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Heavy Metals in Mariam and Dabash Date Fruits (*Phoenix dactylifera* L.) Collected from Dhaka City, Bangladesh and Associated Assessment of Public Health Risk

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Abstract

Heavy metals have become a prominent concern as they continue to emerge in our environment and food chain. This study was conducted to assess the contamination levels of specific heavy metals in two commonly consumed date fruit varieties, Mariam and Dabash, in Bangladesh during the month of Ramadan. The investigation raises significant concerns regarding the elevated metal concentrations of Cd and Ni in Mariam date fruits, which surpass the maximum permissible limit. However, it is worth noting that the average daily intake of these metals does not indicate any immediate serious health issues. While the ADI value for Pb approaches the marginal value for Provisional Maximum Tolerable Daily Intake (PMTDI), there is no evidence of immediate health risks. On the other hand, the hazard index data clearly indicates that Mariam date fruits from New Market pose health risks, as they exceed the hazard index value of 1. This suggests that continuous consumption of these fruits may have adverse effects on health. Regarding Dabash date fruits, the study reveals that they contain heavy metal concentrations of Ni and Cd, which exceed the maximum permissible limits in most samples, raising potential health risks. Nevertheless, the ADI, HQ, and HI data do not indicate any significant health issues, except for the nearly 1 HI value for Badamtali, which calls for attention from the appropriate authorities. In conclusion, this study demonstrates that the contamination of heavy metals, particularly in Mariam date fruits from New Market and Dabash date fruits, may present health risks to consumers. While immediate health issues may not be evident, continuous consumption of these contaminated fruits could pose long-term health concerns. Therefore, it is crucial for the relevant authorities to address this matter promptly and take necessary measures to ensure food safety and protect public health.

Keywords: Metals, *Phoenix dactylifera* L, Bangladesh

Introduction

The date palm is a member of the *Phoenix* genus, which contains 14 species of palms (Salomón-Torres *et al*. 2021) [53]. It belongs to the family Arecaceae and is the oldest edible sweet dessert fruit found in countries around the Arabian Gulf (Vyawahare *et al*. 2009) [59]. It is also a popular fruit in Bangladesh as it is more or less consumed by the general mass daily. During the month of Ramadan, this consumption rate increases among the Muslims. But date fruit is not a native fruit of Bangladesh. Extremely high temperatures and low relative humidity provide optimal conditions for the growth and development of the date palm, as well as for the maturation of the fruits (Palestinian Ministry of Agriculture 2013) [46]. It is broadly distributed in many world regions, including Asia, Africa, Arabian countries, and the Middle East (Pintaud *et al*. 2013) [48].

In Bangladesh, the date fruit is mostly imported from Arabian countries like Saudi Arabia, Iran, Iraq, etc. Saudi Arabia is the largest fruit producer in the world with a scale of a million tons and also the greatest consumer, with 36.6kg per capita annual consumption (FAOSTAT 2016) [26]. There are several varieties of date fruits available in the markets of Bangladesh. Some of them are Mariam, Dabash, Ajwa, Boroi etc. Date fruits also have significant nutritional values. Date fruits are rich in sugar (71.2–81.4% dry weight), and have a protein content of 1.72–4.73% and lipid content of 0.12–0.72% (Assirey 2015) [11]. The predominant mineral was potassium which contained sugar mainly as glucose and fructose (Assirey 2015) [11]. Contains minerals like Al, Ca, Cu, Zn, and many other essential minerals and vitamins like A, B1, B2, and C (Fayad *et al*. 1989) [35]. Date fruits also contain antioxidant properties (Al-Farsi *et al*. 2005).

Some macro and trace elements, including selenium, iron, zinc, and copper, are essential to maintain the good health of humans (Fairweather-Tait *et al*. 2011) [19]. Non-essential trace elements can deposit in different body organs and thus threaten human health (Singh *et al*. 2004) [56] such as renal insufficiency, symptoms of chronic toxicity, liver damage, etc.

The fruit of date palms is highly prone to heavy metal contaminations (Ibrahim *et al*. 2011) [31]. Date fruits can be contaminated by heavy metals through contaminated soil, irrigation water, or maybe deposited air dust. Agricultural soils irrigated with wastewater get severely contaminated with heavy metals. Crops grown on such soils can accumulate a significant amount of heavy metals in different tissues (Khairiah *et al*. 2004; Chojnacha *et al*. 2005 [16]; Muchuweti *et al*. 2006 [42]; Nawal 2014 [45]). The use of treated wastewater in agriculture could help to conserve freshwater and fertilizer application. In many parts of the world, treated wastewater has long been used for irrigation (Levine and Sanot 2004) [39].

Another study showed depending on whether the water irrigated may be treated or groundwater if the water is contaminated, it will also introduce contamination in date fruits (Al-Busaidi *et al*. 2015) [5]. In the origin places, date palms can also intake heavy metals by the alternate bearing. The alternate bearing effect is when plants produce abundant crops of fruit in some years, but sparse yields in others. Street-side shops that openly sell fruits are easily exposed to contamination from the surroundings. They have been reported to have major health cautions which may arise from improper and unhygienic handling of foods by the vendors; those fruits are also exposed to the emission of metals by automobiles and atmospheric pollutants (Anhwange *et al*. 2018). Contamination may also occur by air dust that has heavy metals in it (Aldjain *et al*. 2011) [31].

In terms of Bangladesh, as date fruit is not prominently grown here, it is mainly polluted by environmental aspects and anthropological activity. Air quality is also considerable in this regard as it has raised a concern. Rapid urbanization, traffic exhaust, welding houses, and also brickfields on the edges of the city are directly introducing metal particles and gases into the environment and quietly these are getting into our food chain (Rahman *et al*. 2013) [49].

The consumption of date fruits increases dramatically in the month of Ramadan. Hence, during Ramadan, people are more prone to heavy metal exposure via date fruits. Different studies were carried out to determine the heavy metal contamination of date fruits in foreign countries. But very few works have been done related to date fruits and food security in Bangladesh. A recent study in Dhaka city shows that certain toxic elements like Ni, Pb, and as were present in date fruits, but within the safe limits to consume according to their daily oral dose (Zamir *et al*. 2020) [51]. This investigation will explore the heavy metal concentration of the edible part of date fruits along with human health risk assessment.

Materials and Methods

Sample Collection

As date fruits are not native to Bangladesh, they are mostly imported. Sample collection points were selected based on selling hotspots, where retailers sold date fruits without commercial packaging or labeling and in most cases, did not provide any expiry date. The Mariam variety, a popular type of date fruit, and the Dabash variety, a cheap yet popular type were selected for this investigation. Mariam date fruits were collected from wholesale markets of Medina, during the Hajj period (July 2022) and from three locations of Dhaka City (Badamtali, New Market, and Mirpur) during Ramadan (April 2022), when most of the date fruits entered local markets and outlets. Dabash date fruits were also collected from the same locations.

a. Mariam

b. Dabash

Fig 1: Date fruit sample (a. Mariam, b. Dabash)

Fig 1 shows the date fruit samples collected: Mariam (a) and Dabash (b). To avoid additional contamination, the samples were collected in zipper bags and labeled with the name of the variety and collection point code. They were then sent directly to the laboratory of the Department of Soil, Water, and Environment of the University of Dhaka for heavy metal analysis. Each sample was replicated three times. The sample collection zones and their GPS locations are shown in Table 1 and Fig 2.

Table 1: Sample collection data

Sampling Point	Dhaka, Area of collection	Location		Medina		Medina	
		Latitude	Longitude	Area of collection		Latitude	Longitude
Shop 1	Badamtali	23°42'30''	90°24'17''	Bani Khidrah, shop no. 750, Al Madinah Al Munawwarah 42312, Saudi Arabia	Shop 1	24.840398^0 N	39.320624^0E
Shop 2							
Shop 3							
Shop 1	New Market	23°44'3''	90°23'3''	Bir Uthman, Al Madinah Al Munawwarah 42332, Saudi Arabia	Shop 2	24.5015^0 N	39.5718^0E
Shop 2							
Shop 3							
Shop 1	Mirpur	23°47'56''	90°21'5''	Al Khatim, Al Madinah Al Munawwarah 42318, Saudi Arabia	Shop 3	24.4321^0 N	39.6237^0E
Shop 2							
Shop 3							

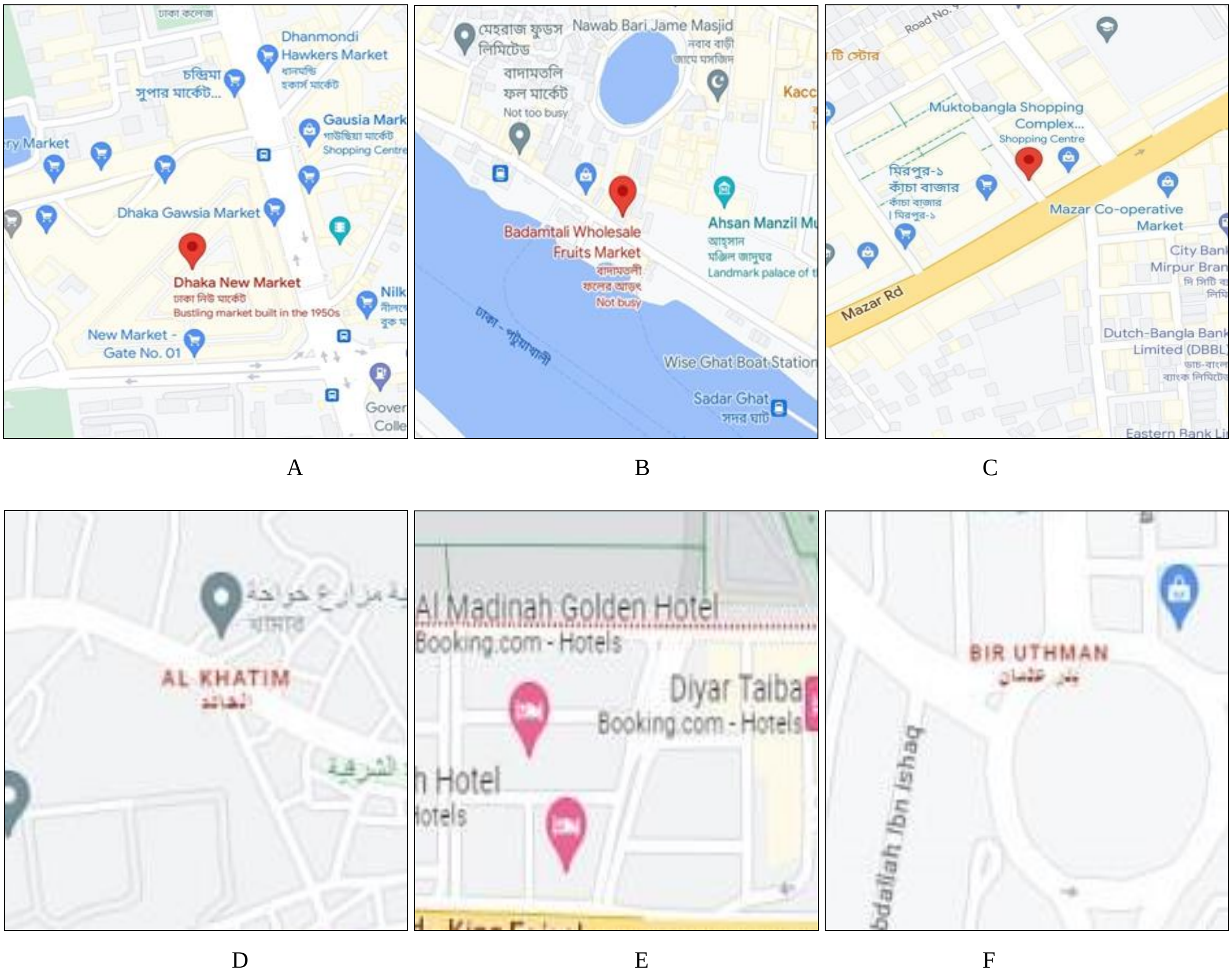
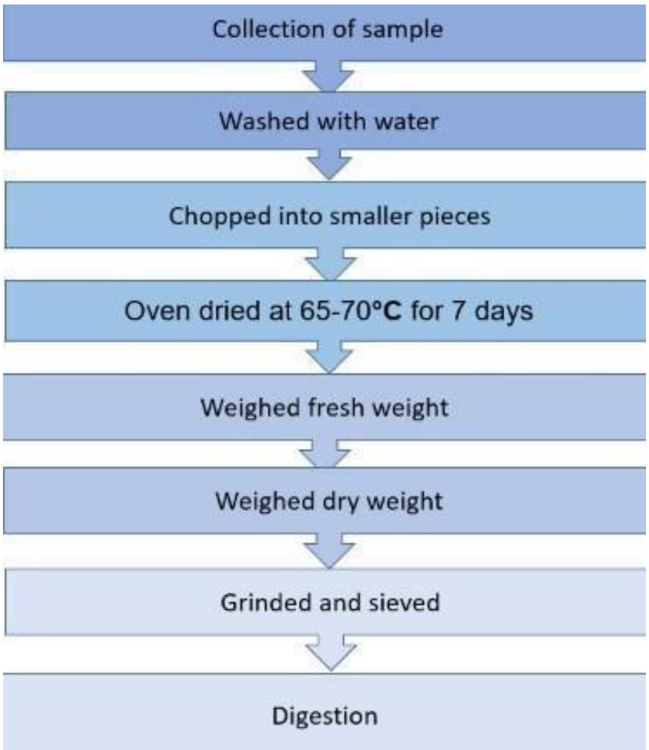


Fig 2: Sample collecting points; A. New Market; B. Badamtali; C. Mirpur; D. Al Khatim (Medina); E. Bani Khidrah (Medina); F. Bir Uthman (Medina)

Sample Preparation and Preservation

After collecting the date fruit samples, they were washed and then chopped into little pieces. They were kept for drying in an oven at 60°-65°C for a week and then weighed again.



The Digestion and Analysis of the Sample

The date fruit samples were digested using a common acid-based digestion technique (Alain *et al*. 2021; Blum *et al*. 1996; Samuel and Babatunde 2021) [7, 14, 54]. The digestion of the samples was done in a closed system using a mixture of HNO3 and HClO4 at a ratio of 2:3 (Blum *et al*. 1996) [14].

The concentrations of heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), copper (Cu), zinc (Zn), iron (Fe), and manganese (Mn) were determined in the extracts using an Atomic Absorption Spectrophotometer (Varian 240).

Public Health Assessment

Average Daily Intake (ADI)

Health hazards resulting from exposure to heavy metals are routinely monitored using health indices such as the average daily intake (ADI), hazard quotient (HQ), and hazard index (HI) (Cui *et al*. 2004; Gall *et al*. 2015; Zhuang *et al*. 2009) [17, 27, 64]. The following equation was used to calculate ADI (Kacholi and Sahu 2018) [37]:

$$ADI = Av_{consumption} \times \%\ DW_{date} \times C_{heavy\ metal}$$

Here, ADI is the average daily intake of heavy metal per kilogram per day (mg/kg-day), $Av_{consumption}$ is the average daily consumption of date fruits per person per day (g/kg-day), $\%DW_{date}$ is the percentage of the dry weight of dates (%DW=[(100−% moisture)/100]), and $C_{heavy\ metal}$ is the average heavy metal concentration of dry weight date fruit (mg/g). The average daily consumption of date fruits is assumed to be 29 g per person for the month of Ramadan (Ali and Hau 2001) [8]. The value 29 g/person-day was therefore used in calculating the ADI values, and the average weight of a person was considered to be 60 kg (FAO/WHO 1993) [22]. A variety of health risks may arise when the ADI value exceeds the maximum permissible value.

Hazard Quotient (HQ)

The ratio of a contaminant's exposure to the point at which there won't be any anticipated health risks is known as the hazard quotient (HQ). The HQ value of less than one is regarded as not potentially harmful to health. However, an HQ value greater than 1 signifies that exposure to a particular pollutant may result in significant health hazards (Bermudez *et al*. 2011; Chary *et al*. 2008) [13, 15]. The hazard quotient was calculated using the following equation (Granero and Domingo 2002) [29]:

$$HQ = ADI / R_fD$$

Here, ADI displays the average daily intake of heavy metals for date fruits (mg/kg/day), while RfD displays the oral reference dosage of the metal (mg/kg-day). RfD is the amount of a specific contaminant that a person can be exposed to daily without experiencing significant health risks throughout their lifetime. The established RfD values in mg/kg-day units for Pb (0.004), Zn (0.30), Cu (0.04), Cr (0.003), Cd (0.0005), Ni (0.02), Fe (0.70), and Mn (0.14). (WHO/FAO, 2013) [61].

Hazard Index (HI)

Hazard index (HI) is used to analyze the potential health hazards when a person is exposed to numerous contaminants at once, as opposed to the hazard quotient (HQ), which is used to measure the health risks caused by any one contaminant. The main cause of this is the cumulative effect of many pollutants. Consequently, determining HI is an effective technique to comprehend the potential health concerns linked to simultaneous human exposure to various contaminants. Similar to the hazard quotient, an HI value greater than 1 indicates possible health hazards.

The following equation (Kacholi and Sahu 2018) [37] illustrates how the hazard index (HI) is the total of the hazard quotients for each pollutant:

$$HI = \sum_{i=1}^{n} HQ$$

Statistical Analysis

The results of the experiment were statistically evaluated by using ANOVA (Analysis of Variance) and Duncan's Multiple Range Test in IBM SPSS statistics version 25 as outlined by Gomez and Gomez (1984) [28]. The letter was employed to evaluate the significance of variations in mean values. For the statistical analysis, a 0.05 level of probability was selected.

Results and Discussion

Heavy metal concentration in Mariam date fruits collected from Medina

Table 2: The concentration (mg/kg) of heavy metals in Mariam date fruits bought from different places of Medina

Medina	Cd	Cu	Cr	Fe	Mn	Ni	Pb	Zn
Shop 1	0.13 a	4.52 c	**1.064 a**	20.079 b	5.730 b	0.002 a	2.379 b	21.269 b
Shop 2	**0.21 b**	3.95 b	**2.451 b**	30.989 c	6.579 c	0.810 b	4.919 c	21.881 c
Shop 3	0.19 b	3.40 a	**1.090 a**	17.589 a	4.369 a	0.003 a	2.069 a	19.649 a
MPL	**0.20** (FAO/WHO 2001)	**40.00** (FAO/WHO 1989)	**1.00** (FAO/WHO 2015)	**450.00** (FAO/WHO 2007)	**500.00** (FAO/WHO 2007)	**1.00** (FAO/WHO 1989)	**5.00** (FAO/WHO 1993)	**60.00** (FAO/WHO 1989)

Mean values with the same letter(s) in a column do not differ significantly from each other at 5% level by DMRT.

The present study revealed that the level of heavy metal concentration in samples collected from three shops in Medina was within the safe limit, except for the Cd concentration in shop 2 and the Cr concentration in all three shops. The concentration of Cd in shop 2 was 0.21 mg/kg, where the maximum permissible limit (MPL) is 0.20 mg/kg. The concentrations of Cr in shops 1, 2, and 3 were 1.06 mg/kg, 2.45 mg/kg, and 1.09 mg/kg, respectively, where the MPL is 1 mg/kg. It was also revealed that the levels of Fe and Mn were very low compared with the MPL. The variations in heavy metal levels occurring among the samples collected from different sites might be due to the uptake capacity of plants that depends on the genetic makeup of the plant and the heavy metal content in the soil. Ibrahim *et al*. (2011) [31] also reported lower concentrations of heavy metals in the fruit of date palms grown in several Riyadh locales.

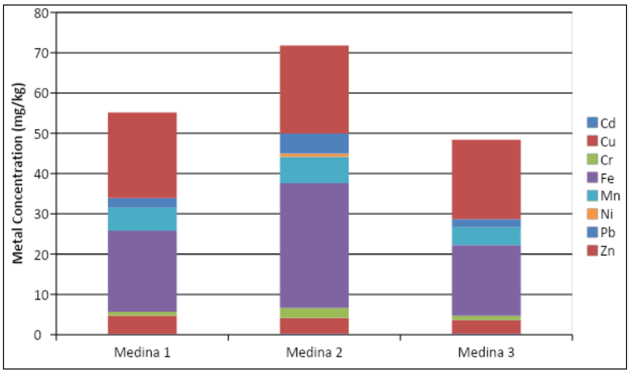


Fig 3: Heavy metal concentrations in Mariam date fruits collected from Medina

Heavy Metal Concentration in Mariam Date Fruits Collected from Dhaka City

Table 3: The concentration (mg/kg) of heavy metals in Mariam date fruits bought from different places of Dhaka

Places	Shop	Cd	Cu	Cr	Fe	Mn	Ni	Pb	Zn
Badamtali	1	0.69 b	2.51 a	0.38 a	31.41 b	3.83 ab	1.73 a	2.04 ab	27.81 d
	2	0.84 b	2.86 ab	0.00 a	23.24 ab	2.26 ab	1.65 a	2.92 ab	20.33 abc
	3	1.03 c	2.30 a	0.00 a	27.31 ab	2.21 ab	1.29 a	2.60 ab	17.38 a
New Market	1	1.06 c	3.33 bc	0.83 ab	25.31 ab	4.30 b	1.13 a	6.53 c	24.79 bcd
	2	0.90 bc	3.77 cd	0.84 ab	26.27 ab	2.79 ab	1.58 a	4.20 bc	25.91 cd
	3	0.79 bc	3.84 cd	4.23 c	30.75 b	4.37 b	1.97 a	3.94 bc	28.35 d
Mirpur	1	0.15 a	2.89 ab	0.99 ab	14.67 ab	2.87 ab	0.71 a	1.06 ab	17.17 a
	2	0.25 a	4.36 d	3.50 c	13.62 ab	3.22 ab	0.00 a	0.00 a	21.59 abcd
	3	0.21 a	2.53 a	2.78 bc	9.46 a	1.76 a	1.88 a	2.03 ab	18.15 ab
MPL		**0.20** (FAO/WHO 2001)	**40.00** (FAO/WHO 1989)	**1.00** (FAO/WHO 2015)	**450.00** (FAO/WHO 2007)	**500.00** (FAO/WHO 2007)	**1.00** (FAO/WHO 1989)	**5.00** (FAO/WHO 1993)	**60.00** (FAO/WHO 1989)

Mean values with same letter(s) in a column do not differ significantly from each other at 5% level by DMRT.

Cadmium Concentration

Cd concentrations in samples collected from Dhaka City were higher than the Maximum Permissible Limit (MPL). The Mariam date fruits collected from New Market Shop 1 possessed the highest Cd concentration (1.06 mg/kg). There were significant differences between samples collected from Mirpur and other sample collection points. Most of the Cd values found exceeded the maximum permissible limit of 0.2 mg/kg, issued by FAO/WHO. The largest amount of Cd identified in date fruits was 0.041 mg/kg in a research done in Saudi Arabia (Walid 2020) [60], which is around 26 times lower than the maximum amount (1.08 mg/kg) observed in this experiment. The presence of elevated levels of cadmium (Cd) in Bangladesh can be attributed to various sources, such as pesticide residue, preservatives, Ni-Cd battery waste, Cd ore smelting, welding, and Cd impurities in phosphate fertilizers, detergents, and petroleum products (Rahman *et al*. 2010) [50]. Even lower levels of Cd exposure can cause non-specific symptoms like nausea, vomiting, headache, and chills. However, long-term exposure to Cd can lead to severe health issues, such as kidney damage, as stated in the ATSDR's 2015 report.

Copper Concentration

The highest Cu concentration was found at 4.36 mg/kg in the samples of Mirpur shop 2, and the lowest was observed at 2.29 mg/kg in the samples of Badamtali shop 3. Significant differences were seen in the values of concentration of Cu. Cu values were below the maximum permissible limit of 40 mg/kg in all cases, issued by FAO/WHO.

Chromium Concentration

The present investigation revealed that the concentration of Chromium (Cr) in samples collected from different shops in Dhaka City was higher than the Maximum Permissible Limit (MPL) set by FAO/WHO (2015) [23] of 1.00 mg/kg. The highest concentration of Cr (4.23 mg/kg) was found in the samples collected from New Market shop 3, while the lowest value (0.00 mg/kg) was found in Badamtali shops 2 and 3. The concentrations of Cr in samples collected from New Market Shop 3 and Mirpur Shop 2 were higher than the detection limit and showed significant differences from other samples. The deposition of Cr in food items can be attributed to various sources, including industrial discharges, sewage, and agricultural practices. Cr is widely used in various industries, such as leather tanning, electroplating, and dyeing, which leads to its release into the environment (Singh and Kumar 2017) [57]. Moreover, the use of Cr-containing pesticides and fertilizers in agriculture can also contribute to the accumulation of Cr in soil and plants (Mondal *et al*. 2019) [41]. The elevated levels of Cr in food items are linked to several health issues, such as lung cancer, kidney damage, and skin allergies (ATSDR 2012) [3].

Iron Concentration

The highest concentration of Fe in Mariam date fruit, 31.41 mg/kg, was found in the samples collected from Badamtali shop 1, and the lowest concentration was found in date fruits from Mirpur shop 3, about 9.46 mg/kg. Only the date fruits from Mirpur Shop 3 were significantly different from Badamtali Shop 1 and New Market Shop 3. All these values are within the maximum permissible limit of 450 mg/kg, addressed by FAO/WHO. Most of the Fe concentration values ranged from 8 mg/kg to 30 mg/kg. In a research done in Al Ain City, United Arab Emirates, similar Fe concentrations were discovered (Zienab *et al*. 2022) [65].

Manganese Concentration

This investigation found almost no significant difference in Mn concentrations among the samples. The highest concentration of Mn in Dhaka city date fruits was found in New Market shop 1, which was 4.30 mg/kg, and the lowest was 2.21 mg/kg, found in Badamtali shop 3. All of these levels, however, fall below the FAO/WHO-mandated maximum acceptable limit of 500 mg/kg. Comparable Mn concentrations have been reported by Idris *et al*. (2019) [1], with a range of 1.1 mg/kg and 3.5 mg/kg and an average of 2.9 mg/kg, respectively. Whereas, another study reported a broad range of Mn content (3.7–12 mg/kg) was found (Kuras *et al*. 2020) [38].

Nickel Concentration

The following study found no significant difference between the concentrations of Ni among the samples. The highest concentration was found at 1.96 mg/kg in New Market shop 3. There was no Ni present in the sample from Mirpur shop 2. Most of these values were greater than the maximum permissible limit of 1 mg/kg, issued by FAO/WHO. Nickel is an essential trace element in several animal species, plants, and prokaryotic organisms, and it is thought to undergo redox metabolism, resulting in the production of the trivalent form and reactive oxygen species (ROS), as stated by Ahmad *et al*. (2016) [4]. Furthermore, studies conducted on experimental animals have shown that nickel can cause cancer, with nickel subsulphide and β-nickel monosulphide being identified as the most potent carcinogens (Jarup 2003) [36].

Lead Concentration

The sample from New Market Shop 2 has the highest concentration of Pb which is 6.52 mg/kg. It was significantly different from most of the samples and also has not exceeded the maximum permissible limit of 5 mg/kg, addressed by WHO/FAO. The lowest concentration was found in the sample from Mirpur shop 2 which had no Pb contamination. Other values were not significantly different from each other and were within the MPL.

Zinc Concentration

The concentration of Zn in the samples ranged from 17.37 mg/kg (Badamtali, shop 3) at its lowest to 28.34 mg/kg (New Market, shop 3) at its highest. The results obtained did not reveal any major differences between them. Samples collected from Mirpur mostly exhibited lower amounts of Zn concentration (17.17 mg/kg to 21.58 mg/kg), while samples collected from New Market mostly showed higher levels (24.78 mg/kg to 28.34 mg/kg) compared to other collection sites. None of these values exceeded the maximum permissible limit of 60 mg/kg set by WHO/FAO. The results obtained did not reveal any major differences between them.Both research on date fruits in Palestine and a study on dates in Saudi Arabia revealed similar Zn concentrations (Walid 2020; Hassan *et al*. 2017) [60, 30].

Heavy metal concentrations in Dabash date fruits collected from Dhaka City

Table 4: Metal concentrations in Dabash date fruits collected from Dhaka City fruit market

Places	Shops	Ni	Pb	Cd	Cr	Cu	Mn	Zn	Fe
Badamtali	1	0.19 a	0.42 a	0.40 b	0.54 a	1.82 ab	3.27 bc	23.15 bcd	18.09 ab
	2	0.05 a	2.24 ab	0.94 c	0.19 a	2.41 b	1.08 a	22.90 bcd	16.88 ab
	3	1.35 ab	2.15 ab	1.10 c	0.00 a	2.13 b	3.01 bc	21.14 abc	19.23 ab
New Market	1	3.20 b	4.44 b	1.05 c	0.00 a	2.23 b	1.85 ab	27.66 d	37.18 d
	2	2.29 ab	3.64 b	1.04 c	0.75 a	2.41 b	1.76 ab	25.38 cd	30.39 cd
	3	1.82 ab	3.47 b	1.10 c	0.68 a	2.06 b	2.23 abc	23.38 bcd	25.38 bc
Mirpur	1	1.32 ab	4.39 b	0.03 a	1.27 a	1.78 ab	3.08 bc	18.61 ab	9.46 a
	2	0.00 a	0.00 a	0.17 a	0.72 a	1.43 ab	5.76 d	19.65 ab	51.37 e
	3	0.00 a	0.00 a	0.24 a	2.81 b	1.03 a	3.77 c	17.80 a	12.09 a
MPL		1.00 (FAO/WHO 1989)	5.00 (FAO/WHO 1993)	0.20 (FAO/WHO 2001)	1.00 (FAO/WHO 2015)	40.00 (FAO/WHO 1989)	500.00 (FAO/WHO 2007)	60.00 (FAO/WHO 1989)	450.00 (FAO/WHO 2007)

Mean values with the same letter(s) in a column do not differ significantly from each other at 5% level by DMRT.

The Table 4 shows metal concentrations in mg/kg for the Dabash date fruits collected from various fruit markets in Dhaka city.

Nickel Concentration

The highest nickel concentration of 3.20 mg/kg was found in New Market Shop 1, and there was no nickel present in Mirpur Shop 2 and Shop 3. Most of these values exceeded the maximum permissible limit of 1 mg/kg, issued by FAO/WHO. Only Badamtali Shop 1 and Shop 2, and Mirpur Shop 2 and Shop 3 were below the MPL. Ni contamination mainly occurs in metal and steel industries, along with Ni-Cd battery waste. Additionally, the combustion of fossil fuels, power plants, and trash incineration plants releases nickel into the air. After undergoing a precipitation reaction, it settles to the ground. Nickel can leach to the nearest groundwater reservoir and also be transported by wastewater, making it more mobile (Wuana and Okieimen, 2011) [63].

Nickel is considered an indispensable trace element in various animal species, plants, and prokaryotic organisms. It is believed to undergo redox metabolism, leading to the formation of the trivalent form and the generation of reactive oxygen species (ROS), as reported by Ahmad *et al*. in 2016 [4]. Additionally, experimental animal studies have demonstrated that nickel can induce cancer, with nickel subsulphide and β-nickel monosulphide identified as the most potent carcinogens (Jarup 2003) [36].

Lead Concentration

The sample from New Market shop 1 had the highest concentration of Pb, at about 4.44 mg/kg, while both samples from Mirpur shop 2 and shop 3 had the lowest concentration of 0 mg/kg. These values were not significantly different from each other and all were within the maximum permissible limit of 5 mg/kg set by FAO/WHO in 1993.

Cadmium Concentration

In this study, the highest concentration of Cd in Dabash date fruits was 1.10 mg/kg found in both the samples of Badamtali shop 3 and New Market shop 3. While the lowest was 0.03 mg/kg, found in the sample of Mirpur shop 1. Most values of Cd concentration for Dabash date fruits exceed the maximum permissible limit (MPL) of 0.2 mg/kg, issued by FAO/WHO. Another research found the Cd concentration of date fruits in Saudi Arabia to be 0.041 mg/kg which is approximately 26 times less than the highest Cd concentration (1.06 mg/kg) observed in this experiment (Walid 2020) [60]. Higher Cd concentrations may result from pesticide residue or preservative actions taken from Bangladesh. Also, Ni-Cd battery waste, Cd ore smelting or welding, and also Cd impurities in phosphate fertilizers, detergents, and petroleum products can cause this contamination. The lower level of Cd exposure can cause non-specific symptoms such as nausea, vomiting headache, and chills. Long-term exposure to Cd may cause critical health issues such as kidney damage. (ATSDR 2015)

Chromium Concentration

In this study, the highest concentration of Cr in date fruits was 2.81 mg/kg, found in the sample collected from Mirpur shop 3, while the lowest value of 0.00 mg/kg was found in the samples collected from Badamtali shop 2 and 3. Most of the Cr values were below the maximum permissible limit (MPL) of 1.00 mg/kg, issued by FAO/WHO (2015) [23]. However, the samples collected from Mirpur Shop 1 and Shop 3 exceeded the maximum permissible limit. The Cr concentration of the sample from Mirpur shop 1 was significantly different from the others. Like Cd, Cr deposition in date, fruits may result from several factors such as industrial activities, the use of pesticides, and fertilizer application. Chromium is commonly used in various industries, such as metal plating, tanning, and textile manufacturing, which may lead to contamination of soil and water. The use of Cr-containing pesticides and fertilizers may also cause deposition in date fruits. Long-term exposure to Cr may cause serious health effects, such as lung cancer, liver damage, and reproductive problems (ATSDR 2012) [3].

Copper Concentration

The highest concentration of Cu was found at 2.41 mg/kg in the samples of New Market shop 2. And the lowest was found at 1.02 mg/kg in the samples of Mirpur shop 3. All of the Cu values were below the maximum permissible limit of 40 mg/kg, issued by FAO/WHO.

Manganese Concentration

In our study, the highest and lowest concentrations of Mn were found in Mirpur shop 2 and Badamtali shop 2, which were 5.76 mg/kg and 1.07 mg/kg, respectively. Only the sample from New Market Shop 3 was significantly different from the other samples. Nevertheless, all of these values remain within the prescribed maximum permissible limit of 500 mg/kg, as stipulated by the Food and Agriculture Organization/World Health Organization (FAO/WHO). Comparable Mn concentrations have been reported by Ibrahim (2011) [31] and Idris *et al*. (2019) [1], with a range of 1.1 mg/kg to 3.5 mg/kg and an average of 2.9 mg/kg, respectively. In contrast, another study reported a broad range of Mn content (3.7–12 mg/kg) (Kuras *et al*. 2020) [38].

Zinc Concentration

The Zn concentrations in the samples were in the range of 17.80 mg/kg (Mirpur, shop 3) at its lowest to 27.26 mg/kg (New Market, shop 1) at its highest. The results were not significantly different from each other. Samples collected from Mirpur consistently show a lower amount of Zn concentration (17.80 mg/kg to 19.64 mg/kg), Whereas, the Zn concentration of samples collected from New Market was higher (23.37 mg/kg to 27.26 mg/kg) than other collection sites. None of these values exceed the MPL (Maximum Permissible Limit) value of 60 mg/kg, issued by FAO/WHO. Comparable levels of zinc concentrations were identified in a research investigation conducted on date fruits in Palestine, as well as in a separate study carried out in Saudi Arabia (Walid 2020; Hassan *et al*. 2017) [60, 30].

Iron Concentration

The study found the highest concentration of Fe 51.37 mg/kg, which was found in the samples collected from Mirpur shop 2, and the lowest concentration was found in samples from Mirpur shop 1, about 9.45 mg/kg. Mirpur shop 2 sample was significantly different from other samples. All these values are within the maximum permissible limit of 450 mg/kg, addressed by FAO/WHO. Here, most of the Fe concentration values ranged from 8 mg/kg to 30 mg/kg. Concordant findings were observed in a research study conducted in Al Ain City, located in the United Arab Emirates (Zienab *et al*., 2022) [65].

Assessment of Public Health Risk

Average Daily Intake (ADI)

Average Daily Intake of Heavy Metals from Mariam Date Fruits

Calculating the amount of heavy metal exposure is essential for assessing the danger to an organism's health (Singh *et al*. 2010) [52]. In the current study, the average daily intake of seven metals was determined based on a person's daily intake of 29g of edible fruits (Ali and Hau 2001) [8]. Long-term consumption of heavy metals is known to have toxic effects on the body (Bahemuka and Mubofu 1999) [12]. Studies have shown that food contaminated with heavy metals can significantly reduce the body's essential nutrients, resulting in immunological deficiencies, growth retardation, disabilities, and an increased risk of upper gastrointestinal cancer (Iyengar and Nair 2000; Türkdoğan *et al*. 2003) [33, 58]. To determine the average daily intake (ADI) of heavy metals, the concentration of each metal was measured in Dabash date fruit samples collected from different locations in Dhaka and Medina. The ADI of the studied date fruits is presented in Table 5.

Table 5: Average daily intake of heavy metals (mg/person/day) in Mariam date fruits collected from Dhaka city markets

Average daily intake (ADI; mg/kg-day) of heavy metals								
Places	**Ni**	**Pb**	**Cd**	**Cr**	**Cu**	**Mn**	**Zn**	**Fe**
PMTDI	0.03 (WHO 1996)	0.21 (FAO/WHO 2003)	0.046 (FAO/WHO 2003)	0.20 (National Research Council Subcommittee 1989)	2.0 (FAO/WHO 2011)	5.0 (National Institute of Nutrition 2009)	20.0 (FAO/WHO 2011)	17.0 (FAO/WHO 2011)
Badamtali 1	0.04 ab	0.05 abc	0.02 b	0.01 a	0.06 ab	0.10 bcde	0.71 e	0.81 b
Badamtali 2	0.04 ab	0.08 bcd	0.02 bc	0.00 a	0.07 bc	0.06 abc	0.53 abc	0.60 ab
Badamtali 3	0.03 ab	0.07 abcd	0.03 c	0.00 a	0.06 a	0.06 ab	0.44 a	0.69 ab
New Market 1	0.03 ab	0.16 e	0.03 c	0.02 ab	0.08 cd	0.11 bcde	0.61 bcde	0.62 ab
New Market 2	0.04 ab	0.10 cde	0.02 bc	0.02 ab	0.09 def	0.07 abcd	0.64 cde	0.65 ab
New Market 3	0.05 b	0.10 bcde	0.02 b	0.10 d	0.09 def	0.11 cde	0.70 de	0.76 b
Medina 1	0.00005 a	0.06 abcd	0.003 a	0.03 abc	0.12 g	0.15 ef	0.54 abc	0.51 ab
Medina 2	0.02 ab	0.13 de	0.005 a	0.06 bcd	0.10 efg	0.17 f	0.56 abcd	0.79 b
Medina 3	0.00007 a	0.05 abc	0.005 a	0.03 abc	0.09 cde	0.11 de	0.50 abc	0.45 ab
Mirpur 1	0.02 ab	0.03 ab	0.004 a	0.03 abc	0.07 abc	0.07 abcd	0.43 a	0.37 ab
Mirpur 2	0.00 a	0.00 a	0.01 a	0.09 d	0.11 fg	0.08 abcd	0.54 abc	0.03 ab
Mirpur 3	0.05 ab	0.05 abc	0.005 a	0.07 cd	0.06 ab	0.04 a	0.45 ab	0.24 a

PMTDI refers to Permitted Maximum Tolerable Daily Intake.

For all fruit samples, the permitted maximum tolerable daily intake (PMTDI) for Cd, Zn, Ni, Pb, Cr, Cu, and Fe is 0.046, 20, 0.3, 0.21, 0.20, 2.00, and 17.0 mg/person-day, respectively. The ADI values were found to be below the PMTDI value.

Average Daily Intake of Heavy Metals from Dabash Date Fruits

Approximating heavy metal exposure levels is important for determining the hazard risk to organisms (Singh *et al*. 2010) [52]. In this study, the average daily intake of eight metals was calculated based on a person's daily intake of 29g of edible fruits, as reported by Ali and Hau (2001) [8], by considering the mean concentration of each metal in the fruits, the corresponding dry weight of fruits, and an average body weight of 60kg for a person. Heavy metals are toxic, and their dangerous effects are noticed when consumed over the long term (Bahemuka and Mubofu 1999) [12]. The calculation of the ADI of heavy metals was done based on the concentration of each metal in Dabash date fruit samples collected from various locations in Dhaka and Medina. The ADI of the studied date fruits is presented in Table 6.

Table 6: Average daily intake of heavy metals (mg/person/day) in Dabash date fruits collected from Dhaka city markets

Average daily intake (ADI; mg/kg-day) of heavy metals								
Places	**Ni**	**Pb**	**Cd**	**Cr**	**Cu**	**Mn**	**Zn**	**Fe**
PMTDI	0.03 (WHO 1996)	0.21 (FAO/WHO 2003)	0.046 (FAO/WHO 2003)	0.20 (National Research Council Subcommittee 1989)	2.0 (FAO/WHO 2011)	5.0 (National Institute of Nutrition 2009)	20.0 (FAO/WHO 2011)	17.0 (FAO/WHO 2011)
Badamtali 1	0.005 a	0.010 ab	0.012 b	0.130 ab	0.044 abc	0.079 bc	0.561 abc	0.438 ab
Badamtali 2	0.001 a	0.057 bc	0.024 c	0.0048 ab	0.061 c	0.027 a	0.584 bc	0.430 ab
Badamtali 3	0.034 ab	0.054 abc	0.028 c	0.00 a	0.054 bc	0.076 bc	0.534 abc	0.486 abc
New Market 1	0.077 b	0.106 c	0.025 c	0.00 a	0.053 bc	0.044 ab	0.613 c	0.895 d
New Market 2	0.055 ab	0.088 c	0.025 c	0.0183 ab	0.058 bc	0.042 ab	0.656 c	0.734 cd
New Market 3	0.044 ab	0.086 c	0.027 c	0.0168 ab	0.050 bc	0.054 abc	0.577 bc	0.626 bc

Mirpur 1	0.032 ab	0.108 c	0.0007 a	0.0313 b	0.043 abc	0.076 bc	0.459 ab	0.233 a
Mirpur 2	0.00 a	0.00 a	0.004 a	0.0177 ab	0.035 ab	0..141 d	0.484 ab	1.266 d
Mirpur 3	0.00 a	0.00 a	0.005 a	0.0695 c	0.025 a	0.093 c	0.439 a	0.298 a

PMTDI refers to Permitted Maximum Tolerable Daily Intake.

Permitted Maximum Tolerable Daily Intake (PMTDI) of Ni, Pb, Cu, Cd, Zn, Mn, Cr, and Fe are 0.03, 0.21, 0.046, 2.0, 20.0, 5.0, 0.2, and 17.0mg/ person/day respectively for all fruit samples. The ADI values of heavy metals for Dabash date fruit were found below the PMTDI value.

Hazard Quotient (HQ) and Hazard Index (HI)

Hazard Quotient (HQ) and Hazard Index (HI) for Mariam date fruits

The potential health risks associated with heavy metal intake through the consumption of date fruits are often estimated using the hazard quotient (HQ) and hazard index (HI) metrics. HQ is a reliable parameter that has been widely used to assess the health risks associated with the consumption of food contaminated with heavy metals, as reported by Zhuang *et al*. (2009) [64] and Bermudez *et al*. (2011) [13]. In contrast, the hazard index (HI) represents the cumulative sum of hazard quotients when multiple heavy metals are present simultaneously, as elucidated by Si *et al*. (2015) [55]. A health index value greater than 1 for date fruits indicates a possible health risk for people consuming those date fruits. In spite of that, the results revealed that the HQ value of all heavy metals in all date fruits was below one, implying the absence of any health risks associated with the presence of these heavy metals.

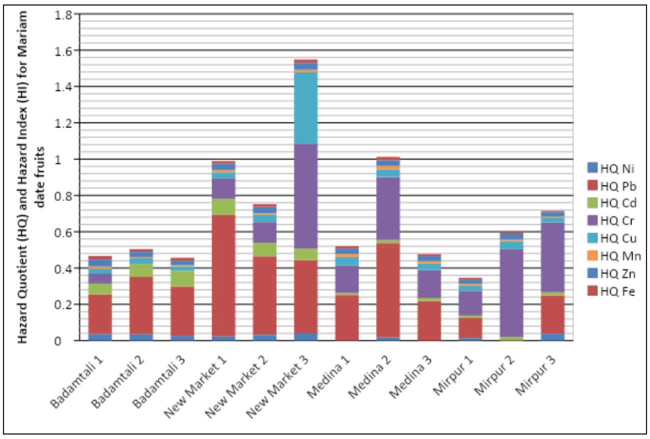


Fig 4: Hazard Quotient (HQ) and Hazard Index (HI) for Mariam date fruits collected from Medina and Dhaka City markets

Among the 12 date fruit samples studied, two were found to have a hazard index (HI) value greater than 1. The highest HI value of 1.55 was detected in the date fruit samples collected from New Market Shop 3, followed by 1.01 and 0.99 for the date fruit samples of Medina 2 and New Market 1, respectively. The lowest HI value of 0.35 was observed in the date fruit sample collected from Mirpur Shop 1. The hazard index values for all the date fruit samples were ranked in decreasing order as follows: New Market Shop 3 > Medina Shop 2 > New Market Shop 1 > New Market Shop 2 > Mirpur Shop 3 > Mirpur Shop 2 > Medina Shop 1 > Badamtali Shop 2 > Medina Shop 3 > Badamtali Shop 1 > Badamtali Shop 3 > Mirpur Shop 1. These findings suggest that date fruit samples from New Market pose a higher health risk than those from Mirpur and Badamtali.

The variability in HI values among date fruit samples from different shops and locations may be attributed to various factors, such as differences in soil, irrigation water, date fruit variety, fertilizers, plant types, and air quality, as reported in previous studies (Al Juhaimi *et al*. 2020; Kuras *et al*. 2020[38]; Perveen and Bokahri 2020) [6, 38, 47].

Hazard Quotient (HQ) and Hazard Index (HI) for Dabash Date Fruits

The potential health risks associated with heavy metal intake through the consumption of date fruits are often estimated using the hazard quotient (HQ) and hazard index (HI) metrics. HQ is a reliable parameter that has been widely used to assess the health risks associated with the consumption of food contaminated with heavy metals, as reported by Zhuang *et al*. (2009) [64] and Bermudez *et al*. (2011) [13]. On the other hand, HI is the sum of the hazard quotients when more than one heavy metal is involved (Si *et al*. 2015) [55]. A health index value greater than 1 for date fruits indicates a possible health risk for people consuming those date fruits. However, the results showed that the HQ value of all heavy metals in all date fruits was below one, which means there was no health risk associated with any heavy metal. Among the 12 date fruit samples studied, the highest HI value of 0.87 was found in the date fruit samples collected from Badamtali Shop 1, and the lowest HI value of 0.20 was found in the date fruit samples collected from Mirpur Shop 2.

The hazard index values for all the date fruit samples were ranked in decreasing order as follows: Badamtali Shop 1 > Mirpur Shop 1 > New Market Shop 2 > New Market Shop 1 > New Market Shop 3 > Mirpur Shop 3 > Badamtali Shop 3 > Badamtali Shop 2 > Mirpur Shop 2.

These findings suggest that date fruit samples from New Market pose a higher health risk than those from other outlets. The differences in HI values among the date samples from different locations and shops could be due to differences in soil, irrigation water, date fruit variety, fertilizers, and plant varieties (Al Juhaimi *et al*. 2020; Kuras *et al*. 2020; Perveen and Bokahri 2020) [6, 38, 47]. Transportation could also be a big factor in high health index (HI).

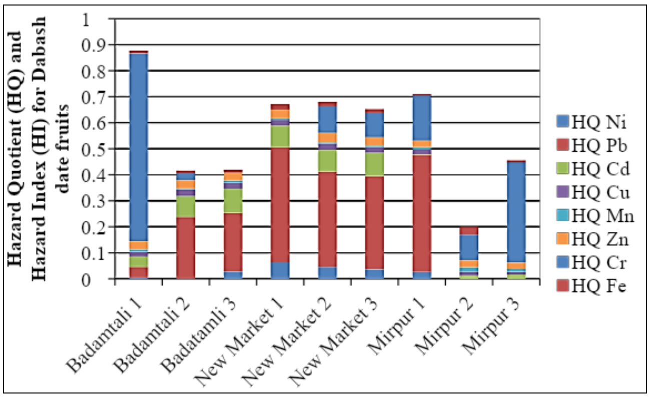


Fig 5: Hazard Quotient (HQ) and Hazard Index (HI) for Dabash date fruits collected from Dhaka City markets

Conclusion

The current investigation raises concern about the higher metal concentration of Cd and Ni in Mariam date fruits as they crossed the maximum permissible limit but considering the average daily intake, there are no serious health issues, although the ADI value for Pb is near to the marginal value for PMTDI. Considering the hazard index data, it is clear that the Mariam date fruits from New Market have health risks as they crossed the hazard index value 1. This study also revealed that Dabash date fruits have heavy metal concentrations of Ni and Cd that have crossed maximum permissible limits in most of the samples which raises some health risks regarding it. But the ADI, HQ, and HI data show no significant health issue, although the HI value for Badamtali is nearly 1, which is a matter of concern. The corresponding authority must look upon the matter.

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