Heliyon 9 (2023) e21746

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Heavy metals induced health risk assessment through consumption of selected commercially available spices in Noakhali district of Bangladesh

Md Shahedul Islam [a], Akibul Islam Chowdhury [a,b], Lincon Chandra Shill [a], Sompa Reza [c], Mohammad Rahanur Alam [a,*,1]

[a] Department of Food Technology and Nutrition Science, Noakhali Science and Technology University, Noakhali, Bangladesh
[b] Department of Nutrition and Food Engineering, Daffodil International University, Savar, Dhaka, Bangladesh
[c] Institute of Nutrition and Food Science, University of Dhaka, Dhaka, Bangladesh

A R T I C L E I N F O

Keywords:
Carcinogenic
Non-carcinogenic
Heavy metals
Spices
Health risk assessment

A B S T R A C T

There are growing concerns for food safety due to the risks associated with heavy metal contamination of culinary herbs and spices in developing countries like Bangladesh. The objective of the present cross-sectional study is to determine the concentrations of the heavy metals Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), and Iron (Fe) in the branded and non-branded spices collected from the Noakhali district by Atomic absorption spectrophotometry method, as well as to assess the health hazard risk associated with heavy metals intake via consumption of spices. The findings revealed that the greatest concentrations of Pb (15.47 ± 1.93), Cd (1.65 ± 0.011), Cr (31.99 ± 3.97), Cu (18.84 ± 1.97), and Fe (9.29 ± 1.71) were found in Cardamom, Coriander leaf, Bay leaf, Dried chili, and Black pepper respectively. Around 37 % of Cr and 5 % of Fe Estimated Daily Intake (EDI) were greater than reference doses (RfD). All spices had Total Hazard Quotient (THQ) values for Pb, Cd, Cu, and Fe that were below acceptable, and 37 % of all spices had Total Target Hazard Quotient (TTHQ) values for Pb, Cd, Cu, and Fe that were over the standard range, suggesting adverse health impacts for consumers. Green chili, ginger, coriander leaf, and all kinds of chili powder and turmeric powder have been reported to have exceptionally high TTHQ levels of Cr. The estimated carcinogenic risk for chromium in non-branded coriander leaf was found to be higher than safe levels. This study provides valuable insights into the commonly consumed spices in Bangladesh and their potential health risks associated with heavy metal contamination. The findings of this study can be used by regulatory authorities to develop effective strategies and actions to mitigate these risks and safeguard public health.

1. Introduction

Globally, food safety is a top priority for the public. Researchers have focused on the hazards associated with consuming contaminated foodstuffs, such as pesticides, heavy metals, or toxins in vegetables and spices, in response to the rising demand for food

* Corresponding author. Department of Food Technology and Nutrition Science, Noakhali Science and Technology University, Noakhali, 3814, Bangladesh.

E-mail address: rahanur.ftns@nstu.edu.bd (M.R. Alam).

[1] Current Address: Department of Nutrition, University of Tennessee, Knoxville, Tennessee, USA.

https://doi.org/10.1016/j.heliyon.2023.e21746
Received 25 March 2023; Received in revised form 26 October 2023; Accepted 26 October 2023
Available online 30 October 2023

and food safety [1]. Due to their abilities as a taste enhancer, color imparter, texture developer/improver, palatability, and medicinal effects, spices are natural ingredients in nearly all traditional cuisines around the world [2–4]. More than a hundred distinct spices are grown across the world, with Asia being the primary producer [5]. The global trade of spices is around USD 3 billion, while the reported per capita daily intake of spices is around 5 g [6].

Heavy metals are one of the severe pollutants in the environment due to their toxicity, persistence, and bioaccumulation problem. Heavy metal refers to heavy metallic chemical elements that have relatively high density and are toxic or poisonous at low concentrations [7]. They include essential and non-essential elements such as Mercury, Cadmium, Chromium, Copper, Zinc, Manganese, Lead, etc. These heavy metals come in contact with over bodies via food, drinking water, and air. They are unsafe as they tend to bioaccumulate (increase in concentration in biological cells over time) [8]. The toxicity can cause a variety of health problems, including kidney diseases, neurobehavioral and developmental abnormalities, high blood pressure, and cancer [9,10].

Human exposure to harmful heavy metals has grown as a result of rising populations, which places greater strains on infrastructure and buildings. Soils that may be utilized to raise crops are contaminated by industrial spills and inadequate handling of chemical waste [11]. Human activities such as mining, fertilizer-based agriculture (including aquaculture), and chemical fishing also lead to the transport and deposition of heavy metals in soils and water [12].

Global concern is growing regarding the widespread contamination of culinary herbs and spices such as curry powder, oregano, black pepper, and turmeric with heavy metals such as lead [13]. As a matter of fact, spices are one of the top five food items that are most frequently contaminated [14,15]. Markets in the United States, Europe, and other regions with well-resourced regulatory authorities nevertheless report cases of contamination of culinary herbs and spices, despite strict regulation. Recently, excessive amounts of lead were found in several brands of turmeric sold in the United States, drawing attention to the potential health risks posed by consuming certain culinary herbs and spices [16]. The consequences of investigations by the FDA caused these turmeric brands to be removed from the shelves [13].

Regulatory organizations in developing countries such as Bangladesh do not sample spices on the market on a regular basis to assess their safety, maybe because these heavy metals are not deemed a hazard. But, very little research has been directed to evaluate heavy metal-related risk assessment in spices in Bangladesh. Rahman, M.A. et al. found twice the amount above the acceptable value of lead in unbranded turmeric samples collected from Dhaka city using atomic absorption spectroscopy [17]. Akter, S. et al. found similar result using the Ion Beam Analysis Technique in Pakistan [18]. Another study, conducted in Chattogram, Bangladesh, merely assessed heavy metals in three spice samples [19]. No other study has been conducted to determine the heavy metal content of the overall spices consumed by consumers in Bangladesh. Additionally, the potential carcinogenic and non-carcinogenic health risks from the consumption of spices have not been studied in Bangladesh. Besides, even in the global context, where heavy metals-induced risk assessment has been studied, it has been done randomly from local markets, not on the basis of consumption [19–21]. Moreover, in those studies, they assessed the health risk by considering average spice consumption and average human body weight based on the existing literature [20,22,23].

In the context of Bangladeshi cuisine, the utilization of a wide array of spices is prevalent due to the strong preference for spicy flavors among the majority of individuals in this geographical area, consumers of Noakhali coastal region are not different from national dietary habit. Besides, coastal areas like Noakhali are more prone to heavy metal accumulation and, subsequently, to human health risks [24]. Moreover, there are very limited studies regarding heavy metal concentration in spices, and any studies that assessed heavy metal-induced health assessments due to spice consumption are not available, although more than 2.6 % of the total cultivated land in Bangladesh is used for spice production [25].

So, the key objectives of our current study were to select the spices on the basis of consumption and ascertain the levels of heavy metals on the basis of consumption, specifically lead, cadmium, chromium, copper, and iron, in both branded and non-branded spices obtained from the study area. Additionally, we sought to evaluate the potential health risks associated with the consumption of these spices in relation to heavy metal intake in terms of actual household members consumption frequencies and their actual body weight.

2. Methods and materials

2.1. Study design and sampling

This study was a cross-sectional observational study that was designed by following a study conducted by Kasozi et al. and Dare et al. [26,27]. A multi-stage probability sampling method was used to collect data on spice consumption frequency from 180 households. A household survey was conducted in six different clusters from three stratified locations. There were two small towns, two paurashavas, and two unions among these six. The six clusters are marked in Fig. S1, and these are identified as Chowmuhani, Maijdee, Bashurhat, Kabirhat, Noakhali Union, and Underchar Union (See Supplementary Fig. S1).

2.2. Data collection

Respondents were asked a set of relevant questions using a structured questionnaire with the remaining three sections, which included household information, demographic & anthropometric information, and consumption frequency of spices.

2.3. Exclusion or inclusion criteria

Only those families whose heads gave their oral and/or written informed consent to participate in the study had their data collected. Anthropometric data were also omitted for members of the family who did not ingest spice-containing foods.

3. Sample collection and preparation

3.1. Sample collection

Based on the consumption patterns observed in the surveyed households, a total of nineteen samples of spices, ranging in commercially available sizes from 50g to 125g, were collected from the Sonapur and Maijdee marketplaces in the Noakhali District of Bangladesh. Non-branded spice samples (n = 15) and branded spice samples (n = 4) were acquired at random from open markets (See Supplementary Table S1).

3.2. Wet digestion of samples

Wet digestion was carried out using a 1:4 concentrated mixture of HNO_3 and H_2S0_4 adapted from two different studies conducted in Malaysia and Pakistan [20,21]. The mixture was heated to 130 °C using a thermostat-controlled heating block for 1 h and was allowed to cool gradually. Each digestion mixture received 2 ml of H_2O_2, and the contents were returned to the oven for further heating. This step was replicated unless a colorless solution was generated. Following filtration, the clear solution was transferred to a 50 ml volumetric flask tube and topped up to the maximum with deionized water.

3.3. Heavy metal determination with atomic absorption spectroscopy (AAS)

The heavy metal determination was performed with a PerkinElmer Inc. PinAAcleTM 900H Atomic Absorption Spectrometer (AAS) with dual beam optics continuum source double-beam background correction using a high-intensity deuterium arc lamp (See lamp specifications at Supplementary Table S2). The heavy metal assessment methodology was modified following three distinct studies conducted in Uganda [26–28]. The equipment was calibrated with a linear calibration through zero using a standard solution and a blank solution containing known concentrations of the heavy metals under investigation. The AAS was performed in triplicate on digested clear solutions for each sampled spice. The linearity (R^2) ranges from 0.9897 to 0.9983 for the standards. The limit of detection (LOD) was set at 0.001 μg/g following a Malaysian study conducted by Nordin and Selamat [21], and the standard measuring time for accurate determination was 3 s [29].

3.4. Calculation of weekly and daily consumption frequencies

The aforementioned computation has been executed by adhering to a series of sequential stages. Initially, homes were queried on a weekly basis on the specific types and quantities of spices that were documented by equation no. 1.

$$\text{Weekly consumption of a spice by a household (g)} = \text{sum of seven days consumption (i.e., Day 1} + \text{Day 2} + \text{Day 3} + \text{Day 4} + \text{Day 5} + \text{Day 6} + \text{Day 7)} \tag{1}$$

Furthermore, the total weekly intake quantity has been translated into a daily consumption rate, with the data given in grams. Additionally, the ingestion rate was determined by dividing the gross values by the total number of household members by the equation no. 2, resulting in per-person consumption (g) per day [30].

$$\text{Per day consumption of that spice (g)} = \text{Consumption in a week} / 7 \tag{2}$$

3.5. Exposure to heavy metals, ingestion rate (IR), and approximate spices consumption

Data from a sample of 180 households was gathered using a specific convenience sampling technique to determine how frequently members of the household consume spices on a daily basis by following the method described above. Participants were asked about their daily and weekly spice consumption, with a focus on the amount in grams. In addition, the weight of each household member was recorded. The daily consumption, i.e., ingestion rate, was then estimated based on the body weight of each family member by following equation no. 3 [30].

$$\text{Ingestion rate (IR), g} = \text{Per} - \text{day consumption of a specific spice} / \text{household members of that particular household} \tag{3}$$

3.6. Human health risk assessment

Following the equations and methods described (See equation (4)), the Estimated Daily Intake (EDI) of selected heavy metals was estimated for each household member to assess the estimated health risk associated with consuming heavy metal contaminants [30].

$$\text{EDI} = (C_{metal} \text{ x IR}) / \text{BW} \tag{4}$$

where, C_{metal} implies the concentration of the metals in mg/kg, IR or ingestion rate expressed in gram per day per person, and BW is average body weight of the household members in kg.

Total Hazard Quotient (THQ) was used to assess the non-carcinogenic risks associated with long-term heavy metal exposure. Total Hazard Quotient (THQ) is the ratio of a substance's levels of exposure over such a specific duration to a reference dose (RfD) (See equation (5)). Exposure levels below a certain level (<1) indicate a lower risk of adverse health effects. Consumption of tainted spices, on the other hand, may cause health hazards if the calculated value of THQ is equal to or greater than 1 (≥1) [20].

$$THQ = EDI / RfD \tag{5}$$

The RfD values for Pb, Cd, Cr, Cu, and Fe are 0.0035, 0.0005, 0.0003, 0.040, and 0.007 mg per kg per day, respectively [31–33].

The Total Target Hazard Quotient (TTHQ) was used to estimate the overall non-carcinogenic risk to human health from exposure to various heavy metals (See equation (6)) [20]. The population may experience adverse health effects if the TTHQ value exceeds 1 [34–36].

$$TTHQ = THQ\ (Pb) + THQ\ (Cu) + THQ\ (Cd) + THQ\ (Fe) + THQ\ (Cr) \tag{6}$$

Cancers risk refers to an individual's increased likelihood of developing cancer due to contact with hazardous carcinogenic compounds such as Pb, Cd, and Cr (See equation (7)) [37].

$$\text{Cancer Risk} = EDI \times CSF \tag{7}$$

where CSF (Cancer Slope Factor) is presented in mg/kg/day.

The US Environmental Protection Agency recognizes a cancer risk in the range of 1×10^{-6} to 1×10^{-4} as appropriate for risk management purposes [38].

3.7. Statistical analysis

The heavy metal concentrations in the spices were recorded in Microsoft Excel in order to calculate the carcinogenic and non-carcinogenic risk parameters. The mean concentration of heavy metals in each sample was analyzed using SPSS software version 26. Normality of data were measured using Kolmogorov–Smirnov test. A one-way analysis of variance (ANOVA) was conducted to assess the statistical significance of the differences in means among all spice samples. The significance level chosen for this analysis was set at less than 0.05. The LSD test was employed to conduct multiple comparisons among means.

4. Result and discussion

4.1. Socio-demographic, anthropometric information and consumption frequency of the study population

There were 180 respondents and 728 household members (including respondents) in the study location; the average household members were 4.03 ± 1.17. Among the 180 respondents, 72.22 % were female, whereas among the 728 household members, 404 (55.5 %) were female. For both respondents and household members, the average age was 36.70 ± 12.96 and 26.40 ± 17.70. Most of the respondents who participated in the study completed their primary (35 %) and secondary education (38.3 %), while only 8.3 %

Table 1
Heavy metals concentrations (mg/kg) in analyzed spices collected from Noakhali district of Bangladesh (mean ± SD).

Sample ID	Lead (Pb)*	Cadmium (Cd)*	Chromium (Cr)*	Copper (Cu)*	Iron (Fe)*
S-1	0.50 ± 0.08	0.80 ± 0.04	21.32 ± 2.24	15.34 ± 2.28	24.52 ± 2.39
S-2	1.04 ± 0.02	1.48 ± 0.03	19.68 ± 1.41	3.81 ± 0.69	18.31 ± 2.01
S-3	1.27 ± 0.02	0.86 ± 0.02	20.40 ± 2.23	12.62 ± 1.62	33.99 ± 3.18
S-4	1.34 ± 0.00	1.43 ± 0.01	15.83 ± 1.91	5.50 ± 1.23	20.93 ± 2.83
S-5	1.03 ± 0.01	0.70 ± 0.04	17.25 ± 1.26	BDL	34.17 ± 3.94
S-6	0.46 ± 0.03	0.73 ± 0.02	12.34 ± 1.23	17.82 ± 1.97	11.16 ± 1.86
S-7	10.32 ± 1.22	1.18 ± 0.02	25.44 ± 2.26	12.43 ± 0.90	13.34 ± 1.62
S-8	0.43 ± 0.01	0.53 ± 0.01	15.22 ± 1.92	8.92 ± 1.57	19.73 ± 2.12
S-9	0.24 ± 0.02	0.47 ± 0.01	20.77 ± 3.03	7.80 ± 0.92	38.34 ± 4.75
S-10	1.12 ± 0.03	0.57 ± 0.01	10.91 ± 1.99	7.55 ± 1.43	27.08 ± 2.54
S-11	3.46 ± 0.12	0.99 ± 0.01	19.13 ± 0.69	7.42 ± 1.20	28.84 ± 3.80
S-12	15.14 ± 1.93	0.09 ± 0.01	15.73 ± 2.41	BDL	11.66 ± 2.23
S-13	0.58 ± 0.05	0.44 ± 0.01	12.23 ± 0.59	7.53 ± 1.06	19.19 ± 3.00
S-14	0.85 ± 0.03	0.53 ± 0.01	11.22 ± 1.60	3.50 ± 0.45	16.33 ± 2.76
S-15	0.88 ± 0.05	0.81 ± 0.00	17.56 ± 1.05	7.47 ± 0.64	21.38 ± 2.21
S-16	0.56 ± 0.01	0.63 ± 0.01	17.07 ± 2.41	13.30 ± 2.38	32.18 ± 3.54
S-17	1.33 ± 0.04	1.65 ± 0.01	27.23 ± 1.50	8.85 ± 0.90	29.59 ± 3.09
S-18	0.61 ± 0.02	0.31 ± 0.00	31.20 ± 3.97	2.03 ± 0.49	31.41 ± 4.12
S-19	0.13 ± 0.00	0.19 ± 0.01	10.93 ± 2.59	BDL	9.51 ± 1.72

Here, BDL means Below the Detection Limit. Besides, the asterisk (*) indicates highly significant differences (i.e., P = 0.000) among the mean of all sample spices based on the one-way ANOVA test statistic.

were higher educated. In the case of spice consumption, we can see that each household usually consumes on average 8.72 ± 1.96 types of spices per week. Besides, they consumed 6.90 ± 6.58 g of mean spices per household per day, whereas the per person per day value is 1.70 ± 1.13 (See Supplementary Table S3).

4.2. Concentrations of selected heavy metals in sampled spices

Table 1 summarizes the concentrations of selected heavy metals, *i.e.*, Pb, Cd, Cr, Cu, and Fe, in the samples selected for this study. It was discovered that the levels of heavy metals in various spices varied substantially. The findings of this investigation are compared to international regulatory requirements and published literature.

Lead (Pb) is considered as a non-essential metal, and it mainly damages the kidneys and liver of the body [39]. Toxicity of lead (Pb) can cause mental retardation, birth defects, autism, allergies, weight loss, hyperactivity, paralysis, brain damage, and even death [40]. Cardamom had the highest Pb content (15.47 ± 1.93) mg/kg, followed by cinnamon (10.05 ± 1.22) mg/kg. When compared to studies done in other countries, we find that concentrations in Pakistan, Romania, and Iraq, respectively, ranged from 4.44 to 15.88 mg/kg [20], 0.04–1.28 mg/kg [41], and 3.21–6.98 mg/kg [42]. Chili powder has been shown to contain the highest levels of lead in Pakistan and Iraq [20,42].

Consumption of cadmium can cause severe diseases even at low concentrations by accumulating in the kidneys and liver [43,44]. The highest concentration of Cd was found in coriander leaf (1.65 ± 0.01) mg/kg, non-branded turmeric powder (1.49 ± 0.02) mg/kg, and branded turmeric powder (1.43 ± 0.01) mg/kg. Most Cd was found in Garam Masala, coriander, and curry powder in Pakistan, South Korea, and Iraq, respectively [20,42,45].

A high concentration of Cr can cause damage to the kidney, liver, and blood cells, although its deficiency causes hyperglycemia and elevated fat levels. Some findings also showed that chromium cause DNA damage in various ways [46]. Among the studied spices, we found that the greatest Cr levels were found in bay leaf (31.99 ± 3.97) mg/kg, coriander leaf (27.58 ± 1.50) mg/kg, and cardamom (25.19 ± 2.26) mg/kg. In Ethiopia [47] and Bangladesh [19], the uppermost Cr concentration was discovered in coriander. In Saudi Arabia [48] and Iraq [42], it was found in cinnamon and curry powder, respectively. Copper (Cu) is an important trace element that plays a vital role in some biological processes of the human body; however, at high concentrations, it can damage the kidneys and blood cells [49].

Copper (Cu) is essential element for human health, however, toxicity of copper can cause anemia, liver and kidney damage, irritation in stomach and intestine etc. [40]. The most significant Cu concentrations were found in dried chili (18.84 ± 1.97) mg/kg, non-branded chili powder (15.36 ± 2.28) mg/kg, and branded cumin (13.81 ± 2.38) mg/kg, respectively. The highest copper level was found in black pepper in Saudi Arabia [48], Turkey [50], and Iraq [42], as well as in turmeric powder in Bangladesh [19].

In the present study, the concentration of chromium and iron in spices were relatively higher than other metals. Black pepper had the greatest iron content, at 9.29 ± 1.72 mg/kg, followed by green chili and branded chili powder, with concentrations of 35.46 ±

Table 2
Ingestion Rate (IR) of spices (kg bw/day/person) and EDI (mg/kg bw/day) of selected heavy metals through each sampled spice.

Sample Id	IR of each spice	EDI of Pb	EDI of Cd	EDI of Cr	EDI of Cu	EDI of Fe
IR and EDI of Non-Branded Spices						
S-1	0.00282	0.00003	0.00005	**0.00128**	0.00090	0.00142
S-2	0.00234	0.00005	0.00007	**0.00097**	0.00018	0.00088
S-5	0.00413	0.00009	0.00006	**0.00149**	0.00000	0.00303
S-6	0.00029	0.00000	0.00000	0.00008	0.00011	0.00007
S-7	0.00010	0.00002	0.00000	0.00005	0.00003	0.00003
S-9	0.00009	0.00000	0.00000	0.00004	0.00001	0.00007
S-10	0.00071	0.00002	0.00001	0.00017	0.00011	0.00040
S-11	0.00148	0.00011	0.00003	**0.00060**	0.00024	0.00089
S-12	0.00058	0.00019	0.00000	0.00018	0.00000	0.00014
S-13	0.00058	0.00001	0.00001	0.00015	0.00009	**0.01435**
S-14	0.00057	0.00001	0.00001	0.00013	0.00004	0.00019
S-15	0.00045	0.00001	0.00001	0.00016	0.00007	0.00021
S-17	0.00403	0.00011	0.00014	**0.00230**	0.00083	0.00242
S-18	0.00018	0.00000	0.00000	0.00012	0.00001	0.00012
S-19	0.00073	0.00000	0.00000	0.00017	0.00000	0.00014
IR And EDI of Branded Spices						
S-3	0.00178	0.00005	0.00003	**0.00074**	0.00047	0.00125
S-4	0.00139	0.00004	0.00004	**0.00045**	0.00016	0.00060
S-8	0.00085	0.00001	0.00001	**0.00028**	0.00017	0.00034
S-16	0.00041	0.00000	0.00001	0.00015	0.00012	0.00027
Total consumption		0.00076	0.00048	0.00951	0.00354	0.02682
RfD (mg/kg/day)		0.0035[a]	0.0005[a]	0.0003[a]	0.04[b]	0.007[a]
MPL (mg/kg/day)		0.1[a]	0.1[a]	0.1/0.25[a],[c]	50[c]	300[c]

*MPL = Maximum Permissible Limit.
[a] U.S. Environmental Protection Agency [52].
[b] Muhseen, Hameed et al. [53].
[c] World Health Organization [54].

3.94 mg/kg and 34.02 ± 3.18 mg/kg, respectively. Compared to comparable research conducted in Iraq, it was shown that the ranges of Red pepper (791.66 ± 6.57) mg/kg and curry powder (830.091 ± 11.54) mg/kg had the greatest quantities of elemental Iron [50].

4.3. Estimated daily intake (EDI) of selected heavy metals

The estimated daily intake of heavy metals from spices is presented in Table 2. EDI of Cr in some spices such as chili Powder (NB), Turmeric Powder (NB), Chili Powder (B), Turmeric Powder (B), Green Chili, ginger, and coriander leaf exceeded the reference dose (RfD) levels; however, none of the heavy metals exceeded the maximum permissible limits (MPL). The EDI of heavy metals through consumption of spices were in order of Fe > Cr > Cu > Pb > Cd. A study discovered an elevated EDI of Cr (0.070) for turmeric [51]. Due to the absence of permissible tolerable daily intake (PTDI) of heavy metals from the consumption of spices, we could not compare the EDI with standard PTDI.

4.4. Non-carcinogenic risk for selected heavy metals

To assess the risk of heavy metals in the Bangladeshi population, THQ and TTHQ were estimated and presented in Table 3. All THQ values except Cr for chili powder (NB), turmeric powder (NB), chili powder (B), turmeric powder (B), green chili, ginger, and coriander leaf were lower than 1, indicating low health risk although the THQ values only provide the risk of value of each metal due to exposure [55]. The mean THQ value for Pb was found to be lower than those from Nigeria (0.125) and Pakistan (0.281) [9,20]. The TTHQ values (considering all the metals) in the studied spices ranged from 0.135 to 8.328. The TTHQ values in some spices were >1, indicating potential health risk. Extremely high TTHQ values of Cr have been found in Green Chili, ginger, coriander leaf, and all forms of chili powder and turmeric powder. Our research had a higher TTHQ score than previous studies conducted in Poland, Pakistan, Egypt, and Nigeria [9,20,56,57].

4.5. Cancer risk (CR) of selected heavy metals

Fig. 1 shows the total cancer risk of heavy metals in spices commonly found in local Bangladeshi markets. The cancer risk of only Cr in coriander leaf was higher than 10^{-4}, indicating that this spice was not safe for human consumption. In this case, the rest of the spice samples were free from cancer risk, i.e., the risk was between 10^{-6} and 10^{-4}. Please see Table S4 in the Supplement for a more thorough comparison with studies from other countries.

Our current study has certain limitations. We have analyzed a limited number of samples that were available at that specific point in time based on consumption records by the study population. Our study only presents the amount of specific heavy metal contents present in our sample but does provide information on the source of contamination. Furthermore, the ingestion rate of the households was computed based on each household's daily or weekly spice usage. Along with some limitations, the present study provided new data regarding the consumption rate of spices and the health risks associated with the consumption of metals from the spices. The prospective studies will be done to assess sources of contamination by metals in the spices with a large sample size and more metal analysis.

Table 3
THQ and TTHQ of heavy metals through consumption of each sampled spice.

Sample ID	THQ of Pb	THQ of Cd	THQ of Cr	THQ of Cu	THQ of Fe	TTHQ of Each Sample
THQ of Non-Branded Spices						
S-1	0.00832	0.09381	4.26516*	0.02241	0.20306	4.59277**
S-2	0.01449	0.14395	3.22698*	0.00451	0.12506	3.51499**
S-5	0.02511	0.12094	4.97085**	0.00000	0.43296	5.54986**
S-6	0.00079	0.00874	0.25235	0.00280	0.01016	0.27483
S-7	0.00591	0.00486	0.17275	0.00063	0.00402	0.18817
S-9	0.00013	0.00176	0.12275	0.00034	0.01009	0.13506
S-10	0.00480	0.01621	0.55454	0.00276	0.05736	0.63567
S-11	0.03025	0.05970	1.98521*	0.00608	0.12778	2.20902**
S-12	0.05300	0.00216	0.61160	0.00000	0.02033	0.68709
S-13	0.00206	0.01066	0.50582	0.00224	0.03322	0.55400
S-14	0.00283	0.01227	0.43371	0.00101	0.02696	0.47678
S-15	0.00239	0.01510	0.52625	0.00180	0.02973	0.57526
S-17	0.03168	0.27452	7.65557*	0.02066	0.34627	8.32869**
S-18	0.00066	0.00241	0.40542	0.00018	0.01708	0.42575
S-19	0.00057	0.00562	0.57965	0.00000	0.02010	0.60594
THQ of Branded Spices						
S-3	0.01341	0.06332	2.45549*	0.01186	0.17888	2.72296**
S-4	0.01100	0.08206	1.51352*	0.00411	0.08566	1.69635**
S-8	0.00213	0.01860	0.92180	0.00416	0.04803	0.99471
S-16	0.00135	0.01063	0.50666	0.00292	0.03918	0.56073

*THQ and **TTHQ values for these samples are greater than the standard limit (>1).

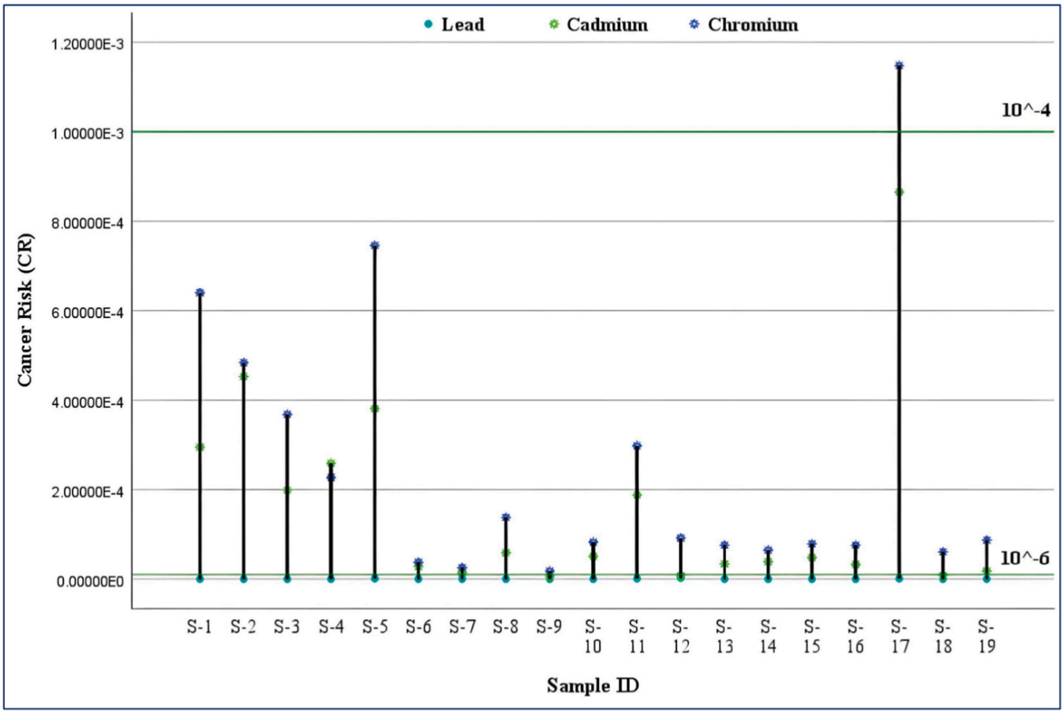

Fig. 1. Cancer risk (CR) of heavy metals through consumption of each sampled spice.

5. Conclusion

The present study revealed the concentration of heavy metals in commonly consumed spices in the Noakhali region of Bangladesh. The concentrations of heavy metals were higher in Chili powder, turmeric powder, green chili, coriander leaves, ginger, and fenugreek. The cumulative risk of studied heavy metals in spices (TTHQ) exceeded >1, indicating a health risk for human consumption. This research will assist regulatory organizations in increasing and improving heavy metal monitoring and evaluation procedures in spices, as well as ensure public health safety in relation to these food commodities. However, an extensive study is necessary to detect more elements in all consumed spices as well as the growing environment and supply chain, such as agricultural soil, water, packaging, etc., to find the source of contamination using a large sample size that represents the regional consumption patterns.

Ethics approval

The study was classified as exempt according to the institutional ethics committee of the Noakhali Science and Technology University.

Submission declaration and verification

The study is reported in accordance with ARRIVE guidelines. The Authors hereby consent to publish this research article. This article has not been published or submitted elsewhere for publication. The authors also declare that this work does not libel anyone or violate anyone's copyright or common law rights.

Data availability statement

Data associated with this study has not been deposited into any publicly available repository. Data will be made available on request.

CRediT authorship contribution statement

Md Shahedul Islam: Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Akibul Islam Chowdhury:** Investigation, Validation, Visualization, Writing – original draft, Writing – review & editing. **Lincon Chandra Shill:** Data curation, Formal analysis, Investigation, Project administration, Validation, Writing – review & editing. **Sompa Reza:** Data curation, Formal analysis, Writing – review & editing. **Mohammad Rahanur Alam:**

Conceptualization, Funding acquisition, Resources, Software, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We acknowledge Research cell of Noakhali Science and Technology University, Bangladesh and University Grants Commission of Bangladesh for funding this research.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e21746.

References

[1] J.F. D'Mello, Food safety: contaminants and toxins, CABI (2003).
[2] L. Luczaj, et al., Wild food plant use in 21 st century Europe, the disapperance of old traditions and the search for new ciusines involving wild edibles, Acta Soc. Bot. Pol. (4) (2012) 81.
[3] D. Bown, Dorling kindersley limited, The Royal Horticultural Society encyclopedia of herbs & their uses (1995).
[4] C.M. Kaefer, J.A. Milner, The role of herbs and spices in cancer prevention, J. Nutr. Biochem. 19 (6) (2008) 347–361, https://doi.org/10.1016/j.jnutbio.2007.11.003.
[5] S. Prasad, S.C. Gupta, B.B. Aggarwal, Micronutrients and Cancer: Add Spice to Your Life, in Nutrition, Diet and Cancer, Springer, 2012, pp. 23–48. https://10.1007/978-94-007-2923-0_2.
[6] B. Kabak, A.D. Dobson, Mycotoxins in spices and herbs–An update, Crit. Rev. Food Sci. Nutr. 57 (1) (2017) 18–34, https://doi.org/10.1080/10408398.2013.772891.
[7] S. Morais, F.G. Costa, M.d.L. Pereira, Heavy metals and human health. Environmental health–emerging issues and practice 10 (1) (2012) 227–245.
[8] S. Martin, W. Griswold, Human health effects of heavy metals. Environmental Science and Technology briefs for citizens 15 (2009) 1–6.
[9] R.N. Asomugha, et al., Heavy metals hazards from Nigerian spices, Rocz. Panstw. Zakl. Hig. (3) (2016) 67.
[10] C. Cabrera, et al., Mineral content in legumes and nuts: contribution to the Spanish dietary intake, Sci. Total Environ. 308 (1–3) (2003) 1–14, https://doi.org/10.1016/S0048-9697(02)00611-3.
[11] S. Dudka, M. Piotrowska, H. Terelak, Transfer of cadmium, lead, and zinc from industrially contaminated soil to crop plants: a field study, Environ. Pollut. 94 (2) (1996) 181–188, https://doi.org/10.1016/S0269-7491(96)00069-3.
[12] I.S. Eneji, R. Sha'Ato, P. Annune, Bioaccumulation of heavy metals in fish (Tilapia zilli and Clarias gariepinus) organs from river benue, north–Central Nigeria, Pakistan Journal of Analytical & Environmental Chemistry (2011) 12.
[13] W. Cowell, et al., Ground turmeric as a source of lead exposure in the United States, Publ. Health Rep. 132 (3) (2017) 289–293, 10.1177/0033354917700109.
[14] E.A. Petrakis, et al., Sudan dyes in adulterated saffron (Crocus sativus L.): identification and quantification by 1H NMR, Food Chem. 217 (2017) 418–424, https://doi.org/10.1016/j.foodchem.2016.08.078.
[15] S. Hagh-Nazari, N. Keifi, Saffron and various fraud manners in its production and trades, II International Symposium on Saffron Biology and Technology 739 (2006), https://doi.org/10.17660/ActaHortic.2007.739.54.
[16] M. Addady, Turmeric recall expanded after confirming presence of Lead, Fortune Magazine (2016) 16.
[17] M.A. Rahman, et al., Analysis of heavy metal contents in some commercial turmeric samples available at Dhaka, Bangladesh. Jahangirnagar University, J. Biological Sci. 9 (1–2) (2020) 13–20.
[18] S. Akter, et al., Analysis of spices available in local market in Bangladesh using ion beam analysis technique, 10.9790/2402-1009024447, J Environ Sci Toxicol Food Technol 10 (2016) 44–47.
[19] P.K. Das, et al., Heavy metal concentration in some common spices available at local market as well as branded spicy in chittagong metropolitan city, Bangladesh, Curr. World Environ. 10 (1) (2015) 101, https://doi.org/10.12944/CWE.10.1.12.
[20] S. Akhtar, et al., Risk assessment of aflatoxins and selected heavy metals through intake of branded and non-branded spices collected from the markets of Multan city of Pakistan, Food Control 112 (2020) 107132, https://doi.org/10.1016/j.foodcont.2020.107132.
[21] N. Nordin, J. Selamat, Heavy metals in spices and herbs from wholesale markets in Malaysia, Food Addit. Contam. B 6 (1) (2013) 36–41, https://doi.org/10.1080/19393210.2012.721140.
[22] S. Kilic, et al., Health risk assessment of exposure to heavy metals and aflatoxins via dietary intake of dried red pepper from marketplaces in Antalya, Southern Turkey, J. Food Sci. 83 (10) (2018) 2675–2681, https://doi.org/10.1111/1750-3841.14322.
[23] M. Mohiuddin, et al., Human health risk assessment for exposure to heavy metals in finfish and shellfish from a tropical estuary, J. King Saud Univ. Sci. 34 (4) (2022) 102035, https://doi.org/10.1016/j.jksus.2022.102035.
[24] P. Liu, et al., Accumulation and ecological risk of heavy metals in soils along the coastal areas of the Bohai Sea and the Yellow Sea: a comparative study of China and South Korea, Environ. Int. 137 (2020) 105519, https://doi.org/10.1016/j.envint.2020.105519.
[25] B. Bbs, Yearbook of agricultural statistics 2016. Statistics and informatics division (SID), ministry of planning, government of the people's republic of Bangladesh, Retrieved 1 (1) (2017) 2021.
[26] K.I. Kasozi, et al., Descriptive analysis of heavy metals content of beef from eastern Uganda and their safety for public consumption, Front. Nutr. 8 (2021) 592340. http://hdl.handle.net/20.500.12306/14205.
[27] S.S. Dare, et al., Behavioural response to self-medication practice before and during covid-19 pandemic in western Uganda, Patient Prefer. Adherence (2022) 2247–2257, 10.2147/PPA.S370954.
[28] K.I. Kasozi, et al., Safety of drinking water from primary water sources and implications for the general public in Uganda, Journal of environmental and public health 2019 (2019), https://doi.org/10.1155/2019/7813962.
[29] P. Elmer, Analytical methods for atomic absorption spectrometry, The perkin elmer corporation, USA. 300pp (1994).
[30] FAO/WHO, Guidelines for the simple evaluation of dietary exposure to food additives CAC/GL 3-1989 adopted 1989. Revision 2014 (formerly guidelines for the simple eva-luation of food additive intake), Food and Agriculture Organizarion (FAO) and World Health Organization (WHO) (2014).

[31] C. Vieira, et al., Mercury, cadmium, lead and arsenic levels in three pelagic fish species from the Atlantic Ocean: intra-and inter-specific variability and human health risks for consumption, Food Chem. Toxicol. 49 (4) (2011) 923–932, https://doi.org/10.1016/j.fct.2010.12.016.

[32] K. Karaboduk, E. Hasdemir, M.L. Aksu, Consideration of heavy metals contamination in Turkish foodstuffs: cemen (fenugreek paste) and hot spicy tomato dip and human health risk assessment. Gazi University Journal of Science 30 (1) (2017) 215–221.

[33] H.R. Gebeyehu, L.D. Bayissa, Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia, PLoS One 15 (1) (2020), e0227883, https://doi.org/10.1371/journal.pone.0227883.

[34] B. Ghasemidehkordi, et al., Concentration of lead and mercury in collected vegetables and herbs from Markazi province, Iran: a non-carcinogenic risk assessment, Food Chem. Toxicol. 113 (2018) 204–210, https://doi.org/10.1016/j.fct.2018.01.048.

[35] A.A. Mohammadi, et al., Carcinogenic and non-carcinogenic health risk assessment of heavy metals in drinking water of Khorramabad, Iran, MethodsX 6 (2019) 1642–1651, https://doi.org/10.1016/j.mex.2019.07.017.

[36] A.A. Ullah, et al., Dietary intake of heavy metals from eight highly consumed species of cultured fish and possible human health risk implications in Bangladesh, Toxicol Rep 4 (2017) 574–579, https://doi.org/10.1016/j.toxrep.2017.10.002.

[37] EPA, U.J.P.P.U.S.E.P.A, Washington DC, Risk-based concentration table (2000).

[38] USEPA, D.J.H.H.E.M.P.A, Risk assessment guidance for superfund. (1989).

[39] R. Ravisankar, et al., Effects of physicochemical properties on heavy metal, magnetic susceptibility and natural radionuclides with statistical approach in the Chennai coastal sediment of east coast of Tamilnadu, India, Appl. Water Sci. 9 (7) (2019) 1–12, https://doi.org/10.1007/s13201-019-1031-8.

[40] G. Pandey, S. Madhuri, Heavy metals causing toxicity in animals and fishes. Research Journal of Animal, Veterinary and Fishery Sciences 2 (2) (2014) 17–23.

[41] E. Marinescu, et al., Assessment of heavy metals content in some medicinal plants and spices commonly used in Romania, FARMACIA 68 (2020) 1099–1105, https://doi.org/10.31925/farmacia.2020.6.18.

[42] I. Jawad, Determination of heavy met herbs available on the Iraq, Adv. Environ. Biol. 10 (1) (2016) 66–69.

[43] S. Batool, N. Khan, Estimation of heavy metal contamination and antioxidant potential of Pakistani condiments and spices. Journal of Biodiversity and Environmental Sciences 5 (3) (2014) 340–346.

[44] B.B. Dagne, et al., Levels of some toxic heavy metals (Cr, Cd and Pb) in selected vegetables and soil around eastern industry zone, central Ethiopia, Afr. J. Agric. Res. 14 (2) (2019) 92–101, https://doi.org/10.5897/AJAR2018.13324.

[45] S. Kumaravel, K. Alagusundaram, Determination of mineral content in Indian spices by ICP-OES, Orient. J. Chem. 30 (2) (2014) 631–636, https://doi.org/10.13005/ojc/300231.

[46] D.B. Bahiru, et al., Levels of some toxic heavy metals (Cr, Cd and Pb) in selected vegetables and soil around eastern industry zone, central Ethiopia, Afr. J. Agric. Res. 14 (2) (2019) 92–101, https://doi.org/10.5897/AJAR2018.13324.

[47] M. Tefera, A. Teklewold, Health risk assessment of heavy metals in selected Ethiopian spices, Heliyon 7 (5) (2021), e07048, https://doi.org/10.1016/j.heliyon.2021.e07048.

[48] Z. Seddigi, et al., Assessment of metal contents in spices and herbs from Saudi Arabia, Toxicol. Ind. Health 32 (2) (2016) 260–269, https://doi.org/10.1177/0748233713500822.

[49] G. Xiang, et al., Determination of trace copper (II) in food samples by flame atomic absorption spectrometry after cloud point extraction. (2011) 1021, 9986/11/3/101.

[50] A. Karatepe, M. Soylak, L. Elçi, Determination of Cu, Fe, and Ni in spices after preconcentration on diaion-HP 20 resin as their zincon complexes. Clean–Soil, air, Water 39 (5) (2011) 502–507, https://doi.org/10.1002/clen.201000313.

[51] N.K. Aba-Quartey, Heavy metal contaminants of selected culinary herbs and spices available in some Ghanaian markets (2018). https://ir.knust.edu.gh/handle/123456789/11601.

[52] I. Usepa, US Environmental Protection Agency's integrated risk information system Environmental protection agency region I, Washington DC 20460 (2011).

[53] Z. Muhseen, et al., Safety evaluation of heavy metals contaminated Xiaochaihu Tang using health risk assessment model, Zhongguo Zhongyao Zazhi (2019), https://doi.org/10.19540/j.cnki.cjcmm.20191015.201.

[54] Organization, W.H, Quality Control Methods for Herbal Materials, World Health Organization, 2011.

[55] N. Shaheen, et al., Health risk assessment of trace elements via dietary intake of 'non-piscine protein source'foodstuffs (meat, milk and egg) in Bangladesh, Environ. sci. pollution res. 23 (2016) 7794–7806, 10.1007/s11356-015-6013-2.

[56] G. Kowalska, The safety assessment of toxic metals in commonly used herbs, spices, tea, and coffee in Poland, Int. J. Environ. Res. Publ. Health 18 (11) (2021) 5779, https://doi.org/10.3390/ijerph18115779.

[57] N.F. Soliman, Metals contents in spices and herbs available on the Egyptian market: assessment of potential human health risk, Open Conf. Proc. J. (2015), https://doi.org/10.2174/2210289201506010024.