Health risk assessment of heavy metals in irrigated fruits and vegetables cultivated in selected farms around Kaduna metropolis, Nigeria

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ABSTRACT
This study assessed heavy metals levels in water, soil, fruits (banana, pawpaw) and vegetables (cucumber, cabbage and garden egg) from Bashama, Danmani and Danbushiya farms within Kaduna metropolis, Nigeria. A total of 63 samples (water (9), soil (9), fruits and vegetables (45)) were randomly collected, processed and analyzed for heavy metals using a microwave plasma atomic emission spectrometer. The heavy metal concentration in soil was found to be highest for Fe (57.30–63.51) mg/kg and the least was observed for Cu (0.45–1.45) mg/kg. High levels of Pb (0.02–0.03) mg/l, Cd (0.07–0.1) mg/l and Fe (3.23–3.42) mg/l were determined in the irrigation water exceeding the World Health Organization (WHO) standard. Some of the heavy metals (Fe, Zn and Cu) found in the various fruits and vegetables were essentials metals. Toxic metals like Pb and Cd were also present with concentrations above the World Health Organization permissible limit of 0.2 and 0.1, respectively. In the fruits and vegetables examined, the average mean concentration of metals showed significant variations with Fe having highest concentration of (7.82 mg/kg) in most of the samples from the farms. Health risk assessment of heavy metals from the fruit and vegetable samples indicated that all metals are within hazard quotients of less than 1 except for Cd, while for the hazard index, all the metals surpass limit of 1 which showed that the samples are likely to be of health concern. For permissible maximum tolerable daily intake in the metals studied, Cd has the highest concentration. The activities around these farms play a significant role in elevating the concentration of Cd and Pb in the fruits and vegetables a little above the WHO set standard of 0.3 mg/kg and 0.2 mg/kg, respectively. Measures to reduce the concentration of heavy metals in fruits and vegetables should be carried out in further works to avoid their health risk in human.

Introduction
The world’s ever increasing population and the adoption of industrial-based life have led to an increase in anthropogenic activities \cite{1}. This advancement in industrialization is meant to improve the standard of living of man, but ironically, the process leads to the discharge of pollutants into aquatic bodies, including rivers,
lakes, ponds and streams [2]. Heavy metal is a persistent pollutant released into water bodies from both point and non-point sources due to agriculture, urbanization and industrialization. This heavy metal tend to affect man in enormous ways particularly due to prolonged consumption which results into severe health effects [3,4].

Man is exposed to heavy metals when polluted water is used for growing of vegetables and fruits especially in Nigeria where such water is considered to contain sufficient plant nutrients and sufficient amount of soluble salts [5]. However, this polluted water tend to have heavy metals in high concentration [5–7]. Due to their cumulative nature and toxicity, when such water is used for irrigation of crops for a long period, they exert potential hazardous effect not only on the plants and soil but also on human health when consumed [5,8,9]. The consumption of heavy metal contaminated fruits and vegetables may lead to different long-term and short-term related diseases; for example, lead (Pb) can adversely influence the intellectual development of children, cause excessive lead in blood and induce hypertension and cardiovascular disease [10,11].

Fruits are good source of vitamins, minerals and antioxidants [12]. The major constituent of fruits (about 75–95%) is water [13]. Other constituents of fruits include celluloses, fibers, pectin and tannins. Vegetables are also important edible crops and are an essential part of the human diet. They are rich in nutrients required for human health and are important source of carbohydrates, vitamins, minerals, and fibers [14,15]. Eating vegetables regularly in diets can have many health benefits by reducing many health related diseases and also helps in converting the fats and carbohydrates into energy [14]. The importance of food is the reason why heavy metal accumulates in aquatic environment and end up accumulating in man. Therefore, the determination and risk analysis of heavy metals in food stuffs is an important part of nutritional and toxicological analyses. Due to industrial and agricultural processes that causes increased concentration of toxicants like heavy metals in the environment that are harmful to both plant and animals [16].

Materials and methods

Study sites

The study was conducted using fruit and vegetable samples cultivated from Bashama, Danbushiya and Danmani farms located at Kaduna South, Chikun and Igabi local government areas, respectively, in Kaduna, Nigeria. The farms supply the inhabitant of Kaduna metropolis with fruits and vegetables. The sources of irrigation water from the farms include wastewater from shallow hand dug wells, streams and river Kaduna. Urban agriculture is done in open spaces along roads, along railway lines, near industries and along landfill streams or river.

Sample collection

A total of 63 samples were used out of which, 45 fruits (Banana and Pawpaw) and vegetables (Cabbage, Garden egg and Cucumber) were collected, placed in a clean polythene bags and labeled from different farms in Bashama, Danbushiya and Danmani three times between January and April 2019. Soil samples (three samples each from the different farms) were collected from the surface at the depth of 0–15 cm using auger and the soil were stored in the polythene bag and labeled properly. The water (three samples each from the different farms) were also collected in a rinsed and dry bottles in the different farms. Collected samples were taken to the Botany Unit at the Department of Biological Sciences, Kaduna State University for preparation. The samples were identified and authenticated at the herbarium of Ahmadu Bello University.
Samples preparation

Soil, fruits and vegetables

The fruit and vegetable samples were washed with distilled water and were dried along with the soil samples in an oven at a temperature of 65–80°C for 4 days. After drying, the samples were then ground in mortar into fine powdery forms. The powdered samples were sieved to obtain very fine particles using a sieve of 0.5 m mesh size [17]. Then, the samples were stored in plastic bags (polyethylene) under airtight conditions until the time of digestion.

Digestion of soil, fruit and vegetable samples

1.0 g of dried powdered of the soil, fruit and vegetable samples were transferred into separately 100 ml round bottom flask and were mixed with 8 ml of a mixture of HNO₃ and HClO₄ (from 100 ml of conc. HNO₃ and 40 ml of 60% HClO₄) and digested at 210°C for 2 h and 30 min on a Kjeldahl digestion apparatus [18,19]. The digested samples were then allowed to cool at room temperature. The mixture was cooled and filtered through a Whatman filter paper into a 50 ml volumetric flask and made up to mark with distilled water. The volume of the filtrate was made up to 100 ml using distilled water and the solutions were further diluted 10 times before determinations of lead (Pb), iron (Fe), zinc (Zn), copper (Cu) and cadmium (Cd) using Microwaves Plasma Atomic Emission Spectrometer (MP-AES).

Digestion of wastewater samples for heavy metals determination

The wastewater samples were digested as follows. The sample, 100 cm³, was transferred into a beaker and 5 ml concentrated HNO₃ was added. The beaker with the content was placed on a hot plate and evaporated down to about 20 ml. The beaker was cool and another 5 ml concentrated HNO₃ was also added. The beaker was covered with watch glass and returned to the hot plate. The heating was continued, and then small portion of HNO₃ was added until the solution appeared light colored and clear. The beaker wall and watch glass were washed with distilled water, and the samples were filtered to remove any insoluble materials that could clog the atomizer. The volume was adjusted to 100 cm³ with distilled water [20]. The concentrations of Cu, Zn, Fe, Cd and Pb in the filtrate of water were estimated using the MP-AES as described in the manufacturer’s instruction manual.

Determination of metal contents in the digested samples

Analytical procedure

Sodium borohydride (NaBH₄) and hydrochloric acid (HCl) as blank solutions were used to record the background optical emission. For each measurement, sample solution (0.8 ml, with HCl) and NaBH₄ solution were pumped into the pipes, respectively, and subsequently mixed in the 3D-printed reaction coil to produce volatile species of analytes. Carrier gas helium was supplemented after the reaction coil to flush the analytes into the 3D-printed two-stage GLS for separating analyte-containing gaseous species from the liquid phase and matrix effectively. The gaseous species were finally transported into the hollow electrode (HE) and guided inside the point discharge, and directly diffused from inside out of the microplasma, with sufficiently participating in interaction and excitation in the microplasma to obtain high excitation efficiency and stability following the MP-AES Manufacturer’s procedure.

Calibration standard solutions were prepared for each of the metals which were prepared from the MP-AES standard stock solutions that contained 1000 mg/l. These intermediate standards were diluted with distilled...
water to obtain five working standards for each metal of interest. Then, Fe, Cu, Zn, Cd and Pb were analyzed with MP-AES. Three replicate determinations were carried out on each sample. All the above listed metals were determined by emission/concentration mode and the instrument read out was recorded for each solution. The same analytical procedure was employed for the determination of elements in the digested blank solutions.

**Quality control/quality assurance**

Several steps were taken to improve the quality control and assurance such as the use of a method blank going through all of the steps with the real samples and the samples with a controlled matrix. The use of multi-elemental controls were added with most of the MP-AES analysis to evaluate the machines performance and to further improve the instrumental progress also internal standards and replicates were used. Multiple samples were also prepared to minimize human error. When it came to equipment and chemicals, all reagents and chemicals were of high quality as glassware was thoroughly cleaned with detergent and deionized water before use and the samples were only kept in polypropylene tubes. Care was taken that the chemicals and other equipment were sufficiently clean.

**Risks assessment factors**

**Transfer factor**

Soil to plant transfer factor was calculated as the ratio of heavy metal in soil to total heavy metals in plant as shown the following equation:

$$\text{TF} = \frac{C_{\text{soil}}}{C_{\text{plant}}}$$  \hspace{1cm} (1)

where TF is the transfer factor, $C_{\text{soil}}$ is the heavy metal concentration in soil, and $C_{\text{plant}}$ is the heavy metal concentration in plant [21].

**Estimated daily intake of metal**

The EDIM was calculated as a product of concentration of metal in vegetable, conversion factor and daily vegetable intake per average body weight as in the following equation:

$$\text{EDIM} = \frac{C_{\text{metal}} \times C_{\text{factor}} \times C_{\text{food}} \times \text{intake(DIM)}}{\text{Average bodyweight}}$$  \hspace{1cm} (2)

where EDIM is the estimated daily intake of metal, $C_{\text{metal}}$ is the heavy metal concentration in vegetables (mg/kg); $C_{\text{factor}}$ is the conversion factor (0.085); DIM is the daily vegetable intake, 65 g/day; average body weight of 60 kg [22].

**Targeted harzard quotient**

Harzard quotient is a proportion of the probable exposure to an element and level at which no negative impacts are expected. When the hazard quotient (HQ) is > 1, it means no potential health effects are expected from exposure, but when the HQ exceed 1, it signifies potential health risks due to exposure [23].

$$\text{THQ} = \frac{\text{EF} \times \text{ED} \times \text{FIR} \times C \times 10^{-3}}{\text{RfD} \times \text{TA} \times \text{WAB}}$$  \hspace{1cm} (3)

EF = 350 days/year; ED = 54 years; FIR = 65 g/person/day; C = metal concentration (mg/kg); RfD = oral reference dose (Cd, Pb, Zn, Cu and Fe were 0.001, 0.0035, 0.3, 0.04 and 0.7, respectively) [24]; WAB is the average body weight (60 kg) and TA is average time for non-carcinogens (ED*365 days/year).

**Hazard index**

Harzard index (HI) is a vital index that assesses overall likely impacts that can be posed by exposure to more than one contaminant. When the HI is greater than 1, the exposure is likely to cause obvious health effect from consuming pollutants contain in foodstuff. The HI is the arithmetic sum of the HQs for each pollutant as shown in the equation:
HI = \sum HQ \quad (4)

**Analysis**

The statistical significance was done using analysis of variance (ANOVA) to determine the difference in the level of heavy metals in the fruits and vegetables samples from the study sites and the values of P < 0.05 were considered significant. Data were subjected to statistical analysis using the Rcommander software [25]. The mean concentrations for the various heavy metal were analyzed.

**Results**

**Concentrations of heavy metals in soil and water from the farms**

The mean concentration (mg/kg) of heavy metals (Fe, Cd, Cu, Pb and Zn) in soil and water collected from Bashama, Danmani and Danbushiya farms Kaduna State, Nigeria is shown in (Table 1), respectively. The heavy metal concentration in soil was found to be highest for Fe followed by Zn, Cd, Pb and Cu in all the studied farms. The metal concentrations ranged from 7.30 to 63.51 mg/kg for Fe, 4.13 to 7.41 mg/kg for Zn, 2.65 to 4.62 mg/kg for Cd, 1.123 to 3.25 mg/kg for Pb and 0.45 to 1.45 mg/kg for Cu.

The heavy metal concentrations in water were found to be highest for Fe and Pb, which were higher than the WHO standard in agricultural water of 0.3 and 0.01 mg/l, respectively, while those of Cu, Zn and Cd were below the recommended limit. The metal concentrations in water ranged from 0.02 to 0.03 mg/l, 3.23 to 3.42 mg/l, 0.06 to 0.07 mg/l, 0.13 to 0.21 mg/l and 0.07 to 0.1 mg/l for Pb, Fe, Cu, Zn and Cd, respectively.

**Concentrations of heavy metals in fruits and vegetables from the farms**

The heavy metal concentrations in the studied vegetables and fruits showed significant variations (Table 2). The metal concentrations ranged from 0.26 to 1.72 mg/kg for Pb, from 2.75 to 7.91 mg/kg for Fe, from 0.26 to 0.56 mg/kg for Cu, 0.1 to 1.29 mg/kg for Zn and 1.21 to 3.55 mg/kg for Cd. By comparing the concentrations of metals among the vegetables and fruits, Fe concentrations were highest in all the samples under study from all farms.

**Soil-transfer factor of fruits and vegetables in the studied farm**

The soil-plant transfer factor ranges from 0.08 to 0.53, 0.05 to 0.13, 0.18 to 0.88, 0.02 to 0.24 and, 1.87 to 5.55 mg/kg for Pb, Fe, Cu, Zn and Cd, respectively, in the fruit and vegetable samples from the selected farms.

| Samples | Pb (mg/kg) | Fe (mg/kg) | Cu (mg/kg) | Zn (mg/kg) | Cd (mg/kg) |
|---------|------------|------------|------------|------------|------------|
| **Soil** |            |            |            |            |            |
| Site A  | 3.25<sup>a</sup> | 63.51<sup>a</sup> | 1.45<sup>a</sup> | 6.98<sup>b</sup> | 0.62<sup>b</sup> |
| B       | 3.06<sup>b</sup> | 61.61<sup>b</sup> | 1.27<sup>b</sup> | 7.41<sup>a</sup> | 0.62<sup>b</sup> |
| C       | 1.12<sup>c</sup> | 57.30<sup>c</sup> | 0.45<sup>c</sup> | 4.13<sup>c</sup> | 0.65<sup>a</sup> |
| WHO/FAO | 1.0–7.0     | 15.0       | 0.6–6.0    | 5.0–10.0   | 3.0        |
| **Water** |            |            |            |            |            |
| Site A  | 0.03<sup>b</sup> | 3.42<sup>a</sup> | 0.07<sup>b</sup> | 0.21<sup>a</sup> | 0.1<sup>b</sup> |
| B       | 0.03<sup>b</sup> | 3.29<sup>b</sup> | 0.06<sup>a</sup> | 0.13<sup>c</sup> | 0.07<sup>a</sup> |
| C       | 0.02<sup>a</sup> | 3.23<sup>c</sup> | 0.06<sup>a</sup> | 0.14<sup>b</sup> | 0.07<sup>a</sup> |
| WHO/FAO | 0.01        | 0.3        | 2          | 5          | 0.02       |
**Table 2.** Heavy metal concentration (mg/kg) with ± standard deviation in the vegetable and fruit samples from the farms.

| Samples      | Pb      | Fe       | Cu       | Zn       | Cd       |
|--------------|---------|----------|----------|----------|----------|
| Cucumber     |         |          |          |          |          |
| Site A       | 0.58ab  | 6.14ab   | 0.46ab   | 0.97ab   | 2.29b    |
| B            | 0.52ab  | 7.82ab   | 0.56ab   | 1.29ab   | 2.22b    |
| C            | 0.56ab  | 6.84ab   | 0.40ab   | 1.0ab    | 3.55ab   |
| Cabbage      |         |          |          |          |          |
| Site A       | 0.26b   | 3.0b     | 0.26b    | 0.55cd   | 1.19c    |
| B            | 0.28b   | 2.92b    | 0.32ab   | 0.42bc   | 1.87bc   |
| C            | 0.28b   | 2.75b    | 0.31ab   | 0.62a    | 1.21c    |
| Garden egg   |         |          |          |          |          |
| Site A       | 1.69a   | 7.29a    | 0.41ab   | 0.94ab   | 1.86bc   |
| B            | 1.62a   | 3.74b    | 0.30ab   | 0.78bc   | 2.95b    |
| C            | 1.72a   | 5.70ab   | 0.34ab   | 0.63bc   | 3.19a    |
| Paw paw      |         |          |          |          |          |
| Site A       | 0.58ab  | 4.93ab   | 0.34ab   | 0.89abc  | 2.86b    |
| B            | 0.63ab  | 7.91a    | 0.39ab   | 0.72bc   | 3.12a    |
| C            | 0.58ab  | 5.77ab   | 0.35ab   | 0.78bc   | 2.26b    |
| Banana       |         |          |          |          |          |
| Site A       | 0.53ab  | 7.27a    | 0.37ab   | 1.11ab   | 3.42a    |
| B            | 0.56ab  | 4.51ab   | 0.32ab   | 0.68a    | 2.63b    |
| C            | 0.57ab  | 4.94ab   | 0.33ab   | 0.10a    | 1.59bc   |
| WHO/FAO      | 0.3     | 42.5     | 4.0      | 6.0      | 0.2      |

Different letters down the columns within the same heavy metal represent significant differences at p < 0.05 [27].

The finding showed that Cd had the highest transferability factors followed by Cu, Pb, Zn and Fe, while cucumber in Danbushiya farm had the highest absorbing capability as shown in Table 3.

**Estimated daily intake of heavy metals from consuming vegetables and fruits from the farms**

The total estimated intake rate for vegetables and fruits calculated was shown in Table 4. The estimated daily intake of Pb, Fe, Cu, Zn and Cd through consumption of vegetables and fruits ranged from 0.02 to 0.05 mg/kg/day, 0.25 to 0.72 mg/kg/day, 0.02 to 0.38 mg/kg/day, 0.01 to 0.12 mg/kg/day and 0.11 to 0.33 mg/kg/day, respectively. Cucumber from Danbushiya contributes the highest permissible maximum tolerable daily intake (PMTDI) for Cd compare to other samples. Only Cd had the highest PMTDI among other metals, with cucumber from Danbushiya contributing the highest PMTDI.

**Targeted HQ and HI from metal exposure from the studied samples**

The calculated target HQ (THQ) and HI values were presented in (Table 5). The findings showed that the THQ values of all heavy metals were <1 in all the vegetable and fruit samples from the three farms except for Cd in all samples from the different farms having THQ > 1. The result for HI showed that all samples have HI values >1, only cabbage from Bashama and Danbushiya have HI lying within 1.

**Discussion**

The findings from this study showed the heavy metals (Pb, Fe, Cu, Zn and Cd) in soil, water, the different vegetables and fruits from the three (Bashama, Danmani and Danbushiya) waste water irrigated farms, Kaduna metropolis, Nigeria and the risk assessment associated with the heavy metals in the samples.

The study suggests the high concentrations of heavy metals in soil samples from the farms to be due to effluents from mechanical workshops (lubricating oil, tyre and fuel
Table 3. Transfer factor of vegetables and fruit samples relative to their soil sources in the farms.

| Samples   | Pb  | Fe  | Cu  | Zn  | Cd  | Efficacy |
|-----------|-----|-----|-----|-----|-----|----------|
| Cucumber  |     |     |     |     |     |          |
| Site A    | 0.18| 0.10| 0.32| 0.14| 3.72| 0.89     |
| B         | 0.17| 0.13| 0.44| 0.17| 3.59| 0.90     |
| C         | 0.50| 0.12| 0.88| 0.24| 5.48| 1.44     |
| Cabbage   |     |     |     |     |     |          |
| Site A    | 0.08| 0.05| 0.18| 0.08| 1.93| 0.46     |
| B         | 0.09| 0.05| 0.25| 0.06| 3.03| 0.69     |
| C         | 0.25| 0.05| 0.68| 0.15| 1.87| 0.60     |
| Garden egg|     |     |     |     |     |          |
| Site A    | 0.17| 0.11| 0.28| 0.13| 3.02| 0.74     |
| B         | 0.17| 0.06| 0.24| 0.11| 4.78| 1.07     |
| C         | 0.51| 0.10| 0.75| 0.15| 3.19| 0.94     |
| Paw paw   |     |     |     |     |     |          |
| Site A    | 0.18| 0.08| 0.23| 0.13| 4.64| 1.05     |
| B         | 0.21| 0.13| 0.31| 0.10| 5.06| 1.16     |
| C         | 0.53| 0.10| 0.77| 0.19| 3.49| 1.02     |
| Banana    |     |     |     |     |     |          |
| Site A    | 0.16| 0.11| 0.25| 0.16| 5.55| 1.25     |
| B         | 0.18| 0.07| 0.25| 0.10| 4.26| 0.97     |
| C         | 0.51| 0.09| 0.73| 0.02| 2.45| 0.76     |
| Average   | 0.26| 0.09| 0.45| 0.13| 3.74|          |

Transfer Factor values > 1 defines the pollution range, while transfer factor values < 1 defines contamination range [28].

combustion), block industries discharged into the surrounding water body without proper treatment and may also be as a result of application of excess agrochemical [29]. High Fe and Zn concentration could be as a result of use of fertilizer, pesticides, organic waste dumping and use of sludge in the area [30]. Blessings [22] carried out similar study on irrigated vegetable farm in Challawa area Kano and their findings were similar to those in this study.

The concentration of heavy metals in water samples from the three farms was higher for Pb, Fe and Cd than the standard, while those of Cu and Zn were lower. The possible sources for Pb might be from car combustion and mechanical shop runoff as the farms are close to high way and Old Panteka mechanical workshop.

The differences in the heavy metal concentration may be as a result of the difference in absorption capacity by different vegetables and fruits and their translocation within plant [31,32]. The concentrations of Pb (0.26–1.69 mg/kg) and Cd (1.19–3.55 mg/kg) in all vegetables and fruits were found to be higher than the WHO/FAO recommended levels of contaminants in food (FAO/WHO, 1996). It is important to know the concentration of heavy metals in these sites due to the anthropogenic activities carried out around the farms, knowing its levels regard to consumption of the produce from the areas. The high levels of the heavy metals in the vegetables and fruits may be due to location of the farm along traffic road, lubricating oil, tyre and brake and fuel combustion which may affect the grown vegetables and fruits [29]. A research conducted in Dar es Salaam, Tanzania, also observed high Pb and Zn in the studied vegetables [33].

In this study, there was high variation in Pb level. Though, the concentrations are quite generally higher than the permissible levels by FAO/WHO of 0.30 mg/kg in the studied samples except for cucumber from all sites which were below the permissible level (0.26–0.29 mg/kg). Similar result was obtained by [34], where the Pb accumulation in vegetables was found to be within the range of 0.34–1.84 mg/kg. Vegetables grown on contaminated soils, through sewage sludge/waste water application, causes lead contamination in vegetables [35].
Table 4. Estimated daily intake (mg/kg/day) of heavy metals from consumption of vegetables and fruits from the sites.

| Samples     | Pb  | Fe  | Cu  | Zn  | Cd  |
|-------------|-----|-----|-----|-----|-----|
| Cucumber    |     |     |     |     |     |
| Site A      | 0.05| 0.57| 0.04| 0.09| 0.21|
| B           | 0.05| 0.72| 0.05| 0.12| 0.20|
| C           | 0.05| 0.63| 0.04| 0.09| 0.33|
| Cabbage     |     |     |     |     |     |
| Site A      | 0.02| 0.28| 0.02| 0.05| 0.11|
| B           | 0.03| 0.27| 0.03| 0.04| 0.17|
| C           | 0.03| 0.25| 0.03| 0.06| 0.11|
| Garden egg  |     |     |     |     |     |
| Site A      | 0.05| 0.67| 0.38| 0.09| 0.17|
| B           | 0.05| 0.34| 0.03| 0.01| 0.27|
| C           | 0.05| 0.50| 0.03| 0.06| 0.29|
| Paw paw     |     |     |     |     |     |
| Site A      | 0.05| 0.45| 0.12| 0.08| 0.26|
| B           | 0.06| 0.73| 0.14| 0.07| 0.29|
| C           | 0.05| 0.53| 0.13| 0.07| 0.21|
| Banana      |     |     |     |     |     |
| Site A      | 0.05| 0.67| 0.03| 0.10| 0.31|
| B           | 0.05| 0.42| 0.03| 0.06| 0.24|
| C           | 0.05| 0.45| 0.03| 0.01| 0.15|
| PMTDI       | 0.21| 15.0| 2.0 | 15.0| 0.064|

Cadmium is a non-essential element in foods and natural waters and with high toxicity that accumulates principally in the kidneys and liver [36,37]. Higher values have been previously reported for leafy vegetables cultivated along road sides (0.27 mg/kg) by [35]. According to [38], the safe limit for Cd consumption in vegetables is 0.2 mg/kg. The concentration of cadmium in this study was above the permissible limit with highest level of Cd recorded in cucumber (3.55 mg/kg) from Danbusiya site and the least was recorded in cabbage (1.19 mg/kg) from Bashama site. This could be due to the high sensibility and transport efficiency of cucumber plant [39].

Zinc is an essential element in human diet and it is required to maintain the functioning of the immune system for normal growth and development. It is also a natural constituent of soils in terrestrial ecosystem and it is taken up actively by roots [37]. Deficiency of Zn from insufficient dietary intake reduced absorption, excessive excretion or inherited defects in zinc metabolism. The estimated daily intake for zinc were found in all samples but does not exceed the PMTDI permissible limit.

The health risk assessment was calculated to assess the level of exposure from ingestion of heavy metal in some fruits and vegetables produce from Bashama, Danmani and Danbusiya farms. Different routes of exposure of heavy metals to human do exist, yet the most significant is the food chain. The estimated daily intake of metals (EDIM), THQ and health index (HI) were calculated and the EDIM showed that Cd (0.11–0.33 mg/kg) was consumed above the PMTDI endorsed by WHO/FAO of 0.064 mg/person/day. This was in contrast with the work of [22], where the estimated daily intake of cadmium (0.00003) in lettuce consumed at chalawwa area, kano was less than that obtained in this study. Cucumber in this study had the highest contribution to daily intake rate of heavy metals, which could be due high absorption and transfer capability. The result was similar to a report by [40] having highest contribution of heavy metals from fluted pumpkin at Eleme, Rivers State, Nigeria.

The THQ is a ratio between the measured concentration and the oral reference dose, weighted by the length and frequency of exposure; amount ingested and body weight [41].
Table 5. THQ of individual metals and their HI from consumption of the vegetables and fruits from the sites.

| Samples   | Pb  | Fe  | THQ | Cu  | Zn  | Cd  | HI  |
|-----------|-----|-----|-----|-----|-----|-----|-----|
| **Cucumber** |     |     |     |     |     |     |     |
| Site A    | 0.15| 0.01| 0.012| 0.003| 2.38| 2.56|
| B         | 0.15| 0.01| 0.015| 0.004| 2.31| 2.49|
| C         | 0.15| 0.01| 0.010| 0.003| 3.69| 3.86|
| **Cabbage** |     |     |     |     |     |     |     |
| Site A    | 0.07| 0.004| 0.007| 0.002| 1.24| 1.32|
| B         | 0.07| 0.004| 0.008| 0.001| 1.94| 2.02|
| C         | 0.07| 0.004| 0.008| 0.002| 1.26| 1.34|
| **Garden egg** |     |     |     |     |     |     |     |
| Site A    | 0.15| 0.011| 0.011| 0.003| 1.93| 2.11|
| B         | 0.15| 0.006| 0.008| 0.003| 3.06| 3.23|
| C         | 0.15| 0.008| 0.009| 0.002| 3.31| 3.48|
| **Paw paw** |     |     |     |     |     |     |     |
| Site A    | 0.15| 0.007| 0.009| 0.003| 2.97| 3.14|
| B         | 0.16| 0.012| 0.010| 0.002| 3.24| 3.42|
| C         | 0.15| 0.009| 0.009| 0.003| 2.35| 2.52|
| **Banana** |     |     |     |     |     |     |     |
| Site A    | 0.15| 0.011| 0.01 | 0.004| 3.55| 3.76|
| B         | 0.15| 0.007| 0.008| 0.002| 2.73| 2.30|
| C         | 0.15| 0.007| 0.009| 0.003| 1.65| 1.82|

THQ and HI > 1 surpasses unity, posing potential health risk.

The parameter defines the exposure duration and the risk with that period. The findings showed that HQ values of all heavy metals were <1 in all vegetables and fruits except for Cd in all samples from the three sites having THQs >1, and highest THQ was observed in cucumber (1.24) from Bashama and least observed in cabbage (3.69) from Danbushiya. When THQ value of a metal exceed 1, the population will experience health risk from exposure to that metal [33]. The high HQ observed in Cd for all vegetables and fruits has significant carcinogenic health effect to it consumers. High HQ for Cd was also reported in chawalla, kano [22,42] in vegetable species planted in contaminated soils. Lower THQ for Cd, Pb, Cu, Zn and Ni was reported by [34] in vegetables from waste water irrigated area which is contrary to this result.

Health index (HI) population via consumption of selected vegetables and fruits at Bashama, Danmani and Danbushiya indicated HI greater than one (HI > 1). Therefore, the health risk of heavy metals exposure through the food chain is considered relatively high. The HI for heavy metals in cucumber, cabbage, garden egg, paw paw and banana were above one (1), which is similar to HI of 2.80 for Cd in adult population, in yam (D. rotundata) obtained from Eleme, South, Nigeria [40]. When the HI >1, it tells us that consuming such produce can cause health effects [24,43]. This indicate that consumer’s health and quality of life may be affected in the near future as the heavy metals accumulation in long term can lead to biomagnifications.

The transfer factor in the vegetables and fruits for heavy metals in this study was quite high. The finding showed that Cd had higher transferability, while banana, paw paw and cucumber having the high absorbing capability from Bashama, Danmani and Danbushiya, respectively. In a study by [22], the transfer of Cd from soil of Challawa area in Kano State was 6.25E-05 to 2.88 and 0.52–4.71 which is comparable to the transfer factor of Cd in all the samples from the three farms. Similarly, a study by [44] indicated that the transfer of Zn (1.05–1.762) and Pb (1.20–5.519) from soil
were similar to those in this research. Vegetables have high TF due to the role played by soil electrolyte in the cause of transfer [45].

The population of these areas may be at risk from long term exposure through consumption of these vegetables and fruits because food grown on contaminated soils are more contaminated with heavy metals posing health concern [46,47]. There are many sources of heavy metals exposure in Nigeria, but the degree of toxicity to humans depends on their daily intake [22]. The repeated use of untreated water for irrigation, application of fertilizer and agrochemical products by farmers may be the main source of heavy metals in agricultural soils [48,49]. The accumulation factors differ significantly among plant species, which may be due to difference in nutrient and soil properties [50,51]. The intake level through consumption of these vegetables vary largely as a result of variation in heavy metal concentrations of the edible parts of vegetables sampled in the three farms [52].

Conclusions

The results revealed that Cd, Pb and Fe content in irrigating water were higher than the agricultural water standard. In soil, Pb, Cu and Zn have concentrations above standard in soil, while in the vegetable and fruit samples, concentration of Pb and Cd were above the set standard of 0.3 and 0.2, respectively. This may result in high health risk by the inhabitant from consumption of vegetables and fruits from the areas. The estimated daily intake of heavy metals indicates that the samples were within safe PMTDI except for Cd that exceed the limit. Also, the THQ shows that only Cd was greater than 1 in all the vegetable and fruits samples. The HI indicates that the vegetables and fruits in this study are of health concern with HI > 1. The studied samples were contaminated by the heavy metals under study as a result of excessive application of agrochemicals and also due to effluents discharge from various industries. Therefore, these studies discourage the use of waste water for irrigation of vegetables and food crops by farmers. It also suggests regular study of heavy metals in soils, water and foodstuffs to avoid extreme accumulation in the food chain. Finally, researchers should give feedback of their result to the farmers and locality from consumption of vegetables and foodstuffs from the research areas and also the health agencies should provide permissible limits for contaminants in food.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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