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Heavy metal concentration and health risk assessment in commonly sold vegetables in Dhaka city market

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Abstract

This study assesses the levels of heavy metals in vegetables (*Cucumis sativus, Solanum lycopersicum, Ipomoea aquatica, Amaranthus cruentus, Basella alba, Brassica oleracea, Musa acuminata*) collected from Kawran Bazar vegetable market located in Dhaka, Bangladesh. Also, it examines potential health risks from the consumption of these vegetables. The samples were randomly collected, processed and analyzed for heavy metals using Atomic Absorption Spectrophotometer. Among the vegetables *Basella alba* had the highest heavy metal content followed by *Cucumis sativus, Amaranthus cruentus, Solanum lycopersicum, Brassica oleracea, Musa acuminate* and *Ipomoea aquatica.* The average daily intake for Cr (0.245 mg/person/day) was above the permissible maximum tolerable daily intake of 0.20 mg/person/day endorsed by WHO/FAO (2013). The hazard quotient (HQ) values for Cd in *Basella alba* (4.400) and *Brassica oleracea* (1.333), for Cr in *Ipomoea aquatica* (1.756), *Amaranthus cruentus* (1.655), *Basella alba* (3.033) and *Musa acuminate* (1.333) as well as the hazard indices (HI) for *I. aquatica* (2.537), *A. cruentus* (2.791), *B.alba* (8.883), *B. oleracea* (2.295), *M. acuminate* (2.999) exceeded unity, signifying presence of health risks from consumption of the vegetables. This study recommends regular monitoring of heavy metals in vegetables and foodstuffs to prevent excessive accrual in food chain.

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Introduction

The city of Dhaka is supplied with food items brought in from all parts of Bangladesh. The major entry points for vegetables in Dhaka city are Kawran Bazar, Gabtali, Jatrabari and Shyambazar. A research programme was undertaken to ascertain the level of contamination of heavy metals in vegetables brought to Dhaka city for consumption by the city dwellers. Though the sampling procedure was random in nature, this programme indicated potential heavy metal contamination of fresh vegetable without the knowledge of the consumers.

In Bangladesh, industrial wastes and effluents are being released at random without treatments onto soils, lakes, canals and rivers. Some of the solid wastes are also used in land fillings. And thus, they pollute soils, natural water systems, ground water and the greater part of the environment as a whole. They put human health, aquatic lives and crop production in grave danger in Bangladesh. They contain heavy metals such as copper (Cu), nickel (Ni), zinc (Zn), lead (Pb), Chromium (Cr) and Cadmium (Cd). Some of them are toxic to plants and some are toxic to both plants and animals (Gerzabek and Ullah, 1990).

The uptake of heavy metals by plants from contaminated soils are of great importance because an excess of dietary intake of some these studied metals (Pb, Zn, Cd, Cr, Ni, Cu) through the contaminated vegetables might be hazardous to the health of the consumers. The application of waste water to the crop land has been practiced for centuries and the accumulation of heavy metals in soils treated with raw municipal and industrial waste waters or the sludge separated from these waters, is now widely recognized (Chang *et al*., 1984).

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With the potential toxicity and persistent nature of heavy metals, and the frequent consumption of vegetables, it is necessary to analyze these food items to ensure the levels of these contaminants meet agreed international requirements (Radwan and Salama, 2006). So, this research program was undertaken to investigate heavy metal concentration in fresh vegetables collected from Kawran Bazar having the following key objectives:

- To determine heavy metal concentration in the studied vegetables
- To determine Average Daily Intake (ADI), Hazard Quotient (HQ) and Hazard index (HI) of heavy metals in the vegetables
- To compare the above mentioned parameters with that of maximum permissible limit of the parameters
- To calculate the health risks associated with consumption of the vegetables.

Materials and methods

Location

The vegetable samples in this study were taken from Kawran Bazar. Kawran Bazar is a wholesale market near the Farmgate area of Dhaka city containing many small sized roadside markets which play an important role in local life. There are also many mobile vegetable and fish hawkers selling their products in the area. The vegetables and fruits in this market mainly come from Narsingdi, Mymensingh, Kishoregonj, Rajshahi, Jessore etc.

Collection of samples

Seven types of common fresh market vegetable samples which are normally consumed were collected from Kawran Bazar, Dhaka, with at least 14 days interval for 2 months. The samples were then brought in the laboratory and the edible parts of the vegetables were collected. The heavy metal content was observed for evaluation of the concentration of these metals. The sample types are given below:

Processing of the samples

The collected vegetables were washed thoroughly with fresh tap water and rinsed three times with distilled water to remove surface pollutants and any items adhering to the surfaces. Samples were sliced into small pieces and open air dried on paper for about 2 hours to eliminate excess moisture. Each sample was weighed, dried in an oven at 80 °C for several hours and reweighed to constant weight. The dried sample was ground in a mortar until it could pass through a 0.2 mm mesh sieve and stored in clean and dry polyethylene bags.

Digestion of the samples

250 mg of sample was digested with 20ml of HNO_3 and 5 ml of $HClO_4$ on a hot plate. After digestion, the samples were cooled, filtered and made up to 100 ml in a volumetric flask.

Analysis of the samples

Lead, zinc, cadmium, chromium, nickel and copper concentration of the studied samples were analyzed using Atomic Absorption Spectrophotometer (AAS).

Average daily intake (ADI)

The ADI of a heavy metal was calculated as a product of average vegetable daily consumption per person, percentage of dry weight of vegetables, and average heavy metal concentration per dry weight vegetable as shown in the following equation:

$$ADI = Av_{consumption} \times \%\, DW_{vegetable} \times C_{heavy\ metal},$$

where ADI is average daily intake of heavy metal per person per day (mg/person/day), $Av_{consumption}$ is average daily consumption of vegetable per person per day (g/day), % $DW_{vegetable}$ is percentage of dry weight of vegetable (% DW = [(100 − % moisture)/100]) and $C_{heavy\ metal}$ is average heavy metal concentration of dry weight vegetable (mg/g). The

Table I. Description of the collected and analyzed vegetable samples

Common name	Local name	Scientific name	Edible parts
Cucumber	Shosha	*Cucumis sativus*	Fruit
Tomato	Tomato	*Solanum lycopersicum*	Fruit
Water spinach	Kalmi	*Ipomoea aquatica*	Shoot (Leaf and stem)
Red amaranth	Lal shak	*Amaranthus cruentus*	Shoot (Leaf and stem)
Indian/Malabar spinach	Pui shak	*Basella alba*	Shoot (Leaf and stem)
Cauliflower	Fulkapi	*Brassica oleracea*	Floret (Head)
Green banana	Kacha kola	*Musa acuminata*	Fruit

average daily consumption of vegetables suggested by WHO guidelines in human diet is 300 to 350 g per person (WHO, 1989). The mean of 325 g/person/day was used in calculating the ADI values in this paper. An average weight of person was considered to be 60 kg (WHO/FAO, 2013).

Hazard quotient(HQ)

Hazard quotient is a proportion of the probable exposure to an element/chemical and level at which no negative impacts are expected. When the quotient is 1, it signifies there are potential health risks due to exposure (Bermudez *et al*., 2011). The HQ is calculated as a fraction of determined dose to the reference dose as shown in the following equation:

$$HQ = \frac{ADI}{R_f d}$$

Where ADI is the average heavy metal intake per day (mg/kg/day) and R_fD is the oral reference dose of the metal (mg/kg/day). R_fD is an approximation of daily tolerable exposure to which a person is expected to have without any significant risk of harmful effects during a lifespan. R_fD for Pb, Zn, Cu, Cd, Cr and Ni is 0.004, 0.3, 0.04, 0.0005, 0.003 and 0.02 mg/kg/day, respectively (WHO/FAO, 2013).

Hazard index (HI)

An exposure to more than one pollutant results in additive effects. Thus, hazard 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 >1, this suggests that there are significant health effects from consuming pollutants contained in a foodstuff. The HI is calculated as an arithmetic sum of the hazard quotients for each pollutant as shown in the following equation:

$$HI = \sum_{i=6}^{6} HQ = \left[\frac{ADI_{Pb}}{R_fD_{Pb}} + \frac{ADI_{Zn}}{R_fD_{Zn}} + \frac{ADI_{Cu}}{R_fD_{Cu}} + \frac{ADI_{Cd}}{R_fD_{Cd}} + \frac{ADI_{Cr}}{R_fD_{Cr}} + \frac{ADI_{Ni}}{R_fD_{Ni}}\right],$$

Where HQ is hazard quotient of a heavy metal, ADI is average daily intake of a heavy metal and R_fD is a reference dose of a heavy metal.

Statistical analysis

The results of the experiment were statistically evaluated by using ANOVA (Analysis of Variance) and Duncan's Multiple Range Test in IBM SPSS statistics version 20 (Gomez and Gomez, 1984). The letter was used for testing the significance of differences between mean values. The 0.05 level of probability was chosen for the statistical judgment.

Results and discussion

Heavy metal concentration in vegetables

The heavy metal concentrations (Cr, Cd, Cu, Pb, Zn and Ni) (mg/kg DW) in the agricultural vegetable foodstuffs are presented in table II. Heavy metal concentrations in the vegetables varied from species to species. . The metal concentrations measured for cucumber were in the decreasing order of Cd<Ni<Cr<Cu<Pb<Zn. The mean concentrations of the metals in Cucumber except for Cu and Zn were higher than the recommended limit value set by WHO (1996) (Table II). Mean concentration of Zn (73.92 mg kg^{-1}) in Indian spinach, cucumber (2^{nd} sampling), water spinach (3^{rd} sampling), red amaranth (2^{nd} and 3^{rd} sampling) and cauliflower (2^{nd} and 3^{rd} sampling) exceeded the limit value of WHO (1996) (50 mg kg^{-1}) (Table III). The higher levels of Zn observed in Indian and Bangladeshi vegetables have also been reported earlier (Tasrina *et al*., 2015; Gupta *et al*., 2013). Although Zn is an essential element for various bioactivities in the human body, its high level in the vegetables can affect consumer health negatively as reported by many authors (Sharma *et al.,* 2007; Danijela *et al.,* 2016). The sources of higher metal contents in the vegetables could be attributed to the location of the field, which is situated along the hectic road traffic/irrigated with contaminated water/use of agrochemicals or disposal of industrial wastes and effluents into the agricultural fields etc. (Kacholi and Sahu, 2018). Heavy metals like Cu and Zn in the field could be ascribed to agricultural products that were added to the soil as fertilizer, while Pb is a contaminant that is known to emanate from traffic activities, such as fuel combustion, lubricating oil, tire and brake wear, road abrasion and road runoff, which in one way or the other can impact roadside grown vegetables (Kacholi and Sahu, 2018).

Average Cd and Cr concentration in all vegetable samples exceeded the limit value of WHO (1996) (Table II and III) (except water spinach and red amaranth for Cd). The mean concentration of Ni and Pb in all vegetable samples exceeded the limit value of WHO (1996) (Table II and III) (except Ni for green banana and Pb for tomato).

The observed mean concentrations of Pb, Zn, Cd, Cr, Ni and Cu, in the 7 vegetables ranged from 0-13.33, 0-176.67, 0-8.00,0-26.67, 0-11.33, 0-15.00 mg/kg, respectively (Table II and III). Average Cu concentration in all vegetable samples (except the red amaranth samples collected in 2^{nd} to 4^{th} phase) did not exceed the limit value of WHO (1996) (Table II and III). It was observed that metal concentrations in the vegetables significantly varied ($p<0.05$) with the time of sampling. This variation could be attributed to differences in absorption capacities of the vegetables and their translocation within the plants (Gupta *et al*., 2013).

The comparison among 7 vegetables showed that Pb concentrations are in decreasing order of cucumber and Indian spinach>green banana>water spinach and cauliflower>tomato and red amaranth, Zn concentrations are in decreasing order of Indian spinach> red amaranth> cucumber> cauliflower> water spinach> tomato> green banana, Cd concentrations are in decreasing order of Indian spinach> red amaranth> water spinach and tomato>cucumber> cauliflower and green banana, Cr concentrations are in decreasing order of red amaranth> tomato> Malabar spinach>cucumber>water spinach> cauliflower> green banana, Ni concentrations are in decreasing order of red amaranth> tomato> cucumber> Indian spinach> water spinach>green banana>cauliflower, and Cu concentrations are in decreasing order of red amaranth> tomato> cucumber> Malabar spinach>green banana> cauliflower> water spinach. Pb concentration in *S. lycopersicum* and in *A. cruentus* was below detection limit. It was also observed that *Indian spinach* contains highest concentrations of Pb, Zn and Cd; *red amaranth* contains highest concentrations of Cr, Ni and Cu. Both *red amaranth* and *Malabar spinach* are leafy vegetables and it is suggested that the leafy vegetables has the highest ability to uptake and accumulate heavy metals.

The strong ability of heavy metals uptake by leafy vegetables were possibly due to the leaves being the main part responsible for photosynthesis, because higher metals were carried to the leaves by mass flow during strong transpiration. As *red amaranth* and *Malabar spinach* are dwarfish plants with leaves closer to the ground, so the leaves were easily exposed to the soil which may be contaminated with heavy metals. Furthermore, another reason for elevated concentration in leafy vegetables may be due to the atmospheric deposition of heavy metals in mining and smelting areas (Zhou *et al*., 2016). The concentration levels of Pb in *Cucumber, water spinach, Malabar spinach, cauliflower* and *green banana*; Zn in *Malabar spinach*; Cd in *tomato, water spinach, red amaranth* and *Malabar spinach*; and Cr in all vegetables exceeded the recommended levels of contaminants in foods given by FAO/WHO (2001).

The elevated heavy metal concentration levels in vegetables might be related to the contaminated soils and irrigation

Table II. Mean concentration of heavy metals in different vegetable samples (mg/kg,dw)

Name of metal	Cucumber					Tomato					Limit values*
	Phase/time of sampling					Phase/time of sampling					
	1st	2nd	3rd	4th	mean	1st	2nd	3rd	4th	mean	
	08.08.09	22.08.09	05.09.09	30.09.09	(mg kg^{-1})	08.08.09	22.08.09	05.09.09	30.09.09	(mg kg^{-1})	(mg kg^{-1}DW)
Cu	15.00	10.00	6.67	3.33	8.75 ab	6.33	10.00	10.00	0.00	6.58 a	10
Cd	0.33	0.00	0.67	0.00	0.25 a	1.00	0.00	0.33	0.00	0.33 a	0.2
Ni	3.33	3.33	6.33	0.00	3.25 a	3.33	3.33	7.33	0.00	3.50 a	0.20-2.70
Zn	36.00	56.67	50.00	0.00	35.67 ab	19.00	44.33	36.67	0.00	25.00 ab	50
Pb	0.00	0.00	13.33	0.00	3.33 a	0.00	0.00	0.00	0.00	0.001 a	0.3
Cr	3.67	3.33	4.00	16.67	6.92 a	5.67	0.00	0.00	13.33	4.75 a	2.3**
	Water spinach					Red amaranth					
Cu	3.33	6.67	3.33	0.00	3.33 a	11.67	10.00	13.33	13.33	12.08 b	10
Cd	0.67	0.00	0.00	0.00	0.17 a	0.67	3.33	0.00	0.00	1.00 a	0.2
Ni	6.00	3.33	2.67	0.00	3.00 a	5.67	3.33	11.33	10.00	7.58 b	0.20-2.70
Zn	32.33	52.00	60.67	5.33	37.58 ab	30.00	59.67	73.33	34.00	49.25 ab	50
Pb	0.00	0.00	0.00	3.33	0.83 a	0.00	0.00	0.00	0.00	0.001 a	0.3
Cr	9.33	6.67	5.00	3.33	6.08 a	26.67	0.00	10.00	13.33	12.50 a	2.3**

*WHO, 1996; **Danijela *et al.,* 2016 (Values marked in blue coloures are indicating>Limit Values and violet=alarming)
Mean values followed by the same letter (s) in a Row donot differ significantly from each other at 5% level by DMRT

Table III. Mean concentration of heavy metals in different vegetable samples (mg/kg, dw)

Name of metal	Cauliflower					Indian/Malabar spinach					Limit values*
	Phase/time of sampling					Phase/time of sampling					
	1st	2nd	3rd	4th	mean	1st	2nd	3rd	4th	mean	
	08.08.09	22.08.09	05.09.09	30.09.09	(mg kg^{-1})	08.08.09	22.08.09	05.09.09	30.09.09	(mg kg^{-1})	(mg kg^{-1}DW)
Cu	0.00	3.33	3.33	6.67	3.33 a	9.33	6.67	10.00	6.67	8.17 ab	10
Cd	0.33	0.00	0.33	0.00	0.17 a	1.00	0.00	8.00	0.00	2.25 a	0.2
Ni	0.00	3.33	3.67	0.00	1.75 a	2.33	3.33	7.67	3.33	4.17 ab	0.20-2.70
Zn	15.00	55.67	66.67	38.00	43.84 ab	3.33	43.67	176.67	72.00	73.92 b	50
Pb	0.00	3.33	0.00	0.00	0.83 a	0.00	0.00	0.00	13.33	3.33 a	0.3
Cr	3.67	3.33	3.33	10.00	5.08 a	1.33	6.67	19.33	10.00	9.33 a	2.3**
	Green banana										
Cu	0.00	0.00	6.67	6.67	3.34 a						10
Cd	0.33	0.00	0.33	0.00	0.17 a						0.2
Ni	0.00	3.33	4.00	0.00	1.83 a						0.20-2.70
Zn	1.00	15.00	46.67	0.00	15.67 a						50
Pb	0.00	10.00	0.00	0.00	2.50 a						0.3
Cr	0.00	4.67	3.30	3.33	2.83 a						2.3**

*WHO, 1996; **Danijela *et al.,* 2016 (Values marked in blue coloures are indicating>Limit Values and violet=alarming)
Mean values followed by the same letter (s) in a row do not differ significantly from each other at 5% level by DMRT

Table IV. Comparison of other reports of metal concentrations (mg/kg, DW) in vegetables

District (Country)	Sampling site description	Cr	Ni	Cu	Zn	Cd	Pb	References
Dhaka (Bangladesh)	Kawranbazar city market	6.78 (0.00-26.67)	3.58 (0.00-11.33)	6.51 (0.00-15.00)	40.13 (0.00-176.67)	0.62 (0.00-8.00)	1.55 (0.00-13.33)	This study
Dhaka (Bangladesh)	Shambazar city market	0.00-11.40	0.00-11.30	1.20-59.00	19.90-325.20	0.00-8.20	0.00-106.0	Tanjina, 2013
Dhaka (Bangladesh)	Industrial area	1.44 (0.61-3.04)	5.34 (1.61-11.7)	18.1 (8.30-34.3)	51.2 (16.3-119)	0.21 (0.009-1.05)	0.76 (0.06-3.45)	Saiful and Hoque, 2014
Dhaka (Bangladesh)	Industrial area	1.66	2.97	3.85	NA	0.62	3.89	Ahmed and Gani, 2008
Noakhali (Bangladesh)	As contaminated area	0.64 (0.18-1.91)	1.44 (0.32-4.67)	20.6 (2.1-86.3)	NA	0.058 (0.006-0.26.5)	3.7 (0.67-16.5)	Rahman *et al.*, 2013
Daboshan (China)	Near mine area	NA	NA	1.18 (0.28-3.61)	10.53 (2.34-40.2)	0.19 (0.001-0.71)	0.17 (0.01-0.39)	Zhuang *et al*., 2009
Varanasi (India)	Urban area	NA	NA	36.4 (20.5-71.2)	NA	2.08 (1.1-4.5)	1.42 (0.9-2.2)	Sharma *et al*., 2007
Permissible levels[a]		2.3[b]	0.2-2.7	10	50	0.2	0.3	

*WHO, 1996; Danijela *et al.,* 2016

water, use of fertilizer and pesticides or due to atmospheric deposition of heavy metals on the surface of the plants during their production, transportation and marketing. Different factors such as plant species, growth phase, soil type, metal species, soil condition, weather and environment greatly influence the uptake of heavy metals by crops. The metal concentrations in the leafy vegetables were slightly higher than fruit vegetables could probably be ascribed to its high foliar surface area and industrial activities. Some common vegetables including Amaranthus species are proficient of accuring high heavy metals levels from contaminated irrigating water or growing soil as reported earlier (Kacholi and Sahu, 2018). These findings suggests that many contaminated vegetables are sold in Kawran Bazar city market (Dhaka, Bangladesh) which are not safe for human consumption. A comparison of the results of this study with some other studies in home and abroad is presented in Table IV, indicating the contamination of vegetables by heavy metals.

Average daily intake (ADI) of heavy metals

The average daily intakes of six metals (Pb, Zn, Cd, Cr, Ni and Cu) were estimated according to the mean concentration of each metal in each vegetable. The ADI and the permitted maximum tolerable daily intake (PMTDI) of studied metals from the consumption of 7 vegetable samples are shown in Table V. The average values of ADI for Pb, Zn, Cd, Cr, Ni and Cu in each vegetable were 0.073, 1.551, 0.027, 0.245, 0.127 and 0.236 mg/person/day, respectively, differed significantly from each other. The ADI values shown in Table V represent that only Cr is consumed above the permitted maximum tolerable daily intake (PMTDI), whereas Pb, Cd, Zn, Ni and Cu were below the permitted value.

The maximum and minimum ADI of chromium were found as 0.546 mg/person/day in *Basella alba* and 0.089 mg/person/day in *Cucumis sativus* respectively. The presence of Cr in the diet is of great importance due to its active involvement in lipid metabolism and insulin function (Ahmed *et al*., 2015). But chronic exposure to Cr may result in liver, kidney and lung damage (Zayed and Terry, 2003). The ADI for Cr was estimated to be 0.245 mg/person/day, which represents 10.85% of the total intake of the heavy metals. The order of contribution for the Cr intake is as follows: Indian/Malabar Spinach>Water Spinach>Green Banana>cauliflower>Tomato>cucumber. Chromium is also essential micronutrient for plants, but in high concentration it could be toxic for plants, animals and humans (Chen *et al*., 2014). Besides the positive effects of Cr for human diet, especially in carbohydrate metabolism, FAO set up the limits for Cr content in vegetables, while such regulations and implications in Bangladesh are still lacking. The ADI of heavy metals indicating that these crops might pose health risks to consumers through vegetables sold in Kawran Bazar city market Dhaka, Bangladesh. The Cr toxicity affects many organs in humans, such as liver, kidney, lungs and spleen, causing severe biochemical defects and cancer. High Average Daily Intake (ADI) of heavy metals has been also reported in Bangladesh (Kacholi and Sahu, 2018).

Very low amount of heavy metals are present in human body, some are essential, and some are not. But they have well defined evidence in human metabolism (Hashmi *et al*., 2005). Lead is a non-essential element and its higher concentration in human body can be the cause of nephrotoxicity, neurotoxicity and damage to liver, lungs and spleen (Rahman *et al*., 2013; Kacholi and Sahu, 2018). Pb is a serious cumulative body poison and enters into the body system

Table V. Average daily intake of heavy metals (mg/person/day)

Name of vegetable	Pb	Zn	Cd	Cr	Ni	Cu
Cucumber	0.043 c	0.464 a	0.003 a	0.089 a	0.042 a	0.114 b
Tomato	0.0001 a	0.488 a	0.006 b	0.093 b	0.068 c	0.171 c
Water Spinach	0.043 c	1.954 d	0.008 c	0.316 f	0.156 d	0.231 d
Red Amaranth	0.0001 a	1.167 b	0.024 e	0.298 e	0.181 e	0.289 e
Malabar Spinach	0.194 d	4.324 e	0.132 f	0.546 g	0.244 f	0.478 g
Cauliflower	0.022 b	1.139 c	0.004 a	0.132 c	0.046 b	0.087 a
Green Banana	0.211 e	1.324 c	0.014 d	0.240 d	0.155 d	0.282 e
Average	0.073	1.551	0.027	0.245	0.127	0.236
PMTDI	0.21	15	0.046[a]	0.2[b]	0.3[c]	2.0

(Mean values followed by the same letter (s) in a column do not differ significantly from each other at 5% level by DMRT). [a]JECFA, 1993; [b]RDA, 1989; [c]WHO, 1996 through air, water and food. It can't be removed by washing fruits and vegetables (Divrikli *et al*., 2003). Gasoline by car exhaust, metal smelting, battery manufacturing, painting on the outside of the building and other factories that use lead emits lead into the air and mixes with the soil. Higher amount of Pb in soil may cause the availability of Pb in vegetables (Islam *et al*., 2017). Results of this study showed that among 7 species of vegetables maximum ADI of Pb was found in *Musa acuminata* (green banana) about 0.211 mg/person/day and minimum in *Brassica oleracea* (cauliflower) about 0.022 mg/person/day. In *Solanum lycopersicum* and in *Amaranthus cruentus* Pb was not in detectable level.

Zinc is a major essential element in human physiological system. Zinc is important for enzymatic function. It takes part in the synthesis of DNA, protein and insulin. Zn is also necessary for normal functioning of the cell including protein synthesis, carbohydrate metabolism, cell growth and cell division (Hashmi *et al*., 2005). But it is toxic to humans when its concentration exceeds tolerable limit. A research showed that chronic exposure to Zn and/or Cu is associated with Parkinson's disease (Gorell *et al*., 1997). The maximum ADI value of Zn is 4.324 mg/person/day found in *Basella alba* and minimum value is 0.464 mg/person/day found in *Cucumis sativus.*

Cadmium is a non-essential element in foods and it accumulates in the kidneys and liver (Divrikli *et al*., 2003). Severe diseases like tubular growth, kidney damage, cancer, diarrhea and incurable vomiting may be caused by higher concentration of cadmium. The highest and lowest ADI values of Cd in vegetable samples were found as 0.132 mg/person/day in *Basella alba* and 0.003 mg/person/day in *Cucumis sativus* respectively.

Nickel plays some role in body functions including enzyme functions. Generally, it occurs more in plants than in animal body. Trace amount of Ni activates some enzyme systems but it is toxic at higher concentration (Divrikli *et al*., 2006). Ni interferes in calcium metabolism which can cause carcinogenic effect in human body. It has also been suggested that high levels of nickel may impair absorption or utilization of iron when iron status is low (Aleksandra and Blaszczyk, 2008). The ADI values in the samples tested varied between 0.042 and 0.244 mg/person/day with the lowest observed in *Cucumis sativus* and highest observed in *Basella alba*.

Trace amount of copper is essential for normal biological activities of aminoxide and tyrosinase enzymes. On the other hand, its excessive intake may cause hemolysis, hepatotoxic and nephrotoxic effects (Hashmi *et al*., 2005). In this study, the ADI value of Cu in all tested samples were between 0.087 and 0.478 mg/person/day; with *Brassica oleracea* having the lowest value and *Basella alba* having the highest value. ADI values for Cu in the samples (0.236 mg/person/day) exceeded the recommended PMTDI (2.0 mg/person/day), which represents 10.85% of the total intake of the heavy metals. The order of contribution for the Cu intake is as follows: Indian/Malabar Spinach>red amaranth>green banana>Water Spinach>tomato>cucumber>cauliflower.

Hazard quotient (HQ)

Hazard quotient of an element represents the level at which no negative impacts are expected (Kacholi and Sahu, 2018). When the quotient is less than 1, it is assumed no potential health effects are expected from the exposure. But when it is greater than 1, this means there are potential health risks (Bermudez *et al*., 2011). The results of the HQs for individual heavy metals for each vegetable are shown in Table VI. The study showed that HQ values for Cd in *Basella alba* and *Brassica oleracea*, for Cr in *Ipomoea aquatica, Amaranthus cruentus, Basella alba* and *Musa acuminata* were above 1 which has significant carcinogenic effects on the consumers. The rest have HQ values less than 1 which does not signify any potential health risk. The findings also showed that HQ values of Pb, Zn, Ni and Cu in all the vegetable samples were below 1 and they possess no potential health effects. But potential health risks may occur when HQ values of all the heavy metals in a vegetable are considered (Zheng *et al*., 2007). So, it is important to estimate hazard index (HI) which includes harmful effects of all heavy metals contained in a vegetable.

From human health point of view, TTHQ (Total Target Hazard Quotient) values of Mn and Cu were >1 through consumption of studied vegetables reported by Shaheen *et al*. (2016) could pose carcinogenic risks to human health due to exposure to these heavy metals and the similar results of Hazard indexes considering for all heavy metals in vegetable samples of this study were also higher than 1 except *Cucumis sativus* and *Solanum lycopersicum* indicating that people would experience significant health risk if they ingest these metals through consuming the studied vegetables (Table VI).

Hazard index (HI)

The results in Table VI show that HI values of *Cucumis sativus, Solanum lycopersicum, Ipomoea aquatica, Amaranthus cruentus, Basella alba, Brassica oleracea* and *Musa acuminata* are 0.882, 0.872, 2.537, 2.791, 8.883, 2.295 and 2.999, respectively. Hazard indexes considering for all the heavy metals in each vegetable sample were higher than 1 except *Cucumis sativus* and *Solanum lycopersicum* which suggests that consumers may experience potential health hazard due to dietary intake of heavy metals. Figure I represents the vegetable samples possess health risk in the decreasing order of *Basella alba* > *Musa acuminata* > *Amaranthus cruentus* > *Ipomoea aquatic* > *Brassica oleracea* > *Cucumus sativus* > *Solanum lycopersicum*.

Table VI. Hazard quotient and hazard index for each studied sample

Names of vegetable	Hazard quotient (HQ)						Hazard index (HI) $= \sum HQ$
	Pb	Zn	Cd	Cr	Ni	Cu	
Cucumber	0.179	0.026	0.100	0.494	0.035	0.048	0.882
Tomato	0	0.027	0.200	0.517	0.057	0.071	0.872
Water Spinach	0.179	0.109	0.267	1.756	0.130	0.096	2.537
Red Amaranth	0	0.065	0.800	1.655	0.151	0.120	2.791
Indian Spinach	0.808	0.240	4.400	3.033	0.203	0.199	8.883
Cauliflower	0.092	0.063	1.333	0.733	0.038	0.036	2.295
Green Banana	0.879	0.074	0.467	1.333	0.129	0.117	2.999

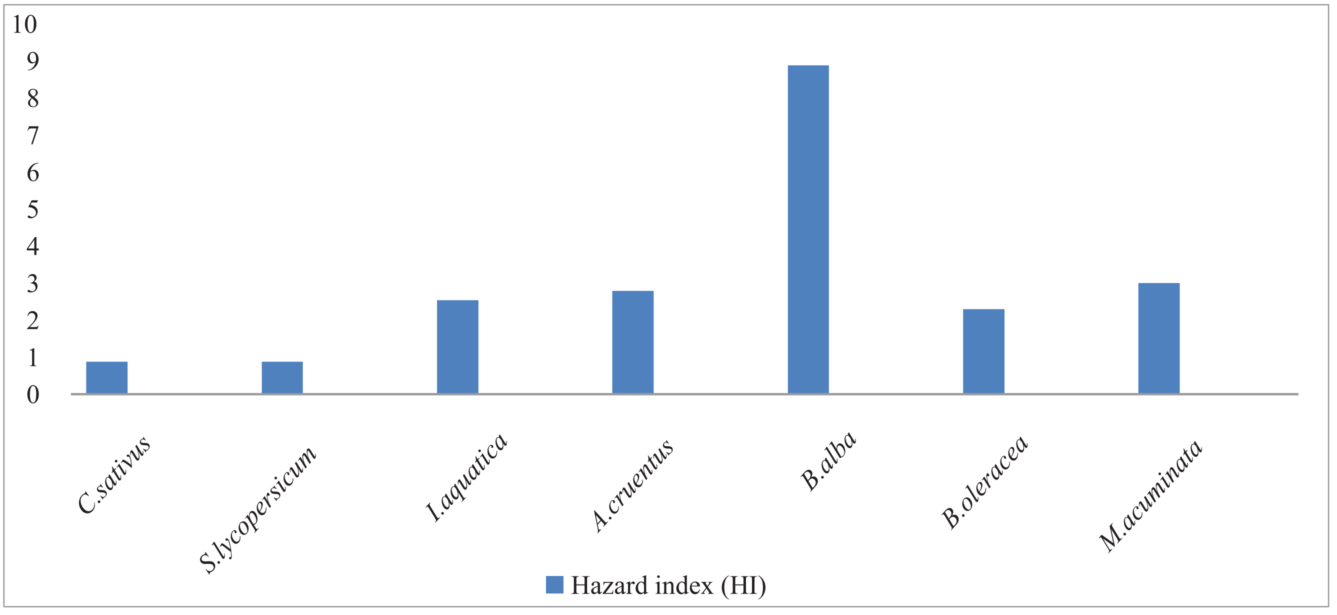

Fig. 1. Hazard index (HI) for 7 vegetable samples

vegetables, leafy vegetables and fruits in Bangladesh is 130, 166 and 44.7 g/day/person, respectively (HIES, 2011). Pb concentration in fruit (mango) (six times higher) and Cd in tomato were found to be above the recommended maximum

Conclusion

In summary, the results revealed that Pb and Cr concentrations were higher than the limit value in most of the vegetables. The average daily intake (ADI) values show that only Cr was consumed above the permissible limit. The average daily intake for Cr (0.245 mg/person/day) in this study was above the permissible maximum tolerable daily intake of 0.21 mg/person/day endorsed by WHO/FAO (2013). Average per capita daily intake of nonleafy allowable concentration (MAC) reported by Bermudez *et al*. (2011). The hazard quotient (HQ) values for Cd in *Basella alba* (4.400) and *Brassica oleracea* (1.333), for Cr in *Ipomoea aquatica* (1.756), *Amaranthus cruentus* (1.655), *Basella alba* (3.033) and *Musa acuminate* (1.333) as well as the hazard indices (HI) for *I. aquatica* (2.537), *A. cruentus* (2.791), *B. alba* (8.883), *B. oleracea* (2.295), *M. acuminate* (2.999) exceeded unity, signifying presence of health risks from consumption of the vegetables.

No matter how low levels of heavy metals are present in vegetables, their presence is not desirable. Therefore, this study suggests the regular scrutiny of the heavy metals present in foodstuff to avoid extreme accrual in the food chain and thus elude human health risks. Consequently, this study encourages environmentalists, administrators, and public health workers to create public awareness to avoid the consumption of vegetables grown in contaminated soils, hence reducing health risks.

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