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Risk Assessment of Heavy Metals Associated with Fluted Pumpkin (Telfairia Occidentalis, Tefoc) Cultivated in Selected Farmlands in Kaa Community, Ogoni, Rivers State, Niger-Delta

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Abstract-* Agriculture remains the primary source of livelihood among the Ogoni people of the Niger Delta, with vegetables playing a vital role in food security and nutrition. High concentrations of heavy metals in soil and crops can have significant consequences for both the environment and human health. The study aimed to evaluate the concentrations of heavy metals in agricultural soil and Telfairia occidentalis (fluted pumpkin leaf) samples, as well as the associated risk. Soil and T. occidentalis samples were collected from five farmlands (K1–K5) in Kaa, a village in the Ogoni region of Rivers States, Niger-Delta, and analysed for specific heavy metals using Atomic Absorption Spectrophotometer following standard digestion procedures. The results of the analysis showed that the soil samples had different concentrations of heavy metals within the following ranges: Fe (2.053-5.307 mg/kg), Mn (1.843-2.873 mg/kg), Zn (3.380-4.433 mg/kg), Cd (0.070-0.850 mg/kg), and Ni (0.320-0.513 mg/kg). No traces of Co were found in any of the samples. In T. occidentalis samples, the amounts of Fe ranged from 1.787 to 4.167mg/kg, Zn ranged from 0.010 to 2.330mg/kg, Mn ranged from 0.826 to 1.053mg/kg, Cd ranged from 0.063 to 0.723mg/kg, and Ni ranged from 0.020 to 0.477mg/kg. Co was absent in all of the samples. The heavy metals analysis revealed that the concentrations of these metals in the soil were found to be within the maximum levels allowed for agricultural soils according to standard criteria. Therefore, the soil in the research region is considered to be of good quality and safe. The metal accumulation patterns reported in T. occidentalis were generally minimal, except for Cd. The average transfer factor (TF) of heavy metals in T. occidentalis throughout the site indicates that Cd had the greatest mean TF (0.86). The study found that the levels of Cd, Ni, Fe, Zn, and Co in the soil and T. occidentalis in the study sites were moderately contaminated, with a contamination factor (CF) ranging from 1 to 3. The Pollution Load Index (PLI) for all the heavy metals (Cd, Mn, Ni, Fe, and Zn) suggests that the contamination levels are rather low. The concentration of Cd in the soil was found to be quite high, measuring 31850.85. The highest ErF (51725.42) was observed in T. occidentalis and soil (38799.91) at sites K5 and K1. These places show an indication of an increase in pollution potential. The Incremental Lifetime Cancer Risk (ILCR) associated with the consumption of T. occidentalis may provide a cancer risk, since the calculated values surpass the maximum threshold of 1×10-4. Based on the results, it can be concluded that consuming T. occidentalis grown in the examined habitat poses no significant danger.. Continuous monitoring of soil quality and regulation of agrochemical use are therefore recommended to safeguard environmental quality and public health.

***Keywords:* Heavy Metals; Hazard Index; Hazard Quotient; Health Risk; Telfairia Occidentalis; AAS**

I. INTRODUCTION

Agriculture is the main source of living and income as it ensures the availability of food among the Ogonis in the Niger Delta. Vegetables are an important source of human diets as they provide specific essential nutrients for the human body (Momta et al., 2024). Their consumption is recommended not only to prevent avitaminosis, but also to reduce the incidence of important diseases such as cancer, cardiovascular diseases, and obesity. However, their production depends on the quality of soil. Fertile soils are crucial for agriculture since they play a vital role in providing the globe with an increased food supply. Therefore, they are an essential component of the environment and ecosystem. It serves as a vital natural resource for facilitating plant growth and acts as a storage facility for the material biogeochemical cycle. Due to its tremendous binding capability, it is often the primary recipient of environmental contamination, making it very sensitive to changes in the environment (Sumithra et al., 2013). Anthropogenic activities frequently lead to the pollution of agricultural soils, either directly or indirectly.

Heavy metal pollution in soil is a significant worldwide environmental issue that endangers humans, animals, microorganisms, and plants. It also leads to the degradation of land surfaces and groundwater (Yang et al., 2010). Heavy metals provide the greatest risk as pollutants in agricultural soils and plants. Similarly, the physiochemical properties of soil significantly influence the concentration of heavy metals and their availability to plants. The concentration of heavy metals in the soil is also influenced by the quantity of fertilisers and pesticides applied to cultivate the plants.

Vegetables can become contaminated with heavy metals from the soil, which can lead to significant health issues (Lim et al., 2008; Zhang et al., 2020). Leafy plants, such as lettuce, are known to have the ability to accumulate heavy metals in their tissues without showing any signs of toxicity (Ramos et al., 2012; Manzoor et al., 2018). The present study was therefore conducted to evaluate the levels of heavy metals in T. occidentalis (fluted pumpkin (FP)) commonly known as Nya-ee by the people of Kaa from selected farmlands in Kaa, an Ogoni community, Rivers State, Niger-Delta, Nigeria and the risk associated.

II. MATERIALS AND METHODS

The study was carried out on five (5) agricultural farmlands located in Kaa, a community in Ogoni, Khana Local Government Area of Rivers State in the Niger-Delta. Kaa community lies between Latitude 4˚34′40.7″N and Longitude 7˚21′54.5″E. The Kaa people, like every other Ogoni community, are predominantly farmers and fishermen that produce food (crops and fish) in commercial quantity. They are described as the food basket of the Eastern Niger-Delta due to their food production. Kaa is also a center for commercial activities because of the presence of a daily market. Apart from farming and fishing activities in the study area, other anthropogenic activities such as construction, transportation (including illegal oil bunkering) take place. Thus, the farmlands used for the study is purely for agricultural activities.

Table 1: Coordinates of Sampling Areas

			Locations		
	K1	K2	K3	K4	K5
Latitude	4˚34´15.9″N	4˚34´43.8″N	4˚35´0.66″N	4˚34´46.8″N	4˚35´17.8″N
Longitude	7˚22´8.11″E	7˚21´48.2″E	7˚22´48.4″E	7˚21´58.8″E	7˚22´11.7″E

Sample collection: Soil samples from the various sampling locations were collected with a soil auger at a depth of 0-20cm in a well labeled polythene bags and were quickly transported to the laboratory for analysis. T. occidentalis (fluted pumpkin leaf) were also obtained directly from selected farmlands in various sampling locations in a well labeled polythene bag and were transported to Chemistry laboratory of Ignatius Ajuru University of Education, Port Harcourt, Rivers State for preparation.

Sample preparation and digestion: The soil samples were evenly distributed on glass plates and subjected to air-drying in an oven at a temperature of 105°C for duration of six hours. Three soil samples, each weighing 5 grammes, were measured and transferred into a beaker with a volume of 100 cm3. The samples underwent digestion using 20 cm3 of aqua regia (3HCl:1HNO3) for a duration of 2 hours on a heated plate within a fume cupboard until the appearance of white vapours. The concentrated solution was mixed with 50 cm3 of deionized water and cooled. It was then passed through Whatman filter paper into a 100 cm3 volumetric flask. The solution was prepared by adding distilled water and then stored in a high-density plastic bottle for subsequent metal analysis (Awode et al., 2008; Ekpete & Owhoeke, 2019).

In addition, T. occidentalis samples underwent a thorough washing process using deionized water to eliminate any soil particles. T. occidentalis samples were cut into pieces and left to dry in the air for 5 days. They were then dried in an oven and ground into a fine powder using a mortar and pestle before extraction. The ground samples were sifted using a 125 µm mesh to achieve greater sample uniformity. Three duplicate samples of each T. occidentalis (5 g) were individually weighed into porcelain crucibles and then digested with 10 cm3 of 98% concentrated HNO3. The combination was subjected to heat in a water bath at a temperature of 150°C for 1 hour until a light-colored solution was achieved by full dissolution. The solution was diluted to a volume of 25 cm3 using distilled water and then passed through a Whatman filter paper. The liquid that passed through the filter was kept in a container made of plastic for the purpose of examining the metal content (Ladipo & Doherty, 2011; Ekpete & Owhoeke, 2019).

Sample Analysis for heavy metals: The amounts of the heavy metals in the digested samples were determined using the Atomic Absorption Spectrophotometer (AAS). The analysed samples contained the following metals: Cadmium (Cd), Nickel (Ni), Iron (Fe), Manganese (Mn), Zinc (Zn), and Cobalt (Co).

Statistical Analysis: The data was analysed in terms of its distribution among the studied parameters in soil and T. occidentalis using basic statistical criteria such as mean ± standard deviation. The heavy metals data was analysed using Statistical version 16.0 software.

III. INDEX MODELS FOR RISK ASSESSMENT

Assessment of transfer factor: The Transfer Factor (TF) is the fraction of the levels of concentration of heavy metals in a plant to the levels of concentration in the soil. The Transfer factors (TF) was based on the method described by Harrison and Chirgawi, (1989)

$$TF = \frac{\text{concentration of heavy metals in plant (mg/kg)}}{\text{Concentration of heavy metals in soil (mg/kg)}} \qquad (1)$$

Contamination factor: The Contamination Factor (CF) was assessed by calculating the fraction of the concentration of a given element in an environmental media divided by the background concentration of the element (Amin et al., 2018).

$$\text{Contamination factor (CF)} = \frac{Cm}{Bn} \qquad (2)$$

The variable "Cm" represents the concentration of heavy metals in soil. The background concentration (Bn) of the heavy metals was determined using data from a prior study conducted by Patrick-Iwuanyanwu and Chioma in 2017. The contamination factor (CF) value of less than 1 indicates low contamination, while CF values between 1 and 3 represent moderate contamination. CF values between 3 and 6 indicate severe contamination, and CF values greater than 6 indicate very high contamination.

Pollution Load Index (PLI): This can be determined using Equation (Topmlinson et al., 1980).

$$PLI = (CF_1 \times CF_2 \times CF_3 \ldots CF_n)^{1/n} \qquad (3)$$

where CF = contamination factor, n = number of study metals, Cmetal = metal pollutant concentration in soil; Cbackground = metal background value.

Ecological risk index assessment: The ecological risk index (ER) was employed to assess the potential ecological danger associated with the accumulation of heavy metals in soil. The integrated potential ecological risk index (RI) is a measure that integrates the individual values of ecological risk (ER) for each heavy metal. The specific calculation formula is as follows:

$$C_f = C_{n(sample)} / C_{n\ (Crust)} \qquad (4)$$

$$ER = T_r \times C_f$$

$$RI = \sum Er$$

where Tr is the toxicity coefficient and CF is the pollution factor.

Estimated Daily Intake (EDI): This was calculated using the equation:

$$EDI = (Cmetal \times Dfood\ intake)/BWaverage \quad (5)$$

Where:
Cmetal refers to the concentration of metal in vegetables, measured in milligrammes per kilogramme (mg/kg). Food intake refers to the amount of food consumed by an individual on a daily basis, measured in kilogrammes per person. According to the World Health Organisation (WHO) guideline from 1989, the recommended daily intake is 0.3 milligrammes per kilogramme of body weight. The term BWaverage represents the average body weight of an individual, assumed to be 60 kilogrammes. This measurement is used to assess the risk of acquiring any sort of cancer as a result of long-term exposure to a carcinogenic pollutant. The RfD, or Reference Dose, is a measure of the potential health risk from exposure to a substance. It is expressed as the oral slope factor in milligrams per kilogramme per day. The USEPA, or United States Environmental Protection Agency (2000), provides guidelines for determining this factor.

Hazard Quotient: This was calculated using the equation:

$$HQ = EDI/RfD \quad (6)$$

Where:
RfD is Oral slope factor in mg/kg-day which based on USEPA guideline (USEPA, 2000) and EDI is Estimated Daily Intake.

Hazard Index (HI): The hazard index can be calculated using Equation:

$$HI = \sum HQ = HQ_{Fe} + HQ_{Cd} + HQ_{Cr} + HQ_{Ni} \quad (7)$$

HI > 1 implies potential non-carcinogenic effects. If the total potential carcinogenic health risk (TCR) $>1 \times 10{-}4$, it indicates a high carcinogenic risk to human body. If the TCR $< 1 \times 10{-}6$, it means the potential carcinogenic health caused by heavy metal exposure can be negligible.

IV. RESULTS

Table 2: Levels (mg/kg) of heavy metals in soil and T. occidentalis (fluted pumpkin) (FP) from the various sampling locations

Location	Cd	Ni	Fe	Zn	Mn	Co
K1(Soil)	0.677±0.020	0.457±0.012	3.330±0.025	3.380±0.030	1.990±0.026	ND
K1(FP)	0.527±0.023	0.020±0.000	2.520±0.111	2.330±0.052	0.590±0.017	ND
K2(Soil)	0.070±0.017	0.320±0.050	2.053±0.050	3.673±0.127	1.903±0.025	ND
K2(FP)	0.063±0.031	0.203±0.021	1.870±0.03	0.397±0.025	0.897±0.025	ND
K3(Soil)	0.853±0.006	0.460±0.017	5.307±0.025	3.563±0.012	1.843±0.056	ND
K3(FP)	0.723±0.021	0.397±0.012	4.167±0.536	2.037±0.012	0.597±0.025	ND
K4(Soil)	0.827±0.012	0.513±0.015	5.173±0.012	4.433±0.567	2.270±0.017	ND
K4(FP)	0.707±0.012	0.443±0.038	4.090±0.036	2.017±0.012	0.917±0.032	ND
K5(Soil)	0.767±0.012	0.420±0.017	3.097±0.006	3.693±0.109	2.873±0.055	ND
K5(FP)	0.590±0.03	0.333±0.045	1.787±0.09	2.073±0.045	1.053±0.057	ND
WHO/FAO(Soil)	1.0	50	10	200	12	50
WHO/FAO(FP)	0.2	0.1	48	6.0	0.2	0.05

ND=Not Detected; FP= Fluted Pumpkin

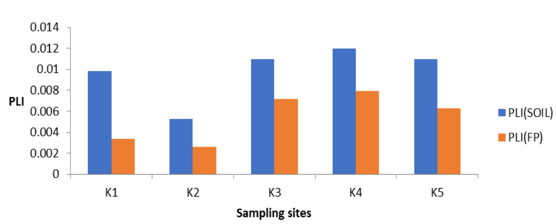
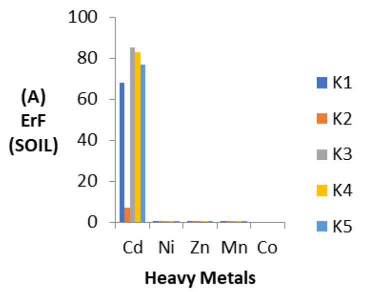


Fig 1. Pollution load index (PLI) of heavy metals in soil and T. occidentalis from various sampling locations



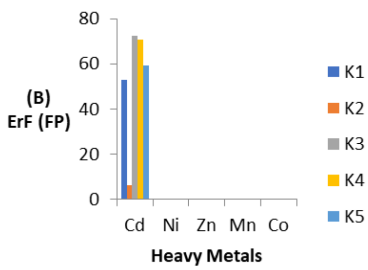
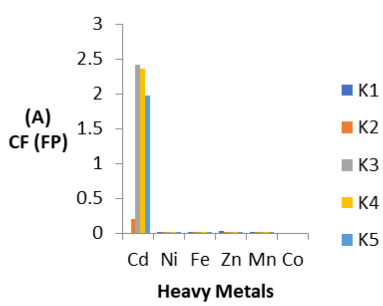


Fig 2(A and B): Ecological risk factor (ErF) of heavy metals in soil and T. occidentalis (fluted pumpkin) (FP) from the various sampling locations



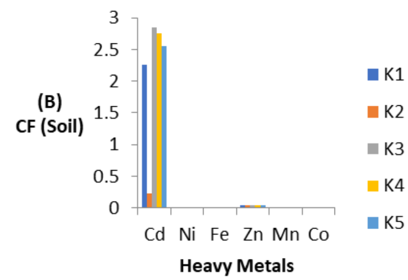
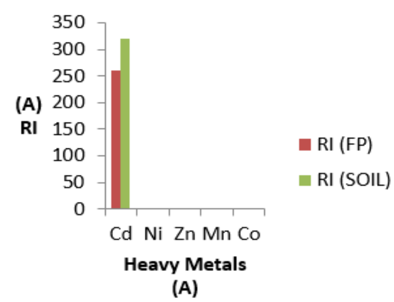


Fig 3(A and B): Contaminated factor of heavy metals in T. occidentalis and soil from various sampling locations



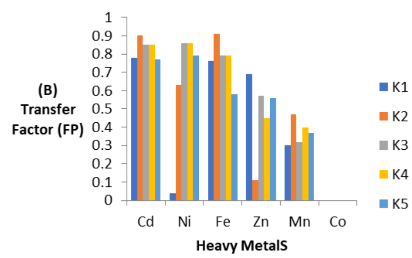


Fig 4: (A) Potential ecological risk factor (RI) of heavy metals in soil and T. occidentalis (fluted pumpkin) (FP) from the various sampling locations
Fig 4: (B) Transfer factor of heavy metals in T. occidentalis (FP) from the various sampling locations

Table 3. CDIing for Heavy Metals in Soils in both adults and children

CDI	Cd		Ni		Fe		Zn		Mn	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
K1	9.27×10^{-7}	2.16×10^{-5}	6.26×10^{-7}	1.46×10^{-5}	4.56×10^{-6}	1.06×10^{-4}	4.63×10^{-6}	1.08×10^{-4}	2.73×10^{-6}	6.36×10^{-5}
K2	9.59×10^{-8}	2.24×10^{-6}	4.38×10^{-7}	1.02×10^{-5}	2.81×10^{-6}	6.56×10^{-5}	5.03×10^{-6}	1.17×10^{-4}	2.61×10^{-6}	6.08×10^{-5}
K3	1.17×10^{-6}	2.73×10^{-5}	6.30×10^{-7}	1.47×10^{-5}	7.27×10^{-6}	1.70×10^{-4}	4.88×10^{-6}	1.14×10^{-4}	2.52×10^{-6}	5.89×10^{-5}
K4	1.13×10^{-6}	2.65×10^{-5}	7.03×10^{-7}	1.64×10^{-5}	7.09×10^{-6}	1.65×10^{-4}	6.07×10^{-6}	1.42×10^{-4}	3.11×10^{-6}	7.26×10^{-5}

K5	1.05×10^{-6}	2.45×10^{-5}	5.75×10^{-7}	1.34×10^{-5}	4.24×10^{-6}	9.90×10^{-5}	5.06×10^{-6}	1.18×10^{-4}	3.94×10^{-6}	9.18×10^{-5}

Table 4. CDIing for Heavy Metals in (T. occidentalis) Fluted Pumpkin in both adults and children

CDI	Cd		Ni		Fe		Zn		Mn	
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
K1	1.35E-03	1.09E-02	5.12E-05	4.16E-04	6.46E-03	5.24E-02	5.97E-03	4.84E-02	1.51E-03	1.23E-02
K2	1.61E-04	1.31E-03	5.20E-04	4.22E-03	4.79E-03	3.89E-02	1.02E-03	8.25E-03	2.30E-03	1.86E-02
K3	1.85E-03	1.50E-02	1.017E-03	8.25E-03	1.07E-02	8.66E-02	5.22E-03	4.23E-02	1.53E-03	1.24E-02
K4	1.81E-03	1.47E-02	1.13E-03	9.20E-03	1.05E-02	8.50E-02	5.17E-03	4.19E-02	2.35E-03	1.91E-02
K5	1.51E-03	1.23E-02	8.53E-04	6.92E-03	4.58E-03	3.71E-02	5.31E-03	4.31E-02	2.70E-03	2.19E-02

Table 5: HQ/HI for Heavy Metals in Soils in both adults and children

CDI	Cd		Ni		Fe		Zn		Mn		HI	HI
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
K1	9.27E-04	2.16E-02	3.13E-05	7.30E-04	6.517E-06	1.52E-04	1.54E-05	3.60E-04	1.95E-05	1.05E-02	1.000E-03	2.33E-02
K2	9.59E-05	2.24E-03	2.19E-05	5.11E-04	4.018E-06	9.37E-05	1.68E-05	3.91E-04	1.86E-05	1.99E-02	1.572E-04	3.67E-03
K3	1.17E-03	2.73E-02	3.15E-05	7.35E-04	1.039E-05	2.42E-04	1.63E-05	3.80E-04	1.80E-05	1.30E-02	1.245E-03	2.90E-02
K4	1.13E-03	2.64E-02	3.51E-05	8.20E-04	1.012E-05	2.36E-04	2.02E-05	4.72E-04	2.22E-05	2.02E-02	1.221E-03	2.85E-02
K5	1.05E-03	2.45E-02	2.88E-05	6.71E-04	6.061E-06	1.41E-04	1.69E-05	3.93E-04	2.81E-05	2.030E-02	1.130E-03	2.64E-02

Table 6: HQ/HI for Heavy Metals in T. occidentalis (Fluted Pumpkin) in both adults and children

CDI	Cd		Ni		Fe		Zn		Mn		HI	HI
	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children	Adult	Children
K1 FP	1.35E+00	1.10E+01	2.60E-03	2.10E-02	9.20E-03	7.48E-02	2.00E-02	1.61E-01	1.08E-02	8.76E-02	1.39E+00	1.13E+01
K2 FP	1.60E-01	1.31E+00	2.60E-02	2.10E-01	6.80E-03	5.55E-02	3.40E-03	2.75E-02	1.64E-02	1.33E-01	2.14E-01	1.74E+00
K3 FP	1.85E+00	1.50E+01	5.10E-02	4.10E-01	1.50E-02	1.24E-01	1.70E-02	1.41E-01	1.09E-02	8.86E-02	1.95E+00	1.58E+01
K4 FP	1.81E+00	1.47E+01	5.70E-02	4.60E-01	1.50E-02	1.21E-01	1.70E-02	1.40E-01	1.68E-02	1.36E-01	1.92E+00	1.56E+01

K5 FP	1.51E+00	1.23E+01	4.30E-02	3.50E-01	7.00E-03	5.30E-02	1.80E-02	1.44E-01	1.93E-02	1.56E-01	1.60E+00	1.30E+01

V. DISCUSSION

Concentrations of heavy metals in soils and fluted pumpkin (T. occidentalis)

The analysis revealed substantial discrepancies in the concentrations of different heavy metals in both the soil and T. occidentalis samples, as shown in Table 2. More precisely, the elements were ordered in terms of their abundance as follows: iron (Fe) was the most abundant, followed by zinc (Zn), manganese (Mn), cadmium (Cd), nickel (Ni), and cobalt (Co). The concentration of Fe in the soil ranged from 2.053 to 5.307mg/kg, while for T. occidentalis it ranged from 1.787 to 4.167mg/kg. The levels fell below the permitted limits set by WHO/FAO for soil and vegetables. The values revealed in this study are lower than those published by Ekpete and Owhoeke (2019), but they are consistent with the findings of Addis and Abebaw (2017). However, they are slightly higher when compared to the values reported by Atta et al. (2022) in soil. The high concentration of Fe can be attributed to its natural abundance, as it is the fourth most abundant element in the Earth's crust. Iron (Fe) is a crucial heavy metal, but when present in excessive concentrations, it can be harmful to the system (Ekpete & Owhoeke, 2019).

The soil and T. occidentalis samples exhibited Zn concentrations ranging from 3.380-4.433mg/kg and 0.397-2.330mg/kg, respectively. The sampling location K1 had the lowest observed value. However, these values were much lower than the suggested guideline limits by FAO/WHO (2001). The measured values were lower than the reported values of 14.91±0.197 and 8.979±0.193 for soil and fluted pumpkin by Ekpete and Owhoeke, (2019) from the dumpsite in Rumuolumeni Port Harcourt. However, they were marginally higher than the values reported by Okwelle and Marcus, (2023) from the dumpsite in Port Harcourt, Rivers State. Zinc (Zn) is an essential metal in the human body due to its involvement in normal growth and development. However, excessive intake of zinc can lead to reduced absorption of iron, gastrointestinal irritation, and disruption of physiological processes (Ekpete & Owhoeke, 2019; Kacholi et al., 2018). Moreover, excessive zinc can be harmful, causing toxic effects on the health of plants and animals (Momta et al., 2024; Nwineewii & Momta, 2022). Deficiency of Zn comes from low food intake, decreased absorption, excessive excretion, or genetic abnormalities in zinc metabolism (Narin et al., 2005).

The soil samples included Mn concentrations ranging from 1.843-2.873mg/kg, whereas T. occidentalis had concentrations ranging from 0.590-1.053mg/kg. These values were found to be below the WHO standard limit of 12mg/kg for Mn in soil, but above the limit of 0.2mg/kg for Mn in T. occidentalis. The Mn concentrations shown in this investigation are comparatively lower than the values reported by Okwelle, (2023) in dumpsites located in Port Harcourt. Manganese (Mn) is a crucial micronutrient that plays a vital role in promoting growth and development. It also supports various metabolic functions in different components of plant cells. It is a necessary coenzyme for the oxygen-evolving complex of the photosynthetic apparatus, facilitating the process of splitting water in the photosystem.

The Cd concentration ranged from 0.070 to 0.853mg/kg in soil and from 0.063 to 0.723mg/kg in T. occidentalis. The reported levels in dumpsites in Port Harcourt (Okwelle, 2023) are lower than these values, however the values reported by Ekpete and Owhoeke (2019) at the dumpsite at Rumuolumeni, Port Harcourt, fall within the same range. The results documented in this study were significantly lower than the acceptable thresholds advised by FAO/WHO (2021). The impact of Cd impacts can be significant to the extent of inducing kidney disease (Momta et al., 2024). The presence of certain enzymes can modify the spatial arrangement of other enzymes, leading to a decrease in their ability to catalyse reactions (Nwineewii & Momta, 2022).

The levels of Ni (0.320-0.513mg/kg and 0.020-0.443mg/kg) found in the soil and T. occidentalis in this study were lower than the recommended limits set by FAO/WHO (2001). They were also below the range of 3.021±0.048mg/kg and 0.596±0.028mg/kg reported by Ekpete and Owhoeke (2019) in a dumpsite at Rumuolumeni in Port Harcourt, as well as the values reported by Okwelle and Marcus (2023). The source of nitrogen in the soil may originate from agricultural discharges (Nwineewii & Momta, 2022). Nickel is crucial in small quantities, but can pose a risk when the maximum acceptable thresholds are above. Elevated levels of nickel in food can lead to lung disease, impact the stomach, liver, kidneys, and immune system, as well as contribute to the development of cancer in both animals and people (Nwineewii & Edem, 2014; Nwineewii & Momta, 2022; Uzamere et al., 2023; Momta et al., 2024). Significantly, the presence of Co was not traceable in both the soil and fluted pumpkin samples. This finding is consistent with the result of Ekpete and Owhoeke (2019) at the Rumuolumeni waste site in Port Harcourt, Rivers State, Nigeria.

Evaluation of pollution indices and health risk of heavy metals in soil and T. occidentalis:

Transfer factor (TF) of heavy metals from soils to T. occidentalis

The average values of TF for Cadmium (Cd), Nickel (Ni), Iron (Fe), Zinc (Zn), and Manganese (Mn) were 1.365, 0.465, 0.735, 0.35, and 3.00, respectively. The TF values exhibited a significant increase compared to the findings reported by Wang et al. (2012), possibly due to the elevated concentrations of plants in this particular investigation. Manganese (Mn) and Cadmium (Cd) exhibited the largest Transfer Factor (TF), indicating their significant accumulation in both soil and T. occidentalis. Conversely, Zinc (Zn) shown the lowest TF in this study, which aligns with the translocation pattern reported by Khan et al. (2008) in agricultural soils located in the southeast of Beijing. Mapanda et al. (2007) discovered a similar pattern in vegetables grown on soils watered with wastewater at Mukuvisi, Zimbabwe. A TF value larger than 1 implies a higher transfer factor, which suggests that the soil has poor retention of metals or that plants have a stronger ability to absorb metals. The average transfer factor (TF) of heavy metals in T. occidentalis throughout the site indicates that Cd had the greatest average TF (0.86).

Contamination Factor (CF) and Pollution Load Index (PLI)

The study results indicate that the soil and T. occidentalis in the study areas were moderately contaminated with Cd, Ni, Fe, Zn, and Co, as evidenced by their CF values falling within the range of 1 to 3. The PLI values for soils at the study sites followed the order: K2 > K1 > K3 > K5 > K4. Similarly, the PLI values for T. occidentalis were in the order: K2 > K1 > K5 > K3 > K4. The Pollution Load Index (PLI) suggests that the contamination levels of Cd, Mn, Ni, Fe, and Zn are reasonably low for all the heavy metals. Therefore, based on Harikumar et al.'s (2009) criteria, none of the sampling sites in this study were found to be contaminated. According to their findings, a PLI value greater than 1 indicates contamination, whereas a PLI value less than 1 indicates the absence of pollution.

Ecological risk factor (ErF) and potential Ecological risk factor (RI)

The ErF values of soils varied between 6.9 and 85.2 for Cd, between 0.02 and 0.04 for Ni, between 0.036 and 0.047 for Zn, and between 0.022 and 0.034 for Mn. Co was not found. The soil's median Cd value was 79.8, indicating a moderate ecological danger. Conversely, the median values of Ni, Zn, and Mn were 0.03, 0.0039, and 0.023, respectively, signifying minimal risk factors. The ErF values of T. occidentalis varied between 6.30 and 72.30 for Cd, between 0.0015 and 0.033 for Ni, between 0.0040 and 0.025 for Zn, and between 0.022 and 0.095 for Mn. Co was not found. The median concentration of Cd in T. occidentalis was 64.95, indicating that the area can be classified as having a moderate ecological risk. On the other hand, the median concentrations of Ni, Zn, and Mn were 0.027, 0.00125, and 0.025, respectively, suggesting a low ecological risk. The ErF (Ecological Risk Factor) of the heavy metals in the soil and T. occidentalis (a species of plant) were ranked in the following order: Cd (Cadmium) > Ni (Nickel) > Fe (Iron) > Zn (Zinc) > Mn (Manganese) > Co (Cobalt). Due to its lower toxicity response factor and significant contribution to plant nourishment, Co is considered to provide the least ecological risk (Sandeep et al., 2019). The Risk Index (RI) values for the heavy metals in the soil samples were 319.5, 0.16, 0.20, and 0.13 for Cd, Ni, Zn, and Mn respectively. These values indicate a moderate level of risk for Cd. The relative incidence (RI) of Cadmium (Cd) in T. occidentalis fell into the moderate risk category (261.30), indicating that it is less likely to significantly increase ecological risk factors (ErF).

Chronic Daily Intake (CDI)

Significant heterogeneity was detected in the levels of Cd, Ni, Fe, Zn, and Mn in the soil samples taken from the adult cohort. The concentration of Cd ranged from 9.589×10-8 to 1.051×10-6, while the concentration of Fe ranged from 7.27×10-6 to 2.81×10-6. Within the younger group, comparable fluctuations were seen, with even wider spectrums, suggesting the possibility of increased exposure or variability in heavy metal pollution. T. occidentalis displayed significant variance in CDIing values, indicating varying degrees of contamination for both adult and children groups. The average levels of heavy metal intake, as determined by CDI analysis, were found to be highest for Cd, followed by Ni, Mn, Zn, and Fe, in both adults and children, based on soil samples. The sequence of abundance for T. occidentalis was as follows: Ni> Cd> Mn> Zn> Fe, for both adults and children. The level of toxicity of heavy metals on human health is closely correlated with their daily consumption. Nevertheless, the act of consuming food or drink was taken into account in this study. Since vegetables are crucial elements of the human diet, we aimed to assess the health hazards to the target population caused by the consumption of vegetables contaminated with heavy metals. The permissible range for CDI is 106–104, as demonstrated by Liang et al. (2017). The findings of the present investigation indicate that the majority of values obtained for both children and adults fall within this range, with the exception of site K1 (Cd) and sites K1 and K2 (Cd and Ni) in adults for the soil. Iyama et al. (2020) also observed similar results, reporting elevated concentrations of Cd and Ni in adult soil samples at certain stations, indicating excessive CDiing.

The lowest Chronic Daily Intake (CDI) of Cadmium (Cd) was seen when T. occidentalis was ingested, ranging from 1.61×10-4 to 1.35×10-3 mg/kg day-1. Cadmium, a superfluous metal, has adverse impacts on human health even at extremely low levels. Exposure to this element can lead to the development of long-lasting health issues, such as reduced liver and kidney function, along with the added danger of tissue buildup that can cause cancer. The study found that children had a higher intake of CDI compared to adults, possibly due to behavioural patterns in children that increase the chances of skin contact (Huang et al., 1999).

Hazard Quotient (HQ) and Hazard Index (HI)

The human health risk quotient (HQ) values associated with the ingestion of T. occidentalis, in terms of heavy metals (Cd, Ni, Fe, Zn, and Mn), are low for both adults and children. The levels of heavy metals obtained from consuming T. occidentalis are often lower. Heavy metal concentrations in T. occidentalis were generally greater than in the soil samples, both in the adult and children groups. Within the group of children, both HQ and HI values exhibited a comparable pattern, with greater values in comparison to the soil samples. The Cd HQ values for soil varied from 9.59×10-5 to 1.05×10-3 and 2.24×10-3 to 2.16×10-2 for adults and children, respectively. The Ni values ranged from 3.15×10-5 to 2.19×10-5 and 5.11×10-4 to 8.20×10-4 for adults and children, respectively. The Fe values ranged from 6.51×10-6 to 1.01×10-5 and 9.37×10-5 to 1.41×10-4 for adults and children, respectively. The Cd HQ values for T. occidentalis varied from 1.60×10-1 to 1.35 and 1.50×10-1 to 1.31 for adults and children respectively. The Ni values ranged from 2.60×10-3 to 2.60×10-2 and 2.10×10-2 to 2.10×10-1 for adults and children respectively. The Fe values ranged from 9.20×10-3 to 1.50×10-2 and 7.48×10-2 to 1.21×10-1 for adults and children respectively. The Zn values ranged from 3.40×10-3 to 1.70×10-2 and 2.75×10-2 to 1.40×10-1 for adults and children respectively. These findings indicate that the likelihood of encountering significant health hazards from heavy metals by consuming T. occidentalis is considerable. In the present study, it was found that the HQ (hazard quotient) and HI (hazard index) values of Cd, Fe, Ni, Mn, and Zn, obtained through the consumption of T. occidentalis, were higher for children compared to adults. This suggests that children are at a higher risk of potential health hazards compared to adults. The divergence in HQ values between adults and children can be attributed to variations in metal consumption, duration of exposure, and body mass between the two age groups (Zhou et al., 2016). Significant disparities were seen in HQ and HI values between adults and children in Chenzhou City, China, as a result of vegetable consumption (Zhou et al., 2016). Notably, the HQ and HI values for children were found to be greater than those for adults. According to this study, the hazard quotient (HQ) values for Cadmium (Cd) in T. occidentalis are greater than 1. This suggests that consuming T. occidentalis in the research area may pose a possible health hazard due to exposure to Cd. Furthermore, the concentration of heavy metals in T. occidentalis declined in the following order: Cd>Ni>Fe>Zn>Mn. This indicates that the possible health concerns associated with consuming T. occidentalis are higher for Cd and Ni compared to Fe, Zn, and Mn.

VI. CONCLUSION

The findings of this study unveiled significant variations in the concentrations of various heavy metals within the soil and T. occidentalis samples.

The average transfer factor (TF) indicated that Mn and Cd exhibited the greatest TF values in this study, implying their significant accumulation in both soil and T. occidentalis. Therefore, it is recommended to prioritise monitoring and studying the impact of these elements on T. occidentalis. Sampling site K5 exhibited high EF (enrichment factor) values for soil and T. occidentalis, suggesting an elevated pollution potential and increased human health risks associated with activities in this area. The value for the concentration of Cadmium (Cd) in T. occidental was greater than 1. This suggests that consuming T. occidentalis may provide a potential health hazard due to exposure to Cd. The Ecological danger Factor (ErF) of the heavy metals present in the soil and T. occidentalis samples was determined to be generally low, indicating a low level of danger. However, Cd (cadmium) was found to have a moderate ErF, suggesting a slightly higher level of risk. The relative incidence (RI) of Cadmium (Cd) in T. occidentalis was found to be in the moderate risk category (261.30), indicating that it is less likely to significantly increase the ecological risk factor (ErF).

VII. RECOMMENDATION

The levels of heavy metals in the soil should be monitored as its accumulation could pose environmental and human health risks especially for children through ingestion. Regulation and control use of pesticides in the cultivation of vegetables is crucial. This is because its consistent use results in the introduction of heavy metals which is consequently transferred into the vegetable. The consumption of this vegetable posed potential risks to health.

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