

Biomonitoring and Biomathematical Modeling of Health Risks Associated with Dumpsite Grown Vegetables in Lagos State

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Abstract

Conversion of dumpsites to farm lands in several communities is a usual practice in Nigeria. Wastes accumulate heavy metals in a variety of forms. This study assessed the concentration, degrees of contamination and attendant health risk of heavy metals (HMs); using two major indigenous vegetables (*Amaranthus viridis* and *Talinum triangulare*) grown on five major dumpsites in Lagos state. After wet digestion, the mean concentrations of the HMs in the vegetable samples were evaluated using Atomic Absorption Spectrophotometer (AAS). Daily intake of Metals (DIM), tangent hazard quotient (THQ) and hazard index (HI) biomathematics were employed in the assessment of non-carcinogenic health risk. Incremental Lifetime Cancer Risk (ILCR) assessment was used to assess Carcinogenicity. HM concentrations detected fell within the following ranges: (0.59 to 0.37), (0.07 to 1.36), (0.30 to 2.21), (0.00 to 0.03) and (0.00 to 0.04) mg/kg; for zinc (Zn), Lead (Pb), Iron (Fe), cadmium (Cd), and chromium (Cr), respectively. Low to moderate variability and statistically significant differences were seen in the concentration of HMs in vegetables, ($p < 0.05$). At Ikorodu, Pb concentration was above the world Health Organization (WHO) permissible range and has the highest contamination factor. DIM and THQ for Fe and Pb were above threshold values (>1); HI values for the vegetables exceeded WHO normal range (>1), except Abule-Egba samples. These values reveal great health risk from consumption of vegetables from four major sites. ILCR values for 43.3% of the samples were above the WHO (10^{-6}) limits, indicating high risk of carcinogenicity over a life time of exposure.

1 Introduction

One of the most crucial problems facing the world today is environmental pollution and it is regarded as one of the biggest difficulties in our contemporary times. Heavy metal toxicity in the environment is on an exponential increase and has become a huge concern (Rakali et al. 2022). These classes of metals are available in almost all environmental niches, but their distribution patterns have been altered by various anthropogenic activities; such as mining, urbanization, agriculture, industrialization, and smelting. Consequently, they tend to build up in some specific locations (Zwolak et al. 2019; Dhaliwal et al. 2020) depending on the rate of pollution and contamination in such niches. Due to their pervasive nature, very low biodegradability, accumulation, toxicity, and relative persistence, increased concentration, heavy metals (HMs) in the environment keep drawing attention and serious concern worldwide. (Kandziora-Ciupa et al. 2021). The harmful effects of HMs on soil biological, biochemical and physicochemical profiles have been documented (Tang et al. 2019; Madu 2020; Sharma et al. 2020). In addition, the accumulation and transport of HMs in the soil have been implicated as source of harmful metals in the food chain, and eventual critical health hazards in living organisms (Chinyere and Madu 2015; Kumar et al. 2019; Mensah et al. 2021). HMs that have been largely aggregated in soils can be easily transported into other environmental compositions, like rivers, groundwater, and plants, thereby resulting in menace to human beings (Jia et al. 2018). Researches have clearly revealed that HMs that exceed the permissible limits damage water quality and render it unusable for its intended purposes like irrigation or drinking (Edokpayi et al. 2018; Ravindra and Mor 2019). Continuous direct or indirect intake

of HMs pose a detrimental impact on humans, and the associated injurious effects begin to manifest years after enduring exposure (Kurma et al. 2019).

Dumps which serve as reservoir for heterogenous wastes (from different sources) have been linked with the accumulation of heavy metals (Chinyere and Madu 2015; Kimani 2010; Hammed et al. 2017). Very many of the dumpsites in Eastern Nigeria, as well as in other regions of Nigeria are vastly exploited for cultivation of numerous edible vegetables and crops-foodstuffs without accurate regular evaluation of the corresponding health and ecological risks (Obasi et al. 2012). Municipal wastes with high concentrations of As, Ni, Zn, Hg, Fe, Cd, Pb, Cu, Mn., etc., end up in natural water reservoirs in the process of being leached from the landfills. These heavy metals are resistant to decomposition by microbes, they further aggregate and are speciated into more toxic methyl compounds. Eventually, they get stored up across the food chain, in hazardous amounts in the human body (Li et al. 2014; Hui et al. 2020). According to Burges et al. (2018) and Keyster et al. (2020), HMs have been found responsible for serious contamination of vegetables in Switzerland. They have been implicated in several diseases like kidney problems, lung cancer etc., and neurological disorders (Okoye et al. 2021; Vanidassane et al. 2021).

Vegetables are common sources of vitamins and minerals which are consumed for healthy living in Nigeria. Indigenous vegetables such as *Celosia argentea*, *Solanum macrocarpon*, *Solanum nigrum*, *Amaranthus viridis*, *Talinum triangulare*, *Senecio bialfrae*, *Crassocephalum cecropioides*, etc, represent a cheap and readily available source of important classes of food and are usually consumed alongside staple diets (Ogunrotimi et al. 2018) *Amaranthus viridis* for instance, is a good source of flavonoids, phenolics, antioxidants with large medicinal and pharmacological effects. It is rich in dietary fiber, proteins, carbohydrates and essential elements like Cu, P, Zn, Mg, Ca, Na, etc. It has been found effective in treating dysentery, inflammations, and as blood purifier (Umakanta and Shinya 2019). *Talinum triangulare* on the other hand is a good diuretic. It is effective in the management of gastrointestinal disorders, asthma, high blood pressure and also rich in flavonoids, proteins, vitamins and minerals (Ikewuchi et al. 2017). Despite the nutritional benefits associated with these vegetables, contamination with heavy metals will over-ride the benefits and expose consumers to detrimental health risks. Few studies have considered human health risk associated with contaminated vegetables in Lagos, a metropitan and highly populated city in Nigeria. This study examined the status, level of heavy metal contamination and possible health implications of these important indigenous vegetable species using mathematical models.

2 Methods And Materials

2.1 Study Area

The study was carried out in five major dumpsites in Lagos state, Nigeria. The sites are relatively wide apart, thereby giving good representation of waste composition in the soils of Lagos state. The dumpsites are randomly and strategically located at Abule-Egba, Alimosho, Ikorodu, and Olusosun. They are nomenclatured: Abule-Egba dumpsite, Alimosho Sulus 1, Alimosho Sulus 2, Ikorodu dumpsite and

Olusosun dumpsite. The specific locations and the coordinates of the dumpsites are given in Fig. 1 and Table 1.

Table 1: Locations and Coordinates of the dumpsites

NAME	POSITION
ABULE – EGBA	N6 39.897 E3 18.238
IKORODU	N6 38.338 E3 32.807
OLUSOSUN	N35.660 E3 22.639
SOULUS1	N34.278 E315.199
SOULUS 2	N6 33.186 E3 13.952

2.2 Sample Collection and Preparation

Ten mature leafy vegetable samples growing at different dumpsites were chosen at random. Two major species were analyzed for their heavy metal contents. They include *Amaranthus viridis* and *Talinum triangulare* (Table 2)

Table 2: Description And Images of Vegetable samples

Sample	Common name	Local name	Scientific name	Image
1	Green Amaranthus, Pig weed, Slender Amaranth	Tete (Yoruba)	<i>Amaranthus viridis</i>	
2	Water leaf	Gbure, Ebe-dondon (Edo)	<i>Talinum triangulare</i>	

The leaves of the harvested vegetables were carefully cleansed and rinsed with deionized water to get rid of soil samples and other attached particles on the plants. The samples were air dried in the laboratory at room temperature. After dryness and constant weight have been attained, the samples were pulverized in porcelain pestle and mortar. The pulverized samples were then made available for wet digestion.

2.3 Extract Preparation

The glassware used for the chemical analysis was thoroughly cleaned with soap and water, and then soaked in an acid bath for 24 hours before use to get rid of contaminants. The acid wash employed was prepared from diluted aqua regia solution which consists of 1 part concentrated nitric acid and 3 parts concentrated hydrochloric acid, mixed with 1-part water; for the brief storage of the solution (Shugar and Ballinger 1996). The acid bath was made using the same grades of acids used for analysis. One gram of the pulverized vegetable sample was taken. Digestion was accomplished using aqua regia solution from HNO₃ acid with 69.5% concentration. At 110°C, 10 mL of aqua-regia HNO₃/HCl (1:3) was poured into each of the 3 test-tubes and was left to boil for 2hours at 110°C until the brown fumes disappeared which signified complete digestion. 20 mL distilled water was added and boiled until it became a clear solution. The mixture was allowed to cool before being filtered using Whatman No. 42 filter paper into a standard volumetric flask (100mL). With distilled water, the volume was adjusted to the mark (Onyedikachi 2018). Heavy metals such as Pb, Fe, Zn, Cr and Cd were analyzed from the digested sample utilizing methods Atomic Absorption Spectrophotometer (AAS). The operational conditions for the functioning of AAS are presented in Table 3.

Table 3

Operational Functioning Conditions for atomic absorption spectrophotometer (AAS) determination

Heavy Metals	Flame gases	Wavelength (nm)	Spectral Band Width (nm)	Atomization flow rate (L/min)
Zinc (Zn)	Air-acetylene	213.9	0.7	0.9
Lead(Pb)	Air-acetylene	283.3	0.7	0.9
Iron(Fe)	Air-acetylene	248.3	0.2	0.9
Cadmium(Cd)	Air-acetylene	228.8	0.7	0.9
Chromium(Cr)	Air-acetylene	357.9	0.7	0.9

2.4 Quality control and Quality assurance

In this investigation, high purity reagents and chemicals were used for quality assurance/quality control purposes. Distilled water was used throughout the study (Onyedikachi, et al. 2018). Glass and plastic items (Merck, Germany) were carefully cleansed with 10% HNO₃ before being washed with distilled water. Each sample was analyzed three times for quality assurance purposes. Metal determination was carried out using Atomic Absorption Spectrophotometer (AAS) VGP 210 model. Standard solutions made in the same acid matrix were applied to analytical blanks in the same manner as samples to assess concentrations as reported earlier. For data reliability assessment, blank samples were repeatedly checked to ensure that results obtained fall within the range.

2.5 Data Analysis

Data obtained was analyzed using Microsoft Excel 2010. Mean of triplicate values, standard deviation and p-values were calculated using the statistical package for social sciences (SPSS). Assessment of variations in vegetables from the different dumpsites was calculated using Coefficient of variations (CV) expressed in percentage (%), as shown in the equation below:

$$CV = \frac{SDV}{Xi} \times 100 \dots\dots\dots (i)$$

where

Xi is the mean,

SDV is the standard deviation.

According to Isiuku and Enyoh (2020), the classification of variation was taken as follows: CV below 20 was considered to have minimal variation, CV between 20 and 50 had moderate variation, and CV beyond 50 had considerable variance.

2.6 Contamination Factor (Cf) and Pollution Load Index (PLI)

Pollution load index (PLI) and the Contamination factor (Cf) were determined in line with the equations represented below (Isiuku and Enyoh 2020). While PLI is determined from the Cf, which is the fifth-root of each individual Cf product of each heavy metal under study, Cf is defined as the ratio of the estimated concentrations of heavy metals in vegetables to reference suggested limits (Bentum et al. 2011; Usero et al. 2000)

$$Cf = \frac{C_m}{R_L} \dots\dots\dots (ii)$$

$$PLI = \sqrt[5]{Cf_{Zn} \times Cf_{Pb} \times Cf_{Fe} \times Cf_{Cr} \times Cf_{Cd}} \dots\dots\dots (iii)$$

where R_L is the FAO/WHO-recommended limit and C_m is the measured heavy metal concentration in the vegetable as provided in Table 4 (FAO/WHO, 2007).

2.7 Average Heavy Metals Daily Intake (DIM)

Mahmood and Malik (2014) and Latif et al. (2018), postulated that the daily heavy metal intake is estimated by applying the equation below:

$$DIM = \frac{\text{Concentration of heavy metal} \times \text{Daily food intake}}{\text{Average weight}} \dots\dots iv$$

Evaluations were generated using the USEPA risk analysis template, with the assumption that an adult's average body weight is 60 kg and the daily intake of vegetable (on the average) for adults is 0.345kg

person⁻¹day⁻¹ (Latif et al. 2018; Wang et al. 2018).

2.8 Hazard Index (HI) and Target Hazard Quotient (THQ)

Based on the THQ, the human health risks associated with the local population's consumption of vegetables were evaluated. THQ is estimated as the ratio between reference oral dose (RfD) and exposure. According to Yu-Jun et al. (2011), it is employed in evaluating the risk of non-carcinogenic effects. If the value of ratio is above 1 or equal to 1, the study population is vulnerable to health risks. HI sums up all the THQs and is important in determining the potential human health risk when several heavy metals are involved. The computed value gives the Hazard quotient. Estimation guidelines for CR and THQ are contained in the Risk-Based Concentration Table, January–June 1996 of USEPA Region III. (USDOE 2011; USEPA 2012; Chien et al. 2015); and is represented by the equation below:

$$THQ = \frac{\text{Daily food intake} * \text{Concentration of Heavy metals}}{\text{Average weight} * RfD} \dots\dots\dots(v)$$

THQ stands for the target hazard quotient, the DIM is the heavy metals consumed daily in (mg/kg/day), concentration of heavy metals in vegetables is given as mgkg⁻¹, 60kg is taken to be the average body weight, and RfD is the dose for oral reference (mg/kg/day). The recommended daily consumption of vegetables for adults is 0.345 kg per person per day (Latif et al.2018; Wang et al. 2018). RfD provides an estimate of the population's oral exposure per day, and this may not necessarily result in hazardous effect over a lifetime; EPA's non-cancer health evaluation typically uses it (Guerra et al. 2018).

Equation for the Hazard Index:

$$HI = i = 15THQ = THQ_{Zn} + THQ_{Pb} + THQ_{Fe} + THQ_{Cr} + THQ_{Cd} \dots\dots\dots(vi)$$

2.9 Cancer Risk Assessment

The likelihood of developing cancer from oral exposure to toxicants over the course of a lifetime is assessed using the Ingestion Cancer Slope Factor, as given by USEPA (1998) and ATSDR (2010). The units for the ICSF are given in (mg/kg/day). The risk of developing cancer from exposure over a lifetime due to location-related chemicals is estimated as given below:

$$ILCR = DIM \times CSF \dots\dots\dots(vii)$$

ILCR stands for Incremental Lifetime Cancer Risk; DIM is the heavy metal consumed daily in (mg/kg/day) and CSF is the ingestion cancer slope factor (mg/kg/day). An ILCR value of less than 1.0E-06 is regarded as insignificant, whilst one between 1.0E-06 and 1.0E-04 is within the permitted limit and one greater than 1.0E-04 is probably dangerous to humans. (Al-swadi et al. 2022).

3 Results

The various values for all the parameters evaluated are presented in tables and charts. Zinc concentration varied from 0.36 to 0.48 mg/kg with mean value of 0.39 mg/kg in *Talinum triangulare* and from 0.45 to 0.66 mg/kg with mean value of 0.56 mg/kg in *Amaranthus viridis* respectively. The coefficient of variations of the Zinc distributions in the vegetables ranged from 1.30 to 4.20 across the study areas. Pb varied from 0.01 to 0.06 mg/kg with mean value of 0.01 mg/kg in *Talinum triangulare* and from 0.02 to 1.36 mg/kg with mean value of 0.28 mg/kg in *Amaranthus viridis* respectively. The coefficient of Pb showed range of 7.89 to 9.12 in the sampled vegetables across the area.

Cadmium concentration varied from 0.01 to 0.00 mg/kg with the mean value of 0.01 mg/kg in *T. triangulare* and from 0.00 to 0.03 mg/kg with the mean value of 0.28 in *A. viridis*. The coefficient of variations of cadmium distributions in the vegetables ranged from 24.7 to 173 in the sampled vegetables across the dumpsites. Fe concentration varied from 0.31 to 1.90 mg/kg with the mean value of 1.32 mg/kg in *T. triangulare* and from 0.30 to 2.21 mg/kg with the mean value of 1.25 mg/kg in *A. viridis* respectively. The coefficient of variations of Fe showed range of 0.26 to 3.98 across the study areas. Cr concentration varied from 0.00 to 0.04 mg/kg with the mean value of 0.02 mg/kg in *Talinum Triangulare* and from 0.02 to 0.04 mg/kg with the mean value of 0.03 mg/kg in *Amaranthus viridis*.

The coefficient of variation of Cr showed range of 0 to 24 in the sampled vegetables across the dumpsites.

Table 4
Concentrations (mg/kg) of Heavy Metals in Vegetables Grown at Different Dumpsites in Lagos

Location	Vegetable	Heavy Metals					
Abule-Egba	<i>A. viridis</i>		Zn	Pb	Cd	Fe	Cr
		Test	0.59 ± 0.01 ^b	0.03 ± 0.001 ^b	0.0003 ± 0.00058	0.78 ± 0.01 ^b	0.02 ± 0.00 ^b
		control	0.29 ± 0.02 ^a	0.01 ± 0.00 ^a	Nd	1.86 ± 0.10 ^a	0.04 ± 0.01 ^a
	<i>T. triangulare</i>						
		Test	0.367 ± 0.0058 ^b	0.01 ± 0.00 ^a	0.013 ± 0.0058	0.307 ± 0.0058 ^b	0.009 ± 0.0017 ^b
		control	0.63 ± 0.12 ^a	0.01 ± 0.00 ^a	Nd	2.36 ± 0.04 ^a	0.03 ± 0.001 ^a
Alimosho S ₁	<i>A. viridis</i>						
		Test	0.48 ± 0.01 ^a	0.04 ± 0.00 ^b	Nd	0.30 ± 0.0058 ^b	0.03 ± 0.0058 ^b
		control	0.32 ± 0.03 ^a	0.04 ± 0.02 ^a	Nd	3.73 ± 0.42 ^a	0.13 ± 0.01 ^a
	<i>T. triangulare</i>						
		Test	0.48 ± 0.00 ^b	0.06 ± 0.0058 ^a	Nd	1.82 ± 0.025 ^b	0.037 ± 0.0058 ^a
		Control	0.28 ± 0.01 ^a	0.063 ± 0.003 ^a	Nd	1.47 ± 0.12 ^a	0.04 ± 0.001 ^a
Alimosho S ₂	<i>A. viridis</i>						
		Test	0.45 ± 0.0058 ^b	0.02 ± 0.0058 ^b	Nd	1.30 ± 0.0058 ^b	0.02 ± 0.0058 ^a
		Control	0.60 ± 0.004 ^a	0.38 ± 0.02 ^a	Nd	2.36 ± 0.25 ^a	0.02 ± 0.003 ^a
	<i>T. triangulare</i>						
		Test	0.40 ± 0.0058 ^b	0.07 ± 0.0058 ^b	Nd	1.30 ± 0.0058 ^b	0.02 ± 0.0012 ^a

Location	Vegetable	Heavy Metals					
Olusosun	A.viridis	Control	0.25 ± 0.002 ^a	0.18 ± 0.01 ^a	Nd	1.03 ± 0.08 ^a	0.03 ± 0.01 ^a
		Test	0.66 ± 0.01 ^b	0.02 ± 0.00 ^b	0.023 ± 0.0058	1.83 ± 0.01 ^b	0.04 ± 0.0058 ^b
		Control	0.22 ± 0.03 ^a	0.04 ± 0.01 ^a	Nd	1.28 ± 0.03 ^a	0.02 ± 0.006 ^a
	T.triangulare						
	Test	0.36 ± 0.015 ^a	0.07 ± 0.0058 ^b	0.023 ± 0.0058	1.92 ± 0.08 ^b	0.022 ± 0.0058 ^a	
	Control	0.24 ± 0.02 ^a	0.15 ± 0.01 ^a	Nd	1.32 ± 0.13 ^a	0.020 ± 0.00 ^a	
Ikorodu	A.viridis	Test	0.60 ± 0.02 ^b	1.36 ± 0.0058 ^b	0.03 ± 0.00	1.12 ± 0.02 ^b	0.02 ± 0.0006 ^b
		Control	0.02 ± 0.00 ^a	0.04 ± 0.01 ^a	Nd	0.05 ± 0.01 ^a	0.001 ± 0.00 ^a
		T.triangulare	Test	0.37 ± 0.0058 ^a	0.03 ± 0.01	Nd	1.30 ± 0.015 ^b
	Control	0.32 ± 0.01 ^a	Nd	Nd	1.01 ± 0.17 ^a	Nd	
	FAO/WHO Std.		99.4	0.3	0.2	4.25	1.3

Values in the table are mean ± standard deviation of triplicate values. Values in the same column for a particular vegetable with different letters are significantly different (P < 0.05). Nd = Not detected

3.1 Assessment of Contamination

The pollution load index (PLI) and contamination factor (CF) values of the heavy metals of interest are depicted in Table 5. CF values ranged from 0.0045 to 0.007 (Zn), -0.07- 4.53 (Pb), 0 -0.15 (Cd) and 0.07– 0.13 (Cr) in *A. Vidris*, and from 0.004 to 0.005 (Zn), -0.23–0.2 (Pb), 0–0.005 (Cd), 0.001–0.004 (Fe), 0– 0.67 (Cr) for *T. triangulare* respectively. The PLI varied from – 0.18 to 0.06 for *A. viridis* and from – 0.01 to 0.07 for *T. triangulare* respectively.

3.2 Health Risk Assessment

The average daily heavy metal intakes (DMI) in the sampled vegetables are illustrated in Fig. 4. Negative values were obtained for DMI for Pb in both vegetables compared to other metals of interest. Fe has the highest value of DMI (0.13).

The Non-Carcinogenic Assessment (THQ) and Health Index (HI) values of the analyzed vegetables are presented in Figs. 5 & 6. The table of results showed that Pb has the highest value for THQ and HI; 2.23 and 3.28 respectively.

The computation of Incremental cancer risk assessment (ILCR) values is illustrated in Table 5.

Table 5				
Computed Incremental Lifetime Cancer Risk (ILCR) Assessment Values				
Vegetable				
Location		Pb	Cd	Cr
ABULE-EGBA	A. viridis	1.45×10^{-6}	1.9×10^{-5}	6.0×10^{-6}
ALIMOSHO S1		1.96×10^{-6}	0.00	4.0×10^{-4}
ALIMOSHO S2		1.02×10^{-6}	4.56×10^{-6}	1.15×10^{-4}
OLUSOSUN		1.02×10^{-6}	4.5×10^{-5}	1.15×10^{-5}
IKORODU		6.63×10^{-5}	7.6×10^{-5}	5.0×10^{-5}
ABULE-EGBA	T. triangulare	4.9×10^{-7}	2.2×10^{-5}	2.9×10^{-5}
ALIMOSHO S1		2.98×10^{-6}	0.00	1.15×10^{-4}
ALIMOSHO S2		3.4×10^{-6}	0.00	6.0×10^{-5}
OLUSOSUN		3.4×10^{-6}	0.00	6.0×10^{-5}
IKORODU		1.7×10^{-6}	0.00	0.00

The ingestion carcinogenic slope factor CSF ($\text{mgkg}^{-1}\text{day}^{-1}$) and reference dose RfD ($\text{mgkg}^{-1}\text{day}^{-1}$) is shown in Table 9 for the metals. CSF values range from 0 to 0.5 while RfD varied from 0.001 to 0.3 ($\text{mg kg}^{-1}\text{day}^{-1}$) for all the metals.

Table 6
Toxicological Parameters of the analyzed metals

Metals	ICSF ($\text{mg kg}^{-1} \text{ day}^{-1}$)	Ingestion reference dose RfD ($\text{mg kg}^{-1} \text{ day}^{-1}$)
Zinc (Zn)	0.00	0.30
Lead (Pb)	0.0085	0.0035
Cadmium (Cd)	0.38	0.001
Iron (Fe)	0.00	0.007
Chromium (Cr)	0.50	0.003
ICSF = Ingestion Carcinogenic Slope Factor		

Source: FAO/WHO (1993), USEPA (IRIS, 2010), USDOE (2011), USEPA (2011a).

4 Discussion

In this study, Zinc (Zn), lead (Pb), cadmium (Cd), iron (Fe), and chromium were analyzed. Heavy metal concentrations were in the order of $\text{Fe} > \text{Pb} > \text{Zn} > \text{Cr} > \text{Cd}$ in the investigated vegetables. Fe has the maximum level of concentration in all the vegetables from the dumpsites as the values ranged from 0.30 and 2.21 (mg/kg).

Alimosho Soulus 2 had the peak of concentration of Fe (2.21 mg/kg) in *Amaranthus viridis*. High concentration of Fe has also been reported in vegetables grown on such contaminated site as reported by (Wegwu et al. 2017; Onyedikachi et al. 2018, 2019). Iron is an essential micronutrient necessary for the transport of oxygen round body. It plays a crucial part in a number of metabolic processes, making it necessary for all living things. Fe is involved in electron transport, DNA synthesis, in addition to oxygen transport among others (Abbaspour et al. 2014). The values of iron from both *A. viridis* and *T. triangulare* were lower than the maximum suggested limit for vegetables and values recorded for some green vegetables acquired in some agricultural farmlands. If allowed for a prolonged time, Fe loads may largely become stored up in soils and foods leading to numerous health challenges linked to iron toxicity. The harmfulness of iron has been reported in tissue damage through cell oxidation and reduction mechanisms, and relative toxicity in intracellular organelles like lysosomes and mitochondria. Vast free radicals that are potentially responsible for cellular damages assist in excessive iron assimilation. According to Grazuleviciene et al. (2009), The Fe induced free radicals of hydrogen invade DNA, causing injury to the cells; malignant transformations and mutation that invariably result in several diseases. Elevated toxicity of iron aggravates tachycardia, hypotension, hepatic necrosis, lethargy and may even lead to death (Jaishankar et al. 2014; Onyekachi et al. 2021).

The mean concentration of Zn was below the permissible limit of 99.4 mg/kg for the vegetables. Zinc concentration was highest in *A. viridis* sample from Olusosun site, while the least was also from Olusosun in *T. triangulare*. The range (0.36 - 0.66) of Zn content in this study is far lower than the advised safe level of 99.4 mgkg⁻¹, demonstrating the safety of the vegetables (FAO/WHO, 2011), although, quite substantial quantity of Zinc had also been reported in vegetables by other researchers like Idirs et al. (2009) with substantial health concerns to consumers. Zinc is a necessary component of the human diet and is regarded as the least toxic of the metals. It makes the immune system work more efficiently (Garba et al. 2018). It is a crucial co-factor for a lot of the body's enzymes. Zinc deficiency in the diet may be considerably more harmful to human health than zinc excess. According to Saraf and Samant (2013), heart disorders can result from lack of zinc and metabolic pathways are disrupted. However, excessive exposure to zinc may generate intestinal and stomach disorders; liver dysfunction; and experience relating to flu-like symptoms. Aside that, in soil, Zn can interfere with the activity of earthworms and microorganisms and earthworms causing reduction in the breakdown of organic matter (Zulfiqar et al. 2020). Zn can affect the levels of high-density lipoproteins, delay sexual maturation, cause growth retardation, diarrhea and exposure to infection (Ametepey et al. 2018).

Highest concentration of Pb was reported at Ikorodu dumpsite (1.36 mg/kg). The values 0.04 mg/kg in *A. Viridis* and 0.06 mg/kg in *T. triangulare* recorded at Alimosho Soulus 2 sites also exceed the daily recommended limit of 0.03 mg/kg (WHO/FAO). The ranges of value obtained in this study were far below the values obtained in vegetables by other researchers though outside the acceptable standard (0.03 mg/kg) Lente et al., (2014) observed Pb concentrations in vegetables with the range of 2.42 to 13.50 mg/kg, Odai *et al.* reported Pb concentrations in vegetables between 5.59 to 10.51 mg/kg, while in China, Suruchi and Pankaj recorded 2.652 mg/kg of Pb in vegetables.

Despite the fact that plants frequently show the ability to gather large amounts of Pb without visible changes in their look or output, Pb is a hazardous component that can be harmful to plants. Pb accumulation in many plants can be several hundred times higher than the upper limit of what is reasonable for human use. This is related to the fact that chronic exposure to Pb can impair the central nervous system and cause slow reaction times, poor comprehension, and behavioral issues in children as well as problems with learning and concentration. According to Funtua (2014), Industries are responsible for being a source of lead. Poor irrigation water, as reported in Kano, Nigeria has also been responsible for high Pb in vegetable (21.22 mgkg⁻¹ to 35.28 mg/kg) (Lawal and Audu 2001). Pb damages human organs like the kidneys, liver, lungs, and spleen at high concentrations. It also impacts children's neurodevelopment and the central nervous system (Isiuku and Enyoh 2019). According to a study, individuals' blood pressure increases are positively correlated with the presence of Pb in the human body (Maihara and Favaro 2006). Pb buildup can occur in many plants at levels that are several hundred times higher than what is considered safe for consumption; which is harmful to humans and isn't even slightly necessary (Muhammad et al. 2008; Onyedikachi et al. 2018). It builds up in the teeth and bones, weakening the joints and making the bones more brittle.

The maximum Cd concentration was found in *Amarantus viridis* at Ikorodu dumpsite (0.03 mg/kg) which is above the recommended limit (0.02 mgkg⁻¹). Since the values ranged from -0.00 to 0.03 (mgkg⁻¹) across the study sites, all levels of heavy metals were found to be within the safe limit of 0.2 mgkg⁻¹ (vegetables) when compared to the FAO/WHO permitted limits (2011). Cadmium poisoning may result from consumption of food like leafy vegetables or common grains. Occupational exposure can also occur from metal plating, plastics and battery industries. Associated effects include fever, vomiting, headaches, fatigue, etc., can result from excessive exposure to cadmium. Toxicodynamics evaluation shows impairment of lung functions (emphysema), pulmonary edema (accumulation of fluids in the lungs), and dyspnea; seizure of breath. Affected people can experience salivation, poor oxygen supply to body tissues; osteomalacia and slight liver dysfunction, among other symptoms. (Nwaichi et al. 2014; NORD 2021).

The average concentration of Cr ranged from 0.00 to 0.004 (mgkg⁻¹). The maximum concentration was found in Alimosho sites and olusosun; in both vegetables, while the least was obtained in *T. Triangulare* at Ikorodu. These ranges of values were found to be below the permissible limits of 1.3mg/kg in vegetables (FAO/WHO 2011). This is similar to reports from Onyedikachi et al. (2021), from the Eastern part of Nigeria where the concentration of chromium ranged from 0.0001 to 0.03mg/kg. Also, Alkatib et al. (2022) recorded chromium concentration below the FAO/WHO safe limits from the region of Bethlehem.

Prolonged exposure to chromium can result in heart diseases, respiratory tract and lung cancer, gastrointestinal troubles, kidney problems, gastrointestinal disorders, heart diseases etc. Signs of chromium accumulation are shown in elevated acid levels of the blood and tissues, water-electrolyte imbalance, reduced blood circulation in the tissues, development of lesions in the major body organs like the liver, kidney and some muscles surrounding the heart (Deng et al. 2019).

The Cf value reflects the extent of each metal's contamination in the vegetables. The importance of Cf intervals has been discussed. Less than 1 and more than or equal to 1 indicate mild contamination, below 3 and above or equal to 2 indicate moderate contamination, below 6 and above or equal to 3 indicate significant contamination, and more than 6 indicates extremely high contamination (Enyoh et al. 2018) as computed in Fig. 2 for toxicity factor. All of the heavy metals in the samples had low Cf values, with the exception of Pb, which had significant contamination. Pb > Cd > Cu > Zn was the CF order for heavy metals in *A. viridis*, and Pb > Cu > Zn > Fe > Cd for *T. triangulare* respectively..

PLI displays the total heavy metals load in each of the studied vegetables. In fig.3, the computed PLI is displayed. The PLI indicates a high amount of pollution in the vegetable sample when it is above a unit. However, when the PLI is less than one unit, it does not indicate any pollution threat. In summary, samples of vegetables are not contaminated with the investigated heavy metals of interest (PLI<1). PLI rank for this study was *T. triangulare* > *A. viridis*. Ikorodu dump site was the most polluted site for both vegetables.

To determine safe amounts of heavy metal ingestion, estimated daily intake or tolerated intake are frequently utilized (Kumar and Mukherjee 2011). The health risk associated with eating vegetables polluted with metals was described using the Hazard Quotient (HQ) scale. The range for the reference dosage and the cancer slope factor used in the calculation of the health risk is shown by the toxicological properties of the researched metals (Fig. 5). This is a comparison between the determined dose and the reference dose (RfD). If the value is less than one, the population might not be at danger; however, if the value is equal to or higher than one, the population is probably exposed to health risks. Researchers have employed this method of risk evaluation (Khan et al. 2015; Li et al. 2017; Mehboob et al. 2018; Sridhara et al. 2019) and the validity has been proven. The Department of Environment, Food and Rural Affairs and Integrated Risk Information System provided the figures for RfD for heavy metals (Abdollahatif et al. 2019; DEFRA 2020). Fig. 4 shows the average daily Heavy Metal intake (DIM) for individual vegetables. DIM values ranged from below 0 to 0.13mg/kg (Fe in Amaranthus). The calculated DIMs were below the established reference dose recommended by PTDI and FAO/WHO (1999), except for Fe ($0.13 > 0.07$) and Pb ($0.007 > 0.0035$). Similarly, low DIMs were reported from other researchers in Nigeria (Onyele and Anyawu 2018; Isiuku and Enyoh 2020; Onyedikachi et al 2021 and other countries (Adamo et al. 2014; Latif et al. 2018). Moreover, elevated DIM value of Zn (84.28-1091.71 mg/person/day) in vegetables grown on a wastewater irrigated land in Varanasi, India, was reported by Singh et al. (2010).

The result for the Target Hazard Quotient, which measures the likelihood that a person will not develop cancer, (Anyawu et al. 2020) is depicted (Fig.5). A population is at risk for health problems if the ratio is greater than or equal to 1. The THQ value has a binary interpretation; it can either be >1 or 1, with >1 signifying a reason to be concerned about a non-cancer health risk (Agoro et al. 2020). Cr, Zn, and Cd had THQs that were below than one. This shows that there may not be many health concerns associated with eating specific metals combined with vegetables for those who consume vegetables from the study sites. Consumers of crops grown in soil sampled from contaminated places may be worried by THQ value >1 values for Fe and Pb. According to Krishna et al. (2014) and Li et al. (2014), the highest THQ value presents a comparatively greater potential risk to human health, especially for those who live in areas with substantial metal pollution. A model called the hazard index is used to assess the risk associated with ingesting different chemicals, including heavy metals. HI value below or equal to 1 implies little or no adverse effects or potential hazard. However, HI above 1, is taken to be very hazardous. The estimated values for Hazard Index as revealed in this study implies that the population that are exposed to all samples from all the dumpsites can result in adverse effects on the people's health; with 70% of the samples having HI values greater than 1.

An estimated risk of developing cancer during a lifetime of 70 years is known as the incremental Lifetime Cancer Risk (ILCR). In this study, the ILCR for the Pb, Zn, Fe, Cd and Cr, is presented in Table 5. As an acceptable anticipated lifetime risk for the activation and proliferation of malignant cells, the USEPA has set the value of the CR range between 10^{-6} (1 in 1,000,000) and 10^{-4} (1 in 10,000) (Onyedikachi et al. 2021). Carcinogenic risk assessment was not done for Zn and Fe because of their physiological importance. The possibility of Pb in the dumpsites causing cancer ranges between $-4.9E-7$ and $6.6E-5$.

Highest value for Pb was found in *A. vidiris* at Ikorodu site ($6.6E-5$). ILCR values for Cd ranged between $-2.2E-5$ and $4.56E-5$. The highest ILCR value for Cd was found in *A. viridis* at Olusosun dumpsite ($4.45E-5$). The ILCR values For Cr ranged between 0 and $4.0E-4$, with Alimosho soulus1 having the highest value. The ILCR values showed that consumption of vegetables planted at these dumpsites will likely result in malignant cells for an estimated period of 70 years. Continuous exposure to, and the consumption of these heavy metals will cause bioaccumulation in the samples examined, which can exacerbate serious health issues.

Conclusion

Zinc (Zn), lead (Pb), iron (Fe), cadmium (Cd), and chromium (Cr) toxicity levels in *A. viridis* and *T. triangulare* vegetables harvested from five dumpsites were examined, and potential health concerns were assessed. Obtained results depict that the levels of Pb in *A. vidiris* in Ikorodu were higher than the WHO/FAO permitted limit of 0.3 mg/kg, raising concerns for the general public health of the consumers. Unlike other metals, contamination factor for Pb was also detected to be above moderate contamination value of > 3 but < 6 . Zn, Cd, and Cr. THQs were found to be below 1, except for Fe and Pb, showing that vegetable consumption from the study sites may not be absolutely safe from major non-cancer health hazards. The CR values for Pb, Cd, and Cr exceed the acceptable expected lifetime risk range for carcinogens, which implies that 43.3% of the samples were below 10^{-6} (USEPA threshold value). It is sufficient to suggest that eating plants harvested from these dumpsites could cause cancer over the course of 70 years due to prolonged period of bioaccumulation. Owing to the fact that increasing dietary intake from diverse foods may lead to the emergence of a variety of health problems related to heavy metal toxicity, there is need for continuous monitoring of these compounds in human diet. More importantly, efficient cleaning and bioremediation of dumpsites must be carried out before using such for agricultural purposes..

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Figures



Figure 1

Map showing the locations of the dumpsites and Study area

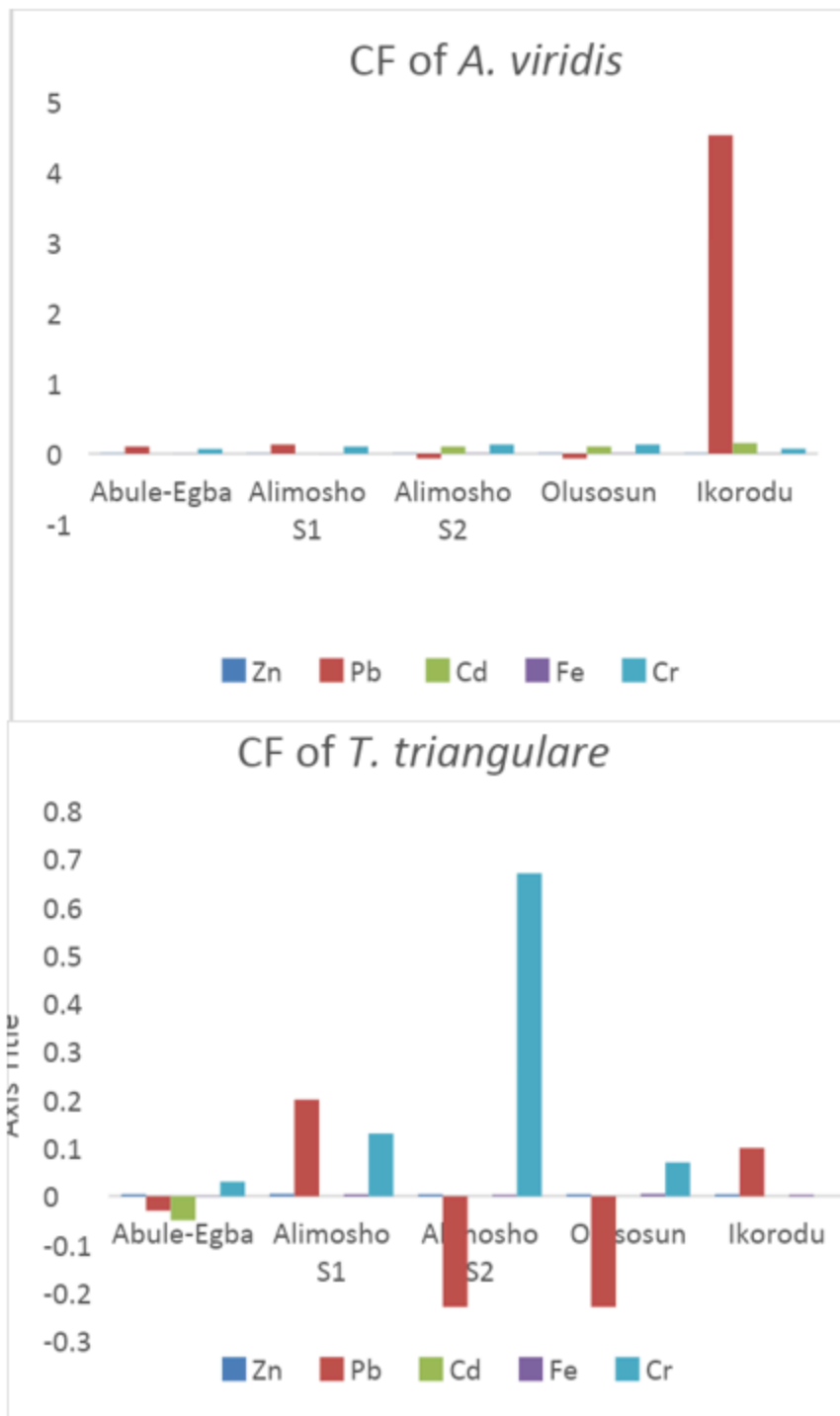


Figure 2

Contamination Factor (Cf) for Heavy Metals in the vegetable species

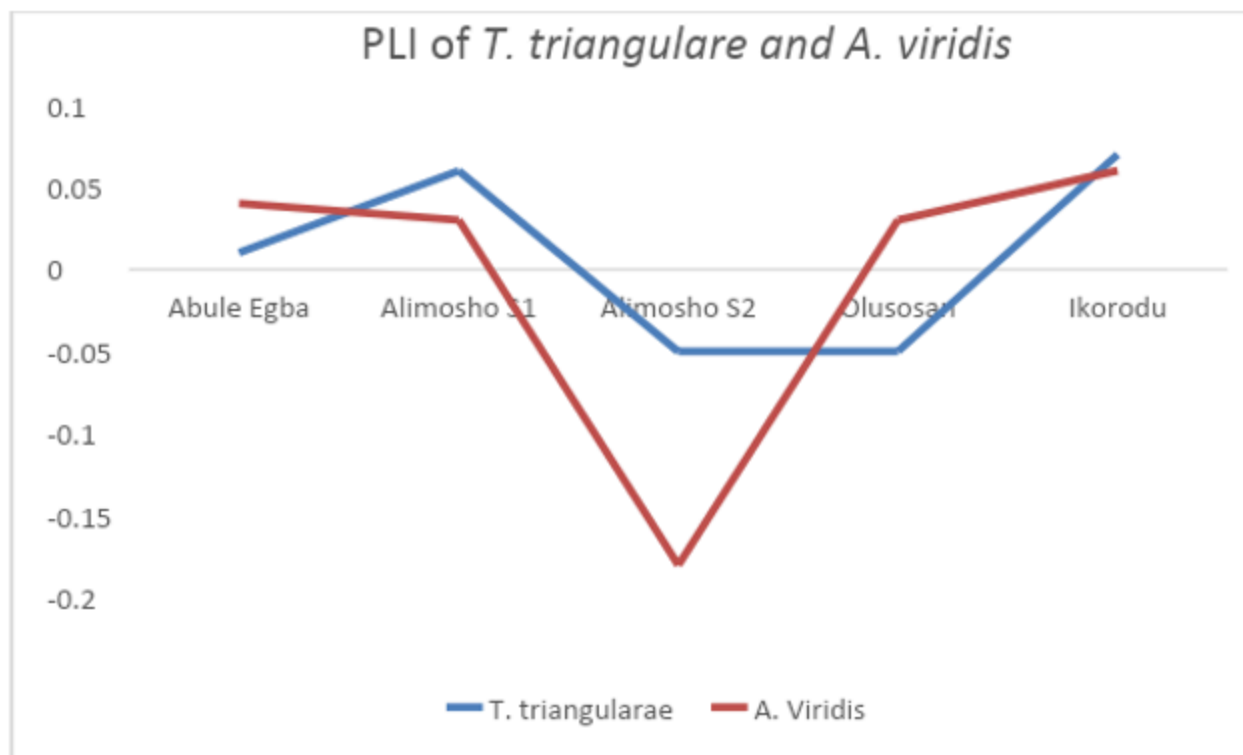


Figure 3

Pollution load index (PLI) of the vegetables at different sites

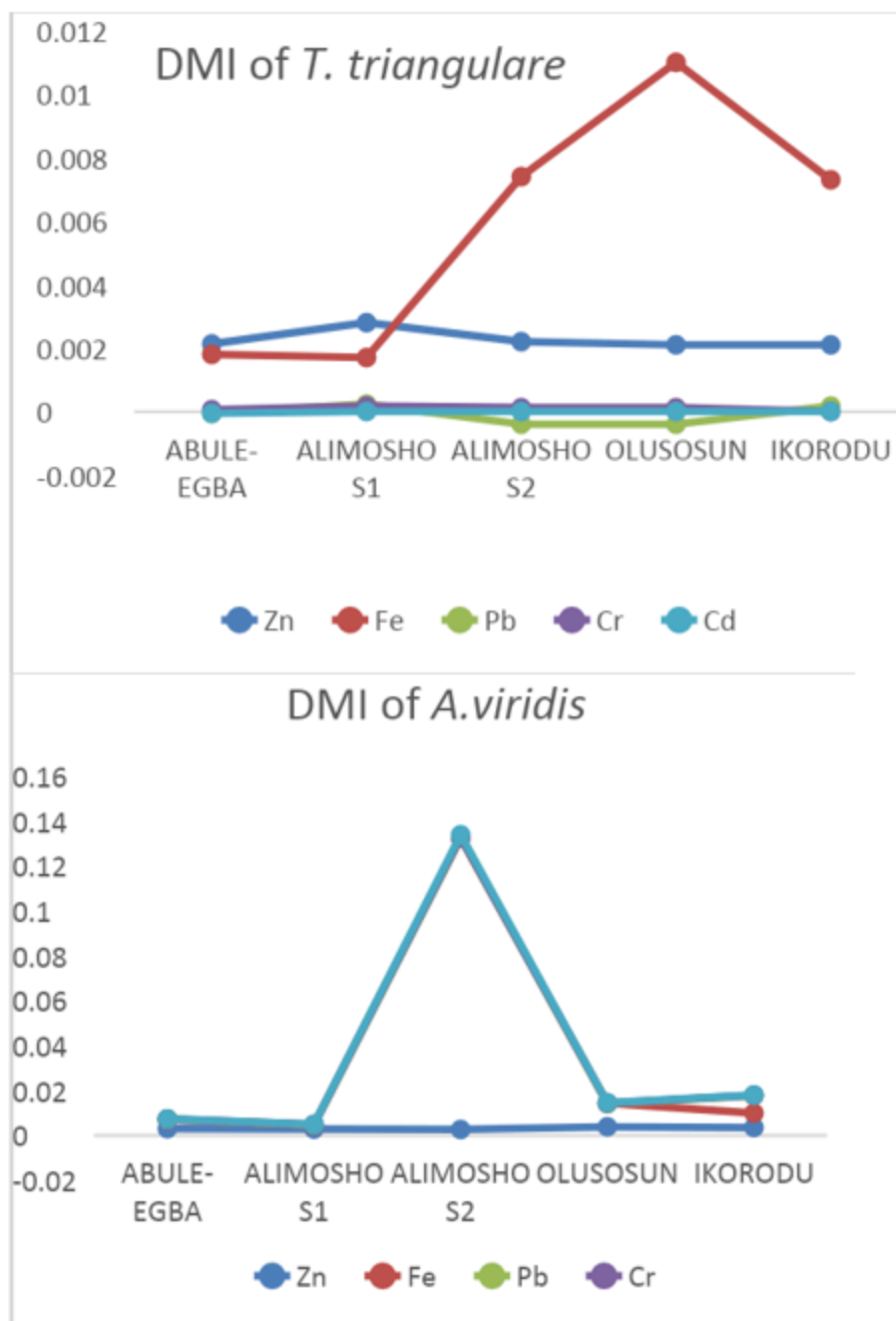


Figure 4

Average Daily Heavy Metals Intake (DMI) in studied Plants(mg/kg/day)

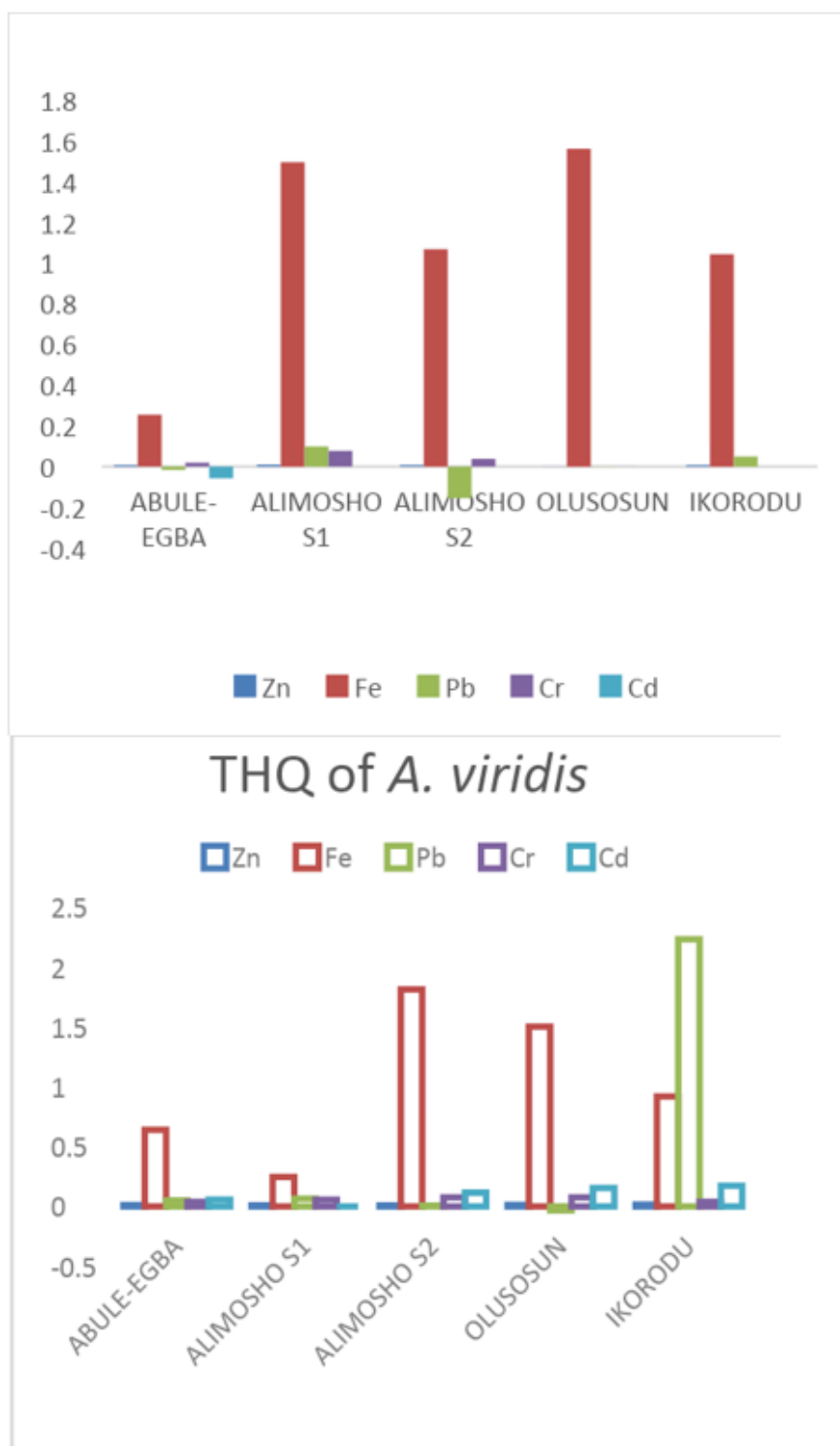


Figure 5

(THQ) Non-carcinogenic Assessment of analyzed vegetables

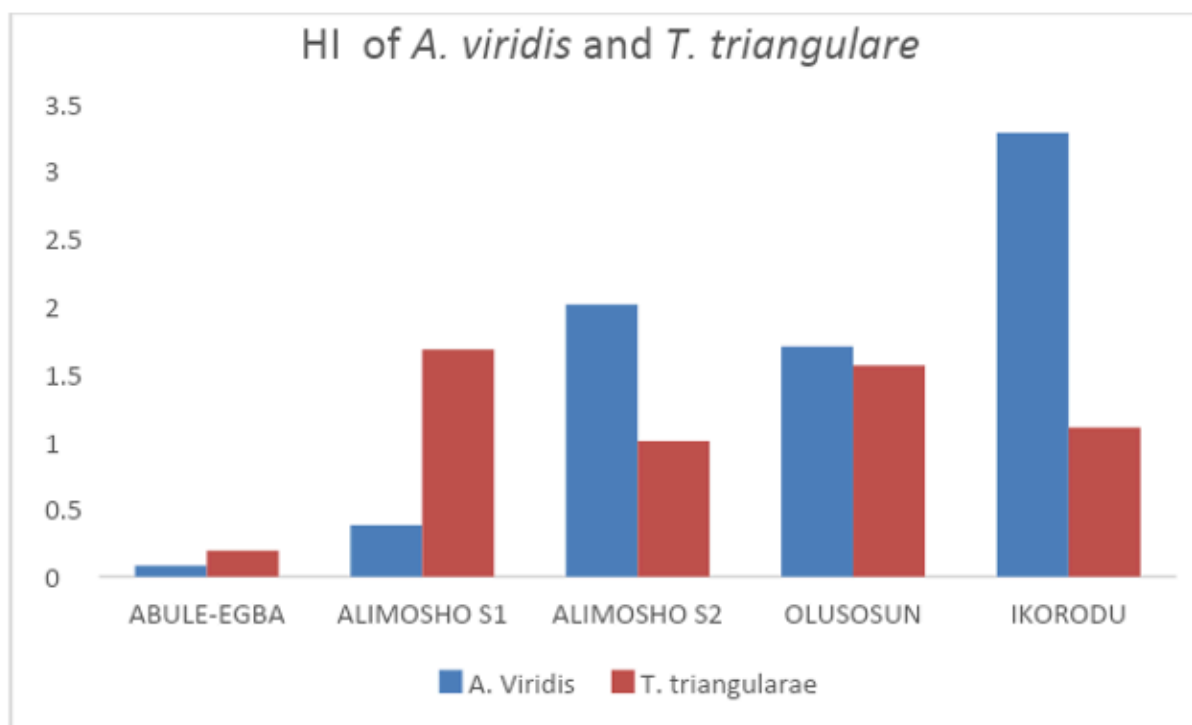


Figure 6

Health Index (HI) of analyzed vegetables