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Consumption of vegetables grown on wastewater irrigated farms along Gombe Road and Bayara and possible human health risk

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Abstract
Vegetables are an important part of all humans and animal diet due to its nutritional contents. Their contamination with heavy metals due to soil and sources of water for irrigation, especially during the dry season continue to poses a threat to their quality and safety to humans and animals health. This study therefore determined the possible health risk of consuming vegetables grown on wastewater irrigated farms along Gombe Road and Bayara using the Atomic Absorption Spectrophotometer. The range of concentration of Fe, Cu and Zn in the vegetables are below the WHO/FAO permissible limits while Cd (2.84 – 4.60mg/kg), Ni (0.71–1.32mg/kg) and Pb elow their reference oral doses. The non-carcinogenic risk (HI) values obtained for each Vegetables in the study sites were higher than 1 while carcinogenic risk (CR) assessments indices were greater than 1.0E-6. Both HI and CR results obtained for children were observed to be higher than those of the adults in most cases. It is therefore suggested that an in-depth toxicological effect analysis in the study farms be carried out, while the consumption of these vegetables from these farms be reduced to mitigate the adverse effects of these heavy.

Keywords: Wastewater, edible vegetables, metal intake, health risk

Introduction

Vegetables are edible stems, leaves, and roots of plants. Some of them are green and leafy-like in appearance. Vegetables constitute an essential portion of human diet consisting of proteins, vitamins, carbohydrates, minerals, other important nutrients and antioxidants that are scarce in supply (Rio *et al*. 2013; Shuaibu *et al*., 2013; Liu 2013) [14, 15]. Vegetables and food crops grown on contaminated soil absorb and accumulate high levels of toxic elements, which are transferred into their aerial parts, and this could cause serious health risks to consumers. The leafy vegetables are mostly consumed in many delicacies such as soups, stews and salads by locals within the study locations. Many of the crops irrigated with wastewater are vegetables. Vegetables are known to accumulate large metal load in their edible and non-edible parts (Shuaibu *et al*., 2013) [15] and this could lead to environmental pollution which threatens food safety and security. Adebayo *et al.* (2020) [1] studied health risks assessment of wastewater irrigated spinach in railway quarters, Bauchi State Nigeria. The results obtained from the study area revealed that the wastewater and spinach collected from the study area contained cadmium, chromium, manganese, nickel and lead in varying concentrations.

Food contamination by toxic metals has remained a challenge for consumers and producers alike. Heavy metals especially zinc, arsenic cadmium, chromium, mercury, and lead have no nutritional value and are considered as cumulative poisons, causing environmental/health hazards. They are therefore reported to be exceptionally toxic. These metals enter the body through ingestion of contaminated water or food crops grown on contaminated land. Unfortunately, the prolong consumption of food items like vegetables containing these metals can cause the modification and damage of vital organs of the body.

Two of the farms under study are situated along Gombe road, within Bauchi metropolis, an area highly developed in infrastructure and experience a lot of human activities whiles the other one within Bayara community. This community is considered as less developed compared to Bauchi metropolis. However, the community has been experiencing speedy development over the last few years, as commercial and industrial activities have continued to expand, leading to an increase in human activities. Due to rapid infrastructural development, the increase amount of wastewater and sewage released in these study areas, and the exposure of vegetables to high levels of air pollutants within these areas, it is expected that the vegetables cultivated within these locations might be contaminated from heavy metals. The objectives of the study therefore is to determine the non-carcinogenic and carcinogenic health risks involved in consuming vegetables harvested from three major commercial farms irrigated with wastewater along Dass Road and Bayara; and to ensure adequate stakeholder decisions on the safety of consuming vegetable sourced from wastewater irrigated farms.

Sampling sites

The three selected vegetable farmlands and irrigation sites are located in Bayara community, Federal Government Girls' College (Gombe R1) and Kofar Idi (Gombe R2). The farm lands were selected because they are among the major vegetable producers within Bauchi L.G.A. they ensure steady supply of vegetables to sellers from close-by markets during the dry seasons. The sources of irrigation water were selected from sewage water dams some kilometers from the study farmland.

Samples collection, preparation and treatment

Vegetable samples were collected from three selected irrigated vegetable farmlands with plastic ladle in polyethylene bags. These samples were labeled prior to analysis. They later washed with 20% (v/v) HNO_3 and then rinsed with distilled water (to remove air-borne pollutants), cut into small pieces with a stainless knife and air dried in the laboratory for 4 days before drying in the oven at 105^0C

for 24 hours. The dried sample were then crushed into powder in a mortar with a pestle and sieved through a 2mm nylon sieve to obtain a fine sample powder, which was transferred into polyethylene containers for analysis.

Sample digestion and analysis

1.5g of the sieved vegetable samples was weighed and transferred into a 100 cm^3 beaker. A mixture of 5.0 cm^3 HNO_3 and 2.0 cm^3 $HClO_4$ will be added to digest the sample. The mixture will then be heated at 110^0C on a hot plate for 1 hour until the content is reduced to 2.0 cm^3. The digest be be allowed to cool before filtering into a 50 cm^3 volumetric flask. The filtrate is then diluted with distilled water to the 50 cm^3 mark (Awofolu, 2005) [3]. The digested samples were analyzed for the heavy metals using the AA320N Atomic Absorption Spectrophotometer (AAS). All assays were done in triplicates.

Human health risk assessment

According to the Human Risk Assessment (HRA) model introduced by the USEPA, Human health risks could be carcinogenic and non-carcinogenic. Carcinogenic health risks (CR) deals the possibility that an individual will develop cancer as a result of his continual exposure to a particular pollutant(s),

$CR = \sum(DIM \times CSF)$

Where DIM = Daily intake of metal and CSF= Carcinogenic slope factor of HM.

$DIM = C_m \times C_f \times D_{food\ intake} / B_w$

C_m = mean concentration of heavy metal in vegetables (mg/kg), C_f = conversion factor for converting fresh to dry weight of the leafy vegetables (0.085), $D_{food\ intake}$ = Daily intake of vegetables (average consumption for adults and children are 0.301 and 0.232 kg/person/day, respectively), B_w = Average body weight (55.9 kg and 32,7kg for adults and children respectively)

Heavy metals	Reference dose (R_fD_i)	Carcinogenic slope factor (CSF kg/day/mg)$^{-1(a)}$
Cd	0.0010	6.1 E-03
Pb	0.0035	8.5 E-03
Ni	0.0200	8.4 E-04
Cu	0.0400	-
Zn	0.3000	-
Fe	0.0600	-

a = Mohammadi *et al*., 2019 [11]

Non-carcinogenic risk (NCR) expresses the toxic effect of individual chronic exposure to pollutants such as genetic and teratogenic (). NCR is assessed by determining the total hazard index (HI).

$HI = \sum(HQ)$

Where HQ is the hazard quotient for a particular pollutant

$HQ = DIM / R_fD_i$, where R_fD is the oral reference dose for individual metal ()

Results and discussion

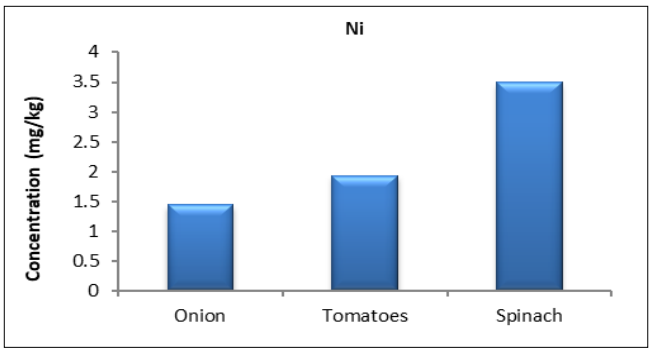
Heavy metal concentrations in the studied vegetables

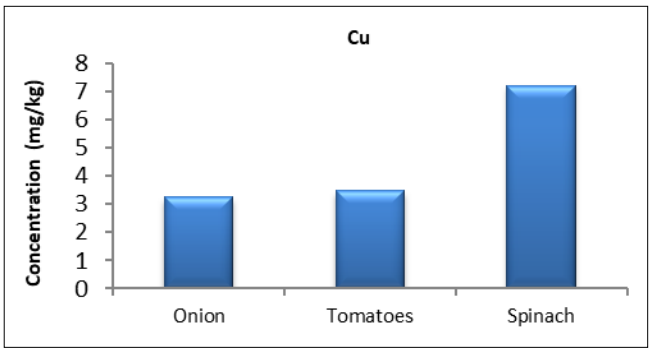
The ranges of concentration of heavy metals in the vegetables studied are shown in Tables 1. The accumulation of heavy metals in the studied edible vegetables parts occurred at different concentrations. The highest limits for Ni in onions (1.44mg/kg) and spinach (1.32mg/kg) were not significantly higher than the 1.50mg/kg set by the WHO/FAO.

Table 1: Range of Heavy metals concentration (mg/kg) in Edible vegetables grown in Bayara, Gombe R1 and Gombe R2 wastewater Irrigated farms

Metals (mg/kg)	Ni	Fe	Pb	Cu	Zn	Cd
Onion	0.27 – 1.44	1.00 – 2.25	0.61 – 1.96	2.14 – 3.25	1.65 – 3.96	1.99 – 6.51
Tomatoes	1.22 – 2.29	0.69 – 1.23	0.44 – 1.38	2.71 – 10.61	1.65 – 6.32	2.32 – 11.67
Spinach	0.71 – 1.32	1.07 – 2.01	1.00 – 1.56	1.34 – 7.22	0.90 – 5.79	2.84 – 4.60
WHO/FOA (2001)	1.50	-	0.30	9.4	73.3	0.21

With the exception of Cu and Zn, the levels of Pb and Cd exceeded the permissible limits of 0.30mg/kg and 0.21mg/kg respectively. The observed levels of metal above the safe limits in these samples indicate that these vegetables may be unsafe for human consumption. In Figure 1, the accumulation of Ni, Cu and Cd for the vegetables in Bayara are in the order: onion<tomatoes<spinach; for Fe and Zn, it is onion<spinach<tomatoes while Pb accumulated in the order: tomatoes<Onion<spinach.





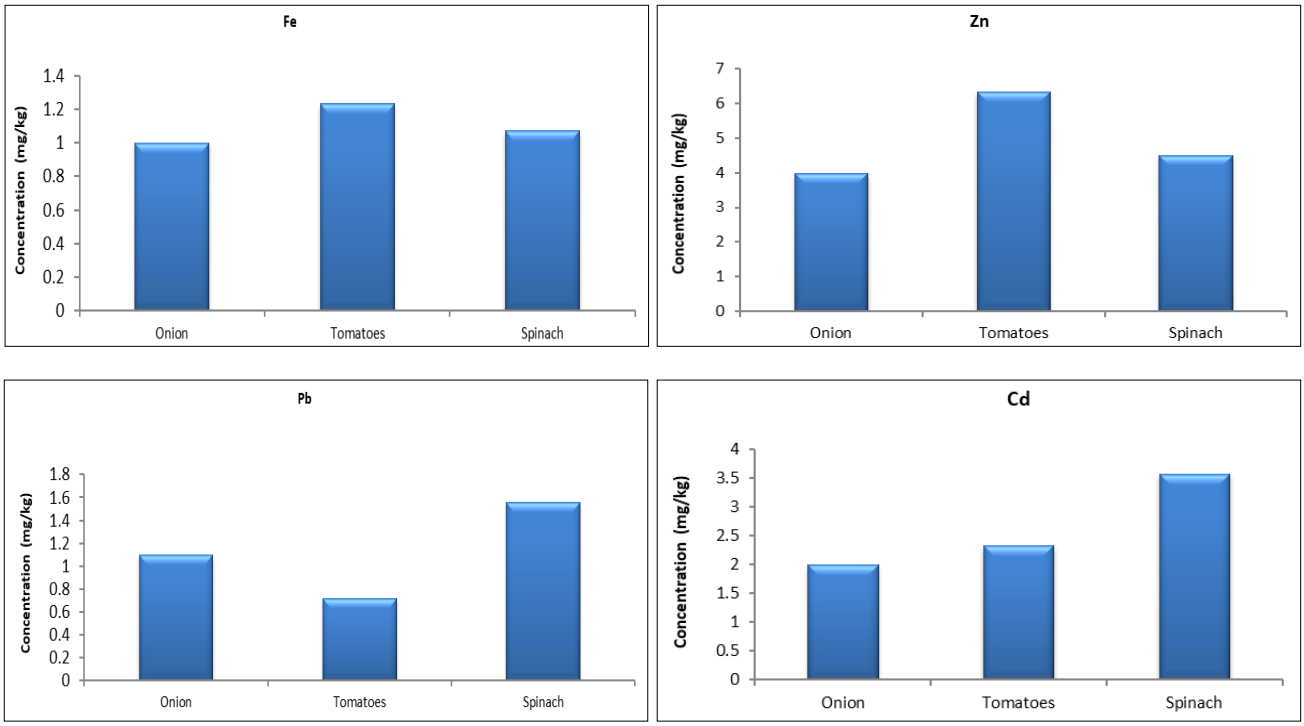


Fig 1: Comparison of heavy metal concentrations (mg/kg) in Edible vegetables grown in Bayara wastewater Irrigated farm

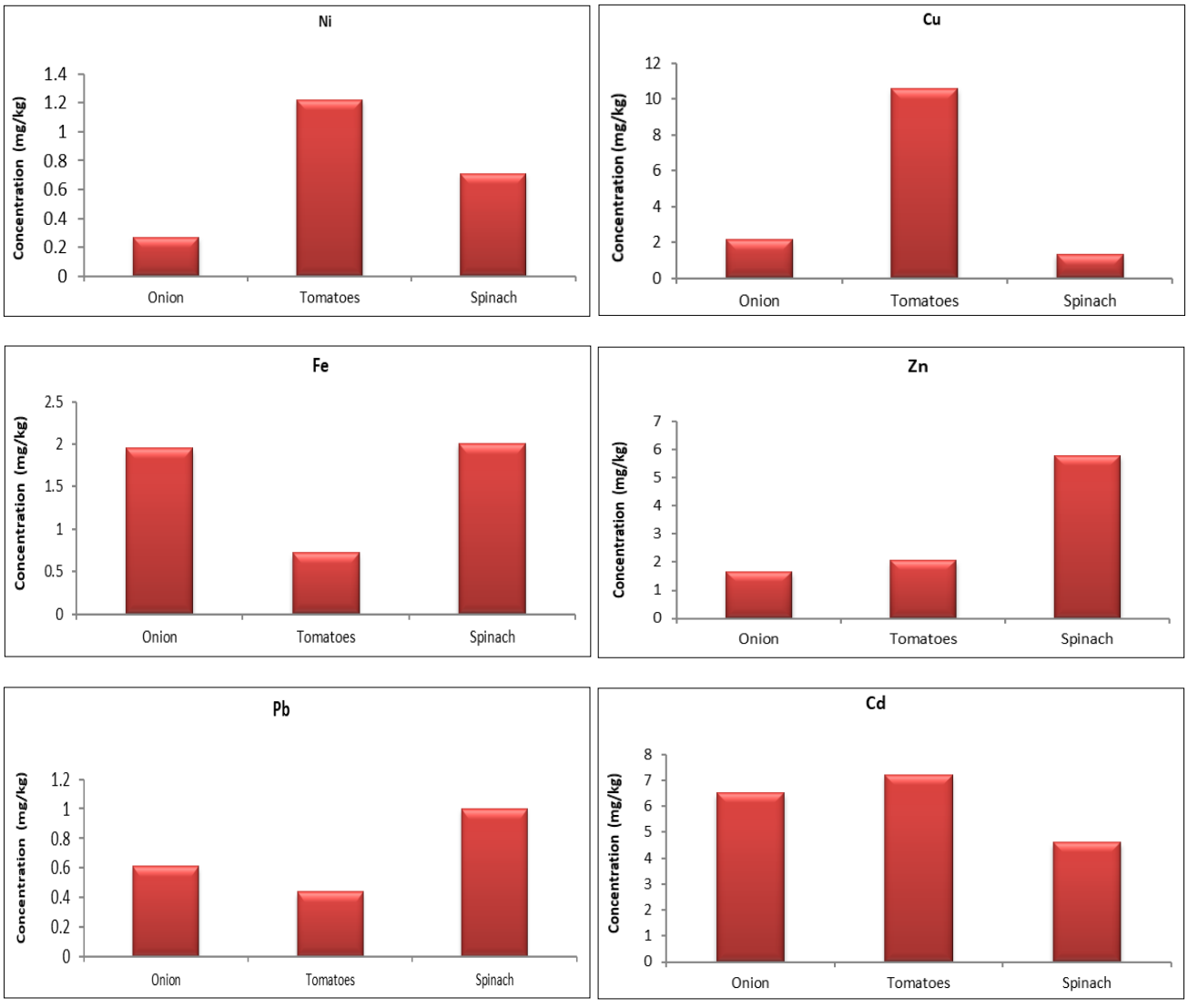


Fig 2: Comparison of heavy metal concentrations (mg/kg) in Edible vegetables grown in GRoad1 wastewater Irrigated farm

In GRoad1, Ni accumulated thus: onion<spinach<tomatoes, for Cu and Cd, it is spinach<onion<tomatoes, Fe and Pb: tomatoes <onion<spinach and Zn is onion< tomatoes< spinach (Figure 2). Alexander *et al*. (2006) [2] reported that Cd accumulated more in spinach compared to other vegetables.

Heavy metal accumulation in vegetables in GRoad2 is in the order: spinach<onion<tomatoes, for Ni and Cd; Pb and Zn: spinach<tomatoes<onion; Fe: tomatoes<Onion<spinach; Cu: tomatoes<Onion<spinach (Figure 3). Adebayo *et al.*, (2020.) [1] reported that the levels of lead in Spinach grown in wastewater irrigated farms in Railway quarters, Bauchi State Nigeria exceeded the permissible and safe limits.

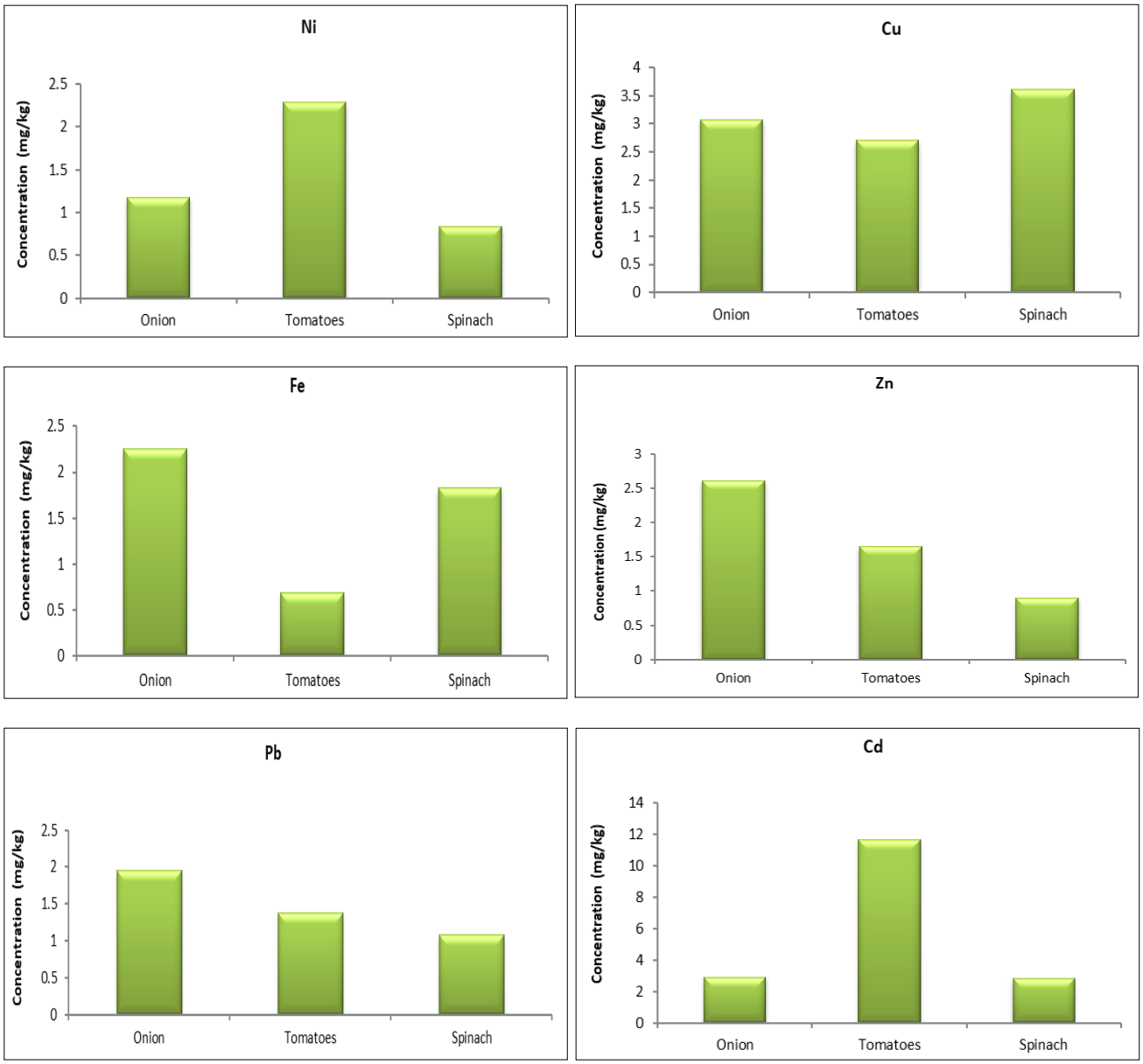


Fig 3: Comparison of heavy metal concentrations (mg/kg) in Edible vegetables grown in GRoad2 farm

Health risk assessment

The result of the daily intake of metal (DIMs) of studied metals via consumption of vegetable for adult and children and the carcinogenic risk (CRs) are summarized in Table 2. In Bayara and Kofar Idi, DMIs for Ni in children are higher in Onions and Spinach while in FGGC, DMIs for Ni in children were higher for all the vegetable samples. In Bayara and FGGC, Fe DMI through all vegetables was higher in children, while in Kofar Idi, it was only higher for onions in adults. With the exception of tomatoes in Kofar Idi, the DMIs for Pb, Cu and Zn for the vegetables in the study locations were also observed to be higher in Children.

DMI of the vegetables for Cd in the various locations was only observed to be higher in onions for adults in Bayara. However, the estimated DIMs for the heavy metals via the consumption of the vegetable in this study were below their reference oral doses (RfDs), except for Cd. The exposure to these heavy metals through vegetable consumption may not result in any deleterious effects on the consumers. Most of the DIMs for children compared to adults in this study were observed to be higher than those of adults and these results agreed with the values of CDIs reported in (Najmi *et al*., 2023) [12].

Table 1: Estimated daily intake of metal (DIM)

DIMs (mg/kg)						
Vegetables	**Ni**	**Fe**	**Pb**	**Cu**	**Zn**	**Cd**
BAYARA						
Onion Adult	6.137 E-4	4.692 E-4	4.692 E-4	1.386 E-3	1.632 E-3	8.483 E-3
Children	8.687 E-4	6.030 E-4	6.630 E-4	1.960 E-3	2.389 E-3	1.200 E-3
Tomatoes Adult	8.228 E-4	5.245 E-4	3.069 E-4	1.479 E-3	2.695 E-3	9.894 E-4
Children	1.164 E-4	7.400 E-4	4.340 E-4	2.099 E-3	3.811 E-3	1.400 E-3
Spinach Adult	5.627 E-4	4.565 E-4	3.995 E-5	3.079 E-3	1.914 E-3	1.518 E-3
Children	7.965 E-4	6.450 E-4	9.440 E-4	4.360 E-3	2.708 E-3	2.150 E-3
G ROAD 1						
Onion Adult	5.032 E-4	9.588 E-4	8.356 E-5	1.309 E-3	1.110 E-3	1.250 E-3
Children	7.115 E-4	1.357 E-4	1.182 E-3	1.851 E-3	1.574 E-3	1.767 E-3
Tomatoes Adult	9.767 E-4	2.941 E-4	5.882 E-5	1.156 E-3	7.038 E-4	4.977 E-3
Children	1.381 E-4	4.165 E-4	8.322 E-4	1.646 E-3	9.954 E-5	7.038 E-3
Spinach Adult	3.579 E-4	7.803 E-4	4.607 E-5	1.539 E-3	3.842 E-4	1.211 E-3
Children	5.066 E-4	1.103 E-3	6.511 E-4	2.177 E-3	7.565 E-4	1.750 E-3
G ROAD 2						
Onion Adult Children	1.156 E-4	8.313 E-4	2.601 E-5	9.129 E-4	7.038 E-4	2.776 E-3
	1.632 E-4	1.176 E-3	3.681 E-4	1.290 E-3	9.954 E-4	3.926 E-3
Tomatoes Adult	5.202 E-4	3.069 E-4	1.879 E-5	4.524 E-3	8.781 E-4	3.066 E-3
Children	7.276 E-4	4.344 E-4	2.652 E-4	6.399 E-3	1.243 E-3	4.336 E-3
Spinach Adult	3.026 E-4	8.568 E-4	4.267 E-5	5.712 E-4	2.469 E-3	1.962 E-3
Children	4.284 E-4	1.212 E-3	6.035 E-4	8.084 E-4	3.492 E-3	2.428 E-3

The results of the non-carcinogenic risk assessment (Hazard Quotient, HQ and Hazard Index, HI) in Fig 4-6 showed that all the HQs derived for Cd in all the vegetables were higher than the other heavy metals in the study locations. Cd and Pb were observed to be the major contributors to the HQ and HI values obtained in this study. Both metals were also reported in Zhou (2016) [17] to be the leading elements, contributing to the potential health risks faced by residents from the consumption of vegetables.

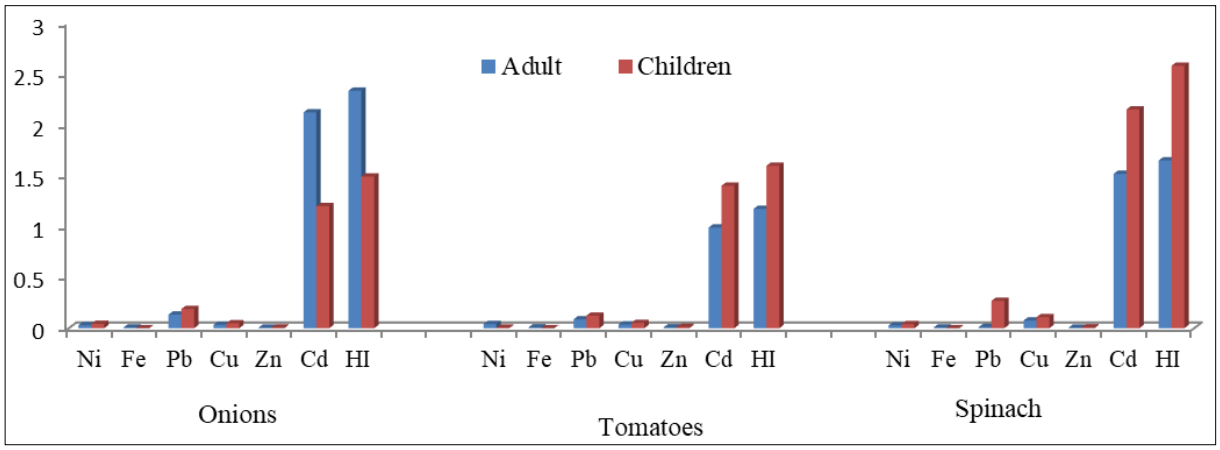


Fig 4: Heavy metal hazard quotient and hazard index (HI) of vegetables in Bayara Irrigated farm

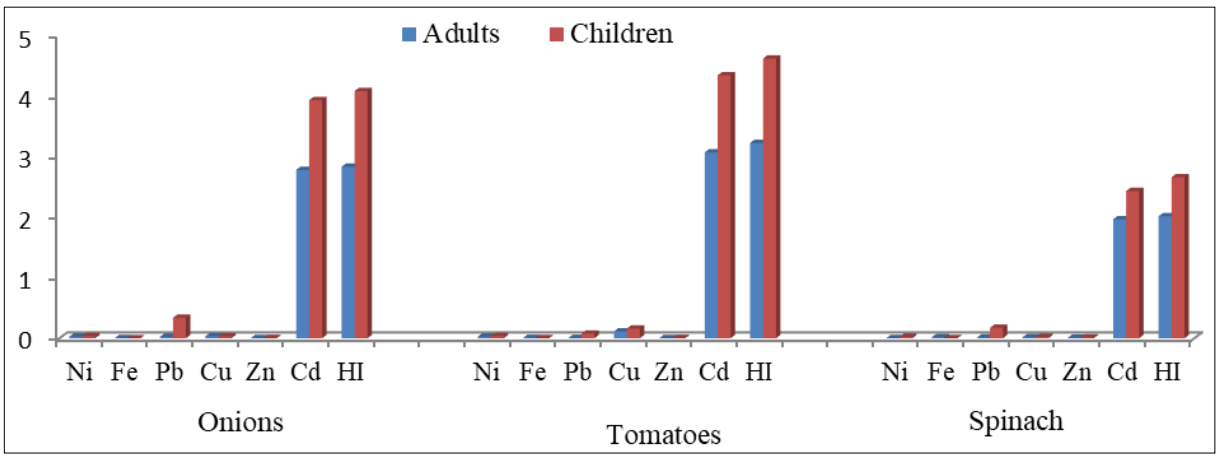


Fig 5: Heavy metal hazard quotient and hazard index (HI) of vegetables in GRoad1 Irrigated farm

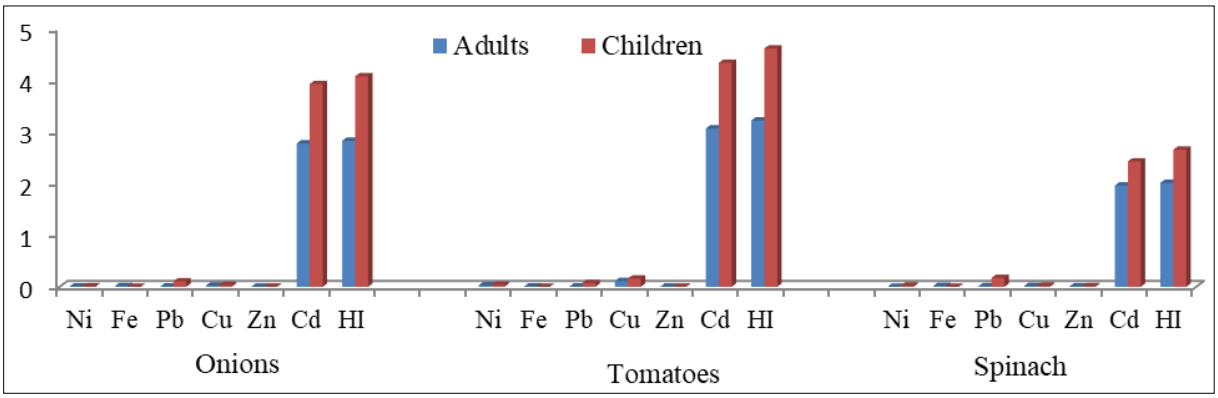


Fig 6: Heavy metal hazard quotient and hazard index (HI) of vegetables in GRoad2 Irrigated farm

With the exception of onions in Bayara, the HQ and HI values obtained for children were observed to be higher than those of the adults in most cases. Mawari *et al*., (2022) [9] observed higher HQ values for Cd in vegetables compared to the other metals in their study and reported lower HI values for onions (0.1196667) and tomatoes (0.1359167) compared to the values in this study. The HI values obtained for the vegetables in this study are greater than 1 (HI >1), indicating that the vegetables grown in these farms are unsafe for consumption. The potential health risks of accumulating these heavy through vegetable consumption in this study are very high.

The estimated CRs from the intake of the studied vegetables in all the sites exceeded 1.0E-06 set by the Agency for Toxic Substances and Disease Registry (ATSDR). This is an indication that there is a need for an in-depth toxicological effect analysis in these study areas. CRs values calculated for the vegetables in children in the study sites are all higher than those of adults. The ASTDR noted that children are more susceptible to develop cancer and tumor, when exposed to carcinogens.

Table 2: Carcinogenic Risk (CR) for Adults and Children

Adult				Children		
Vegetables	**Bayara**	**G Road1**	**G Road2**	**Bayara**	**G Road1**	**G Road2**
Onion	9.678E-6	1.515E-5	1.924E-5	1.366E-5	2.143E-1	2.722E-5
Tomatoes	9.335E-6	3.618E-5	2.092E-5	1.321E-4	1.901E-4	2.932E-5
Spinach	1.333E-5	3.570E-4	1.585E-5	2.181E-5	1.6640E-5	6.647E-5

The CR values calculated for the vegetables in Bayara for adults increased in the order: tomatoes<onions<spinach, while for children: onions<spinach<tomatoes. In G Road1, CRs for adult were observed in the order: spinach>tomatoes>onions, while it was onions>spinach>tomatoes in children. In G Road2, it increased thus: tomatoes>onions>spinach for adults and spinach > tomatoes > onions for children. The high CRs values reported in this study is an indication that individuals within the study locations may likely develop cancer as a result of the continual exposure to these heavy metals via the consumption of these vegetables. Studies have shown that increased intake of non-essential metals like Cd and Pb can damage the skeleton and bones, vital organs like the kidney, liver and lung; and affect the immune system. They can also impact the ability of children to develop intellectually (Huang *et al*., 2014; Mawari, *et al*., 2023) [6].

Conclusions

The levels heavy metals detected in the vegetables varied greatly according to their locations. The ranges in the concentrations of Ni, Cd and Pb in vegetables were observed to be above the permissible limits set by the WHO/FAO. The vegetables in the various locations in this study have high hazard quotients and carcinogenic risks, which were majorly contributed by Pb and Cd. Residents, particularly children within these study area or customers who patronize these farms may face serious health risks due to the regular consumption of these vegetables from these wastewater irrigated farms. Concerned bodies should therefore ensure regular monitoring of irrigation farms and their sources of irrigation water within Bauchi in order to enforce standards. This will limit the exposure of consumers to toxic metals and their consequent health risks.

Acknowledgments

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