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Comparative study of heavy metal content of *Manihot esculenta* tubers and soil in Rivers State, Nigeria: Effect on histology of kidney and liver of Wistar rats

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Abstract
There is a concern that *Manihot esculenta* Crantz (Euphorbiaceae) grown in Rivers State, Nigeria may be contaminated with heavy metals due to industrial activities with likely risk to human health. This study determined the heavy metal contents in the soil and tubers of *M. esculenta* and potential health risks in Wistar rats. Tubers harvested from different farms in Rumuji, Omoku and Gokhana areas of the state with their corresponding soil samples were combined and analyzed for heavy metals such as Pb, Cd, Hg, Cr, As and Ni. The control group rats received normal feed while test groups were fed with 30g of blended tubers from the locations respectively for 28 days. The liver and the kidneys were harvested for histopathological examination. Nickel, Pb, and Cr were present in the three locations while Cd and As were not found in Rumuji and Omoku but were present in Gokhana with a concentration of (0.01 ± 0.00 and 0.01±0.00 mg/kg) respectively. Bioconcentration factor was >1 for Pb and Cr in Rumuji. Liver histopathology showed fatty degeneration while the kidney tissues exhibited occluded Bowman's capsule space. Heavy metals concentrations were within permissible limits although histological findings indicated some degree of hepatotoxicity and nephrotoxicity.

Keywords: *Manihot esculenta;* Tubers; Heavy metals; Kidney; Liver

INTRODUCTION

One of the foremost public health problems that require urgent attention is environmental pollution. The increase in urbanization and industrialization activities has produced a corresponding increase in energy utilization, business activities and waste runoff [1]. This has contributed to different forms of environmental pollution. The major reported forms of environmental pollution are air, water, and soil pollution [2]. Environmental pollution is a very serious public health concern as evidence supports that it causes more annual deaths than Malaria, HIV/AIDS, and Tuberculosis. According to the World Health Organization, annual deaths caused by environmental pollution and its complication is approximately nine million [3].

Furthermore, heavy metals which are one of the environmental contaminants have been implicated in cardiovascular diseases, reproductive disorders, central nervous system breakdown and development of different forms of cancer [4].

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The effects of some pollutants can be seen directly, such as in air and water pollution, while some other forms of pollution, e.g., chemical contamination of the soil may not be too obvious. National reports in Nigeria have shown that air pollution is a major problem in several cities in the country [5]. Data have revealed that the average annual level of particulate matter in Nigeria is almost ten times above the World health organization allowable level of 5µg/m^3. The number of premature deaths due to air pollution was roughly calculated to be 11,200 [5].

If chemical contaminants are present in the soil, it could lead to the presence of these chemicals in food grown on the soil therefore causing harm to a lot of people who consume the produce. Some of the toxic chemical contaminants that can be present in soil and consequent ly, food grown on the soil are heavy metals such as copper (Cu), nickel (Ni), chromium (Cr), lead (Pb), cadmium (Cd), mercury (Hg), iron (Fe) and arsenic (As). Iron, copper and nickel are essential for their biochemical and physiological functions at low concentrations though they may become toxic at high concentrations. Lead, cadmium, and mercury have been implicated in metabolic disorders even at low concentrations [6].

There has been serious global concern about heavy metal poisoning in recent years. Human exposure and manifestation of the adverse effects have also been noticed to be exponential due to their wide usage in technology, agriculture, and domestic applications [7]. Agricultural products are one of the most important means through which these heavy metals can enter the human system and cause the observed adverse effects [8]. This is because the heavy metals which accumulate in the soil through different means can also accumulate in crops grown on the soil which are then ingested by humans and animals leading to toxicity [9].

Leaded paint and gasoline, mine tailings, land fertilizer application, sewage sludge disposal, pesticides, animal manures, wastewater irrigation, coal combustion residues, petrochemical spills, and atmospheric deposition are all potential sources of heavy metal contamination that can affect soil quality [10].

Lead and cadmium have been reported to be toxic to animals even at very low concentrations [11]. They are toxic because they may have interrelated negative effects that could contribute to ongoing degenerative changes, especially in the brain system, liver, and kidneys [12]. They also cause many harmful health effects by producing free radicals, which damage DNA, cause lipid peroxidation, and deplete protein sulfhydryls such as glutathione [13]. The hazardous levels of the various metals and how they affect certain organs vary. Lead poisoning causes a condition known as plumbism [14], as well as severe gastrointestinal problems [15]; cadmium is a cumulative poison, causing anaemia [16] and hepatic disorder [17].

Nigeria as a nation depend largely on the local production of food for consumption and sustenance of economic activities [18]. Therefore, it is very important to monitor the degree of contamination of the soil because of its necessity in food production. It is also important to assess the degree of migration of potentially toxic substances into the farmed products. This is done by scientifically studying the level of such contaminants as heavy metals in both the soil and agricultural products. Emurotu and Onianwa, [9], observed that metal concentrations in agricultural soils were within the regulatory limits, however the concentration of nickel, cobalt and cadmium were above the safe limits in some of the evaluated food crops in Kogi state, Nigeria.

Manihot esculenta Crantz. is also called cassava, manioc, yuca, balinghoy, mogo, mandioca, kamoteng kahoy or tapioca. It is a South American-native perennial woody shrub of the spurge family, Euphorbiaceae. It is also grown in tropical and subtropical areas

worldwide because the roots (tubers) are a rich source of edible starch. The tubers are a major food source in the developing world, in equatorial regions including Africa, South America, and Oceania [19]. Although the raw tuberous roots are extremely poisonous, they can be eaten after being thoroughly cooked [20]. It is a major source of carbohydrate for Nigerians and is widely consumed in form of *garri*, *fufu* and tapioca which is also exported to other countries. Rivers State (in southern, Nigeria), is characterized by a high level of urbanization activities such as petroleum refining, manufacturing and modern agricultural practices involving the use of pesticides and fertilizers. Therefore, understanding the extent of heavy metal contamination in these locations is essential for mitigating its impact on the environment and preserving its natural resources for future generations. Information on the heavy metal content in cassava tubers and soil samples in Rivers State, Nigeria is necessary to assess the potential risks to human health, to help in devising mitigation measures and to guide decision-making for food safety, agriculture, and public health. Hence, in this study, we evaluated the heavy metal (lead, cadmium, mercury, chromium, nickel and arsenic) contents in the soil and tubers of *M. esculenta* and their effects on the histology of the kidney and liver of Wistar rats and the likely health risks that may be associated with its consumption in Rivers State.

EXPERIMENTAL METHODS

Study locations. This study was carried out in Rivers State, Nigeria. Rivers State has three senatorial areas out of which a location each was selected. Hence, Rumuji, Omoku and Gokhana were selected as study sites. Rumuji community is situated in Emuoha local government area and lies within the tropical rainforest of the Niger Delta. The major occupation of the people is farming with a few others engaging in trading and public service [21]. There are a few oil processing facilities and an array of crude oil pipelines in this location.

Omoku is the capital of Ogba/Egbema/Ndoni local government area of Rivers State, Nigeria noted for its coastal ridge barriers, mangrove swamps, low land rain forest as well as flood plains. It is bothered by Sombreiro River in the East and Orashi River in the West, a central business hub and is also a host to oil exploration activities [22]. Hence the influx of people and increase in anthropogenic activities in this town may lead to contamination of the soil and plants in it.

Gokhana is situated in the Ogoni region of Rivers State. This land is rich in crude oil and is characterized by a high level of exploration activities which may likely put the area at the risk of heavy metal contamination [23].

Sample collection and preparation. The fresh tubers of *M. esculanta* were collected from some privately owned farmlands in Rumuji, Omoku and Gokhana towns of Rivers state Nigeria. They were placed in precleaned and sterilized separate polyethylene bags. The tuber samples were identified and authenticated by Dr. M. Suleiman in the Department of Pharmacognosy and Phytochemistry, Faculty of Pharmaceutical Sciences, University of Port Harcourt. The samples were collected from five randomly selected sampling sites in each of the selected study locations, aggregated together and properly labelled. A portion of the collected samples were transported to Springboard Research Laboratory at Awka in Anambra State. Nigeria for further processing and analysis of the heavy metals. Care was taken to make sure the soil samples were not cleared from the tubers before sending them out.

The remaining samples were scrapped of the soil particles, washed, cut into smaller pieces and air dried until constant dry weight was achieved. The dried samples were pulverized into powder using an electric grinding machine, then stored in airtight plastic containers and kept until required for use.

Soil sample collection and preparation. About one kilogram of soil sample was collected into a clean polyethylene bag from each of the sites where the tubers were collected with the consent of the owners at 0-20 depth using a steeliness steel auger and pooled together to form a composite soil sample from Rumuji, Omoku and Gokhana towns separately. The carefully packed, and labelled samples were then transported to Springboard Research Laboratory at Awka in Anambra state, Nigeria for pretreatment and analysis.

Heavy metal analysis of *M. esculenta* tubers and soil digests

Preparation of *M. esculenta* samples using wet digestion. Dried and homogenized samples of two grammes each from (Rumuji, Omoku and Gokhana separately was weighed into separate 100 mL conical flasks to which 20 mL of the acid mixture (650 mL concentrated nitric acid; 80 mL perchloric acid; 20 mL concentrated sulfuric acid) was added. The mixture was heated to ashing in a thermostatically controlled muffle furnace until a clear digest was obtained at 80°C. Thereafter, the digest was allowed to cool at room temperature of about 27^{o}C and filtered out through Whatman No.42 filter paper. Each filtrate was transferred into separate sample bottles and made up to 100 mL mark with distilled water for metal analysis [24]. Each sample was digested and analyzed in triplicate. Reference solutions in the optimum concentration range were prepared daily by diluting the single stock element solutions with water containing 1.5 mL concentrated nitric acid/liter. A calibration blank was prepared using all the reagents except for the metal stock solutions.

Preparation of soil samples using dry digestion. Soil samples of two grammes each from each of the three locations were put into separate and properly labelled crucibles. These were placed into a muffle furnace for ashing at a temperature of 550^{0}C for three hours. The samples were then removed from the furnace and allowed to cool. The dry ash was emptied into a 250 mL beaker to which was added 20 mL of 20% H_2SO_4 and heated over a water bath for 20 minutes. The solution was filtered and made up to 50 mL with distilled water, after which it was stored in a sample bottle for heavy metal analysis [24].

Reference solutions in the optimum concentration range were prepared daily by diluting the single stock element solutions with water containing 1.5 mL concentrated nitric acid/liter. A calibration blank was prepared using all the reagents except for the metal stock solutions.

Bioconcentration factor (BCF). Bioconcentration factor is the ratio of the heavy metal concentration in the edible part of the plant relative to the heavy metal concentration in the medium which is the soil sample [29]. Heavy metal uptake by plant from the soil was determined by using the formula of Kachenko and Singh, [30] as shown below:

BCF = (Concentration of heavy metal in edible part of plant (mg/kg)/ (Concentration of heavy metal in soil (mg/kg)

Values of BCF greater than 1 implies that the plant can accumulate the metal under consideration.

Experimental protocol. The animals were obtained and allowed to acclimatize for one week under ambient conditions with free access to normal feed and water. The rats were grouped into four with six rats each (three males and three females) of similar body weights respectively.

The method of Das et al., [31] was modified and adopted in this study. Group 1 was fed with 30g of normal animal feed, group 2 received pulverized Rumuji cassava, group 3 was fed with pulverized Omoku cassava while

group 4 animals were fed with pulverized Gokhana cassava of 30g weight daily for 28 days consecutively. Groups 2, 3 and 4 had the assigned cassava for three hours daily after which it is withdrawn and replaced with normal animal feed till 7:00PM. They are then left with only water till 7:00AM the next morning The animals were sacrificed on the 29th day and their kidneys and livers were harvested into properly labelled sterile containers of 10% neutral buffered formalin and sent to the Department of Anatomy in the Faculty of Basic Medical Sciences for histopathological analysis. Ethical approval was obtained from the University of Port Harcourt Research ethics committee with approval number UPH/CEREMAD/REC/MM92/048.

Histopathological analysis. The tissues were placed in containers of 10% neutral buffered formalin and allowed to fix properly after which grossing or cut-up was done and the representative tissue was placed in a tissue cassette. The tissues were then processed using different grades of ethanol (70-100%) to facilitate dehydration. Cleaning was done with several changes of xylene. Impregnation was carried out with the aid of molten paraffin wax at 68^{0}C in a hot air oven. Embedding was carried out with moulds, molten paraffin wax, forceps and tissue cassette that has the identification number of the tissue after which microtomy was done using microtome (Leica RM2235). Sections were picked unto the slides using hot water bath (Raymod A Lamb section mounting Bath), allowed to drain, labelled, and placed on slide dryer (Raymond Lamb- Model E18.1 Hotplate) in preparation for staining. Sections were stained in Ehrlich Haematoxylin for 15 mins, rinsed in water, blued in Scot's tap water (2 dips), counterstained in eosin for 5 mins, allowed to dry and cleared with xylene. Slides were mounted using dibutylphthalate polystyrene xylene (DPX) mountant with coverslips and allowed to dry.

Microscopic examination of the kidney and liver sections of all the groups were done with the aid of a microscope at a magnification of 400 and micrographs [32].

Statistical analysis. All the data obtained were expressed as mean ± standard error of mean (SEM). Statistical analysis of data was done using one-way analysis of variance (ANOVA), followed by Tukey HSD post hoc test. Statistical package for the social sciences (SPSS) version 23 (IBM, New York, USA) was used for data analysis. Comparison was carried out between the control and test groups and among the test groups. P-values were taken as significant at $P<0.05$.

RESULTS

Concentration of heavy metals in *M. esculenta* tubers. Cadmium, mercury and arsenic were absent in Rumuji tubers, Gokhana had the highest levels of lead, mercury and nickel while chromium was highest in Rumuji. Gokhana tubers were found to contain all the evaluated metals while Omoku also had all the metals except cadmium and arsenic that were absent. There was a statistically significant ($P<0.05$) difference in the levels of lead, mercury, and arsenic in Gokhana soil when compared to Rumuji and Omoku samples. (Table 2).

Concentration of heavy metals in soil samples. The mean concentration of chromium was the same in the soil samples of all the locations, lead and cadmium were absent in Omoku while cadmium and mercury were found only in Gokhana soil. Arsenic was absent in Gokhana soil but present in Rumuji and Omoku soil samples (Table 3). There was a statistically significant ($P<0.05$) difference in the lead, cadmium, and mercury content of Gokhana soil when compared to that of Rumuji and Omoku (Table 3).

Bioconcentration Factor. This was found to be greater than one for lead and chromium in

Rumuji and Gokhana while nickel also had a BCF value greater than one at Omoku and Gokhana. The BCF values for cadmium, mercury and arsenic were found to be zero in Rumuji, cadmium and arsenic were also found to be zero in Omoku while that of mercury was greater than one in Gokhana. Nickel had a BCF value of less than one at Rumuji. Lead and mercury were not detected in Omoku soil and arsenic was also absent in Gokhana soil, therefore their BCF values could not be determined because the heavy metal levels in the tubers were indivisible by the zero values of those metals in the corresponding soils.

Table 1: Proximate composition of *Manihot esculenta* tubers

Parameters	Composition %
Moisture content	5
Crude protein	23.87
Ash content	6.53
Crude fibre	13.66
Lipids	6
Carbohydrates	43.8

Table 2: Concentration of heavy metals (mg/ kg) in *M. esculenta* tubers

	Location		
Metals	Rumuji	Omoku	Gokhana
Lead	0.02± 0.00	0.01 ± 0.00	0.05 ± 0.00*
Cadmium	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00
Mercury	0.00 ± 0.00	0.01 ± 0.00	0.09 ± 0.00*
Arsenic	0.00± 0.00	0.00± 0.00	0.01 ± 0.00*
Chromium	0.08 ± 0.06	0.03 ± 0.00	0.07 ± 0.00
Nickel	0.02 ± 0.00	0.2 ± 0.10	0.05 ± 0.00

Values represent concentration of heavy metals (Mean ± SEM) *Statistically significant at P<0.05

Table 3: Concentration of heavy metals (mg/kg) in *M.esculenta* soil

	Location		
Metals	Rumuji	Omoku	Gokhana
Lead	0.01± 0.00	0.00 ± 0.00	0.04 ± 0.00*
Cadmium	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.00*
Mercury	0.00 ± 0.00	0.00 ± 0.00	0.06 ± 0.00*
Arsenic	0.02 ± 0.00*	0.03 ± 0.00*	0.00 ± 0.00
Chromium	0.03± 0.00	0.03 ± 0.00	0.03 ± 0.00
Nickel	0.03 ± 0.00	0.03 ± 0.00	0.02 ± 0.00

Values represent concentration of heavy metals (Mean ± SEM) *Statistically significant at P<0.05

Table 4: Maximum permissible levels of heavy metals in soils and plants

Elements	Target values in soil (mg/kg)	Permissible limit in plant (mg/kg)
Lead	85	2
Cadmium	0.8	0.02
Mercury	2	0.02
Chromium	100	1.3
Arsenic	14	0.15
Nickel	35	10

WHO,1996. Target values represent desirable maximum levels of elements in unpolluted soils

Table 5: Bioconcentration factor

	Location		
Metals	Rumuji	Omoku	Gokhana
Lead	2		1.25
Cadmium	0	0	1
Mercury	0		1.5
Arsenic	0	0	
Chromium	2.67	1	2.33
Nickel	0.67	6.67	2.5

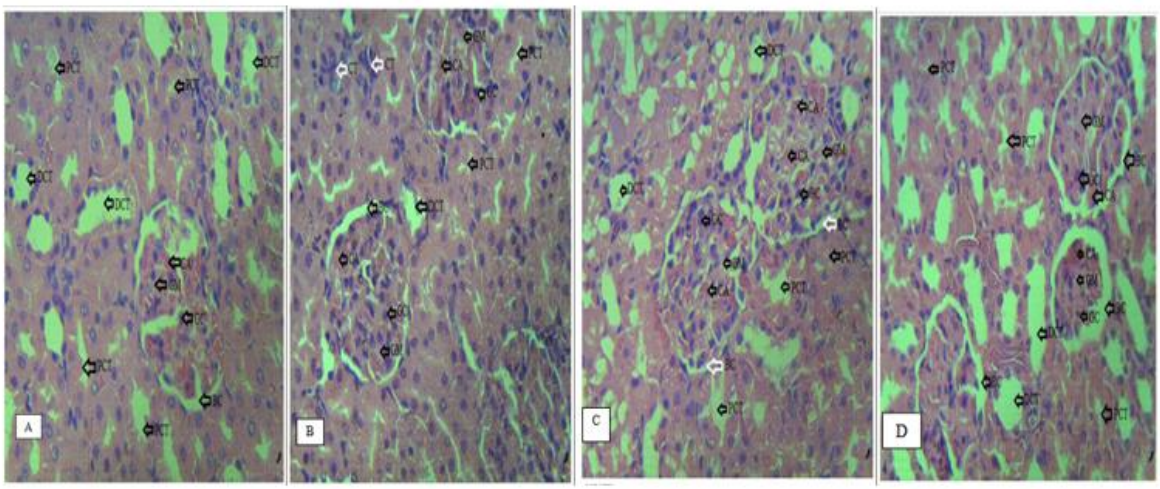

Figure 1 A-D : Photomicrographs of the kidney tissues of rats. (H & E) X 400.

The kidney tissue of the control group (A) showed normal architecture including test group (D) treated with 30g of from Gokhana. Animals treated with 30g of *M. esculenta* tubers from Rumuji (B) exhibited collapsed renal tubules while Omoku (C) showed occluded Bowman's capsule space (Figure 1 A-D).

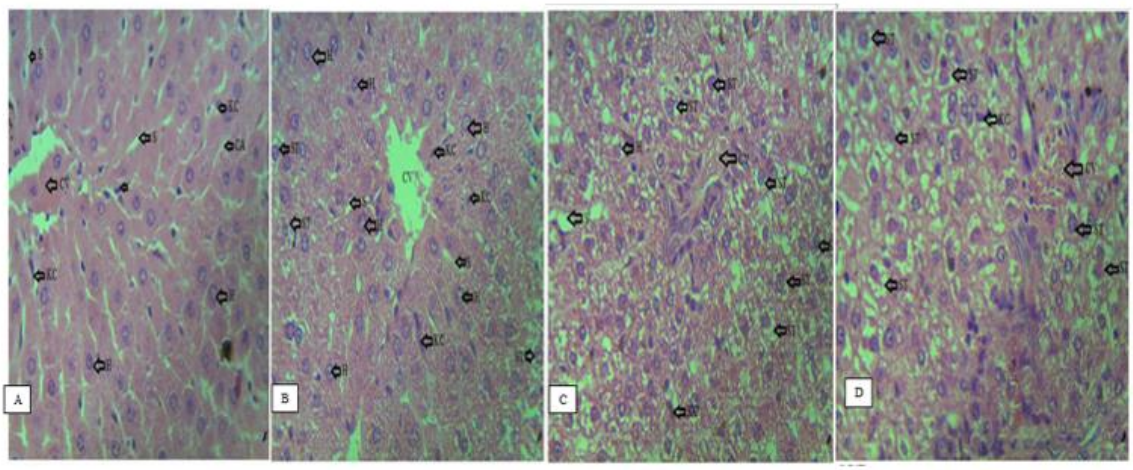

Figure 2 A-D : Photomicrographs of the liver tissues of rats. (H&E X 400).

The liver tissue of control showed normal histo-architecture (A). Rats treated with 30g of *M. esculenta* from Rumuji showed hypertrophic kuppfer cells (B), those exposed to Omoku tubers exhibited different grades of stenosis (C) while the group fed with Gokhana tubers showed fatty degeneration (D) as shown in Figure 2 A-D

DISCUSSION

This study assayed the heavy metal concentration in *M. esculenta* tubers and their different soil samples collected from Rumuji, Omoku and Gokhana communities in Rivers State. The samples from the different locations showed a heavy metal concentration lower than the minimum permissible amount for all the metals studied. The study recorded an average concentration of 0.02, 0.01 and 0.05 mg/kg of lead in Rumuji, Omoku and Gokhana tubers respectively (Table 2). These values were below the minimum acceptable values of 2 mg/kg for plants [33].

The primary sources of lead in the environment include the burning of gasoline, (which contains tetraethyl lead), lead-acid batteries that are abandoned as waste, bullets, compounds used to preserve wire, dyes, household furnishings, and paints, as well as the usage of lead in these products [34]. When evaluating the biological makeup of humans, lead is not a significant heavy metal. Omobowale et al., [35], observed in their study that oxidative parameters including malondialdehyde (MDA) and lipid peroxidation were increased while Wang et al. [36], reported that the superoxide dismutase, glutathione peroxidase and catalase levels were reduced in animals when exposed to lead. Increase in lead concentration may result in its buildup in the human body which may lead to variety of physiological imbalances or ailments, for example anaemia [37], cough [38], artherosclerosis [39], headaches, migraines, brain disorders, and central nervous system damage [40].

Many locations throughout the world have recorded cases of cadmium poisoning. It is a widespread health issue that, in some circumstances, can lead to yearly fatalities. Cadmium adversely affects the cardiovascular [41], renal [42], with the central and peripheral nervous system [43].

Cadmium has also been reported to induce different forms of cancer such as lung and prostate cancer through its activity on cell proliferation, differentiation, apoptosis, cell signaling and other related cellular effects [44]. The cadmium levels in the *M. esculenta* tubers from the locations of study were below the minimum acceptable levels as only the samples from Gokhana had a detectable level of 0.01 mg/kg (Table 2), which is far below the WHO's permissible value of cadmium in plants of 0.02 mg/kg, while the other locations had no detectable values. This value was also lower than the mean concentration of 0.18 mg/kg reported for cadmium in samples harvested in some parts of Ikwerre local government area of Rivers state (45).

Only samples from two locations, Omoku and Gokhana had detectable values for the presence of mercury in the tubers. The Omoku samples had an average concentration of 0.01 mg/kg while the Gokhana samples had an average value of 0.09 mg/kg (Table 2). The concentration of mercury present in Gokhana tuber was higher than the permissible limit of 0.02 mg/kg stipulated by WHO [33]. Mercury is among the top ten chemicals rated by the WHO as chemicals of crucial public health concern. Exposure to mercury at high concentrations is associated with damage to the lungs, gut lining, brain, and kidney [46].

Rumuji, Gokhana and Omoku tubers have a mean concentration of 0.08, 0.07 and 0.03 mg/kg each for chromium respectively which were below the permissible limit of 1.3 mg/kg recommended by [33]. Only the Gokhana samples recorded the presence of arsenic in the tubers as they were absent in the samples from the other locations (Table 2).

The Omoku samples had the highest concentration of nickel which was 0.2 mg/kg compared to Rumuji and Gokhana which had concentrations of 0.02 and 0.05 mg/kg respectively (Table 2). Although this value for the Omoku community is very high compared to the other samples, it is still far below the permissible limit of 10 mg/kg for nickel set by

[33], which implies that it is not a cause for concern.

Analysis of the soil samples collected from the Rumuji, Omoku and Gokhana communities in Rivers State revealed the presence of some of the heavy metals in the samples but the values were considerably lower than the minimum permissible values for the metals. The soil samples from Gokhana community showed the highest level of heavy metal contamination as it tested positive for all the metals assayed except for arsenic. The Rumuji community had the second recorded high concentration of the heavy metals studied. The soil samples there contained lead, chromium, arsenic and nickel but was found to be negative for cadmium and mercury. However, arsenic, chromium and nickel only were found in Omoku soil samples (Table 3).

The maximum permissible limit for lead is 85 mg/kg in soil samples according to [33]. Based on this reference value, the soil samples collected from the three locations can be said to be safe from lead contamination. This is because, Rumuji community had about 0.01 mg/kg, Gokhana had 0.04 mg/kg as mean concentrations of lead while it was not detectable in Omoku soil (Table 3). These values were far less than the concentration of lead reported by Edori et al.,[34], in Gokhana LGA with an average concentration of 2.685 mg/kg. The reason for the disparity is not known now but more studies need to be done to understand that. All communities except Gokhana showed no level whatsoever for cadmium. The cadmium level in Gokhana soil sample was observed to be 0.01 mg/kg which was also lower than the reference value of 0.8 mg/kg according to [33].

The result obtained in this study for cadmium level was also found to be of higher concentration than what was observed in some petroleum impacted areas of Olomoro Delta state which was below detectable levels [47]. High amounts of cadmium are known to be extremely toxic and have been linked to numerous cases of food poisoning in humans. Even very little amounts of cadmium can cause harmful alterations in kidney function. It replaces zinc in the body of humans through some metabolic processes, leading to hypertension and renal damage [48]. A high concentration of cadmium in a soil or plant sample is a need for concern but the value of 0.01 mg/kg (Table 3), for cadmium in this study suggests that the cadmium concentrations in the study areas are well below the minimum permissible levels.

Similar results were also observed for the presence of mercury as both Rumuji and Omoku soil samples had no observable concentrations of the element. Gokhana on the other hand had an average concentration of 0.06 mg/kg (Table 3), which is also below the 2 mg/kg recommended by [33]. The value obtained was slightly higher than the result obtained in soil samples from Andoni, Rivers State which had an average soil mercury concentration of 0.01 mg/kg [49].

A high concentration of mercury in humans can cause mercury poisoning which is characterized by damages to the brain and kidneys, personality changes (irritability, shyness, and nervousness), tremors, changes in vision, deafness, muscle in coordination, loss of sensation, and difficulties with memory [50].

The concentrations for arsenic, chromium and nickel were also found to be much lower than the maximum permissible values in all the locations. All the soil samples had a value that is much lower than 14 mg/kg which is the target value stipulated by [33], which signifies a positive outcome for arsenic contamination. Omoku and Rumuji soil samples had a concentration of 0.03 and 0.02 mg/kg respectively while the Gokhana samples showed no detectable level of arsenic (Table 3). The level of arsenic contamination was lower than the values reported by [51], in some selected locations in Port Harcourt, Rivers

State which had an average arsenic concentration of 0.42 mg/kg.

The concentration of chromium was found to be 0.03 mg/kg in all the locations. These values are very much lower than the maximum permissible level of 100 mg/kg recommended by WHO, [33]. They were also lower than the mean chromium values of 4.185 mg/kg in the soil samples of Gokhana LGA of Rivers State reported by Edori et al., [51].
Nickel levels were also found to be 0.03 mg/kg in both Rumuji and Omoku while Gokhana samples had just 0.02 mg/kg (Table 3). All values were still very much lower than the reference value of 35 mg/kg (33). Values obtained were also lower than those reported by Edori et al., [51], in the oil-bearing communities of Gokhana LGA, Rivers State.

The dangers posed by heavy metal accumulation in soils and food samples are immense and calls for more study and intervention. In some cases, some plants are used in the phytoremediation process to facilitate the uptake of heavy metals in the soil. The assessment of the plants that can be useful in this process is done using what is called the Bioconcentration factor (BCF), [52]. The bioconcentration factor is a ratio of the metallic content in the plants to that in the soil. This factor is indicative of their danger to humans. A BCF value greater than 1 indicates that the plant under consideration could be an accumulator for the heavy metal under evaluation [53]. From the results of this study, it could be inferred that the cassava tubers in the study location are potential accumulators for some of the heavy metals under study. In the Rumuji community lead and chromium had a BCF value greater than 1 which is indicative of the relative accumulation abilities on the cassava tubers. In the Omoku community, only chromium and nickel showed potential for accumulation in the tubers while in Gokhana, lead, mercury, chromium, and nickel showed high propensity to accumulate which was demonstrated by their high BCF values (Table 5).

Histhopathological results of the kidney revealed collapsed renal tubules (Figure 1B), in the animals exposed to *M. esculenta* tubers from Rumuji while the group treated with Omoku samples showed occluded Bowman's capsule space (figure 1C). Histology of the liver tissue showed hypertropic kuppfer cells (figure 2B), in the animals fed with *M. esculenta* tubers from Rumuji while those treated with Omoku tubers had various grades of stenosis (figure 2C) and those exposed to Gokhana tubers exhibited fatty degeneration (Figure 2D). The hepatotoxicity and nephrotoxicity observed in this study may probably be attributed to the presence of heavy metals with BCF greater than one such as lead and chromium in Rumuji, nickel in Omoku, and chromium, lead with mercury in Gokhana communities.

Conclusion. It can be concluded that the heavy metal concentration in the cassava tubers and soils from these locations are within the acceptable limits which makes them safe for consumption. Although histological evidence suggests some damage to some of the liver and kidneys indicating possible hepatotoxicity and nephrotoxicity.

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