah *et al.*, 2017, Hajaret *al.*, 2014).

The world cassava processing market stood at 311.5 million metric tonnes in 2022 (Food and Agricultural Organisation, 2023, World Food Programme, 2023). Nigeria is the world greatest producer of cassava with production volume of 60.1 million metric tonnes (Ogwuet *al.*, 2023a, Adezugo, 2023, Ozah, 2023). Cassava is Nigeria rural economy mainstay with 9.085736 hectares of land being put into its cultivation annually (IKuemonisa, 2020, Aduda, 2021, Ogagu, 2021). The region for cassava production in Nigeria is the Niger Delta which also doubles asNigeria oil belt (Ogwuet *al.*, 2022a, Ogwuet *al.*, 2022b). Oil exploitation is associated with oil spills which degrades the environment and hults its ecosystem services (Ogwu *et al.*, 2022a, Ogwu *et al.*, 2023a, Ogwuet *a.*, 2023c). Nigeria recorded 822 oil spills cases between 2020 and 2021 with 28,0003 barrels of oil spilled to terrestrial and aquatic environment (Friend of the Earth, 2022, Nigeria Environmental Society, 2022, National Oil Spills Detection and Response Agency (NOSDRA), 2023). Oil iscomposed of hydrogen, carbon, nitrogen, sulphur, oxygen and varying percentage of varying heavy metals (Atshana&Atshana, 2012, Aworegba2015, United States Environmental Protection Agency, 2015)

Bioavailability of heavy metals in the soil environment results in bioaccumulation and biomagnification of the metals in crops grown in the environment (Ogwuet *al.*, 2023a, Ogwuet *al.*, 2023b, Bamgboye, 2020). Consumption of heavy metals contaminated foods is associated with health complications such as renal failure, lung, nose and throat cancers, cardiovascular problems, memory loss amongst others (Bike *et al.*, 2015, Benson *et al.*, 2015, Ali *et al.*, 2013, Ahmad &Ashraff, 2011).

The focus of this study is the determination of the heavy metals content of cassava roots grown in the Niger Delta oil bearing regions of Nigeria. The heavy metals investigated are Cd, Cr, As, Pb and Co.

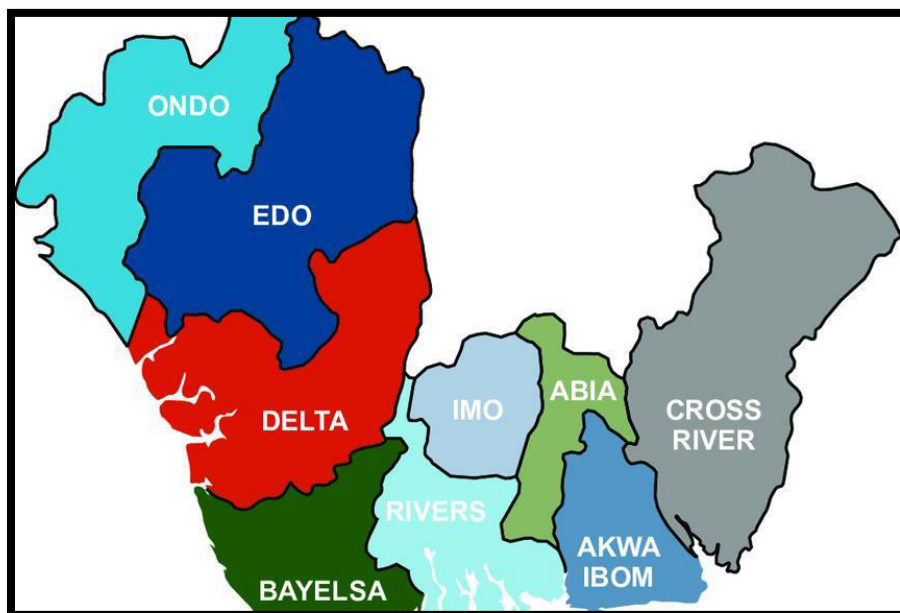
The study was guided by research questions as;

- What are the concentrations of Cd, Cr, As, Pb and Co in cassava roots grown in the Niger Delta?
- Are the concentrations of Cd, Cr, As, Pb, and Co in the cassava roots within the World Health Organisation(2014) Maximum Permissible Concentrations (MPC) for heavy metals in foods?
- are cassava roots produced in the Niger Delta healthy for human consumption?
- Can the cassava produced in the region be exported to international markets considering Codex Alimentarius standard for agricultural produce export?

The study was guided by a hypothesis as;

Ho: there is no significant difference between the heavy metals concentrations in the cassava roots grown in the Niger Delta and WHO Maximum Permissible Concentrations for heavy metals in food crops and produces.

## Study Area



**Figure 1: Map of Niger Delta**  
**Source: Oladeinde (2021)**

Niger Delta is the delta of the River Niger in Nigeria. It covers nine states of southern Nigeria and it is located at the Gulf of Guinea within geographical coordinates of latitude 3° and 4°N and longitude 4° and 8°E with an area of 70000km<sup>2</sup> (7.5% of Nigeria land mass), separating the Bight of Bonny from the Bight of Benin.

The Niger Delta is the hydrocarbon zone of Nigeria whose inhabitants are mainly agrarians producing yams, cocoyam, vegetables, maize plantain and cassava in commercial scale.

## Materials and Methods

5 out of the 9 states that make up Niger Delta region were randomly selected to make the study states. These were Delta, Bayelsa, Rivers, Akwa-Ibom and Imo state.

From each of the 5 states, an oil producing community was randomly selected for samples collection and the communities selected were; Delta state; Okpai oil producing community, Bayelsa state; Sagbama, Rivers State; Ogoni oil producing community, Akwa-Ibom state; Eketoil producing community and Imo State; Oguta oil producing community.

From each of the oil producing communities, 5 agrarian quarters/villages were randomly selected for samples collection and these were Okpai in Delta state and the villages were samples were collected were, Oluchi Okpai-Ashaka, Obi-eze, Obodo Oyibo, Okpai Anieze; Sagbama Bayelsa state and the selected villages were Abuku, Angalabiri, Asamabiri, Anibeze and Ebendebiri, Ogoni (River state) and the villages randomly selected were Babbe, Gokana, Ken-Khana, Eleme and Toi. Eket (Akwa-Ibom state) and the villages/quarters were Samples were collected were Ikot-Abasi, Esiturua, Afara Atai, Edet-Urua, and Ebanawhile in Imo state the oil producing community is Oguta and the quarters sampled were Batu, Ama Ozua, Enigbo, Obegwu and Ogwunna.

From each of the villages, moderate cassava root sizes were collected from 5 spots in 5 farms with the assistance of the villager in each quarter/village. The samples collected from farms were then bulked and composite collected in each case were well labelled and stored for analysis.

### **Sample Preparation**

The cassava roots were washed with clean water to remove the associated dirt. They were later washed with doubled distilled water and again with deionized water. The barks of the cassava roots were then peeled with stainless scapels and knives and then washed again with double distilled water. The edible part left were then diced with stainless knives into small cubes and were later oven dried with Agilent G2545a Hybridization oven for 12 hours to achieve a constant weight. The dried roots were then milled into powder with high quality Agilent laboratory blender/homogenizer.

### **Digestion of Cassava Root Samples**

2.0g of each of the cassava samples from each village from the varying oil producing communities were weighted out into digestion vessels that have been thoroughly washed with 65 percent nitric acid ( $\text{HNO}_3$ ) and 40 percent hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) together with one ml of hydrochloric acid (HCl).

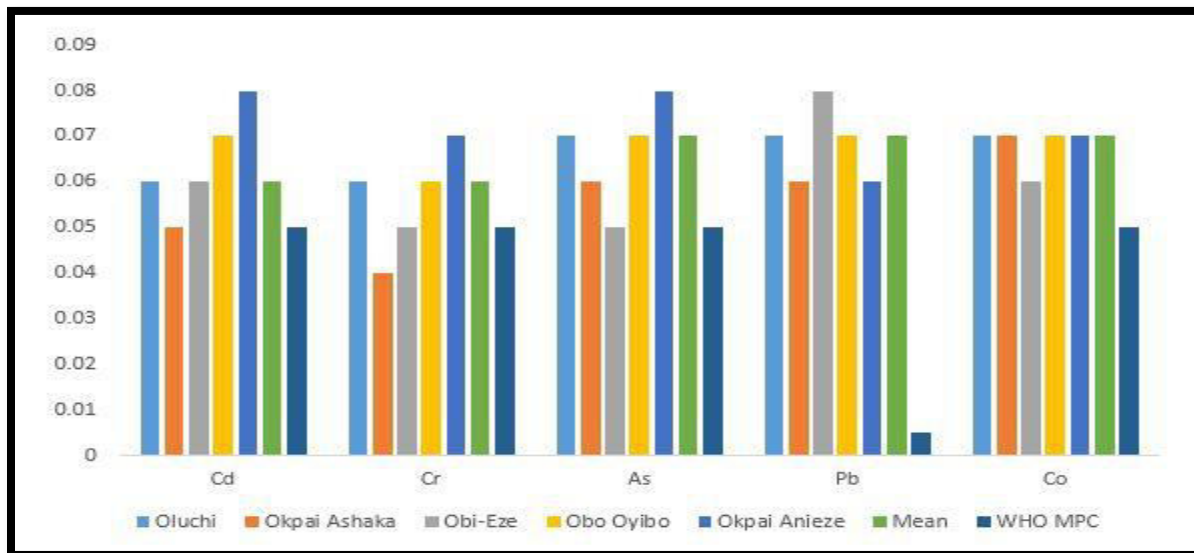
The samples in the digestion vessels tightly sealed are placed in steam bath at  $60^\circ\text{C}$  for 1 hour 30 minutes until digestion is completed indicated by the appearance of clear colour of the digests. 20 ml of water was added and heated for another half an hour and the vessels then removed from the digester and the digests allowed to cool for two hours (2hrs). Water was added to mark and the digests allowed to cool further at room temperature. The digests were later transferred into 50 ml volumetric flask and water added to 50 ml mark. The digests were filtered using Merck Germany filter into plastic sample bottles of 50 ml. The metals, Cd, Cr, As, Pb and Co were determined using Analytic Jena's NOVAA 800 Atomic Adsorption Spectrophotometer (AAS).

### **Results**

The results of the analysis of the heavy metals in cassava roots from oil bearing communities of the Niger Delta are as in Figures 2-6 while the grand mean results of the heavy metals is as in Figure 7.

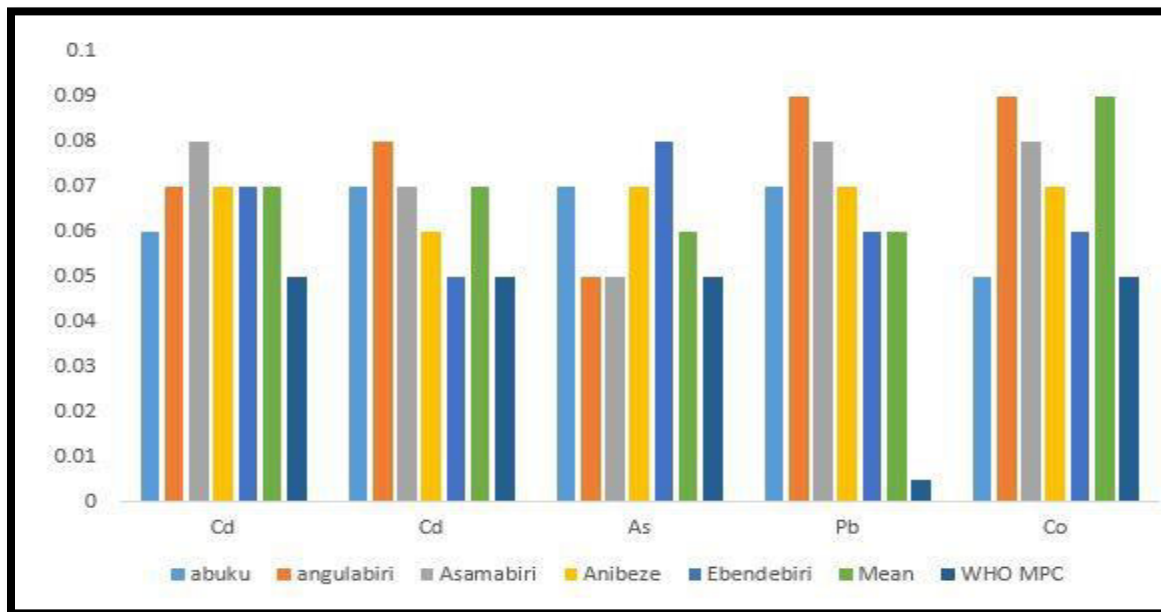
The results of the heavy metals in cassava roots in Okpaioil bearing community Delta state are as in Figure 2.

**Figure 2: results of the heavy metals content in cassava roots in Okpai and WHO MPC in mg/kg.**



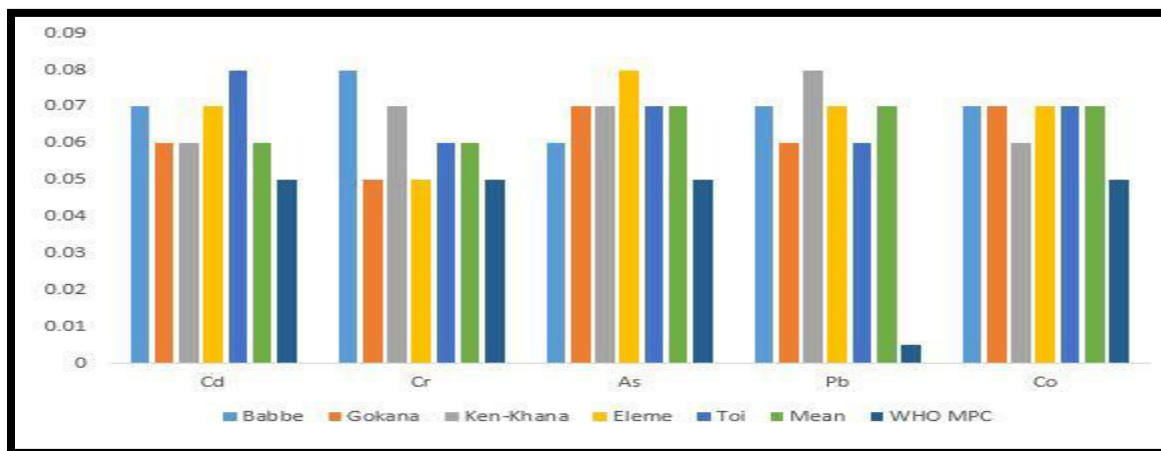
The results of the heavy metals in cassava roots in Sagbama oil producing communities Bayelsa state are as in Figure 3.

**Figure 3: results of the heavy metals content in cassava roots in Sagbama oil producing community and WHO MPC in mg/kg**



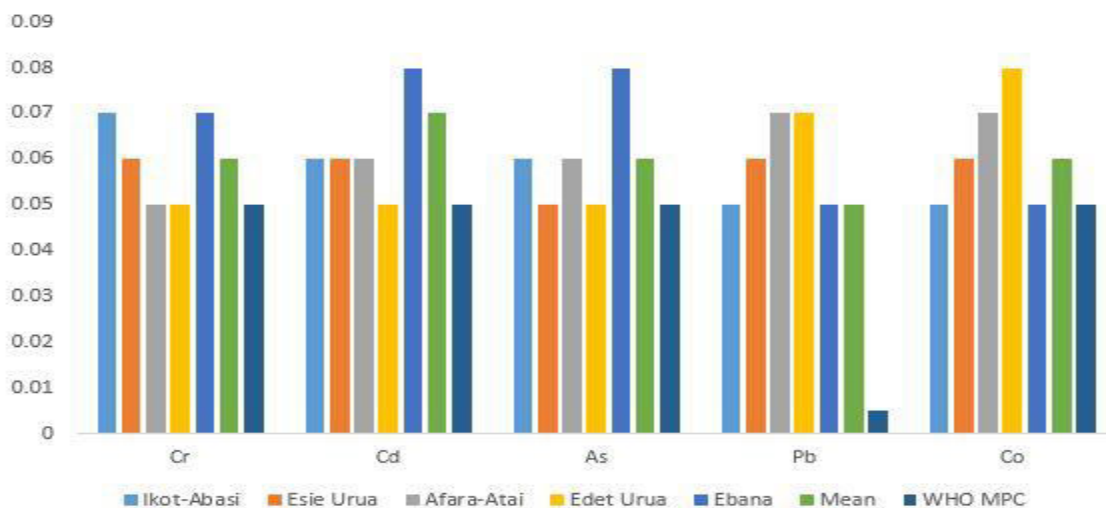
The results of the heavy metals content in cassava roots in Ogoni oil bearing community River state are as in Figure 4.

**Figure 4: results of the heavy metals in cassava roots in Ogoni oil bearing community and WHO MPC in mg/kg**



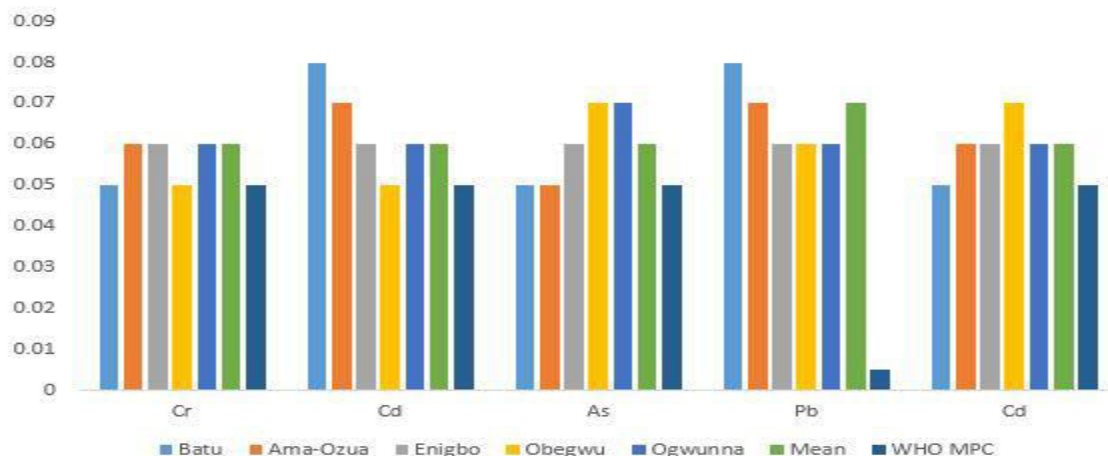
The results of the heavy metals in cassava roots harvested in Eket oil bearing community Akwa-Ibom state are as in Figure 5.

**Figure 5: results of the heavy metals content of cassava roots in Eket oil bearing communities and WHO MPC in mg/kg.**



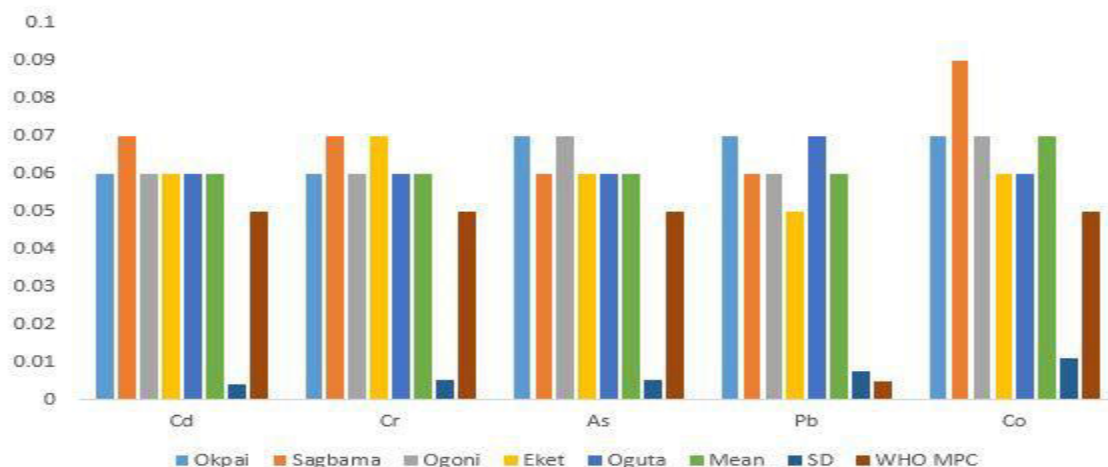
The results of the heavy metals content of cassava roots grown in Oguta oil producing community Imo state are as in Figure 6.

**Figure 6: results of the heavy metals in cassava roots harvested in Oguta and WHO MPC in mg/kg.**



The grand mean of the heavy metals measured in 5 oil producing communities in 5 Niger Delta states are as in Figure 7.

**Figure 7: grand mean results of the heavy metals in cassava roots harvested in Niger Delta oil producing states and WHO MPC in mg/kg.**



The grand means of the heavy metals in cassava roots in the Niger Delta oil producing communities of Nigeria were further subjected to test of significance deploying special package for social sciences (SPSS) model 29 at 0.05 level of significance The p value was 0.48, thus rejecting  $H_0$ .

### Discussion

The analyses of the cassava roots harvested from Niger Delta oil bearing communities presented varying concentrations of the heavy metals investigated.

The mean concentrations of Cd the analyses revealed is 0.06 mg/kg in OKpaiOgoni, Eket and Oguta to 0.07 mg/kg in Sagbama. The deviation from the critical point established by WHO of 0.05 mg/kg is as a result of input of Pb by anthropogenic sources. High content of Pb in cassava was reported in (Yaret al., 2001, Wang et al., 2005). The presence of Pb above the recommended level in human system results in health complications



such as cancer of the lungs, sinus and liver (Vermaet *al.*, 2013), bone degeneration, memory loss and death (Ogwuet *al.*, 2023d).

The analysis of the cassava roots cultivated in oil producing communities of the Niger Delta for Cr showed varying results ranging from 0.06mg/kg in Okpai, Ogoni and Oguta to 0.07 mg/kg in Sagbama and Eket with a grand mean of 0.06 mg/kg. The WHO MPC for Cr is 0.05 mg/kg. The elevated content of Cr in the cassava roots is attributable to the impact of oil exploitation in the communities. Increased content of Cr in cassava was in the reports present in (Uwahet *al.*, 2009, Singh *et al.*, 2010). Ingestion of Cr in human system causes varying health problems such as dermatitis and cancer of the lungs (Sharma *et al.*, 2010, Sharma *et al.*, 2008, Ogwuet *al.*, 2023c).

Laboratory analysis of cassava tubers grown in oil bearing communities of the Niger Delta for the As showed that the concentration is between 0.06 mg/kg in Oguta, Eket and Sagbama to 0.07 mg/kg in Ogoni and Okpai with grand mean of 0.06 mg/kg, while the WHO MPC for As is 0.05 mg/kg. The high content of As noticed in the roots is as a result of As being bioavailable in the soil as a result of oil exploration and extraction in the region. Similar reports of high content of As in roots and tubers were in (Shafiqet *al.*, 2012, Ogwuet *al.*, 2023a, Opeluwaet *al.*, 2012). Effects of As in man include poor cognitive development, skin lesions and cardiovascular diseases (Osuochaet *al.*, 2014, Olalade&Ologundudu, 2007, Mohammed & Folorunsho, 2015), infant mortality, reduction in sperm motility in male (Mbonget *al.*, 2013, Okeshwari&Chandrappa, 2006).

Analyses of cassava roots grown in the Niger Delta oil bearing communities for the content of Pb revealed the concentrations of Pb to be between 0.05 mg/kg in Eket to 0.07 mg/kg in Okpai with a grand mean of 0.06 mg/kg. WHO MPC for Pb is 0.005 mg/kg. This increased Pb concentration in the cassava roots in the region is traceable to the impact of oil exploitation and spillage into the environments. This report of high content of Pb in Cassava roots is in agreement with the reports in (Lokeshappaet *al.*, 2012, Khan *et al.*, 2031, Kabata-Pamidlas&Pendas, 2011). The effects of ingestion of Pb contaminated foods include intellectual disability, convulsion and coma (John *et al.*, 2009, Fassiret *al.*, 2005). It also attacks the central nervous system and may leave the survivor with low intellectual capability (Jacob, 2010, Chiroma, 2003).

Analysis of cassava roots grown in the Niger Delta for the Co content also showed varying mean concentrations ranging from 0.6 mg/kg in Eket and Oguta to 0.09 mg/kg in Sagbama with a ground mean of 0.07 mg/g. The WHO MPC for Co is 0.05 mg/kg. The high content of Co in the cassava roots is the concomitant effect of input of Co into the environment through oil activities. High content of Co in roots grown in industrial areas was in the reports of (Amusanet *al.*, 2003, Aduet *al.*, 2012, Adelasoye, 2014). The effects of Co in man include visual loss, hearing loss, heart diseases (Abegunde, 2015) weakness, fatigue, and peripheral neuropathy (Gideon & Josephine, 2008).

### Conclusion and Recommendations

Oil is Nigeria economic mainstay contributing 85 percent of Gross Domestic Product (GDP) and 95 percent of foreign exchange earning. Oil exploration and exploitation activities most often especially in the third world countries such as Nigeria leave the environment of operation highly degraded through incessant oil spillages. Crude oil is a complex compound containing hydrogen, carbon and oxygen and varying percentage of heavy metals and metalloids that bioaccumulate in crops in the soil and in aquatic organisms in marine environment.

The analysis of the cassava roots grown in the Niger Delta oil bearing communities revealed that the heavy metals investigated have bioaccumulated in the edible roots making them unhealthy for human consumption. Consequent upon the results of the analyses, the study recommend thus:

- Cassava roots grown in the soil bearing communities of the Niger Delta are unfit for human consumption due to heavy metals contamination.
- The cassava are also not suitable for export because of their failure to scale Codex Alimentarius conditions for export of agricultural produce.



- The impacted environment should be remediated.
- The Agencies charged with monitoring oil production environment: National Environmental Standards Regulation and Enforcement Agency (NESREA) and National Oil Spills Detection and Response Agency (NOSDRA) are enjoined to step up their surveillance on the oil companies in the Niger Delta for compliance to set standards.

### Acknowledgement

We acknowledge the contributions of persons whose input led to the success of this research. We appreciate the contributions of the laboratory analyst Dr. J. P. Uyimadu of National Institute for Oceanography and Marine Research (NIOMR) Victoria Island, Lagos, Nigeria, Mr. Onyema Donatus Ani, the computer specialist who undertook the computer typing and Mr. Omoye Israel for statistical computations.

We also appreciate the assistance and contributions of the research assistants in various oil bearing communities who carried out the samples collection from the farms and lastly, we extend a word of appreciation to the farmers in the oil producing communities who allowed samples collection from their farms.

### References

1. Abegunde SM, Agibade SA, Awonyemi IO. (2015). Assessment of heavy metal distribution and contamination in atmospheric dust from major roads in Ado-Ekiti, Ekiti State using pollution index. *Turkish Journal of Agriculture-food Science and Technology*, 6(9): 1196 –1199.
2. Adelasoye KA, Ojo OA. (2014). Accumulation of heavy metal pollutants in soil and cassava leaf and their effects on soil microbial population on roadsides in Ogbomoso, Nigeria. *International Journal of Applied Agriculture and Apiculture Research*.10:1-2.
3. Adu AA, Aderinola OJ, Kusemiju V. (2012). Heavy metal concentration in garden lettuce (*Lactuca sativa* L.) grown along Badagryexpressway, Lagos, Nigeria. *Transnational Journal of Science and Technology*. 2(7): 115-130.
4. Ahmad, M. S. & Ashraf, M. (2011). Essential roles and hazardous effects of nickel in plants. *Revolution in Environmental Contamination and Toxicology*, 214: 125-67.
5. Ali, S., Farooq, M. A., Yasmeen, T., Hussain, S. & Arif, M. S. (2013). The influence of silicon on barley growth, photosynthesis and ultra-structure under chromium stress. *Ecotoxicology & Environmental Safety*, 89: 66-72.
6. Amusan A, Bada S Salami A. (2003). Effect of traffic density on heavy metal content of soil and vegetation along roadsides in Osun state, Nigeria. *West African Journal of Applied Ecology*, 4:107–144.
7. Aworegba, C. a. (2015). Oil spillages and its impact on *Bufobufo* the Niger Delta. *Journal of Marine Ecology* 18(3), 21-28.
8. Bamgboye, J. C. (2020). Evaluation of the impact of oil spill on larva motility of *Tilapia zili*. *Journal of Environmental Monitoring* 15(3), 91-97.
9. Benson, N. U., Enyong, P. A. & Fred-Ahmadu, O. H. (2016). Trace Metal Contamination Characteristics and Health Risks Assessment of *Commelina africana* L. and Psammitic Sand flats in the Niger Delta, Nigeria. *Applied and Environmental Soil Science*, 2016: 14.
10. Boke, A., Megersa, N. & Teju, E. (2015). Quantitative Determination of the Heavy Metal Levels in the Wild Edible Plant Parts and their Corresponding Soils of the Central and Western Regions of the Oromia State, Ethiopia. *Journal of Environmental and Analytical Toxicology*, 5:5.
11. Chiroma TM, Hymore FK, Ebawele RO. (2003). Heavy Metal contamination of Vegetables and Soils irrigated with sewage water in Yola. *NJER*, 2(3): 25-31.

12. Fosu-Mensah, B. Y., Emmanuel Addae, E., Yirenya-Tawiah, D. &Nyame, F. (2017). Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. *Cogent Environmental Science*, 3: 1405887.
13. *Friends of the Earth Nigeria* (2022). *Oil spillage in Nigeria, 2005 to 2022. A publication of Friends of the Earth, Abuja, Nigeria.*
14. Hajar, A. W. I., Sulaiman, A. Z. B. &Sakinah, A. M. M. (2014). Assessment of heavy metals tolerance in leaves, stems and flowers of *Steviarebaudiana* plant. *Environmental Sciences*, 20: 386 – 393.
15. Hind S. J., Mushrifah, I., Aminah, A. &Kadhum, A. A. H (2014).Determination of Heavy Metals in Soil and Different Parts of *Diplaziumesculentum* (Medicinal Fern). *AIP Conference Proceedings*, 1614, 713 – 718.
16. Ido-Ido, G. &Ogbeibu, A. E. (2010). Bioaccumulation of the Heavy Metals in Cassava Tubers and Plantain Fruits Grown in Soils Impacted with Petroleum and Non-Petroleum Activities. *Research Journal of Environmental Sciences*, 4 (1): 33-41.
17. Itanna F. (2002). Metals in leafy vegetables grown in Addis Ababa and toxicological implications. *Ethiopian Journal of Health Development*, 16(3):295-302.
18. Jacob JO. (2010). Assessment of Heavy Metals Bio-accumulation in Spinach, Jute Mallow and Tomato in farms within Kaduna Metropolis, *American Journal of Analytical Chemistry*, 2(1): 1346.
19. Jassir MS, Shaker A, Khaliq MA. (2005). Deposition of heavy metal on green leafy vegetables sold on roadsides of Riyadh city, Saudi Arabia. *Bulletin of Environmental Contamination and Toxicology*, 75: 1020–1027.
20. John R, Gadgil K, Sharma G. (2009). Heavy metal toxicity: Effect on plant growth, biochemical parameters and metal accumulation by *Brassica juncea* L. *International Journal of Plant Production*, 3:66-70.
21. Kacholi, D. S. &Sahu, M. (2018). Levels and health risk assessment of heavy metals in soil, water and vegetables of Dar es Salaam, Tanzania. *Journal of Chemistry*, 2018, 9
22. Khan MN, Wasim AA, Sarwar A, Rasheed M.F. (2011). Assessment of heavy metal toxicants in the roadside soil along the N-5, National Highway, Pakistan. *Environmental Monitoring and Assessment*,182: 587-595.
23. Khan, S., Cao, Q., Zheng, Y. M., Huang, Y. Z. & Zhu, Y. G. (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. *Environmental Pollution*, 152(3): 686-692.
24. Lokeshappa B, Shivpuri K, Tripathi V, Dikshit AK (2012). Assessment of Toxic Metals in Agricultural Produce. *Food and Public Health*, 2(1): 24-29.
25. Lokeshwari H, Chandrappa GT. (2006). Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. *Current Science*, 91, 622-627.
26. Luo, X. S., Yu, S., Zhu, Y. G. & Li, X. D. (2012). Trace metal contamination in urban soils of China. *Science and Total environment*, 421: 17 – 30.
27. *Malaysia Food Regulation (1985)*. *Warta Kerajaan Malaysia*, volume 29. Ministry of Health Malaysia, Kuala Lumpur
28. Mbong EO, Ogbemudia FO, Okon JE, Umoren UB. (2013). Evaluation of concentration of heavy metals in leaf tissues of three improved varieties of *Manihotesculentacrantz*. *Journal of Environmental Research and Management* 4(3): 0214-0218
29. Mee-Young, S., Young-Eun, C., Chana, P., Ho-Yong, S. &JaeHwan, L. (2013). The Contents of Heavy Metals (Cd, Cr, As, Pb, Ni, and Sn) in the Selected Commercial Yam Powder Products in South Korea. *Preview in Nutrition and Food Science*, 18(4):249- 255.
30. Mohammed SA, Folorunsho JO. (2015). Heavy metals concentration in soil and *Amaranthusretroflexus* grown on irrigated farmlands in the Makera Area, Kaduna, Nigeria. *Journal of Geography and Regional Planning*, 8(8): 210-217

31. Mohsen B, Mohsen S. (2008). Investigation of metal accumulation in some vegetables irrigated with waste water in Shahre Rey –Iran and Toxicological implications. *Am-Euras. Journal of Agricultural and Environmental Science*, 4(1):86-92.
32. Moradi, A., Honarjoo, N., Fallahzade, J. & Najafi, P. (2013). Assessment of heavy metal pollution in soils and crops of industrial sites, Isfahan, Iran. *Pakistan Journal of Biological Sciences*, 16(2): 97-100.
33. Muhammad F, Farooq A, Umer R. (2008). Appraisal of Heavy Metal Contents in different Vegetables grown in the Vicinity of an Industrial Area. *Pakistan Journal of Botany* 40(5):2099-2106.
34. National Oil Spills Detection and Response Agency (2023). Oil spillages in Nigeria 2021 – 2022. A publication of NOSDRA Abuja, Nigeria.
35. Nigeria Environmental Society (NES) (2022). Oil spillage and ecosystem services in Nigeria. A bulletin of NES Abuja.
36. Nwineewii, J. D. & Neeka, J. B. (2017). Heavy metal concentrations in sediments from Eleme creeks in relation to the Eleme (Indorama) petrochemicals company, Rivers State, Nigeria. *International Journal of Chemical Studies*, 5(5): 377-380.
37. Ogunlesi, M., Okiei, W., Adio-Adepoju, A. & Oluboyo, M. (2017). Electrochemical determination of the levels of cadmium, copper and lead in polluted soil and plant samples from mining areas in Zamfara State, Nigeria. *Journal of Electrochemical Science and Engineering*, 7(4): 167-179.
38. Ogwu C, Imobighe M, Okofu S, Attamah F (2022), Speciation of heavy metals in fish species in the wetlands of oil-bearing communities of the Niger Delta; *IJB*, V21, N2, August, P169-178 innspub.net
39. Ogwu C. (2021). Heavy metals loadings of *Telfairia occidentalis* (Fluted pumpkin) grown in Ekpan (Host community of Warri Refinery and Petrochemical) Nigeria. *Quest Journals: Journal of Research in Agriculture and Animal Science*. 8(1), 16-20
40. Ogwu C., Azonuche J E and Okumebo V. O. (2021). Heavy metals content of *Telfairia occidentalis* (fluted pumpkin; order: Violales, Family: Cucurbitaceae) grown in Ebedei (An oil and gas bearing community) Niger Delta, Nigeria. *Quest Journals: Journal of Research in Humanities and Social Science*. 9(4), 74-78
41. Ogwu C., Ideh Victor, Imobighe Mabel (2022), Bioaccumulation of heavy metals in some pelagic and benthic fish species in selected wetlands in oil-bearing communities of the Niger Delta; *International Journal of Biosciences*. 20 (6), Pp. 128-139. innspub.net
42. Ogwu C., Obi-Okolie, F. & Abvbunudiogba, R. E. (2023b). Quantification of the Heavy Metals in the Groundwater of IKEJA Industrial Estate, IKEJA Lagos. *Journal of Research in Environmental and Earth Sciences*. 9(3) 69-73.
43. Ogwu C., Azonuche J. E and Okeke, M. (2020). Heavy metals contamination status of *Telfairia occidentalis* (Fluted pumpkin) grown in Uzere oil rich community, Niger Delta. *Quest Journal: Journal of Research in Agriculture and Animal Science*. 7(7), 12-17
44. Ogwu C., Azonuche J., and Achuba F (2021). Heavy metals quantification of *Telfairia occidentalis* (Fluted pumpkin, Order: Violales, family: Cucurbitaceae) grown in Niger Delta oil producing areas. *International Journal of Biosciences*. 13(2) 170-179.
45. Ogwu, C., Ossai, A. C., Ejemeyovwi D. O. & Unuafé, S. E. (2023a). Speciation of the Heavy Metals In The Ground waters Of Oshodi/Isolo/Ilasamaja industrial Estate Lagos Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*. 17(3), 1-6.

46. Ogwu, C., Ossai, A. C., Ejemeyovwi D. O. &Unuafé, S. E. (2023d). Characterization of the Heavy Metals in the Aquifer of Matori Industrial Estate Lagos Nigeria. *Journal of Research in Environmental and Earth Sciences*. 9(3), 20-26
47. Oladeinde O. (2021). How job opportunities can solve Niger Delta unrest - Group from [www.premiumtimesng.com](http://www.premiumtimesng.com)
48. Oliveira, H. (2012). Chromium as an Environmental Pollutant: Insights on Induced Plant Toxicity. *Journal of Botany*, 2012.
49. Ololade IA &Ologundudu A. (2007). Concentrations and bioavailability of cadmium by some plants. *African Journal of Biotechnology*, 6(16):1916-1921.
50. Opaluwa OD, Aremu M O, Ogbo LO, Abiola KA, Odiba IE, AbubakarMM, Nweze NO. (2012). Heavy metal concentrations in soils, plant leaves and crops grown around dump sites in Lafia Metropolis, Nasarawa State, Nigeria. *Advances in Applied Science Research*, 3(2):780-784.
51. Osuocha UK, Chukwu EC, Ezekwe AS, Imo C, Charles SU, Ibe C, Ikpo JC (2014). Heavy metal bioaccumulation of selected tuber crops from Ishiagu, Ebonyi State, South East, Nigeria. *Journal of Biodiversity and Environmental Sciences*, 5(2):136-140.
52. Ozah, C. (2023). Cassava and the rural economy of the Niger Delta. *Journal of Social Sciences*, 12(3), 42-45.
53. Panda, S. K., Chaudhury, I. & Khan, M. H. (2003) Heavy metals induce lipid peroxidation and affect antioxidants in wheat leaves. *Biological Plantarum* 2: 289-29
54. Rasaq, A. O., Oladipo, A. L., Gregory, O. A., Olumayowa J. O. &Owolabi, M. S. (2015). Concentration of heavy metals in root, stem and leaves of *Acalypha indica* and *Panicum maximum jacq* from three major dumpsites in Ibadan metropolis, South West Nigeria. *American Journal of Chemistry*, 5(1): 40-48.
55. Sandalio LM, Dalurzo HC, Gomez M, Romero-Puertas MC, del-Rio LA. (2001). Cadmium induced changes in the growth and oxidative metabolism of pea plants. *Journal of Experimental Botany*, 52, 2115–2126.
56. Sangwan, P., Kumar, V. & Joshi, U. N. (2014). Effect of Chromium(VI) Toxicity on Enzymes of Nitrogen Metabolism in Clusterbean (*Cyamopsis tetragonoloba* L.). *Enzyme Research*, 784036.
57. Shafiq M, Iqbal, MZ, Arayne, MS, AtharM. (2012). Biomonitoring of heavy metal contamination in *Pongamia pinnata* and *Peltophorum pterocarpum* growing in the polluted environment of Karachi, Pakistan. *Journal of Applied Botany and Food Quality*, 85: 120–125.
58. Shah, A., Niaz, A., Ullah, N., Rehman, A., Akhlaq, M., Zakir, M. & Khan, M. S. (2013). Comparative Study of Heavy Metals in Soil and Selected Medicinal Plants. *Journal of Chemistry*, 2013, 5 pages.
59. Sharma RK, Agrawal M, Marshall FM. (2008). Heavy metals (Cu, Cd, Zn and Pb) contamination of vegetables in Urban India: a case Study in Varanasi. *Environmental Pollution*, 154: 254–263.
60. Sharma S, &Prasade FM. (2010). Accumulation of Lead and Cadmium in Soil and Vegetable Crops along Major Highways in Agra (India). *Journal of Chemistry*, 7(4), 1174-1183.
61. Singh A, Sharma RK, Agrawal M, Marshall FM. (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. *International Society for Tropical Ecology*, 51:375-387.
62. Singh, M., Kumar, J., Singh, S., Singh, V. P., Prasad, S. M. & Singh, M. P. V. V. B. (2015). Adaptation Strategies of Plants against Heavy Metal Toxicity: A Short Review. *Biochemistry and Pharmacology*, (Los Angel) 4, 161.
63. Singh, S., Zacharias, M., Kalpana, S. & Mishra, S. (2012). Heavy metals accumulation and distribution pattern in different vegetable crops. *Journal of Environmental Chemistry and Ecotoxicology*, 4(10):170–177.
64. Uwah EI, Ndahi NP, Ogugbuaja VO. (2009). Study of the levels of some agricultural pollutants in soils, and water leaf (*Talinum triangulare*) obtained in Maiduguri, Nigeria. *Journal of Applied Sciences in Environmental Sanitation*, 4(2):71-78.

65. Verma DK, Gupta AP, Dhakeray R. (2013). *Bioindicators: A comparative study on uptake and accumulation of heavy metals in some plant's leaves of M.G. Road, Agra City, India. International Journal of Environmental Pollution and Solutions, 2:37-53.*
66. Wang XL, Sato T, Xing BS, & Tao S. (2005). *Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Science of the Total Environment, 350, 28-37.*
67. Yap CK, Mohd-Fitr, MR, Mazyhar IY, & Tan SG. (2010). *Effects of metal contaminated soils on the accumulation of heavy metal in different parts of Centellaasiatica: Sains Malaysia, 39: 347-352.*

Corresponding email [chukwudiogwu008@yahoo.com](mailto:chukwudiogwu008@yahoo.com)