

Heavy Metals Toxicity in Selected Vegetables and Soil from Akpajo, Eleme Local Government, Rivers State

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Abstract

Threat to life from anthropogenic contamination of soil and food crops harvested from our environment is now of immense public health concern. This study investigated heavy metals' contentment in selected vegetables and soil water from Akpajo, in Eleme Local Government Area of Rivers State and probable toxicity effects on exposure to these food crops. Vegetables (*Telfairia occidentalis* (pimpkin leaf) and *Vernonia amygdalina* (Bitter leaf) and Soil from an agricultural farm land were collected and analyzed for Lead (Pb), Cadmium (Cd), Nickel (Ni), Arsenic (As) and Mercury (Hg) contents using Atomic Absorption Spectrophotometer (model: S4=71096). The maximum mean levels (mgkg^{-1}) obtained for Pb 5.392 ± 0.001 and Cd ($0.396 \pm 0.001 \text{mg/kg}$) were seen in *V. amygdalina* with minimum Pb ($3.35 \pm 0.029 \text{mg/kg}$) and Cd ($0.288 \pm 0.001 \text{mg/kg}$) seen in the soil and *Telfairia occidentalis*, (Pumpkin Leaf) samples respectively. Maximum Ni value ($1.99 \pm 0.00 \text{mg/kg}$) was obtained from the sampled soil with the minimum value ($1.108 \pm 0.001 \text{mg/kg}$) seen in *Telfairia occidentalis*. Arsenic and Hg were shown to be below detectable limits. Chronic Daily Intake (CDI), Target Hazard Quotients (THQ) and TCR were used for heavy metals health risk assessment (HRA), which gave values higher than standard as stipulated by USEPA. These toxicological indices revealed that adult and children population exposed to these samples could be highly at risk as values obtained were above potential risk-free limit of 10^{-6} to 10^{-4} set by USEPA. It is however recommended that strict measures be developed and adopted to restrict further pollution of surrounding agricultural soil.

Keywords: Heavy metals, Health Risk Assessment, *Telfairia occidentalis*, *Vernonia amygdalina*, Toxicity

INTRODUCTION

Heavy metal residues vegetables and soils as well as their hazardous effects on the health of people are a matter of great concern to food hygienists and environmental toxicologists.

Subsequently, to safeguard the consumers, periodical evaluation of levels of heavy metals in vegetables and surrounding soils from suspected polluted and unpolluted areas are of major importance [1], as these pollutants of interest on accumulation in an ecosystem not only have a bad influence on food but also affect the health of human beings through the food chain. For example; the Itai-itai disease known as one of the four big Pollution Disease of Japan of the Toyama Jintsu River area was the documented case of mass cadmium poisoning [2]. Heavy metals are known to be discharged into the environment via variety of ways, such as; irrigation with polluted water, use of chemical-based fertilizers, industrial effluents dumps, oil spillage and lots more [3,4,5,6,7] They eventually contaminate and pollute the exposed soil furthermore leading to probable uptake by plant to levels that may seem toxic on bioaccumulation in such plant [5,7,8,9]. This however, makes it expedient for a periodic evaluation of soils, plants and plant products for probable toxicity effects. Several reports have shown that heavy metals can have serious deleterious consequences for human health when vegetables polluted with these metals are ingested [5,7,9,10]. Studies have also shown that heavy metals seen in soil and dust could pose both non carcinogenic and carcinogenic risks to exposed populations [8,10,11]. Heavy Metals have been reported to diffuse into the soil and water from where they could be taken up by plants which could further be bio-accumulated and biomagnified within the food chain making it more toxic to the living organism especially human [8,9,10]. Heavy Metals are not biodegradable but could be cycled in the food chain and the entire food web. This could still lead to hyperaccumulation in plants which naturally provides nourishment for humans and animals with resultant toxicity effects as these metals remain recalcitrant within the food web with numerous negative impacts posing threats to life [8, 9, 10, 12,13]. In the light of the above, it has now become a high public health concern as several health-related issues linked to food poisoning by these heavy metals is now on record [8,11,13], calling for the need to constantly check our environment, farm and food crops for probable contamination and or pollution from anthropogenic and probable natural sources. This study however evaluated the level of heavy metals in selected commonly consumed vegetables and soil from Akpajo, in Eleme Local Government of Rivers State.

MATERIALS AND METHODS

Apparatus/Equipment

Atomic Absorption Spectrophotometer (flame AAS) model: S4=71096, Burner, Hollow cathode lamps, Graphical display and recorder, Pressure reducing valves.

Reagents

Air, Acetylene, Metal free water, Stock metal solution, Hydrogen tetraoxosulphate (vi) acid (H_2SO_4), Trioxonitrate (v) acid (HNO_3), Perchloric acid (HClO_4), potassium chloride solution, Aluminium nitrate solution. All were of analytical grade.

Sample Collection

Soil sample, pumpkin and bitter leaf were obtained from a farm close in Akpajo in Eleme Local Government in Rivers State. They were properly preserved and taken to the laboratory for the analysis.

Pre-Treatment and Preservation

In the laboratory, the vegetable samples were thoroughly washed with running tap water in the order to remove dust particles and any other dirt that might be present. The samples were then oven dried for about three days under proper hygienic condition to prevent contamination from environment. They were now pounded using sterilized pestle and mortar to obtain homogenized samples, filtered to obtain fine powder, kept in airtight sample containers and stored at room temperature ready for analysis.

Wet Digestion Method

A total volume of 100ml of H_2SO_4 , HNO_3 , and HClO_4 in the ratio of 40%:40%:20% was mixed together respectively. One gram of the sample was weighed into a conical flask; 2ml of the mixed acid was added to each of the conical flask. The sample were digested in a fume cupboard with a hot plate, until white fumes appeared. The digest was then cooled and filtered into 100ml volumetric flask and made up to the 100ml mark with distilled water.

Analysis of Heavy Metals using Atomic Absorption Spectrophotometer (AAS)

A hollow cathode lamp of desired metal was installed and the wavelength dial set. The equipment was allowed to warm up about 10-20 minutes for energy source to stabilize and the current was readjusted. Suitable burner head was installed, and the position adjusted. Air was turned on and its flow rate adjusted to give maximum sensitivity for the metal being measured. Blank was aspirated to zero the instrument. Standard solution was aspirated and the aspiration rate of the nebulizer was adjusted to obtain maximum sensitivity. Blank was aspirated again to re-zero the instrument. The samples were then aspirated into the flame and atomized. The machine analyzed the samples and their absorbances were recorded.

Heavy Metals Risks Assessment

Estimated Daily Intake (EDI) of Metals:

The health risks associated with the consumption/intake of heavy metals via various exposure routes were calculated using stipulated toxicological indices [14]

Estimated Daily Intake (EDI) of heavy metal;

$$\text{EDI} = \frac{C_{\text{metal}} \times IR}{BW_{\text{average}}}$$

Where: C_{metal} = is the metal concentration in sample in mg/kg, equation breakdown is as seen in table 1 and 2

Translocation Factor (TF):

Is the concentration of heavy metals seen in soil which is absorbed by plants. This is totally dependent on the availability of these metals and plant species.

$$\text{TF} = \frac{\text{Metal concentration in edible part of plant}}{\text{Metal concentration in soil from where the plant was grown}}$$

Table 1 Reference Values and Standards for Risk Assessments

Exposure variable	Unit	Adult	Child
Exposure frequency (EF)	day ⁻¹	365	365
Exposure duration (ED)	year	70	6
Body weight (BW)	kg	70	15
Fish ingestion rate (IR _{ingestion})	mgday ⁻¹	0.227	0.114
Vegetable ingestion rate (IR _{ingestion})	gday ⁻¹	345	345
Soil ingestion rate (IR _{ingestion})	mgday ⁻¹	100	200
Water ingestion rate (IR _{ingestion})	mlday ⁻¹	2.2	0.114
Inhalation rate (IR _{inhalation})	m ³ day ⁻¹	20	10
Dermal adherence factor (AF)	mg cm ⁻²	0.07	0.2
Dermal exposure area (SA)	cm ²	5800	2800
Particle emission factor (PEF)	m ³ kg ⁻¹	1.36×10 ⁹	1.36×10 ⁹
Dermal adsorption fraction (ABS)	Unitless	0.13	0.13
Life span (AT) Average	day	70 × 365 = 25,550,	70 × 365 = 25,550,
Conversion factor (CF)	kg mg ⁻¹	1 × 10 ⁻⁶	1 × 10 ⁻⁶
Dermal exposure ratio (FE)		0.61	0.61
Dermal absorption factor	ABSnon-carcinogenic	0.001 mg/cm ²	0.001mg/cm ²
	ABS carcinogenic	0.03 mg/cm ²	0.03 mg/cm ²
maximum acceptable risk level (RL)	(dimensionless)	10 ⁻⁵	10 ⁻⁵

[14,15,16,17,18,19,20]

Table 2 Recommended standard values for dusts HRA

Parameters	Pb	Cd	Ni	As
RFD _{ing}	0.0035	0.001	0.02	3.00E-04
RFD _{inh}	3.50E-02	0.001	0.0206	1.00E-03
RFD _{dermal}	5.25E-04	0.00001	1.0E-03	1.00E-05
CSF _{ing}	0.0085	6.3	1.7	1.5
CSF _{inh}	4.20E-02	6.3	9.10E-01	1.50E+01
CSF _{dermal}	-	-	1.7	1.5

[14,18,19, 21, 22,23]

Target Hazard Quotient (THQ):

THQ was used for non-carcinogenic risk estimation of heavy metals consumption was determined using THQ values. This the ratio of determined dose of pollutant to a reference level assumed harmful or ratio of measured concentration to oral dose. THQs estimation was done according to the methodology described by USEPA [14].

$$THQ = \frac{Efr \times ED \times FIR \times C}{RfDo \times B_{average\ weight} \times ATn \times 10^{-3}}$$

Where C is metal concentration in sample in mg/kg, equation breakdown is shown in table 3. [16,24]. In addition, based on EPA guidelines, it was assumed that ingested doses were equal to absorbed contaminant doses [24].

Hazard Index (HI):

The hazard index is estimated using;

$$\text{Total hazard index (HI)} = \sum THQ (THQ_{pb} + THQ_{cd} + THQ_{cr} + THQ_{n\dots\dots\dots}) \text{ or}$$

$$HI = THQ_{\text{ingest}} + THQ_{\text{dermal}} + THQ_{\text{inhale}}.$$

Depending on exposure routes of sample

Carcinogenic Health Risk**Cancer Risks (CR):**

The estimated daily dose and the cancer slope factor are multiplied together to find the lifetime cancer risk (LCR) posed by the metal(s) of interest. Cancer slope factors are estimates of carcinogenic potency and are used to relate estimated daily dose of a substance over a lifetime exposure to the lifetime probability of excess tumor. The ingestion cancer slope factors evaluate the probability of an individual developing cancer slope factors are expressed in units of (mg/kg/day)⁻¹. Lifetime probability of contracting cancer due to exposure to carcinogenic chemicals is calculated as follows:

$$LCR = EDI \times CSF$$

Where:

EDI is the estimated Daily intake of each heavy metal (mg/kg/day)

CSF_{ing} is ingestion cancer slope factor (mg/kg/day)⁻¹

The USEPA, [14] states that 10⁻⁶ (1 in 1,000,000) to 10⁻⁴ (1 in 10,000) represent a range of permissible lifetime risks for carcinogens. Chemical for which the risk factor falls below 10⁻⁶ may be eliminated from further consideration as a chemical of concern. The risk associated with the carcinogenic effect of target metal is express as the excess probability of contracting cancer over a lifetime of 70 years.

$$TLCR = LCR_{\text{ingest}} + LCR_{\text{dermal}} + LCR_{\text{inhale}}.$$

Data Analysis

Statistical analysis was done using SPSS Version 23.0 to determine the one-way analysis of variance (Anova), and a Turkey Post Hoc for the multiple comparison of mean values (n=3).

RESULTS AND DISCUSSION**Mean Concentration of Heavy Metals in Samples**

The mean concentration of heavy metals in the sampled vegetables and soil is shown in table 3. Heavy metals such as Pb, Cd, Ni, As, Hg were assayed having noted the high industrialization notable within Eleme LGA and possible pollution from anthropogenic sources. The result revealed significant level of each heavy metal across the samples, though As and Hg were shown to be below detectable limits. *Vernonia amygdalina* (Bitter leaf)) was shown to have maximum values of Pb (5.392±0.001mg/kg) and Cd (0.396±0.001mg/kg) while minimum Pb

($3.35 \pm 0.029 \text{ mg/kg}$) and Cd ($0.288 \pm 0.001 \text{ mg/kg}$) were seen in the soil and *Telfairia occidentalis*, (Ugu Leaf) samples respectively. Maximum values ($1.99 \pm 0.00 \text{ mg/kg}$) for Ni was seen in the soil sample while the minimum value ($1.108 \pm 0.001 \text{ mg/kg}$) was obtained in *Telfairia occidentalis*, (Ugu Leaf).

Lead is the most abundant metal in all samples, followed by Nickel then Cadmium, Arsenic and Mercury were below detectable limits. Lead and cadmium were shown to have values which exceeded standards by WHO [25] in plants but were below WHO permissible limit for Pb and Cd in soil. However, Ni level was shown to be below permissible limits for both plant and soil samples.

Table 3: Mean Concentration of Heavy Metals in Samples

Sample		Pb(mg/kg)	Cd(mg/kg)	Ni(mg/kg)	As(mg/kg)	Hg(mg/kg)
Telfairia occidentalis		3.808 ± 0.005^a	0.288 ± 0.001^a	1.108 ± 0.001^a	BDL	BDL
Vernonia amygdalina		5.392 ± 0.001^a	0.396 ± 0.001^a	1.548 ± 0.001^a	BDL	BDL
Soil		3.35 ± 0.029^a	0.29 ± 0.002^a	1.99 ± 0.00^a	BDL	BDL
WHO (1996)	Plant	2	0.02	10		
	Soil	85	0.8	35		

Values are Mean $\pm$ SEM, means in the same column with same superscript alphabet are significantly different at $p \leq 0.05$, $n=3$,

Levels of assayed heavy metals were seen to vary amongst sampled vegetables, this could be attributed to variance in the absorption capacity of various plants for different heavy metals as shown using transfer factors [26]. Lead (5.392 mgkg^{-1}) and Cadmium (0.396 mgkg^{-1}) levels were significantly higher in *Vernonia amygdalina* than in *Telfairia occidentalis* Pb 3.35 mgkg^{-1} , Cd 0.29 mgkg^{-1} while Ni was notably higher in *Telfairia occidentalis* 1.99 mgkg^{-1} than in *Vernonia amygdalina* 1.548 mgkg^{-1} .

Transfer factor depicts the ratio of heavy metal contents in plants compare to that in soil. The transfer factor of Pb ranged from 1.137 to 1.610, Cd from 0.557 to 0.993 and Ni 0.778 to 1.366 with maximum values seen in *Vernonia amygdalina* for all assayed heavy metals

Table 4 Transfer Factor

Samples	Pb	Cd	Ni	As	Hg
Telfairia occidentalis	1.137	0.993	0.557	0	0
Vernonia amygdalina	1.610	1.366	0.778	0	0

The transfer factor (TF) as shown in table 4. is the ratio of heavy metal levels in plants to that in soil. It depicts the migration potential of a given heavy metal from the soil to the plant. The transfer factor is a function of factors such as soil organic matter, particulate size of soil, pH, and metal availability. The highest TF seen in *Vernonia amygdalina* (Bitter leaf) for Pb (1.61), Cd (1.366) and Ni (0.778) could instill high concerns as the three (3) heavy metals (Pb, Cd, and Ni) with high transfer value are all non-essential and toxic element to plants, animals and

humans. The transfer quotients of 0.1 depicts that the plant is removing the element from its tissues, while transfer quotients and or coefficients above 0.50 indicates significant chances of food crops contamination by heavy metals. [27].

Therefore, individuals and animals within Akpajo in Eleme LGA who rely on these sources of food are indirectly consuming high load of heavy metals while human who feed on the animals that fed on the plants are more exposed as they are also bioaccumulating and biomagnifying these heavy metals.

Lead known to be from environmental sources such as agrochemicals and industrial wastes may be deleterious to living organisms as their level exceeds standards values [28], thereby increasing their ability to cause adverse health effects such as; inhibiting enzyme activities which may lead to water imbalance and altering membrane permeability, mineral nutrition disturbance and hormonal status alterations, [29]. Pb could also affect and or damage the Liver, central nervous system and kidneys [30,31,32]. In plants, Pb could cause lipid peroxidation, ATP production inhibition, impaired uptake of some essential elements, (like Mg and Fe), induced deficiency of CO₂ as a result of stomatal closure and DNA damage [33].

Cadmium exits within the environment via anthropogenic activities linked to industrial processes such as; refining and extraction [34]. It is relatively devoid of beneficial effects known and could be harmful to living organisms at levels exceeding set values [28,32,35]. Cadmium is notably toxic even on low absorption via ingestion; high Cd ingestion in food on chronic exposure could causes bone disorders [36,37,38]. High cadmium concentration is absorbed in the kidney in human [39].

Ni toxicity could result to loss of body weight and liver damage on long term exposure. Pb, Cd and Ni, has been proved to be possible carcinogen [40,41], studies have shown increase in respiratory cancer amongst refinery workers [42].

Health Risk Assessment of the Heavy Metal Contents, Present in the Sampled Vegetables and Soil.

The heavy metal level was further evaluated for probable risks (risk assessment) on exposure, using toxicological indices which includes;

Chronic Daily Intake (CDI)

The Chronic daily intake for the three exposure pathways (ingestion, dermal and inhalation) for soil and ingestion for vegetable was evaluated and results are presented in Tables 5 and 6. the results revealed high CDI levels which were above the reference doses (RFD) as recommended by USEPA, [14]. The results obtained gave CDI_{ingest} value for Pb ranging from 4.79E-06 mgkg⁻¹day⁻¹ (in soil) to 7.70E+00mgkg⁻¹day⁻¹ (in *Vernonia amygdalina* (Bitter leaf)); and 4.47E-05mgkg⁻¹day⁻¹ (in soil) to 7.19E+01mg kg⁻¹ day⁻¹(in *Vernonia amygdalina* (Bitter leaf)), for adult and children population respectively. Cd ranged from 4.14E-07mgkg⁻¹day⁻¹ (in soil) to 5.66E-01mgkg⁻¹day⁻¹ (in *Vernonia amygdalina* (Bitter leaf)); and 3.87E-06mgkg⁻¹day⁻¹ (in soil) to 5.28E+00mg kg⁻¹ day⁻¹(in *Vernonia amygdalina* (Bitter leaf)), for adult and children population respectively with Ni ranging from range from 2.84E-06mgkg⁻¹day⁻¹ (in soil) to 2.21E+00mgkg⁻¹day⁻¹ (in *Vernonia amygdalina* (Bitter leaf)); and 2.65E-05mgkg⁻¹day⁻¹ (in soil)

to $2.06 \times 10^1 \text{ mg kg}^{-1} \text{ day}^{-1}$ (in *Vernonia amygdalina* (Bitter leaf)), for adult and children population respectively.

Table 5 Chronic Daily Intake Dose ($\text{CDI}_{\text{ingest}}$) ($\text{mg kg}^{-1} \text{ day}^{-1}$) for Vegetables

SAMPLE	Pb		Cd		Ni		As	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Telfairia occidentalis, (Ugu Leaf)	5.44E+00	5.08E+01	4.11E-01	3.84E+00	1.58E+00	1.48E+01	-	-
Vernonia amygdalina (Bitter leaf)	7.70E+00	7.19E+01	5.66E-01	5.28E+00	2.21E+00	2.06E+01	-	-
RFD	0.0035	0.0035	0.001	0.001	0.02	0.02		

The $\text{CDI}_{\text{dermal}}$ for the soil sample where higher in Pb ($1.19 \times 10^{-6} \text{ mg kg}^{-1} \text{ day}^{-1}$, $5.72 \times 10^{-6} \text{ mg kg}^{-1} \text{ day}^{-1}$), $\text{CDI}_{\text{inhalation}}$ were also shown to be higher in Pb ($7.36 \times 10^{-10} \text{ mg kg}^{-1} \text{ day}^{-1}$, $1.72 \times 10^{-9} \text{ mg kg}^{-1} \text{ day}^{-1}$) for adult and children population respectively. However, these values as seen in the soil sample were below the recommended reference dose. The study also reveal that oral route (ingestion) is the higher means of exposure to these contaminants this corroborates the works earlier done by Zheng *et al.*, [11,43,44]; on dusts and soil samples. The result which revealed major exposure route to be by ingestion then dermal contact with the least being inhalation, also corroborates with earlier reports by Moya *et al.*, and Olujimi *et al.*, [11,45,46] who reported that major exposure pathway of heavy metals is in the order ingestion > dermal contact > inhalation.

Table 6: Chronic Daily Intake Dose (CDI) ($\text{mg kg}^{-1} \text{ day}^{-1}$) SOIL SAMPLE

SAMPLE	Pb (mg/kg)		Cd(mg/kg)		Ni(mg/kg)		As(mg/kg)	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Ingest	4.79E-06	4.47E-05	4.14E-07	3.87E-06	2.84E-06	2.65E-05	-	-
Dermal	1.19E-06	5.72E-06	1.03E-07	4.95E-07	7.04E-07	3.40E-06	-	-
Inhalation	7.36E-10	1.72E-09	6.37E-11	1.49E-10	4.37E-10	1.02E-09	-	-

Where: E=exponential.

Target Hazard Quotient and Hazard Index

Tables 7 and 8 presents the THQ and HI values on exposure to heavy metal contents in sampled vegetables and soil for the adult and children population. Three exposure routes (dermal contact, ingestion and inhalation) were considered for soil while one exposure route (ingestion) was considered for vegetable. The results depict that same trend as the CDI was

observed in THQ and HI. The results shows that THQ ingest values for Pb, Cd and Ni were higher than 1 in all samples

Table 7: Target Hazard Quotient (THQ_{ingest}) and Hazard Index for Seafoods, Vegetables and Water

SAMPLE	Pb		Cd		Ni		As		HI	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
<i>Telfairia occidentalis</i> , (Ugu Leaf)	1.55E+03	1.45E+04	0.41E+03	3.84E+03	7.91E+01	7.39E+02	-	-	2.04E+03	1.91E+04
<i>Vernonia amygdalina</i> (Bitter leaf)	2.2E+03	2.05E+04	0.57E+03	5.28E+03	1.11E+02	1.03E+03	-	-	2.88E+03	2.69E+04

Table 8: Target Hazard Quotient (THQ) (mg kg⁻¹day⁻¹) for Soil Sample

SAMPLE	Pb (mg/kg)		Cd(mg/kg)		Ni(mg/kg)		As(mg/kg)		ΣHI	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Ingest	0.001367	0.01276	0.000414	3.87E-03	1.42E-04	1.33E-03	-	-		
Dermal	0.002258	0.01089	0.01026	4.95E-02	7.04E-04	3.40E-03	-	-		
Inhalation	2.09E-07	4.88E-07	6.37E-08	1.49E-07	2.12E-08	4.95E-08	-	-		
Hazard Index	3.63E-03	2.37E-02	1.07E-02	5.34E-02	8.46E-04	4.73E-03	-	-		
ΣHI									1.51E-02	8.18E-02

Where: E=exponential.

except in soil, were obtained values were below 1. However, THQ dermal and inhalation for the soil sample also had values below 1. This result entails that consumption of sampled vegetables could cause adverse non-carcinogenic health effects for the exposed adult and child populations. The obtained HI gave values greater than one (except for the sampled soil) these values are above the standard values as set by USEPA [14]. This shows that the sample fish and vegetables could have probable adverse health effects which is attributable to the high industrial activities within this region leading to high anthropogenic sources of contaminants.

Life Cancer Risks (LCR) and Total Life Cancer Risks (TLCR)

Tables 9 to 10 shows carcinogenic risks results from exposure to sampled vegetables and soil obtained from in Akpajo in Eleme LGA of Rivers State. The life cancer risks (LCR) for three (3) exposure routes (LCR_{ingest}, LCR_{dermal} and LCR_{inhalation}) and the total life cancer risks were calculated. The LCR was in the order LCR_{ingest}>LCR_{dermal}>LCR_{inhalation} in the soil sample while LCR_{ingest} was used to estimate the carcinogenic risk on exposure to the sampled vegetables. USEPA [11] denoted values within 10⁻⁶ to 10⁻⁴ as tolerable range. While 10⁻⁴ is the upper tolerable limit and 10⁻⁶ the lower tolerable limit [11].

Table 9: Life Cancer Risks (LCR) and Total Life Cancer Risks (TLCR) for Vegetables

SAMPLE	Pb		Cd		Ni		As		TLCR	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
<i>Telfairia occidentalis</i> , (Ugu Leaf)	4.62E-02	3.70E-02	2.59E+00	2.07E+00	2.69E+00	2.15E+00	-	-	5.33E+00	4.26E+00
<i>Vernonia amygdalina</i> (Bitter leaf)	6.55E-02	5.24E-02	3.56E+00	2.85E+00	3.76E+00	3.01E+00	-	-	7.39E+00	5.91E+00

Table 10: Life Cancer Risks (LCR) and Total Life Cancer Risks (TLCR) for Soil Sample

SAMPLE	Pb (mg/kg)		Cd(mg/kg)		Ni(mg/kg)		As(mg/kg)		ΣLCR	
	Adult	Child	Adult	Child	Adult	Child	Adult	Child	Adult	Child
Ingest	4.07E-08	3.25E-08	2.61E-06	2.09E-06	4.83E-06	3.87E-06	-	-		
Dermal	1.01E-08	4.17E-09	6.46E-07	2.67E-07	1.20E-06	4.95E-07	-	-		
Inhalation	3.09E-11	6.18E-12	4.02E-10	8.03E-11	3.98E-10	7.96E-11	-	-		
LCR	5.08E-08	3.67E-08	3.26E-06	2.36E-06	6.03E-06	4.37E-06	-	-		
ΣLCR									9.34E-06	6.76E-06

Where: E=exponential

The observed values for adult and children population on consumption of the assayed sample gave figures which exceeds the upper tolerable limit of 10^{-4} except for the soil sample which TLCR is 9.34×10^{-6} , 6.76×10^{-6} which is within the lower tolerable limits. These values have shown that the samples have high potency for carcinogenic risks as maximum of 739 cases in every 10,000 are estimated on consumption of *Vernonia amygdalina* (Bitter leaf) as against 1 in 10,000 cases postulated by USEPA [11]. The result is however suggestive that the exposed adult and children population could be highly at risk.

CONCLUSION

This study determined the concentration of heavy metals in sampled vegetables and soil. The obtained results showed presence of heavy metal at levels notably high as compared to guidelines set by WHO. This no doubt calls for urgent measures to curtail further accumulation of these heavy metal in the samples.

The Health Risk assessment of the heavy metal contents, present in the samples were also evaluated. The calculated CDI, THQ, HI, LCR and TLCR, gave values which depicts high risk potency for both carcinogenic and non-carcinogenic adverse health effects. As HI levels were seen to be notable above 1 in assayed vegetables, while the LCR and TLCR on exposure to these vegetables gave values higher than the upper tolerable limit of 10^{-4} as set by USEPA. This indicates high risk potency on exposure and or consumption of this samples.

It is therefore recommended that strategies be put in place prevent heavy metal accumulation in plants as this could evidently reduce acute and chronic health risks to the exposed population.

References

1. Zhou, H; Yang, WT; Zhou, X; Liu, L; Gu, JF; Wang, WL (2016). Accumulation of heavy metals in vegetable species planted in contaminated soils and the health risk assessment. *Int. J. Environ. Res. Public Health*. 13(3): 289.
2. Masanori, K. (2012). Role of experts and public participation in pollution control: The care of Itai-itai diseases in Japan. *Ethics so Eviron. Polit*, 12:99-111.
3. Koivula, M. J., Kanerva, M., Salminen, J.P., Nikinmaa, M. and Eeva, T. (2011). Metal pollution indirectly increases oxidative stress in great tit (*Parus major*) nestlings. *Environmental Research*. 111(3):362-370
4. Hembrom, S, Singh. B., Gupta, S.K. and Nema, A.K. (2020). A comprehensive evaluation of heavy metal contamination in foodstuff and associated human health risk: A global perspective. In: *Contemporary Environmental Issues and Challenges in Era of Climate Change*. Singapore: Springer; 2020. pp. 33-63
5. Olua, V., Nwaichi, E. O., & Wegwu, M. O. (2021). Toxicological Evaluation of *Telfaria Occidentalis* and *Talinum Triangulare* Grown in Freshly Recovered Petroleum-Polluted Soil. *European Journal of Applied Sciences*, 9(5). 262-271.
6. Gupta, N., Yadav, K.K., Kumar, V., Krishnan, S., Kumar, S. and Nejad, Z.D. (2021). Evaluating heavy metals contamination in soil and vegetables in the region of North India: Levels, transfer and potential human health risk analysis. *Environmental Toxicology and Pharmacology*;82:103563
7. Olua, V., Wegwu, M. O. & Nwaichi, E. O (2021). Hepatotoxicity of Farm Produce from Recently Remediated Crude Oil Polluted Site Amended Using Formulated Agrowastes. *International Journal of Innovative Science and Research Technology*; 6(10) 353 – 358
8. Proshad R, Kormoker T, Islam MS, Chandra K. (2019). Potential health risk of heavy metals via consumption of rice and vegetables grown in the industrial areas of Bangladesh. *Human and Ecological Risk Assessment: An International Journal*. 24(4);921-943
9. Kharazi A, Leili M, Khazaei M, Alikhani MY, Shokoohi R. (2021). Human health risk assessment of heavy metals in agricultural soil and food crops in Hamadan, Iran. *Journal of Food Composition and Analysis*. 100:103890
10. Pollard, A.J., Reeves RD, Baker AJ. (2014). Facultative hyperaccumulation of heavy metals and metalloids. *Plant Science*. 217:8-17
11. Olua V., Patrick-Iwuanyanwu K. C. and Nwaichi, E. O, (2018) "Heavy Metals Contents and Health Risk Assessment of Classroom Corner Dusts in Selected Public Primary Schools in Rivers State, Nigeria." *Journal of Environment Pollution and Human Health*, vol. 6, no. 4: 138-147. doi: 10.12691/jephh-6-4-3.
12. Clemens S, and Ma J.F. (2016). Toxic heavy metal and metalloid accumulation in crop plants and foods. *Annual Review of Plant Biology*. 67:489-512
13. Hu, Y., Bai, Z., Zhang, L., Wang, X., and Zhang L, (2007) Health risk assessment for traffic policemen exposed to polycyclic aromatic hydrocarbons (PAHs) in Tianjin, China. *Science of The Total Environment* 382: 240–250

14. United States of Environmental Protection Agency (USEPA). (2011). Integrated. risk information system. Washington, DC: US EPA, 2011. Available at: <http://www.epa.gov/IRIS/>. Retrieved 02/07/2021.
15. U.S. Environmental Protection Agency, (2001) Supplemental guidance for developing soil screening levels for superfund sites. 93554–24. Washington, D.C: Office of Emergency and Remedial Response.
16. Wang, X.; Sato, T.; Xing, B. (2005). Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. *Science of The Total Environment*. 350, 28–37.
17. Wei, B., and Yang, L. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemistry Journal*. 94:99–107.
18. United States of Environmental Protection Agency (USEPA). (2002). Supplemental guidance for developing soil screening levels for superfund sites. OSWER 9355/4-24. Washington, DC: Office of Emergency and Remedial Response, and peaceful coexistence Africa World Press, Trenton, New Jersey, pg 72.
19. US Environmental Protection Agency. Framework for Determining a Mutagenic Mode of Action for Carcinogenicity: Review Draft. (2007). Available online: <http://www.epa.gov/osa/mmoaframework/pdfs/MMOA-ERD-FINAL-83007.pdf>.
20. US Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume 1: Human Health Evaluation Manual (Part A); (1989). Office of Emergency and Remedial Response: Washington, DC, USA.
21. United States Department of Energy. The risk assessment information system (USDOE). Oak Ridge, TN: US Department of Energy's Oak Ridge Operations Office (ORO). 2011 Available at: <https://rais.ornl.gov/>.
22. MEP (Ministry of Environmental Protection of the People's Republic of China). Technical Guidelines for Risk Assessment of Contaminated Sites; China Environmental Science Press: (2014). Beijing, China. (In Chinese).
23. U.S. Environmental Protection Agency, (1999) Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals). 92857–01B. Washington, D.
24. USEPA, US Environmental Protection Agency. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment), 2004)
25. World Health Organization (WHO) (1996). Permissible limits of heavy metals in soil and plants. Geneva, Switzerland
26. Singh, A., Sharma, R.K, Agrawal, M. and Marshall, F.M (2010). Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. *Tropical Ecology*, 51(2S):375-387.
27. Thornton, L., & Farago, M. (1997). The geochemistry of Arsenic. In C. O. Abernathy, R. L. Calderon, & W. R. Chappell (Eds.), *Arsenic exposure and health effects* (pp. 2–15). Chapman and Hall.
28. Aydinalp, C. and Marinova, S. (2009). The Effects of Heavy metals on Seed Germination and Plant Growth on Alfalfa plant (*Medicago sativa*). *Bulgarian Journal of Agricultural Science*. 15(4), 347-350.
29. Seregin, I.V. and Ivaniov, V.B. (2001). Physiological aspects of cadmium and lead toxic effects on higher plants. *Russian Journal of Plant Physiology*, 48: 606-630.

30. Ademoroti, C. M. A. (1996). Environmental Chemistry and Toxicology, Foludex Press Ltd., Ibadan. 171-204.
31. Rudolph, A.M., Rudolph, C.D. and Hosteher, M.K. (2003). Lead. Rudolph pediatrics (21st edition). Magraw-hill professional.369.
32. Uaboi – Egbenni, P. O., Okolie, P. N. Martins, O. and Teniola, O. (2010). Studies on the occurrence and distribution of heavy metals in sediments in Lagos Lagoon and their effects on benthic microbial population. African Journal of Environmental Science and Technology. 4(6), pp. 343-351, Available online at <http://www.academicjournals.org/AJES>
33. Pourrut, B., Shahid, M., Dumat, C., Winterton, P. and Pinelli, E. (2011). Lead Uptake, Toxicity, and Detoxification in Plants. Reviews of Environmental Contamination and Toxicology,213: 113-136.
34. Flower, L. (2006). Environmental Pollution -Especially Air Pollution - and Public Health. Assumption University Journal of Technology, 10(1): 29-37.
35. Gough, L. P., Shacklette, H. T. and Case, A. A. (1979). Element Concentrations Toxic to Plants, Animals and Man. U.S. Geological Survey, Washing-ton, DC, p, 1466.
36. Obata, H. and Umebayashi, M. (1997). Effects of Cadmium on mineral nutrient concentrations in Plants differing in tolerance for cadmium. Journal of Plant Nutrition, 20:1.
37. Asia, I. O., Ekpo, K. E., Amayo, K. O. and Jegede, D. A. (2008). Determination of Lead, Cadmium and Mercury in surrounding water and organs of some species of fish from Ikpoba River in Benin city, Nigeria. International Journal of Physical Sciences.3(11): 289-292.
38. Luevano, J. and Damodaran, C. (2014). A review of molecular events of cadmium-induced carcinogenesis.Journalof Environment Pathology,Toxicology and Oncology.33(3):184-194.
39. Perry, H.M. Jr., Thind, G.S. and Perry, E.F. (1976). The biology of cadmium. The Medical Clinics of North America, 60(4):759 – 769.
40. IARC (2012). Nickel and nickel compounds in IARC.
41. ATSDR. (2015). Agency for Toxic Substances and Disease Registry. Public Health Statement for Chlorfenvinphos.<https://www.atsdr.cdc.gov/phs/phs.asp?id=930&tid=193>
42. Cogliano, V.J., Baan, R., Straif, X.,Grosse, Y., Lauby – Secretan, B.,ElGhissassi, F., Bouvard, V., Benbrahim – Tallaa, L.,Guha, N.,Freeman, C., Galichet L. and Wild, C.P. (2011). Preventable exposures associated with human cancers. Journal of the National Cancer Institute, 103(24):1827-1839.
43. Zheng, N., Liu, J., Wang, Q., Liang, Z., (2010). Health risk assessment of heavy metal exposure to street dust in the zinc smelting district, Northeast of China. Sci. Total Environ. 408, 726–733.
44. Junhua, M. and Wichitra, S. (2012). Distribution and Health Risk Assessment of Heavy metals in Surface Dusts of MahaSarakham Municipality. Procedia - Social and Behavioral Sciences, 50: 280 – 293
45. Moya, J., Bearer, C.F. and Etzel, R.A. (2004). Children’s behavior and physiology and how it affects exposure to environmental contaminants. Pediatrics,113:996–1006.
46. Olujimi, O., Steiner, O. and Goessler, W. (2015). Pollution indexing and health risk assessments of trace elements in indoor dusts from classrooms, living rooms and offices in Ogun State, Nigeria. Journal of African Earth Science; 101:396–404.