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Trace Metal Contamination of Vegetables Grown Near the Tannery Estate in Savar, Bangladesh: Human Health Risk Assessment

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ABSTRACT

*Environmental pollution caused by tanneries is a long-term problem in Bangladesh. The present study investigated the levels of five globally alarming trace metals (Cd, Pb, Cu, Ni and Cr) in three commonly consumed leafy vegetables with corresponding soils (spinach - *Spinacia oleracea* ; broccoli - *Brassica oleracea* var-italica and stem amaranth - *Amaranthus viridis*), grown around the tannery estate in Savar, Bangladesh. Both in the soil and the vegetable samples, the observed trend of mean concentration of heavy metals was Cd>Cr>Cu>Ni>Pb. Excluding Cu and Cr in the vegetable samples, the level of all the studied metals in all the samples was higher than the maximum permissible limits set by the WHO. Plant transfer factor (PTF) was calculated in order to evaluate the metal uptake of the vegetables from the soil. PTF was found in increasing sequence of broccoli > stem amaranth > spinach and the trend of metal uptake found was, for spinach: Cu>Pb>Ni>Cr>Cd, for broccoli: Cu>Cr>Pb>Ni>Cd and for stem amaranth: Ni>Cu>Pb>Cr>Cd. Contamination factor (Cf) values revealed that the soil samples were highly contaminated by Cd. The values of the pollution load index (PLI) for spinach and stem amaranth were higher than 1, denoting the polluted state of the soil. To evaluate the potential health risk, target hazard quotient (THQ), hazard index (HI), and target cancer risk (TR) were analysed and the results showed that most of the values were significantly higher than the threshold values. This environmental assessment study should be of use during planning and management that aims to protect human health and the environment.*

KEYWORDS

Heavy metals, Tannery, Pollution, Human health, Savar

INTRODUCTION

Vegetables are an important source of nutrition and play an important role in human health [1]. But the ingestion of vegetables with large concentrations of heavy metals can pose a risk to the public health [2]. In recent years, heavy metal pollution has become one of the most serious environmental issues globally, due to its toxicity, persistence, and bioaccumulation in the environment [3–7]. Due to the unavailability of fresh water to the urban vegetable farmers, they use wastewater for vegetable cultivation. Almost all of the cultivated lands are contaminated with heavy metals, with the

predominant contribution by industrial effluents, pesticides, fertilizers, and other anthropogenic activities. This has resulted in the cultivation of contaminated vegetables [8–10]. Independent of the concentration in the soil, heavy metals are reported to readily accumulate at high levels in vegetables [11]. Metal concentration in vegetables depends on multiple factors, like the soil texture, the growth media, and the nature and type of the vegetable species [12].

While some trace metals, like Zn, Cu, Mn, and Fe, are important, some are regarded as hazardous to human health, e.g. Cd, As, Pb and Hg etc. Exposure to an extensive amount of these metals may have detrimental health effects [13,14]. After several years of exposure, prolonged heavy metals intake has a detrimental effect on human health, even at low concentrations [15–17]. When metals enter the environment, they may accumulate in the food chain and cause serious ecological damage, and also pose carcinogenic and other adverse effects on human health due to the bio-magnification over time [18].

Among these, Cd and Pb are reported to contribute to kidney damage, increased blood pressure and heart diseases [19]. The hexavalent Cr is reported to cause liver damage, respiratory tract cancer and stomach cancer [20,21].

Dhaka, the capital city of Bangladesh, is one of the most densely populated cities in the world. In this city, for approximately five decades, tannery industries were functioning at Hazaribagh, at the bank of the Buriganga river [22]. Due to severe environmental damage at Hazaribagh, and contamination of the Buriganga, the question of the relocation of tannery industries first surfaced up in 1991 [23]. After many ups and downs the government forced the tanneries to shift to a half-complete tannery estate at Hemayetpur, Savar by a judicial verdict in 2017 [24].

Savar is one of the most significant sub-districts of Bangladesh, having 59.6% of the sub-district economy as industry [25]. Manufacturing plants in this area include ceramic factories, beverage industries, garments industries etc. Considering this industrial development potential, the government shifted the tanneries beside the Dhaleshwari river [25]. However, many of the tanneries are still struggling to meet the compliance. In the tannery estate there is supposed to be a functional Central Effluent Treatment Plant (CETP) and proper solid waste management, which is not completely functioning and lacks capacity to treat the total effluent discharged from all the tanneries even after the completion of the tannery estate project [26]. Recent reports have shown that the water of Dhaleshwari River is being contaminated by the effluent discharged from the tannery estate. Moreover, there is no solid waste management system except for the open dumping on the banks of the Dhaleshwari River [26]. Based on that, a parliamentary body recommended to shut down the Savar Tannery Industrial Estate [26].

During the leather processing, various chemicals, such as chromium, ammonium, salts, solvents etc., are being used. These chemicals act as a source of heavy metals in the water when discharged into the river water without proper treatment. Since the farmers are growing different kinds of vegetables around the tannery estate and use the river water and ground water for irrigating their lands, the main source of heavy metals found in the soil and the vegetables at the tannery area in Savar, Dhaka is the tannery wastages. Tannery solid waste and effluents are discharged in the environment with partial treatment as the CETP (Central Effluent Treatment Plant) is not functioning properly. In the upper portion of Savar Upazila, the industries are well established and consequently all the previous studies focused on that part of the area [27,28]. After the tannery relocation, there has been hardly any study yet reporting the heavy metal level at the lower portion of the sub-district where the tannery estate is situated. Studies on the level of heavy metals in the water and fish of the Dhaleshwari River in association with the tannery discharge indicate the extent of the contamination [29–31]. In the very recent study by Hossain et al. [32], the heavy metal level in the soil of the tannery estate was compared with the soil of a non-industrialized area. However, they grew some specific species of vegetables in the tannery estate soil and the soil of the non-industrialized area. The aim of this study was to investigate the levels of heavy metals in the vegetables and the corresponding soil grown near the tannery estate in Savar, Dhaka. The present study also tried to investigate the health risks associated with the ingestion of these contaminated vegetables.

EXPERIMENTAL

Study area

The Upazila of Savar is situated at 23.8583° N and 90.2667° E with an area of 280.13 km², which is shown in Figure 1 [25]. It is one of the most important industrial regions of Bangladesh that is considered particularly prone to environmental contamination. The distance of this Upazila from the northwest of Dhaka metropolitan (the capital city of Bangladesh) is 25 km [25]. The area comprises of a variety of industries such as leather, textile, dyeing, battery manufacturing, garments, pharmaceuticals, and different food processing industries producing huge volumes of effluents, being discharged treated or untreated randomly into nearby water bodies. Hemayetpur, a part of this Upazila is located at the bank of the Dhaleshwari River. The tanneries had been shifted from Hazaribagh, Dhaka to Hemayetpur, Savar, Bangladesh more than 3 years ago [33].

Figure 1. Sampling site of the study area (Hemayetpur, Tannery Estate, Savar)

Sampling

Samples of three highly consumed leafy green vegetables, namely spinach, broccoli, and stem amaranth with the corresponding soil samples were collected from different fields within a one-kilometre area around the tannery estate in Savar, Bangladesh as shown in Figure 1. A brief description of the collected vegetables is presented in Table 1. Six samples ($n=6$) of each vegetable of similar size and age, each weighing 250 g, were collected from each field and packed in distilled water-washed polyethylene bags. The samples were immediately transferred to the laboratory of the Institute of Leather Engineering and Technology, University of Dhaka. The edible portions (leaves of palong shak and broccoli and the stem portion of data shak) were segregated, washed with distilled water, and chopped into small pieces. The samples were oven-dried at 80 °C for 72 hours and then ground and screened through a 2-millimetre sieve. The resultant powder was preserved at room temperature until the digestion. The soil samples were air-dried and sieved through a 2 mm mesh-sized sieve and preserved in airtight plastic bags at room temperature until the digestion.

Table 1. Description of the collected and analysed vegetable samples

Local Name	English Name	Scientific Name	Edible Parts
Palong shak	Spinach	<i>Spinacia oleracea</i>	Leaf
Broccoli	Broccoli	<i>Brassica oleracea</i> var-italica	Leaf
Data shak	Stem amaranth	<i>Amaranthus viridis</i>	Stem

Determination of metals

The samples of both soils and vegetables (1.00 ± 0.001 g each) were put into 100-millilitre beakers separately. The beakers contained 15 ml of the tri-acid mixture (65% HClO_4 (concentrated), 70% H_2SO_4 (concentrated), and 70% high purity HNO_3 (concentrated) in 1:1:5 ratio), which was then digested at 80°C by using a hotplate until the solution had become transparent [34]. The solution was filtered by using a Whatman filter paper No. 1 and 50 ml of deionized water. The filtrate was then analysed for concentrations of Cu, Cd, Pb, Cr, and Ni using an Atomic Absorption Spectrophotometer (Model PinAAcle 900H, Perkin–Elmer, USA). The measurements were made by using hollow cathode lamps (HCL) of Cd, Cu, Cr, and Ni at wavelengths of 228.8 nm, 324.75 nm, 357.87 nm, and 232.0 nm and the electrodeless discharge lamp (EDL) of Pb at the wavelength of 283.31nm, respectively, along with the air-acetylene flame. Linear calibration was performed beforehand using standard solutions (2 ppm, 4 ppm, and 6 ppm) of the five metals in question. The standards were supplied by Perkin–Elmer, USA. The detection limits for all the studied metals were 0.001 – 0.1 ppm. In order to check the sensitivity of the instrument, standard solutions were run frequently.

Assessment of contamination in soil

Plant transfer factor (PTF)

Plant transfer factor (PTF) is defined as the division of the concentration of heavy metals in a crop (mg/kg fresh weight) and the concentration of the heavy metals in the soil (mg/kg dry weight) [35]

$$\text{PTF}_{\text{metal}} = \frac{M_v}{M_s} \quad (1)$$

where M_v = heavy metal concentration (mg/kg fresh weight) in plant or vegetable tissues and M_s = metal concentration in the soil (mg/kg dry weight).

Contamination factor (Cf)

The contamination factor (Cf) is one of the most popular methods to evaluate heavy metal contamination in soils and sediments. Cf is the ratio of the concentration of each metal in the soil by

the background value [36,37]. The background values for Cd, Cu, Ni, Cr and Pb are 0.3 mg/kg, 45 mg/kg, 68.0 mg/kg, 90.0 mg/kg and 20.0 mg/kg, respectively [38]. The formula used was

$$Cf = \frac{C_{\text{metal}}}{C_{\text{background}}} \quad (2)$$

where C_{metal} = the concentration of a heavy metal and $C_{\text{background}}$ = the background concentration of the metal. According to Hakanson, $Cf > 6$ is very high contamination; $3 < Cf < 6$ denotes considerable contamination; $1 < Cf < 3$ denotes moderate contamination; and $Cf < 1$ denotes low contamination [36].

Pollution load index (PLI)

In order to estimate the pollution level of the soil of the agricultural fields of the study area, an integrated approach of pollution load index (PLI) of the five studied metals (Cu, Cd, Pb, Cr, and Ni) is calculated, according to Tomlinson et al. [39] and Nasehi et al. [40]. The pollution load index is used to obtain a comparative and straightforward means for assessing the trace metal pollution level. PLI has been defined as the n th root of the product of the n contamination factor (Cf):

$$PLI = \sqrt[n]{Cf_1 \times Cf_2 \times Cf_3 \times \dots \times Cf_n} \quad (3)$$

where Cf denotes the contamination factor and n denotes the number of metals. Tomlinson et al. [39] suggested that $PLI > 1$ indicates the presence of pollution, and PLI below 1 means the absence of metal pollution [41,42].

Human health risk assessment

Health risks associated with the consumption of vegetables contaminated with metals were evaluated by calculating target hazard quotient (THQ), hazard index (HI), and target cancer risk (TR).

Target hazard quotient (THQ)

Target hazard quotient (THQ) was calculated by the following equation [43]

$$THQ = \frac{EF \times ED \times FIR \times MC}{WAB \times ATn \times RfD} \times 10^{-3} \quad (4)$$

where EF represents the exposure frequency (365 days/year), ED denotes the exposure duration (70 years) for non-cancer risk; FIR is the vegetable consumption rate, which is 167.3 g/person/day for

Bangladesh [44]. MC denotes the trace metals concentration in vegetable samples (mg/kg; fresh weight-fw), the average body weight is represented by WAB, which is 60 kg; [43], and ATn is the average exposure time for non-carcinogens (365 days/year for 70 years, ATn = 25,550 days) [43]. RfD indicates the oral reference dose of metal (mg/kg/day) [Cr=3.0×10⁻³, Pb=3.5×10⁻³, Ni =2.0×10⁻², Cu=3.7×10⁻², and Cd=1.0×10⁻³] [29,43,45].

Hazard index (HI)

Using the target hazard quotient values, the hazard index (HI) was determined by using the following equation [43]

$$HI = THQ (Cr) + THQ (Cd) + THQ (Cu) + THQ (Ni) + THQ (Pb) \quad (5)$$

where HI represents the hazard index. HI > 1 denotes hazardous; HI < 1 denotes safe [29].

Target cancer risk (TR)

TR was computed to measure carcinogenic risks. TR was calculated by equation (6) [43]

$$TR = \frac{ED \times EF \times FIR \times MC \times CPSo}{ATc \times WAB} \times 10^{-3} \quad (6)$$

where EF represents exposure frequency (365 days/year), ED denotes the exposure duration (70 years for non-cancer risk), as used by USEPA, FIR is the vegetable ingestion rate 167.3 g/person/day [44]. MC denotes metal concentration (mg/kg; fw), and the averaging time duration of carcinogens is denoted by ATc (365 days/year for 70 years). WAB is the average body weight, which is 60kg. CPSo is the cancer potency slope factor of the metals for the oral route (mg/kg/day) [Cd=0.38 [46,47], Pb=0.0085, Cr=0.5, and Ni=1.7 [29,45,48]].

Data analysis

All the data analysis was done by Microsoft Excel 2019 software.

RESULTS AND DISCUSSION

Trace metals in soil and vegetables

Trace metal concentrations in vegetables and soil were assessed to evaluate the potential health risk to the consumers of these vegetables. Average metal concentrations found in vegetables and corresponding soil samples are presented in Table 2. All the values for vegetables and soils are based

on fresh weight (fw) and dry-weight (dw) respectively. In all the soil and vegetable samples, the average level of metals found was in a declining trend of Pb>Ni>Cu>Cr>Cd (Table 2).

Table 2. Estimated metal concentration in analysed vegetable and soil samples

Sample		Spinach (n=6)	Broccoli (n=6)	Stem amaranth (n=6)	MAC ^a	ASV ^b
Vegetable (mg/kg fw±SD)	Cd	0.50±0.01	0.22±0.014	0.44±0.006	0.2	-
	Pb	8.9±0.052	6.42±0.118	7.35±0.077	0.3	-
	Cu	1.99±0.019	1.14±0.013	2.14±0.01	10	-
	Ni	3.91±0.086	3.22±0.04	2.86±0.047	0.2-2.7	-
	Cr	0.84±0.022	0.46±0.017	0.78±0.027	2.30*	-
Corresponding soil (mg/kg dw±SD)	Cd	4.10±0.013	1.65±0.059	2.98±0.208	0.003	0.3
	Pb	90.73±0.037	89.66±0.013	90.8±0.015	0.1	20
	Cu	28.8±0.079	35.6±0.106	27.15±0.177	0.1	45
	Ni	39.04±0.069	30.09±0.025	59.34±0.082	0.05	68
	Cr	7.71±0.069	7.07±0.025	6.92±0.082	0.1	90

^aMAC- Maximum Permissible Limit [49]; * [50], ^bASV- Average Shale Value [38]

The mean concentration of Cd was at maximum in the spinach soil sample - 4.10 mg/kg and at minimum in the soil sample of broccoli - 1.65 mg/kg. In vegetable samples, the maximum mean concentration of Cd was also found in spinach, 0.50 mg/kg, and the minimum in broccoli, 0.22 mg/kg. Studies suggest that Cd is capable of exerting hazardous effects on the kidneys, the digestive system, and the skeletal system since it is classified as a human carcinogen [51].

The mean concentration of Pb was highest in the soil of stem amaranth - 90.80 mg/kg, whereas in the stem amaranth it was 7.35 mg/kg. Pb was lowest in the case of broccoli soil, 89.66 mg/kg, but this value was much higher than the average shale values (ASV), i.e. the preindustrial values. This indicates that anthropogenic activities have contributed to the increase of Pb and Cd concentration in the soil samples of the study area. However, in vegetable samples, the mean concentration of Pb was 8.90 mg/kg for the spinach and 6.42 mg/kg for the broccoli. Like Cd, Pb is also reported to induce kidney damage, along with increased blood pressure and cardiovascular diseases, which is a serious matter for concern [19]. All the values for Cd and Pb found in the present study were above the maximum permissible limits (MAC) for vegetables as outlined by the WHO [49].

The values for Cu in the soil samples were ranged from 27.15 mg/kg to 35.60 mg/kg, whereas the values for Ni ranged from 30.09 to 59.34 mg/kg. However, the values for Cu and Ni in soil and vegetables were below the ASV, but significantly higher than MAC.

Cr value was the highest in the soil of spinach - 7.71 mg/kg, which was lower than ASV and the lowest was in the case of stem amaranth soil - 6.92 mg/kg. The mean Cr concentration in vegetables varied

from a minimum of 0.46 mg/kg for the broccoli to 0.84 mg/kg for the spinach, which were below the MAC. Cancer of the gastrointestinal and central nervous system might develop due to chronic exposure to high levels of chromium [52].

The high value of trace metals in soils and vegetables might be attributed to the use of contaminated water of Dhaleshwari River for irrigation purposes. These values found for vegetables in this study were compared with some other similar studies conducted in Bangladesh (Table 3). It was observed that concentrations of Cd and Ni in this study were similar to those in comparable studies but Pb accumulation seemed pretty high. This high Pb concentration might be attributed to the use of dye containing Pb in the tannery. The Cr and Cu uptake in vegetables in the present study was relatively low.

Table 3. Comparison of metals in water (mg/kg) with international limit and some other studies in Bangladesh

Vegetable Species	Cd	Pb	Cu	Ni	Cr	Location	Reference
Spinach (n=6)	0.50	8.9	1.99	3.91	0.84	Tannery area, Savar Bangladesh	Present Study
Broccoli (n=6)	0.22	6.42	1.14	3.22	0.46	Tannery area, Savar Bangladesh	Present Study
Stem amaranth (n=6)	0.44	7.35	2.14	2.86	0.78	Tannery area, Savar Bangladesh	Present Study
Jute	0.044	0.697	-	-	2.182	Savar, Bangladesh	[27]
Red amaranth	0.046	0.721	-	-	2.431	Savar, Bangladesh	[27]
Zucchini	0.041	3.362	-	-	1.842	Savar, Bangladesh	[27]
Okra	0.049	0.643	-	-	2.193	Savar, Bangladesh	[27]
Stem amaranth	0.042	1.951	-	-	1.681	Savar, Bangladesh	[27]
Brinjal	-	0.90	10.1	0.7	1.0	Chittagong, Bangladesh	[53]
Cucumber	-	0.64	10.0	<0.65	3.2	Chittagong, Bangladesh	[53]
Tomato	-	0.70	10.3	<0.65	0.6	Chittagong, Bangladesh	[53]
String bean	-	0.64	938	5.4	7.4	Chittagong, Bangladesh	[53]
Lady's finger	-	0.91	4.6	2.1	5.1	Chittagong, Bangladesh	[53]
Hyacinth bean	-	0.57	9.2	3.9	6.0	Chittagong, Bangladesh	[53]
Ipomoea batatas	0.05	0.20	20.76	-	-	Sylhet, Bangladesh	[54]
Raphanussativu s var. longipinnatus	0.05	0.50	19.24	-	-	Sylhet, Bangladesh	[54]
Luffaacutangula	0.06	1	21.64	-	-	Sylhet, Bangladesh	[54]
Solanummelong ena	0.08	0.80	17.24	-	-	Sylhet, Bangladesh	[54]
Oryza sativa	0.07	0.20	19.08	-	-	Sylhet, Bangladesh	[54]
WHO/FAO(2007)	0.2	0.3	10	0.2-2.7	2.30*		[49]; *[50]

Assessment of contamination in soil

Plant transfer factor (PTF)

Plant transfer factor (PTF) is a popular tool to assess the trace metal uptake into vegetables from the soil. Higher PTF values suggest poor metal retention in the soil and greater translocation in plants [55]. In this study the PTF was found in decreasing order of $\text{Cd} > \text{Cr} > \text{Ni} > \text{Pb} > \text{Cu}$ in the spinach, $\text{Cd} > \text{Ni} > \text{Pb} > \text{Cr} > \text{Cu}$ in the broccoli, and $\text{Cd} > \text{Cr} > \text{Pb} > \text{Cu} > \text{Ni}$ in the stem amaranth. Figure 2 shows the level of plant transfer factor in the studied vegetables. Considering all the metals, PTF was recorded in decreasing sequence of spinach > stem amaranth > broccoli. The highest PTF was observed at 0.148 for the stem amaranth in the case of Cd while the lowest was at 0.032 for the broccoli in the case of Cu.

Figure 2. Estimated plant transfer coefficient (PTF)

Contamination factor (Cf) and the pollution load index (PLI)

Contamination factors (Cf) of each metal had been calculated using the average shale value of the earth's crust [38]. The obtained Cf values are graphically presented in Figure 3. For the soils of all the considered vegetable species, Cu, Ni and Cr showed a low degree of Cf ($\text{Cf} < 1$). Cf values for Cd showed a considerable degree to a very high degree of contamination ($\text{Cf} > 3$ & $\text{Cf} > 6$). Overall, values of Cf for the spinach and broccoli soil samples were in decreasing trend of $\text{Cd} > \text{Pb} > \text{Cu} > \text{Ni} > \text{Cr}$. For soil samples of stem amaranth, the observed trend of Cf values was $\text{Cd} > \text{Pb} > \text{Ni} > \text{Cu} > \text{Cr}$. The Cf values for Pb were found at a considerable degree of contamination for all the studied samples.

Figure 3. Contamination factor of the metals for soil samples

The obtained Cf values were used to compute the pollution load index (PLI) of the studied soil samples. The results of PLI are visually presented in Figure 4. In this study, PLI values for the spinach and stem amaranth samples were found above 1, suggesting the polluted condition of the soil. The PLI value for the broccoli was at 0.93 denoting the unpolluted status of soil ($PLI < 1$).

Figure 4. Pollution load index for the soil samples

Human health risk assessment

More than twenty million people living in Dhaka city consume different species of vegetables on an almost daily basis. Among these vegetable species, the three studied vegetable species are very widely consumed. Target hazard quotient (THQ) has been widely used to evaluate the possible health threats. The THQ above 5 suggests the exposed population is unsafe; THQ in between 1 and 5 denotes that the exposed population is in the level of concern interval and THQ less than 1 suggests the exposed population is supposed to be safe [56]. The results of THQ of the studied metals associated with the consumption of vegetables are presented in Table 4. The THQ values for each metal through vegetable consumption were in the increasing sequence of $\text{Cr} > \text{Cd} > \text{Cu} > \text{Ni} > \text{Pb}$. The THQ for Cd ranged from 0.613 to 1.394, 5.115 to 7.090 for Pb, for Cu 0.859 to 1.613, 3.987 to 5.45 for Ni, and 0.427 to 0.781 for Cr. All the THQ values for Cr were less than 1, which revealed that the ingestion of Cr from vegetable consumption does not pose a major threat to human health. However, THQ for Cr investigated by Amin et al. [27] was greater than 1 for all the studied vegetable samples. All the THQ values for Pb were above 5, denoting that Pb may pose a major risk to the consumers. This finding is in an agreement with the findings of Amin et al., [27] who found higher THQ values of Pb in the vegetable species, stem amaranth and zucchini. The hazard index (HI) was computed to assess the combined effects of multiple metals. The HI values for spinach, broccoli, and stem amaranth were 16.216, 11.504, and 13.407 respectively (>1) indicating high potential for non-carcinogenic health risks. Jolly et al. [53] also reported similar high hazard index (above 1) for the vegetables grown near Kalurghat, heavily industrialized area in Chittagong, Bangladesh.

Table 4. THQ, HI, and TR for metals in analysed vegetable samples

Sample	Target Hazard Quotient (THQ)					Hazard Index (HI)	Target Cancer Risk (TR)			
	Cd	Pb	Cu	Ni	Cr		Cd	Pb	Ni	Cr
Spinach (n=6)	1.394	7.09	1.499	5.45	0.781	16.216	5.30E-04	2.11E-04	1.85E-02	1.17E-03
Broccoli (n=6)	0.613	5.115	0.859	4.489	0.427	11.504	2.33E-04	1.52E-04	1.53E-02	6.41E-04
Stem amaranth (n=6)	1.226	5.856	1.613	3.987	0.725	13.407	4.66E-04	1.74E-04	1.36E-02	1.09E-03

The carcinogenic risk associated with the ingestion of studied vegetable species was evaluated by assessing target cancer risk (TR) and is presented in Table 4. The TR values ranged from 2.33E-04 to 5.30E-04 for Cd, 1.52E-4 to 2.11E-4 for Pb, 1.36E-02 to 1.85E-2 for Ni and 6.41E-4 to 1.17E-3 for Cr. All the TR values were significantly higher than the threshold value of 10^{-4} . The highest contributing metal

in TR was found to be Ni among all three vegetable species. This high cancer risk is worse than the findings of Amin et al. [27] where the values were less or equal to the threshold value of 10^{-4} . This draws attention to a serious health concern for the inhabitants who are consuming the vegetables grown near the studied area.

CONCLUSION

The current study showed that vegetables and soils collected from the farmlands located in the vicinity of the tannery estate at Savar, Bangladesh accumulate Cd, Cu, Ni, Pb, and Cr at high concentrations in contrast with the maximum permissible limits. High PTF values indicated the increased uptake of metals from the soil for the vegetables. Cd was found to transfer at a higher degree than other studied metals, which is potentially carcinogenic. The non-carcinogenic risk, THQ values for all the metals except Cr, were higher than the threshold limit, whereas HI and TR values for all the metals were higher than the threshold limit. The THQ, HI, and TR values revealed that the consumption of vegetables from this area might pose serious human health risks in the long run. Considering the findings of this study, there is a dire need of extensive further research taking all the possible parameters into account. The present study suggests that immediate action must be taken to stop the further water contamination of the Dhaleshwari River and the usage of this water for irrigation purposes by regulating wastewater discharge from the tanneries and effluent treatment. This study recommends that constant monitoring of this area of study as well as an improved waste management system be assured in order to protect human health and the ecosystem.

Author Contributions

Conceptualization – Nehar UHB and Hasan MJ; methodology – Hasan MJ; formal analysis – Nehar UHB and Ali MF; investigation – Hasan MM and Ali MF; resources – Nehar UHB; writing-original draft preparation – Nehar UHB and Hasan MJ; writing-review and editing – Nehar UHB, Hasan MM, Hasan MJ and Ali MF; visualization – Nehar UHB.; supervision – Nehar UHB. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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