

Health Risk Assessment of Some Heavy Metals Contamination in Vegetables Sold at Bichi Local Government Area, Kano State – Nigeria

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Abstract

Vegetables are the source of essential nutrients for health maintenance and treatment of various diseases. However, they are a major source of heavy metals contamination. This study evaluates the levels of heavy metals in selected vegetables sold in Bichi and their potential health risks. The collected samples were ashed using concentrated HNO₃ and analyzed using AAS. The concentrations of the heavy metals detected were in the range of 0.18 to 0.04; 1.64 to 0.63; 0.01; 3.44 to 0.67, and 0.17 to 0.06 mg/kg, for Cu, Fe, Cd, Pb, and Zn respectively. The concentrations of heavy metals were below WHO/FAO recommended levels except Pb, which is above the tolerable limit. The highest concentration of Pb (3.44 mg/kg) where detected in pepper, and the least in carrots (0.67 mg/kg). The Estimated Daily Intake values of individual heavy metals from the consumption of vegetables were 1.08×10^{-3} , 1.66×10^{-2} , 1.42×10^{-7} , 3.52×10^{-2} , and 1.36×10^{-3} mg/kg body weight/day for Cu, Fe, Cd, Pb, and Zn respectively which were less than the Maximum tolerable daily intake. The Hazard Index of all vegetables is 6.83×10^{-2} which is less than 1, indicating that, the consumption of these vegetables may result in non-carcinogenic health risks. The Target Cancer Risks value of Pb was 2.99×10^{-7} , which is less than the standard risk limit (10^{-6}). This shows that, despite the high concentration of Pb in the samples, the calculated parameters have clearly indicated that, there are no carcinogenic health risks to consumers.

KEYWORDS: Vegetable, Heavy Metals, Estimated Daily Intake, Hazard Index, and Target Cancer Risk

INTRODUCTION

Vegetables especially leafy are the most significant dietary source of nutrients as they contain

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protein, carbohydrates, fibers, vitamins, minerals, trace elements, etc., and also contain antioxidants which are essential for health maintenance, prevention and treatment of various diseases (Garg *et al.*, 2014; Islam *et al.*, 2018; Asrade and Ketema2023). However, it becomes deleterious to humans as well as animals as it accumulates toxic metals in their tissues when grown in contaminated soils.

Both natural and anthropogenic activities have been considered for the release of trace metals into the environment. The activities such as rapid improvements in agriculture, industrialization, vehicular exhaust, construction, wastewater irrigation, sludge application, etc. are the causes of trace metals contamination in vegetables. Therefore, the presence of trace metals in the vegetable is of great concern due to their non-biodegradable nature, long half-lives and toxicity to humans and other organisms (Islam *et al.*, 2015; Islam *et al.*, 2018; Verma *et al.*, 2020; Yuan *et al.*, 2020; Alsafran *et al.*, 2021; Sadi *et al.*, 2021). Trace/heavy metal is any metallic element with a relative density greater than 4 g/cm³. (Sadi *et al.*, 2021).

Trace metals pollution is one of the most severe environmental and human health problems which is associated with many activities (Sadi *et al.*, 2021). Lead (Pb) and cadmium (Cd) are among the most abundant trace metals and are particularly toxic (Sadi *et al.*, 2021). They are potentially appear in human bodies through ingestion of contaminated food, skin exposure, and inhalation (Alsafran *et al.*, 2021). The excessive amount of these metals in food is associated with the etiology of several diseases, especially vascular, kidney, nervous as well as bone diseases (Sadi *et al.*, 2021). Pb is well known for its toxicity and adverse effects on human health. Absorption of ingested Pb may constitute a serious risk to public health. Some chronic effects of Pb poisoning are stomachache, heartburn, constipation, and anemia (Sadi *et al.*, 2023). High levels of trace metals in soil or food pose a severe health risk to humans. The potential toxicants find their way into the living systems via the food chain, following bioaccumulation in edible plants, including leafy vegetables grown in or irrigated with contaminated soil or water, respectively (Alsafran *et al.*, 2021; Abdullahi *et al.*, 2022).

Fresh vegetables are also the major sources of trace metals, which contain both essential and toxic heavy metals over a wide range of concentrations in the human diet because metals and other elements can be present naturally in food or can enter food as a result of human activities such as industrial and agricultural processes, which cause chronic and acute health problems such as depression, cancer, osteoporosis, brain and nervous system damage, metabolic abnormalities, respiratory disorders, vascular diseases, kidney or bone damage, low intelligent quotients in children, and irregular functioning of the human and animal reproductive systems (Islam *et al.*, 2018). Consumption of vegetables contaminated with heavy metals over a long period can seriously diminish some of the essential nutrients in the body and can cause a reduction in immunological defenses, intrauterine growth retardation, impaired physical-social behavior, and disabilities associated with malnutrition (Sadi *et al.*, 2023). Carcinogenic, mutagenic, or neurotoxic effects that may be chronic, sub-chronic and acute have also been testified due to metal poisoning (Kadir *et al.*, 2008). Some employees were tested having kidney problems (Rai *et al.*, 2019).

The detrimental effects of heavy metals during pregnancy and fetal development have been widely documented. Especially in developing countries like Nigeria, environmental pollution is becoming a major concern because of poor waste management systems, absence the of a monitoring system, and rapid economic activities (Sadi *et al.*, 202; Abdullahi *et al.*, 2022; Sadi *et al.*, 2023). Therefore, vegetable quality and safety have become a major public concern globally, mostly in developing countries like Nigeria. Therefore, the objectives of this research are; to determine the concentration of selected heavy metals (Cu, Fe, Cd, Pb, and Zn), in carrot, pepper, cabbage, onion, and tomato samples sold in Bichi Local Government Area, Kano State – Nigeria using Flame Atomic Absorption Spectrophotometer (FAAS) and also to evaluate the estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI), and target cancer risk (TCR) for selected heavy metals due to their detrimental effects on living organisms related to the consumption of these vegetables.

MATERIALS AND METHODS

Description of the Study Area and Sampling Site

The study area, Bichi town is the headquarters of Bichi Local Government, Kano State in the Northern part of Nigeria. The town is situated in the northwestern part of the State. It is one of the oldest towns in Kano. Bichi town is blessed with basic infrastructures such as health facilities, educational institutions, electricity, potable water supply, recreational facilities, and good link roads between the town and its villages and other parts of the state. It is an area of Hausa-speaking people that lies approximately between longitude 8°5'E; and 8°25'E and latitude 12°13'N and 12°30'N of the equator. It shares boundaries to the North with Kunchi, to the South with Dawakin Tofa, Northwest with Tsanyawa, Southwest with Bagwai, and to the East with Makoda. Bichi local government has an area of 612 km² and a population of 277,099 as of the 2006 national census (Bernard and Ayeni 2012; Mahmoud *et al.*, 2023).

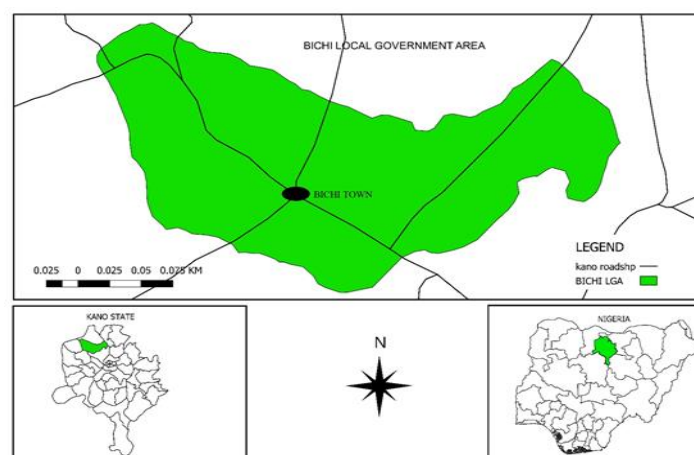


Fig 1: Map of Kano State, Nigeria showing Bichi Local Government Area.

Source: Modified From Kano State Administrative Map

Materials

Atomic Absorption Spectrophotometer (AAS) was used for this analysis. Certified Atomic Absorption Spectroscopic standard stock solutions (1000 mg/L) of Cd, Cu, Fe, Pb, and Zn were prepared using, Cadmium (II) chloride (CdCl₂), Copper (II) chloride dihydrate (CuCl₂.2H₂O), Iron (II) chloride hexahydrate (FeCl₂.6H₂O), Lead (II) chloride (PbCl₂), and Zinc chloride (ZnCl₂). Working standard solutions of 2, 4, 6, 8, and 10 mg/L were prepared by appropriate dilutions of the stock solution. Deionized water was used in the preparation of all the solutions. All the chemicals and reagents were of analytical grade and were purchased from Sigma Aldrich or Merck (Germany)

Sample collection

Samples of fresh vegetables were collected randomly (Three samples for each vegetable) to estimate the total heavy metal content (Cu, Fe, Cd, Pb, and Zn) in the 50 samples.

Sample Preparation and Treatment

About 200 g of each of the five edible portions of vegetable samples were used for analysis while damaged or rotten samples were removed. The samples were stored in polythene bags until analysis under refrigerated conditions (<10°C). The samples were thoroughly washed and then oven-dried at 105 °C for 48 h to determine the moisture content. Dried samples were powdered in a manual grinder and were used for heavy metal analysis.

Procedure for Ashing

Powdered samples (3 g each) with three replicates for each vegetable were accurately weighed and placed in a porcelain crucible and two drops of concentrated nitric acid (HNO₃) were added to the solid as an ashing aid. The dry ashing process was carried out in a muffle furnace by a stepwise increase in temperature up to 550°C and then left to ash at this temperature for 6 h. The ash was dissolved in 20 mL of 0.5 molar acids (HNO₃) and stirred very well. The ash suspension was filtered in a 100 mL plastic bottle with Whatman No. 1 filter paper and the volume was made up to the mark with more deionized water (Sadi *et al.*, 2021).

Statistical Analysis

In the analysis of the data, IBM SPSS Statistics Software Version 23 was used and the results were expressed as Mean ± Standard deviation (SD). Parametric tests of one-way analysis of variance (ANOVA), a confidence level of 95%, and a significance level of 0.01 were considered in comparing the average concentration of the metals in the vegetables.

Health risk assessment

The long-term effects of these heavy metals due to the consumption of vegetables were evaluated by calculating the Estimated Daily Intake of metals (EDI)

$$EDI = \frac{FIR \times CM}{BW} \dots \dots \dots (1)$$

(FAO, 2006; Zhang and Ma, 2016; Liang *et al* 2018; Islam *et al.*, 2018; Asrade and Ketema 2023).

The non-carcinogenic health risks parameters such as target Hazard Quotient (THQ), Total Target Hazard Quotient (TTHQ) and Hazard Index (HI) were calculated using equations 2, 3 and 4

$$THQ = \frac{EFr \times ED \times FIR \times CM}{RfD_o \times BW \times AT} \times 10^{-3} \dots \dots \dots (2)$$

$$TTHQ \text{ (individual vegetable)} = THQ_{\text{metal}(1)} + THQ_{\text{metal}(2)} + THQ_{\text{metal}(3)} + \dots + THQ_{\text{metal}(n)} \dots (3)$$

$$HI = TTHQ_{\text{vegetable}(1)} + TTHQ_{\text{vegetable}(2)} + TTHQ_{\text{vegetable}(3)} + \dots + TTHQ_{\text{vegetable}(n)} \dots \dots \dots (4)$$

(Chien *et al.*, 2002; Hu, *et al.*, 2017; Liao, *et al.*, 2016; USEPA, 2007; FAO/WHO, 2011) and the target carcinogenic risk (TCR) was calculated using equations 5 and 6

$$TR = \frac{EFr \times ED \times FIR \times CM \times SF}{BW \times AT} \times 10^{-3} \dots \dots \dots (5)$$

$$TCR = CR_{\text{vegetable}(1)} + CR_{\text{vegetable}(2)} + CR_{\text{vegetable}(3)} + \dots \dots \dots + CR_{\text{vegetable}(n)} \dots \dots \dots (6)$$

(FAO/WHO, 2011; USEPA, 2010; USEPA, 2015). Table1, showed the constant values involved in the health risk assessment of heavy metals in the vegetables.

Table 1: Description of Factors Involved in Health Risk Assessment in Vegetables.

Risk Exposure Factors	Symbols	Values	Units
Vegetable Ingestion Rate	FIR	0.17	Kg/person/day
The concentration of heavy metals	CM		mg/kg/fresh weight
Average body weight	BW	60	Kg for adult
Exposure frequency	EFr	365	Days/year
Exposure duration	ED	70	Years
Average time, carcinogens	AT	25, 550	Days
Oral Slope factor	SF		(mg/Kg/day) ⁻¹

(USEPA, 2010; USEPA, 2015)

AT = Average exposure time for non-carcinogenic effects (ED × 365 days/year); RfDo = Oral reference dose (mg/kg/day). The RfDos are 0.001, 0.04, 0.7, 0.3, and 0.0035 mg/kg/day for Cd, Cu, Fe, Zn, and Pb, respectively. To determine the appropriate THQ, it is assumed that all lead ions are inorganic. If the value of HI is less than the unity, the exposed population is unlikely to experience obvious adverse effects. If HI is greater than unity there is a potential health risk. The target carcinogenic risk (TCR) factor (lifetime cancer risk), Oral slope factor from the Integrated Risk Information System USEPA database was 8.5×10^{-3} (mg/kg/day) for Pb (Islam *et al.*, 2018; Asrade and Ketema 2023).

RESULTS AND DISCUSSION

All the results provided here are means of three replicates. The average values of concentrations (mg/kg) were shown in the Tables below;

Table 2: Percentage of Moisture in the Vegetable Samples

Samples	Weight of Fresh Sample (g)	Weight of Dried Sample(g)	Weight of Water (g)	Percentage of Moisture (%)
Carrot	200	17	183	91
Pepper	200	20	180	90
Cabbage	200	16	184	92
Onion	200	21	179	89
Tomato	200	11	189	95

Table 2 shows the percentage of moisture in different samples of vegetables in the range of 89.00 % to 95.00 %. The water content of the fresh samples was in the order Tomato >Cabbage>Carrot>Pepper>Onion. This shows that, in all the samples analyzed, the tomato has the highest amount of water (95.00%) while the onion has the least (89.00%).

Table 3: Mean Concentrations of Heavy Metals in the Samples

Vegetable	Scientific name	Mean Conc. (mg/kg)±SD				
		Cu	Fe	Cd	Pb	Zn
Carrot	<i>Daucus carota</i>	0.06±0.00	1.42±0.00	0.01±0.00	0.67±0.00	0.16±0.00
Pepper	<i>Capsicum</i>	0.05±0.00	1.40±0.00	0.01±0.00	3.44±0.00	0.17±0.00
Cabbage	<i>Brassica oleracea</i>	0.05±0.00	0.75±0.00	0.01±0.00	2.86±0.00	0.10±0.00
Onion	<i>Allium cepa</i>	0.04±0.00	0.63±0.00	0.01±0.00	2.78±0.00	0.06±0.00
Tomato	<i>Lycopersicon esculentum</i>	0.18±0.00	1.64±0.00	0.01±0.00	2.66±0.00	0.08±0.00
FAO/WHO		4.00	42.5	0.30	0.03	6.00

Table 3, shows the average concentration of heavy metals (Cu, Fe, Cd, Pb, and Zn) in the analyzed vegetable (carrot, pepper, cabbage, onion, and tomato) samples. Cu was detected in all of the selected vegetable samples in the range between 0.18 to 0.04 mg/kg. The lowest concentration was recorded in onion (0.04 mg/kg) and the highest was in tomato (0.18 mg/kg) but did not exceed the safe limit, 4.0 mg/kg, set by the FAO/WHO. Similar results were reported by Sadi *et al.*, (2021).

The concentration of Cu (mg/kg) in the vegetables was in the following order; tomatoes (0.18) > carrots (0.06) > pepper = cabbage (0.05) > onions (0.04) as presented in Table 3. Similar results were also reported by Sadi *et al.*, (2021).

The concentration of Fe in the analyzed vegetable samples was found between 1.64 to 0.63 mg/kg. Tomato has the highest amount of Fe (1.64 mg/kg) followed by carrot (1.42 mg/kg) then pepper (1.42 mg/kg), cabbage (0.75 mg/kg), and onion (0.63 mg/kg). This results in good agreement with the results reported by Sadi *et al.*, (2023).

The maximum allowable limit for Fe in vegetables set by FAO/WHO is 42.5 mg/kg shown in Table 3. Hence, the concentration of Fe in all the samples was found to be within the tolerable limit of 42.5 mg/kg (Sadi *et al.*, 2023).

Cd is a non-essential metal and the highest concentration of Cd was 0.01 mg/kg in all the vegetable samples as indicated in Table 3. Considering the food safety standards, Cd in vegetable species was lower than the recommended FAO/WHO permissible level of 0.30 mg/kg, indicating safety for human consumption.

The level of the Pb in the vegetable samples ranged between 0.67 to 3.44 mg/kg and the highest concentration of Pb was observed in pepper followed by cabbage and carrot has the least. This implies that the concentration of Pb in all the vegetable samples exceeded the safe limit of 0.03 mg/kg set by the FAO/WHO. Hence the products might be unsafe for human consumption. Similar results were reported by Sadi *et al.*, (2021); Sadi *et al.*, (2023); Asrade and Ketema (2023).

Zn was detected in all of the selected vegetable samples in the range between 0.06 to 0.17mg/kg. The lowest concentration value was recorded in onion (0.06 mg/kg) and the highest was in pepper (0.17 mg/kg) all are within the safe/ tolerable limit (6.0 mg/kg), set by FAO/WHO (Islam *et al.*, 2018; Sadi *et al.*, 2021). The concentration of Zn (mg/kg) in the vegetables was obtained in the following order; pepper > carrots > cabbage > tomato> onions as indicated in Table 3. Similar results were reported by Islam *et al.*, (2018). Zn is essential not only to humans, but also to food crops themselves. There are a numerous studies that confirms the positive correlation of Zn in plant tissues and Zn in surrounding habitat (Reboredo *et al.*, 2019). Zinc is also a key element in the growth and development of human. However, an excess of it will jeopardize human health, causing health risk to human being (Terrin *et al.*, 2015). Since there is no specialized Zn storage system in human body, daily intake of Zn is necessary to maintain a steady state (Rink and Gabriel 2000)

Human Health Risk Assessment

Table 4: Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI) and Target Cancer Risk (TCR) of heavy metals (for the adult population) from Consumption of Vegetables in Bichi town.

Parameters	Vegetables	Cu	Fe	Cd	Pb	Zn	Total
EDI (mg/kg body weight/day)	Carrot	1.70E-4	4.02E-3	2.83E-3	1.90E-3	4.53E-4	9.37E-3
	Pepper	1.42E-4	3.97E-3	2.83E-3	9.75E-3	4.82E-4	1.72E-2
	Cabbage	1.42E-4	2.13E-3	2.83E-3	8.10E-3	2.83E-5	1.32E-2
	Onion	1.13E-4	1.79E-3	2.83E-3	7.88E-3	1.70E-4	1.28E-2
	Tomato	5.10E-4	4.65E-3	2.83E-3	7.54E-3	2.27E-4	1.58E-2
EDI for all vegetables		1.08E-3	1.66E-2	1.42E-2	3.52E-2	1.36E-3	6.84E-2
MTDI		4.00E-2	7.00E-1	2.1E-02	2.1E-01		
THQ	Carrot	4.25E-6	5.75E-6	2.83E-6	5.42E-4	1.51E-6	9.37E-3
	Pepper	3.54E-6	5.67E-6	2.83E-6	2.79E-3	1.61E-6	1.72E-2
	Cabbage	3.54E-6	3.04E-6	2.83E-6	2.32E-3	9.44E-7	1.32E-2
	Onion	2.83E-6	2.55E-6	2.83E-6	2.25E-3	5.67E-7	1.28E-2
	Tomato	2.28E-5	6.64E-6	2.83E-6	2.15E-3	7.56E-7	1.58E-2
HI=∑TTHQ							6.83E-2
TR	Carrot				1.61E-8		1.61E-8
	Pepper				8.29E-8		8.29E-8
	Cabbage				6.89E-8		6.89E-8
	Onion				6.70E-8		6.70E-8
	Tomato				6.41E-8		6.41E-8
TCR							2.99E-7

MTDI = Maximum tolerable daily intake; EDI values for each heavy metal (mg/kg/body weight/day). (WHO 1985; ATSDR 2000)

Estimated Daily Intake of Heavy Metals (EDI)

The EDI values of heavy metals through the ingestion of different vegetables are listed in Table 4. The mean values of total EDI of individual heavy metals from the consumption of all analyzed vegetables were 1.08×10^{-3} , 1.66×10^{-2} , 1.42×10^{-2} , 3.52×10^{-2} , and 1.36×10^{-3} mg/kg body weight/day for Cu, Fe, Cd, Pb, and Zn respectively which were less than the maximum tolerable daily intake (MTDI) as shown in table 4. A similar result was reported by (Islam *et al.*, 2018).

Non-Carcinogenic Health Risk Assessment

The estimated target hazard quotient (THQ) for non-carcinogenic risk of heavy metals via five evaluated vegetable ingestion for adult inhabitants is presented in Table 4. The results showed that the THQ of all the metals in carrot, pepper, cabbage, onion, and tomato were 9.37×10^{-3} , 1.72×10^{-2} , 1.32×10^{-2} , 1.28×10^{-2} , and 1.58×10^{-2} respectively. The descending order of THQ for vegetable samples was in the order of pepper > tomato > cabbage > onion > carrot. However, the HI of all vegetables is 6.83×10^{-2} which was less than 1 ($1 < HI$) indicating that if individuals eat these types of vegetables in their diet, may result in non-carcinogenic health risks to consumers.

Carcinogenic health risk assessment

Target carcinogenic risks (TCRs) of Pb ranged from 8.29×10^{-8} in pepper to 1.61×10^{-8} in carrot (Table 4). However, the total value of TCRs was 2.99×10^{-7} for Pb which is less than the standard risk limit (10^{-6}). These results showed that Pb in vegetables does not have carcinogenic health risks to consumers (USEPA 2010). Therefore, based on the finding of this research, the potential health risk to humans due to Pb through the consumption of vegetables should be disregarded. This results were compared with literatures reported by Islam *et al.*, (2018) and Asrade and Ketema (2023) in Figure 2.

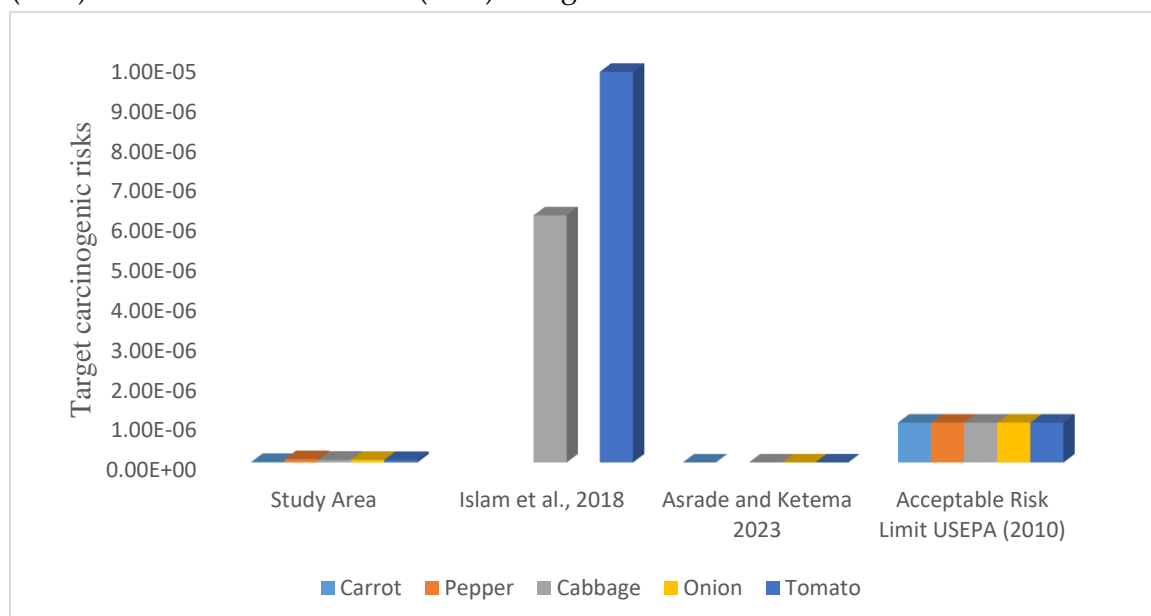


Figure 2: Target carcinogenic risks (TCRs) assessment via vegetable consumption for Pb to the population in the study area and literatures reported by Islam *et al.*, (2018) and Asrade and Ketema (2023).

In a study involving cabbage, onion and tomato samples, Asrade and Ketema (2023) reported the TCRs value of Pb in cabbage, onion and tomato samples were lower than the acceptable risk limit (10^{-6}), and concluded that consuming these vegetables in the area does not have potential cancer risk to the resident population. In a separate study, slam et al., (2018) found a significantly higher TCRs than the acceptable level of Pb in cabbage and tomato samples and concluded that Pb poses cancer risks in the study area.

CONCLUSION

This research has shown that the vegetables were contaminated by Pb due to their high concentration recorded in all the samples. The concentration was higher than the recommended values set by WHO/FAO. However, the concentration of all other heavy metals was found to be within the safety baseline levels/tolerable limits for human consumption. The THQ and HI showed that the consumption of vegetables may result in non-carcinogenic health risks to consumers. The results also showed that, despite the high concentration of Pb in the samples, the calculated parameters have clearly indicated that, there are no any carcinogenic health risks to consumers. This study suggests regular monitoring of the heavy metals present in vegetables, to prevent heavy metal toxicity that is associated with the consumption of these vegetables sold in Bichi Local Government Area, Kano State - Nigeria.

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