Biological and Environmental Sciences Journal for the Tropics
Volume 21, Number 2, August 2024. Pp 87 - 100
https://dx.doi.org/10.4314/bestj.v21i2.10

Research article

Assessment of heavy metals content in vegetables and their potential human health risk in Bauchi, Nigeria

*****AbdulHameed, A.,[1] Danlami, F.[1] and Yuguda, A. U.[2]

[1]Department of Ecology, Abubakar Tafawa Balewa University, Bauchi.
[2]Department of Environmental Management Technology, Abubakar Tafawa Balewa University, Bauchi

*****Corresponding Author: gesunnam.aa@gmail.com

Submission: 03/05/2024
Accepted 08/08/2024

Abstract
The human dietary uptake of heavy metals through contaminated food crops has led to carcinogenic and non-carcinogenic health concerns in humans. This study evaluates the possibility of developing cancer and non-cancer human health risk in both adults and children from the consumption of heavy metals contaminated vegetables sold in four selected markets in Bauchi, State. Five selected vegetable samples were collected from each market, prepared, and digested and the concentrations of heavy metals (Cd, Pb, Cr and Zn) were determined using the atomic absorption spectrometry test. The mean concentration of Cd in most of the vegetable samples collected from the markets had exceeded the permissible limit set by WHO, while the mean values of Cr, Pb, and Zn were below the permissible limits. The mean values of heavy metals obtained in this study were 0.626, 0.044, 0.04, 0.01 mg/kg, for Zn, Cd, Cr, and Pb respectively. The computed hazard quotient and hazard index values discovered in this study were below the threshold value of 1, indicating that the population (both adults and children) is not at risk of developing non cancer risk. The study, found that the consumption of the selected vegetables for both adults and children will not expose the population to any carcinogenic human health risk. However, continues uptake of these metals over time could lead to potential health risk in both children and adults. Regular monitoring of heavy metals in food crops and screening of metals contents in fertilizer, pesticides and wastewater should be enforced by regulatory agencies.

Key words**:** Heavy metals, Health risk, Vegetables

INTRODUCTION

Heavy metals are one of the major sources of cancer and non-cancer-related diseases in human health (Bawa, 2023). The accumulation of these metals in food crops and their transfer along human ecological food chain is one of the major pathways into the human system (Kamunda *et al*., 2018). Even though some of these metals play an essential role in the metabolism of the human body but the non-essential ones such as cadmium, lead, mercury, and arsenic are non-biodegradable, persistent and have been classified as carcinogenic (Fakhri *et al*, 2018;Esmaeilzadeh *et al.*, 2019). Carcinogenic heavy metals even at low concentration can alter physiological function and cause severe adverse health effects on humans (Rai *et al*., 2019).

The geological history of the soil and anthropogenic activities such as wastewater irrigation, fertilizer and pesticides application, untreated effluents, industrial discharge are among the direct or indirect sources of metal contamination of agricultural soil and food crops (Bawa *et el*., 2021, Liu *et al*., 2021; Bawa, 2023;Ma *et al.*, 2023). Contamination of food crops by heavy metals is the main non – occupational exposure pathway of heavy metals into human system (Zhong *et al*, 2018; Sun *et al*, 2020b; Zheng *et al*., 2020, Lin *et al*., 2021,). Heavy metals and other pollutants contamination in food crops are responsible for about 420-960 million foodborne related illness and caused about 420,000 deaths annually (WHO, 2021). The Environmental Protection Agency of the United States (USEPA) has established standard for heavy metals maximum tolerable daily intake limits and the reference doses for oral exposure, and a standard formula for estimation of potential non cancer and cancer risk indices. Many studies have used these indices (Estimated daily intake, Hazard Quotient, Hazard index and Cancer risk indices) to evaluate the possibility of potential cancer and non-cancer on human through the consumption of metals contaminated food crops (Shaheen e*t al*., 2016; Rai *et al*., 2019; Singh *et al*., 2010; Sun *et al.,* 2022).

In Nigeria, there is long-term practice and use of metal-based fertilizers and pesticides, waste water irrigation, and use of industrial effluents especially in the dry season irrigation of farms (Mohammadi *et al*, 2019). Most of our agricultural crops are grown with these sources of irrigation practices without any form of regulation or screening by regulatory agencies (Yuduga *et al*, 2015; Barau *et al*., 2018; Ogbo and Patrick-Iwuanyanwu, *et al*., 2019; Bawa *et al*., 2021). Many studies in Nigeria have found high concentrations of heavy metals in fertilizers, pesticides, wastewater, and industrial effluents used for irrigation at concentrations above the permissible limits (Egbueri, *et al*., 2020; Izah and Aigberua, 2020; Bawa *et al*., 2021,). Food crops produced from these contaminated sources are supplied directly into the markets and transported to other parts of the country and neighboring countries without any form of screening for metals and other contaminants. Many studies have linked the consumption of heavy metals contaminated food crops in humans as one of the possible sources of cancer (Dhar *et al*, 2021; Mohammadi *et al*, 2019). The growing cases of cancer recorded in Nigerian hospitals (Nwofor, 2017) and more recently in northern parts (Bawa, 2023, Bawa *et el*., 2021) could be linked with possible long term intake of metal based pesticide contaminated crops. There is paucity of information though on the statistics of cancer caused due to heavy metal intake in northern Nigeria but a few example should suffice of the growing health concern For example in Kano in the northwestern Nigeria about 13.2% was reported in a total of 47,734 specimens (Yusuf *et al* ., 2017). Whereas in Nguru a northeastern part of Nigeria a high percentage of 69.6% was reported (Hadiza *et al*., 2018).

Many of the studies carried out in Nigeria and in particular northern Nigeria focused mainly on the assessment of heavy metals concentration in food crops, soil, and irrigation sources (Bawa *et al*., 2021a, 2021b, 2021c, Bawa 2023). However, studies on the potential risks of developing cancer and non-cancer from dietary intake of food metal contaminated crops are mostly overlooked. Hence, this study aimed to evaluate the potential risk of developing non-cancer and cancer risk in both children and adult from the consumption of heavy metals contaminated vegetables. Results from this study would provide data on the health risk or otherwise to both adult and children associated with the consumption of vegetables treated with pesticides in the farms in northern Nigeria.

Methodology

Study area

The study was carried out in four markets namely Kasuwan mata, Muda Lawal, Bayara, and Wunti. in Bauchi, a metropolis of Nigeria. These markets were the major markets for the supply and distribution of all the vegetables sold in Bauchi**.** The markets are mainly supplied with fresh vegetables daily from farm lands located within Bauchi and neighboring States such as Gombe, Plateau, Jigawa and Yobe States. The vegetables sold and distributed at these markets are normally consumed by both children and adults in Bauchi state Nigeria.

Samples collection

Three replicates of 500g each of the edible parts of five vegetables (*Solanum lycopersicum* (L.), *Capsicum annuum* (L.), *Spinacia oleracea* (L.), *Daucus carota* (L.), and *Allium cepa* (L.) were randomly bought from the sellers at four markets namely Kasuwan mata, MudaLawal, Bayara, and Wunti. All the vegetable samples were collected between the months of October to December, 2023. The vegetable samples were collected in polythene bags, labeled and transported to Department of Biological Sciences, Abubakar Tafawa Balewa University (ATBU) Bauchi, Nigeria.

Preparing Samples

The vegetable parts were washed thoroughly with several changes of distilled water to remove any sand and cut into tiny pieces in the Biology Laboratory at ATBU, dried at 80°C in the oven, pulverized in a stainless steel blender model (HL-2571), and filtered through a 2mm screen and stored at room temperature prior to analysis.

Heavy Metal Analysis

A mixture of three acids (tri acid) consisting of nitric acid, perchloric acid, and sulfuric acid 5:1:1 ratio was used for the digestion. One gram of each plant sample was digested with 15ml of the tri-acid in 50 ml volumetric flask by heating at 80^{o}C until a transparent solution was obtained. These transparent solutions were then filtered through Whatman Number 42 filter paper and diluted to 50 ml with distilled water (Ma *et al.,* 2017). The concentrations of Cd, Pb, Cr, and Zn in the filtrate were determined using atomic absorption spectrophotometer (AAS) Buck Scientific 210 GP. Specific lamps for each of the heavy metals was fitted in the ASS using appropriate drift blanks.

Assessment of Health Risks

Based on the US-EPA and IRIS (2006) description, the average mean value of heavy metals concentration in the edible sections of all the tested vegetables were used to develop health risk assessment indices in this study.

Estimated Daily Intake (EDI)

The estimated daily intake of metals (EDI) was determined using the formula below to ascertain the health risks of taking food crops contaminated with heavy metals. (US-EPA and IRIS, 2006; Zhong *et al,* 2018).

$$EDI= (M×K×I)/W$$

Where M is metals concentration in food crops (mg/kg), K is the conversion factor (0.085) used in the conversion of fresh weight of the vegetable to dry weight, I is the daily vegetable intake and W is the average body weight. The average daily intake (I) of vegetable for adults in Nigeria is 0.13 kg/d, while that of children is one third (0.04 kg/d) of it (Raajimakers *et al*., 2018). The estimated average adult body weight is 68kg (Chinedu and Emiloju, 2014), Children average weight age (6-12 years) in Nigeria was taken as 29.37 kg (Eze *et al.,* 2017).

Hazard Quotient

Risk to human health by the intake of metal-contaminated vegetables was characterized using a hazard quotient (HQ) (USEPA, 1989). HQ is the ratio between exposure and the reference oral dose (R_fD). If the ratio is lower than one (1), there will be no obvious risk. An estimate of the potential hazard to human health (HQ) through consumption of vegetables grown in metal-contaminated soil is described in Eq. (1):

$$HQ = (Div) \times C_{metal})/R_fD \times Bo$$

Where *(Div)* is the daily intake of vegetables (kg per day), (C_{metal}) is the concentration of metal in the vegetable (mg kg^{-1}), R_fD is the oral reference dose for the metal (mg kg^{-1} of body weight per day), and Bo is the human body mass (kg). R_fD is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime, generally used in EPA's noncancer health assessments.

The daily rate of human exposure that is not expected to have a substantial negative impact on health over the course of a lifetime is calculated as the risk-free dose, or RfD. The oral reference values for heavy metals were Cr=1.5 mg/kg/bw/day, Cd=0.001 mg/kg/bw, Pb=0.004 mg/kg/bw/day, mg/kg/bw/day, and Zn=0.3 mg/kg/bw/day (US-EPA, 2006).

Hazard Index

According to the US-EPA (2006), the Hazard Index (HI), which is the total of all the Hazard Quotients given in the equation below, was used to calculate the potential risk that numerous heavy metals pose to human health.

$$H = Q = Cd + Pb + Cr + Cu + Zn$$

Target Cancer Risk (TCR)

TCR is the likelihood that an adult or child would get cancer at some point in their lifetime as a result of prolonged exposure to carcinogenic metals (Liu *et al.* 2020a). It is calculated by using the CPSF equation (USEPA, 2019; Liu *et al,* 2020b).

TCR=EDI×CPSF According to (USEPA, 2019), the CPSF values were determined to be Cr=0.5 and Pb=0.0085 (mg/kg/day).

Statistical Analysis

The data was analyzed using the 2014 version of the statistical program "R". According to Dytham (2011), the mean difference in the concentration of each heavy metal between plant parts was calculated using a one-way (ANOVA) and Duncan mean multiple comparison test at $p = 0.05$

RESULTS AND DISCUSSION

Heavy Metal Concentrations in Vegetables

The mean concentrations of the heavy metals (Zn, Cd, Pb, and Cr) in the vegetables are presented in (Table 1). The result obtained for zinc showed the highest concentration of 0.626 mg/kg in *Allium cepa* from Wunti market. In all, zinc concentrations in the vegetables were below the permissible limit of 40 mg/kg (WHO, 2011).

Table1. Mean concentration of heavy metals (mg/kg) in vegetables sampled from markets in Bauchi, Nigeria

Markets	Plant	Scientific Name	Cd	Pb	Zn	Cr
Kasuwan Mata	Tomato	*Solanum lycopersicum*	0.015± 0.003[a]	0.008±0.013[ab]	0.117±0.047[a]	0.001±0.001c
	Pepper	*Capsicum annuum*	0.017±0.003[b]	0.009±0.011[a]	0.127±0.029[a]	0.002±0.001c
	Spinach	*Spinacia oleracea*	0.033±0.002[ab]	0.005±0.004[a]	0.082±0.009[a]	0.00±0.00c
	Carrot	*Daucus carota*	0.02±0.0001[a]	0.030±0.023[a]	0.118±0.037[a]	0.000±0.000c
	Onions	*Allium cepa*	0.043±0.005[b]	0.009±0.01[a]	0.073±0.015[a]	0.00±0.000d
Muda						
	Tomato	*Solanum lycopersicum*	0.002± 0.002[b]	0.001±0.000[b]	0.115±0.026[a]	0.041±0.007a
	Pepper	*Capsicum annuum*	0.010±0.004[c]	0.005± 0.005[a]	0.110±0.035[a]	0.045±0.005a
	Spinach	*Spinacia oleracea*	0.025±0.006[c]	0.006±0.003[a]	0.078±0.001[a]	0.018±0.01a
	Carrot	*Daucus carota*	0.01±0.010[a]	0.004±0.009[b]	0.403±0.285[a]	0.040±0.005a
	Onions	*Allium cepa*	0.032±0.002[c]	0.001±0.001[b]	0.09±0.018[a]	0.025±0.005a
Bayara						
	Tomato	*Solanum lycopersicum*	0.011± 0.006[a]	0.002±0.006[ab]	0.050±0.011[b]	0.0043±0.003c
	Pepper	*Capsicum annuum*	0.026±0.006[a]	0.00±0.000[a]	0.070±0.019[b]	0.002±0.002c
	Spinach	*Spinacia oleracea*	0.039±0.005[a]	0.000±0.000[a]	0.033±0.01[b]	0.007±0.003bc
	Carrot	*Daucus carota*	0.028±0.000[b]	0.00±0.00[b]	0.042±0.01[a]	0.000±0.000c
	Onions	*Allium cepa*	0.115±0.006[a]	0.01± 0.00[b]	0.041±0.01[a]	0.008± 0.001c
Wunti						
	Tomato	*Solanum lycopersicum*	0.012±0.006[a]	0.012±0.008[a]	0.069±0.027[b]	0.021±0.006b
	Pepper	*Capsicum annuum*	0.022±0.003[ab]	0.007±0.008[a]	0.111±0.015[a]	0.023±0.007b
	Spinach	*Spinacia oleracea*	0.0316±0.006[bc]	0.000±0.000[a]	0.075±0.039[a]	0.016±0.004ab
	Carrot	*Daucus carota*	0.028±0.002[c]	0.001±0.003[b]	0.143±0.004[a]	0.019±0.003b
	Onions	*Allium cepa*	0.044± 0.004[b]	0.01± 0.00[b]	0.626±0.23[a]	0.017±0.005b
Maximum allowable limit		FAO/WHO	0.02 mg/kg	0.3	40	2.3

Nonetheless, long term bioaccumulation of Zn over time may lead to higher levels that could result to human health risk. The trace of zinc found in this study could be attributed largely to the heavy metals content in agrochemicals such as pesticides and possibly zinc contaminated irrigation water. Previous study (Yuguda e*t al*., 2015) reported zinc contents in some agricultural herbicides and insecticides (Defarge *at al*., 2018, Barau *et al*., 2018, Bawa *et al*., 2021) and later found traces of heavy metals including Zn in vegetables fumigated with pesticides. Differences in Zn levels in plants could be associated with human practices and the choice of pesticides usage. For example in Imo in the eastern part of Nigeria higher level of zinc was reported in vegetables (Isiuku and Enyoh, 2020). In Paki, Kaduna state in the northwestern Nigeria, Bawa, (2023) reported 44.0 mg/kg in *Cucumis. sativus* while Babandi *et. al* (2019) recorded 83.30 mg/kg in carrot. In Iran, Khezerlou *et al*., (2020) reported 46.8 mg/kg in lettuce obtained from markets in Iran whereas Cabral- Pinto *et al.* (2019) in Portugal recorded zinc 37.6 mg/kg in tomato. Similar contents in tomatoes, peper and onion were also reported in Nigeria, 186.08 and 79.83 mg/kg by Bawa e*t al*., (2021b, 2021c).Prolonged and excessive uptake of zinc contaminated vegetables may lead to health challenges (Khezerlou *et al*., 2020).

The level of cadmium in most of the vegetables sampled from the markets were above the WHO, (2011) permissible limits of 0.02 mg/kg, the highest concentration was in *Allium cepa* 0.044 mg/kg from Wunti market while *Solanum lycopersicum* had the least of 0.002 mg/kg. Most of the vegetables samples from Bayara market had elevated levels of cadmium compared to other markets. The value obtained in this study was lower compared with similar reported cases in some parts of Africa and Asia that were known for indiscriminate pesticides application. For example 1.33mg/kg of Cadmium in cabbage from vegetables sampled from Kumasi market Ghana was reported by Apau *et al***.,** (2022)**.** Shahriar *et al*, (2020) in Bangaladesh also found 44 mg/kg in rice sampled from their markets. Similar concentration of cadmium was found in vegetable 0.011mg/kg by Isiuku and Enyoh, (2020) in eastern part of Nigeria. Another study in northwest Nigeria showed 1.33 mg/kg cadmium in *Z. mays* (Bawa, 2023) and 8.70 mg/kg in onion (Babandi *et al.,* (2019). Khezerlou *et al.,* (2020) recorded 1.60 mg/kg cadmium in tomatoes in Iran market. Cabral- Pinto *et al.* (2019) in Portugal found 0.27 mg/kg cadmium in cabbage. The presence of cadmium in vegetables samples recorded in this study might be linked with either one or both of the following sources: water irrigation, pesticides application in agricultural farmlands. Additional studies in Nigeria found 7.67, 4.68, and 6.14 mg/kg of cadmium in vegetables fumigated with metal based pesticides (Bawa *et al*, (2021, 2012b, and 2021d). Cadmium has relatively high mobility and can easily be absorbed by plants (Asdeo & Loonker, 2011**);** this could explain their presence in all the vegetables collected from the study sites. Human exposure to cadmium could result to accumulation in human organs such as nerves, lungs, kidney and skeletal system, causing cancer and other health risk to human (Sharma *et al*., 2016; Ametepey *et al*., (2018).

The concentration of chromium in the vegetables from all the markets ranged from 0.045 mg/kg in *Capsicum annuum* from Muda market to 0.001 mg/kg in *Solanum lycopersicum* from Kasuwan Mata market. The level of chromium obtained in all the vegetables samples were lower than WHO, (2011) permissible limit of 2.3 mg/kg, indicating that all the vegetables under investigation were not contaminated with chromium. The maximum chromium concentrations discovered in this study which is located in northeastern Nigeria was lower compared to 1.50 mg/kg in *D. carota* in northwestern Nigeria (Bawa, 2023) and the values of 65.10 mg/kg in carrot reported by Babandi *et al*., 2019. In Asia, Khezerlou *et al.*, (2020) found 6.89 mg/kg chromium in Iran markets. In Europe however, Cabral- Pinto *et al*. (2019) recorded 1.92mg/kg of chromium in cabbage. The trace of chromium discovered in this study might be attributed to waste irrigation water from industrial and domestic sources and application of metal base agro pesticides. Bawa *et al*, 2021, 2021a, 2021b) had previously found chromium contents in pepper, carrots, onion with no source of contaminated irrigation water but fumigated with metal based pesticides in northern Nigeria. Excessive chromium uptake in human has been linked with ulcer, pulmonary cancer, chromosomal damage and changes in DNA replication (O'brien *et al*., 2001; Spector *et al*., 2011).

The concentration of lead (Pb) was the least among the metals in the all the vegetables samples collected from markets. The highest concentration of Pb was 0.012mg/kg in *Solanum lycopersicum* from Wunti market while the minimum was 0.001 mg/kg in *Allium cepa* from Muda Lawal market. The study found that the level of Pb in all the vegetables under this study was lower than the WHO, (2011) permissible limits of 0.3 mg/kg. Even though this study discovered low concentration of Pb in the vegetables samples, the maximum concentration of Pb is similar to the 0.11 mg/kg in green beans obtained by Apau *et al.*, (2022) from Kumasi market in Ghana. Isiuku and Enyoh, (2022) also found low trace of Pb 0.012 mg/kg in *Pterocarpus mildbraedii* (Harms) vegetables in eastern Nigeria and Cabral- Pinto *et al.* (2019) in Portugal reported 0.121 mg/kg in tomato. The Pb content obtained in this study was lower compared to 5.33 mg/kg in *Crocus sativus* (L.), sampled from vegetables fumigated with metal-pesticides in Paki, northwestern Nigeria (Bawa, 2023). Babandi *et al*., (2019) and Khezerlou *et al*., (2020) found 16.84 mg/kg of Pb in onions and 1.88mg/kg in lettuce respectively. Prolonged lead uptake has been shown to affect human immunological system, neurobehavioral and skeletal, circulatory (Elledge *et al*., 2014).

Health risk assessment

The hazard quotient evaluates the non-cancer potential human health risk from the consumption of metals in food. It estimates the ratio of the potential exposure to a metals and the level at which no adverse effects are expected. Hazard Quotient values greater or equal to 1 indicates potential adverse health risk from the consumption of food for a particular metal. The estimated hazard quotient of all the vegetables in this study for adult and children from the sampling areas are presented in (Table 2 and 3).

Table 2: Estimated Adult hazard quotient value of metals from the consumption of the vegetables collected from markets

Plant	Scientific Name		Markets			
		Metals	Kasuwan Mata	Muda	Bayara	Wunti
Tomato	*Solanum lycopersicum*	Cadmium	0.001828	0.000244	0.0013401	0.001462
		Lead	6.09E-05	0.000244	0.000000	0.000366
		Zinc	4.75E-05	4.67E-05	2.03E-05	2.8E-05
		Chromium	8.12E-08	3.33E-06	3.25E-07	1.71E-06
Pepper	*Capsicum annuum*	Cadmium	0.002071	0.001218	0.003168	0.00268
		Lead	0.000274	0.000152	0.00000	0.000213
		Zinc	5.16E-05	4.47E-05	2.84E-05	4.51E-05
		Chromium	1.87E-07	3.66E-06	1.62E-07	1.87E-06
Spinach	*Spinacia oleracea*	Cadmium	0.004021	0.003046	0.004752	0.003777
		Lead	0.000152	0.000183	0.00000	0.00000
		Zinc	3.33E-05	3.17E-05	1.22E-05	3.05E-05
		Chromium	1.62E-07	1.46E-06	0.0000	8.12E-07
Carrot	*Daucus carota*	Cadmium	0.00268	0.001231	0.003411	0.003411
		Lead	0.000914	0.000122	0.00000	3.05E-05
		Zinc	4.79E-05	0.000164	1.705E-05	3.05E-05
		Chromium	1.62E-07	3.25E-06	0.00000	5.81E-05
Onions	*Allium cepa*	Cadmium	0.005239	0.003899	0.014011	0.005361
		Lead	0.000274	3.05E-05	0.00000	0.00000
		Zinc	2.96E-05	4.02E-05	1.67E-05	0.000254
		Chromium	0.0000	2.03E-06	1.67E-05	1.38E-06

The estimated hazard quotient values in all the vegetables obtained in this study for both adult and children were lower than the value of 1. This implies that the consumption of all the studied vegetables from all the markets will not pose any potential human health risk to the population.

Table 3**:** Estimated Children hazard quotient value of metals from the consumption of the vegetables collected from markets

Plant	Scientific Name	Hazard Quotient	Markets			
		Metals	Kasuwan mata	Muda	Bayara	Wunti
Tomato	*Solanum lycopersicum*	Cadmium	0.003733	0.000498	0.002738	0.002987
		Lead	0.000124	0.000498	0.000000	0.000747
		Zinc	9.71E-05	9.54E-05	4.15E-05	5.72E-05
		Chromium	1.66E-07	6.8E-06	6.64E-07	3.48E-06
Pepper	*Capsicum annuum*	Cadmium	0.004231	0.002489	0.006471	0.005476
		Lead	0.00056	0.000311	0.00000	0.000436
		Zinc	0.000105	9.13E-05	5.81E-05	9.21E-05
		Chromium	3.82E-07	7.47E-06	3.32E-07	3.82E-06
Spinach	*Spinacia oleracea*	Cadmium	0.008213	0.006222	0.009707	0.007716
		Lead	0.000311	0.000373	0.00000	0.00000
		Zinc	6.8E-05	6.47E-05	2.49E-05	6.22E-05
		Chromium	0.0000	2.99E-06	0.0000	1.66E-06
Carrot	*Daucus carota*	Cadmium	0.005476	0.002514	0.006969	0.006969
		Lead	0.001867	0.000249	0.00000	6.22E-05
		Zinc	9.79E-05	0.000334	3.48E-05	0.000119
		Chromium	3.32E-07	6.64E-06	0.0000	3.15E-06
Onions	*Allium cepa*	Cadmium	0.010702	0.007965	0.028623	0.010951
		Lead	0.00056	6.22E-05	0.000000	0.00000
		Zinc	6.06E-05	8.21E-05	3.4E-05	0.000519
		Chromium	0.0000	4.15E-06	1.33E-06	2.82E-06

The result showed <1 hazard quotient values from the consumption of the studied metals, the estimated (HQ) ranged from 0.014011-0000244, 0.000914-0.00000, 0.000254-1.22E-05, 5.81E-05-0.00000 for Cd, Pb, Zn, and Cr respectively for adult and 0.010951-0.000498, 0.001867-0.00000, 0.000519-2.49E-05, 7.47E-06-0.0000 for Cd, Pb, Zn and Cr respectively for children. Similar low HQ value of 0.58 was found in rice by Shahriar *et al.*, (2020) in Bangladesh. The HQ values obtained in this study was lower than (Hazard quotient values was reported in Ghana, Pb 0.91 in green beans,13.90 in carrot (Adults), 4.14 in Green beans, (children), Cd 13.90 in carrot, 60.83 in carrot (children) sampled from markets in Kumasi, Ghana (Apau *et al*., 2022). Bawa, (2023) showed HQ values for Pb 0.13 and 0.28, Cd, 0.16 and 2.36, Cr 0.02, 0.12 for adult and children in vegetables fumigated with pesticides. Baghaie and Fereydoni, (2019) found Pb 0.73 and 0.63 for both male and children, Cd 0.34 and 0.29 in both male and children.

Hazard index

Hazard index is an estimate of the cumulative non cancer risk resulting from simultaneous exposure to more one metal and it's computed as the sum of aggregate hazard quotient from the consumption of food or substance. In this study the computed hazard index values from the consumption of the vegetables for both adult and children are presented in (Table 4).

Table 4: Estimated hazard index (HI) of metals from the consumption of vegetables collected from markets

Plant	Scientific Name		Markets			
		Hazard Index	Kasuwan mata	Muda	Bayara	Wunti
Tomato	*Solanum lycopersicum*	Adult	0.001936	0.000537	0.001361	0.001857
		Children	0.003955	0.001098	0.00278	0.003794
Pepper	*Capsicum annuum*	Adult	0.002397	0.001419	0.003196	0.00294
		Children	0.004897	0.002899	0.00653	0.006007
Spinach	*Spinacia oleracea*	Adult	0.004206	0.003262	0.004764	0.003808
		Children	0.008593	0.006663	0.009732	0.00778
Carrot	*Daucus carota*	Adult	0.003642	0.001519	0.003428	0.003501
		Children	0.007441	0.003104	0.007004	0.007153
Onions	*Allium cepa*	Adult	0.005543	0.003971	0.014028	0.005616
		Children	0.011323	0.008113	0.028658	0.011473

This study found that *Allium cepa* from Bayara market had the highest hazard index values of 0.014028 and 0.028658 in adult and children respectively, while *Solanum Lycopersicum* from Muda market had the least hazard index value of 0.000537 and 0.001098 for adult and children respectively. The hazard index values obtained showed that the consumption of the all vegetables collected from markets will not pose any potential non cancer risk for both adult and children. This implies that the cumulative uptake of these metals through the consumption of all investigated vegetables is unlikely to pose any non-cancer risk for both adult and children. The study found higher hazard index values in children compared to adult in the studied vegetables and across all the markets. Hence children are susceptible to potential non-cancer risk than adult from the intake of food crops contaminated with heavy metals. Similar HI values was reported by Bawa, (2023) 0.41 and 2.91 for adults and children respectively in vegetables fumigated with pesticides. Khezerlou *et al*., (2020 obtained HI value of 14.33 in cabbage and 14.1 for lettuce both both male and children. Similarly Baghaie and Fereydoni, (2019) in Iran through the consumption of vegetables for Pb observed 2.87 and 2.5, Cd in 1.85 and 1.59 in both male and children.

Target Cancer Risk

The possibility that a person may get cancer as a result of exposure to pollutants is estimated using the term "target cancer risk" (NYSDOH, 2017). Target cancer risks were evaluated by the New York State Department of Health as follows: less than 10^{-6} implies minimum carcinogenic risk, 10^{-5}–10^{-3} indicates moderate cancer risk, and 10^{-3}–10^{-1} indicates high cancer risk (NYSDOH, 2017). The estimated cancer risk results for both adult and children are presented in (Table 5).

Table 5: Estimated Target Cancer Risk (TCR) value of heavy metals from the consumption of vegetables collected from markets

Markets	Plant	Scientific Name	Cd mg/kg		Pb mg/kg		Cr mg/kg	
			Adult	Children	Adult	Children	Adult	Children
Kasuwan Mata	Tomato	*Solanum lycopersicum*	0.000323	0.000659	2.44E-08	4.98E-08	7.17E-07	1.46E-06
	Pepper	*Capsicum annuum*	0.000366	0.000747	1.1E-07	2.24E-07	1.65E-06	3.37E-06
	Spinach	*Spinacia oleracea*	0.00071	0.001449	6.09E-08	1.24E-07	0.00	0.00
	Carrot	*Daucus carota*	0.000473	0.000966	3.66E-07	7.47E-07	1.43E-06	2.93E-06
	Onions	*Allium cepa*	0.000925	0.001889	1.1E-07	2.24E-07	0.00	0.00
Muda								
	Tomato	*Solanum lycopersicum*	0.000043	8.78E-05	9.75E-08	1.99E-07	2.94E-05	6.E-05
	Pepper	*Capsicum annuum*	0.000215	0.000439	6.09E-08	1.24E-07	3.23E-05	6.59E-05
	Spinach	*Spinacia oleracea*	0.000538	0.001098	7.31E-08	1.49E-07	1.29E-05	2.64E-05
	Carrot	*Daucus carota*	0.000217	0.000444	4.87E-08	9.96E-08	2.87E-05	5.86E-05
	Onions	*Allium cepa*	0.000688	0.001406	1.22E-08	2.49E-08	1.79E-05	3.66E-05
Bayara								
	Tomato	*Solanum lycopersicum*	0.000237	0.000483	0.00	0.00	2.87E-06	2.87E-06
	Pepper	*Capsicum annuum*	0.000559	0.001142	0.00	0.00	1.43E-06	1.43E-06
	Spinach	*Spinacia oleracea*	0.000839	0.001713	0.00	0.00	0.00	0.00
	Carrot	*Daucus carota*	0.000602	0.00123	0.00	0.00	0.00	0.00
	Onions	*Allium cepa*	0.002473	0.005051	0.00	0.00	5.73E-06	5.73E-06
Wunti								
	Tomato	*Solanum lycopersicum*	0.000258	0.000527	1.46E-07	2.99E-07	1.50E-05	3.07E-05
	Pepper	*Capsicum annuum*	0.000473	0.000966	8.52E-08	1.74E-07	1.64E-05	3.37E-05
	Spinach	*Spinacia oleracea*	0.0006665	0.001362	0.00	0.00	7.16E-06	1.46E-05
	Carrot	*Daucus carota*	0.000602	0.00123	1.21E-08	2.49E-08	1.36E-05	2.78E-05
	Onions	*Allium cepa*	0.000946	0.001933	0.00	0.00	1.21E-05	2.49E-05

This study found that the estimated cancer risk values from the consumption of the selected vegetables across the markets in Bauchi, were all within the minimum carcinogenic and below the risk of developing any cancer. Hence the intake of the all the studied metals through the consumption of these vegetables will not pose any potential cancer risk for both adult and children. However, our study found higher TCR values for Cd in both adults and children compared to other metals across all markets. Among the studied vegetables *Allium cepa* from Wunti market had the highest TCR values compared to other vegetables. The TCR value obtained in this study was below the threshold value capable of causing any potential cancer risk compared to TCR reported in other studies which fall within cancer risk. Studies by Babandi *et al.*, (2019) falls within the threshold values capable of causing cancer, their study found target cancer risk for adult from the consumption of vegetables grown in Sharada industrial area 5.0×10^{-4} for Cd, $3.0 \times 10^{-3}$for Cr and 3.6×10^{-3} for Pb. Similar study by Khezerlou *et al*., (2020) from vegetables consumption in Iran found TCR values for Pb 0.032 and 0.19 males which fall within range capable of causing cancer risk.

CONCLUSION

In this study, there are generally low concentrations of all the heavy metals (Cd, Pb, Cr and Zn) recorded in the vegetable samples collected in all the markets. Among the metals, only cadmium had mean concentration above the WHO permissible limits in most of the vegetable samples. The concentration of heavy metals in vegetable samples from Wunti markets had higher concentrations compared to the other markets. *Allium cepa* showed higher concentrations of metals compared to other vegetable samples. The estimated health risk indices revealed that the population will not experience any potential non-cancer human health for both children and adults. It was concluded that the presence of trace metals in these vegetable samples could possibly be from agropesticides and heavy metals contaminated irrigation water. This study underscores the need for comprehensive screening of food crops for heavy metals by regulatory agencies.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgement

We thank the Tertiary Education Trust Fund (TETFund), Abuja, Nigeria for fully funding this research.

REFERENCE

Ametepey, S. T., Cobbina, S. J., Akpabey, F. J., Duwiejuah, A. B., & Abuntori, Z. N. (2018). Health risk assessment and heavy metal contamination levels in vegetables from tamale metropolis, Ghana. *International Journal of Food Contamination*, 5(1) p1-8. https://doi.org/10.1186/s40550-018-0067-0

Asdeo, A., & Loonker, S. (2011). A comparative analysis of trace metals in vegetables. ***Research** Journal of Environmental Toxicology*, 5(2), 125–132. https://doi.org/10.3923/rjet.2011.125.132

Apau, J., Siameh, M. O., Misszento, J. A., Gyamfi, O., Osei-Owusu, J., Kwaansa-Ansah, E. E., & Acheampong, A. (2022). Determination of potentially toxic elements in selected vegetables sampled from some markets in the Kumasi metropolis. *Cogent Public Health*, 9(1), 2145699.

Bawa, U. (2023). Heavy metals concentration in food crops irrigated with pesticides and their associated human health risks in Paki, Kaduna State, Nigeria. *Cogent Food & Agriculture*, 9(1), 2191889.

Bawa, U., AbdulHameed, A., Nayaya, A.J., Ezra, A.G. (2021a). Health risk assessment of food crops fumigated with metal based pesticides grown in north-eastern Nigeria, *Research Journal of Environmental Toxicology*, 15 (1): 1-10 DOI: 10.3923/rjet.2021.1.10

Bawa, U., AbdulHameed, A., Nayaya, A.J., Ezra, A.G. (2021b). Assessment of health risks from consumption of food crops fumigated with metal based pesticides in Gwadam, Gombe State, Nigeria, *Bayero Journal of Pure and Applied Sciences*, 14(1):100-110 https://doi.org/10.4314/bajopas.v14i1.14

Bawa, U., AbdulHameed, A., Nayaya, A.J., Ezra, A.G. (2021c). Health risk assessment of heavy metals from pesticides use in Plateau state, Nigeria. *Bayero Journal of Pure and Applied sciences*, 14(1):130-141 https://doi.org/10.4314/bajopas.v14i1.17

Bawa, U., AbdulHameed, A., Nayaya, A.J., Ezra, A.G., Jibrin, M. (2021d).Bioaccumulation and Human Health Risk of Heavy Metals from Pesticides in Some Crops Grown in Plateau State, *Nigeria Biology and Life Sciences Forum* 4, no. 1: 12. https://doi.org/10.3390/IECPS2020-08737

Babandi, A., Ya'u, M., Muhammad Yakasai, H., Shehu, D., Babagana, K., Ibrahim, A., ... & Ezeanyika, L. (2020). Non-carcinogenic and carcinogenic risk potentials of metals exposure from vegetables grown in Sharada industrial area Kano, Nigeria. *Journal of Chemical Health Risks*, 10(1), 1-15.

Baghaie, A. H., & Fereydoni, M. (2019). The potential risk of heavy metals on human health due to the daily consumption of vegetables. *Environmental Health Engineering and Management Journal* 2019, 6(1), 11–16

Barau, B. W., Abdulhameed, A., Ezra, A. G., Muhammad, M., Kyari, E. M., & Bawa, U. (2018). Heavy metal contamination of some vegetables from pesticides and the potential health risk in Bauchi, northern Nigeria. *AFRREV STECH: An International Journal of Science and Technology***,** 7(1), 1-11. https://doi.org/10.4314/stech.v7i1.1

Cabral-Pinto, M. M., Inácio, M., Neves, O., Almeida, A. A., Pinto, E., Oliveiros, B., & Ferreira da Silva, E. A. (2020). Human health risk assessment due to agricultural activities and crop consumption in the surroundings of an industrial area. *Exposure and Health*, 12, 629-640.

Defarge, N., Spiroux de Vendomois, J., & Seralini, G.E. (2018). Toxicity of formulants and heavy metals in glyphosphate-based herbicides and other pesticides, *Toxicology Reports*, 5:156-163.

Dhar, P. K., Naznin, A., Hossain, M. S., & Hasan, M. (2021). Toxic element profile of ice cream in Bangladesh: A health risk assessment study. Environmental monitoring and assessment, 193(7), 1-15. https://doi.org/10.1007/s10661-021-09207-7

Dytham, C. (2011). *Chosing and using statistics, a biologist guide*. 3rd ed:Wiley-Blackwell p31-36

DOH, N. (2007). Hopewell precision area contamination: Appendix C-NYS DOH. Procedure for evaluating health risks for contaminants of concern. Available at: http://www. health. ny. gov/environmental/investigations/hopewell/appendc. htm.

Egbueri, J. C., Ukah, B. U., Ubido, O. E., & Unigwe, C. O. (2022). A chemometric approach to source apportionment, ecological and health risk assessment of heavy metals in industrial soils from southwestern Nigeria. *International Journal of Environmental Analytical Chemistry*, 102(14), 3399-3417.

Elledge, M. F., Redmon, J. H., Levine, K. E., Wickremasinghe, R. J., Wanigasariya, K. P., & Peiris- John, R. J. (2014). Chronic kidney disease of unknown etiology in Sri Lanka: Quest for understanding and global implications. RTI Press Research Brief [Internet]. https://doi.org/10.3768/rtipress.2015.rb.0009.1502

Esmaeilzadeh, M., Jaafari, J., Mohammadi, A. A., Panahandeh, M., Javid, A., & Javan, S. (2018). Investigation of the extent of contamination of heavy metals in agricultural soil using statistical analyses and contamination indices. *Human and Ecological Risk Assessment:*

Eze, J.N., Oguonu, T., Ojinnaka, N.C., Ibe, B.C. (2017). Physical growth and nutritional status assessment of school children in Enugu, Nigeria. *Nigerian Journal of clinical practice*, (20(1),64-70,DOI: 10.4103/1119-3077.180067

Fakhri, Y., Bjørklund, G., Bandpei, A. M., Chirumbolo, S., Keramati, H., Pouya, R. H., & Ghasemi, S. M. (2018). Concentrations of arsenic and lead in rice (Oryza sativa L.) in Iran: a systematic review and carcinogenic risk assessment. *Food and chemical toxicology***,** 113, 267-277.

Hadiza A. U. , Bala M. A., Ibrahim M. S., Mohammed B. , Pindiga U. H. (2018). Pattern of

Cancers at a rural referral centre in North-Eastern Nigeria. *Borno Medical Journal* 15(1) 21-28

Hart, A. D., Azubuike, C. U., Barimalaa, I. S. and Achinewhu, S. C., (2005). Vegetable consumption pattern of households in selected areas of the old Rivers State in Nigeria. AfricanJ.Food,Agric.Nutr.Dev.**5**, Available from https://www.ajol.info/index.php/ajfand/article/view/135964 [Acessed on 25 December 2020].

Isiuku, B. O., & Enyoh, C. E. (2020). Monitoring and modeling of heavy metal contents in vegetables collected from markets in Imo State, Nigeria. *Environmental Analysis***,** *Health and Toxicology*, 35(1).

Izah, S. C., & Aigberua, A. O. (2020). Microbial and heavy metal hazard analysis of edible tomatoes (*Lycopersicon esculentum*) in Port Harcourt, Nigeria. *Toxicology and Environmental Health sciences***,** 12, 371-380.

Kumar, A., Manas, D., & Ruplal, P., (2017). Concentration of trace metals and potential health risk assessment via consumption of food crops in the south Chotanagpur of Jharkhand, India, *Pharmal Innovation Journal* 6:(9):159-167.

Khezerlou, A., Dehghan, P., Moosavy, M. H., & Kochakkhani, H. (2021). Assessment of heavy metal contamination and the probabilistic risk via salad vegetable consumption in Tabriz, Iran. Biological trace element research, 199, 2779-2787.

Liu, Q., Liao, Y., Xu, X., Shi, X., J., Chen, Q., Shou, L.(2020a**).** Heavy metal concentrations in tissues of marine fish and crap collected from the middle coast of Zhejiang province, China. Environmental monitoring and assessment, 192(5), 1-12. DOI: https://doi.org/10.1007/s10661-020-8234-1

Liu, S., Liu, Y.L., Yang, D.F., Li, C., Zhao, Y., Ma, H.M., Luo, X.R., Lu, S.Y., (2020b). Trace elements in shellfish from Shenzhen, China: implication of coastal water pollution and human exposure. Environ. Pollut. 263, 114582. https://doi.org/10.1016/j.envpol.2020.114582.

Lin, S., Ali, M.U., Zheng, C., Cai, Z., Wong, M.H., (2021). Toxic chemicals from uncontrolled e-waste recycling: exposure, body burden, health impact. *J. Hazard. Mater*., 127792 https://doi.org/10.1016/j.jhazmat.2021.127792.

Mohammadi, A. A., Zarei, A., Majidi, S., Ghaderpoury, A., Hashempour, Y., Saghi, M. H., Ghaderpoori, M. (2019). Carcinogenic and non-carcinogenic health risk assessment of heavy metals in drinking water of Khorramabad, Iran. MethodsX, 6, 1642-1651. https://doi.org/10.1016/j.mex.2019.07.017

Ma, L., Yang, Z.G., Kong, Q., Wang, L., (2017). Extraction and determination of arsenic species in leafy vegetables: method development and application. *Food Chem*. 217, 524–530. https://doi.org/10.1016/j.foodchem.2016.09.015.

Ogbo, A.B., & Patrick-Iwuanyanwu, K.C. (2019). Heavy metals contamination and potential human health risk via consumption of vegetables from selected communities in Onelga, Rivers state Nigeria, *European Journal of Nutrition and Food Safety*. 9(2):134-151.

O'Brien, T., Xu, J., and Patierno, S.R. (2001). Effects of glutathione on chromium induced DNA Crosslinking and DNA polymerase arrest. In Molecular Mechanisms of Metal Toxicity and Carcinogenesis, Springer Us: 173-182.

Rai, P.K., Lee, S.S., Zhang, M., Tsang, Y.F., Kim, K.H., (2019). Heavy metals in food crops: health risks, fate, mechanisms, and management. *Environ. Int.* 125, 365–385. https://doi.org/10.1016/j.envint.2019.01.067

Rattan, R. K., Datta, S. P., Chhonkar, P. K., Suribabu, K. and Singh, A. K., (2005). Long-term impact of irrigation with sewage effluents on heavy metal content in soils, crops and groundwater—a case study. *Agriculture. Ecosystem.*

Environvironment. 109, 310–322, DOI:10.1016/j.agee.2005.02.025

Shahriar, S., Rahman, M. M., & Naidu, R. (2020). Geographical variation of cadmium in commercial rice brands in Bangladesh: Human health risk assessment. *Science of the Total Environment*, 716, 137049.

Shaheen, N., Irfan, N.M., Khan, I.N., Islam, S., Islam, M.S., Ahmed, M.K., (2016). Presence of heavy metals in fruits and vegetables: health risk implications in Bangladesh. *Chemosphere* 152, 431–438. https://doi.org/10.1016/j.chemosphere.2016.02.060.

Sun, T., Wu, H., Wang, X., Ji, C., Shan, X., & Li, F. (2020). Evaluation on the biomagnification or biodilution of trace metals in global marine food webs by meta analysis. *Environmental pollution*, 264, 113856.

Sun, S., Cao, R., Lu, X.B., Zhang, Y.C., Gao, Y., Chen, J.P., Zhang, H.J., (2021b). Levels and patterns of polychlorinated dibenzo-p-dioxins and dibenzofurans and polychlorinated biphenyls in foodstuffs of animal origin from Chinese markets and implications of dietary exposure. Environ. Pollut. 273, 116344. https://doi.org/10.1016/j.envpol.2020.116344.

Spector, J.T., Navas-Acien, A., Fadrowski, J. E., Guallar, E., Jaar, B., & Weaver, V.M. (2011). Associations of bllod lead with estmimated glomerular filtration rate using MDRD, CKD EPI and serum cystatin C-based equations Nephrol Dial Transpl 26 (9):2786-92. doi:10.1093/ndt/gfq773

Sharma, A., Katnoria, J. K., & Nagpal, A. K. (2016). Heavy metals in vegetables: Screening health risks involved in cultivation along wastewater drain and irrigating with wastewater. SpringerPlus, 5(1), 1–16. https://doi. org/10.1186/s40064-016-2129-1

US-EPA and IRIS, (2006). United States, Environmental Protection Agency, Integrated Risk Information System. Available from https://www.epa.gov/iris [Acessed on 25 December 2020].

USEPA, I. R. I. S. (2011). Integrated risk information system. Environmental Protection Agency Region I, Washington DC, 20460.

Ukah, C. O., & Nwofor, A. M. (2017). Cancer incidence in south-east Nigeria: a report from Nnewi cancer registry. *Orient Journal of Medicine*, 29(1-2), 48-55.

Yuguda, A. U., Abubakar, Z. A., Jibo, A. U., AbdulHameed, A. and Nayaya, A. J. , (2015). Assesment of toxicity of some agricultural pesticides on earthworm (Lumbricus terrestris). *American Eurasian Journal Sustainable Agriculture* 9, 49–59, Available from http://www.aensiweb.net/AENSIWEB/aejsa/aejsa/2015/May/49-59.pdf [Acessed on 25 December 2020].

World Health Organisation (2020). https://www.who.int/countries/nga/en/

WHO, (2021). Health Topics-Food Safety. Retrived from https://www.who.int/health-topics/ food-Safety. (Accessed 21 December 2022).

Yusuf, Ibrahim; Atanda, Akinfenwa Taoheed; Umar, Ali Bala; Imam, Mohammed, Ibrahim; Mohammed, A. Z.; Ochicha, Ochicha; Haruna, Muhammad Sanusi (2017),*Annals of Tropical Pathology* 8(2):p 87-93.

Zheng, S., Wang, Q., Yuan, Y., Sun, W., (2020). Human health risk assessment of heavy metals in soil and food crops in the Pearl River Delta urban agglomeration of China. *Food Chemistry* 316, 126213. https://doi.org/10.1016/j.foodchem.2020.126213.

Zhong, T., Xue, D., Zhao, L. and Zhang, X., (2018). Concentration of heavy metals in vegetables and potential health risk assessment in China. *Environ. Geochem. Health* 40, 313–322, DOI: https://doi.org/10.1007/s10653-017-9909-6.