# HEAVY METAL CONTAMINATION IN SELECTED VEGETABLES HARVESTED FROM INDUSTRIAL ZONES NEAR DHAKA, BANGLADESH

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**ABSTRACT**

Vegetables play a crucial role in the human diet, providing a rich source of essential nutrients, including vitamins, minerals, fiber, and antioxidants. Regular consumption of vegetables is linked to numerous health benefits and can help prevent various diseases. However, vegetables cultivated in contaminated soil, irrigated with polluted water, and treated with excessive inorganic fertilizers may accumulate harmful heavy metals, posing significant health risks to consumers. This study aimed to evaluate the presence and concentrations of heavy metals in vegetables harvested from areas near industrial zones. Additionally, it assessed the potential health risks associated with the consumption of these contaminated vegetables. The study analyzed four types of vegetables—red spinach, water spinach, cauliflower, and brinjal—for the probable presence of toxic heavy metals, including lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr). The concentrations of these metals were measured using an Atomic Absorption Spectrophotometer, with all results expressed on a fresh weight (fw) basis. The health risks associated with the intake of these metals were evaluated through Estimated Daily Intake (EDI) calculations, non-carcinogenic risk assessments using the Target Hazard Quotient (THQ), Total Target Hazard Quotient (TTHQ), and Hazard Index (HI), as well as carcinogenic risk evaluations based on total Carcinogenic Risk (CR). The analysis revealed that the concentrations of heavy metals exceeded the maximum allowable limits set by the FAO/WHO for lead in all vegetable samples, except for water spinach, and for cadmium (Cd) in leafy vegetables. The EDI values for all heavy metals in the vegetables were found to surpass the maximum permissible daily intake (MTDI). While the THQs for all heavy metals, except for lead (Pb) in cauliflower, were below 1, indicating no immediate health hazards for the adult population. The total TTHQs for lead (Pb) and cadmium (Cd) exceeded 1 across all vegetable types, signifying substantial health risks.

**KEYWORDS:** Heavy metals, Environment, Pollution, Vegetables, Food, Nutrition, Public Health, Climate change, Toxicology.

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## Introduction

Micronutrient deficiencies remain a significant public health challenge, particularly in low-income countries. While the focus has traditionally been on protein-energy malnutrition, the impact of micronutrient deficiencies on health has acquired increasing attention. These deficiencies can adversely affect both children and adults, leading to stunted growth, impaired cognitive function, and weakened immune systems. According to the World Health Organization (2005), approximately 1 billion individuals in developing nations suffer from micronutrient deficiencies, with an additional billion at risk. Alarmingly, more than one-third of deaths among children under five years of age can be attributed to these deficiencies (Black et al., 2013).

Vegetables play a crucial role in addressing micronutrient deficiency-related health issues, as they are rich sources of essential vitamins and minerals. Epidemiological studies indicate that preschool children and other vulnerable populations face unacceptably high rates of mortality and malnutrition when their vegetable intake falls below 200 grams per person per day (Keatinge et al., 2011). Vegetables provide key nutrients such as vitamins, minerals, fiber, and antioxidants. Regular consumption of both raw and cooked vegetables supports human growth and development while helping to prevent a range of diseases. However, it is important to note that vegetables grown in contaminated soil, irrigated with polluted water, or treated with excessive inorganic fertilizers can accumulate heavy metals, posing serious health risks to consumers (Akanda et al.,2023, Mamun et al.,2024). Research has shown that several heavy metals, including lead (Pb), mercury (Hg), chromium (Cr), cadmium (Cd), and arsenic (As), are highly toxic to living organisms (Gupta et al., 2021).

Heavy metals have long biological half-lives which make them highly alarming environmental and food contaminants (Labhade, 2013). Heavy metals are also non-biodegradable. So, their presence in the food supply can pose significant risks to human health. To ensure public health safety, it is essential to control the contamination of heavy metals in food chain. These heavy metals can enter the food chain through various metabolic processes, where they may undergo biomagnification at different trophic levels. Consuming food contaminated with heavy metals can significantly deplete the body of essential nutrients, which in turn can weaken the immune system. Consequences of such exposure include intrauterine growth retardation, impaired psychosocial development, disabilities resulting from malnutrition, and an increased risk of upper gastrointestinal cancers (Tasrina et al., 2015).

Leafy vegetables, in particular, are more prone to accumulating heavy metals in their edible portions compared to grain or other crops. These vegetables absorb heavy metals and can store them in both edible and inedible parts, potentially leading to serious health concerns in both animals and humans upon consumption. Chronic exposure to these hazardous heavy metals through soil and vegetables can have detrimental effects on health, although these adverse outcomes may not be visible for several years after exposure (Tasrina et al., 2015).

Industrial activities often release untreated or inadequately treated wastewater, effluent, and sludge into the environment, which can degrade soil quality by increasing the concentration of contaminants, including heavy metals (Rahman et al., 2012). While the capacity of different plant species to absorb heavy metals varies significantly, plants can uptake these heavy metals from the soil through their roots, transport them to their shoots, and ultimately accumulate them in their tissues. Reports indicate that fruits, vegetables, and cereals account for approximately half of the dietary intake of lead, copper, and chromium, with some exceeding permissible limits in urban areas (Parvin et al. 2014).

## Methodology

### Selection and Collection of Samples

Four types of vegetable samples were selected for proximate analysis and measurement of heavy metal concentration. This study focused on two leafy vegetables—red spinach and water spinach—and two non-leafy vegetables—cauliflower and round brinjal.

Samples were collected from three locations: Jhawchor Bazar, Rajfulbaria Bazar, and Basa Bazar, all situated near the Dhaleshwari River in the Savar Union. Several industries such as; garments, packaging, leather goods, plastic etc. are situated in this area. The samples were collected from local markets in the industrial area of Savar, Dhaka (see Figure 1). Collected samples were from local growers who sell their products in local markets. Composite samples were then prepared for analysis. All collected samples underwent further processing in the laboratories of the Institute of Nutrition and Food Science (INFS) at the University of Dhaka and the Bangladesh Council of Scientific and Industrial Research (BCSIR).

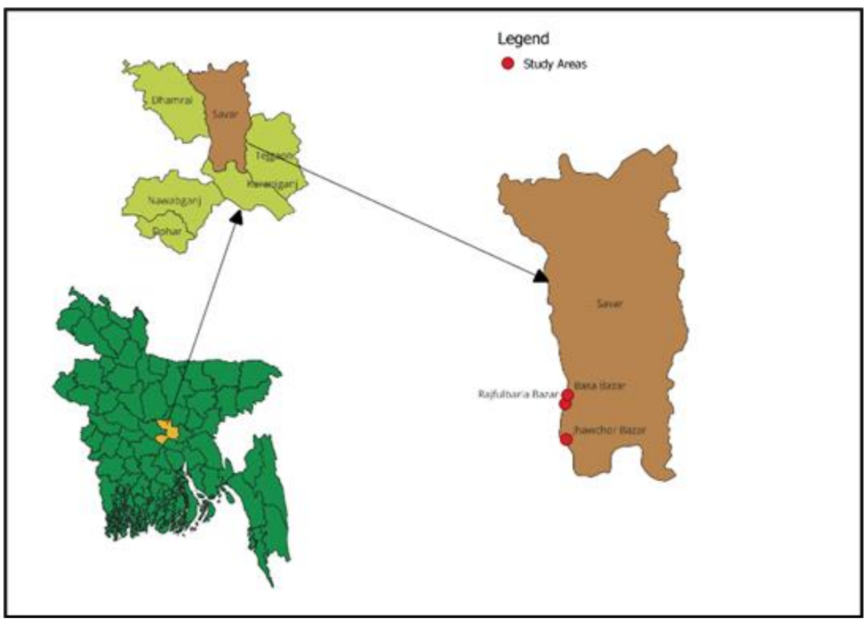


**Figure 1.** Map of the study area.

### Sample Preparation:

Upon collection, the vegetable samples were thoroughly washed to eliminate any extraneous materials. They were then air-dried to remove excess moisture. The samples were then properly dressed; each sample was chopped and minced to achieve a homogeneous consistency. For the purposes of this study, a composite sample consisting of a uniform mix of units from the same type of vegetable was created.

For proximate analysis, portions of the composite samples were immediately set aside for moisture and ash analysis. The remaining samples were oven-dried and subsequently grinded into a fine powder. The prepared samples were stored in airtight Ziploc bags and desiccated until further analysis. For heavy metal analysis, portions of the composite samples were dried at 80°C overnight to ensure complete moisture removal. The dried samples were then grinded using a pestle and mortar. The resulting powdered samples were also stored in airtight Ziploc bags until analysis.

All analyses were conducted using homogeneous samples, ensuring consistency and reliability in the results. Proximate composition of the samples were determined on dry weight basis according to the methods approved by AOAC

International, 2000 (AOAC, 2000). The moisture, ash, fat and protein content of the samples were analyzed in triplicate.

**Assessment of Health Risk**

The values of heavy metal accumulation in edible parts of vegetables were used to calculate the Estimated Daily Intake (EDI) of metals, Target Hazard Quotients (THQ), Hazard Index (HI) and Target Cancer Risk (CR) separately for Bangladeshi population.

**Estimated daily intake (EDI)**

The household income and expenditure survey's data on average concentrations of various heavy metals in food samples were used to calculate estimated daily intakes (EDIs) (HIES, 2022), which were then multiplied by the body weight of the person (FAO, 2006) and the weight of the food items they were consuming.

Formula used:

$$EDI = \frac{FIR \times C}{BW}$$

Where,

C = Heavy metal concentration in food (mg/kg)

FIR = Food ingestion rate (g/person/day)

BW = Body weight (60 kg for an adult in Bangladesh)

**Non-carcinogenic risk**

The Target Hazard Quotient (THQ) and Total Target Hazard Quotient (TTHQ) were calculated using the following formula (FAO/WHO, 2011)

$$THQ = \frac{Efr \times ED \times FIR \times C}{RfD \times BW \times AT} \times 10^{-3}$$

TTHQ (individual food) = THQ metal 1 + THQ metal 2 + ………….. + THQ metal n.

A Hazard Index (HI) based on the USEPA's Guidelines for Health Risk Assessment of Chemical Mixtures has been developed to evaluate the total potential for noncarcinogenic impacts from multiple heavy metals. (USEPA, 1989):

HI = ΣTTHQ

= TTHQ food 1 + TTHQ food 2 + ………….. + TTHQ food n,

Where,

THQ = Target Hazard Quotient

FIR = Food Ingestion Rate (g/person/day)

EFr = Exposure Frequency (365 days/year)

ED = Exposure Duration (70 years)

C = Metal Concentration in foods (mg/kg)

RfD = Oral Reference Dose (mg/kg/day)

AT = Averaging Time for noncarcinogens (365 days/ year × number of exposure years).

The oral reference doses are 0.0035, 0.001, 0.02, and 1.5mg/kg/day for lead, cadmium, nickel, and chromium respectively (USEPA, 2015b). It is assumed that all of the chromium ions in the vegetables are trivalent which is noncarcinogenic in order to estimate the proper RfD for THQ. The subjected population is not likely to develop overt negative consequences if THQ < 1. There may be a health risk if THQ is ≥ 1(Wang et al., 2005), necessitating the implementation of relevant interventions and protective measures.

**Carcinogenic risk of heavy metals**

The target Carcinogenic Risk (CR) factor (USEPA, 1989) is calculated by the following formula:

$$TR = \frac{Efr \times ED \times FIR \times C \times Csfo}{BW \times AT} \times 10^{-3}$$

Where,

AT = Averaging Time for carcinogens (365 days/ year × number of exposure years)

TR = Target Cancer Risk or the risk of cancer over a lifetime

Csfo = Oral Carcinogenic Slope Factor was $8.5 \times 10^{-3}$ $(mg/kg/day)^{-1}$ for Pb (USEPA, 2015a), 0.38 $(mg/kg/day)^{-1}$ for Cd, 0.5 $(mg/kg/day)^{-1}$ for Cr and 0.84 $(mg/kg/day)^{-1}$ for Ni (Naseri et al., 2021).

**Results:**

**Proximate nutrient contents of selected vegetables**

Table 1 stated the proximate nutrient contents of selected vegetables (g/100g fresh weight). The highest moisture content was found in brinjal (93.24%) and the lowest was found in red spinach (88.40%). Red spinach had the highest fat and ash content.

**Table 1.** Proximate nutrient composition of selected vegetables (g/100g fresh weight).

| VEGETABLES | MOISTURE (%) | PROTEIN (%) | FAT (%) | CRUDE FIBER (%) | ASH (%) | CARBOHYDRATE (%) | TEV (KCAL/100G) |
|---|---|---|---|---|---|---|---|
| **RED SPINACH** | 88.40 ± 0.13 | 3.15 ± 0.02 | 0.16 ± 0.01 | 1.39 ± 0.07 | 1.89 ± 0.04 | 6.40 | 39.64 |
| **WATER SPINACH** | 89.12 ± 0.19 | 4.27 ± 0.04 | 0.15 ± 0.03 | 2.08 ± 0.10 | 1.22 ± 0.03 | 5.24 | 39.39 |
| **CAULIFLOWER** | 88.74 ± 0.12 | 3.26 ± 0.02 | 0.06 ± 0.00 | 0.41 ± 0.05 | 0.82 ± 0.02 | 7.12 | 42.06 |
| **BRINJAL** | 93.24 ± 0.43 | 0.11 ± 0.01 | 0.13 ± 0.01 | 1.30 ± 0.03 | 0.39 ± 0.02 | 6.13 | 26.13 |

*TEV = Total energy value.

Table 2 shows the concentration of heavy metals in vegetables (fresh weight). Pb in cauliflower and Cd in red spinach and water spinach were found higher than Maximum Allowable Concentration (MAC).

**Table 2.** Concentration (mg/kg fw) of heavy metals in the composite samples of selected vegetables.

| Vegetables | Heavy metals (mg/kg fw) | | | |
|---|---|---|---|---|
| | Pb | Cd | Ni | Cr |
| Red Spinach | 0.71 ± 0.002 | 0.30 ± 0.004 | 0.92 ± 0.011 | 0.23 ± 0.006 |
| Water Spinach | 0.08 ± 0.000 | 0.11 ± 0.002 | 0.16 ± 0.030 | 0.12 ± 0.005 |
| Cauliflower | 1.31 ± 0.015 | 0.01 ± 0.000 | 0.21 ± 0.005 | BDL |
| Brinjal | 0.57 ± 0.002 | 0.04 ± 0.002 | 0.09 ± 0.002 | BDL |
| **MAC (FAO/WHO, 2002)** | 0.1 | 0.05 | 10 | 2.3 |

**MAC = Maximum allowable concentration; fw = fresh weight*
**BDL = Below detection limit*

Table 3 showed estimated daily intake (EDI) of heavy metals from samples. The table also showed the comparison with the corresponding maximum tolerable daily intake (MTDI) in the Bangladeshi population.

**Table 3.** Estimated daily intake (EDI) of heavy metals in vegetables.

| Vegetables | Estimated daily intake (EDI) of heavy metals (mg/day) | | | |
|---|---|---|---|---|
| | Pb | Cd | Ni | Cr |
| Red Spinach | 2.3914 | 0.9969 | 3.1088 | 0.7738 |
| Water Spinach | 0.2684 | 0.3690 | 0.5337 | 0.4178 |
| Cauliflower | 4.4101 | 0.0366 | 0.7079 | ND |
| Brinjal | 1.9156 | 0.1290 | 0.3189 | ND |
| EDI from all vegetables | 8.9855 | 1.5314 | 4.6692 | 1.1916 |
| **MTDI** | 0.21 | 0.021 | 0.3 | 0.2 |

**MTDI = Maximum tolerable daily intake*
**ND = Not detected*

The EDI for Pb were high in almost all vegetables. EDI for all the heavy metals were high in leafy vegetables like red and water spinach. Brinjal had high level of Pb and Cd. The highest level of Pb was found in cauliflower.

**Non-carcinogenic risk of heavy metals from consuming vegetables**
Table 4 showed that all the THQ (Target Hazard Quotient) values are less than 1 except for Pb in cauliflower.

**Table 4.** Target hazard quotient of heavy metals.

| Vegetables | Target hazard quotient (THQ) | | | | |
|---|---|---|---|---|---|
| | Pb | Cd | Ni | Cr | TTHQ |
| Red Spinach | 0.683 | 0.996 | 0.155 | 5.2E-4 | 1.836 |
| Water Spinach | 0.077 | 0.369 | 0.027 | 2.8E-4 | 0.4726 |
| Cauliflower | 1.260 | 0.037 | 0.035 | ND | 1.332 |
| Brinjal | 0.547 | 0.129 | 0.016 | ND | 0.6922 |
| **TTHQ from vegetables** | 2.567 | 1.531 | 0.234 | 8E-4 | **HI** =4.333 |

**TTHQ = Total THQ*
**HI = Hazard Index*

**Carcinogenic risk of heavy metals from consuming vegetables**
Table 5 shows the carcinogenic risk for the selected vegetables.

**Table 5.** Target carcinogenic risk (CR) of heavy metals of selected vegetables.

| Vegetables | Target carcinogenic risk (CR) | | | |
|---|---|---|---|---|
| | Pb | Cd | Ni | Cr |
| Red Spinach | 2.03E-5 | 3.79E-4 | 2.61E-3 | 3.87E-4 |
| Water Spinach | 2.28E-6 | 1.4E-4 | 4.48E-4 | 2.09E-4 |
| Cauliflower | 3.75E-5 | 1.39E-5 | 5.95E-4 | ND |
| Brinjal | 1.63E-5 | 4.9E-5 | 2.68E-4 | ND |
| **Total CR** | 7.64E-5 | 5.82E-4 | 3.92E-3 | 5.96E-4 |

## Discussion

In proximate analysis, notable differences were observed in the nutrient values across the various vegetables. Moisture content was the highest among all vegetables, ranging from 88.40% to 93.24%, while fat content was the lowest, varying from 0.06% to 0.16%. The nutrient composition generally followed this descending order: moisture > carbohydrate > protein > fat. Additionally, the content of crude fiber and ash varied among the different vegetables. The mean moisture content ranged from 88.40% in brinjal to 93.24% in red spinach. For water spinach and cauliflower, the mean moisture content was found to be 89.12% and 88.72%, respectively, which closely aligns with the values reported in the Food Composition Table (FCT) for Bangladesh (water spinach: 87.1% and cauliflower: 91.8%) (FCT, 2014). The mean moisture content can be ranked in descending order as follows: brinjal > water spinach > cauliflower > red spinach.

In terms of protein content, water spinach showed the highest level at 4.27%, while brinjal had the lowest at 0.11%. The mean protein content can be ranked as follows: water spinach > cauliflower > red spinach > brinjal. The protein levels in all vegetables were consistent with the FCT values (FCT, 2014). The ash content exhibited a pattern similar to that of crude fiber, with red spinach displaying the highest value at 1.89%, while brinjal recorded the lowest at 0.39%. These values were close to those reported in the Food Composition Table (FCT, 2014). The mean crude fiber content ranked in descending order as follows: red spinach > water spinach > cauliflower > brinjal.

Cauliflower had the highest carbohydrate, with a value of 7.12%. The mean carbohydrate content followed this descending order: cauliflower > red spinach > brinjal > water spinach. A significant difference was observed in carbohydrate levels when compared to the corresponding FCT values for the selected vegetable samples (FCT, 2014). Because the FCT measured available carbohydrates, whereas this study estimated total carbohydrates. The total energy content of the two leafy vegetables was nearly identical, with red spinach at 39.69% and water spinach at 39.39%. However, a significant difference was noted in cauliflower, which had an energy content of 42.06%, compared to brinjal at 26.13%. The total energy content ranked in descending order as follows: cauliflower > red spinach > water spinach > brinjal.

Heavy metals—specifically lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni)—in the most commonly consumed vegetables in Bangladesh, measured in milligrams per kilogram (mg/kg) of fresh weight. Red spinach exhibited the highest concentration of nickel at 43%, followed closely by water spinach at 34%. In terms of lead, cauliflower and brinjal showed the highest levels, with concentrations of 85% and 81%, respectively. Notably, the levels of chromium in both cauliflower and brinjal were below detection level. The results from this study was similar to Mizan et al. (2023). The overall ranking of heavy metal concentrations in the analyzed vegetables was as follows: red spinach > cauliflower > brinjal > water spinach. Among the vegetables examined, the mean concentrations of lead were found to decrease in the following order: cauliflower > red spinach > brinjal > water spinach. The lead levels in these vegetables ranged from 0.08 to 1.31 mg/kg. In a related study conducted in Chapai Nawabganj, Bangladesh, lead concentrations in 24 different vegetable types ranged from 0.00003 to 0.0007 mg/kg (Islam et al., 2015). Other studies in Bangladesh reported mean lead contents of 0.5 mg/kg (Islam et al., 2015), 3.7 mg/kg (Rahman et al., 2013), and 3.9 mg/kg in various vegetables (Ahmad & Goni, 2010). According to the findings of this study, the lead content in all analyzed vegetables exceeded the maximum allowable concentration level, with the exception of water spinach.

The mean concentration of cadmium (Cd) in the analyzed vegetable samples was ranked in the following order: red spinach > water spinach > brinjal > cauliflower. Red spinach exhibited the highest mean Cd concentration at 0.30 mg/kg, while cauliflower had the lowest at 0.01 mg/kg. Recent studies conducted in Bangladesh reported varying mean Cd levels in different vegetables, with findings of 0.6 mg/kg (Ahmad & Goni, 2010), 0.06 mg/kg (Rahman et al., 2013), and 0.1 mg/kg (Islam et al., 2015). The Cd levels in the leafy vegetables (red spinach and water spinach) exceeded the established safety limits, whereas the non-leafy vegetables (cauliflower and brinjal) remained within acceptable levels. Mizan et al. (2023) also found similar results. During the cultivation period the uncontrolled use of various fungicides, insecticides, and phosphate-containing fertilizers containing Cd metal might be the cause of high Cd concentration (Alam et al., 2018).

The nickel (Ni) concentrations in the vegetable samples ranged from a low of 0.09 mg/kg in brinjal to a high of 0.92 mg/kg in red spinach. Importantly, all Ni levels were below the permissible limits. Previous studies in Bangladesh reported Ni concentrations in vegetables as 1.4 mg/kg (Rahman et al., 2013), 1.9 mg/kg (Islam et al., 2015), and 3.0 mg/kg (Ahmad & Goni, 2010). The mean Ni concentration in the vegetable samples was ranked as follows: red spinach > cauliflower > water spinach > brinjal. The mean concentrations of chromium (Cr) were 0.23 mg/kg in red spinach and 0.12 mg/kg in water spinach, both of which fell within the maximum allowable range. However, the levels of Cr in cauliflower and brinjal were below the detection limit. Recent studies have revealed varying concentrations of chromium (Cr) in different vegetables, with findings of 0.6 mg/kg reported by Rahman et al. (2013) and 7.90 mg/kg by Maleki and Zarasvand (2008).

All analyzed vegetable samples contained detectable levels of heavy metals, with the exception of chromium in two non-leafy vegetable varieties. Notably, lead (Pb) was found to have the highest concentration among the total metal content in the vegetables. Alarmingly, the levels of heavy metals in these samples exceeded the maximum allowable concentrations (MAC) established by the FAO/WHO for lead in all vegetables, with the sole exception of water spinach. Additionally, cadmium (Cd) levels surpassed the MAC in leafy vegetables among those tested.

The total daily intakes for Pb, Cd, Ni, and Cr were found to be 8.9855 mg, 1.5314 mg, 4.6692 mg, and 1.1916 mg, respectively. The estimated daily intake of heavy metals from vegetable consumption ranked in the following order: Pb > Ni > Cd > Cr. Notably, all values for daily dietary intake from vegetables exceeded the established MTDI levels. The results indicate that THQ values for all heavy metals were below 1, with the exception of lead in cauliflower. Mizan et al. (2023) showed the closes results to the current study. The total THQ (TTHQ) values for the vegetable samples were ranked as follows: red spinach > cauliflower > brinjal > water spinach. Both red spinach and cauliflower exhibited TTHQ values greater than 1, suggesting a potential health risk. Conversely, the TTHQ values for water spinach and brinjal were below 1, indicating minimal or no significant health concerns associated with the consumption of these vegetables.

The cumulative noncarcinogenic effects of various elements are expressed by the HI value. Table 3 shows that, for consumption of all four vegetable samples, HI was 4.333>1, showing that consuming vegetables may have a negative impact on consumers' health. The target carcinogenic risks (TCRs) associated with chromium (Cr), cadmium (Cd), nickel (Ni), and lead (Pb) were calculated, as the ingestion of these compounds can lead to both non-carcinogenic and carcinogenic effects, depending on the level of exposure. Generally, an excess cancer risk below 10^-6 is considered minimal, while a risk exceeding 10^-4 is deemed significant. Risks that fall between these two thresholds (10^-6 to 10^-4) are typically regarded as acceptable. The calculated carcinogenic risk (CR) values for Pb in red spinach, water spinach, cauliflower, and brinjal were 2.03E-5, 2.28E-6, 3.75E-5, and 1.63E-5, respectively. For Cd, the CR values were 3.79E-4 for red spinach, 41.4E-4 for water spinach, 1.39E-5 for cauliflower, and 4.9E-5 for brinjal. The CR values for Ni were 2.61E-3 for red spinach, 4.48E-4 for water spinach, 5.95E-4 for cauliflower, and 2.68E-4 for brinjal. In the case of Cr, the values for red spinach and water spinach were 3.87E-4 and 2.09E-4, respectively, while the values for cauliflower and brinjal were negligible, indicating no significant concentration of Cr. The analysis revealed that the total CR values for Cd, Ni, and Cr in the examined vegetables fell within the unacceptable range (>10^-4), indicating a potential health risk. In contrast, the CR for Pb was within the acceptable range (10^-6 to 10^-4). These findings underscore the potential health risk from consuming these toxic elements (Mizan et al., 2023).

## Conclusion

This study evaluated the concentrations of four heavy metals—lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr)—in commonly consumed vegetables in Bangladesh. The findings revealed that red spinach exhibited the highest average concentration of all metals, while water spinach had the lowest. Specifically, the highest levels of Pb were detected in cauliflower, while red spinach showed elevated concentrations of Cd, Cr, and Ni. Notably, the total Pb content was the most significant among the metal concentrations in the vegetables analyzed. The estimated levels of Pb and Cd surpassed the maximum allowable concentrations for vegetables, raising concerns about potential human health risks. While the calculated THQ values were below 1 for most vegetables—indicating no significant non-carcinogenic risk—cauliflower was an exception due to its elevated Pb levels. The TTHQ values for red spinach and cauliflower exceeded 1, suggesting a potential health risk associated with their consumption. Our analysis indicated that only the Target Risk (TR) for Pb fell within the acceptable range, whereas the TR for Cd, Ni, and Cr was deemed unacceptable. This study highlights the chronic exposure of consumers to heavy metal pollution, which poses both carcinogenic and non-carcinogenic health risks.

In light of these findings, we recommend that the Government of Bangladesh implement routine monitoring of hazardous heavy metals and metalloids in the daily diets of its citizens. This proactive approach is essential for enforcing regulatory limits and assessing the risks associated with long-term exposure. Furthermore, we advocate for further investigation into the sources of heavy metal contamination, such as soil, water, and fertilizers, to better understand their accumulation in food.

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## Conflict of interest

The authors declare no conflict of interest which may have inappropriately influenced them in writing this article.

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