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A Review on Heavy Metals in Vegetables Available in Bangladesh

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ABSTRACT

Background: During recent years various anthropogenic and natural activities contribute to high levels of heavy metals in environments. These toxic metals are accumulated in foods mainly in vegetables which consuming them may cause different fetal diseases among humans. Therefore, the main aims of this study were to review the heavy metals level in vegetables and to evaluate related human health risks indifferent parts of Bangladesh.
Methods: Various keywords such as heavy metals, vegetables, and health risk were used to search published articles from 2015-2020 on heavy metals in vegetables (Searching Location: Khulna, Bangladesh). Twenty two articles were selected to review the present study.
Results: In this review, the level of Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, and Pb in vegetables was considered for study which their level in many researches were above the safe limits recommended by joint FAO/WHO (Food and Agricultural Organization/World Health Organization) leading to health hazards for human being.
Conclusion: This study showed that vegetables cultivated in the contaminated areas were the main sources of heavy metals entrance to human body which pose severe health risks. Thus proper waste management systems should be suggested to reduce the heavy metals level in environments.

1. Introduction

Vegetables are the main diet for Bengali people. More than 90 types of vegetables are grown in this country [1]. These vegetables are the essential sources of vitamins, minerals, fiber, thiamin, folic acid, and niacin for the proper function of human body. Moreover, vegetables prevent the development of different type of diseases like cardiovascular diseases and gastrointestinal cancers [2, 3]. Therefore, the daily consumption of vegetables for an adult aged 31-60 years and weighing 60 kg has been prescribed 130 g [4]. However, vegetables are being contaminated with different toxic substances like heavy metals due to different anthropogenic activities and natural processes [5]. Volcanic eruption, corrosion of earth crusts, deposition of ores, and fire of forests are the main natural sources of heavy metals whereas application of agrochemicals (fertilizer, insecticide, and fungicide), manure, industrial waste water in fields, electroplating, discharge of waste batteries, mining, textile industries, metal production, cable coating, and galvanizing etc. are the anthropogenic sources of heavy metals in air, soil, and water environment [6, 7]. The level of Mn, Zn, As, Cd, and Pb is being increased by phosphate fertilizers in the agricultural fields, while manures elevate the level of Cu, Zn, and As in soil [8]. Moreover, rapid industrialization and urbanization cause increased level of traffic activities that

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contribute the accumulation of heavy metals in roadside environments [9]. When vegetables are cultivated in these polluted environments, heavy metals are absorbed by the plants and vegetables and accumulated with the vegetable and plant tissue [5, 10]. Consuming these vegetables is the major exposure of heavy metals in human body. These metals can combine with proteins, enzymes, nucleic acids, and bio-membrane which interfere the normal functions of these biomolecules due to their non-biodegradable, stability, toxicity, and bioaccumulation in nature [3, 11, 12, 13]. Although some heavy metals such as Mn, Fe, Cu, Zn, and Mo are essential for the biological functions (cofactor of enzyme) of human body, they are toxic at high concentration [14, 15]. On the other hand, some heavy metals including Cd, As, Hg, and Pb are toxic and biologically unnecessary even at low concentrations [16]. The exposure of these heavy metals may cause consciousness, renal disorder, muscular disorder, and neurological disorders such as Parkinson's disease, and Alzheimer's disease. Moreover, heavy metals disrupt brain, lungs, liver, and kidneys functions [17, 18]. Among these metals, copper is a micronutrient but long-term exposure to copper at high concentration can cause nose, mouth and eyes irritation, bad headaches, and gastrointestinal effects (vomiting and diarrhea) [13]. On the other hand, As, Cd, Pb, and Hg act as carcinogens in human body [14]. The toxic metals like Pb has no biological functions in the human body even at low concentration. Exposure to Pb can cause anemia, hypertension, brain damage, abnormal hemoglobin synthesis, bone, renal, reproductive, nervous system disorders, and children learning ability decrease, neurohematological damages, and cancers [15, 16]. Combination of Cadmium and Zinc inhibit calcium ion absorption that is harmful for bone and teeth growth [17]. Further, Cadmium causes liver and kidneys damage, prostate cancers, arthritis and bone pains, anemia and, blood pressure in humans [16].

Bangladesh is a developing country in south Asia. Industrialization and urbanization are being grown rapidly. However, the waste materials from these mills and factories are being dumped here and there. Therefore, the environments are being polluted with wastes and garbage containing toxic materials and heavy metals. Recently, many studies have been conducted to monitor the level of heavy metals in vegetables and assess the health risks due to exposure to heavy metals, while the studies have not sufficiently discussed reducing way of food contaminations. Thus, the main challenge of these studies is the lack of proper household, industrial, and other waste materials treatments. Eventually, establishment of effluent treatment plants and various waste materials separation can be conducted to reduce the heavy metals content in environments.

Food contamination is an alarming issue in developed countries. Therefore, the food safety was the burning question in our country. For this reason, the present study aimed to review the level of heavy metals in vegetables and health risks to make the people aware about environment pollutions, food safety, and a risk-free life. Some studies were selected to fairly well represent the whole Bangladesh about the contamination of vegetables with heavy metals. Basically, these type of studies are not new works in environmental science. The present study can help the researchers as well as the local inhabitants to become aware about the contamination status of heavy metals in different parts of Bangladesh compared to other studies. Moreover, the related authority become conscious about the pollution and try how to reduce the level of heavy metals in waste materials.

2. Materials and Methods

2.1. Method of data collection

This study was conducted to review the level of heavy metals in available vegetables in Bangladesh. The papers that have been published from 2015 to 2020 have been selected for the present study. Different articles were searched in Google Scholar, Scopus, Springer Link and Web of Science about assessment of heavy metals in vegetables, determination of the level of heavy metals in vegetables available in Bangladesh, health risk assessment of heavy metals in vegetables, level of heavy metals in vegetables: A review, etc. Some heavy metals (Cr, Mn, Fe, Ni, Cu, Zn, As, Cd, and Pb), etc. Table 1 shows common vegetables and analyzed heavy metals.

2.2. Study areas

Bangladesh is a country located in South Asia which lies between 20°34′-26°38′north latitudes and 88°01′-92°41′ east longitudes. There are eight divisions and 64 districts in Bangladesh. The eight divisions are- Rangpur, Rajshahi, Mymensingh, Sylhet, Dhaka, Khulna, Barisal, and Chittagong (Figure 1).

Figure 1: Geographical locations of the study areas

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In this study, eight divisions have been fairly covered for the investigation of heavy metals in vegetables. Lalmonirhat district lies in Rangpur division; Bogra, Pabna, and Rajshahi district lie in Rajshahi division; Mymensingh and Tangail district lie in Mymensingh division; Sylhet district lie in Sylhet division; Gazipur and Dhaka district lie in Dhaka division; Bagerhat, Jashore, Kushtia, Khulna, and Jhenaidah district lie in Khulna division; Patuakhali district lie in Barisal division, and Chittagong district lie in Chittagong division. The geographical locations of the study areas eight divisions have been shown in Table 1.

Table 1: Geographical locations of the study areas

Division	Longitude	Latitude	Area (km^2)
Rangpur	25°50′N	89°00′E	16,184.99
Rajshahi	25°00′N	89°00′E	18,174.40
Mymensingh	24°10′N	90°25′E	10,584.00
Sylhet	24°30′N	91°40′E	12,298.40
Dhaka	24°10′N	90°25′E	20,508.80
Khulna	22°55′N	89°15′E	22,284.22
Barisal	22°30′N	90°20′E	13,225.20
Chittagong	22°55′N	91°30′E	33,771.18

2.3. Heavy metals analysis

Heavy metals can be determined by various methods. Generally, the vegetable samples are digested and the content of heavy metals are estimated. A general procedure for heavy metal analysis has been described as follows: A fixed amount of vegetable (1g or 0.5g) sample was taken and was digested by a mixture of HNO_3 and H_2O_2; HNO_3, H_2SO_4, and $HClO_4$; HCl and HNO_3; HNO_3; HNO_3 and $HClO_3$ (Table 2). Then the samples were filtered and diluted with deionized water. Heavy metals concentration in vegetables were determined by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) or Atomic Absorption Spectroscopy (AAS). The methods, chemicals, reaction conditions, and the instruments for heavy metal analysis have been shown in Table 2.

2.4. Types of heavy metals in vegetables

Vegetables are the common foods in human diet. Most of the people in Bangladesh consume vegetables regularly. But unfortunately, the vegetables are being contaminated with toxic heavy metals. These heavy metals are entered into the food chain and transferred to human body. In this study, the obtained data of heavy metals in vegetables from various area indicated the contamination status of these toxic metals. Common vegetables and the detected heavy metals have been shown in Table 3.

3. Results and Discussion

3.1. Heavy metals contents in vegetables

During recent years, food safety has been become a great challenge for Bangladesh due to lack of proper management of industrial and household waste materials. In addition, toxic materials are being accumulated with foods that are harmful for human health. Therefore, this study was conducted to raise awareness among the people about their food safety. The results of the published articles from 2015 to 2020 have been shown in Table 4.

Alam *et al*. (2019) showed that the concentrations of Mn, Fe, Cu, Zn, Cd, and Pb ranged from 28.88 to 136.40 mg/kg, 14.65 to 35.89 mg/kg, 17.24 to 21.84 mg/kg, 29.60 to 64.80 mg/kg, 0.05 to 0.08 mg/kg, and 0.20 to 1.00 mg/kg, respectively (Table 4). The average concentrations of the heavy metals were below the safe limit. The higher content of Cd was found in eggplant. The highest levels of Cu, Mn, Cd, and Pb were noticed in vegetables and the values were 19.59, 45.85, 0.06, and 0.54 mg/kg respectively (Figure 2a). These values were above the safe limit. The maximum amount of Cu and Pb content was observed in ridge gourd. Moreover, the highest amount of Zn and Cd was found in radish and eggplant, respectively [19]. Haque *et al*. (2018) studied on heavy metals in tomato and high concentration of Cu (43.10 mg/kg) was noticed [20]. Furthermore, the highest concentration of Cr was observed in tomato (380.20 mg/kg) in Mymensingh (Table 4). This fruit vegetables were cultivated in industrial waste soil where the average value of Cr was found 79.43 mg/kg which was higher than the world safe limit (70 mg/kg) [33]. This value was above the safe limit (2.30 mg/kg) recommended by joint FAO/WHO due to the presence of higher concentration of DTPA (Diethylene triamine penta acetic acid) in soil [20, 43]. Rahman *et al*. (2020) determined the heavy metal concentrations in vegetable samples available in Bangladesh. The average value of Mn, Fe, Cu, Zn, Cd, and Pb were measured 30.83, 429.27, 9.91, 32.19, 0.58, and 8.88 mg/kg, respectively in vegetables. It was found that the mean concentrations of Zn (32.19 mg/kg), Cd (0.58 mg/kg), and Pb (8.88 mg/kg) were above the safe limit. Among these metals, the highest amount of Fe was found in red spinach (807.12 mg/kg) (Table 4). This study also showed that Fe is more abundant in leafy vegetables. The content of Fe in leafy, fruit, and root vegetables were 659.14, 358.60, and 270.07 mg/kg, respectively [21]. Ahmed *et al*. (2018) showed that the mean concentrations of Cr, Cu, Zn, As, Cd, and Pb in the vegetables was 5.59, 16.58, 51.78, 0.80, 0.12, and 6.04 mg/kg, respectively (Figure 2b). The lowest concentration was found for Cd (0.12 mg/kg). The level of all the metals were above the safe limit. As a result, long term exposure to these metals interrupt the biological processes in human body [22]. Ahmed *et al*. (2019) carried on another analysis in Gazipur and observed that the mean values of Cu, Zn, As, Cd, and Pb were above the safe limit found in dry and wet season. Moreover, high level of Cr was noticed in dry season (19.34 mg/kg). The mean values of Cu, Zn, As, Cd, and Pb in dry season were 14.80, 62.73, 1.26, 0.34, and 6.27 mg/kg respectively whereas 16.60, 51.77, 0.80, 0.13, and 6.04 mg/kg, for wet season (Table 4).

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Table 2: Methods, chemicals, reaction conditions, and instruments for heavy metals analysis in vegetables

Serial no.	Location	Method	Chemicals	Temp. (°C)	Instrument	Ref.
1	Sylhet	Wet Digestion	HNO_3, $HClO_3$	--	AA-7000	[19]
2	Mymensingh	Wet Oxidation	HNO_3, $HClO_4$	180-200	AA-7000	[20]
3	Lalmonirhat	Wet Digestion	HNO_3, $HClO_4$, H_2SO_4	80	AA-AT 1000	[21]
4	Gazipur	Wet Digestion	HNO_3, H_2O_2	120–130	ICP-MS	[22]
5	Gazipur	Wet Digestion	HNO_3, H_2O_2	120–130	ICP-MS	[23]
6	Patuakhali	Microwave Digestion	HNO_3, H_2O_2	--	ICP-MS	[24]
7	Jhenaidah	Wet Digestion	HNO_3, H_2SO_4, $HClO_4$	80	AAS Varian SpectrAA-220	[25]
8	Chittagong	Wet Digestion	HNO_3, $HClO_4$,H_2O_2	100	AA240 FS, GTA 120-AA240Z	[26]
9	Patuakhali	Microwave Digestion	HNO_3, H_2O_2	--	ICP-MS	[27]
10	Khulna	Wet Digestion	HNO_3, $HClO_4$, H_2SO_4	80	AA-7000	[28]
11	Kushtia	Wet Digestion	HNO_3, H_2SO_4,$HClO_4$	80	AAS Varian SpectrAA-220	[29]
12	Jashore	Wet Digestion	HNO_3, H_2SO_4, $HClO_4$	80	AA-7000	[30]
13	Dhaka	Microwave Digestion	HNO_3, H_2O_2	--	ICP-MS, Agilent 7700	[31]
14	Bogra	Microwave Digestion	HNO_3, H_2O_2	--	ICP-MS	[32]
15	Dhaka	Wet Digestion	HNO_3, HCl	--	AAS	[33]
16	Rajshahi	Wet Digestion	HCl, HNO_3	180-220	AAS	[34]
17	Tangail	Microwave Digestion	HNO_3, H_2O_2	--	ICP-MS, Agilent 7700	[35]
18	Dhaka	Wet Digestion	HNO_3, $HClO_4$, H_2SO_4	80	AA-6800	[36]
19	Dhaka	Microwave Digested	HNO_3	90	AAS	[37]
20	Pabna	Microwave Digestion	HNO_3	--	FAAS, Zeeman AAS, CVAAS, novAA350, HGAAS, AA 240	[38]
21	Gazipur	Microwave Digestion	HNO_3, HF	--	ICP-MS	[39]
22	Bagerhat	Wet Digestion	H_2SO_4, $HClO_4$, HNO_3	80	AA-7000	[40]

The higher contents of Zn, As, and Pb were observed in vegetables due to textile, dye, garment, battery, and metallurgy factories. Dye and pigments used in garments, plastics, pesticides, and fertilizers might contribute the level of Cr and Cd in vegetables [23]. Islam *et al.* (2017) reported that the maximum concentrations of Ni, Cu, As, Cd, and Pb were above the reference limits. The maximum values were found as Ni (17.00 mg/kg), Cu (45.00 mg/kg), As (2.60 mg/kg), Cd (2.20 mg/kg), and Pb (8.80 mg/kg). The presence of these metals in vegetables was due to anthropogenic activities such as atmospheric deposition, agrochemicals application such as fertilizers, insecticides, and manures) in agricultural fields [24]. Islam *et al.* (2018) pointed out that the maximum amounts of Zn, As, Cd, and Pb was observed in tomato (50.00 mg/kg), spinach (0.36 mg/kg), cabbage (0.51 mg/kg), and potato (0.57 mg/kg) (Table 4). On the other hand, the mean value of Mn (6.90 mg/kg) in spinach was below the toxic limit (500.00 mg/kg) [25]. Furthermore, Hasan *et al.* (2019) analyzed the concentration of heavy metals in vegetables in Chittagong. The mean concentration was as follows: Cu (11.78 mg/kg), Zn (70.68 mg/kg), and Pb (0.59 mg/kg). The concentrations of Cu, Zn, and Pb were analyzed in soil and the concentrations were 95.00, 33.00, and 22.80 mg/kg, respectively. Moreover, the average concentration of Fe was found as 486.38 mg/kg that was higher than reference value (450.00 mg/kg). The contents of Ni were was ranged from 1.72 to 2.74 mg/kg. The lowest and the highest concentration were observed in papaya (1.72 mg/kg) and banana (2.74 mg/kg) (Table 4). Generally, these heavy metals might be contributed by ship breaking industries in this area [26, 44]. Islam *et al.* (2018) showed that the concentrations of Cr (3.90 mg/kg), Ni (12.00 mg/kg), Cu (32.00 mg/kg), As (7.90 mg/kg), Cd (0.16 mg/kg), and Pb (4.50 mg/kg) in vegetable samples which were higher than the recommended permissible levels (Table 4) [27]. Dhar *et al.* (2018) showed the highest level of Mn, Fe, Ni, Cu, Zn, As, and Pb were determined in vegetables. Among these metals, the concentrations of Ni (2.56 mg/kg) and As (0.11 mg/kg) exceeded the recommended limit (Figure 2c). Nickel can be easily absorbed by plants from soil. Moreover, the accumulation of higher content of Ni may be due to applying several inorganic fertilizers and pesticides ($NiSO_4$). The main source of As in vegetables was waste water in irrigation purposes [28]. Islam *et al.* (2017) investigated the heavy metal concentrations in common edible vegetables of industrial area in Kushtia where high level of Zn (31.66 mg/kg), As (0.22 mg/kg), Cd (0.35 mg/kg), and Pb (0.54 mg/kg) was noticed (Table 4). Generally, earth crust, metal smelting, burning fossil fuel, applying organic as along with inorganic agrochemicals and alloys etc. enhance the level of these metals [29]. Ara *et al.* (2018) found out that heavy metals in vegetables and the limit of Zn, Cd, and Pb was above the safe limits. They also showed that the maximum amount of Mn (130.18 mg/kg) was observed in tomato but lower than standard value (270.00 mg/kg). The highest concentration of Fe (446.68 mg/kg) was found in tomato which was above the safe limit (Figure 2d). Leafy vegetables contained higher content of Fe. Since As and Fe take part in photosynthesis and chlorophyll formations [30].

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Table 3: Heavy metals in common vegetables available in Bangladesh

Serial no.	Locations	Name of vegetables	Heavy metals	Ref.
1	Sylhet	Sweet potato, Radish, Ridge gourd, Eggplant	Mn, Fe, Cu, Zn, Cd, Pb	[19]
2	Mymensingh	Tomato	Cr, Mn, Fe, Cu, Zn, Pb	[20]
3	Lalmonirhat	Red spinach, Spinach, Water spinach, Cauliflower, Tomato, Papaya, Eggplant, Kholrabi, Radish	Mn, Fe, Cu, Zn, Cd, Pb	[21]
4	Gazipur	Taro, Kang kong, Helencha, Brinjal, Sponge gourd	Cr, Cu, Zn, As, Cd, Pb	[22]
5	Gazipur	Radish, Amaranth, Red amaranth, Spinach, Indian spinach, Taro, Bottle gourd, Yard long bean, Pumpkin, Kang kong, Helencha, Brinjal, Spong gourd	Cr, Cu, Zn, As, Cd, Pb	[23]
6	Patuakhali	Brinjal, Bottle gourd, Bean, Chili, Carrot, Amaranth, Pumpkin, Potato, Red amaranth, Tomato	Cr, Ni, Cu, As, Cd, Pb	[24]
7	Jhenaidah	Tomato, Spinach, Bean, Brinjal, Potato, Cauliflower, Cabbage, Radish	Mn, As, Zn, Cd, Pb	[25]
8	Chittagong	Ladies Fnger, Papaya, Bottle gourd, Teasle gourd, Banana	Cr, Mn, Fe, Ni, Cu, Zn, Cd, Pb	[26]
9	Patuakhali	Brinjal, Green amaranth, Red amaranth, Bottle gourd, Tomato, Pumpkin, Chili, Carrot, Bean, Onion, Potato, Lentil	Cr, Ni, Cu, As, Cd, Pb	[27]
10	Khulna	Cabbage, Coriander leaf, Carrot, Potato, Radish, Cauliflower	Mn, Fe, Ni, Cu, Zn, As, Pb	[28]
11	Kushtia	Carrot, Potato, Brinjal, Tomato, Bean, Papaya, Cauliflower, Spinach	Mn, Zn, As, Cd, Pb	[29]
12	Jashore	Red spinach, Spinach, Kholrabi, Radish, Tomato, Sweet gourd	Mn, Fe, Cu, Zn, Cd, Pb	[30]
13	Dhaka	Brinjal, Bottle gourd, Pumpkin, Tomato	Cr, Ni, Cu, As, Cd, Pb	[31]
14	Bogra	Bean, Cauliflower, Spinach, Brinjal, Tomato, Potato, Carrot, Chili, Bottle gourd, Cucumber, Green banana, Bitter gourd	Cr, Ni, Cu, Zn, As, Cd, Pb	[32]
15	Dhaka	Red amaranth, Mustard green, Jute leaf, Water spinach, Bottle gourd, Spinach	Cr, Fe, Ni, Cu, Zn, Cd, Pb	[33]
16	Rajshahi	Red amaranth, Indian green spinach, Water spinach, Arum leaves, Kidney bean, Eggplant, Tomato	Cr, Ni, Cd, Pb	[34]
17	Tangail	Sponge guard, Bitter gourd, Papaya, Okra, Bean, Brinjal, Chili, Bottle gourd, Cucumber, Indian spinach	Cr, Ni, Cu, As, Cd, Pb	[35]
18	Dhaka	Bitter melon, Carrot, Cauliflower, Potato, Tomato, Sweet gourd, Cucumber, Brinjal, Red amaranth, Arum, Malabar spinach, String bean, Bean	Cr, Ni, As, Cd, Pb	[36]
19	Dhaka	Tomato, Red amaranth, Cauliflower, Arum	Cr, Mn, Ni, Zn, As, Cd, Pb	[37]
20	Pabna	Potato, Red amarantha, Spinach amarantha, Carrot, Cabbage, Tomato, Brinzal	Cr, Co, Ni, Cu, Zn, As, Cd, Pb, Hg	[38]
21	Gazipur	Papaya, Eggplant, Bottle gourd, Cauliflower, Radish, Indian spinach, Jute leaf, Water spinach, Water cress	V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, Pb	[39]
22	Bagerhat	Red amaranth, Spinach, Water spinach, Cauliflower, Tomato, Pumpkin, Papaya, Brinjal, Turnip, Radish	Mn, Fe, Cu, Zn, Cd, Pb	[40]

Islam *et al.* (2015) assessed the heavy metals concentrations in vegetables in the vicinity of industries and observed that the mean concentrations of Ni (3.23 mg/kg), Cu (11.75 mg/kg), As (0.80 mg/kg), and Pb (0.83 mg/kg) were above the reference limits (Table 4) [31]. Islam *et al.* (2016) concluded that the mean values of As (0.24 mg/kg) and Cd (0.06 mg/kg) exceeded the permissible limits (Figure 3a). In this area, As polluted ground water and As-enriched agrochemicals were used for cultivations [32]. Begum *et al.* (2019) carried out an analysis in agricultural fields beside the Buriganga River, Dhaka. The results revealed that the mean concentrations of Cr in vegetables and soil were 250.50 and 511.67 mg/kg, respectively. This higher level of Cr was found due to discharge of untreated tannery wastes in the river and these agricultural fields were immerged under the river. The level of Fe in vegetables was 1752.05 mg/kg in vegetables. On the other hand, 2362.56 mg/kg of Fe was observed in jute leaf. In the same study, the maximum amount of Fe in soil was noticed as 38353.65 mg/kg. Therefore, this huge amount of Fe in soil may elevate the level in vegetables. The mean concentration of Ni in soil was determined as 53.57 mg/kg that was above the world safe limit (50.00 mg/kg). It may be predicted that the highest amount of Ni (7.86 mg/kg) was found in bottle gourd. It was observed that 18.35 and 7.35 mg/kg of Pb was found in bottle gourd and spinach, respectively. In addition, the maximum, minimum, and mean values of Zn and Cd exceeded the permissible limits. The ranges of Zn and Cd were (83.10-174.60) and (0.78-3.65) mg/kg, respectively (Table 4) [33]. Rahman *et al.* (2017) pointed out that the concentrations of Cr, Ni, Cd, and Pb obtained from the studied vegetables were below the permissible limits as recommended by WHO/FAO [34]. In this regard, Proshad *et al.* (2018) compared the heavy metal concentrations in vegetables based on standard values set by joint FAO/WHO. The Cr and Ni contents in most of the vegetables exceeded the safe values. The mean concentrations of Cr ranged from 2.10 (Indian spinach) to 33.16 (Brinjal) mg/kg (Figure 3b).

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Table 4: Concentration (mg/kg) of heavy metals in vegetables available in Bangladesh

City	Content	Cr	Mn	Fe	Ni	Cu	Zn	As	Cd	Pb	Ref.
Sylhet	Mean	--	125.11	26.63	--	19.59	45.85	--	0.06	0.54	[19]
	Min	--	28.88	14.65	--	17.24	29.60	--	0.05	0.20	
	Max	--	136.40	35.89	--	21.84	64.80	--	0.08	1.00	
	Mean	--	125.11	26.63	--	19.59	45.85	--	0.06	0.54	
Mymensingh	Mean [a](GIS)	380.20	68.62	142.03	--	43.10	--	--	--	--	[20]
	Mean [b](GFS)	176.28	59.76	138.90	--	31.77	--	--	--	--	
Lalmonirhat	Mean	--	30.83	429.27	--	9.91	32.19	--	0.58	8.88	[21]
	Min	--	8.21	237.12	--	3.89	12.11	--	0.21	2.62	
	Max	--	82.51	807.12	--	12.78	48.13	--	0.78	12.33	
Gazipur	Mean	5.59	--	--	--	16.58	51.78	0.80	0.12	6.04	[22]
	Min	4.34	--	--	--	12.85	44.82	0.63	0.09	4.98	
	Max	8.04	--	--	--	23.98	56.39	1.07	0.14	8.10	
Gazipur	Mean [c](DS)	19.34	--	--	--	14.80	62.73	1.26	0.34	6.27	[23]
	Mean [d](WS)	5.59	--	--	--	16.60	51.77	0.80	0.13	6.04	
Patuakhali	Min	0.37	--	--	0.03	0.35	--	0.01	0.001	0.04	[24]
	Max	5.40	--	--	17.00	45.00	--	2.60	2.20	8.80	
Jhenaidah	Mean	--	3.80	--	--	--	35.00	0.19	0.38	0.46	[25]
	Min	--	0.97	--	--	--	15.00	0.09	0.23	0.26	
	Max	--	6.90	--	--	--	50.00	0.36	0.51	0.57	
Chittagong	Mean	2.24	32.31	486.38	2.21	11.78	70.68	--	0.07	0.59	[26]
	Min	1.25	4.83	97.80	1.72	2.86	17.70	--	0.02	0.28	
	Max	3.09	97.80	813.00	2.74	18.90	118.20	--	0.15	1.15	
Patuakhali	Min	0.27	--	--	0.02	0.25	--	0.01	0.001	0.03	[27]
	Max	3.90	--	--	12.00	32.00	--	7.90	0.16	4.50	
Khulna	Mean	--	7.19	97.05	2.56	4.19	7.06	0.11	--	2.69	[28]
	Min	--	1.13	8.59	0.21	0.56	2.19	0.005	--	0.15	
	Max	--	20.02	165.06	6.24	9.13	22.11	0.17	--	4.24	
Kushtia	Mean	--	3.67	--	--	--	31.66	0.22	0.35	0.54	[29]
	Min	--	2.01	--	--	--	16.83	0.10	0.13	0.33	
	Max	--	6.49	--	--	--	49.89	0.43	0.55	0.80	
Jashore	Mean	--	33.30	190.32	--	9.31	28.23	--	0.51	5.45	[30]
	Min	--	11.33	69.52	--	1.12	12.52	--	0.24	0.61	
	Max	--	130.18	446.68	--	30.80	47.76	--	0.77	14.79	
Dhaka	Mean	0.69	--	--	3.23	11.75	--	0.80	0.15	0.83	[31]
	Min	0.60	--	--	1.60	10.00	--	0.05	0.02	0.72	
	Max	0.84	--	--	4.80	16.00	--	0.14	0.42	1.00	
Bogra	Mean	0.62	--	--	0.46	1.70	2.83	0.24	0.06	0.49	[32]
	Min	0.01	--	--	0.01	0.09	0.21	0.02	0.002	0.04	
	Max	2.53	--	--	1.55	3.73	7.58	1.51	0.25	1.39	
Dhaka	Mean	250.50	--	1752.05	2.50	2.40	121.36	--	1.55	12.80	[33]
	Min	188.00	--	1144.10	1.00	1.35	83.10	--	0.78	7.35	
	Max	322.00	--	2362.56	7.86	6.25	174.60	--	3.65	18.35	
Rajshahi	Min	0.19	--	--	0.26	--	--	--	0.02	0.02	[34]
	Max	0.32	--	--	0.30	--	--	--	0.02	0.16	
Tangail	Mean	16.26	--	--	16.11	13.99	--	2.28	1.86	7.93	[35]
	Min	2.10	--	--	1.41	2.97	--	1.31	0.09	0.84	
	Max	33.16	--	--	37.52	25.45	--	3.89	4.09	28.14	
Dhaka	Mean	1.40	--	--	0.64	--	--	0.48	0.16	1.10	[36]
	Min	0.09	--	--	0.03	--	--	0.13	0.01	0.37	
	Max	2.50	--	--	2.00	--	--	0.85	0.74	2.20	
Dhaka	Min	0.00	--	--	--	--	--	0.00	0.00	0.00	[37]
	Max	0.02	--	--	--	--	--	0.07	0.001	0.04	
Pabna	Min	< 0.10	0.99	6.44	< 0.10	--	1.21	< 0.10	< 0.10	0.12	[38]
	Max	0.50	5.72	136.30	0.84	--	8.49	< 0.10	< 0.10	1.60	
Gazipur	Min	0.01	0.03	0.01	0.04	0.04	0.34	0.01	0.10	0.02	[39]
	Max	10.00	2.00	0.07	0.70	1.30	25.00	0.10	240.00	0.80	
Bagerhat	Mean	--	35.24	489.47	--	9.65	33.59	--	0.48	8.15	[40]
	Min	--	2.24	99.25	--	1.50	11.29	--	0.05	0.49	
	Max	--	210.70	1661.30	--	42.06	90.23	--	1.15	31.13	
Safe limit	FAO/WHO	2.30[e]	500.00[f]	450.00[f]	1.50[e]	10.00[e]	20.00[e]	0.10[e]	0.05[e]	0.50[e]	

[a]GIS-Grown in Industrial Soil and [b]GFS- Grown in Farm Soil; [c]DS- Dry Season and [d]WS- Wet Season, [e]FAO/ WHO standard, 1984 [41]; [f]FAO/WHO standard, 1989 [42]

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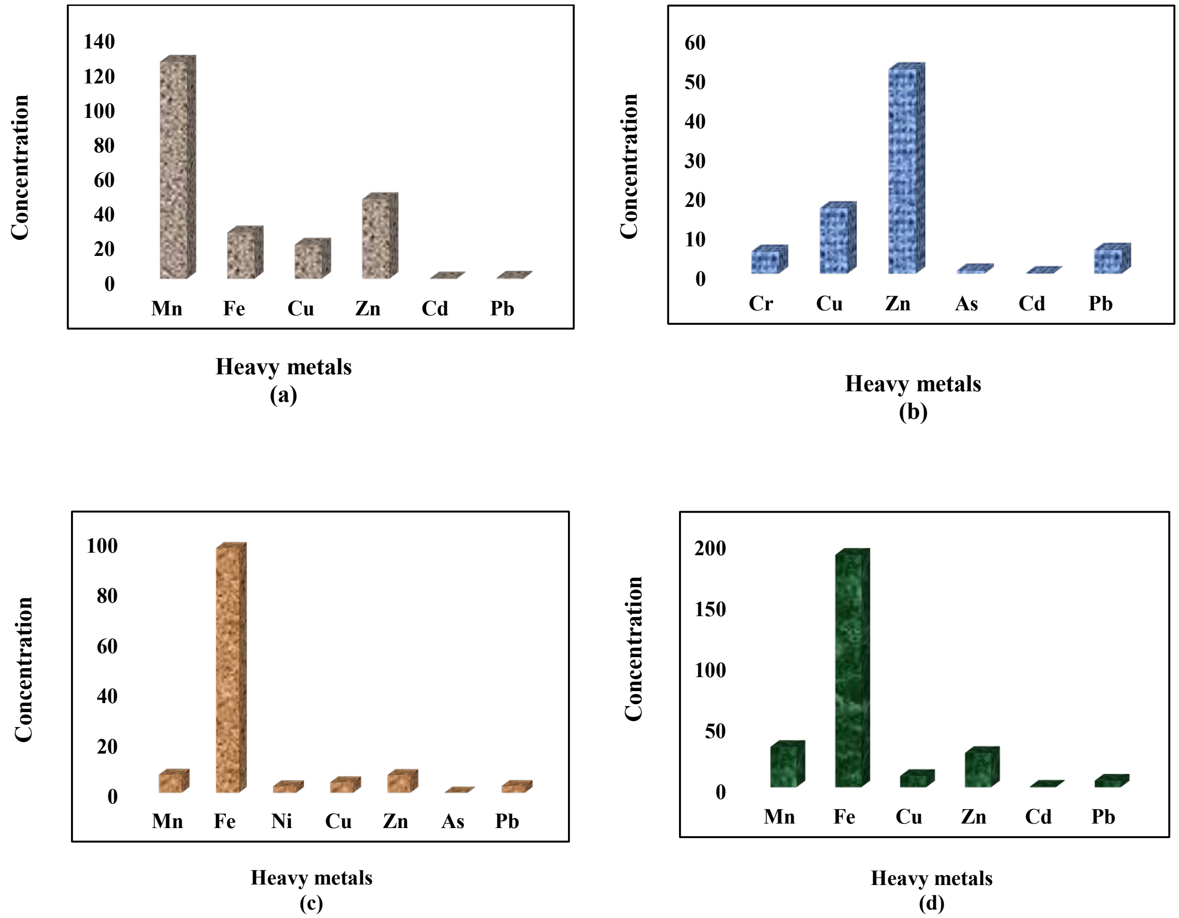

Figure 2: Heavy metals Concentrations in vegetables found in (a) sylhet [19], (b) Gazipur [22], (c) Khulna [28], and (d) Jashore [30]

The higher content of Cr may be resulted from untreated polluted water from tannery, textile, dying, and brick kiln etc. In this study, Ni contents were ranged from 1.41 (cucumber) to 37.52mg/kg (okra). Moreover, the Ni contents crossed the standard safe limit due to leaching of waste water from different industries. The mean concentrations of Cu ranged from 2.97 to 25.45mg/kg in sponge gourd and papaya, respectively. Moreover, As contents in all the vegetable samples crossed the standard value (0.10 mg/kg). This indicated that the higher contamination of As in vegetables by As may cause serious health risks to the human body. High level of As in vegetable samples may be explained due to the higher concentration of As in soil during crop productions and the excessive use of As containing fertilizers and pesticides. The average concentrations of Cd ranged from 0.09 to 4.09 mg/kg. Water bodies and air are the main sources of Cd in vegetables. The minimum and maximum level of Pb was noticed as 0.84 and 28.14 mg/kg, respectively (Table 4). Lead smelting activities may lead to higher level of Pb in vegetable samples [35]. Rahman *et al.* (2019) performed an investigation on vegetables where the highest content of As was found in red amaranth (0.85 mg/kg) and the minimum concentration was observed in Malabar spinach (0.13 mg/kg). Cd contents in vegetables ranged from 0.01 to 0.74 mg/kg with mean concentration of 0.16 mg/kg. The maximum concentration of Cd was found in bean (0.74 mg/kg) and the minimum was noticed in sweet gourd (0.01mg/kg) (Figure 3c). The concentrations of Pb in ranged from 0.37 to 2.20 mg/kg (mean value 1.10 mg/kg). In this study, maximum and minimum concentrations of Pb were observed in string bean (2.20 mg/kg) and arum (0.37 mg/kg) (Table 4) [36]. Real *et al.* (2017) evaluated the heavy metal level in vegetables. It was revealed that concentration range of As was found in arum (0.00 to 0.07) mg/kg that was below the reported value (0.1 mg/kg). The levels of Cr, Cd, and Pb found in vegetables were within the safe limits. The level of other heavy metals like Cr, Mn, Fe, Ni, Zn, As, and Cd exceeded the recommended limits set by FAO/WHO [37].

Tasrina *et al.* (2015) measured the level of toxic metals in vegetables. They showed that the concentrations of Pb in vegetables were above the toxic level. This concentrations varied from 0.12 to 1.60 mg/kg. The highest content was

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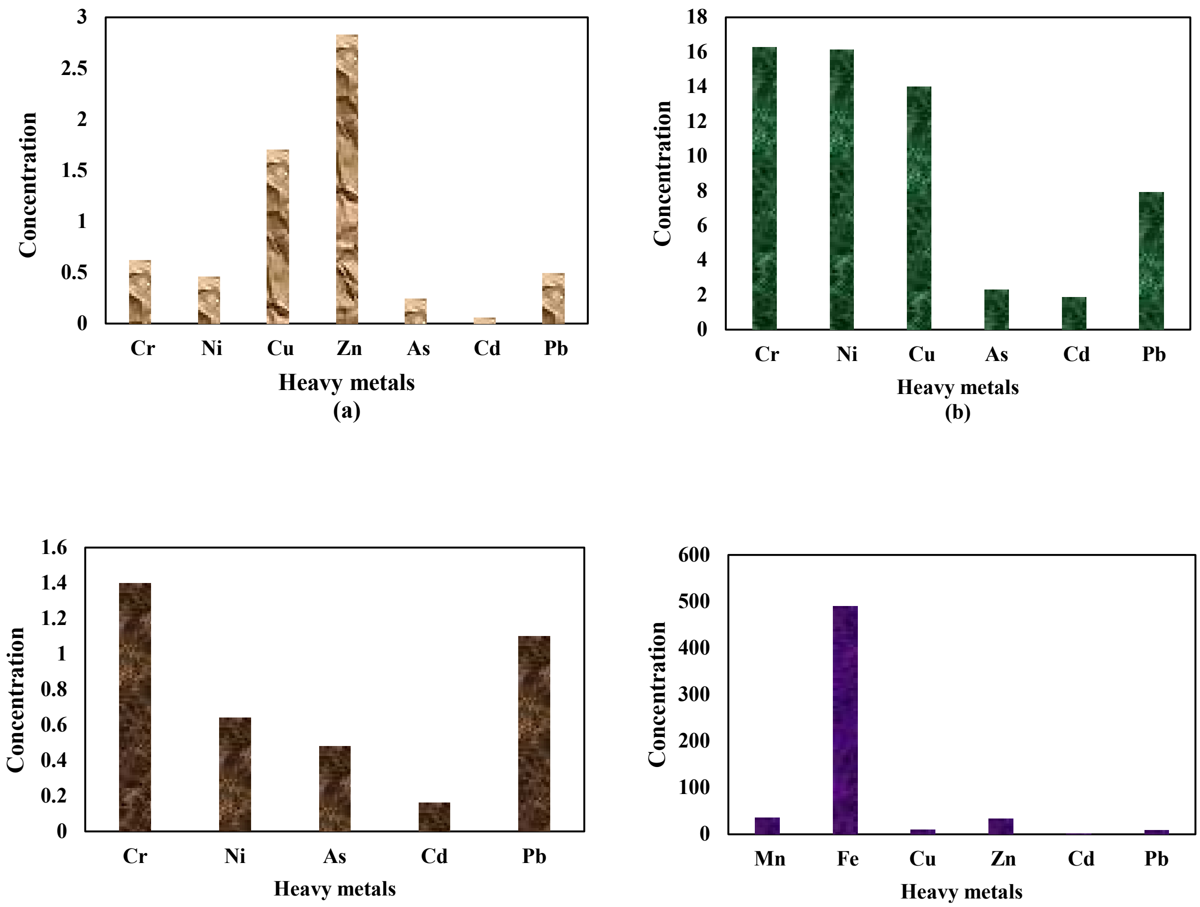

Figure 3: Heavy metals concentrations in vegetables found in (a) Bogra [32], (b) Tangail [35], (c) Dhaka [36], and (d) Bagerhat [40]

found in spinach amarantha (1.60 mg/kg) whereas the lowest content was in cabbage (0.12 mg/kg). Anthropogenic activities such as irrigation with waste water, applying sludge and agrochemicals, waste materials combustion, and high traffic systems are the reasons for high level of Pb in vegetables [38]. Sultana *et al.* (2017) concluded that all the heavy metals contents (except Cu) were above the toxic levels in root and leafy vegetables where Pb and Zn exceeded the safe limits for fruit vegetables. Furthermore, the concentrations of Zn and Pb in fruits vegetables crossed the tolerable limits (Table 4). Higher content of Zn, Cd, and Pb were noticed in leafy vegetables due to deposition from metal industries or vehicle emissions [39]. Ara *et al.* (2018) determined the heavy metal contents in leafy, fruit, and root vegetables. The levels of Mn, Fe, Cu, and Pb (except Zn and Cd) were higher in leafy vegetables than fruit and root vegetables (Figure 3d). On the other hand, the highest amount of Fe was observed in all the vegetables ranging from 99.25 to 1661.30 mg/kg in the vegetable (Table 4). Generally, Fe takes part in photosynthesis and chlorophyll synthesis in vegetables.

Therefore, the Fe contents in leafy vegetables were higher compared to fruit and root vegetables [40]. From the above discussions, it can be predicted that the anthropogenic activities are the main sources of toxic heavy metals in our environments that are altering our ecological balance and impacting our health.

3.2. Health risks assessments

The target hazard quotient (THQ) values of Cr for edible part of tomato were observed as 6.15 and 13.26 for male as well as 10.63 and 22.93 for female farm and industrial contaminated soils, respectively. These values surpassed the safe limit (1.0). Therefore, the consumption of this tomato may cause health risks due to high level of Cr [20]. This study revealed that the highest target hazard quotient (THQ) values of Pb were noticed in leafy (8.01), fruit (5.05), and root (8.21) vegetables which were above the reference limits. Moreover, the target cancer risk (TCR) values of Pb and Cd showed a higher cancer risks [21]. The hazardous index (HI) of studied metals from most of the vegetables were greater

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than one, indicating the consumption of these types of vegetables might cause the health risks due to exposure to heavy metals. Furthermore, the TCR values of As and Pb were ranged from 0.03 to 0.48 and 0.0004 to 0.025 respectively that were higher than acceptable risk limit (0.000001) [24]. Moreover, the carcinogenic and non-carcinogenic risks were assessed for the intake of contaminated vegetables. The hazardous index (HI) values of all the heavy metals were above the acceptable limit (1.0). Eventually, the target cancer risk (TCR) values were 6.4×10^{-3} for As and 8.7×10^{-5} for Pb that were above the threshold value. Therefore, accumulation of these metals may pose serious health hazards [25]. The target hazard quotient (THQ) values of As for *L. siceraria*, *S. lycopersicum*, *C. maxima*, and *L. culinaris* were 3.69, 1.52, 1.22, and 1.25 respectively, that were above the safe limit (1.0). The target carcinogenic risk (TCR) of As and Pb were greater than threshold level, indicating potential cancer risks to human body [27]. The target hazard quotient (THQ) indicated the health risks due to the exposure of As, Ni, and Pb. However, the HI values were higher than the safe limit (HI=1.0) for vegetables (4.03). Further, the target cancer risk (TCR) values of Pb and As were exceeded USEPA risk threshold ($10^{-6)}$. The overall analyses showed that the intake of these contaminated vegetables lead to the carcinogenic as along with non-carcinogenic effects [28].

3.3. Comparison of heavy metal contents with other studies

At present, different countries in the world are conducting these types of studies due to the importance of food safety for their populations. Therefore, it is necessary to compare the present study with other studies in different countries in the world to find out the pollution level as well as to take effective measures. This review study has been compared with the following studies shown in Table 5.

In the present study, the highest level of Cr was found in Mymensingh (380.20 mg/kg) (Table 4) whereas 22.30 mg/kg (Table 5) was observed in Turkey [20, 48]. The Mn content in soil of Bagerhat was determined as 210.70 mg/kg [23]. A study carried out in Pakistan revealed that the concentration of Mn was 87.37 mg/kg in vegetables [47]. Moreover, Fe is the more abundant element in earth crusts. The high level of Fe was noticed in Dhaka (2362.56 mg/kg) [33]. On the other hand, the high amount of Fe in vegetables was found in Ethiopia (612.00 mg/kg) [53]. Table 4 indicates the highest amounts of Ni (37.52 mg/kg), Cu (45.00 mg/kg), Zn (174.60 mg/kg), As (7.90 mg/kg), Cd (240.00 mg/kg), and Pb (31.13 mg/kg) were observed in Tangail, Patuakhali, Dhaka, Patuakhali, Gazipur, and Bagerhat respectively [24, 27, 33, 35, 39, 40]. Different studies have shown that high levels of Ni (32.51 mg/kg), Cu (27.85 mg/kg), Zn (220.00 mg/kg), As (9.00 mg/kg), Cd (3.08 mg/kg), and Pb (123.97 mg/kg) were found in Pakistan, Turkey, Ethiopia, Bolivia, Pakistan, and Turkey, respectively (Table 5) [47, 48, 53, 55]. Dhaka, Gazipur, Patuakhali, and Bagerhat are the industrial areas. Therefore, the level of heavy metals in these areas may be potentially due to lack of proper management of waste materials. Moreover, the heavy metal contents in developed countries are lower than developing countries.

Table 5: Comparison of heavy metal contents in vegetables (mg/kg) with international reports

Country	Content	Cr	Mn	Fe	Ni	Cu	Zn	As	Cd	Pb	Ref.
India	Min	<0.05	--	10.35	0.03	0.36	1.56	--	0.02	0.12	[45]
	Max	<0.05	--	89.10	0.98	2.99	23.76	--	0.67	6.54	
Chaina	Min	*ND	--	--	0.001	0.02	0.01	*ND	*ND	*ND	[46]
	Max	1.04	--	--	1.69	8.25	25.60	0.48	0.10	0.66	
Pakistan	Min	0.20	6.57	--	0.18	0.11	0.20	--	0.01	0.01	[47]
	Max	5.01	87.37	--	32.51	10.94	63.91	--	3.08	4.23	
Turkey	Min	9.84	--	--	4.03	1.50	--	--	0.70	47.12	[48]
	Max	22.30	--	--	18.60	27.85	--	--	1.61	123.97	
Greece	Min	<0.40	--	22.30	--	--	10.10	<0.10	--	--	[49]
	Max	0.63	--	261.00	--	--	61.00	0.31	--	--	
Kosovo	Min	*ND	0.002	0.002	0.002	*ND	0.09	--	*ND	*ND	[50]
	Max	0.07	1.34	11.86	0.33	0.66	17.02	--	0.007	0.06	
Tanzania	Min	--	--	--	--	0.25	1.48	--	0.01	0.19	[51]
	Max	--	--	--	--	1.60	4.93	--	0.06	0.66	
Nigeria	Min	--	--	--	*ND	--	--	--	*ND	*ND	[52]
	Max	--	--	--	1.30	--	--	--	0.37	3.89	
Ethiopia	Min	8.42	--	483.00	--	13.40	110.00	--	1.62	2.56	[53]
	Max	13.50	--	612.00	--	23.90	220.00	--	1.91	3.97	
Brazil	Min	--	--	--	<0.02	5.30	83.10	--	< 0.01	0.06	[54]
	Max	--	--	--	<0.02	3.70	28.50	--	< 0.01	0.06	
Bolivia	Min	0.30	--	23.00	0.10	5.00	78.00	1.00	0.04	0.70	[55]
	Max	0.50	--	150.00	0.60	14.00	200.00	9.00	1.00	3.00	
Australia	Min	--	--	--	--	0.21	1.47	--	< 0.005	< 0.02	[56]
	Max	--	--	--	--	23.00	128.00	--	2.22	57.00	
Canada	Min	--	--	22.00	0.09	--	9.00	--	0.03	0.04	[57]
	Max	--	--	560.00	3.10	--	84.00	--	1.20	16.00	

*ND: Not Detected

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Generally, developed countries are conducting their agricultural and industrial activities in a systematic way due to their developed technologies.

3.3. Recommendations for waste management system

Waste management system is new term in Bangladesh. Unplanned industries are being installed here and there but waste treatment plants are not constructed due to high cost. Therefore, they are not processing their waste materials in a proper way before dumping as a result the environment is being seriously affected. Hence, necessary steps should be taken to identify the possible sources of pollutants. Household as well as industrial wastes should be processed separately. Moreover, the organic and inorganic parts of the waste materials can be separated and the volume of waste materials can be reduced to dump easily. Heavy metals in liquid substances can be separated by different analytical techniques. Integrated waste management plant can be helpful for this purposes where industries with no plant can easily treat their waste materials. Additionally, systematic traffic system and alternative use of fossil fuel can lower the atmospheric depositions of heavy metals in vegetables. Using organic fertilizers, pesticides, and herbicides in lieu of inorganic ones can also reduce the amount of heavy metals in soil and vegetables. Waste materials spread can be controlled by confining the dumping places. Moreover, government can establish different environment protection rules in this regards.

4. Conclusion

This review study was conducted in different districts of Bangladesh. This study does not represent the whole country. Despite of its limitations, this review provides an overall pollution status of heavy metals in vegetables. In this study, many experiments have showed that the level of heavy metals in vegetables are above the safe limits. This can be explained due to anthropogenic activities like excessive use of manures, wastewater from industries, fertilizers, and pesticides in agricultural fields. Moreover, the atmospheric depositions from vehicle emissions and different particulate matters produced from industries may contribute the level of heavy metals in vegetables. Therefore, regular monitoring should be needed to establish a data base system for further any study in these areas.

Authors' Contributions

M.H.A., conceptualization, study design, drafting of the manuscript, and supervision; M.A.R.K., writing and revision of the manuscript. Besides, all the authors have gone through and approved the final manuscript.

Conflicts of Interest

The Authors declare that there is no conflict of interes.

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