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 acuminata 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 acuminata (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. acuminata (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.

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:

| 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                 |

**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 HNO₃ and 5 ml of HClO₄ 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:

$$\text{ADI} = \frac{\text{Av}}{\text{consumption}} \times \% \text{ DW}_{\text{vegetable}} \times C_{\text{heavy metal}}$$

where ADI is average daily intake of heavy metal per person per day (mg/person/day), \(\text{Av}_{\text{consumption}}\) is average daily consumption of vegetable per person per day (g/day), \(\% \text{ DW}_{\text{vegetable}}\) is percentage of dry weight of vegetable (% DW = [(100 – % moisture)/100]) and \(C_{\text{heavy metal}}\) is average heavy metal concentration of dry weight vegetable (mg/g).
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:

\[ HQ = \frac{ADI}{R_D} \]

Where ADI is the average heavy metal intake per day (mg/kg/day) and R_D is the oral reference dose of the metal (mg/kg/day). R_D 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_D 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:

\[ HI = \sum_{i=1}^{6} HQ_i = \left( \frac{ADI_{Pb}}{R_D_{Pb}} + \frac{ADI_{Zn}}{R_D_{Zn}} + \frac{ADI_{Cu}}{R_D_{Cu}} + \frac{ADI_{Cd}}{R_D_{Cd}} + \frac{ADI_{Cr}}{R_D_{Cr}} + \frac{ADI_{Ni}}{R_D_{Ni}} \right) \]

Where HQ is hazard quotient of a heavy metal, ADI is average daily intake of a heavy metal and R_D 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 (2nd sampling), water spinach (3rd sampling), red amaranth (2nd and 3rd sampling) and cauliflower (2nd and 3rd 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 0.13-3.33, 0.008-0.266, 0.08-0.176, 0.008-0.15, 0.008-0.15 and 0.008-0.15 mg/kg, respectively (Table II and III). Average Cu concentration in all vegetable samples (except the red amaranth samples collected in 2nd to 4th 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 | limit values* |
|               | 1st | 2nd | 3rd | 4th | mean (mg kg^{-1}) | 1st | 2nd | 3rd | 4th | mean (mg kg^{-1}) | (mg kg^{-1}DW) |
| Cu            | 08.08.09 | 22.08.09 | 05.09.09 | 30.09.09 | mean | 08.08.09 | 22.08.09 | 05.09.09 | 30.09.09 | mean | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cd            | 15.00 | 10.00 | 6.67 | 3.33 | 8.75 ab | 6.33 | 10.00 | 10.00 | 0.00 | 6.58 a | 6.58 |
| Ni            | 0.33 | 0.00 | 0.67 | 0.00 | 0.25 a | 1.00 | 0.00 | 0.33 | 0.00 | 0.33 a | 0.33 |
| Zn            | 3.33 | 3.33 | 6.33 | 0.00 | 3.25 a | 3.33 | 3.33 | 7.33 | 0.00 | 3.50 a | 3.50 |
| Pb            | 36.00 | 56.67 | 50.00 | 0.00 | 35.67 ab | 19.00 | 44.33 | 36.67 | 0.00 | 25.00 ab | 25.00 |
| Cr            | 0.00 | 0.00 | 13.33 | 0.00 | 3.33 a | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 a | 0.00 |
| Water spinach | 3.67 | 3.33 | 4.00 | 16.67 | 6.92 a | 5.67 | 0.00 | 0.00 | 13.33 | 4.75 a | 4.75 |
| Red amaranth  | 11.67 | 10.00 | 13.33 | 13.33 | 12.08 b | 11.67 | 10.00 | 13.33 | 13.33 | 12.08 b | 12.08 |
| Cu            | 0.67 | 0.00 | 0.00 | 0.00 | 0.17 a | 0.67 | 3.33 | 0.00 | 0.00 | 1.00 a | 1.00 |
| Cd            | 6.00 | 3.33 | 2.67 | 0.00 | 3.00 a | 5.67 | 3.33 | 11.33 | 10.00 | 7.58 b | 7.58 |
| Ni            | 32.33 | 52.00 | 60.67 | 5.33 | 37.58 ab | 30.00 | 59.67 | 73.33 | 34.00 | 49.25 ab | 49.25 |
| Zn            | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 a | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 a | 0.00 |
| Pb            | 9.33 | 6.67 | 5.00 | 3.33 | 6.08 a | 26.67 | 0.00 | 10.00 | 13.33 | 12.50 a | 12.50 |

*WHO, 1996; **Daniela et al., 2016 (Values marked in blue colours 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 Phase/time of sampling | Indian/Malabar spinach Phase/time of sampling | Limit values* |
|---------------|-----------------------------------|---------------------------------------------|---------------|
|               | 1st 2nd 3rd 4th mean              | 1st 2nd 3rd 4th mean                        | (mg kg⁻¹)     |
| 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     | 1.33 6.67 19.33 10.00 9.33 a                | 2.3**         |
| Zn            | 1.00 15.00 46.67 0.00 15.67 a      | 1.33 6.67 19.33 10.00 9.33 a                | 2.3**         |
| Pb            | 0.00 10.00 0.00 0.00 2.50 a        | 0.00 10.00 0.00 2.50 a                      | 0.3           |
| Cr            | 0.00 4.67 3.30 3.33 2.83 a         | 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 | 3.58 | 6.51 | 40.13| 0.62 | 1.55 | 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 | 5.34 | 18.1 | 51.2 | 0.21 | 0.76 | Saiful and Hoque, 2014          |
| Dhaka (Bangladesh) | As contaminated area      | 0.64 | 1.44 | 20.6 | NA   | 0.058| 3.7  | Rahman et al., 2013            |
| Daboshan (China)  | Near mine area            | NA   | NA   | 1.18 | 10.53| 0.19 | 0.17 | Zhuang et al., 2009            |
| Varanasi (India)  | Urban area                | NA   | NA   | 36.4 | NA   | 2.08 | 1.42 | 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 accruing high heavy metals levels from contaminated irrigating water or growing soil as reported earlier (Kacholi and Sahu, 2018). These findings suggest 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.

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 | 0.2 | 0.3 | 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). 1JECFA, 1993; 2RDA, 1989; 3WHO, 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 (Goerll 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 aminooxide 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.
represents the vegetable samples possess health risk in the decreasing order of *Basella alba* > *Musa acuminata* > *Amaranthus cruentus* > *Ipomoea aquatica* > *Brassica oleracea* > *Cucumis sativus* > *Solanum lycopersicum*.

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

| Names of vegetable | Pb     | Zn     | Cd     | Cr     | Ni     | Cu     | Hazard quotient (HQ) | Hazard index (HI) |
|--------------------|--------|--------|--------|--------|--------|--------|---------------------|------------------|
| 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**

### 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 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 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 acuminata* (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. acuminata* (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 foodstuffs 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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