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POTENTIAL HUMAN HEALTH RISK ASSESSMENT OF HEAVY METALS VIA CASSAVA TUBERS FROM OGWASHI-UKU, NIGERIA

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ABSTRACT

Heavy metals such as Cu, Pb, Zn and Cd are ubiquitous in our environment and this study seeks to investigate the concentration of heavy metals in cassava tubers cultivated under high voltage electric power lines and thus assess the associated human health risk arising from its consumption in three communities in Aniocha South LGA, Delta State. Cassava tuber samples were collected from farm under the power lines using a spade. Standard laboratory procedures were adopted for determination of the concentration of heavy metals in the samples using Atomic Absorption Spectrophotometer (AAS). Results revealed that the concentration of heavy metals in the samples range from 7.35$\pm$0.05, 9.57$\pm$3.24, 0.84$\pm$0.43 and 0.22$\pm$0.08 mg/kg for Cu, Zn, Pb and Cd respectively. Bioaccumulation of heavy metals from soil to root revealed Zn > 1 in samples across all sampled locations. The life carcinogenic risk value showed that consumption of cassava tubers cultivated under high voltage power lines in the sampled communities by the local populace are not under any immediate carcinogenic threat. However, THI revealed that continuous consumption of these cassava tubers may pose the emergence of carcinogenic threat.

Keywords: AAS, Heavy Metals, Concentration, Cassava, Ogwashi-Uku

INTRODUCTION

In Nigeria, availability of land for farming is gradually becoming a problem to farmers. This may be as a result of population growth, urbanization, industrialization, land degradation, land ownership and other environmental factors. It has therefore led farmers to cultivating various crops under high voltage power lines. In Delta State, high voltage power lines cuts across many rural communities and most farmers cultivate directly under these power lines (Adamu, 2019).
Cassava is a staple crop and it is a very important source of dietary carbohydrates for human survival (Thompson and Kelly, 1990; Arai, 2002). Over the years, many findings have been reported on the contamination of agricultural farmlands (soils and crops) by heavy metals others claim that these metals is one of the most critical environmental issues worldwide.
Heavy metals can build up in food crops that naturally have the ability to absorb toxic substances, including heavy metals. These metals can then move through the food chain in environments that are contaminated. Even at low levels of exposure, they can be toxic to plants, animals and humans more than in cases of inhalation and dermal contact pathways (Loutfy et al., 2006; Khan et al., 2008; Singh et al., 2010). Therefore, the contamination of plants with heavy metals should not be underestimated, as foodstuffs are essential components of the human diet. Although plants take up some trace element that serves as nutrients and are vital for their growth.
Cassava tubers, as a staple crop, are cultivated in nearly all farmlands of the Niger Delta, particularly in Delta State, Nigeria. Consequently, they are commonly consumed food products in many households. The high demand for cassava makes it susceptible to heavy metal contamination.
Heavy metals primarily enter food crops through contaminated farmland, where they are absorbed by the plants' roots (Gupta, 1995; Lokeshwari and Chandrappa, 2006; Ijabor et al., 2023). Eating crops grown in such contaminated soil can pose serious health risks to humans, as highlighted in reports by Dikioye et al. (2018).
Field studies on plants and crops exposed to 50-60 Hz frequencies found no harmful effects. However, it is well established that trees can suffer damage when exposed to electric field strengths much higher than those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This damage is often caused by corona discharge at the tips of the leaves. It's important to emphasize that such elevated field levels are usually found only near very high voltage power lines (Matthes et al., 2000).
Health risk assessment provides the necessary information needed to estimate the level of heavy metal contamination on food crops consumed by human and also evaluate its impact on human health (Nkpaa et al., 2016). Tuber crops take up the heavy metals and accumulate them in their edible and non-edible parts in high levels that are capable of causing devastating health effects after consumption and accumulation in the human body (Naser et al., 2012). It is therefore important to assess the uptake, bio-accumulation, and potential health risks of heavy metals via consumption of cassava tubers cultivated under high voltage power lines.
The objectives of this research are to examine the concentration and absorption of heavy metals in cassava roots in Aniocha South Local Government Area, Delta State, Nigeria. Additionally, the study assesses the potential health risks to humans from consuming these tubers in the selected communities. This assessment uses methods such as estimated daily intake (EDI), target hazard quotient (THQ), health index (HI), and carcinogenic risk (CR).

MATERIALS AND METHODS

Study Area

Ogwashi-Uku is a community locatedwithin Aniocha South Local Government Area of Delta State of Nigeria. The local government lies on coordinate 6°08'N 6°29'E in the Southern part of Nigeria.Ogwashi-Uku is the headquarters of the local government. It shares boundary with Oshimili South to the North, Ika South to the West and Ndokwa West.

Sample Collection

Cassava leaves, and roots were randomly collected from three different farms. in three locations (Isah-Ogwashi road, Polytechnic road and Issele-Uku road) situated in Aniocha South L.G.A. Control samples were collected from another cassava farmland 1000 km away from the high voltage power line in Ogwashi-Uku. Soil samples were collected ata depth of 15 cm using a sterilized soil auger, while cassava tubers were obtained using a spade.

Preparation, Digestion of samples, and Pre-Treatment of cassava plant

Cassava samples were peeled and thoroughly washed with distilled water. They were then sliced and placed in a dehydrator at 80°C for 2-3 days, followed by air drying in an oven at 100°C. The dried samples were screened through a 2 mm sieve to remove coarse particles, defective samples, and impurities prior to chemical analysis.

For the soil samples, 0.5 g of air-dried soil was measured and transferred into a 250 ml conical flask. This was followed by the addition of 5 ml of concentrated H_2SO_4, 25 ml of concentrated HNO_3, and 5 ml of concentrated HCl. The flask was heated in an oven at 105°C for 90 minutes and then allowed to cool to room temperature. After cooling, 20 ml of distilled water was added, and the mixture was filtered to complete the digestion process. Finally, the resulting solution was transferred to a 50 ml volumetric flask, filled to the mark, and allowed to settle for at least 15 hours. The filtrate was then analyzed for total concentrations of Cu, Pb, Zn, Ni, and Cd using an Atomic Absorption Spectrometer (AAS).

Bioaccumulation Factor (BF)

Bioaccumulation factor (BF) is needed in order to quantify the level of heavy metal in the root tubers and soils. This was calculated by comparing the concentration of heavy metals in cassava tubers to the concentration of heavy metals in the soil (Peris et al., 2007; Oseni et al., 2015) where value ≥ unity is used as an indication of the plants potentials to phytoremediate or phytoextracts (Zhang et al., 2022; Santillan et al., 2010). It is calculated as follows:

$$BF = \frac{C_{roottubers}}{C_{soil}} \quad (1)$$

Where; $C_{root\ tubers}$ = Concentration of Heavy Metals in root tubers (mg/kg), and C_{soil} = Concentration of Heavy Metals in Soil (mg/kg). However, BF was not calculated for this study since we did not measure heavy metal concentration in soil.

Human Health Risk Assessment of Heavy Metals

Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) and Life Carcinogenic Risk (CR) were used to assess the risk associated with heavy metals in cassava from directly under high voltage power lines in Aniocha south. The calculations were based on descriptions by USEPA (USEPA, 2011)

Estimated Daily Intake (EDI) of Heavy Metals

The estimated daily intake (EDI) of heavy metals (Cu, Pb, Zn, and Cd) depends on both the metal levels in the crops and the consumption rate of the root tubers. It is measured in mg/kg per day.

The EDI was calculated for both children and adult using equation 2:

$$EDI = \frac{C_{HM} \times C_f \times D_{fi}}{BW_{Avg}} \quad (2)$$

Where; C_{HM} = Heavy Metal concentration (mg/kg), C_f= Conversion Factor (0.085), D_{fi} = Daily Food Intake (0.209 kg/person for children and 0.418 kg/person for adults), and BW_{Avg} = Average Body Weight (32.7 kg for childrenand 60 kg for adults) (USEPA, 2011; Khan et al., 2009; Orajiaka-Uchegbu et al., 2020).

Target Hazard Quotient (THQ) of Heavy Metals

The non-carcinogenic health risks associated with cassava consumption by the local populace were evaluated using the target hazard quotient (THQ) and this was determined using the relation of USEPA (USEPA, 2011).

$$\text{Target Hazard Quotient (THQ)} = \frac{EDI}{RFD} \quad (3)$$

Where; EDI = Estimated Daily Intake of Metal in mg/kg/day and RFD = Oral reference dose (Pb, Cd, Cu, As and Mn were 0.001 mg/kg/day, 0.0035 mg/kg/day, 0.04 mg/kg/day, 0.0003 mg/kg/day and 0.14 mg/kg/day respectively) (USEPA, 2011; Khan et al., 2009; Orajiaka-Uchegbu et al., 2020).

Life Carcinogenic Risk (CR) of Heavy Metals

Life Carcinogenic Risk (CR) of heavy metals was determined using the standard of USEPA (USEPA, 2011)

$$\text{Life Carcinogenic Risk (CR)} EDI \times CSF_{ing} \quad (4)$$

Where; EDI is the Estimated Daily Intake in heavy metals in mg/kg/day and $CSF_{ing}$is the Cancer Slope Factor due to ingestion (Pb, Cd and As were 0.0085 mg/kg/day, 0.38 mg/kg/day and 1.5 mg/kg/day respectively) (USEPA, 2011; Orajiaka-Uchegbu et al., 2020).

RESULTS AND DISCUSSION

Using AAS, heavy metals were analyzed in cassava roots and leaves samples from Ogwashi-Uku. The analysis of the samples revealed that the concentrations of most elements were significantly below the threshold limits established by the World Health Organization (WHO). Additionally, the total dissolved solids (TDS), electrical conductivity (EC), and pH levels were within the standards set by the U.S. Environmental Protection Agency (USEPA).

Concentration of heavy metals in cassava roots and leaves are presented in Table 1 and 2

Table 1: Mean Concentration of Heavy Metals in Cassava roots

Sample	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Cadmium (Cd)
Roots	6.29±0.0346	0.48±0.2100	8.49±2.2430	0.113±0.0058	0.1167±0.0833
Control	3.1667±0.0251	0.1867±0.0058	4.0067±0.0115	0.0007±0.0006	0.02±0.0100
Limits					

Table 2: Mean Concentration of Heavy Metals in Cassava leaves

Sample	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Cadmium (Cd)
Leaves	5.90667±0.6813	0.7833±0.2250	6.2633±0.5781	0.1367±0.0058	0.1033±0.0153
Control	3.333±0.1069	0.1667±0.00578	4.03±0.1308	0.1433±0.0153	0.0667±0.0115

Table 3: Estimated Daily Intake (EDI) of Cassava roots for Children and Adults

Sample	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Cadmium (Cd)
EDI for Children					
Roots	0.003462	0.000264	0.004673	6.22018E-05	6.606E-05
Control	0.001745	0.000105	0.002207	3.85321E-07	1.101E-05
EDI for Adults					
Roots	0.003774	0.000288	0.005094	6.78E-05	0.000072
Control	0.001902	0.000114	0.002406	4.2E-07	0.000012

Table 4: Computed Target Hazard Quotient (THQ) of Cassava roots for Children and Adults

	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Nickel (Ni)	Cadmium (Cd)
THQ for Children					
Roots	0.08656	0.013211	0.15578	0.000444	0.01887
Control	0.043624	0.005229	0.073578	2.75229E-06	0.0031455
THQ for Adults					
Roots	0.09435	0.0144	0.01698	0.000484	0.020571
Control	0.04755	0.0057	0.00802	0.000003	0.003429

Table 5: Computed Life Carcinogenic Risk (CR) of Cassava roots for Children and Adults

	Lead (Pb)	Cadmium (Cd)
CR for Children		
Roots	3.64954E-06	2.30092E-05
Control	7.95413E-07	1.46422E-05
CR for Adults		
Roots	3.64954E-06	2.30092E-05
Control	7.95413E-07	1.46422E-05

Discussion

The results of heavy metal concentrations Cr, Pb, Zn, Ni, and Cd are summarized in Table 1.

The levels of metal bioaccumulation in cassava roots reported in this study are generally below the safe limits set by WHO/FAO (2001). Additionally, there was evidence that metal concentrations decreased with increasing distance from each site. Cadmium (Cd) was found to bioaccumulate in cassava roots, likely due to low pH levels. Previous research has shown that cadmium is highly mobile and can be easily absorbed by plants through their roots, moving into woody tissue and eventually reaching the upper parts of the plant (Adu et al., 2012). This observation aligns with the findings of our study. Itanna (2002) and Muhammad et al. (2008) noted a direct relationship between cadmium levels in the root zone and its absorption by plants.

Zinc accumulated more in cassava roots (9.82 mg/kg) compared to the leaves, indicating effective mineral absorption by the roots. Chiroma et al. (2014) found that heavy metal concentrations varied in different parts of plants irrigated with sewage water; iron (Fe) accumulated in both roots and leaves, while zinc (Zn) was primarily found in the roots, with gradual translocation to the leaves. Amusan et al. (2003) studied heavy metal uptake in plants and found that lead (Pb) uptake increased significantly in waterleaf (Talinum triangulare) and okra (Abelmoschus esculentus), with leaf concentrations rising by 200% and 733%, respectively, and a 126% increase in okra fruit compared to the control.

Research has shown a direct relationship between lead levels in plants and traffic density (Turan et al., 2011; Shafiq et al., 2012; Verma et al., 2013). One possible explanation for this is that lead uptake may be influenced by soil pH and organic matter content. According to Sharma and Prasade (2010), only about 3% of lead in the soil is transferred from the roots to the shoots of plants, with the majority being absorbed through the leaves.

In this study, copper (Cu) concentration was highest in the roots (6.29±0.0346 mg/kg), and all samples of cassava were found to have copper levels within safe limits. Adelasoye and Ojo (2014) reported that cassava leaves near high-traffic areas contained higher concentrations of heavy metals compared to those near low-traffic roads. Similarly, plant leaves located closer to roads had higher metal concentrations than those 20 to 30 meters away.

Muhammad et al. (2008) investigated how three vegetables responded to copper toxicity and found that copper levels increased in both the roots and shoots. However, the increase in copper concentration was more pronounced in the roots. Generally, most of the copper accumulated in the roots, with only a small portion (10%) transported to the shoots. Moshen and Moshen (2008) also noted that the concentration of copper in the shoots was significantly affected by the copper concentration in the soil.

Statistical analysis indicated no significant differences in the bioaccumulation of heavy metals among different parts of the cassava plant, suggesting that cassava does not act as a hyper-accumulator. Additionally, studies have shown that leafy vegetables are more effective at accumulating heavy metals in their edible parts compared to grains and fruit crops, likely due to their higher transpiration rates (Jacob, 2010).

The results of estimated daily intake (EDI), Target Hazard Quotient (THQ) and Target Cancer Risks (TCR) of Cassava roots for Children and Adults using concentration of Cu, Pb, Zn, Ni, and Cd as presented in Table 3, 4 and 5.However, Table 5 shows no Life Carcinogenic Risk for Cu, Zn and Ni. This is due to the fact that they are generally not classified as carcinogen, and there is no established cancer slope factor (CSF) for CU, Zn and Ni.

The estimated daily intake (EDI), target hazard quotient (THQ) and life carcinogenic risk (CR) was calculated and results presented in Tables 2, 3 and 4.

The results of the EDI of individual heavy metals were determined by using equation suggested by Dhar et al (Dhar et al., 2020).

The EDI values of each heavy metal for children and adults are very low when compared with recommended limit of 1 as suggested by the New York State Department of Health. The ratio of EDI to rfd for this study is less than 1.0 which is also evident in table 3, implying that these metals do not pose any potential health risks (Dhar et al., 2020).

THQ values for the metals considered as shown in Table 4. They are also less than 1. This implies non-carcinogenic risk for children and adults consuming the cassava roots.

The absence of CSF for Cu, Zn, and Ni, the TCR was calculated only for Pb and Cd. The values calculated for TCR is presented in Table 5. USEPA permissible limit for TCR is 10^{-4} (USEPA, 2019). The target cancer risk (TCR) values found in this study are all below the limits recommended by the U.S. Environmental Protection Agency (USEPA).

CONCLUSION

The analysis of heavy metals in cassava roots and leaves collected near high voltage power lines in Ogwashi-Uku, Delta State, was performed using a Flame Atomic Absorption Spectrophotometer. The results detected the presence of Copper (Cu), Lead (Pb), Zinc (Zn), and Cadmium (Cd) in these samples. Importantly, all heavy metal concentrations were found to be below the limits set by the World Health Organization (WHO). While these metals can be toxic at high levels and may pose significant health risks with prolonged exposure, the evaluation of various health indices, including Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Total Cancer Risk (TCR), indicates that the levels of Cu, Pb, Cd, and Zn in the cassava roots and leaves do not pose a health threat to children or adults in the area. However, it remains essential to monitor the accumulation of these metals in water samples. Furthermore, the consumption of poorly processed cassava roots should be discouraged to prevent the introduction of these toxic metals into the human body.

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