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INVESTIGATING THE IMPACT OF PROXIMITY TO DUMPSITE ON MERCURY AND ARSENIC LEVELS IN CASSAVA (*Manihot esculenta*)

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ABSTRACT: *This study assessed the impact of proximity to dumpsite on mercury and arsenic levels in cassava tubers and peels. A total of eight soil samples and eight plant samples were collected at 10 m and 20 m away from the dumpsite. Two soil and two plant samples each were collected from the east, west, south and north of the dumpsite. The samples were collected from a depth of 0 to 10 cm. Cassava tubers were collected very close to where the soil samples were obtained. The heavy metal in both soil and cassava tuber showed no significant difference (t < 0.05) except with that found on the cassava peel gotten from 20 m away from the dumpsite in both Hg (9.086 mg/kg) and As (0.600 mg/kg). The soil properties showed low to strong association with the heavy metal concentration in the soil and that in the cassava tubers and peels. pH had strong correlation with Hg (r = 0.616) and a weak correlation with the As (r = 0.137) in the cassava tuber. It was found that the BAF of Hg and As in the tuber and peel were all greater than 1. The BTF of cassava tuber of both Hg and As were above 1, which is an indication that there was an effective translocation of these metals to the cassava tuber from the cassava peel. This implies that cassava has the capability of a good bio-accumulator for Hg and As.*

KEY WORDS: Dumpsite, Heavy metal, Mercury, Arsenic, Cassava.

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INTRODUCTION

Environmental pollution is a burden to humanity and a global challenge. It occurs at all spheres of the environment: hydrosphere, lithosphere and atmosphere. Anthropogenic activities contribute daily to environmental pollution (Osuji et al., 2004). Indiscriminate waste disposal, equipment failure, personnel negligence and sabotage are some of the human factors that contaminate the environment (Osuji et al., 2004). However, each pollution case is degrading to the environment as both biotic and abiotic components are either directly or indirectly affected (Ekweozor, 1985).

Heavy metals are among the contaminants in the environment. Though they are naturally occurring, however, their distribution and concentration are largely anthropogenic. Thus, heavy metals are important environmental pollutants, particularly in areas with high populations. Their presence in the atmosphere, soil and water, even at trace levels, can pose high risk to organisms. Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food quality (safety and marketability), crop growth (due to phytotoxicity) and environmental health (soil flora/fauna and terrestrial animals) (Ma et al., 1994; Masky & Calvert, 1990).

Poor waste management in most urban and suburban areas creates the critical passage for heavy metals into the environment. However, most farmers are ignorant of metals and their ecological implications. Thus, crop production is sometimes done in polluted and degraded environments. Cassava, a tropical food crop, is an important component in the diet of more than 800 million people round the world Food and Agricultural Organization (FAO, 2007). It is the third largest carbohydrate food source within the tropical regions, after rice and corn (Ceballos et al., 2004). Cassava constitutes an important functional food component by contributing carbohydrate, vitamins, iron, calcium and other nutrients which have marked health effects (Thompson & Kelly, 1990; Arai, 2002). Crops inherently take up toxic substances including heavy metals which are subsequently transferred along the food chain and cassava is not exempted (Singh et al., 2010). As such, the extent of heavy metal concentration in food crops is very critical to animal and human health. Hence, heavy metal contamination of the food items is one of the most important aspects of food quality assurance (Wang et al., 2005; Radwan & Salama, 2006; Khan et al., 2011). Contamination of foods by heavy metals has become a challenge for producers and consumers. The major channel through which heavy metals get to crops are their growth media (soil) from which these heavy metals are taken up through the roots (Lokeshwari & Chandrappa, 2006).

Research on the mechanism of heavy metal uptake by crops from contaminated soils has gained increasing attention as heavy metal accumulation in crops may lead to the lowering, damage and alteration of animal or human physiological functions through the food chain (Gupta, 1995). Crops show certain reactions to the increasing toxic elements concentration in soil, depending upon the sensitivity of plants, exposure intensity and chemical species. Although there exist previous studies on metal uptake by plants (Mishra & Dubey, 2006; Jan & Parray, 2016; Okon & Akwowo, 2017; Nasitu et al., 2017; Ahiakwo et al., 2018; Nwawuike & Ishiga, 2018; Rai et al., 2019; Alengebawy et al., 2021), there is dearth of information on the impact of dumpsite proximity on heavy metal bioaccumulation (Ejiogu et al., 2017; Ogbonna et al., 2020; Okereke et al., 2020). It is against this backdrop that this work assessed the concentration of mercury and arsenic and their proximate bioaccumulation in the cassava crop in near-by farmland.

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MATERIALS AND METHOD

Site Description

The study was carried out in an open waste dump site in Orji, Owerri North, Imo state, Nigeria. Orji, a satellite town to Owerri, is located within latitudes 5.5096 to 5.5333N and longitudes 7.0391 to 7.0667E. The area has a dense population. It is inhabited mostly by artisans, traders, civil servants, Imo State University students, businessmen and women.

Sample Collection

A total of eight soils and eight plant samples were collected at 10 m and 20 m away from the dumpsite in east, west, north and south direct. Two soil and two plant samples each were collected from the east, west, south and north of the dump site. The samples were collected from a depth of 0 to 10 cm using a trowel. Cassava tubers were collected very close to where the soil samples were obtained (10 m and 20 m). The cassava tubers collected were packaged in well-labeled transparent sterile cellophane bags.

Sample Preparation

All the obtained soil samples were air dried, crushed and sieved through a 2 mm mesh and repackaged in labeled ziplock bags before subjecting them to laboratory analysis. The cassava tubers harvested from the farms near the dumpsite were separately washed with fresh running water to remove sand, dirt and other contaminants and peeled. Furthermore, the cassava tuber samples were washed with deionised water for more cleaning. The cassava tuber samples were sliced separately using a decontaminated stainless steel knife, packaged in a paper bag and dried in the oven at 60^oC until constant weight was obtained. The cassava peels were also processed in the same way as cassava tubers. Prior to digestion and heavy metal analysis, the dried cassava tubers and peels were then ground with porcelain mortar and pestle. Precaution was taken to avoid contamination by decontaminating with ethanol after each grinding.

Laboratory Analysis

Particle size distribution otherwise known as mechanical analysis was determined by hydrometer method (Bouyoucos, 1962) using sodium hexametaphosphate as dispersant. The 'textured triangular diagram' (Loganathan, 1984) was used to determine textural class. Soil pH was measured in water suspension (1:2.5) using the glass electrode coupled pH meter. The electrical conductivity (EC) was measured using water suspension too (1:5) using EC meters. The method put forth by Black (1965) was employed in the determination of the soil organic carbon. The ammonium acetate (NH_4OAC) method at pH 7.0 was used to extract the cation exchange capacity (CEC) and was determined by percolating the NH_4OAC extract by 10% NaCl (Chapman, 1995). One gram of each of the sieved soil and cassava plant samples was digested using the nitric/perchloric acid digestion procedure, as described by Odu et al. (1986). The concentrations of heavy metals, Hg and As were determined using atomic absorption spectrophotometer following the standard procedures described by APHA (1995).

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Environmental Risk Assessment

Bioaccumulation Factor (BAF)

The heavy metal concentration in the cassava tuber, peel and soil were used in calculating the bioaccumulation factor as the ratio of heavy metal concentration in the cassava tuber (Ct) and cassava peel (Cp) to the heavy metal concentration in corresponding soil samples from each of the sampling distances away from the dumpsite.

$$BAF(Ct) = \frac{T_{mc}}{S_{mc}} \quad (1)$$

$$BAF(Cp) = \frac{P_{mc}}{S_{mc}} \quad (2)$$

Where :

T_{mc} = Tuber metal concentration

P_{mc} = Peel metal concentration

S_{mc} = Soil metal concentration

BAF > 1 indicates effective accumulation (Cluis, 2004).

Bio-translocation Factor (BTF)

The rate at which metals concentrated on the cassava peel were transferred to the tuber was determined using bio-translocation factor (BTF). According to Nwawuike and Ishiga (2019), bio-translocation factor is given as concentration in leaf divided by concentration in root. In line with this formula, this study formulated bio-translocation factor for cassava tuber as follows:

$$BTF = \frac{T_{mc}}{P_{mc}} \quad (3)$$

Where:

T_{mc} = Tuber metal concentration;

P_{mc} = Peel metal concentration

BTF > 1 indicates effective translocation (Rezvani and Zaefarian, 2011)

Data Analysis

Soil and plant data collected was subjected to descriptive statistical analysis to determine the mean and standard deviation. T-Test was used to compare the level of heavy metal concentration between the two proximities away from the dumpsite. Comparison of each of the heavy metals with its permissible level were illustrated in graphs using MS Excel, 2010.

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Correlation analysis was used to compare the relationship between soil properties and heavy metal concentration in the soil and cassava tubers and peels.

RESULTS AND DISCUSSION

The Soil Physicochemical Properties of the Study Area

The results of the physicochemical parameters of the dumpsite soil samples determined are shown in Table 1. The texture of the soil collected from the dumpsite had a high percentage of sand relative to clay and silt. At 10m and 20m away from the dumpsite, the highest mean of % sand, % clay and % silt were (89 %, 87.2 %), (6.72 %, 8.8 %) and (4.25 %, 3.8 %) respectively. The mean for pH and OM ranged from 6.7 to 7.2% and 2.85 to 2.92% respectively.The highest value was recorded in soil collected at 10m away from the dumpsite. The soil pH around the farmlands near the dumpsite were less acidic. This result agrees with the findings of Uba et al. (2008). The highest electrical conductivity value of 5.0 dS/m and CEC (31 Cmol/kg) were obtained from soil collected 20m away from the dumpsite. The higher values of electrical conductivity and CEC found at 20 m away from dumpsite implies that there are more presence of metals which is one of the constituents of refuse dumpsite and more soluble salts in the soil at that proximity (Arias et al., 2005; Karaca, 2004; Singer & Munns, 1999). The high values of electrical conductivity and CEC is due to the amount of clay content present in the soil (Madzhieva et al., 2014).

Table 1: Soil Physicochemical Properties of the Study Area

Direction	FS (%)	CS (%)	TSand (%)	Clay (%)	Silt (%)	pH	OM (%)	EC (dS/m)	CEC (Cmol/kg)
	10 meters								
East	23	64	87	6	7	7.6	2.89	5	32.8
West	30	59	89	9	2	7.3	3.03	5	30.4
South	28	61	89	6	5	6.2	2.13	2	24
North	31	60	91	6	3	7.5	3.65	6	29.6
Mean ± SD	28±1.8	61±1.1	89±0.8	6.75±0.8	4.25±1.1	7.2±0.3	2.92±0.3	4.5±0.9	29.2±1.9
	20 meters								
East	24	65	89	6	5	7.2	2.68	7	37.6
West	26	54	80	17	3	7.2	3.44	5	31.2
South	32	57	89	6	5	7	2.13	5	23.2
North	31	61	92	6	2	5.3	3.16	3	32.0
Mean ± SD	28.3±1.9	59.3±2.4	87.5±2.6	8.8±2.8	3.8±0.8	6.7±0.5	2.85±0.3	5±0.8	31.0±3.0

Note: FS = Fine sand, CS = Coarse sand, Tsand = Total sand

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Heavy Metal Concentration in Soil, Cassava Tuber and Cassava Peel

The results of the mean concentration of heavy metals in the soil and cassava tuber samples are shown in Table 2. The heavy metal in both soil and cassava tuber showed no significant difference ($t < 0.05$) except with that found on the cassava peel gotten from 20 m away from the dumpsite in both Hg (9.086 mg/kg) and As (0.600 mg/kg). The results in Figures 1a and 2 show that the mean of Hg concentrations in soil (4.190 mg/kg, 4.795 mg/kg), cassava tuber (10.60 mg/kg, 10.60 mg/kg) and the cassava peel (7.571 mg/kg, 9,086 mg/kg), surpasses the soil (2 mg/kg) and food (1 mg/kg) permissible limit according to International standard and European standard at both distances (10 m and 20 m). Also according to the same international and European standard of 20 mg/kg in soil and 0.2 mg/kg in food, the As concentration in the soil (0.384 mg/kg, 0.152 mg/kg) in both distances are below the permissible limit while the cassava peel (0.462 mg/kg, 0.60 mg/kg) and cassava tuber (0.876 mg/kg, 0.876 mg/kg) were well above the permissible limit (Figures 1b and 2).

Table: The Heavy Metal Concentrations of Mercury and Arsenic in both Soil and Cassava Plant Near the Farmland Soil in the Study Area

Direction	Hg_{Soil}	Hg_{Peel}	Hg_{Tuber}	As_{Soil}	As_{Peel}	As_{Tuber}
	mg kg^{-1}					
	10 meters					
East	4.038	6.057	10.095	0.129	0.554	1.107
West	3.029	8.076	12.114	0.166	0.554	0.922
South	5.855	10.095	10.095	1.129	0.369	0.738
North	3.836	6.057	10.095	0.111	0.369	0.738
Mean ± SD	4.190±0.6	7.571±1.0^{b}	10.600±0.5	0.384±0.20	0.462±0.1^{b}	0.876±0.10
	20 meters					
East	4.846	8.076	12.114	0.111	0.369	0.922
West	3.23	10.095	10.095	0.184	0.738	0.738
South	6.663	10.095	12.114	0.148	0.738	0.922
North	4.442	8.076	8.076	0.166	0.554	0.922
Mean ± SD	4.795±0.7	9.086±0.6^{a}	10.600±1.0	0.152±0.02	0.600±0.1^{a}	0.876±0.04

Note: Hg = Mercury. As = Arsenic

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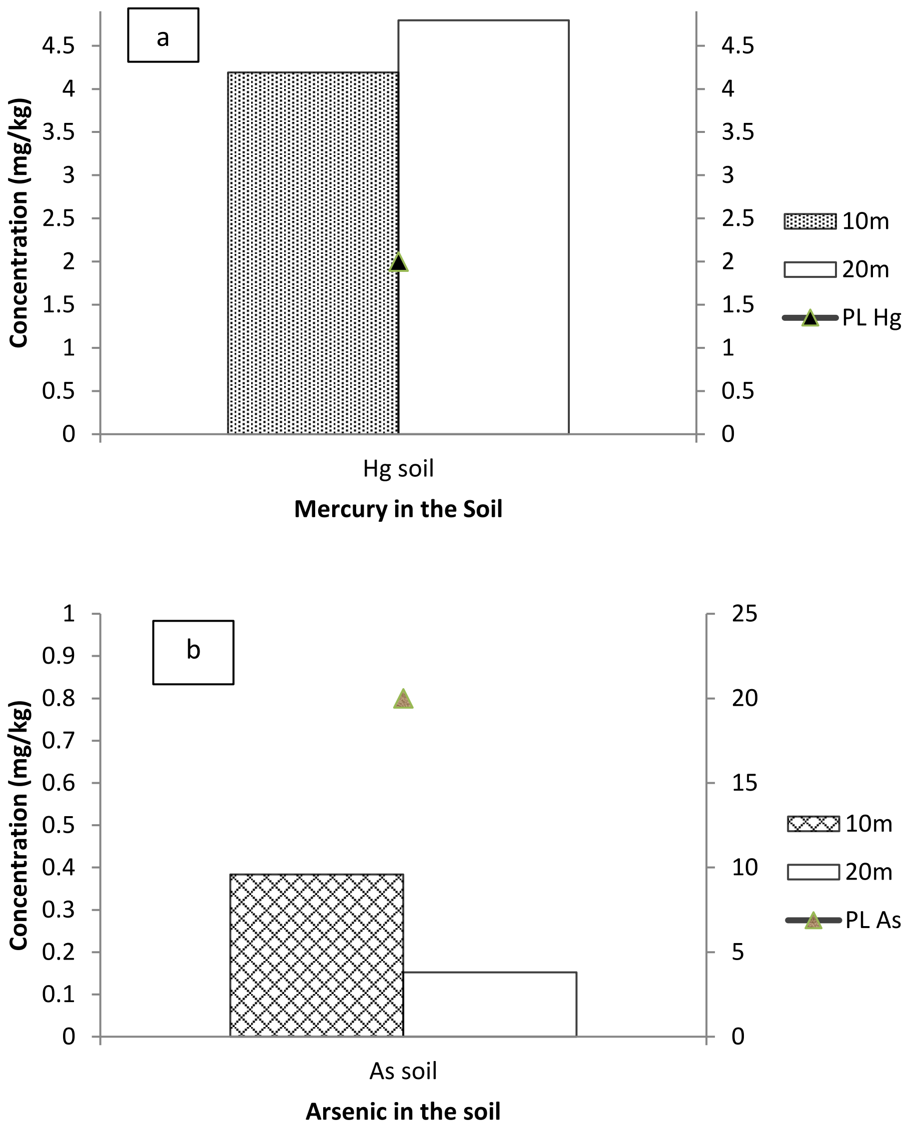

Figure 1: Heavy metal concentration in farmland soil and soil permissible limit for Hg and As World Health Organization/Food and Agricultural Organization (WHO/FAO, 2001)

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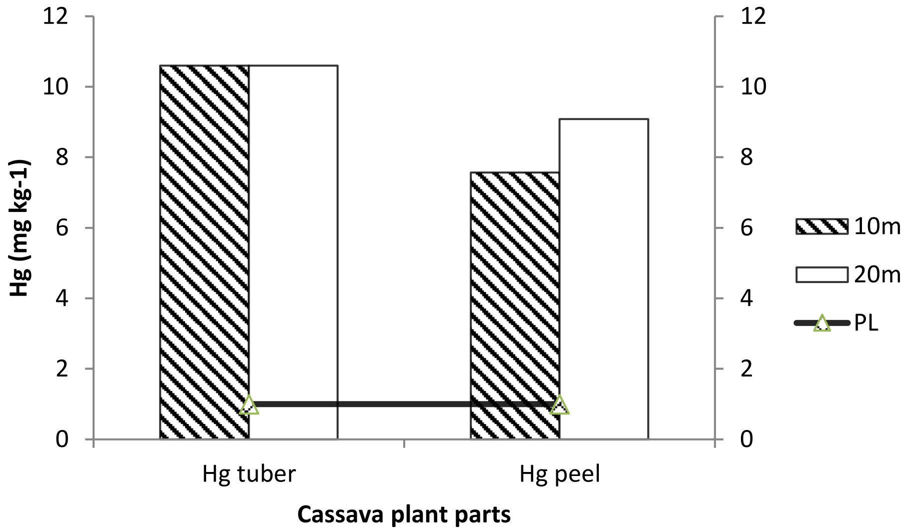

Figure 2: Mercury concentration from cassava plant harvested from the farmland soil and Hg permissible limit for Food World Health Organization/Food and Agricultural Organization (WHO/FAO, 2001)

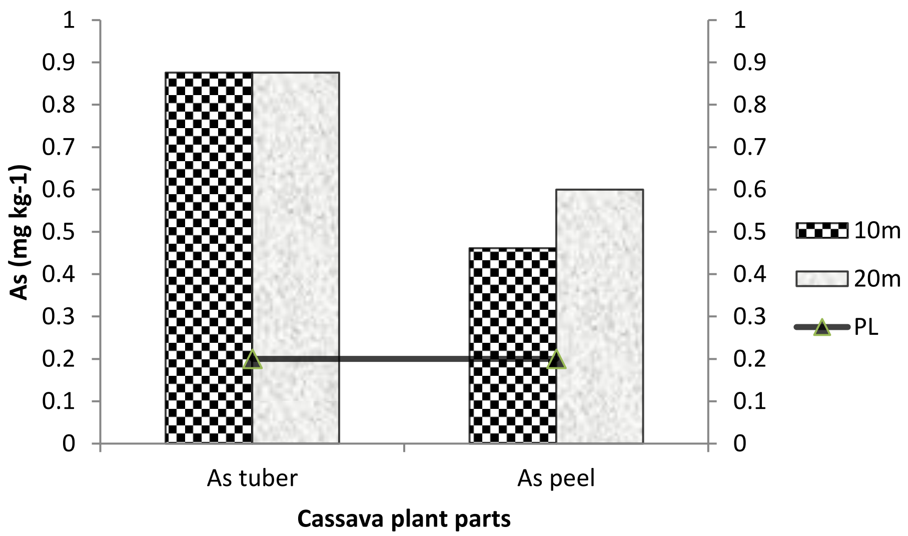

Figure 3: Arsenic concentration from cassava plant harvested from the farmland soil and As permissible limit for Food (Codex &World Health Organization/Food and Agricultural Organization WHO/FAO, 2015)

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Relationship between Soil Properties and Heavy Metal Concentration in both Soil and Cassava Plant Parts

The results of the correlation between soil properties and heavy metal concentrations in both soil and cassava tubers and peels are presented in Table 3. The soil properties showed low to strong association with the heavy metal concentration in the soil and that in the cassava tubers and peels. The pH showed strong correlation with Hg in the tuber (r = 0.616) and a weak correlation with the As (r = 0.137) in the tuber. This implies that as the pH increases, the concentration of heavy metals going into the tuber decreases and as the pH decreases, the concentrations of heavy metals going into the tuber increases. This variation in pH may affect the biogeochemical cycling and availability of soil nutrients. This was supported by the works of Arias et al. (2005). OM had a strong negative correlation with Hg (r = -0.850) and As (r = -0.542) in the soil, an indication that an increase in OM will trigger reduction in heavy metal availability in the soil. The OM also showed weak to strong negative correlation in the cassava tuber and peel respectively for both metals. This explains the fact that OM also determines the rate at which heavy metals bio-translocate in the plant tissues. Clay content and CEC showed strong negative correlation with the heavy metal concentration in the soil and a weak negative correlation with heavy metal concentration the cassava tubers and peels. This result implies that an increase in the soil clay content and CEC reduces bio-accumulation of metal cassava tubers and peels but plays a little part in bio-translocation.

Table 4.3: Relationship between Soil Physicochemical Properties and the Heavy Metal Concentration in both Soil and Cassava

	pH	*OM*	*Hg soil*	*As soil*	*Hg tuber*	*As tuber*	*Hg peel*	*As peel*	*%sand*	*%clay*	*%silt*	*EC*	*CEC*
pH	1												
OM	0.21	1											
Hg soil	0.32	**-0.85**	1										
As soil	0.40	**-0.54**	0.42	1									
Hg tuber	**0.62**	-0.40	0.18	-0.16	1								
As tuber	0.14	-0.20	0.02	-0.44	0.14	1							
Hg peel	0.35	-0.53	0.46	0.47	0.18	-0.42	1						
As peel	0.05	0.00	-0.02	-0.37	0.06	0.19	0.43	1					
%sand	0.38	-0.18	0.34	0.05	-0.08	0.19	-0.39	**-0.55**	1				
%clay	0.20	0.43	**-0.53**	-0.13	-0.03	-0.39	0.41	**0.56**	**-0.89**	1			
%silt	0.34	**-0.56**	0.48	0.19	0.23	0.46	-0.10	-0.10	-0.11	-0.35	1		
EC	**0.76**	0.34	-0.28	**-0.74**	0.57	0.19	-0.41	-0.03	-0.14	0.08	0.10	1	
CEC	0.19	0.50	**-0.57**	**-0.54**	-0.04	0.35	**-0.52**	-0.24	-0.09	0.10	-0.04	**0.56**	1

Bioaccumulation (BAF) and Bio-Translocation Factor (BTF) of Cassava Near Dumpsite

The results of the bioaccumulation factors of heavy metals in peel and tuber of cassava are shown in Table 4.4. It was found that the BAF of Hg and As in the peel and in the tuber were all greater than 1. This indicates that cassava has high efficiency in bioaccumulation of these metals. However, an increase was observed with the peel further away from the dumpsite with the tuber showing a decreasing trend. This decrease observed might be as a result of less anthropogenic effect arising from waste from the dumpsite or influence of soil properties.

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The BTF of the cassava tuber in both distances away from the dumpsite are presented in Table 4.4. The results indicate higher translocation at 10 meters away from the dumpsite in both Hg and As, which decreases moving further away from the dumpsite (20 meters). The BTF of cassava tuber of both Hg and As were above 1, which is an indication that there was an effective translocation of these metals to the cassava tuber from the cassava peel. This implies that cassava has the capability of a good bio-accumulator for Hg and As. The decrease obtained moving further away from the dumpsite could be due to variation in clay and CEC content in the soil or as a result of lower anthropogenic activities from the dumpsite.

Table 4.4: Environmental Risk Assessment of Cassava Plant Parts

Distance from dumpsite	Bioaccumulation				Bio-translocation	
	Hg_{peel}	Hg_{tuber}	As_{peel}	As_{tuber}	Hg	As
	(mg/kg)					
10 meters	1.80	2.53	1.20	1.90	1.40	1.90
20 meters	1.89	2.21	3.95	1.46	1.17	1.46

CONCLUSION

This study revealed that plants grown near a dumpsite have the high risk of bioaccumulation of heavy metal beyond the permissible limits. This is because the concentrations of mercury and arsenic in the cassava plants were relatively high (BAF and BTF > 1) and are linked to high concentrations of the metals in the soil. The data obtained showed that mercury concentration in the dumpsite soils is above the permissible level while concentration of arsenic in the soil is below the permissible limit. This study concluded that the availability of heavy metals in the soil depends on the type and quantity of wastes at the dumpsite. Also, heavy metal availability is highly controlled by soil pH, OM, clay content and CEC of the soil. However, there is a need for environmental education to inform farmers of the dangers of cultivating near dumpsites. Also, proper and safer methods of waste management should be adopted by the government.

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