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Estimation of Potential Health Risk Due to Consumption of Carrots, Cabbage and Onions Grown in Challawa River Basin Around Challawa Industrial Layout, Kano, Nigeria

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Abstract

Contamination of food by heavy metals has made dietary intake one of its major entry routes into humans. Contents of lead, cadmium , chromium and zinc in carrots, cabbage and onions grown in Challawa River basin around Challawa industrial layout Kano was measured to estimate potential public health risk using Shimadzu atomic absorption spectrophotometer (model AA-6800, Japan) after wet digestion. The ranges of concentrations (mg/kg) were: (Pb) 0.34-1.03, (Cd) 0.20-0.36, (Cr) 1.19-3.76 and (Zn) 2.09-4.54 for carrots, (Pb) 0.46-0.76, (Cd) 0.21-0.51, (Cr) 0.24-0.47 and (Zn) 1.87-5.32 for cabbage and (Pb) 0.56-0.95, (Cd) 0.01-0.16, (Cr) 0.34-0.56 and (Zn) 5.23-19.43 for onions. Lead and cadmium concentrations were found to be above WHO/FAO permissible levels except for cadmium in onions. Zinc content of onions was also above acceptable limits. The average values of Estimated Daily Intake (EDI) of the metals were above the recommended daily intakes (RDI) and upper tolerable daily intakes (UL), except for zinc in carrots and cabbage. The average Target Hazard Quotient (THQ) of lead and cadmium for the crops were found to be above 1.00 indicating potential health risk, cadmium in onions being the only exception. Hazard index (HI) for a typical adult of body weight 70 kg considered in this study was found to be 2.74 for carrots, 3.05 for cabbage and 2.02 for onions. The study concludes that perennial intake of these vegetables from the study area is likely to induce serious adverse health effects.
Keywords: Vegetables; Heavy metals; Dietary intake; Permissible levels; Health risk.

1. Introduction

Vegetables are an important part of human diet as they are a rich source of nutrients. They constitutes significant functional food components by contributing protein, vitamins, calcium, iron and other nutrients which have marked health effects [1]. Be that as it may, the intake of heavy metal-contaminated vegetables may pose a risk to human health; hence the heavy metal contamination of food is one of the most important aspects of food quality assurance [2]. The effect of heavy metal contamination of vegetables cannot be underestimated. Human exposure to toxic heavy metals such as cadmium, lead, chromium and zinc is known to be responsible for many human health problems. Although human bodies have got homeostatic mechanisms that enable them to tolerate small fluctuations in the intake of heavy metals, the intake of such metals above or below certain permissible or recommended levels have devastating acute and chronic health implications [3]. Contaminated vegetables are a major source of such heavy metals to man. Considering the fact that vegetable is a particularly a very important source of heavy metal exposure, Monitoring the concentrations of various metals in vegetable is critical and undertaking a risk assessment appears to be justified. This can be done by intake measurement which is a quantitative evaluation of exposure [4]. Risk in this context is therefore a function of the amount of exposure to a given metal (dose) and the toxicity of the metal, That is, for a given metallic element, the higher the dose, the more severe the impact. The dose below which there is no effect could be said to be the threshold dose. Adequate knowledge of heavy metals in vegetable is of significant interest because some of the elements (zinc, copper, iron etc) are essential for human health while others such as lead and cadmium are toxic even at very low concentration. Depending on concentration and chemical form, even the essential metals can demonstrate toxic effects [5]. The increasing awareness in terms of the importance of vegetables to human diet suggests that the monitoring of toxic metals in vegetables should be carried out frequently to prevent excessive build up of these metals in the human food chain [6].

The main sources of heavy metals to vegetable crops are their growth media (soil, water, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage. Studies have shown that heavy metals in soil are associated with various chemical forms that relate to their solubility which directly bear on their mobility and biological availability [7, 8]. Heavy metals in soluble form have high relation to their uptake by plants. These toxic chemicals are persistent in the environment and are subject to bioaccumulation in food-chains [9]. Vegetables grown

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on heavy metal contaminated soils accumulate higher amounts of metals than those grown in uncontaminated soils. Apart from the concentrations of heavy metals in soils, the degree of uptake and bioaccumulation in vegetables is influenced by such factors as climate, the nature of soil, chemical properties of the soil, plant species and the degree of maturity of the plants at the time of the harvest [10]. With the ever increasing human population, urbanization and industrialization, the contamination of water bodies with toxic metals has become a matter of great concern. Rivers passing through developing cities are used for irrigation of the vegetables grown on their banks. Waters of such rivers have often been reported to be polluted by heavy metal and most of these lands are contaminated with heavy metals through industrial effluents, sewage, sludge, and atmospheric depositions from both industrial and vehicular emissions. Vegetables grown in such lands, therefore, are likely to be contaminated with heavy metals and unsafe for consumption [7, 8].

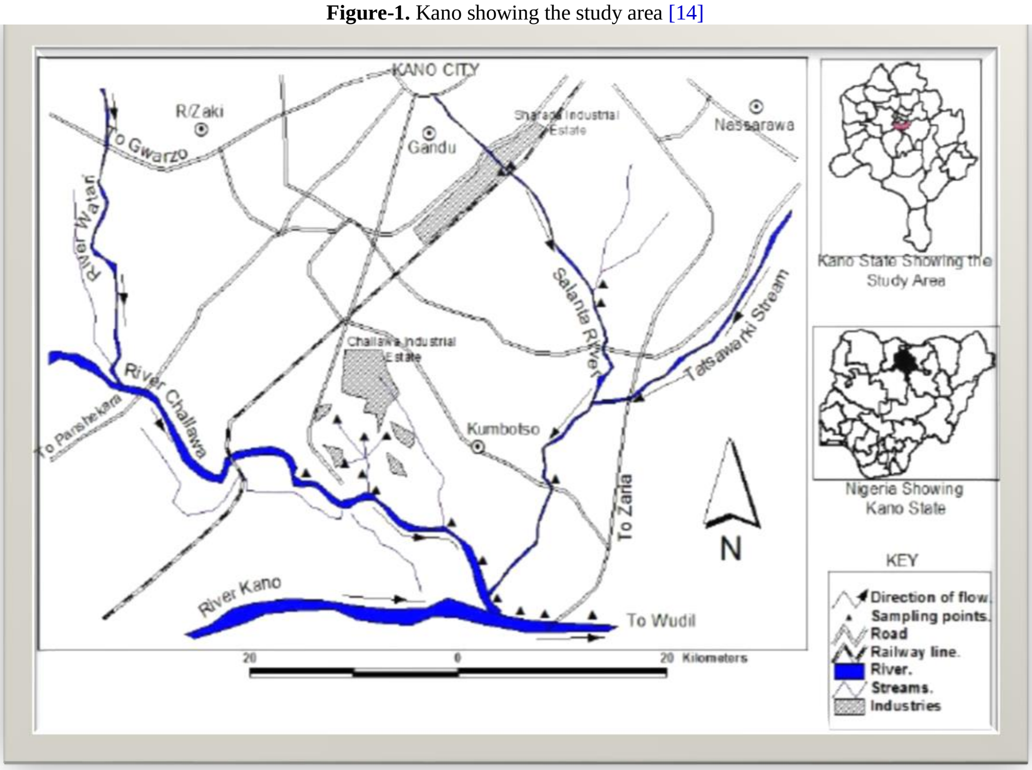
Challawa industrial layout is one of the three major industrial areas of Kano. It harbours several industries such as textiles, tanneries, plastics and many other wet industries. Effluents from these industries are discharged through drain and canals which meets at a confluence point, flows down through farm land where it is used for irrigation and eventually empties into Challawa River. River Challawa itself is an important resource which supplies water for drinking, irrigation and other agricultural activities including fishing. With the sustained drive of the federal government of Nigeria to diversify its economy from oil to agriculture due dwindling oil prices and mass unemployment, Nigerians are increasingly returning to the farm and one area that has greatly received a boost is food crop production. This study was undertaken to assess the heavy metal contents of carrots, cabbage and onions cultivated in Challawa River basin around Challawa industrial layout Kano and to estimate potential public health risk.

2. Materials and Methods

2.1. Study Location

Kano (Lat. 11° 59 m 18.3s N, Long 08° 32 m 05.8s E) 418 m above sea level is located in Kano State, occupies central position of Northern Nigeria [11]. Industrially, it is one of the most developed cities in Northern Nigeria with three main industrial estates namely Bompai, Challawa and Sharada. Each harbours large number of wet industries tannery and textile are some of its dominating industries. The indiscriminate discharges of untreated effluent need to be addressed urgently. Presently the state is experiencing myrids of problems that are challenging its sustainable development [12, 13]. Effluent from Challawa industrial estate are discharged untreated through drains and canals that eventually flow into Chalawa River. Challawa River (Lat 11° 52 m 41s N, Long 08° 28 m 09s E) 515 m above sea level originate from the Challawa Gorge dam in Challawa village and stretches down to River Kano where it empties into Lake Chad [11]. The river receives waste from tanneries and textile industries, urban water storm and agricultural runoff from farming communities along the river course. The River is a major source of water supply to a large number of communities along its course. It is also used for irrigation, bathing, fishing, etc. The domestic water supply for Challawa, Sharada and Bompai industrial areas and the surrounding environment in general comes from River Challawa.

Figure-1. Kano showing the study area [14]



2.2. Sample Collection and Preservation

Procedure for sample collection preservation and preparation was adopted from Abida, *et al.* [15]. Four sampling points were established along Callawa River basin, around Challawa industrial layout. Sampling point 1 was around the point source (the identified effluent discharge point), sampling point number two was 500 meters downstream of sampling point 1 and sampling point 3 was 500 meters downstream of sampling point 2. The fourth sampling point which was 1000 meters upstream of the point source (sampling point 1) served as control. Four farms were selected for each crop, one farm around each of the sampling points. Crop samples were collected from the established farms into black polyethene bags. Collected samples were transported to the Environmental Laboratory, National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria for analysis.

2.3. Sample Preparation and Analysis

Carrots, cabbage and onions samples collected were thoroughly washed to remove all adhered soils, cut into pieces and air dried for 5 days in the laboratory. The dried samples were pulverized, passed through 1 mm sieve and digested. The digestion of 1 g was carried out using 10 ml of concentrated nitric acid and perchloric acid according to Awofolu [16].

2.4. Metal Analysis

Lead, Cadmium , Chromium and Zinc concentrations in the digests were determined by Atomic Absorption Spectrophotometry, using Shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) at National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria. The calibration curve was prepared by running different concentrations of the standard solutions. The instrument was then set to zero by running the respective reagent blanks and metal concentrations determined. Average values of three replicates were taken for each determination. Data obtained were subjected" to statistical analysis

2.5. Analytical Quality Assurance

Appropriate quality assurance procedures and precautions were taken to ensure the authenticity of the results. Samples were carefully handled to avoid cross-contamination. Glasswares were properly cleaned and deionized water was used throughout the study. All the reagents used- HNO_3 (Riedel-deHaen, Germany) and $HClO_4$ (British Drug House Chemicals Limited, England) were of analytical grade. In order to check the reliability of the analytical method employed for metal determination, one blank and combine standards was run with every batch of samples to detect background contamination and monitor consistency between batches. The result of the analysis was validated by digesting and analyzing Standard Reference Material, Lichens coded IAEA-336 following the same procedure. The analyzed values and the certified reference values of the metals determined were compared to ascertain the reliability of the analytical method employed.

2.6. Statistical Analysis

Data collected was subjected to statistical test of significance using the Analysis of Variance (ANOVA) test to assess significant variation in metal levels across the sampling locations. Probabilities less than 0.05 ($p < 0.05$) was considered to be statistically significant. Duncan multiple test or Donnette T was adopted for multiple comparison of parameters between sampling stations depending on whether the homogeneity test was greater than or less than 0.05. Pearson product moment correlation coefficient was used to determine the association between metal levels in the samples at $\alpha = 0.05$. SPSS software 17.00 for windows was used for all statistical analysis.

The estimated daily metals intake from the edible tissues of the vegetables in this study was determined according to A., *et al.* [17] following equation (1)

$$EDI = \frac{CHM \times DAC}{BW} \quad \text{..} (1)$$

Where CHM (mg/kg) is the concentration of heavy metals in the edible tissues of vegetables; DAC represents the daily average consumption of carrots, cabbage and onions; and BW is the body weight. The DAC for this study was taken from Sharma, *et al.* [18] as 400g. An adult's average body weight of 70kg was used for the EDI evaluation.

An estimate of the potential hazard to human health (Target Hazard Quotient- THQ) through consumption of the vegetables grown along Challawa River basin around Challawa industrial area was computed using equation (2).

$$\mathrm{THQ} = \frac{(Div) \times Cmetal}{RfD \times Bo} \text{..} (2)$$

Where *(Div)* is the daily intake of vegetables (kg per day), (Cmetal) is the concentration of metal in the vegetable (mg/kg), RfD is the oral reference dose for the metal (mg/kg body weight per day), and Bo is the human body mass (kg). RfD is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime. The methodology for estimation of target hazard quotients (THQ) was adopted from *USEPA Region III Risk-Based Concentration Table, January–June 1996 cited in Guerra, et al. [5]*. The value of RfD for Pb (0.0035 per day) was taken from [19]. Values of RfD for Cr (1.5 mg/kg per day), Cd (0.001 mg/kg per day) and Zn (0.300 mg/kg per day) were taken from Integrated Risk Information System [20]. The average Bo was taken as 70 kg for adults [19].

The hazard index (HI) was computed as the sum of the average Target Hazard Quotients of the heavy metals under study [5, 21] as described in Equation (3, 4, and 5) for carrots, cabbage and onions respectively

$$HI_{carrots} = \Sigma\, THQ_{carrots} = THQ_{carrotsPb} + THQ_{carrotsCd} + THQ_{carrotsCr} + THQ_{carrotsZn} \quad \text{.........................(3)}$$

$$HI_{cabbage} = \Sigma\, THQ_{cabbage} = THQ_{cabbagePb} + THQ_{cabbageCd} + THQ_{cabbageCr} + THQ_{cabbageZn} \quad \text{.....................(4)}$$

$$HI_{onions} = \Sigma\, THQ_{onions} = THQ_{onionPb} + THQ_{onionsCd} + THQ_{onionsCr} + THQ_{onionsZn} \quad \text{............................(5)}$$

3. Results

3.1. Analytical Quality Assurance

The analyzed values of the standard reference materials (lichen coded IAEA – 336) were found to be within the range of the certified reference values for the metals determined suggesting the reliability of the method employed (Table 1).

Table-1. Results of analysis of reference material (Lichen IAEA -336) compared to the certified reference value (mg/kg).

Metal (mg/kg)	Pb	Cr	Cd	Zn
A Value	5.18	0.167	3.86	65.86
R value	4,2-5.5	0.1-2.34	3.1-4.1	56-70

A. Value=Analyzed value R. value =Reference value.

3.2. Metal Content of Edible Crop Tissues

Result obtained from the determination of metal contents of edible carrot, cabbage and onions tissues are presented in Table 2 while the spatial distribution of the Average metal concentration in edible crop tissues across the sampling points and the control are shown in Figure 2a, b and c.

Table 2 indicates that the order of detection of lead was; Sampling Station 1 > Sampling Station 2 > Sampling Station 3. The concentration ranged between 0.34 mg/kg - 1.03 mg/kg for lead, 0.20 mg/kg - 0.36 mg/kg for Cadmium, 1.19 mg/kg - 3.76 mg/kg for Chromium and 2.45 mg/kg - 4.54 mg/kg for Zinc. The lowest concentration for each of the metals was recorded at Sampling Station 3 and the highest concentration at Sampling Station 1. Statistical analysis revealed that the difference in concentration of Lead, Cadmium, Chromium and Zinc in edible carrots tissues across the sampling stations were statistically significant (ANOVA, $p < 0.05$). Lead content of carrots from sampling station 1 was found to be significantly higher than sampling station 2 and sampling station 3. Lead content of edible carrots tissues from sampling station 2 was found

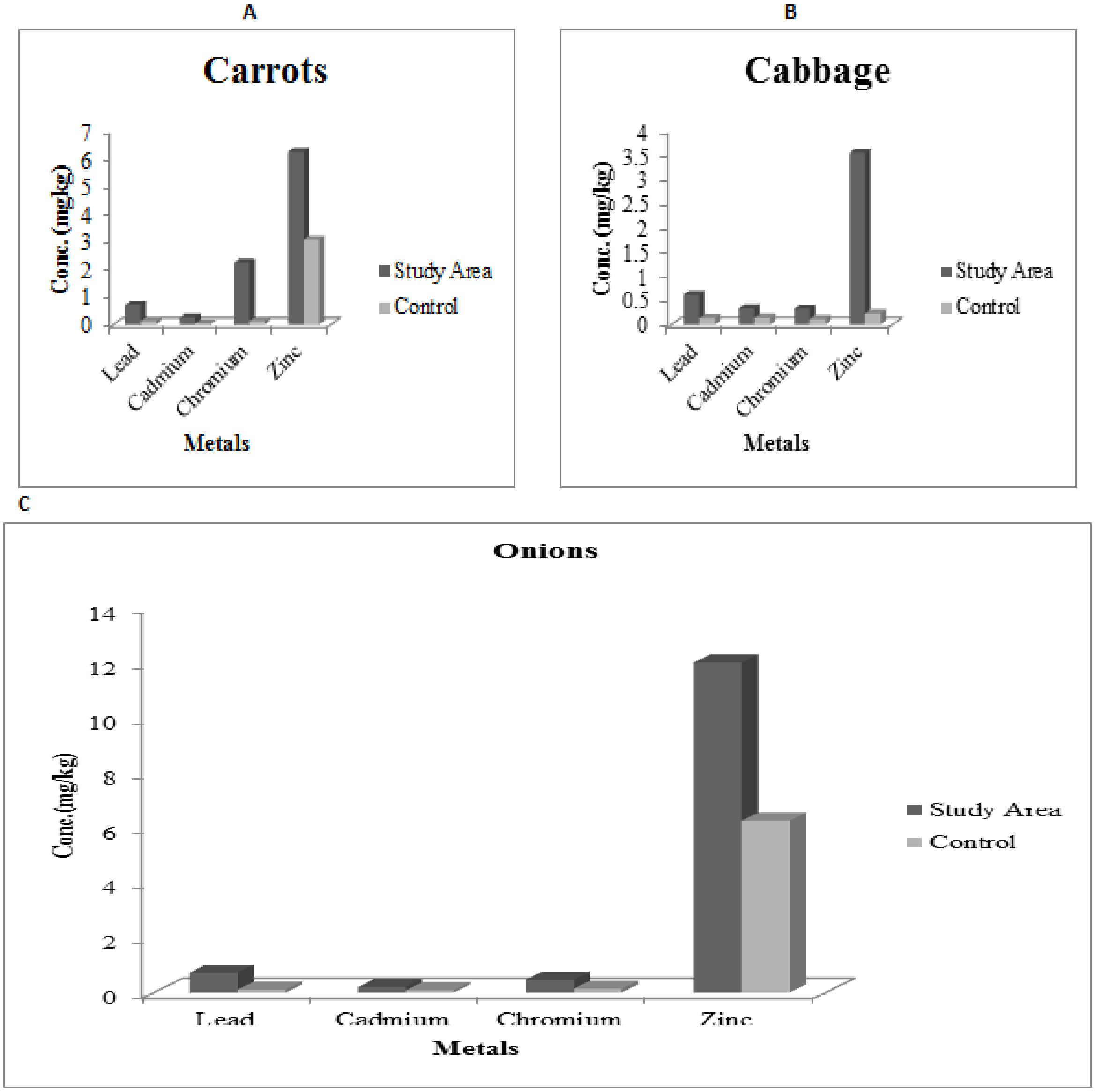
Table-2. Metal levels of Edible Carrots, Cabbage and Onions Tissues from River Challawa Basin around Challawa Industrial Area, Kano, Nigeria (mg/kg)

Element		Carrots				Cabbage				Onions			
Lead	Sampling Month	Sampling Station 1	Sampling Station 2	Sampling Station 3	(Control)	Sampling Station 1	Sampling Station 2	Sampling Station 3	(Control)	Sampling Station 1	Sampling Station 2	Sampling Station 3	(Control)
	February	1.02	0.89	0.34	0.1	0.68	0.54	0.46	0.11	0.66	0.62	0.56	0.11
	March	1.03	0.67	0.43	0.1	0.75	0.67	0.54	0.13	0.78	0.74	0.71	0.10
	April	1.01	0.76	0.34	0.2	0.76	0.64	0.57	0.15	0.95	0.84	0.71	0.12
	Mean ± SD	1.02 ±0.01	0.77 ±0.11	0.37 ±0.05	0.13 ±0.06	0.73 ±0.04	0.62 ±0.07	0.52 ±0.06	0.13 ±0.02	0.80 ±0.15	0.73 ±0.11	0.66 ±0.09	0.11 ±010
	Range	0.34 - 1.03			0.1 - 0.2	0.46 - 0.76			0.11 – 0.15	0.56 - 0.95			0.10 – 0.12
Cadmium	February	0.34	0.31	0.24	0.02	0.32	0.28	0.21	0.11	0.11	0.11	0.08	0.02
	March	0.21	0.21	0.20	0.02	0.48	0.32	0.28	0.14	0.13	0.1	0.09	0.01
	April	0.36	0.26	0.21	0.04	0.51	0.38	0.28	0.16	0.16	0.13	0.07	0.22
	Mean ± SD	0.30 ±0.08	0.26 ±0.05	0.22 ±0.02	0.03 ±0.01	0.44 ±0.10	0.33 ±0.05	0.26 ±0.14	0.14 ±0.03	0.13 ±0.03	0.11 ±0.02	0.08 ±0.12	0.08 ±0.12
	Range	0.20 - 0.36			0.02 –0.04	0.21 - 0.51			0.11 – 0.16	0.08 - 0.16			0.01 – 0.22
Chromium	February	2.48	2.21	1.19	0.16	0.38	0.26	0.24	0.10	0.48	0.45	0.34	0.13
	March	3.39	2.1	1.56	0.12	0.43	0.34	0.27	0.11	0.54	0.51	0.39	0.19
	April	3.76	2.33	1.2	0.10	0.47	0.36	0.25	0.12	0.56	0.52	0.45	0.10
	Mean ± SD	3.21 ±0.66	2.21 ±0.12	1.32 ±0.21	0.13 ±0.03	0.43 ±0.05	0.32 ±0.05	0.25 ±0.02	0.11 ±0.01	0.53 ±0.04	0.49 ±0.04	0.39 ±0.06	0.14 ±0.05
	Range	1.19 - 3.76			0.10 –0.16	0.24 - 0.47			0.10 – 0.12	0.34 - 0.56			0.10 – 0.19
Zinc	February	4.54	3.21	2.56	2.98	2.45	2.43	1.87	0.21	10.72	15.31	5.23	6.95
	March	3.43	3.42	2.45	2.43	4.98	3.98	3.64	0.26	15.38	12.87	8.36	5.63
	April	4.23	3.54	2.09	3.78	5.32	4.11	3.21	0.23	19.43	11.62	9.35	6.22
	Mean ± SD	4.07 ±0.57	3.39 ±0.16	2.67 ±0.25	3.06 ±0.68	4.25 ±1.57	3.51 ±0.93	2.91 ±0.92	0.23 ±0.03	15.18 ±4.35	13.27 ±1.88	7.65 ±2.15	6.27 ±0.66
	Range	2.09 - 4.54			2.43 –3.78	1.87 -5.32			0.21 – 0.26	5.23 -19.43			5.63 – 6.95

To be higher than sampling station 3. Chromium content of edible carrots tissues from sampling station 2 was found to be significantly higher than sampling station 3. The difference in chromium content between carrots from sampling station 1 and sampling station 2 and between sampling station 1 and sampling station 3 were not statistically significant at 95 % confident level. Zinc content of carrots from sampling station 3 was significantly lower than sampling stations 1 and sampling station 3. The difference in Zinc concentration between sampling station 1 and sampling station 2 was not statistically significant at 95% confidence level. Cadmium content of carrots from the three established sampling points did not display any statistically significant difference. The spatial distribution of the Average metal content in edible carrot tissues from established sampling stations in the study area and the control is presented in Figure 2. The difference in average metal concentration between the study area (sampling stations 1, 2 and 3) and the control was found to be statistically significant (ANOVA, $p < 0.05$) for the metals under study. Positive correlation was observed between carrots lead content and carrots cadmium levels (r =

0.654), carrots lead content and carrots chromium content (r = 0.900), and between carrots cadmium content and carrots chromium content (r = 0.530). However, only the correlation between carrots lead content and carrots chromium content was found to be statistically significant at 99% confidence level. On the other hand, negative correlation was observed between carrots lead content and carrot Zinc content (r = -0.432), carrots cadmium content and carrots Zinc content (r = -0.248) and also between carrots chromium content and carrots Zinc content (r = -0.388). The correlations were however, not statistically significant. Table 2 shows that Lead, Cadmium, Chromium and Zinc content of edible cabbage tissues followed the order: Sampling Station 3>Sampling Station 2>Sampling Station 1.

Fig-2. Spatial Distribution of the Average concentration Lead, Cadmium, Chromium and Zinc in edible tissues of crops across sampling points and the control.



The ranges of the concentrations were 0.46 - 0.76 mg/kg, 0.21- 0.51 mg/kg, 0.24 - 0.47 mg/kg and 1.87-5.32 mg/kg respectively. The lowest concentrations of all the metals were recorded at sampling station 3 in the month of February and the highest concentration at sampling station 1 in the month of April. Statistical analysis shows that the differences in Lead, Cadmium and Chromium content of edible cabbage tissues across the established sampling stations from the point source downstream were statistically significant (ANOVA, $p < 0.05$), sampling station 1 being significantly higher than sampling station 3 for each of the three metals. Sampling station 1 was also higher than sampling station 2 for Lead and chromium. Zinc content of edible cabbage tissue however, did not show any statistically significant difference across the sampling stations. The difference in metals concentration between the study area and the control was found to be statistically significant (ANOVA, $p < 0.05$), Zinc being the only exception. A strong positive correlation was observed between cabbage lead content and cabbage cadmium levels (r = 0.921), cabbage lead content and cabbage chromium content (r = 0.955), and between cabbage lead content and cabbage Zinc content (r = 0.797). The correlations were significant at 99% confidence level except the correlation between cabbage lead content and cabbage Zinc content that was significant at 95% confidence level. A strong positive correlation was also observed between cabbage cadmium content and cabbage chromium content (r = 0.936), cabbage cadmium content and cabbage Zinc content (r = 0.897) and between cabbage chromium content and cabbage Zinc content (r = 0.772). The correlations were significant at 99% confidence level except for the correlation between cabbage chromium content and cabbage Zinc content that was significant at 95% confidence level.

The order of detection of Lead, Cadmium, Chromium and Zinc in edible Onions tissues followed the order: Sampling Station 1>Sampling Station 2 >Sampling Station 3. The concentration ranged between 0.56 mg/kg - 0.95 mg/kg for lead, 0.08 mg/kg - 0.16 mg/kg for Cadmium, 0.34 mg/kg - 0.56 mg/kg for Chromium and 5.23 mg/kg - 19.43 mg/kg for Zinc. The lowest concentration for each of the metals was also recorded at Sampling Station 3 in the month of February except cadmium that recorded its lowest value in April. The highest concentrations were recorded at Sampling Station 1 in April except Zinc that recorded its highest value in February. Statistical analysis revealed that the difference in concentration of Chromium and Zinc in edible onion tissues across the established sampling stations were statistically significant (ANOVA, $p < 0.05$), the contents of these metals in onions from sampling station 1 being significantly higher than sampling station 3. The content of two the metals in edible onion tissues from sampling station 2 were also found to be higher than sampling station 3. Lead and Cadmium content of edible onion tissues from the established sampling stations in the study area were not statistically significant (ANOVA, $p < 0.05$). The difference in metal concentration between the study area and the control was found to be statistically significant (ANOVA, $p < 0.05$) for all the metals except Chromium. A positive correlation was observed between onions lead content and onions cadmium levels ($r = 0.127$), onions lead content and onions chromium content ($r = 0.569$), onions cadmium content and onions chromium content ($r = 0.726$), onions cadmium content and onions Zinc content ($r = 0.338$) and between onions chromium content and onions Zinc content ($r = 0.494$). Only the correlation between onions cadmium content and onions chromium content was statistically significant ($p < 0.05$). On the other hand a negative correlation ($r = 0.934$) was observed between onions lead content and onions Zinc content ($p > 0.05$).

Table 3 revealed that the average values of the estimated daily lead, cadmium, chromium and zinc intake from the consumption of edible tissues of vegetable from Challawa River Basin around Challawa industrial area were: 4.11, 1.49, 12.84 and 19.30 respectively for carrots, 3.56, 5.92, 1.91 and 20.33 respectively for cabbage and 4.17, 0.61, 2.69 and 68.71 respectively for onions.

The Target Hazard Quotient computed for the metals under study as presented in Table 4 revealed the average values displayed by lead, cadmium, chromium and zinc were: 1.18, 1.49, 0.01 and 0.06 respectively for carrots, 1.02, 1.96, 0.0006 and 0.07 for cabbage and 1.19, 0.061, 0.0018 and 0.22 respectively for onions.

The hazard index (HI) computed for the crops were: 2.74 for carrots, 3.05 for cabbage and 2.02 for onions

Table-3. Estimated daily metal intake (mg/kg b.w. /day) for metals in carrots, cabbage and onion bulbs across sampling locations

	Carrots				Cabbage				Onions			
	Lead	cadmium	Chromium	zinc	Lead	cadmium	Chromium	zinc	Lead	cadmium	Chromium	zinc
Sampling Station 1	5.83	1.74	18.34	23.26	4.17	2.54	2.46	24.29	4.57	0.74	3.03	86.74
Sampling Station 2	4.40	1.49	12.63	19.37	3.54	1.89	1.83	20.06	4.17	0.63	2.80	75.83
Sampling Station 3	2.11	1.26	7.54	15.26	2.97	1.49	1.43	16.63	3.77	0.46	2.23	43.71
Average	**4.11**	**1.49**	**12.84**	**19.30**	**3.56**	**5.92**	**1.91**	**20.33**	**4.17**	**0.61**	**2.69**	**68.71**
Control	0.74	0.17	0.74	17.49	0.74	0.80	0.63	1.31	0.63	0.46	0.80	36.83
UL(mg/ day)	0.240	0.064	130µg/day	40.00	0.240	0.064	130µg/day	40.00	0.240	0.064	130µg/day	40.00
RDI(mg/ day)	0.00	0.00	0.003-1.5	11(8)	0.00	0.00	0.003-1.5	11(8)	0.00	0.00	0.003-1.5	11(8)

Figures in brackets () indicate the RDI for female

Table-4. Target Hazard Quotient (THQ) of metals in carrots, cabbage and onion bulbs from Challawa River Basin

	Carrots				Cabbage				Onions			
	Lead	cadmium	Chromium	zinc	Lead	cadmium	Chromium	zinc	Lead	cadmium	Chromium	zinc
Sampling Station 1	1.67	1.71	0.01	0.08	1.19	2.51	0.001	0.08	1.31	0.74	0.002	0.29
Sampling Station 2	1.26	1.49	0.01	0.06	1.01	1.89	0.001	0.07	1.19	0.63	0.002	0.25
Sampling Station 3	0.60	1.26	0.01	0.05	0.85	1.49	0.000	0.06	1.08	0.46	0.001	0.15
Average	1.18	1.49	0.01	0.06	1.02	1.96	0.0006	0.07	1.19	0.61	0.0018	0.22
Control	0.21	0.17	0.00	0.06	0.21	0.80	0.00	0.004	0.18	0.46	0.0005	0.12

4. Discussion

4.1. Metal Concentration of Edible Crop Tissues

Lead, Cadmium, chromium and zinc content of edible carrots (*Daucuscarota L.)*, cabbage (*Brassica oleracea.)* and Onions (*Allium cepa*) tissues across sampling stations (Table 2) in the study area all followed the order: sampling station 1 > sampling station 2 > sampling station 3. The order of these metals in soil and water used for irrigation [22] were fund to follow the same sequence suggesting uptake of the metals from the soil and water may be responsible for their presence at the concentration determined in the different crops. The fact that no statistically significant (ANOVA, $P > 0.05$) difference was observed in metals level (manganese being the only exception) across the three sampling stations reflects the fact no significant difference in metals level across the sampling stations was displayed in growth medium (soil and water) all through the study [22]. On the average, the lowest concentration of each metal in the study was also recorded in the month of February and the highest concentration in April. This observation could be explained on the basis of the water used for irrigation. The volume of River Challawa used for irrigation was observed to decrease as the dry season progressed. The concentration of the contaminants in the water increases as the volume decreases. The use of a more concentrated water at the peak of the dry season for irrigation resulted to higher uptake by the plant. Metal content of edible crop tissues from sampling stations along River Challawa basin (study area) were found to be higher than those from the control. The observation also followed the order of the metals concentrations in soil and water indicting that crop grown in areas with less input of metals from anthropogenic sources accumulates lower amounts of the contaminants. The soil and water chemistry as well as the species and age of plants also play significant roles in the uptake of metals by plants [23].

The mean lead concentration of edible crop tissues from the study area were found to be higher than WHO/FAO safe limit of 0.3 mg/kg for lead in edible vegetable. Consuming crops from the study area (Challawa river basin from the point source downstream) poses serious toxicological risk. Lead concentration of edible crops tissues from the control station was however within the acceptable limit. The Pb content of the cabbage in this study area was found to be higher than (0.460 mg/kg) reported for cabbage from waste water irrigated areas of Varanasi, India [23]. Lower ranges - 0.071-0118 mg/kg and 0.05-0.315 mg/kg were reported for cabbage from Kastina central market Nigeria [24] and for cabbage grown around Morogoro Municipality, Tanzania [25] respectively. Lead is a toxic element that can be harmful to plants, although some plants usually show ability to accumulate large amounts of lead without visible change in their appearances or yield. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible form human consumption [26]. Lead concentration of edible carrot tissues in the study was found to be lower than 41.6 - 84.6 mg/kg reported for carrots grown on peri-urban area of Lahore district of India [27]. A range of 0.50 - 3.10 mg/kg with mean of value 1.61 mg/kg was reported for carrots from Baia Mare area, North-Western Romania [28]. A higher range (5.870-7.537 mg/kg) was reported in onions grown on irrigated soil [29] and a mean value of 11.30 mg/kg for onion grown with waste water in Meerut City Region [30]. Exposure to low lead levels over prolonged period leads to chronic poisoning (it accumulates in the body and can build to toxic level under continuous exposure). Lead is one of the limited classes of element that can be described as purely toxic. Most other elements though toxic at high concentration are actually required nutrients at lower levels [31]. There is no exposure level below which lead appear to be safe. Lead is number 2 in the Agency for Toxic Substances and Disease Registry (ATSDR) Top 20 list, and account for most of the cases of pediatric heavy metal poisoning.

The average chromium content of edible crop tissues in this study were found to be lower than the WHO/FAO safe limit of 0.5 mg/kg, thus pose no significant health risk. The concentrations of chromium recorded in this study were found to be lower than 5.83 mg/kg reported for cabbage from in irrigated wastewater in Skhirat region, Morocco by AL Jaboobi, *et al.* [32] but higher than 0.175 mg/kg reported for wastewater irrigated area of Varanasi, India by Singh, *et al.* [23]. Chromium levels in edible carrots tissues recorded in this study were lower when compared to 13.9-35.8 mg/kg range reported for carrots grown on peri-urban area of Lahore district India by Ajmal, *et al.* [27]. A higher range (5.870-7.537 mg/kg) was reported in onions grown on irrigated soil [29] and a mean value of 11.30 mg/kg for onion grown with waste water in Meerut City Region (Deepar *et al.*, 2013). Chromium (Cr) is considered as essential nutrient and a health hazard. While hexavalent chromium [Cr(VI)] is considered harmful even in small dose, trivalent chromium [Cr(III)] is considered essential for good health in moderate intake [33]. Chromium is a toxic human carcinogen that causes or increases the rate of cancer; ingestion of high concentration often results in lung function and blood system problems, gastrointestinal burns, hemorrhage, generalized oedema, pulmonary oedema, liver damage and kidney damage. Symptoms are diarrhea, abdominal pain, indigestion and vomiting. Death may be the result of pulmonary or cardiac arrest. Skin contact causes a number of skin problems including rashes and sores [31].

Zn is a known cofactor of the superoxide dismutase enzymes, stabilize phosphate group and co-ordinate with organic bases. Yet elevated level of dietary Zn intake can have negative effect on Cu balance. The concentration of Zn in edible tissues of carrots and cabbage in the study was found to be within the set limits of international standards 5.00 mg/kg [34]. Consumption of these crops in the study area does not pose any toxicological risk with respect to Zinc intoxication except for onion.

The mean cadmium concentration in the edible carrots and cabbage tissue (Table 2) in this study were found to be higher compared to WHO/FAO 2007 safe limit of 0.2 mg/kg and thus pose significant risk to human health. Onion was however not indicted with respect to cadmium poisoning. Eating food with very high levels severely irritates the stomach, leading to vomiting and diarrhea. Long-term exposure to lower levels of cadmium in food or water leads to a buildup of cadmium in the kidneys and possible kidney disease. Other long-term effects are lung damage and fragile bones [35]. Cadmium levels ranging from 0.11-1.61µg/g for carrots and 0.01-0.44 µg/g for have previously been reported for carrots and cabbage grown in the vicinity of Challawa industrial area, Kano [36].

The significant positive correlations observed between carrots lead content and carrot chromium content, between onions cadmium content and onions chromium contents, and between cabbage metal contents indicates that an increase in the concentration of any of the metal is associated with an increase in the concentration of the metal to which it is positively correlated, suggesting that same source is responsible for the presence of the pair at the concentrations determined. The significant negative correlation observed between onions lead content and onions zinc contents indicates that increase in the concentration of lead in onions is associated with a decrease in the concentration of zinc in onions, suggesting different sources are responsible for their presence at the concentrations determined or one of the metals has a strong inhibiting/antagonistic effect on the bioaccumulation of the other in the vegetable

4.2. Estimated Daily Intake (EDI)

In order to assess the health risk of any pollutant, it is absolutely necessary to estimate the level of exposure. One very significant aspect of such estimation is by the evaluation of the daily intake. The estimated daily intake (EDI) of heavy metals is widely used to describe safe levels of metallic intake through food consumed [5, 37]. It also combines data on the levels of heavy metals in foodstuff with quantities of food consumed on the daily basis [5]. The EDI thus depend on both the metal concentration in edible portion of the food crops and the amount of the food crop consumed. In this study, the approximate daily lead, chromium, nickel and manganese intake for people living in Kano and its environs through the consumption of carrots, cabbage and onions cultivated along Challawa River basin around Challawa industrial area estimated were compared with the recommended daily intakes/or allowances and the upper tolerable daily intakes for the metals (UL) (Table 3). Tolerable Daily Intake (TDI) is an estimate of the amount of elements in air, food or drinking water that can be taken in daily over a lifetime without appreciable health risk. The average values of the estimated daily intake of lead, Cadmium, chromium and zinc for carrots, cabbage and onions were above the recommended daily intakes for the metals (Table 3). The estimated daily intake of lead, Cadmium, chromium and zinc for the crops from the control station though also above the recommended daily intake for the metals were found to be about 6, 9, 17, and 1.1 times (in that order), lower than the average estimated daily intake for carrots from the sampling stations under study, 5, 8, 3 and 16 times (respectively), lower than the average estimated daily intake for cabbage from the study area and 7, 3, 1 and 2 times (respectively), lower than the average estimated daily intake for onions from the study area. The average values of the estimated daily intake of the metals for the crops under study were again found to be above the upper tolerable daily intakes (UL) for the metals (Table 3), the estimated daily intake of zinc in carrots and cabbage being the only exception. The estimated daily metal intake computed in this study were expressed per kilogram body weight (mg/kg b.w. /day) so that for an average adult of 70kg body weight, the average value of EDI of say lead for carrots, cabbage and onions is equivalent to 4.11, 3.56 and 4.17 multiplied by 70 which is equal to 287.7, 249.2 and 291.9 mg per day respectively. The average EDI of lead for carrots, cabbage and onions across the sampling stations

The results obtained from the estimation of daily intake (EDI) of lead, cadmium, chromium and zinc in the study clearly implies that the perennial intake of carrots, cabbage and onions harvested from Challawa River basin around Challawa industrial layout is likely to induce serious adverse health effects.

4.3. Target Hazard Quotients (THQ)

Risk to human health by the intake of metal-contaminated carrots, cabbage and onions was also characterized using Target Hazard Quotient (THQ). THQ is the ratio between exposure and the reference oral dose (R*f*D). When the ratio is lower than one (1), there is no obvious risk. THQ-based risk assessment method indeed provides an indication of the risk level due to exposure to pollutants [38, 39]. THQ method employed in this study considered only exposure to the selected heavy metals through consumption of onions bulbs, without taking into account other exposure routes like dermal contact, soil ingestion, and other factors such as the presence of agrochemicals and herbicide molecules. The average THQs of lead and cadmium for carrots and cabbage, and lead for onions were found to be above 1.00. THQ-based risk assessment in this study thus indicates that, the consumption of these crops from the area under study poses serious toxicological risk with respect to lead and cadmium intoxication. The average THQs of chromium and zinc for the three crops under study were below 1.00. The two metals were therefore not implicated in the study.

4.5. Hazard Index (HI)

To evaluate the potential risk to human health through more than one heavy metal, the hazard index (HI) has been developed [5, 21]. It assumes that the magnitude of the adverse effect will be proportional to the sum of multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organ [5]. There is serious concern for potential health effects when the Hazard Index is greater than 1. Even though there was no apparent risk when each metal was analyzed individually, the potential risk could be multiplied when considering all metals are considered together. The hazard index for a typical adult of body weight 70 kg considered in this study was found to be 2.74 for carrots, 3.05 for cabbage and 2.02 for onions. The relative contributions of Pd, Cr, Ni, and Mn to the aggregated risk were 43.86 %, 54.48 %, 0.06 % and 2.19 % respectively for carrots, 33.44 %, 64.26 %, 0.02 % and 2.30 % for cabbage and 58.91 %, 30.20 %, 0.09 % and 10.89 % for onions. Consumption of these crops from the study area therefore poses serious cause for concern.

5. Conclusion

Human exposure to toxic heavy metals is known to be responsible for many human health problems. Findings of the present study show that Lead and cadmium content of carrots, cabbage and onions cultivated along Challawa River basin around Challawa industrial layout Kano were found to be above WHO/FAO permissible levels except for cadmium in onions. Zinc content of onions was also above acceptable limits. The average values of Estimated Daily Intake (EDI) of the metals were above the recommended daily intakes (RDI) and upper tolerable daily intakes (UL), zinc in carrots and cabbage being the only exception. The average Target Hazard Quotient (THQ) of lead and cadmium for carrots and cabbage, and lead for onions were found to be above 1.00. Hazard index (HI) for a typical adult of body weight 70 kg considered in this study was found to be 2.74 for carrots, 3.05 for cabbage and 2.02 for onions. The study concludes that perennial intake of these vegetables from study area is likely to induce serious adverse health effects.

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