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Research article

Trace metals concentration in vegetables of a sub-urban industrial area of Bangladesh and associated health risk assessment

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Abstract: Trace metals contamination of vegetables in the sub-urban industrial area of Bangladsh are increasing day by day. The mostly consumed vegetables like tomato (*Lycopersicon lycopersicum*), spinach (*Spinacea oleracea*), bean (*Lablab purpureus*), brinjal (*Solanum melongena*), potato (*Solanum tuberosum*), cauliflower (*Brassica oleracea var botrytis*), cabbage (*Brassica oleracea var cupitata*), and radish (*Raphanus sativus*) were collected from industrial area. Trace metals arsenic (As), manganese (Mn), zinc (Zn), cadmium (Cd) and lead (Pb) were measured using atomic absorption spectrophotometer (AAS). The descending order of trace metals followed the order of Zn>Mn>Pb>Cd>As. The results revealed that every vegetable contained the highest concentration of Zn range from 15 ± 1.4 to 50 ± 4.0 mg/kg fresh weight. Trace metals in vegetables exceeded the permissible level of FAO and WHO standard. The non-carcinogenic and carcinogenic risks were estimated on the basis of estimated daily intake (EDI), target hazard quotient (THQ), hazard index (HI) and target carcinogenic risks (TRs). The EDI values of all trace metals were below the maximum tolerable daily intake (MTDI). Total target hazard quotient (TTHQ) were greater than 1, indicated that if people consume these types of vegetables in their diet, they might pose risk to these metals. Finally, the total cancer risks (TRs) values were 6.4 × 10^{-3} for As and 8.7 × 10^{-5} for Pb which were greater than threshold value of USEPA (10^{-6}), indicating that the consuming inhabitants of these vegetables are exposed to As and Pb with a lifetime cancer risk.

Keywords: Bangladesh; food security; trace metals; health risk; vegetables

1. Introduction

Vegetables is the most important dietary source of nutrient as it contains carbohydrates, protein, vitamin, fibers, minerals, trace elements etc. and also contain antioxidants [1]. But, it becomes deleterious to human as well as animals as it accumulates toxic metals in their tissue when grown in contaminated soil. Both natural and anthropogenic activities have been considered for the release of trace metals into the environment. The activities such as rapid industrialization, vehicular exhaustion, waste water irrigation, sludge application etc. are the causes of trace metals contamination in vegetables. Therefore, the presence of trace metals in vegetable are of great concern due to their non-biodegradable nature, long half-lives and toxicity to humans and other organisms [2–5].

Trace metals like Cd, Pb and As have been considered as the most hazardous and toxic elements in nature as they cause carcinogenic and non-carcinogenic health effects [6,7]. The most prominent chronic effect is in the skin, lungs, liver and blood systems. Various health effects such as peripheral vascular diseases, neurologic and neurobehavioral disorder, diabetes, hearing loss, portal fibrosis and hematologic disorders, arsenicosis etc. due to consumption of As was reported in different regions of the world [8,9]. Arsenical compounds cause genotoxicity to human and methylated form of As prevents DNA repair process and also produce reactive oxygen species (ROS) in spleen and liver [10]. In addition, the adverse health effects of Pb have been extensively documented as it's acute and chronic exposure could cause encephalopathy to ataxia and a reduced level of consciousness, which may lead to coma and death, weakness in fingers, wrists, or ankles and miscarriage for pregnant women learning and concentration difficulties in children and long-term exposure to human cause memory damage [11]. Further, Cd is marked potential carcinogens and mother of a number of diseases associated with cardiovascular, liver, kidney, bladder, nervous system, blood and bone diseases. It can disrupter to the endocrine system, especially reproductive hormones such as progesterone and testosterone and also increase the risk of ovarian and breast cancer [12–15]. Furthermore, Mn is necessary for the development of human but, it may cause manganism in excessive concentration [16]. The toxicity of Zn results in growth retardation, delayed sexual maturation, infection susceptibility, and diarrhea in children and affects enzymatic activity in human [17]. Environmental protection Agency EPA [18] has classified Pb and Cd as probable human carcinogens (group B2). IARC has placed Cd and its compounds in group 1 (carcinogenic to humans) and classified inorganic Pb compounds as "probably carcinogenic to humans" (group 2A) while Pb as "possibly carcinogenic to humans" (group 2B). Inorganic As is classified as a known carcinogen (USEPA group A). Therefore, it is undoubtedly important to assess the metal concentrations in vegetables and associated health risks.

The availability of trace metals in vegetables may depend on a number of factors such as physicochemical properties of soil, plant species, growth condition and state of surrounding environment and the presence of other ions [19]. Numerous industries (textiles, metals processing, electronic goods, power plant, pharmaceuticals, battery manufacturing, Pb-Zn melting, brick fields, etc.)

are situated near the selected fields. Most of the treated and untreated industrial effluents are discharged to the rivers located near to the fields. During dry season, the local farmers incorporate polluted sediment to the agricultural fields as organic matter supply. Moreover, several acres of agricultural land are irrigated with contaminated river of the study area. Several studies have reported the concentration of trace metals in vegetables of Bangladesh and some other countries [7,20–25]. However, no detailed study on the concentration of trace metals in vegetables in the study areas of Bangladesh have been conducted so far and metal toxicity data is severely insufficient to assess the health risk of trace metals from commonly consumed vegetables. Although, Jhenaidah district, Bangladesh is facing a great threat from the pollution of air, water, and agricultural land due to rapid industrialization and other anthropogenic activities. Therefore, the present study aimed to investigate the contamination levels of five trace metals (As, Pb, Cd, Mn, and Zn) in the edible parts of vegetables and to assess health risk to the local residents via the consumption of selected vegetables around the industrial area of Jhenaidah, Bangladesh.

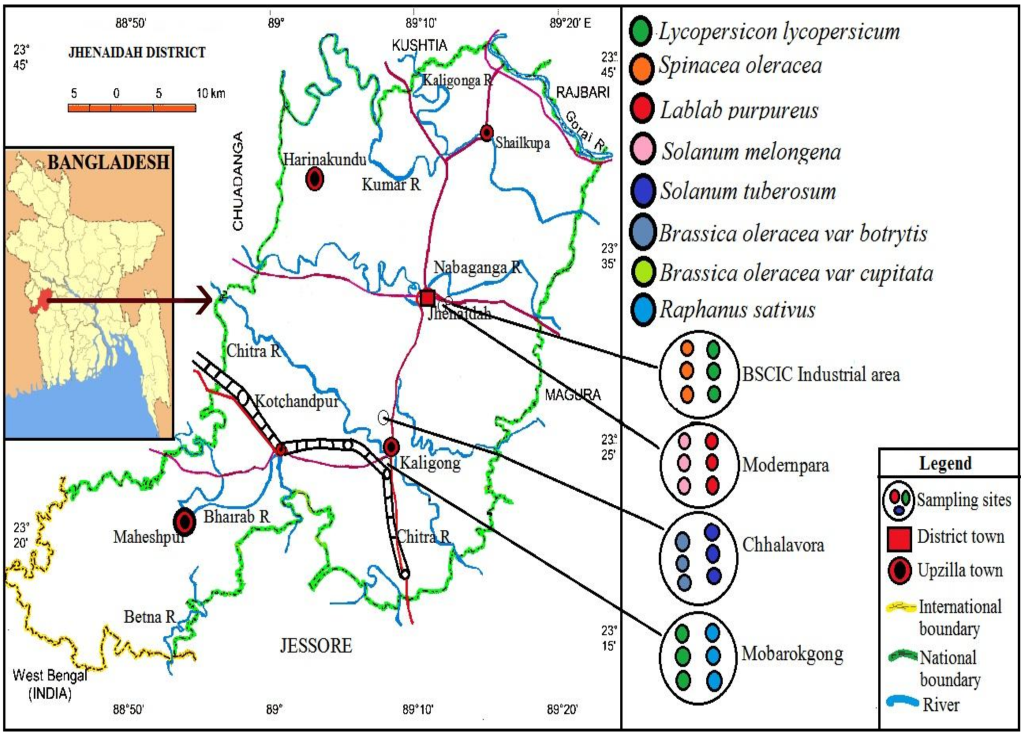

Figure 1. Map of the stydy area showing different sampling sites and variety of collected samples of Jhenaidah district in Bangladesh.

2. Materials and methods

2.1. Study area and sampling

The most consumed eight type's vegetable items, 160 samples of tomato (*Lycopersicon lycopersicum*), spinach (*Spinacea oleracea*), bean (*Lablab purpureus*), brinjal (*Solanum melongena*), potato (*Solanum tuberosum*), cauliflower (*Brassica oleracea var botrytis*), cabbage (*Brassica oleracea var cupitata*), and radish (*Raphanus sativus*) were collected in March 2015 from the industrial areas of Jhenaidah district, Bangladesh (Figure 1). Geographically this district is situated between latitudes 23°15′ and 23°45′ N and longitude 88°45′ and 89°15′ E. Average annual temperature is between 37.1 °C and

11.2 °C with annual rainfall 1467 mm. The district is bordered by Kushtia district to the north, Jessore and 24 Parganah of West Bengal (India) to the south, Magura and partly of Rajbari district to the east, Chuadanga and 24 Parganah of West Bengal (India) to the west.

2.2. Pretreatment of sample

Only the edible parts of vegetables were selected and washed thoroughly with tap water and then with deionized water to remove any soil and dirt particles. Then the samples were partially dried in air and cut into small pieces with a stainless steel knife. The small pieces of samples separately dried in an electric oven at 80 °C for 48 hours to obtain constant weight. The moisture contents in vegetables were calculated by recording the fresh and dry weights. The dried vegetable samples were crumbled with a porcelain mortar and pestle and sieved through 2-mm nylon sieve and stored in airtight clean zip lock bag in freezer condition up to chemical analysis was carried out.

2.3. Digestion of the treated samples

The samples (each of 1.0 g) were taken in a long glass test tube and digested with tri-acid mixture such as HNO_3, H_2SO_4 and $HClO_4$ (Wako Chemical Co, Japan) in the volume ratio 5:1:1 keeping the temperature at 80 °C in the paraffin oil bath for three hours up to the samples solution became transparent. The digested vegetable samples were then transferred into a Teflon beaker, and total volume was made up to 50 mL with deionized water. The digested solution was then filtered by using syringe filter (DISMIC®—25HP PTFE, pore size = 0.45 µm) Toyo Roshi Kaisha, Ltd., Japan and stored in 50-mL polypropylene tubes (Nalgene, New York).

2.4. Instrumental analysis and quality assurance

For trace metals, samples were analyzed by using atomic absorption spectrophotometer (AAS Varian SpectrAA-220) fitted with a specific hollow cathode lamp of particular metal. Direct flame (air-acetylene) was used for Pb, Mn, Cd and Zn at the wavelength 283.3, 279.5, 228.8 and 213.9 nm, respectively and As was analyzed with Hydride Vapor Generation (HVG) method using argon as a carrier gas at wavelength 193.7 nm [26]. All chemical reagents were analytical grade. Various metal stock solutions were prepared from high purity compound (99.9%) purchased from Sigma-Aldrich (St. Louis, MO, USA). To avoid contamination freshly prepared double deionized distilled water produced by three steps procedure as, distillation, deionization, and ultra purified water quality is set by high-class level (Electrical Conductivity is 0.054 µS/cm) were used. The certified reference materials (INCT-CF-3—Corn flour from the National Research Council, Canada) were analyzed to confirm analytical accuracy and good precision (relative standard deviation bellow 20%) of the applied method (Table S1).

3. Data analysis

3.1. Estimated daily intake (EDI) of heavy metals

The Estimated daily intakes (*EDI*) of heavy metals due to consumption of vegetables were calculated with the following equation:

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

where CM = Concentration of trace metal in vegetable (mg/kg fresh weight), FIR = Vegetables ingestion rate (0.17 kg/person/day) [27], BW = Average body weight (60 kg for adult) [28].

3.2. Non-carcinogenic risk

The target hazard quotient (THQ) and total target hazard quotient (*T*THQ) were used to estimate non-carcinogenic risks that were provided in the U.S. Environmental Protection Agency (USEPA) Region III's Risk-based Concentration Table [29]. The non-carcinogenic risks for each individual metal through vegetables consumption were assessed by THQ [30]. The formula used for calculating the target hazard quotient is as follows:

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

$$TTHQ_{(individual\ vegetable)} = THQ_{metal\ (1)} + THQ_{metal\ (2)} + THQ_{metal\ (3)} + \ldots + THQ_{metal\ (n)} \quad (3)$$

In order to assess the overall potential for non-carcinogenic health effects from more than one trace metal, a hazard index (HI) has been formulated based on the guidelines for health risk assessment of chemical mixtures as follows [30]:

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

where, *T*THQ = Total THQ from individual vegetable item; THQ = Target hazard quotient (dimensionless); EFr = Exposure frequency (365 days/year); ED = Exposure duration (70 years);
CM = Concentration of trace metals in vegetable (mg/kg fresh weight); FIR = Vegetables ingestion rate (170.04 kg/Person/day) [4,5]; BW = Average body weight (60 kg) [4,28]; AT = Average exposure time for noncarcinogenic effects (ED × 365 days/year); RfDo = Oral reference dose (mg/kg/day). The RfDos are 0.0003, 0.14, 0.3, 0.003 and 0.0035 mg/kg/day for AS, Mn, Zn, Cd, and Pb, respectively [31]. To determine the appropriate RfDo for THQ, it is assumed that all arsenic ions are inorganic. If value of THQ is less than the unity, the exposed population is unlikely to experience obvious adverse effects. If THQ is greater than unity there is a potential health risk [32].

3.3. Carcinogenic risk of As and Pb

Cancer risk is the probability of an individual lifetime health risk from carcinogens. The target carcinogenic risk (TR) factor (lifetime cancer risk) [30] can be calculated as,

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

where, AT = Average exposure time for noncarcinogenic effects (ED × 365 days/Year); SF = Oral Slope factor $(mg/kg/day)^{-1}$; Oral slope factor from the Integrated Risk Information System USEPA database was 1.5 $(mg/kg/day)^{-1}$ for As and 8.5×10^{-3} $(mg/kg/day)^{-1}$ for Pb [29,31].

Total cancer risk (*T*CR) of individual trace metal from all vegetables can be calculated from the following equation:

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

3.4. Statistical analysis

The data were statistically analyzed using the statistical package, SPSS 16.0 (SPSS, USA). The means and standard deviations of the metal concentrations in vegetables were calculated.

4. Results and discussions

4.1. Trace metals contamination in vegetables

The concentrations of trace metals (mg/kg fw) in the edible parts of vegetables are summarized in Table 1. The concentration of metals varied greatly among vegetable species with the descending order of Zn>Mn>Pb>Cd>As. Differences in concentrations of trace metals in different vegetables is due to the variation in absorbing and accumulating capabilities of different species [1,33,34]. The concentration of As in vegetables ranged from (0.09 ± 0.01) mg/kg in brinjal to (0.36 ± 0.10) mg/kg fw in spinach. The concentrations of As in vegetables were higher than the recommended FAO/WHO safe limit indicating As might pose health risk due to vegetables consumption. The range of As in home-grown vegetables from Samta village, Bangladesh was 0.02–0.49 mg/kg [33]. The range of As was 0.07–3.9 mg/kg in vegetables from Chandpur and Jamalpur districts [35] and <0.04–1.9 mg/kg in vegetables from Sathkhira, Rajshahi and Comilla districts [36]. Two recent works on heavy metals contamination in vegetables conducted in Bangladesh reported As concentration of vegetables as 0.2 (0.009 to 7.9) mg/kg [7] and 0.05 (0.01–0.2) mg/kg [37]. In the study area, huge amount of As contaminated ground water [38] is being used for irrigation along with various As-enriched fertilizers and pesticides for the cultivation of vegetables [33,39]. Moreover, the substance containing As might be transformed by the addition of carbon and hydrogen as a methyl group (CH_3) resulting in methyl arsines which is much more toxic to living things than the unmethylated forms [40].

The concentration of Mn ranged from (0.97 ± 0.29) mg/kg in radish to (6.9 ± 0.65) mg/kg fw in spinach (Table 1). In the previous literatures, median concentration of Mn was found as 65 mg/kg [37] and ranged from 0.18 to 2.8 mg/kg [41]. A very recent study conducted by Shaheen et al. [42] showed that the lowest amount of Mn was found in potato (6.9 mg/kg) and the highest level was observed in bean (28 mg/kg), which was higher than the present study. The concentration of Zn in all vegetables except cauliflower were higher than the FAO/WHO permissible limit (20 mg/kg) (Table 1), indicated that Zn might pose toxic effect to human health. The mean concentration of Zn in vegetables was in line with the vegetables from India, which were 5.0–5.3 mg/kg [43] and 1.9–4.8 mg/kg [44]. In the literature, Median Zn concentration in vegetable samples was found to be 50 mg/kg in a severely As-contaminated area of Bangladesh [37] and another study in Bangladesh the range was 19 to 42 mg/kg [45] which was in line with the present study.

Table 1. Concentration of trace elements (mg/kg fresh weight) in the vegetables collected from agricultural fields in Jhenaidah industrial area in Bangladesh.

Common name	Scientific name	Trace metals				
		As	Mn	Zn	Cd	Pb
Tomato	*Lycopersicon lycopersicum*	0.16 ± 0.01	4.6 ± 0.76	50 ± 4.0	0.37 ± 0.01	0.41 ± 0.03
Bean	*Lablab purpureus*	0.21 ± 0.04	2.8 ± 0.32	28 ± 3.3	0.29 ± 0.01	0.53 ± 0.05
Brinjal	*Solanum melongena*	0.09 ± 0.01	3.7 ± 0.48	25 ± 3.0	0.42 ± 0.02	0.54 ± 0.05
Cabbage	*Brassica oleracea var cupitata*	0.31 ± 0.06	6.1 ± 0.83	38 ± 3.7	0.51 ± 0.04	0.26 ± 0.02
Spinach	*Spinacea oleracea*	0.36 ± 0.10	6.9 ± 0.65	40 ± 4.1	0.48 ± 0.02	0.33 ± 0.03
Cauliflower	*Brassica oleracea var botrytis*	0.10 ± 0.02	3.3 ± 0.43	15 ± 1.4	0.30 ± 0.01	0.51 ± 0.07
Potato	*Solanum tuberosum*	0.12 ± 0.01	1.9 ± 0.27	43 ± 3.9	0.45 ± 0.03	0.57 ± 0.06
Radish	*Raphanus sativus*	0.17 ± 0.03	0.97 ± 0.29	35 ± 3.5	0.23 ± 0.02	0.49 ± 0.04
Mean values		0.19 ± 0.04	3.8 ± 0.50	35 ± 3.4	0.38 ± 0.02	0.46 ± 0.04
FAO/WHO [50]		0.10*	n/f†	20*	0.05*	0.50*

†n/f = Not found. *Permissible limit (mg/kg fresh weight).

Cadmium is a non-essential metal and the highest concentration of Cd was observed in cabbage (0.51 ± 0.04 mg/kg fw) and the lowest level was observed in radish (0.23 ± 0.02 mg/kg) (Table 1). Considering the food safety standards, Cd in vegetable species were higher than the recommended FAO & WHO permissible level (Table 1), indicating unsafe for human consumption. The Cd concentration in vegetables collected from Samta village in Bangladesh varied between 0.01 and 0.22 mg/kg [33]. The mean Cd concentration of vegetables from Matlab in Bangladesh was 0.03 mg/kg [46] which was much lower than that found in this study. Recent studies conducted in Bangladesh reported Cd concentration in vegetables ranged from 0.008 to 0.056 mg/kg fw [42], 0.001 to 1.6 mg/kg fw [47] and 0.006 to 0.3 mg/kg fw [37]. Among the vegetables, the highest concentration of Pb was found in potato (0.57 ± 0.06 mg/kg) and the lowest was found in cabbage (0.26 ± 0.02 mg/kg). The concentrations of Pb in bean, brinjal, cauliflower and potato was higher than the recommended FAO and WHO permissible limit (Table 1), which suggested that Pb might pose toxic effect due to the consumption of those vegetables. In our study, the Pb concentration was higher than the study conducted in Samata village, Jessore, Bangladesh [33] which ranged from 0.14 to 1.7 mg/kg. Some Recent studies conducted in Bangladesh where Pb concentration in various vegetable species were (0.005–0.057 mg/kg) [42], (0.03 to 6.3 mg/kg) [7] and (0.7–17 mg/kg) [37].

4.2. Health risk assessment

4.2.1. Estimated daily intake of heavy metals

The dietary exposure approach of vegetables consumption is a reliable tool for investigating a population's diet in terms of nutrients, bioactive compounds and contaminants intake, providing important information about the potential nutritional deficiencies or exposure to food contaminants [48]. The possible routes of trace metals exposure to human are oral, dermal and nasal, but oral is the main route [49]. Since, vegetables contribute about 16% of the total diet in Bangladesh [33], therefore, EDI is an important tool to evaluate health risks associated with trace metals via vegetables consumption. The EDI values of trace metals via ingestion of different vegetables are listed in Table 2. The mean values of total EDI of individual heavy metal from the consumption of all analyzed vegetables were 4.3×10^{-3}, 8.6×10^{-2}, 7.8×10^{-1}, 8.6×10^{-3} and 1.0×10^{-2} for As, Mn, Zn, Cd, and Pb, respectively which were less than the maximum tolerable daily intake (MTDI) (Table 2).

Table 2. Estimated Daily Intake (EDI) of trace elements (for adult population) through consumption of vegetabes in Jhenaidah district, Bangladesh.

Common	Trace metals				
name	As*	Mn*	Zn*	Cd*	Pb*
Tomato	4.5E-04 ± 2.4E-05	1.3E-02 ± 2.1E-03	1.1E-01 ± 1.1E-02	1.0E-03 ± 2.8E-05	1.1E-03 ± 8.5E-05
Bean	5.9E-04 ± 1.1E-04	7.9E-03 ± 9.0E-04	8.1E-02 ± 9.5E-03	8.2E-04 ± 2.8E-05	1.5E-03 ± 1.4E-04
Brinjal	2.5E-04 ± 2.8E-05	1.0E-02 ± 1.3E-03	7.3E-02 ± 8.5E-03	1.1E-03 ± 5.6E-05	1.5E-03 ± 1.4E-04
Cabbage	8.8E-04 ± 1.7E-04	1.7E-02 ± 2.3E-03	1.0E-01 ± 1.0E-02	1.4E-03 ± 1.1E-04	7.3E-04 ± 5.6E-05
Spinach	1.0E-03 ± 2.8E-04	1.9E-02 ± 1.8E-03	1.1E-01 ± 1.1E-02	1.3E-03 ± 5.6E-05	9.3E-04 ± 8.5E-05
Cauliflower	2.8E-04 ± 5.6E-05	9.2E-03 ± 1.2E-03	4.4E-02 ± 4.0E-03	8.5E-04 ± 2.8E-05	1.4E-03 ± 1.9E-04
Potato	3.4E-04 ± 2.8E-05	5.6E-03 ± 7.6E-04	1.2E-01 ± 1.1E-02	1.2E-03 ± 8.5E-05	1.6E-03 ± 1.7E-04
Radish	4.8E-04 ± 8.5E-05	2.7E-03 ± 8.2E-04	9.9E-02 ± 9.9E-03	6.5E-04 ± 5.6E-05	1.3E-03 ± 1.1E-04
EDI from all vegetables	4.3E-03	8.6E-02	7.8E-01	8.6E-03	1.0E-02
**MTDI [42]	1.3E-01	(2.0 to 5.0)E+00	6.0E+01	2.1E-02	2.1E-01

Note: *(Mean ± SD) (mg/kg body weight/day), **MTDI = Maximum tolerable daily intake

4.2.2. Non-carcinogenic health risk assessment

The estimated target hazard quotient (THQ) for non-carcinogenic risk of trace metals via eight evaluated vegetable ingestion for adults inhabitants are presented in Figure 2. The results revealed that the THQ of As in tomato, bean, cabbage, spinach, potato and radish was higher than 1 indicated that if people consume these types of vegetables in their diet, they might be at risk due to metal exposure. Potential health risks from exposure to vegetables are therefore of great concern. The descending order of *T*THQ for vegetable samples were in the order of spinach>cabbage>bean>tomato>radish>potato>brinjal>cauliflower. Total THQ of individual metal from the consumption of all vegetables contributed 61.08, 12.69, 12.39, 11.18 and 2.67% for As, Pb, Cd, Zn and Mn, respectively (Figure 3).

4.2.3. Carcinogenic health risk assessment

Due to the lack of oral slope factor of Cd, target carcinogenic risks (TRs) derived from the intake of As and Pb through the consumption of different vegetables are listed in Table 3. Target carcinogenic risks of As ranged from 8.9×10^{-4} in bean to 1.5×10^{-3} in spinach and 9.8×10^{-6} in tomato to 1.3×10^{-5} in potato (Table 3). However, total values of TR were 6.4×10^{-3} for As and 8.7×10^{-5} for Pb which were higher than the acceptable risk limit (10^{-6}) [29] indicating that the inhabitants consuming these vegetables are exposed to As and Pb with a lifetime cancer risk. Therefore, based on the results of the present study, the potential health risk for the local inhabitants due to heavy metal exposure through consumption of vegetables should not be ignored.

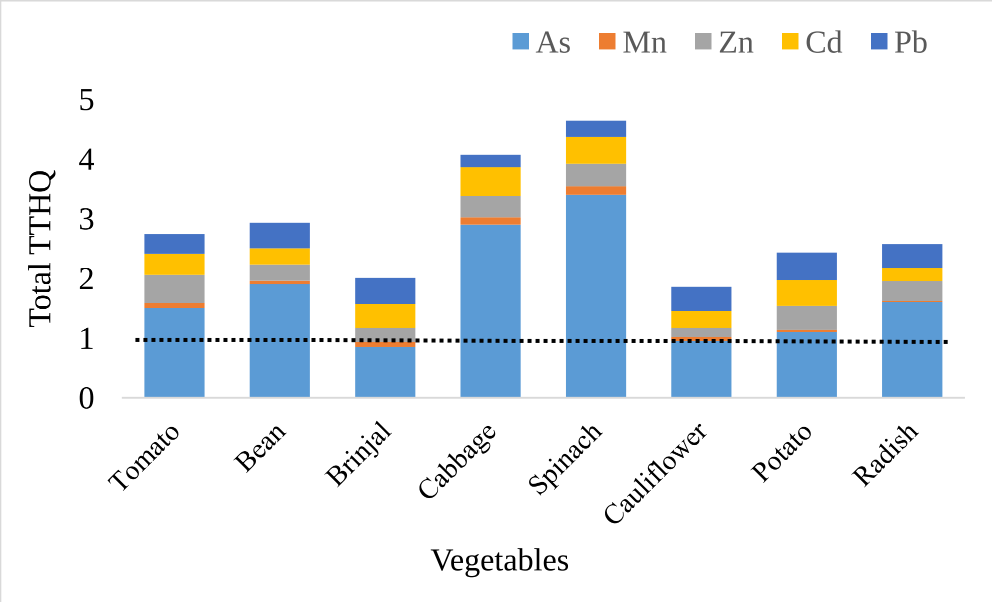

Figure 2. Total metal target hazard quotient (TTHQ) values due to the consumption of vegetables (Horizontal dot line indicates the the acceptable risk).

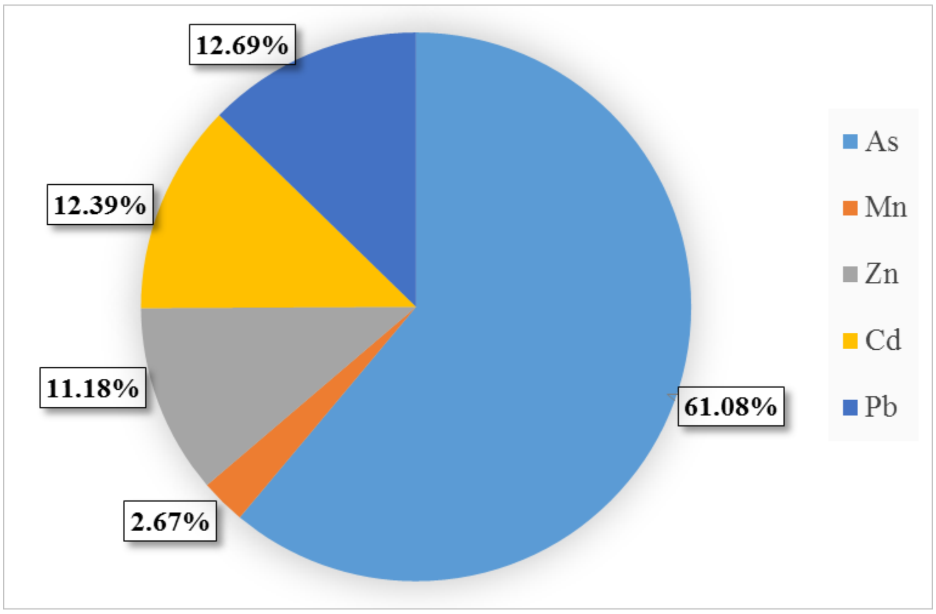

Figure 3. Total target hazard quotient (THQ) of individual metal from all vegetables consumption.

Table 3. Target carcinogenic risks (TRs) assessment via vegetable consumption for As and Pb to the population in the study area.

Common name	As*	Pb*
Tomato	6.8E-04 ± 4.2E-05	9.8E-06 ± 7.2E-07
Bean	8.9E-04 ± 1.7E-04	1.2E-05 ± 1.2E-06
Brinjal	3.8E-04 ± 4.2E-05	1.3E-05 ± 1.2E-06
Cabbage	1.3E-03 ± 2.5E-04	6.2E-06 ± 4.8E-07
Spinach	1.5E-03 ± 4.2E-04	7.9E-06 ± 7.2E-07
Cauliflower	4.2E-04 ± 8.5E-05	1.2E-05 ± 1.6E-06
Potato	5.1E-04 ± 4.2E-05	1.3E-05 ± 1.4E-06
Radish	7.2E-04 ± 1.2E-04	1.1E-05 ± 9.6E-07
***T*CRs	6.4E-03	8.7E-05

Note: *Target cancer risks (Mean ± SD), **Total cancer risk (Mean)

5. Conclusions

In conclusion, the present study revealed that the studied vegetables were contaminated by As, Zn, Cd and Pb. The concentration of trace metals were slightly higher than the FAO and WHO permissible limit, which could be a potential health concern to the local residents. The THQ and HI evidenced that the consumption of the vegetables may result in adverse non-carcinogenic health risks to the consumers. The results also showed that As and Pb in vegetables might exert lifetime carcinogenic health risk to the consumers. Only the dietary exposure of commonly consumed vegetables was taken into consideration to estimate health risk.

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Conflict of interest

The authors declare there is no conflict of interest.

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