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EXPOSURE TO HEAVY METALS IN FRUITS AND VEGETABLES FROM THE ETELEBOU DUMPSITE IN BAYELSA STATE AND ITS HEALTH IMPLICATIONS

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ABSTRACT: *Fruits and vegetables are energy-dense foods containing vitamins, minerals, fibre and other bioactive compounds, which help in preventing major diseases. However, accessing quality and safe food crops for consumption has left us with unanswered question and concerns such that "Should the simple act of eating lead to diseases and death? Hence, the need to analyze the suitability and safety of selected self-grown and cultivated bitter leaf, fluted Pumpkin and guava fruit collected from dumpsite (Etelebou) in Yenagoa, Bayelsa State. Heavy metals such as Pb, Cd, Cr, Ni, As, V, Mn, Co, Fe, Cu and Zn were analysed via FAAS. Results show that the concentration of Pb, Cd and Co were higher than the WHO recommended limit for edible fruits and the Recommended Dietary Allowance (mg/day); Fe and V have the highest and least transfer factor respectively. Generally, the concentrations (mg/kg) of heavy metals in the soil were higher than the vegetables and fruit grown around the investigated soil vicinity. The analyzed health risk models (DIM, CDI, HRI, THQ and ILCR) show no significant toxicity effect on the consumer at the moment. However, due to the potential toxicity/cumulative behavior of metals and rate of vegetable consumption, further harvesting of vegetables from the dumpsite should be discouraged to avert future health challenges.*

KEYWORDS: Fruits and Vegetable, Waste Dumpsite Soil, Heavy Metals, Total Transfer of Metals, Health Implication.

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INTRODUCTION

Fruit and vegetable agriculture is a lucrative but technically demanding (caregiving involving pest and disease control, rich organic soil, watering/irrigation and overall monitoring) venture whose products are in high demand particularly among urban dwellers, and that has paved the way for urban agriculture. Urban agriculture (practice of cultivating fruits and vegetables on available land space within the living neighborhoods) is gaining prominence, as it is not only committed but also serves as a complementary source of income and is easily practiced within a limited space. However, the limited agricultural land space and poor land tenure system have made farmers to start visiting waste dumpsites for fruits and vegetable agriculture (farming), taking advantage of the organic-rich soil, which can easily transfer chemical pollutants such as heavy metals into the crops.

Record shows that soil acts as a sink or source of pollutants (Khan *et al.*, 2010). Soil quality determines the quality of the products. Thus, vegetables grown on an unhealthy land within municipal wastes can absorb heavy metals and mobile ions present from the unlined leachate in the soil through their roots and transfer them into the fruits and the edible parts of the crop (Fosu-Mensah *et al.*, 2017; Aralu & Okoye, 2020; Matthew *et al.*, 2022).

The accumulation of these heavy metals in plants has a direct negative influence on the physiological activities of plants, such as photosynthesis, gaseous exchange, and nutrient absorption which result in plant growth reduction and dry matter accumulation (Nyiramigisha *et al.*, 2021). Thus, food quality and quantity (yield) is affected. These affect the food chain by promoting bioaccumulation and magnification via the consumption of contaminated food, creating heavy metal exposure pathways into the human systems.

Sadly, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the human body and is further responsible for decreasing immunological defenses, intrauterine growth retardation, disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Ajayi, 2017). These have raised concerns about potential health risks, food safety as well as its detrimental effects on the soil ecosystem and human health.

The concern is further exacerbated as the fruits and vegetables, particularly the leafy greens, are consumed raw, increasing the vehicles for the transmission of both heavy metals and human pathogens that were traditionally associated with foods of animal origin, thus making fruits and vegetable commodities of the highest concern from a microbiological and chemical safety perspective. It is against this backdrop this study is conducted to determine the level of heavy metal concentration in the soil, fruits and vegetables grown in the dumpsite (Etelebou). Therefore, the aim of this study is to determine the levels of heavy metals in the edible fruit parts (*Musa acuminate)* and vegetable parts (*Telfairia Occidentailis* and *Vernonia amygdalina)* collected from the Bayelsa State Central dumpsite (*ETELBOU)* compared with safety standards, and conduct risk exposure via consumption.

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MATERIALS AND METHODS

Description of the Study Location

The study location is at the ETELEBOU Central waste dumpsite, off Yenagoa-Amassoma road in Yenagoa Local Government Area of Bayelsa State. The ETELEBOU is the largest and biggest dumpsite in the state receiving over 95% household and industrial waste (solid and liquid waste) in Yenagoa metropolis and environs since the year 2000 (Ebuete *et al.*, 2022). Currently, the dumpsite is in duo: Abandoned Etelebou, which is adjacent, but directly laying along the Yenagoa-Amassoma Road while the active ETELEBOU is about 200 meters away from the main Yenagoa-Amassoma Road, through a minor access road (Abaningi road) linking Okolobiri Town (Simon & Ayotamuno, 2022).

The active Etelebou dumpsite is located within latitude $4^{o}59^{I}28.320^{II}$N - $5^{o}01^{I}6.342^{II}$N and longitude $6^{o}19^{I}38.346^{II}$E - $6^{o}20^{I}18.942^{II}$E covering an area of about 1.5 km^2 within a low swampy land (5 meters below sea level) (Ebuete *et al.*, 2022) (Fig. 1).

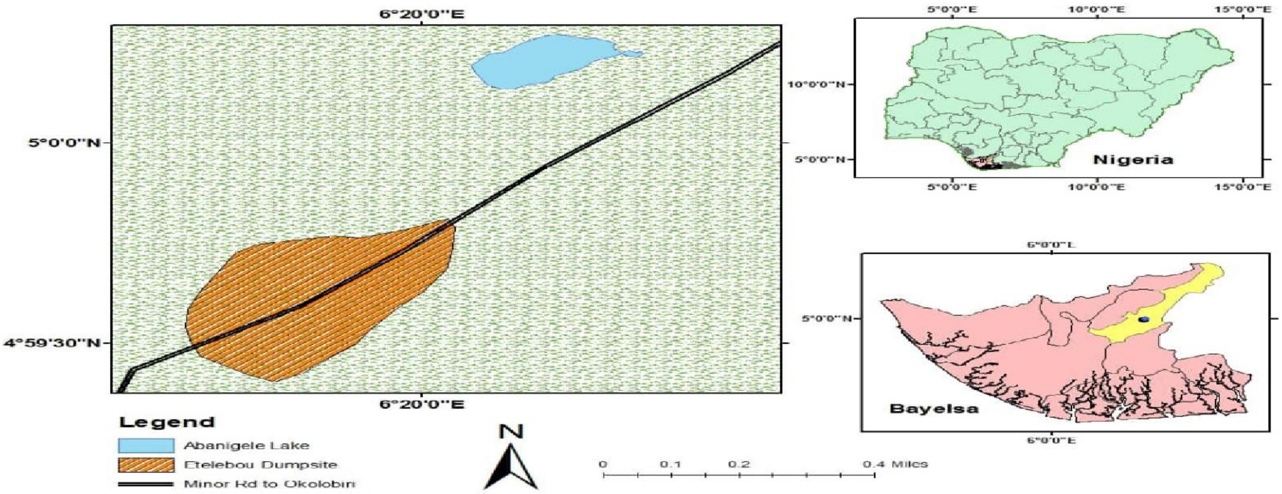

Fig. 1: Showing the Etelebou Dumpsite

Source: Ebuete *et al.* (2022)

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Fig. 2: Picture showing Etelebou Dumpsite **Source:** Researcher

Collection and Treatment of Vegetable Samples

A total of nine (9) samples of each vegetable species (*Telfairia occidentalis, Talinum triangulare and Amaranthus hybridus*) were collected from the dumpsite during the wet season, where leachate level is high due to rainfall and when the fruits and vegetables are at peak blossoming and succulent for consumption. Samples of the vegetables and fruits were carefully picked and packed into clean polythene bags. The vegetables were washed under running water and later with distilled water and air-dried at room temperature. Composite samples of each plant were formed and then pulverized to fine powder.

Collection and Treatment of Soil Samples

The soil samples were collected at the base of the plants within the dumpsite; 16 samples of soil were collected during the wet season at a depth of 30 cm; visible remains of debris were removed. Thirty grams (30 g) of the soil sample was oven-dried to a constant weight at $105^{O}C$, ground and sieved to uniform particle size.

All reagents and chemicals were of analytical grade. Glass and plastic items (Merck, Germany) were carefully cleaned with 10% HNO_3 before being washed with distilled water.

Sample Digestion and AAS Analysis

One gram (1 g) of each sample (fruit, vegetables and soil) was digested with a 20 mL solution of concentrated HNO_3/H_2SO_4 containing 3:1 and 5 mL of $HClO_4$ was also added to each content. After digestion, a clear solution was obtained. The digests were cooled and diluted with 20 mL distilled water, filtered into a 100 mL flask and distilled water was added to make up the mark (Markmanuel *et al.*, 2022).

Heavy metal concentrations (mg/kg) were analyzed using FAAS (Thermo-Elemental Atomic Absorption Spectrophotometer) (S4-71096 model). All analyses were carried out in triplicates.

Statistical

Hazard Exposure Evaluation

The potential hazard of human exposure to the heavy metals (Pb, Cd, Cr, Ni, As, V, Mn, Co, Fe, Cu and Zn) derived from the ingestion of the investigated bitter leaf, fluted pumpkin and guava fruits were estimated using the models of the United State Environmental Protection Agency (USEPA, 2017) such as Estimated Daily Intake (EDI), Total Transfer Factors (TTF), Heavy Metals Translocation Factor (MTF), Health Risk Index (HRI) and Target Hazard Quotients THQ) to evaluate cancer and non-cancer hazards on the local consumers.

Potential Non-cancer and Cancer Hazard

a. **Total Transfer Factors (T.T.F) =** $\mathbf{\frac{MC_F}{MC_S}}$……………..(Equ 1) (Aralu & Okoye, 2020)

where MC_F is Metal Concentration in fruits (the sum concentration in fruits and peels; MC_S is Metal Concentration in soil).

b. **Estimated Daily Intake of Metal (DIM) =** $\mathbf{\frac{MC_F \times C_F \times D_{IM}}{Bwt}}$ ......(Equ 3) (Yaqub *et al*., 2021)

where MC_F is Concentration of heavy metal in vegetable (mg/kg); CF is Conversion factor (0.085, from fresh to dry weight, Ojiego *et al*., 2022), D_{IM} is Daily Intake of Vegetable (400 g/kg_FAO/WHO, 2004), Bwt is Average body weight (70 kg Markmanuel *et al.*, 2023).

c. **Average Daily Intake of Metals (ADIm) =** $\mathbf{\frac{MC_F \times DIM}{Bwt}}$ ……….……(Equ 4) (*Ibid*, 2023)

where ADIM is the average daily intake (mg/kg-bw/day) of metal in fruits after peels (Pawpaw and Banana); MC_F is the metal concentrations in the fruits samples; DIM is the daily ingestion rate of the fruits by Bayelsan adults (400 mg/kg/person/day); Bwt is the average body weight for adults (70 kg).

d. **Chronic Daily Intake of Metals (CDIM) =** $\mathbf{\frac{ADIm \times EF \times ED}{AT \text{ i.e., } (EF \times ED)} \times 10^{-3}}$…………….(Equ 5)

where CDIM is the chronic daily intake (mg/kg-bw/day) of the metals; ADI is the average daily intake of metals; EF is the exposure frequency (365 days/year); ED is the exposure duration

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(70 years for adults - Samaila *et al.*, 2021); AT is the average exposure lifetime for non-carcinogens (EF×ED) adults (365 days/years × 70 years), 1.0^{-3} is background check.

e. **Health Risk Index (HRI) was measured using equation** $= \frac{EDI}{ORD} \times 10\text{-}3$ ……….(Equ 6)

where EDI and ORD represent Estimated Daily Intake of Metal and Oral Reference Dose, respectively.

f. **Target Hazard Quotients (THQ)** $= \frac{EF \times ED \times DIM \times Cm}{ORD \times Bwt \times AT} \times 10^{-3}$ …(Aralu & Okoye, 2020) (Equ 7)

where EF = Exposure frequency (350 days/year, Udofia, 2020); ED is the exposure duration, taking 70 years for adults (Markmanuel *et al.*, 2023); AT = Average exposure time for non-carcinogens (365 days/year x 70 years) (*Ibid*, 2023); DI = daily intake of vegetables (400g_FAO/WHO, 2004); Cm = Concentration of metals in the media. The cumulative targeted quotient $\sum$ **THQ =** $THQ_{Pb} + THQ_{Cd} + THQ_{Cr}$………+ THQ_{Zn}.

Table 1: Mean heavy Metals Concentrations (mg/kg) in soil, fruit, vegetables and recommended limit

Metals	**Bitterleaf**		**Fluted pumpkin**				**Guava Fruit**			**RDA**	**WHO MPL**
	Range	**S.D**	**Mean**	**Range**	**S.D**	**Mean**	**Range**	**S.D**	**Mean**		**Edible Plants mg/kg**
Pb	0.157-0.176	0.010	0.167	0.377-0.598	0.132	0.518	0.080-0.082	0.002	0.082	….	0.43
Soil	**3.152-4.356**	**0.693**	**3.952**	**5.351-5.897**	**0.446**	**5.714**	**1.973-2.082**	**0.062**	**2.044**		
Cd	0.016-0.050	0.019	0.038	0.005-0.008	0.002	0.007	0.023-0.048	0.013	0.034	….	0.02
Soil	**0.355-0.813**	**0.230**	**0.597**	**0.156-0.170**	**0.008**	**0.008**	**0.178-0.398**	**0.120**	**0.316**		
Cr	0.081-0.130	0.028	0.113	0.056-0.063	0.015	0.060	0.469-0.474	0.002	0.471	m35, w25	1.3
Soil	**5.721-8.130**	**1.205**	**6.910**	**12.182-17.947**	**2.931**	**15.372**	**8.549-11.202**	**1.331**	**9.810**		
Ni	0.026-0.069	0.025	0.054	0.013-0.019	0.003	0.016	0.023-0.052	0.017	0.033	.08-.13	1.63
Soil	**1.847-2.060**	**0.110**	**1.969**	**0.420-0.991**	**0.287**	**0.687**	**1.198-1.646**	**0.239**	**1.470**		
As	0.015-0.016	0.001	0.016	0.041-0.051	0.005	0.047	0.004-0.014	0.005	0.009	2.14µg/kg	0.1
Soil	**0.154-0.218**	**0.033**	**0.191**	**0.487-0.830**	**0.186**	**0.70**	**0.272-0.585**	**0.170**	**0.467**		
V	0.002-0.019	0.010	0.013	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	**BDL**	<1.8	**-**

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Soil	**0.346-1.002**	**0.343**	**0.617**	**0.102-0.528**	**0.243**	**0.247**	**0.259-0.585**	**0.177**	**0.462**		
Mn	0.150-0.152	0.001	0.151	0.081-0.091	0.005	0.087	0.300-0.311	0.006	0.305	m 2.3, w 1.8	2
Soil	**1.876-2.486**	**0.337**	**2.264**	**2.544-3.169**	**0.349**	**2.946**	**3.429-3.769**	**0.177**	**3.628**		
Co	0.005-0.008	0.002	0.006	0.138-0.140	0.001	0.139	0.052-0.064	0.006	0.058	.005-.04	0.01
Soil	**0.316-0.813**	**0.252**	**0.588**	**2.101-2.684**	**0.308**	**2.451**	**0.847-1.364**	**0.297**	**1.190**		
Fe	1.398-1.865	0.272	1.709	3.438-4.114	0.390	3.888	4.552-4.696	0.080	4.604	m 8, w 18	20
Soil	**5.291-6.864**	**0.907**	**6.338**	**3.088-3.890**	**0.451**	**3.608**	**7.131-7.915**	**0.398**	**7.564**		
Cu	1.350-1.352	0.001	1.351	0.251-0.542	0.157	0.431	1.829-1.831	0.001	1.830	2-5	10
Soil	**5.013-5.810**	**0.449**	**5.531**	**8.412-8.952**	**0.271**	**8.696**	**2.732-3.172**	**0.248**	**3.018**		
Zn	0.894-1.510	0.354	1.303	1.504-1.764	0.133	1.649	2.701-3.216	0.297	2.873	50	50
Soil	**3.187-3.585**	**0.230**	**3.32**	**2.425-2.898**	**0.237**	**2.673**	**3.062-3.925**	**0.492**	**3.357**		

Sources: *Researcher, 2023. Bibi et al. (2023) for all RDA, WHO variables, where S.D (Standard Deviation), RDA (Recommended Dietary Allowance mg/day), m (men) and w (women) and BLD (Below Detection Limit)*

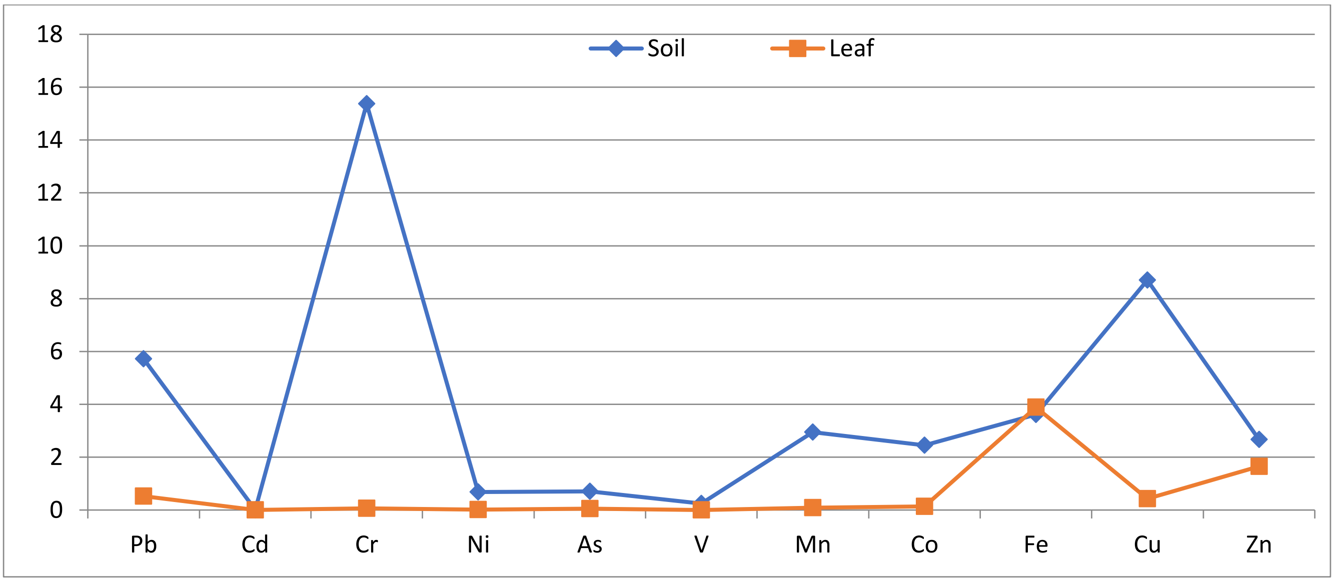

Chart 1: Heavy Metals Concentration in the soil and fluted pumpkin

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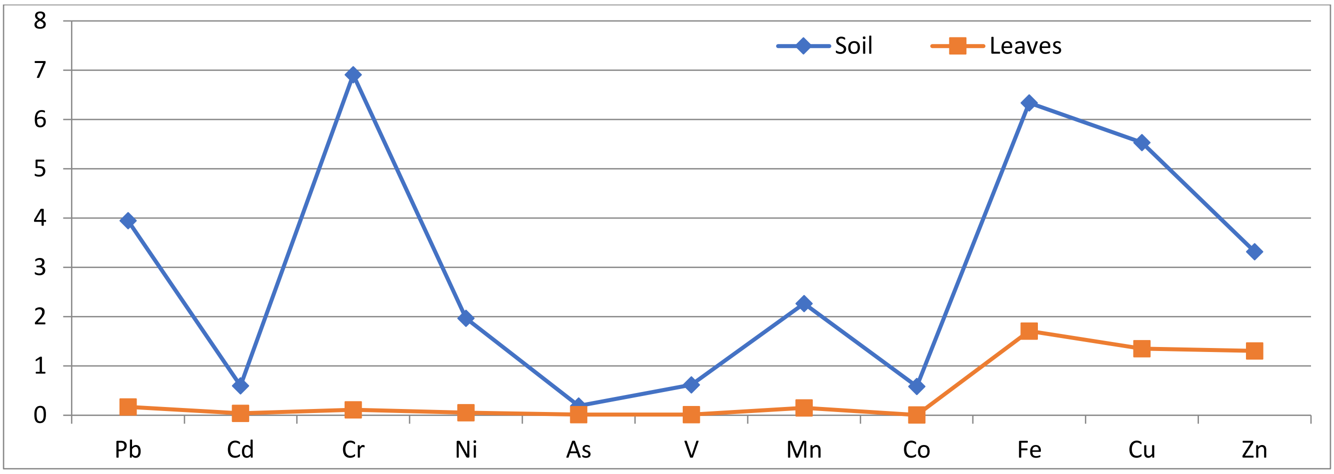

Chart 2: Heavy Metals concentration in the soil and bitter leaf

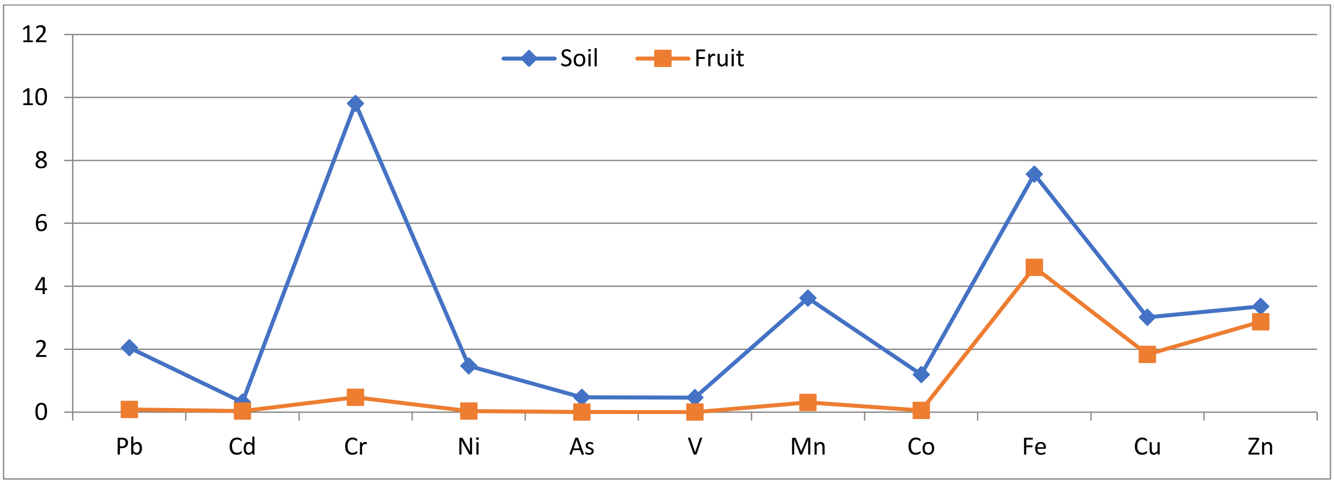

Chart 3: Heavy Metal concentrations in the soil and guava fruits

Table 2: Non-cancer hazard (mg/kg) in soil, fruits and vegetable samples

	TTF			**EDI**			**DIM**			**HRI**		
Metals	B.L	F.P	G.F	B.L	F.P	G.F	B.L	F.P	G.F	B.L	F.P	G.F
Pb	0.087	0.271	0.043	0.081	0.252	0.040	0.954	2.960	0.469	0.203	0.630	0.1
Cd	0.020	0.004	0.018	0.019	0.003	0.017	0.217	0.040	0.194	0.019	3.0^{-3}	0.017
Cr	0.059	0.031	0.246	0.055	0.029	0.229	0.650	0.343	2.692	3.7^{-5}	1.9^{-5}	1.5^{-4}
Ni	0.023	0.008	0.017	0.026	0.008	0.016	0.308	0.092	0.189	1.3^{-3}	4.0^{-4}	8.0^{-4}
As	0.008	0.025	0.005	0.008	0.023	0.004	0.092	0.268	0.051	0.027	0.077	0.013
V	0.007	BDL	BDL	0.006	BDL	BDL	0.074	BDL	BDL	1.2^{-3}	BDL	BDL
Mn	0.079	0.046	0.160	0.073	0.042	0.148	0.863	0.497	1.743	5.2^{-3}	3.0^{-3}	0.011
Co	0.003	0.073	0.030	0.003	0.068	0.028	0.034	0.794	0.332	1.0^{-4}	2.3^{-3}	9.3^{-4}
Fe	0.894	2.034	2.408	0.830	1.89	2.236	9.766	22.22	26.308	1.2^{-3}	2.7^{-3}	3.2^{-3}
Cu	0.707	0.226	0.957	0.656	0.209	0.889	7.720	2.463	10.458	0.016	5.2^{-3}	.022
Zn	0.682	0.863	1.503	0.633	0.801	1.396	7.446	9.423	16.417	2.1^{-3}	2.7^{-3}	4.7^{-3}

Source: *Researcher, 2024. Where: B.L = Bitter Leaf; F.P = Fluted Pumpkin; G.F = Guava Fruits*

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Table 3: Non-cancer hazard (mg/kg) in soil, fruits and vegetable samples (Cont.)

Indices Metals	**CDI**			**THQ**		
	B.L	F.P	G.F	B.L	F.P	G.F
Pb	9.5^{-4}	3.0^{-3}	4.9^{-5}	5.3^{-3}	5.0^{-2}	1.3^{-3}
Cd	2.2^{-4}	4.0^{-5}	1.9^{-4}	1.2^{-4}	4.0^{-6}	9.4^{-5}
Cr	6.5^{-4}	3.4^{-4}	2.7^{-3}	7.0^{-7}	2.0^{-7}	1.2^{-5}
Ni	3.1^{-4}	9.2^{-5}	1.9^{-4}	1.2^{-5}	1.1^{-6}	4.5^{-6}
As	9.2^{-5}	2.7^{-4}	5.1^{-5}	7.0^{-5}	6.0^{-6}	2.2^{-5}
V	7.4^{-5}	BDL	BDL	2.7^{-5}	BDL	BDL
Mn	8.6^{-4}	5.0^{-4}	1.7^{-3}	1.3^{-4}	4.4^{-5}	5.4^{-4}
Co	3.4^{-5}	7.9^{-4}	3.3^{-4}	9.7^{-8}	5.3^{-5}	9.2^{-6}
Fe	9.8^{-3}	.022	.026	3.4^{-4}	1.8^{-3}	2.5^{-3}
Cu	7.7^{-3}	2.5^{-3}	.011	3.7^{-3}	3.8^{-4}	6.8^{-3}
Zn	7.5^{-3}	9.4^{-3}	.016	4.1^{-4}	7.4^{-4}	2.3^{-3}
ΣTHQ				1.1^{-2}	5.3^{-2}	1.4^{-2}

Source: *Researcher, 2024.*

Lead (Pb): Lead is a metalloid, a nonessential metal to both plants and animals and any concentration beyond 0.3 mg/kg can alter soil chemistry, negatively affect the soil organisms and plants depending on the soil for nutrition. The mean concentration of lead (Pb) was 0.167 mg/kg, 0.518 mg/kg and 0.082 mg/kg for bitter leaf, fluted pumpkin and guava. These values were within the maximum permissible limits of 0.43 mg/kg for edible plants except for fluted pumpkin (Table 1 and 2) (Bibi *et al.*, 2023). The mean concentrations of lead in the soil were 3.952 mg/kg; 5.714 mg/kg and 2.044 mg/kg which were below the recommended permissible level of 85 mg/kg for heavy metals in soils (Yap *et al.*, 2021). However, the concentration differences accounted for 92%, 83% and 92% while the metal transfer mechanisms were 0.087 mg/kg, 0.271 mg/kg and 0.043 mg/kg respectively which is an indication of poor transfer mechanisms. The presence of Pb is traceable to vehicle servicing, and repair activities and the combustion of heterogeneous waste within the site. The high concentrations of Pb in fluted pumpkin can affect different tissues and organs in human body like brain, heart, kidney, liver, gastro-intestine, hematopoietic, reproductive and endocrine system, and further cause lipid damage and increased production of ROS in plants (Matović *et. al.*, 2015). Further study by Otugboyega *et al.* (2023) recorded 0.07-1.36 mg/kg in Lagos dumpsite; Mathew *et al*. (2022) reported a range of 1.727-1.738 mg/kg in Muwo Metropolis, Niger State. In Port Harcourt, Iyama *et al.* (2022) reported a range of 0.87-6.80 and 0.64-2.19 mg/kg in the soil and bitter leaf; Ang and Ng (2000) 0.63-8.71 mg/kg and Ahmad-Mahir *et al.* (2009) 0.1-0.04 mg/kg in guava.

Cadmium (Cd): Cd is the 7th most toxic heavy metals according to ATSDR ranking and also a nonessential element capable of affecting plant metabolisms, inhibiting seed germination and inducing genetoxicity in plants (Gebeyehu & Bayissa, 2020). The mean concentration of Cadmium in the plant parts and fruits were 0.038 mg/kg, 0.007 mg/kg and 0.034 mg/kg in bitter leaf, fluted pumpkin and guava respectively, which were above the 0.02 mg/kg maximum permissible level for edible plants except for fluted pumpkin (Table 1). The mean concentrations of Cadmium in soil were 0.597 mg/kg, 0.008 mg/kg and 0.316 mg/kg respectively, which accounted for 88%, 7% and 81% differences respectively, indicating a

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slower transfer process of only 0.020, 0.004, and 0.018 mg/kg respectively (Table 3). Bibi *et al.* (2023) opined that there is human inability to excrete cadmium; thus, the kidney inhibits its excretion by reabsorbing cadmium, such that it causes endocrine disruptor, osteoporosis, testicular degeneration, hypercalciuria, renal dysfunction, renal stone formation, influence calcium metabolism, height loss and carcinogenicity in humans while in plants, it results in deficiency in nutrition (Gebeyehu & Bayissa, 2020; Mathew *et al.*, 2022). The presence of Cd is linked to the heterogeneous waste especially from death batteries, sewage sludge, and fossil fuels. Previous records from Otugboyega *et al.* (2023) recorded 0.00-0.03 mg/kg; Ang and Ng (2000) recorded 0.06-0.55 mg/kg for seedless Guava; Ahmad-Mahir *et al.* (2009) 0.03-0.06 mg/kg and Dhiman *et. al.* (2011) 0.003 mg/kg for guava fruits; Ojiego *et al.* (2022) recorded 0.18-0.16 mg/kg for fluted pumpkin and Mathew *et al.* (2022) recorded 0.045 mg/kg for bitter leaf.

Chromium (Cr): The mean concentration values of chromium (Cd) were 0.113 mg/kg, 0.060 mg/kg and 0.471 mg/kg in bitter leaf, fluted pumpkin and guava fruit respectively, which are within the RDA of 35 mg/kg for men, 25 mg/kg for women and 1.3 mg/kg limit for edible plants recommended by WHO (Table 1) (Bibi *et al.*, 2023). The concentrations around the soil base were 6.910 mg/kg, 15.372 mg/kg and 9.810 mg/kg that accounted for about 97%, 99% and 91% differences respectively, indicating, poor metal transfer mechanisms such as 0.059, 0.031 and 0.246 mg/kg respectively (Table 2). Primandani *et al.* (2020) opined that Cr is required for the metabolism of proteins, fats and carbohydrates around 0.05-0.2 mg/day^{-1} but the records show that the exposure to further Cr causes nephrotoxicity, inflammation of the skin, respiratory system disorder, liver damage and ulcer formation in humans while interfering with the photosynthetic process in plants (Manzoor *et al.*, 2018). Aralu and Okoye (2020) recorded 0.83 mg/kg in Anambra State; Iyama *et al.* (2022) recorded 5.91 mg/kg in soil and 0.88 mg/kg in bitter leaf; Otugboyega *et al.* (2023) also recorded a range between 0.00-0.04 mg/kg in bitter leaf while Udofia *et al.* (2020) recorded 0.32-0.81 mg/kg in Guava.

Nickel (Ni): Nickel (Ni) is a micronutrient element required by plants and humans for their normal metabolisms in nucleic acid, and it serves as a cofactor of enzyme in enzymatic reactions (Osemudiamen *et al.*, 2023). The mean concentrations of Ni were 0.054 mg/kg, 0.016 mg/kg and 0.033 mg/kg in bitter leaf, fluted pumpkin and guava fruits, which were within the recommended dietary allowance of 11 mg/day for men and 8 mg/day for women, and also within the WHO maximum permissible limits of 50 mg/kg for edible plants (Table 1). The mean concentrations of Ni in the soil were 1.969 mg/kg, 0.687 mg/kg and 1.470 mg/kg, which are within the 35 mg/kg limit recommended by WHO for soils (Yap *et al.*, 2021). The differences between soil and plant crops were 95%, 95% and 96% with a slower metal transfer mechanism between 0.028 mg/kg, 0.008 mg/kg and 0.017 mg/kg in bitter leaf, fluted pumpkin and guava respectively. Similarly, Yap *et al.* (2021) reported 0.011 mg/kg for guava; Mathew *et al.* (2022) reported 0.511 mg/kg and Iyama *et al.* (2022) reported 1.42-3.30 mg/kg in bitter leaf, while Okwelle and Marcus (2023) reported 0.274-0.070 mg/kg in pumpkin.

Arsenic (As): Arsenic (As) is a non-essential and toxic element that accumulates in plants via oxidative and/or genotoxic mechanisms (Patel *et al.*, 2023); it causes chlorosis, inhibits root extension and proliferation (Raychaudhuri *et al.*, 2021). The mean concentration of As were 0.016, 0.047 and 0.009 mg/kg respectively in bitter leaf, fluted pumpkin and guava which are within the maximum permissible limit of 0.5 mg/kg for edible plants, while in the soil were 0.191 mg/kg, 0.70 mg/kg and 0.467 mg/kg respectively. The differences in fruits and soil accounted for 85%, 87% and 96% respectively, showing a poor transfer mechanism of only

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0.008, 0.025 and 0.005 mg/kg respectively, indicating that the locations cannot function as hyperaccumulators for As. Similarly, Patel *et al.* (2023) recorded 0.048-0.21 mg/kg in guava and 0.090-0.26 mg/kg in better leaf; Basha *et al*. (2014) reported 0.016-0.096 mg/kg in bitter gourd.

Vanadium (V): Vanadium is a trace mineral only required by humans less than 1.8 milligram per day to increase the effect of insulin. In this study, Vanadium was only recorded in bitter leaf with 0.013 mg/kg, which is within the recommended daily consumption of less than 1.8 mg/day. However, 0.617 mg/kg, 0.247 mg/kg and 0.462 mg/kg were recorded around the soils of the respected plants, signifying an insignificant transfer of the metal from soil to plants since it is less than 1 mg/kg. However, the concentration in the soil of bitter leaf is graciously high to function as hyperaccumulators for vanadium (V). A similar record was captured by Osemudiamen *et al.* (2023) (0.07 mg/kg) in pumpkin in Benin city.

Manganese (Mn): Manganese is the 5th most common metal on the earth's crust, necessary for the synthesis of urea, glycoprotein, proteoglycan and metabolism of pyruvate in humans and in plants. It is required for oxidation–reduction process in trace amount (≤ 2 mg/kg) (Bibi *et al.*, 2023). The mean concentrations of Manganese (Mn) were 0.151 mg/kg; 0.087 mg/kg and 0.305 mg/kg which are within 2.3 mg/kg and 1.8 mg/kg recommended dietary allowance (RDA) per day for men and women and 2 mg/kg maximum permissible limit by WHO (Table 1) (Bibi *et al.*, 2023). However, around the vegetables, fruit plants and soil were 2.264 mg/kg, 2.946 mg/kg and 3.628 mg/kg for bitter leaf, fluted pumpkin and guava respectively (Table 1). This accounted for about 88%, 97% and 85%, signifying a slower transfer mobility of the element from the soil to the edible fiber and fruits at 0.078 mg/kg, 0.046 mg/kg, and 0.160 mg/kg respectively for bitter leaf, fluted pumpkin and guava. Similarly, Ahmad-Mahir *et al.* (2009) reported mean concentrations between 0.87-1.16 mg/kg in guava, but Aralu and Okoye (2020) reported a higher concentration of 1.53 mg/kg in bitter leaf.

Cobalt (Co): Co is a trace element acting as vitamin B12 and as a cofactor for various enzymes in DNA synthesis in human (Bibi *et al.*, 2017). The mean concentrations of Cobalt (Co) were 0.006 mg/kg, 0.139 mg/kg and 0.058 mg/kg, which are above the WHO maximum permissible level of 0.01 mg/kg for edible plants except for bitter leaf (Table 1). This can cause cancer, immunological, respiratory, cardiac, hepatic, hematological, dermal, lung parendemic and renal problems in human and limit the level of chlorophyll, protein, iron and activity of catalase in plant leaf (Bibi *et al.*, 2017; Janadeleh, *et al.*, 2015). The concentrations of Cobalt in soils around these plant fruits were 0.588 mg/kg, 2.451 mg/kg and 1.190 mg/kg which accounted for 98%, 89% and 91% respectively while the transfer factor were 0.003 mg/kg, 0.073 mg/kg and 0.030 mg/kg respectively (Table 2), indicating poor bioaccumulation and transfer of the element into plant tissues. Anyanwu *et al.* (2022) reported similar concentrations of cobalt in a range of 0.265-0.942 mg/kg.

Iron (Fe): Iron is the 2nd most abundantly found element on the earth's crust, vital for all living species (Soetan *et al.*, 2010). The mean concentrations of iron (Fe) were 1.709 mg/kg, 3.888 mg/kg and 4.604 mg/kg in bitter leaf, pumpkin and guava fruits respectively. These values were within the recommended dietary allowance of 8 mg/day for men and 18 mg/day for women and also within the 15 mg/kg WHO maximum permissible limits (MPL) for edible plants (Table 1). The mean concentrations of Fe around the fruit plants and soil were 6.338 mg/kg, 3.608 mg/kg and 7.564 mg/kg, which accounted for 58%, 4% and 24% difference respectively between the fruits and soil, indicating a higher metal transfer between 0.894

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mg/kg, 2.034 mg/kg and 2.408 mg/kg for bitter leaf, pumpkin and guava fruits respectively (Table 2). The location functions as a hyperaccumulator of iron (Fe), similar to the report of Okwelle and Marcus (2023); Otugboyega *et al.* (2023) also recorded 0.30-2.21 mg/kg. Kamal *et al.* (2016) opined that plant species effectively translocate trace metals like iron from roots to the shoots, suggesting plants as a suitable phytoextraction. Iron is a key constituent of myoglobin, cytochrome and hemoglobin and is required for oxidative energy production in the human body (Bibi *et al.*, 2023). Therefore, the intake of fruits and vegetables rich in iron is recommended.

Copper (Cu): Copper is an essential element required in trace amount by humans to promote human growth, iron absorption, bone formation, crucial part of several enzymes, normal metabolic functions and energy provider (Bibi *et al.*, 2023); thus, its deficiencies result in anemia, skeletal problems, osteoporosis and reduction in number of white blood cells (WBC). The mean concentration values of Cu were 1.351 mg/kg, 0.431 mg/kg and 1.830 mg/kg in bitter leaf, pumpkin and guava fruits respectively, which are within the recommended dietary allowance of 2-5 mg/day and WHO maximum permissible limit of 10 mg/kg (Table 1). The concentration values of Cu in the soil around the vegetables and fruit plants were 5.531 mg/kg, 8.696 mg/kg and 3.018 mg/kg; also, these values were within the WHO permissible limits (36 mg/kg) for heavy metals in soils (Yap *et al.*, 2021), although the differences between soils and plants accounted for 61%, 91% and 25% respectively. The metal transfer mechanisms between the media were 0.707 mg/kg, 0.226 mg/kg and 0.957 mg/kg respectively (Table 2), which shows that Cu is not easily mobilized in both plants particularly in fluted pumpkin. Similarly, Aralu and Okoye (2020) reported 0.87 mg/kg, Mathew *et al.* (2022) reported 0.155 mg/kg in bitter leaf and Yap *et al.* (2021) reported 0.25-7.58 mg/kg in guava fruits.

Zinc (Zn): The mean concentrations of Zn in the fruits were 1.303 mg/kg, 1.649 mg/kg, 2.873 mg/kg in bitter leaf, fluted pumpkin and guava fruits respectively, while around the fruit plants and soil were 3.32 mg/kg; 2.673 mg/kg; and 3.357 mg/kg respectively (Table 1) which are within the WHO permissible limit for heavy metals in soils (Yap, *et al.*, 2021). The differences in concentrations between the plants and the soil accounted for 44%, 24% and 8% respectively. However, the values were within the recommended dietary allowance of 11 mg/day for men and 8 mg/day for women; the recorded values were below the WHO permissible limits for edible plants at 50 mg/kg according to Bibi *et al*, (2023). It was observed that the metal transfer values (TF) of zinc were 0.682, 0.863 and 1.503 mg/kg in bitter leaf, fluted pumpkin and guava respectively, indicating that the transfer factor (tf) was greater than 1 for guava. This implies that the locations can function as hyperaccumulators for zinc (Zn). Since zinc possesses the ability to create strong, flexible and exchangeable complexes with organic molecules, the concentration level via the ingestion of the fruits and vegetable will help promote cellular growth, metabolism, neurobehavioral development, susceptibility to infection and differentiation (Roohani *et al.*, 2013). Similarly, Mathew *et al.* (2022) reported 1.144 mg/kg, Okwelle and Marcus (2023) (1.084-0.753 mg/kg) and Ojiego *et al.* (2022) (1.82-1.76 mg/kg) for pumpkin; Yap *et al.* (2021) recorded 0.25-7.58 mg/kg and Udofia *et al.* (2020) recorded 2.22-3.01 mg/kg in guava fruits.

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Potential Non-cancer Hazard

The biotoxic effects of heavy metals depend on the concentration and oxidation states of heavy metal, mode of deposition, chemical composition of vegetables, physical characterization, and the consumption rate (Manzoor *et al*., 2018). In this study, the metal transfer factor (TF) was used to estimate the capacity of plants for the accumulation of metals from contaminated soil. The calculated results of TF showed that the highest TF was with Fe, followed by Cu > Zn, Pb > Mn >Cr > Cd >Ni and vanadium was the least. The Daily Intake of Metals (DIMm) is the amount of nutrient content ingested from vegetables and fruits that is considered adequate for the daily healthy living of an individual. The DIM_m values ranged between 0.034-9.766 mg/kg, 0.040-22.22 mg/kg and 0.004-2.236 mg/kg. The Chronic Daily Intake (CDIm) of the metal is the amount of nutrient content of the vegetables and fruits which an individual is exposed to over a long period (70 years the assumed lifetime), which is unlikely to produce any adverse health effect in the future. These values ranged between 2.2^{-4} - 9.8^{-3}, 9.2^{-5} - 0.022 and 5.1^{-5} - 0.016 mg/kg in bitter leaf, fluted pumpkin and guava respectively. The CDIm values are all less than one (<1) indicating safe limit (1 mg/kg/day/person). The estimated Daily Intake of Metals ranged between 0.003-0.830 mg/kg, 0.003-1.89 mg/kg and 0.004-2.236 mg/kg respectively in bitter leaf, fluted pumpkin and guava fruits.

The Health Risk Index was calculated to determine the risk on population by consuming vegetables and fruits contaminated with heavy metals: 3.7^{-5} - 0.027, 1.9^{-5} - 0.630 and 1.5^{-4} - 0.1 for bitter leaf, fluted pumpkin and guava fruit respectively. These values were also within the safe limits of (<1), which implies that adults consuming these agricultural products are unlikely to experience non-carcinogenic hazards at the moment. The targeted Hazard Quotient ranged between 9.7^{-8} - 3.7^{-3}, 2.0^{-7} - 5.0^{-2} and 4.5^{-6} - 6.8^{-3} in bitter leaf, fluted pumpkin and guava respectively, while the cumulative targeted hazard quotient was 1.1^{-2}, 5.3^{-2}, 1.4^{-2} which is also less than 1, and this implies that the exposed consumers are unlikely to experience non-carcinogenic hazard at the moment. The result of this study is similar to the report of Yap *et al.* (2021).

CONCLUSIONS

The results obtained from this study revealed that contaminated soil, particularly waste dumpsite soil, generates pollutants such as heavy metals. This is because all the soils investigated which were collected around the vicinity of the vegetables and fruits show higher concentrations of the metals compared to the vegetables and fruit. The toxic heavy metals (Pb, Cd, Cr, Ni, As, V, Mn, Co, Fe, Cu and Zn) present in the heterogeneous waste were responsible for polluting the soil, which transfer and translocate into fruits and vegetables. Within the vicinity of the dumpsite (Etelebou), agricultural residues, organic waste and combustible material residues combined to form a polluted organically rich soil that attracts farmers. Unfortunately, the fruits and vegetables grown in such an environment are enriched with Pb, Cd, Mn, Fe, Co, V, Zn, Ni, Cu, and Cr. The results also showed that toxic heavy metals like Fe, Pb, As, Co, Cu, and Cr have the highest potential to transfer from soil to plants and bioaccumulate, while V and Zn have the least transfer. Although the calculated Risk Indexes such as EDI, DIM, HRI and THQ calculated show no significant toxicity effect on the consumer at the moment, over time, the accumulative effect will result in potent serious health hazards. It is therefore recommended that:

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1. The waste management in Yenagoa should adopt more professional management practices other than the rudimentary waste transfer practices within the state.

2. Farmers should be discouraged with policy implementations from accessing the dumpsite for agricultural use.

3. Finally, toxicological study should be undertaken to determine the safety of other agricultural products in the dumpsites (Etelebou).

REFERENCES

Ahmad-Mahir, R., A. Aminah and B. S. Ismail, (2009): Concentration of Heavy Metals in Guava Plant Parts and Soil in the Sungai Wangi Plantation, Perak, Malaysia. *International Journal of Agricultural Research*, 4: 310-316. DOI: 10.3923/ijar.2009.310.316).

Ajayi, O. A. (2021): Comparative Assessment of Heavy Metals Uptake of Vegetables Cultivated on a Dumpsite at Abraham Adesanya Polytechnic Ijebu-Igbo, Ogun State, Nigeria. *J. Chem. Soc. Nigeria*, 46(4):0651-0655.

Alsafran, M.; K. Usman, M. Rizwan, T. Ahmed and Jabril, H.A. (2022): The Carcinogenic and Non-Carcinogenic Health Risks of Meta (oid)s Bioaccumulation in Leafy Vegetables: A Consumption Advisor, *Front. Environ Sci.*,9(34):344-356. https://doi.org/10.3389/fenvs.2021.742269.

Ang, L.H. and Ng, L.T. (2000): Trace element concentration in Mango (*Mangifera indica L*.), seedless Guava (*Psidium guajava L*.) and Papaya (*Carica papaya L*.) grown on agricultural and ex-mining lands of Bidor, Perak. *Journal of Tropical Agricultural Science*, 23:15-22.

Aralu, C.C. and Okoye, P.A.C (2020): Assessment Of Heavy Metals Levels In Soil And Vegetables In The Vicinity of Unlined Waste Dumpsite in Nnewi, Anambra State Nigeria, *J. Chem. Soc. Nigeria*, 45(4):687-696.

Basha, A.M., N. Yasovardhan, S.V. Satyanarayana, G.V.S. Reddy and Kumar, A.V. (2014): Trace metals in vegetables and fruits cultivated around the surroundings of Tummalapalle uranium mining site, Andhra Pradesh, India; *Toxicology Reports* 1(2014):505-512, https//dx.doi.org/10.1016/j.toxrep.2014.07.011.

Bibi S, Fatima N, Syed M, Shah W, Naz A and Rizwan M (2017). A review on the heavy metal cobalt: source, environmental impact, effect on human health and remediation. **4th International Water Conference Climate Change & Disaster Risk Management for sustainable development & Businesse**s. *Pure Appl. Biol.*, 12(2):835-847; https://dx.doi.org/10.19045/bspab.2023.120083.

Bibi, M., F. Samiullah, F. Behlil, S. Afzal and Sahifa, G. (2023): Essential and non-essential heavy metals sources and impacts on human health and plants; *Pure Appl. Biol.*, 12(2):835-847, http://dx.doi.org/10.19045/bspab.2023.120083.

Dashu, E. (2017): Microbial Effect of Refuse Dump on the Composition of Leafy Vegetables Grown in the Vicinity of Dump Site Along River Benue, Mubi Road, Yola, *International Journal of Environment, Agriculture and Biotechnology (IJEAB);* 2(4):1895-1899, https://dx.doi.org/10.22161/ijeab/2.4.54 ISSN: 2456-1878).

Dhiman, A., A. Nanda and S. Ahmad (2011): Metal Analysis in Citrus Sinensis Fruit Peel and Psidium Guajava Leaf, *Toxicol Int*.; 18(2): 163–167. doi: 10.4103/0971-6580.84271.

Article DOI: 10.52589/AJENSR0-HV4ID9HL
DOI URL: https://doi.org/10.52589/AJENSR0-HV4ID9HL

Ebuete, A.W., D. P. Wodu and Ebuete, E. (2022): Dumping on Waters: The Lacunae in Waste Management in the Niger Delta, Nigeria; *Am. J. Environ. Clim.* 1(2):100-109. DOI: https://doi.org/10.54536/ajec.v1i2.602

Ebuete, A.W.; Y. Eremasi and Berezi, K.O. (2022).Waste Dumping on Surface Water: Disposal Impact Assessment in Yenagoa Metropolis, Nigeria. *Multidisciplinary Journal of academic Research and Development,* 2(1), 11-25.

Fosu-Mensah, B.Y., E. Addae, D. Yirenya-Tawiah and F. Nyame (2017): Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. *Cogent Environmental Science,* 3(1):1405887; https://doi.org/10.1080/23311843.2017.1405887.

Gebeyehu, H.R. and Bayissa, D.L. (2020): Levels of heavy metals in soil and vegetables and associated health Risks in Mojo area. Ethiopia; *PloS One*,15(1): e0227883; doi:10.1371/journal.pone.0227883

Halder, M., Rahman T., A. Mahmud, S.A. Jim and Akbor, M.A. (2022): Are the vegetables grown in the soil of municipal solid waste dumping sites safe for human health? An assessment from trace elements contamination and Associated health risks, *Nanotechnology, monitoring & Management*, 18:100731

Iyama,W.A.; Okpara, K. and Techato, K. (2022): Assessment of Heavy Metals in Agricultural Soils and Plant (*Vernonia amygdalina* Delile) in Port Harcourt Metropolis, Nigeria; *journal of Agriculture* 12(27). https:// doi.org/10.3390/agriculture12010027.

Janadeleh, H., M. Kardani, M.K. Rad and Salemi, M. (2015): Study of heavy metals effects on plants. **Third International Symposium On Environmental and Water Resources Engineering**.

Kamal, A.K.I; Islam, M.R. and Hassan, M. (2016): Bioaccumulation of trace metals in selected plants within Amin Bazar Landfill Site, Dhaka, Bangladesh, *Environ. Process,* 3:179-194. https://doi.org/10.1007/s40710-016-0123-9.

Kassaye, Y.A., L. Skipperud, S. Meland, E. Dadebo, J. Einset and B. Salbu (2012): Trace element mobility and transfer to vegetation within the Ethiopian Rift Valley lake areas. *J. Environ. Monit.*, 14(10):2698-2709.

Khan, S.; Rehman, S.; Khan, A.Z.; Khan, M.A. and Shah, M.T. (2010). Soils and vegetables enrichment with heavy metals from geological sources in Gilgit, Northern Pakistan. *Ecotoxicol. Environ. Saf.*, 73, 1820-1827.

Manzoor, J., M. Sharma and Wani, K. A. (2018): Heavy metals in vegetables and their impact on the nutrient quality of vegetables: A review, *Journal of Plant Nutrition*, 23(9):1-22; DOI: 10.1080/01904167.2018.1462382

Mathew, J.T; A. Mamman, M. Musah, Y. Azeh, A. Inobeme, M.T. Umar, A.A.Otori, E.Y. Shaba, A.I. Muhammed and Yisa, P.S. (2022): Assessment of Selected Heavy Metal Content on Dumpsites Soil and Vegetables Grown in Muwo Metropolis, Niger State, Nigeria, *J. Appl. Sci. Environ. Manage.*, 26 (9) 1473-1478.

Matović V, Buha A, Đukić-Ćosić D & Bulat Z (2015). Insight into the oxidative stress induced by lead and/or cadmium in blood, liver and kidneys. *Food and Chem Toxicol* 78: 130-140.

Markmanuel, D.P., Amos-Tautau B.M.W., Songca, S. P. (2022): Tin concentrations and human health risk assessment for children and adults in sea food and canned fish commonly consumed in Bayelsa State, Nigeria. *J Appl Sci Environ Manag.* 26 (7): 234-240. doi: 10.4314/Jasem.v26i7.12

Markmanuel, D.P., Godwin J, and Ebue, A.W. (2023): Potential cancer and non-cancer hazard of some heavy metals in children and adults via consumption of canned chicken luncheon and Turkey luncheon. *Discovery,* 59: e56d1237

Article DOI: 10.52589/AJENSR0-HV4ID9HL
DOI URL: https://doi.org/10.52589/AJENSR0-HV4ID9HL

Nyiramigisha, P., C. Komariah and Sajidan, B. (2021): The concentration of heavy metals zinc and lead in the soil around the putri cempo landfill. Indonesia; *IOP Conf, Ser. Earth Environ. Sci.*, 824 (1) (2021), 10.1088/1755-1315/824/1/012050.

Ojiego, B.O., G.I. Ogu, F. Dantanko, J.C. Okolo and K.E. Audu (2022): Health risk assessment for selected heavy metals in Telfairia occidentalis (fluted pumpkin) leaf retailed in markets within Lokoja Metropolis; VU-International Journal of Agricultural Sciences, 4(3):125-134, Doi: 10.21608/svuijas.2022.154693.1225.

Okwelle, P. L., and Marcus, A. C. (2023). Heavy metal levels in fluted pumpkin (Telfairia occidentalis L.) leaf and soil from selected dumpsites in Port Harcourt Metropolis, Rivers State, Nigeria. *FNAS Journal of Scientific Innovations*, 4(1):89-96. www.fnasjournals.com.

Osemudiamen, E.; O. Grace and Ozekeke, O. (2023): Nickel and Vanadium in Edible Fruits and Vegetables, Potential Health Risk or Not? *NIPES Journal of Science and Technology Research*, 5(2):92-101; https://doi.org/10.5281/zenodo.8010133.

Otugboyega, J.U., F.U. Madu, O.O. Otugboyega, A.M. Ojo, A.J. Adeyeye and J. A. Ajayi (2023): Biomonitoring and Biomathematical Modeling of Health Risks Associated with Dumpsite Grown Vegetables in Lagos State; *Research Square,* https://doi.org/10.21203/rs.3.rs-2727806/v1.

Patel, K.S.; K.P. Pandey, P. Martin-Ramos, W.T. Corns, S. Varol, P. Bhattacharya and Zhu, Y. (2023): A review on Arsenic in the Environment: Bioaccumulation, remediation and disporsal; *RSC Adv*, 13(22):14914-14929; doi:10.1039/d3ra02018e.

Primandani, A., A. Sajidan and Masykuri, M. (2020): Soil and Banana Crops (*Musa Paradisiaca L*) risk by Chromium (Cr) accumulation through leachate and its health risk assessment, **16th International Conference on Mathematics, Science, and Education (ICMSE 2019);** *Journal of Physics Conference Series*, 1567(2020) 042058. Doi:10.1088/1742-6596/1567/4/042058.

Raychaudhuri, S.S.; Pramanick, P. Talukder, P. and Basak (2021): Chapter 6-Polymines, Metallothioneins, and Phytochelatins" Natural defense of plants to mitigate heavy metals in Bioactive Natural Products, edited by Atta-ur-Rahman *Elsevier*, 69 (227-261). https://doi.org/10.1016/B978-0-12-819487-4.00006-9.

Roohani, N., R.Hurrell, R. Kelishadi and Schulin, R. (2013): Zinc and its importance for human health: An integrative review. *J of Res in Med Sci: the Off J of Isfahan Uni of Med Sci* 18(2): 144.

Samaila, B., B. Maidamma, B. Usman, A.I. Jega and Alhaji, S.A. (2021): Assessment of Hazard Index and incremental Life Cancer Risk Associated with metals in the soil, *SPR,* 1(4):298-319. Doi:https//doi.org/10.52152/spr/2021.148

Simon, C.E. and Ayotamuno, M.J. (2022): Leachate Pollution Index Determination at Yenagoa Central Waste Dump during the First Quarter of 2019, Bayelsa State, Nigeria; *Acta Scientific Environmental Science*, 1(1): 23-28.

Soetan K, Olaiya C & Oyewole O (2010): The importance of mineral elements for humans, domestic animals and plants-A review. *Afri J of Food Sci* 4(5): 200-222.

Udofia, U. U., Udiba U. U., Akpan E. R. and Antai E. E. (2020): Potential human health risk assessment of heavy metals intake through consumption of fluted pumpkin(Telfairia occidentalis) purchased from major markets in Calabar Metropolis, Nigeria, *Issues in Biological Sciences and Pharmaceutical Research* 8(5):85-97; https://doi.org/10.15739/ibspr.20.010.

Yap, C. K., A. Razali, R. Nulit, S.H.T. Peng, C.W. Yap, H. Okamura, M. S. Ismail (2021): Biomonitoring of Heavy Metals in the Guava (Psidium guajava) for Their Health Risk Assessment in Kluang, Malaysia. *Food Science and Engineering*. 2(1):13-20. https://ojs.wiserpub.com/index.php/FSE/article/view/691.

Article DOI: 10.52589/AJENSR0-HV4ID9HL
DOI URL: https://doi.org/10.52589/AJENSR0-HV4ID9HL