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Human Health Assessment of Heavy Metals through Consumption of Vegetables from Some Agricultural Locations in Borno State, North East Nigeria

Joseph C. Akan, Zakari Mohammed, Ayuba M. Jatau and Fanna I. Abdulrahman

Department of Pure and Applied Chemistry, University of Maiduguri, P.M.B 1069, Maiduguri, Borno State, Nigeria

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ABSTRACT

The aim of this study was to determine the concentration and conduct risk assessment of heavy metals in some selected vegetables (tomatoes (*Solanum lycopersicum*), spinach (*Spinacia oleracea* onion (*Allium cepa*), cabbage (*Brassica oleracea*) and lettuce (*Lactuca sativa*) from Gongolong and Alau Dam agricultural locations. The vegetable samples were digested and analyst using Perkin-Elmer A-Analyst 300 Atomic Absorption Spectroscopy (AAS). The concentration of the studied heavy metals in the vegetables exceeded the maximum permissible limits as specify by Food and Agriculture Organization/World Health Organization (FAO/WHO). Results from average daily intake (ADI) were below the provisional tolerance daily intake and are safe for human consumption. Hazard quotient (HQ) values for all the metals were less than the USEPA permissible limit of 1, and does not pose any serious health risk, except Cd and As from Gongolung agricultural location which indicate potential non-cancer health risk. HI values for Cd and As from Gongolong location and Cu, Ni, Cd, As and Pb were greater than the USEPA threshold limit of 1, indicating server non-cancer health risk. The research therefore recommends regular check of heavy metals in vegetables be conducted so as to protect human health and the environment.

1. Introduction

Heavy metals can enter human body through inhalation, ingestion and dermal contact absorption [1, 2]. They also accumulate in soil, plants and in aquatic biota [3,4]. Heavy metals can persist for a long time within different organic and inorganic colloids before becoming available to living organisms [1, 5]. They are non-degradable and therefore do not decay with time. The have been growing concerned over the levels of heavy metals in vegetables as a results of irrigation using polluted water [6]. Heavy metals can pose health risk in animal and humans, and high levels of heavy metals in vegetables and other foods can cause bone marrow, renal, cardiovascular, psychosocial dysfunctions, gastrointestinal cancer, kidney and nervours system [7,8]. The sources of heavy metals in plants includes contaminated water, fertilizer application, industrial waste, sewage disposal and pesticides application, also the contaminated vegetables consume by man and other animals may cause several physiological problems [6,7]. Repot by [9,10] shows that vegetables contained some constituent such as protein, fibre, nutritional values, antioxidants, carbohydrate, vitamin and minerals, and are important diet to human and animals. During digestion, vegetables in their forms act as neutralizing agent for acidic substances, and also have a firmness texture which are made of pectin substances and cellulose [9]. The occurrence and presence of heavy metals have been reported in various cities of the world in vegetables [8, 9, 11, 12,13, 14], rice [15], cereals [16]. Several methods have been used for determination of heavy metals as highlighted my [17, 18, 19] and food analysis [20, 21, 22, 23, 24]. Alau Dam and Gongulong agricultural areas have a long history of large scale production of vegetables for human consumption, as well as use of agrochemicals. Irrigation of vegetables is a common practice in Alau Dam and Gongulong agriculture areas. Various types of waste containing hazard chemicals and toxic metals within the Maiduguri Metropolis are discharged directly into River Ngada. Vegetable farmers within the drainage line of river Ngada used the contaminated water for irrigation. Larger quantity of vegetables are harvested and sold in the markets within the city of Maiduguri, also report from different study have shown serious health problem arise from the accumulation of heavy metals

∗ Corresponding author. joechemakan@yahoo.com Tel: +2348036000506

from vegetables irrigated by wastewater [25]. Several study have reported the levels of heavy metals and risk assessment on the consumption of vegetables in Nigeria [26, 27, 28, 29, 30]. Study involving risk assessment on the consumption of vegetables has not been carried out in the study area. Hence, this study is aim to determine the concentrations of heavy metals in vegetable samples and to conduct risk assessment by evaluating human health risk course by heavy metals and to establish recommendations on the safety vegetables.

2.MATERIAL AND METHODS

2.1 Collection of Vegetable Samples

The method used by [27] was adopted for this study. Vegetables samples were collected from Alau Dam and Gongolong agricultural location. At each sampling locations, twenty gram (20g) each of the five vegetables sample namely, spinach, lettuce, tomato, cabbage and onion were collected from three different points to provide replicate samples of each crop. The samples were collected in clean polyethylene bag, labeled and transported to the Department of Chemistry Laboratory, University of Maiduguri and preserved in a refrigerator at 4 ^{O}C until analysis.

2.2 Digestion of Vegetable Samples

Accurately 2g of each of the vegetable samples were weighed into 250cm^3 conical flasks, 10ml of mixture of nitric acid and hydrochloric acid in a ratio of 1:3 was added to each samples. The solution were then heated on hot plate inside fume cupboard until white dense fume was observed. The solutions were then removed and allowed to cool to avoid over flow before 3cm^3 of 30% H_2O_2 was then added. The solutions were then heated again until the volume reduced to 2ml. Then the digests were allowed to cool, and then filtered into 100ml volumetric flask. The content was diluted to 100ml mark with distilled water.

$$ADI = \frac{C \times IR \times ED \times EF}{BW \times AT}$$

2.3 Determination of Heavy Metals

Determination of Cr, Mn, Fe, Cu, Ni, Hg, Cd, As and Pb were made directly on each final solution using Perkin-Elmer Analyst 300 Atomic Absorption Spectroscopy (AAS).

2.4 Calibration of Solutions

Standard solution of each sample Cr, Mn, Fe, Cu, Ni, Hg, Cd, As and Pb were prepared according to Sc 2000 manufacturer procedure for Atomic absorption spectroscopy to be used. A known 1000 mg/l concentration of the metal solutions was prepared from their salts.

2.5 Quality Control and Quality Assurance

The quality assurance and quality control were performed to confirm the accuracy of the methods used for analysis using spike recovery method. The spike recovery was done by adding a known amount of analyte concentration and analyzing it again [31].

Recovery were ranged between 90.91% to 96.87%. Black was analyzed after the analysis of 7 samples of the rice is digested. The LOD in mg/kg for Cr, Mn, Fe, Cu, Ni, Hg, Cd, As and Pb were 0.002, 0.001, 0.001, 0.001, 0.004, 0.0003, 0.0003, 0.001 and 0.004 respectively, while LOQ in mg/kg for Cr, Mn, Fe, Cu, Ni, Hg, Cd, As and Pb were 0.01, 0.004, 0.004, 0.004, 0.01, 0.001, 0.001, 0.004 and 0.01.

2.6 Human Health Risk Assessment of Heavy Metals in Rice

The hazard quotient (HQ) and hazard index (HI) of heavy metals were used to estimate the non-carcinogenic risk of consumption of rice by the population [32].

Table 1. Parameters Values for Human Health Risk Assessment of Heavy Metals in Soil Samples [32]

Parameters	Highlight of Parameters	Values
ADI	Estimated daily intake	To be calculated
C	Concentration	Present study
IR	Ingestion rate	0.063
ED	Exposure duration	70 years
EF	Exposure frequency	365 days/year
BW	Average body weight	70kg
AT	Average time	365 day/year x ED

According to [32], hazard quotients represent a ratio of the exposure dose for each heavy metal divided by an oral chronic reference dose (RfD). If HQ < 1, no adverse effects occur; HQ > 1, signifies adverse effects [33].

$$HQ = \frac{ADI}{RfD}$$

The oral reference doses (RfD) used for each of the metals in mg/kg/day are Hg = 1.0 x 10-4, As = 3.0 x 10-4, Pb = 4.0 x 10-3, Cd = 1.0 x 10-3, Ni = 2.0 x 10-2 and Cr = 1.5 [32]. In order to evaluate the overall adverse effects of non-carcinogenic risk, hazard index approach was used [34]. The HI is the sum of HQ through the three exposure pathways for heavy metals. If HI < 1 non-carcinogenic effects is unlikely to occur, whereas if HI > 1 it signifies adverse non-carcinogenic effects are likely to occur [32].

$$HI = HQ_1 + HQ_2 + HQ_3 + \ldots\ldots\ldots\ HQ_n$$

2.7 Statistical Analysis

Data collected were subjected to one-way analysis of variance (ANOVA). All statistical calculations were performed with SPSS for windows.

3. Results and Discussion

The mean concentrations and standard deviation of some heavy metals (Cr, Mn, Fe, Cu, Ni, Cd, Hg, As and Pb) in vegetable samples (spinach, lettuce, tomato, cabbage and onion) from Alau Dam and Gongulon Agricultural location are presented in Table 2 and 3.

The highest levels of Cr was detected in spinach obtained from Alau Dam agricultural location, with a value of 8.03±0.98 mg/kg, while the lowest value of 1.92±0.02 mg/kg was detected in onion samples from Gongolong agricultural location. Cr concentration from the two agricultural locations were higher than the values of 0.33±0.049 – 0.02±0.004mg/kg reported by [26]; but were lower than values of 37.33 to 111.95 mg/kg reported in vegetables by [8]. The Cr levels obtained from the present study were higher than the permissible limits of 0.1-0.2 mg/kg [35].

The highest concentration of Mn 18.92±1.92 mg/kg was recorded in onion from Alau Dam agricultural location, while cucumber recorded a lowest value of 4.89±0.03 mg/kg from Gongolong agriculture location. [38] in a similar study carried out from North Central, Nigeria reported a higher concentration range between 220.65±33.24 and 29.85±8.35mg/kg when compared to the present study. The level of Mn in all the vegetable samples were higher than the maximum permissible limit of 0.3mg/kg as prescribed by [35].

The highest Fe concentration of 63.29±6.03 mg/kg was detected in cucumber samples from Alau Dam location, while tomatoes from Gongolong location recorded the lowest concentration values. [37] in a similar study carried out on vegetables grown along river Yedzaram in Uba area, Adamawa State reported a lower concentration range of 48.67±0.1 to 31.72±0.71mg/kg. Results from the present study were lower than those reported by [7, 8]. The concentration of Fe in the vegetable samples were higher than the maximum limit of 0.3 mg/kg as described by [35].

The highest concentration of 5.95±0.24 mg/kg Cu was detected in cabbage sample, while Onion recorded the lowest value of 0.87±0.01 mg/kg. [38] reported a concentration of Cu in vegetable ranging from 9.8±1.7 to 2.7±0.5mg/kg; 0.46 to 6.67 mg/kg by [8,] and 21.09 to 23. 53 mg/kg by [14].

Table 2. Mean Concentrations of Some Heavy Metals in Vegetable Samples from Alau Dam Agricultural Location

	Concentrations (mg/kg)								
Samples	**Cr**	**Mn**	**Fe**	**Cu**	**Ni**	**Cd**	**Hg**	**As**	**Pb**
Tomatoes	$6.09^{a}\pm0.33$	$11.19^{a}\pm1.23$	$56.99^{a}\pm8.02$	$7.94^{a}\pm0.11$	$3.29^{a}\pm0.02$	$6.93^{a}\pm0.23$	$1.29^{a}\pm0.01$	$1.09^{a}\pm0.01$	$2.20^{a}\pm0.04$
Spinach	$8.03^{b}\pm0.98$	$16.26^{b}\pm2.29$	$48.32^{b}\pm7.92$	$4.93^{b}\pm0.83$	$1.94^{b}\pm0.05$	$5.00^{b}\pm0.33$	$2.18^{a}\pm0.09$	$1.19^{b}\pm0.01$	$2.06^{b}\pm0.01$
Cabbage	$4.82^{c}\pm0.42$	$15.92^{c}\pm3.39$	$58.92^{c}\pm9.38$	$5.95^{c}\pm0.24$	$3.93^{c}\pm0.08$	$2.29^{c}\pm0.01$	$1.98^{c}\pm0.02$	$1.23^{c}\pm0.02$	$1.59^{c}\pm0.03$
Onion	$3.12^{d}\pm0.18$	$18.92^{d}\pm1.92$	$41.23^{d}\pm5.93$	$1.92^{d}\pm0.13$	$5.49^{d}\pm0.22$	$3.39^{d}\pm0.22$	$2.73^{d}\pm0.04$	$1.74^{d}\pm0.02$	$2.99^{d}\pm0.05$
Lettuce	$7.01^{e}\pm0.11$	$14.92^{e}\pm2.29$	$63.29^{e}\pm6.03$	$3.39^{e}\pm0.03$	$4.39^{e}\pm0.18$	$2.22^{c}\pm0.18$	$1.44^{e}\pm0.02$	$1.35^{e}\pm0.01$	$1.84^{e}\pm0.01$

Within Columns Mean with different letters are statistically different, P< 0.05

and were all higher than results of the present study. The concentrations of Cu in all the vegetables were higher than the maximum limit of 0.1mg/kg as described by [35]. The concentration of Ni in the vegetable sample with a value of 5.49±0.22 mg/kg was observed to be the highest in onion, while spinach with a value of 0.76±0.01 mg/kg shows the lowest concentration. [39]

in a similar studied reported a higher concentration range of 35.00±17.00 to 9.00±3.00 mg/kg. The concentration of Ni in the vegetable samples

studied exceeded the maximum standard limit of 0.1 mg/kg as describe by [35]. The concentration of Cd (6.93±0.23 mg/kg) was significantly higher in tomatoes from Alau Dam location, while the lowest concentration was recorded in lettuce from Gongolong location with a value of 1.07±0.03 mg/kg. This concentration was higher than those reported by [8] (0.00 to 0.94 mg/kg). However, the concentrations of

Within Columns Mean with different letters are statistically different, $P< 0.05$

Cd in the vegetable samples was significantly higher than the standard permissible limit of 0.02mg/kg reported by [35]. For Hg concentration, lettuce from Alau Dam location recorded the highest (2.73±0.04 mg/kg), while same lettuce from Gongolong recorded the lowest concentration of 0.32±0.01 mg/kg. The concentration of Cd in the study samples agreed with that of [40]. The concentrations of Hg in all the vegetables were higher than the maximum limit of 0.05mg/kg as reported by [41].

As concentration in the vegetable samples revealed that onion obtained from Alau Dam recorded the highest concentration with a value of 1.74±0.02 mg/kg, while lettuce collected from Gongolong location recorded the lowest value of 0.21±0.01mg/kg. [42] reported a similar ranged of concentration of (1.73±0.20 to 0.15±0.10mg/kg), also [43] in a similar study carried out in Kano and Adamawa, Nigeria, also reported a concentration of As in vegetable samples ranging from 0.01 to 2.00 µg/g.

The concentrations of As in all the vegetable samples were compared with standard permissible limits, and exceeded the [41] permissible limit of 0.01 mg/kg. The concentration of Pb was significantly higher in onion sample from Alau Dam location with value of 2.99±0.05mg/kg and the lowest concentration was recorded in spinach from Gongolong with a value of 0.56±0.01mg/kg. However, Pb results obtained from the present study were lower than values reported by [7,39] with values ranging from 0.12 to 1.60 mg/kg; [8] (0.00 to 1.47 mg/kg); 16.57 to 24.07 mg/kg by [26].

The concentration of Pb in the vegetable samples were higher than the permissible limit 0.1mg/kg as specify by [27].

3.1 Risk Assessment of Heavy Metals in Vegetables

The average daily dose of some heavy metals (Cr; Fe; Cu; Ni; Cd; As and Pb) in vegetable samples (spinach, lettuce, tomato, cabbage and onion) from Gongulon and Alau Dam Agricultural location are presented in Table 4 and 5, and Hazard quotient (HQ) and hazard index (HI) of heavy metals are presented in Table 6 and 7, while carcinogenic risk (CR) assessment of heavy are presented in Table 8 and 9.

Results from average daily intake (ADI) values from the study vegetables were lower than the recommended standard values of Cr 0.05-0.2, Mn 20mg, Fe 0.048mg, Cu 3mg, Ni 1.4mg, Hg 0.0003mg, Cd 0.06mg, As 0.13mg, Pb 0.214mg respectively by [27], this shows that the vegetable samples from the study locations are free of risks.

The present results is in agreement with EDI study carried out in Bangladesh [44]; Dar Salaam, Tanzania by [45]; Lagos Nigeria by [28,29], The health risks from consumption of contaminated vegetables by adult population were assessed based on Hazard Quotient (HQ) which is the ratio of determined dose level. If HQ>1, the exposed population will have detrimental health effect [46].

HQ values for all the heavy metals studied were below the threshold value of 1, except Cd and As which were higher than the accepted HQ value of 1. Higher HQ values of Cd, Cr, As, and Pb was also reported by [45,47] for Pb. However, higher HQ value of Cd and As is an indication of potential health risk of the metal through consumptions of vegetable.

The hazard index (HI) value expresses the combined non-carcinogenic effects of multiple elements for consumption of selected vegetable, the value of HI in this study shows that Cu, Ni, Cd, As and Pb were higher than the acceptable value of 1, indicating a non-carcinogenic potential health risk through consumption of vegetables. Higher HI values in vegetables were also reported by [9,45].

Results of the present study were lower than values reported by [6,8,28]

Cancer risk (CRs) derived from the intake of (Cd, As, Pb, Ni, Cr) were calculated on how metals may promote carcinogenic effects depending on the exposure dose. The total CRs above this ranged of $1.0 \times 10^{-6.}$ to 1.0×10^{-4} is unacceptable [48]. The ILECR values of the study metals were observed

Table 3. Mean Concentrations of Some Heavy Metals in Vegetable Samples from Gongolong Agricultural Location

	Concentrations (mg/kg)								
Samples	**Cr**	**Mn**	**Fe**	**Cu**	**Ni**	**Cd**	**Hg**	**As**	**Pb**
Tomatoes	3.92[a]±0.01	9.03[a]±0.16	26.39[a]±3.22	2.92[a]±0.03	2.21[a]±0.03	4.77[a]±0.14	0.88[a]±0.01	0.88[a]±0.01	1.34[a]±0.01
Spinach	5.82[b]±0.22	11.92[b]±1.09	34.39[b]±2.29	3.22[b]±0.13	0.76[b]±0.01	2.98[b]±0.06	1.07[a]±0.02	0.27[b]±0.01	0.56[b]±0.01
Cabbage	3.11[c]±0.04	8.29[c]±0.83	42.29[c]±1.97	2.98[c]±0.11	1.66[c]±0.02	1.54[c]±0.02	0.55[c]±0.01	0.77[c]±0.01	0.66[c]±0.01
Onion	1.92[d]±0.02	14.92[d]±2.11	35.09[d]±2.98	0.87[d]±0.01	3.44[d]±0.16	2.43[d]±0.01	1.02[d]±0.01	0.54[d]±0.01	1.43[d]±0.02
Lettuce	4.89[e]±0.03	6.92[e]±0.23	41.76[e]±4.11	1.98[e]±0.01	2.18[e]±0.07	1.07[c]±0.03	0.32[e]±0.01	0.21[e]±0.02	0.83[e]±0.01

Table 4. Average Daily Dose of Some Heavy Metals in Vegetable Samples from Gongolong Agricultural Location

	Daily Dose (mg/kg day-1)						
Samples	**Cr**	**Fe**	**Cu**	**Ni**	**Cd**	**As**	**Pb**
Tomatoes	3.53E-03	2.38E-02	2.63E-03	1.99E-03	4.29E-03	7.92E-04	1.21E-03
Spinach	5.23E-03	3.10E-02	2.90E-03	6.84E-04	2.68E-03	2.43E-04	5.04E-04
Cabbage	2.80E-03	3.81E-02	2.68E-03	1.49E-03	1.39E-03	6.93E-04	5.94E-04
Onion	1.73E-03	3.16E-02	7.83E-04	3.10E-03	2.19E-03	4.86E-04	1.29E-03
Lettuce	4.40E-03	3.76E-02	1.78E-03	1.96E-03	9.63E-04	1.89E-04	7.47E-04
TDD	**1.77E-02**	**1.62E-01**	**1.08E-02**	**9.23E-03**	**1.15E-02**	**2.40E-03**	**4.34E-03**

Table 5. Average Daily Dose of Some Heavy Metals in Vegetable Samples from Alau Dam Agricultural Location

	Daily Dose (mg/kg day-1)						
Samples	**Cr**	**Fe**	**Cu**	**Ni**	**Cd**	**As**	**Pb**
Tomatoes	5.48E-03	5.13E-02	7.15E-03	2.96E-03	6.24E-03	9.81E-04	1.98E-03
Spinach	7.23E-03	4.35E-02	4.44E-03	1.75E-03	4.50E-03	1.07E-03	1.85E-03
Cabbage	4.34E-03	5.30E-02	5.36E-03	3.54E-03	2.06E-03	1.11E-03	1.43E-03
Onion	2.81E-03	3.71E-02	1.73E-03	4.94E-03	3.05E-03	1.57E-03	2.69E-03
Lettuce	6.31E-03	5.70E-02	3.05E-03	3.95E-03	2.00E-03	1.22E-03	1.66E-03
TDD	**2.62E-02**	**2.42E-01**	**2.17E-02**	**1.71E-02**	**1.78E-02**	**5.94E-03**	**9.61E-03**

Table 6. Hazard Quotient and Hazard Index of Some Heavy Metals in Vegetable Samples from Gongolong Agricultural Location

	(mg/kg day-1)						
Samples	**Cr**	**Fe**	**Cu**	**Ni**	**Cd**	**As**	**Pb**
Tomatoes	3.65E-03	7.33E-02	1.79E-01	1.48E-01	6.24E+00	3.27E+00	4.95E-01
Spinach	4.82E-03	6.21E-02	1.11E-01	8.73E-02	4.50E+00	3.57E+00	4.64E-01
Cabbage	2.89E-03	7.58E-02	1.34E-01	1.77E-01	2.06E+00	3.69E+00	3.58E-01
Onion	1.87E-03	5.30E-02	4.32E-02	2.47E-01	3.05E+00	5.22E+00	6.73E-01
Lettuce	4.21E-03	8.14E-02	7.63E-02	1.98E-01	2.00E+00	4.05E+00	4.14E-01
HI	**1.74E-02**	**3.46E-01**	**5.43E-01**	**8.57E-01**	**1.78E+01**	**1.98E+01**	**2.40E+00**

Table 7. Hazard Quotient and Hazard Index of Some Heavy Metals in Vegetable Samples from Alau Dam Agricultural Location

(mg/kg day-1)							
Samples	**Cr**	**Fe**	**Cu**	**Ni**	**Cd**	**As**	**Pb**
Tomatoes	2.35E-03	3.39E-02	6.57E-01	4.97E-01	1.07E+00	1.98E-01	3.02E-01
Spinach	3.49E-03	4.42E-02	7.25E-01	1.71E-01	6.71E-01	6.08E-02	1.26E-01
Cabbage	1.87E-03	5.44E-02	6.71E-01	3.74E-01	3.47E-01	1.73E-01	1.49E-01
Onion	1.15E-03	4.51E-02	1.96E-01	7.74E-01	5.47E-01	1.22E-01	3.22E-01
Lettuce	2.93E-03	5.37E-02	4.46E-01	4.91E-01	2.41E-01	4.73E-02	1.87E-01
HI	**1.18E-02**	**2.31E-01**	**2.69E+00**	**2.31E+00**	**2.88E+00**	**6.01E-01**	**1.08E+00**

Table 8. Carcinogenic Risk Assessment (mg/kg day-1) of Some Heavy Metals in Vegetable Samples from Gongulong Agricultural Location

CR Values ($mg/kg\ day^{-1}$)					
Samples	**Cd**	**As**	**Pb**	**Ni**	**Cr**
Tomatoes	1.87E-03	1.47E-03	1.68E-05	5.03E-03	2.74E-03
Spinach	1.35E-03	1.61E-03	1.58E-05	2.97E-03	3.61E-03
Cabbage	6.18E-04	1.66E-03	1.22E-05	6.01E-03	2.17E-03
Onion	9.15E-04	2.35E-03	2.29E-05	8.40E-03	1.40E-03
Lettuce	5.99E-04	1.82E-03	1.41E-05	6.72E-03	3.15E-03
ILECR	**5.35E-03**	**8.91E-03**	**8.17E-05**	**2.91E-02**	**1.31E-02**

Table 9. Carcinogenic Risk Assessment (mg/kg day-1) of Some Heavy Metals in Vegetable Samples from Alau Dam Agricultural Location

CR Values ($mg/kg\ day^{-1}$)					
Samples	**Cd**	**As**	**Pb**	**Ni**	**Cr**
Tomatoes	1.29E-03	1.19E-03	1.03E-05	3.38E-03	1.76E-03
Spinach	8.05E-04	3.65E-04	4.28E-06	1.16E-03	2.62E-03
Cabbage	4.16E-04	1.04E-03	5.05E-06	2.54E-03	1.40E-03
Onion	6.56E-04	7.29E-04	1.09E-05	5.26E-03	8.64E-04
Lettuce	2.89E-04	2.84E-04	6.35E-06	3.34E-03	2.20E-03
ILECR	**3.45E-03**	**3.60E-03**	**3.69E-05**	**1.57E-02**	**8.85E-03**

to be higher than the maximum acceptable limit of 1.00E-04 with exception of Pb. [47] also reported a higher CRs value of Ni, Cd and Cr in vegetable grown in Guangdong, China. Also [8] reported higher CRs values of 5.49×10^{-5} to 1.25×10^{-3}. Hence the population and the consumers that depend these vegetables grown around the study areas are at risk of cancer related illness.

4. CONCLUSION

The results revealed that, all the studied metals in the vegetable samples were higher than the set standard permissible limits. Findings from average daily intake (ADI) revealed that consumption of vegetables from the study locations are reasonable safe and free from risk. Hazard quotient (HQ) and hazard Index (HI) results revealed that consumption of vegetables could pose non-carcinogenic risks to human health due to high level of Cd and As (HQ) and Cu, Ni, Cd, As and Pb (HI). Results from cancer risk assessment shows probability of developing cancer related illness with respect to the Cd, As, Ni and Cr. Due to the risk observed from results of risk assessment, it is therefore recommended that regular check of the heavy metals present in the vegetables be conducted by environmentalists and public health workers and create public awareness to avoid the consumption of vegetables irrigated by wastewater.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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