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### **TOTAL DIET STUDY OF BANGLADESH**

**ANALYSIS OF CONTAMNANTS, TOXINS AND HARMFUL RESIDUES  
IN THE FOODS AND ASSESSMENT OF DIETARY EXPOSURE**

**(FINAL REPORT)**



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**IN THE FOODS AND ASSESSMENT OF DIETARY EXPOSURE**

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## EXECUTIVE SUMMARY

Food is the most important route for accumulating chemical elements (essential and toxic) and other contaminants. Current knowledge about human exposure to toxic elements and contaminants as well as beneficial substances and their health effects, such as developmental is evolving. In Bangladesh, health complications have increased many folds, many of which are related to unsafe food. The Total Diet Study (TDS) is one of the most cost-effective means to determine the exposure of a population to unsafe levels of toxic chemicals through food. A TDS determines not only the population's dietary exposure to harmful chemical substances but also to beneficial and necessary ones across their entire diets. It helps to monitor the levels of harmful or beneficial substances in the diet. The objectives of this research study were to determine the levels of trace elements, vitamins, heavy metals, colors, preservatives, aflatoxins, and pesticide residues in foods, to perform dietary exposure analysis of each chemical, and provide recommendations to reduce deleterious substances in the diet.

Seven hundred and eight ( $59 \times 3 \times 4$ ) food samples representing 15 different food groups were collected from Mymensingh, Rajshahi, Khulna, and Chattogram divisions of Bangladesh. The food samples, where applicable, were processed and cooked/boiled in water collected from the respective area with no salt added. The edible coefficient and dry weight of the food samples were calculated. All food samples were digested with ultrapure nitric acid and hydrogen peroxide for determining trace elements and heavy metals, and analysis was done by ICP-MS. The daily intake of trace elements, heavy metals, and others by the people of the four divisions was calculated from the food consumption data, as recorded in HIES (2016).

The concentration of trace elements (Zn, Fe, Cu, and Se), heavy metals (As, Cd, Pb, and Cr), and others varied between food groups, between items within a food group, and between locations of food items collection. However, the heavy metal concentration of individual food items and human consumption of each food item is important for assessing health implications. Rice among the foodstuffs has the highest consumption with an adult man consuming on an average about 350 g rice daily.

Rice contained beneficial elements such as Zn which on an average was 17.4 mg/kg, Fe 10.4 mg/kg, Cu 6.53 mg/kg, and Se 0.26 mg/kg, and harmful elements, notably As on an average 184 µg/kg, Cd 78.9 µg/kg, Pb 193 µg/kg and Cr 718 µg/kg (Cr is essential for human). Generally,

rice flakes, hilsa fish, prawn fish, and coriander seeds showed higher values for trace elements and heavy metals.

Dietary Fe and Zn intake were the lowest in Mymensingh division and the highest in Khulna division. Generally, all the population of the four divisions had sufficient dietary intake of Cu and Se. For all elements the contribution of cereals mainly rice was the highest, 68-71% for dietary Zn intake, 57.4-71.5% for Fe intake, 54-91% for Cu intake, and 46.71-68.54% for Se intake. Next to cereals, vegetables consumption had a higher contribution which for Zn was 5.38-14.16%, Fe was 12.3-24.2%, Cu was 3.6-4.4% and for Se was 9.41-25.43%.

The dietary intake of As, Cd, and Pb by the studied population of four divisions was calculated for estimated carcinogenic risks posed by the heavy metals with reference to acceptable daily intake.<sup>1</sup> The population of Mymensingh division had the lowest cancer risk from As and Cd, but the highest cancer risk due to dietary Pb intake. The population of Khulna showed the highest cancer risk due to dietary intake of As while the population of Chittagong division showed the highest cancer risk to Cd intake.

$\beta$ -carotene intake from the selected vegetables and fruits varied widely among the four divisions of Bangladesh. The highest mean intake (0.142 mg/d) was observed in Khulna division followed by Mymensingh (0.093 mg/d), Chattogram (0.092 mg/d), and Rajshahi (0.071 mg/d). Vegetables and fruits contribute only 1.2-2.4% of the RDA (Recommended Dietary Allowances) of  $\beta$ -carotene for an adult among the four divisions. Intake of Riboflavin (B2) by the adult male from the vegetables and fruits source also varied significantly among Mymensingh, Rajshahi, Khulna, and Chattogram divisions of Bangladesh. The highest mean intake (0.32 mg/d) was noted for Mymensingh division followed by Chattogram (0.27 mg/d), Khulna (0.21 mg/d) and Rajshahi division (0.09 mg/d). Vegetables and fruits contribute 3.6-12.8% of the RDA of Riboflavin for an adult in the four divisions. Considering vitamin-C intake by the adult male from the source of vegetables and fruits markedly differed with the four divisions of the country. Chattogram division (67 mg/d) showed the highest vitamin C intake, followed by Khulna (51 mg/d), Rajshahi (35 mg/d) and Mymensingh division (32 mg/d). These food items contribute 40-84% of the RDA of Vitamin C for an adult male of the four divisions.

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<sup>1</sup> The acceptable daily intake (ADI) is defined as the maximum amount of a chemical that can be ingested daily over a lifetime with no appreciable health risk, and is based on the highest intake that does not give rise to observable adverse effect.

The use of preservatives in terms of SO<sub>2</sub> and Na-benzoate was much evidenced in pickles from Mymensingh and Rajshahi locations, similarly, sunset yellow color in orange juice was mainly detected in samples from those two locations. Regarding aflatoxins, rice samples from Khulna and Chattogram and pulses from all locations except Chattogram showed a good presence of this mycotoxin. The mean Na-benzoate intake was about 10 times higher than that of the mean SO<sub>2</sub> intake, however, division-wise intake of SO<sub>2</sub> and Na-benzoate among HH individuals was found quite close. The estimated daily intake (EDI) of SO<sub>2</sub> and Na-benzoate among different divisional HHs was far below the acceptable daily intake (ADI) value.

A noticeable variation was observed in the mean intake of total aflatoxins among division-wise household individuals. The highest total aflatoxins intake (2.89 µg/day) was observed in Khulna HH individuals followed by Chattogram (2.11 µg/day) and then Mymensingh (0.29 µg/day), and the lowest aflatoxins intake (0.012 µg/day) by the Rajshahi individuals. For the case of mean intake expressed in estimated daily intake (EDI), both Khulna and Chattogram HH's exposure largely exceeds ADI.

The following conclusions are drawn from this study:

1. The concentration of trace elements (Zn, Fe, Cu, and Se) and heavy metals (As, Cd, Pb, and Cr) varied widely among the four divisions of Bangladesh.
2. All the household adults of Mymensingh division, 93% household adults of Rajshahi division, 97% household adults of Khulna division, and 85% household adults of Chattogram division showed the dietary intake of Zn below the RDA.
3. All the household adults of Mymensingh division, 98% household adults of Rajshahi division, 99% household adults of Khulna and Chattogram divisions had the dietary intake of Fe below RDA.
4. Population of the four divisions showed sufficient dietary intake of Cu and Se.
5. The dietary intake of As, Cd, and Pb by the studied population across the four divisions pose estimated cancer risks. The population of Mymensingh division has the lowest estimated cancer risk from As and Cd, but the highest estimated cancer risk due to dietary Pb intake. The population of Khulna, exhibits the highest estimated cancer risk due to dietary intake of As while the population of Chattogram division shows the highest

estimated risk due to Cd intake. The adult female has the highest estimated cancer risk from Pb, Cd and As compared to adult male and boys and girls.

6. Cereals, especially rice, are the major food component determining the dietary intake of the trace elements and heavy metals by the population of four divisions.
7. All the households of the four divisions of Bangladesh show a lower intake of beta carotene, riboflavin, and vitamin C than the RDA.
8. A population of 11 to 15 per 100,000 with hepatitis B virus (HBV) lose hepatitis B surface antigen (HBsAg) and consequently the HBV positive individuals per year are at underestimated risk of cancer due to dietary intake of aflatoxins.



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## ABBREVIATIONS

ADI	Acceptable Daily Intake
As	Arsenic
Cd	Cadmium
Cu	Copper
Cr	Chromium
FAO	Food and Agriculture Organization of the United Nations
Fe	Iron
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
ILCR	Incremental Life Cancer Risk
IRIS	Integrated Risk Information Systems
kg	Kilogram
mg/kg	milligram per kilogram
Pb	Lead
RDI	Recommended Dietary Intake
Se	Selenium
TDS	Total Diet Study
USEPA	United States Environmental Protection Agency
USDOE	United States Department of Energy
µg/kg	Microgram per kilogram
WHO	World Health Organization
Zn	Zinc

## 1. INTRODUCTION

Diversified and safe food systems are one of the keys to a vibrant food industry which can enable the delivery of healthy diets for improving nutrition. Human exposure to toxic chemicals in food and nutritional imbalances are now known to be responsible for a range of health problems and are implicated in many others. In Bangladesh, health complications have increased by many fold in the last decade, many of which are related to unsafe food. Reports from the Directorate General of Health Services (DGHS) point to the magnitude of the food related diarrhoea, and that on average, mortality from diarrhoeal diseases accounts for at least 3,850 deaths each year and diarrheal morbidity among 5.7 million people.

As part of measures to protect public health, WHO recommends total diet studies (TDS) as one of the most cost-effective methods for assuring that chemicals in the diet are at safe levels. TDS helps to measure the quantity of chemical substances ingested by the general population and by various specific population groups (by region, age, etc.). These data are needed to assess the health risks for the consumer associated with chemical substances. Unlike routine surveillance monitoring, total diet studies are designed to be health-oriented and population based. TDS is one of the science-based methods to assure that people are not exposed to unsafe levels of toxic chemicals through food. A TDS will look at food from a diet based perspective and will include the analysis of chemicals ubiquitous in foods or the environment, or widely present in the food supply. By obtaining concentrations for these chemicals in a large proportion of the diet it is then possible to obtain realistic estimates for the intake of these chemicals by a population.

A total diet study (TDS) is a large-scale project that examines patterns of intake and exposure to different chemicals across the diet of a population. A TDS determines population dietary exposure not only to harmful chemical substances but also to beneficial and necessary ones across their entire diets. A TDS consists of selecting, collecting and analysing commonly consumed foods purchased at the retail level, processing the foods as for consumption, pooling the prepared food items into representative food groups, homogenising the pooled samples and analysing them for harmful toxins and nutrients (EFSA et al., 2011).

Rice, among the food items, is the principal route of heavy metals and minerals entry into human body which is especially important for Bangladeshi people since their diet is dominantly rice based. Jahiruddin et al. (2017) estimated daily intake of heavy metals from rice as 18.6-214 µg



for As, 2.6-119 µg for Cd and 25.0-241 µg for Pb, based on 400g daily rice consumption for 60 kg Bangladeshi adult people. They determined that the rice component of the diet alone may contribute up to 46%, 57% and 50% of the Maximum Tolerable Daily Intake (MTDI) for As, Cd and Pb, respectively.

Moreover, a range of organic contaminants is being added with different food items during production, transport, preservation and even in the market. Some of these organic compounds are simply toxic to carcinogenic (EFSA, 2015).

The use of harmful chemicals starts at the farm level and goes to the consumers through middlemen and retailers (sellers) who use harmful chemicals to keep their fruits, vegetables, and food items 'fresh'. Poisonous colouring agents like Auramine, rhodamine-b, malachite green, yellow-g, allura red, and sudan red are applied on food items for colouring, brightness, and freshness (Galvin-King et al., 2018). Juice and fruit drinks could be unsafe by the presence of toxic chemicals like chrome, tartrazine, and erythrosine.

Williams et al. (2006) reported that vegetables, pulses, and spices are less important to total As intake than water and rice. They found the highest level of As in rice from southwest Bangladesh, varying from 0.29-0.51 µg/g As. Roychowdhury et al. (2003) have done a comprehensive study on the daily dietary intake of As and some other heavy metals (Cu, Ni, Mn, Zn and Se) through foods consumption (vegetables, cereals, spices and bakery products) by the people living in the arsenic-affected area of West Bengal, India. They conclude that poor nutritional status could be an underlying factor for illness of people exposed to arsenic contaminated food and drinking water. Naser et al. (2009) reported a significant transfer of cadmium, lead and nickel from soils to vegetable crops (spinach, tomato and cauliflower) grown in industrially polluted soils of Konabari (Gazipur district) and Keraniganj (Dhaka district) in Bangladesh.

Our previous study with technical support from FAO determined heavy metals, trace elements and minerals in selected foods collected from Dhaka city markets - Hazaribagh, Kawran Bazar and Gulshan representing low, medium and high-income markets (Islam et al., 2013). The concentration of minerals, trace elements and heavy metals in food stuffs varied widely among the three markets which were attributable to the location variation where the foods had been grown and marketed. The present research is a follow-up study to bridge the gaps in the earlier

study and towards examining foods across the food systems approach and using the latest available national food consumption data.

The present study aims at analysing multiple samples of the contaminants, toxins, and harmful residues in foods covering different seasons from major geographical regions of Bangladesh. This reflects the food systems approach as adopted in the Second Country Investment Plan (CIP2) for nutrition-sensitive systems (2016-2020). The research is a Total Diet Study (TDS) accompanied with a comprehensive dietary risk exposure analysis.

### **Objectives**

- i. Carry out a Total Diet Study (TDS) for Bangladesh, disaggregated by groups and geographical locations. This includes analysis of trace elements (zinc, iron, copper and selenium), vitamins (B2, C and  $\beta$ -carotene), organic contaminants, heavy metals (arsenic, cadmium, lead and chromium), food colours (tartrazine and brilliant blue), food preservatives (sodium benzoate and potassium meta-bisulphite-KMS), mycotoxins and pesticide residues in food consumed on a national level basis.
- ii. Perform a detailed dietary exposure analysis of each chemical using the results from the TDS.
- iii. Make recommendations to reduce deleterious substances in the diet to permissible levels and develop strategies to meet dietary nutrient requirements.

## **2. LITERATURE REVIEW**

Developing countries lag behind in the area of heavy metals research. However, in recent years, several research reports have emerged on heavy metal contamination in fruits and vegetables (Parveen et al., 2003; Gupta et al., 2007). Recently, Suruchi and Khanna (2011) provided a comprehensive global review of the heavy metal contamination in different vegetables grown in and around urban areas. Even low concentrations of heavy metals have damaging effects to man and animals because there is no good mechanism for their elimination, from the body. Heavy metals are persistent environmental contaminants which may be deposited on the surfaces and then adsorbed into the tissues of vegetables.

### **2.1 Trace elements in foods**

Some investigations have been carried out in Bangladesh on the trace elements concentration in vegetables. Alam et al. (2003) analyzed vegetable samples from Samta village of Jessore district. Average Cu concentrations in leafy and non-leafy vegetables were 15.5 and 8.51  $\mu\text{g/g}$ , respectively. The Zn concentrations in vegetables were in the range of 10.0- 55.0  $\mu\text{g/g}$ . Lady's finger had the highest Zn concentration while ash gourd had the lowest Zn concentration. Islam et al. (2005) carried out an experiment to determine the extent of trace elements in 24 different types of vegetables grown on five intensively vegetable growing areas of Chapai Nawabganj of Bangladesh. A wide variation in concentrations of Fe and Zn among the vegetables was observed. The Zn concentrations of leafy vegetables, fruity vegetables, and root and tuber vegetables ranged from 5.81-25.40  $\mu\text{g/g}$ , 9.61-30.48  $\mu\text{g/g}$  and 1.98-18.5  $\mu\text{g/g}$ , respectively. The average Fe concentrations of leafy vegetables (281  $\mu\text{g/g}$ ) were statistically higher compared to those found in root and tuber vegetables (222  $\mu\text{g/g}$ ) and fruity vegetables (129  $\mu\text{g/g}$ ).

Evidence from Murshidabad district of West Bengal, India showed concentrations of Cu, Ni, Mn and Zn in different food samples of which varied from 0.33-14.1 $\mu\text{g/g}$ , 0.0002-7.68  $\mu\text{g/g}$ , 0.22-101  $\mu\text{g/g}$  and 0.84-64.9  $\mu\text{g/g}$ , respectively (Roychowdhury et al, 2003).

The nutritive potential of each ingredient, in terms of trace element contents, was evaluated using instrumental neutron activation analysis (INAA). Four minor (Na, K, P and Cl) and 16 trace elements (Br, Co, Cr, Cs, Cu, Fe, Hg, Mn, Mo, Rb, Sb, Sc, Se, Sr, Th and Zn) were determined in six cereals, nine vegetables and 20 spices and condiments, including two betel leaves (Singh and Garg, 2006). None of the carbohydrate-rich cereals or potatoes was rich in any of the

essential elements while leafy vegetables showed higher contents of Fe and other nutrients. Fe-Zn ratio was well correlated with Fe contents in cereals and spices. Among the various spices analyzed, cinnamon was the highest in Fe, Co, Cr, Na, K, P and Zn, whereas turmeric and curry leaves were found to be particularly rich in Se. Cumin and mustard seeds were rich in Cu. Overall, the spices analyzed are known to be a source of essential oils and minerals like potassium, manganese, iron, and magnesium which have beneficial anti-oxidant properties (Fasoyiro, 2015). Some environmental contaminants, such as Hg, Cr, Br and Th, were also present in significant amounts.

Spallholz et al. (2008) determined that concentrations of Se in rice, vegetables, and fish from different areas of Bangladesh. The average Se concentration of rice was  $0.111 \pm 0.015$  mg/kg with a range of 0.07-0.16 mg/kg. Such levels were similar to Se levels in rice from China (Chen et al. 2002) but were low in comparison to the reported Se levels in rice from Louisiana in the U.S., reported to contain 0.46 mg Se/kg. The mean Se value for rice from Bangladesh was higher than Se values of 0.012 mg/kg of rice from the Keshan diseased areas of China. Gourds and potatoes from Jessore averaged 0.471 and 0.181 mg Se/kg, respectively.

Islam et al. (2012) observed the amount of Zn in different arums, bananas, vegetables, and pulses which are locally available in Chattogram region of Bangladesh. The amount of Zn in 20 samples of arums was found to vary from 0.3174-9.0755  $\mu\text{g/g}$ . The highest and lowest value was found in arums of *Typhonium trilobatum* (Patiya) and *Amorphophallus campanulatus* (Satkaniya) respectively. In bananas the concentration of Zn varied from 0.1430 to 2.7360  $\mu\text{g/g}$ . The highest and lowest value was found in banana of *Musa acuminata* in Satkania and Ramgarh upazila respectively. The amount of Zn in vegetables was found to vary from 0.92-7.59  $\mu\text{g/g}$ . Zinc in pulses was found to vary from 1.29-29.50  $\mu\text{g/g}$ . The highest and lowest values were found in *Lathyrus sativus* and *Phaseolus aureus*, respectively. From four types of food, the highest value of Zn was found in pulse species of *Lathyrus sativus* and the lowest value of Zn in banana species of *Musa acuminata* respectively of Chittagong region, Bangladesh.

Iron is found in animal products such as red meat, fish such as shell fish, cat fish, and poultry. Iron from animal products is more bioavailable, with better absorption compared to that from plant produces. Animal liver and various shellfish contain on an average more than 20 mg/kg copper. Meats normally have an average Cu content of about 2.5 mg/kg (Schorrocks and

Alloway, 1988) while recently Islam (2018) reported Cu content of 0.581-15.99 mg/kg (fresh weight) in meats. Food contains chromium at concentrations ranging from <10 to 1300 µg/kg (ATSDR, 1989). The highest concentrations have been found in meat, fish, fruit, and vegetables. Utensils used in the preparation of food may contribute to chromium levels. Spallholz et al. (2008) determined the concentrations of Se in fishes from different areas of Bangladesh. Seven different unidentified fish sampled in Jessore averaged 1.318 mg Se/kg. Fish was the single highest source of dietary Se per unit dry weight. The Se content of the fish from Bangladesh was similar to values reported for U.S. tuna ( $1.075 \pm 0.093$  mg/kg) and flounder ( $0.825 \pm 0.024$  mg/kg).

Rahman et al. (2013) obtained Cu level in drinking water in Bangladesh as 0.34-19.37 µg/L with a mean of 4.64 µg/L, while WHO's guideline value is 2000 µg/L. Levels of Se in tap water samples from public water supplies around the world are usually much less than 10 µg/L but may exceed 50 µg/L (Gore et al., 2010). Drinking-water from a high soil Se area in China was reported to contain 50-160 µg/L (IPCS, 1987). Approximately 18% of the population of the USA are exposed to drinking-water levels between 2 and 60 µg Se/L and <0.1% to levels between 60 and 120 µg Se/L (ODW, 1987). In the Netherlands, the chromium concentration of 76% of the supplies was below 1 µg/L and of 98% below 2 µg/L (Fonds et al., 1987).

A study was performed by Norton et al. (2017) with 22 rice cultivars, mostly landraces of the *aus* subpopulation, plus some popular improved *indica* cultivars from Bangladesh, for their response to AWD (alternative wetting and drying) in Bangladesh. The concentration of elements in the rice grain were affected when plants were grown under AWD compared to CF (continuous flooding) : Ni, Cu, Cd and Fe increased, but Na, K, Ca, Co, P, Mo and As decreased in the grains of plants grown under AWD. These data suggest that there is no genetic adaptation amongst the cultivars screened for response to AWD, except for grain Cd concentration and imply that breeding specifically for AWD is not needed.

## **2.2 Heavy metals in foods**

Heavy metals are the elements having specific gravity greater than 5 (density  $>5 \text{ g cm}^{-3}$ ). There are 38 heavy metals, of them 13 are used and/or discharged by industries e.g. Cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), arsenic (As), tin (Sn) and zinc (Zn). Some heavy metals are plant nutrients (micronutrients) such as Fe, Mn, Zn, Cu, Mo, Co, Ni and some are

essential for animals e.g. Cr, Ni and Sn. The other metals viz. Cd, As, Hg and Pb are not considered essential for plants and animals. Toxic heavy metals have adverse effects on plants, animals and humans.

The main threats to human health from heavy metals are associated with exposure to lead, cadmium, mercury and arsenic. These elements are known as toxic heavy metals. Absorption of heavy metals through foods could have serious consequences on health causing various diseases such as kidney disease, damage to the nervous system, diminished intellectual capacity, heart disease, gastrointestinal diseases, bone fracture and cancer (Jarup, 2003).

Determination was made on the concentration of heavy metals in 24 different types of vegetables grown in Chapai Nawabganj of Bangladesh (Islam et al., 2005). The lowest concentration of As (0.31  $\mu\text{g/g}$ ) was recorded with bottle gourd and the highest concentration of As (0.81  $\mu\text{g/kg}$ ) was observed with cabbage. The Pb and Cd concentrations of the vegetables ranged from 0.03 - 0.70  $\mu\text{g/kg}$  and 0.02 - 0.36  $\mu\text{g/kg}$ , respectively. Heavy metals are easily accumulated in the edible parts of leafy vegetables, as compared to grain or fruit crops (Mapanda et. al, 2005).

The contents of Pb, Cu, Cr, Zn and Cd in various leafy vegetables viz., spinach, coriander, lettuce, radish, cabbage and cauliflower grown in an effluent irrigated fields in the vicinity of an industrial area of Faisalabad, Pakistan were assessed (Farooq et al., 2008). The contents of Cu, Zn, Cr, Pb and Cd were below the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives, 2017. The leaves of spinach, cabbage, cauliflower, radish and coriander contained higher concentrations of Cu (0.923 mg/ kg), Cd (0.073 mg/kg), Cr (0.546 mg/kg), Zn (1.893 mg/kg) and Pb (2.652 mg/kg) as compared to other parts of each vegetable.

Rapid and unorganized industrialization and urbanization have contributed to an elevated level of heavy metals in the urban environment of the developing countries such as China (Wong et al., 2003), India (Tripathi et al., 1997; Khillare et al., 2004; Sharma et al., 2008a,b) and Bangladesh (Alam et al. 2003; Islam et al., 2005; Naser et al., 2009; Islam et al., 2013; Zakir et al., 2018).

Naser et al. (2009) studied the levels of Pb and Cd in spinach (*Spinacia oleracea*), tomato (*Lycopersicon esculentum*) and cauliflower (*Brassica oleracea*) and in the rhizosphere soils of the industrially polluted (Konabari, Gazipur; Keranigonj, Dhaka), and non-polluted (BARI, Gazipur) areas. Their concentrations varied with the metals and locations, showing the trend:

Ni>Pb>Cd and directly polluted> indirectly polluted>non-polluted soils. The order of the elements in spinach, tomato, and cauliflower and their concentration ranges in µg/g of dry weight were Pd (0.767-1.440), (1.027-1.968), (0.486-1.119); and Cd (0.559-1.40), (0.630-1.303), (0.506-0.782), respectively. Lead concentration was higher in tomato, followed by spinach and the least in cauliflower irrespective of the locations. Cadmium concentration was found in the order of spinach>tomato>cauliflower in the industrially polluted areas. Lead and Cd concentrations in the studied vegetables were higher than those found in vegetables from other countries, but they were lower than the maximum levels allowed in India.

Singh and Taneja (2010) observed higher concentrations of Zn, Cu, and Mn in the vegetable foodstuffs, showing a range of 25.2 to 50.0 mg/kg, 2.4 to 9.8 mg/kg and 0.18 to 2.8 mg/kg, respectively.

Banerjee et al. (2011) assessed the Pb, Cd, Cu and Cr levels in vegetables (cauliflower, brinjal and Indian spinach) collected from different markets in Kolkata, India. Heavy metal content was found highest in unwashed samples followed by washed and boiled samples. Permissible limits of Cu, Pb, Cd and Cr in vegetables as recommended by WHO/FAO are 40, 0.3 0.2 and 2.3 mg/kg, respectively (Maleki and Zarasvand, 2008).

A case study was conducted by Singh and Ghosh (2011) to investigate the entry of As in food materials in Bihar (India). Water samples were highly intoxicated with a mean value of 0.141mg/l (n=20). The mean value of As in soil was 0.027mg/kg (n=6). All food samples were as positive. Wheat recorded the maximum (0.024mg/kg) and the minimum was in maize (0.011mg/kg). Poor nutrition and dependency on these contaminated water and food sources are therefore of great importance to their overall health.

Uraguchi and Fujiwara (2012) reviewed that in Japan, a major source of human Cd-intake is rice grains. Al-Rmalli et al. (2012) reported that in puffed rice, which is commonly consumed by Bangladeshis, contained much higher levels of Cd (mean 67.9 µg/kg) and Pb (mean 98 µg/kg), compared to uncooked rice (Cd, 37.2 µg/ kg; Pb, 18.9 µg/kg). This may be related to the illegal practice of using urea for whitening puffed rice in Bangladesh.

An investigation was done on the Cd and Pb contents of 67 samples of different brands of rice grains (*Oryza sativa*) from central Iran (Shakerian et al.; 2012). Cadmium concentration in rice grains ranged from 0.0378 to 0.1225 mg/kg (dry weight basis) and its average concentration was

0.062 ± 0.019 mg/kg and Pb content ranged from 0.0405 to 0.1281 mg/kg dry weight and its average concentration was 0.068 ± 0.0185 mg/kg.

Jiang et al. (2012) determined the contents of As, Hg, Pb and Cd in milled rice of 216 genotypes in China. The As, Hg, Pb and Cd contents in milled rice ranged from 5.06 to 296.45, 2.46 to 65.85, 4.16 to 744.95 and 5.91 to 553.40 ng/g, respectively. The averages of As and Pb contents for indica rice were higher than those of japonica rice, while the averages of Hg and Cd contents were in contrast.

The Cd concentration in different fishes of Bangladesh, as reported by Al-Rammali et al. (2012) was in a range of 0.7 - 0.8 µg/kg for small fish and big fish, but it was quite high for Hilsha fish eggs (mean 47 µg/kg).

Biswas et al. (2012) estimated the concentrations of Cu, Mn, Zn, Fe, Cr, and Pb in nine commercially important and locally consumed fish species (*Sarda orientalis*, *Scomberomorus commerson*, *Rastrelliger kanagurta*, *Sardinella longiceps*, *Paraplagusia bilineata*, *Cynoglossus lida*, *Cynoglossus macrostomus*, *Lepturacanthus savala*, and *Siganus javus*) collected from coastal waters of Kalpakkam, eastern part of India. Their concentration (µg/g) in the examined fish species ranged as follows: Cu (0.8–6.5), Zn (14.3–27.9), Mn (0.5–8.8), Fe (17.6–117.0), Cr (0.24–1.78), and Pb (0.18–2.29).

The concentration of home-grown vegetables in a severely As-contaminated area of Bangladesh was assessed by Rahman et al. (2012). The median concentrations of As, Cd, Cr, Co, Cu, Pb, Mn, Ni and Zn in vegetables were 90 µg/kg, 111 µg/kg, 0.80 mg/kg, 168 µg/kg, 13 mg/kg, 2.1 mg/kg, 65 mg/kg, 1.7 mg/kg, and 50 mg/kg, respectively.

Al-Rmali et al. (2012) determined the levels of Cd in different food items from Sylhet districts. They reported Cd levels in rice grains (37.2 ± 30 µg/kg), puffed rice (67.9 ± 102 µg/kg), leafy vegetables (31 ± 29 µg/kg), nonleafy vegetables (7.6 ± 8 µg/kg), fruits (2.3 ± 1.2 µg/kg), and spices (89 ± 87 µg/kg). The content of Cd in leafy and nonleafy vegetables varied between 0.7 and 0.8 µg/kg (in ivy gourd and peas) to 4 (lentils) and 4.9 µg/kg (beans). The highest Cd levels were detected in leafy vegetables (ranged from 3.3 to 303 µg/kg). Different varieties of leafy vegetables were found to have particularly high levels of Cd, with mean concentrations ranging from 46.4 to 100.5 µg/kg.



An analysis was done on 210 cow milk samples from Madaripur, Chandpur, Satkhira, Jessore and Faridpur for total As analysis. The milk arsenic concentration over the locations was  $26.2 \pm 2.8 \mu\text{g/ml}$  (Ghosh et al., 2013).

Islam et al. (2013) identified zinc, iron and selenium as deficient in the Bangladeshi diets. Cereals contribute about 60% for Zn and 55% for Fe to the daily intake of these minerals. More than 90% people are taking Zn at less than RDI (Recommended Daily Intake) of 12 mg Zn/day and more than 95% people are taking Fe less than RDI of 17 mg Fe/day through various food sources. Bangladeshi children suffer from high rates of micronutrient deficiencies, particularly vitamin A, iron, iodine and zinc deficiency (iCDDR, 2013).

Saha and Zaman (2013) investigated the concentrations of heavy metals (Pb, Mn, Cr, Cd and As) in vegetables, fruits, and fish species collected from Shaheb Bazar of Rajshahi City, Bangladesh. The highest concentrations of Mn and As in vegetables (onion and pointed gourd, respectively), Cr and Cd in fruits (black berry and mango, respectively), and Pb in fish (catla) are recorded.

Meharg et al. (2013) first time reported cadmium (Cd) contamination in rice. The mean dietary exposure among infants, toddlers and other children ranged, across Bangladesh, Sri Lanka and China, from 0.20 to 0.45  $\mu\text{g/kg}$  body weight (bw) per day and from 0.47 to 1.37  $\mu\text{g/kg}$  bw per day (min-max UB), with the maximum value estimated in infants.

The Pb concentration of rice samples varied significantly with growing seasons, varieties used and locations of cultivation. It was found that the Pb concentration in rice decreased three-fold from Bagha (0.232 mg/kg) and Chapai Nawabganj (0.231 mg/kg), to Baghmara (0.080 mg/kg) (Jahiruddin et al., 2017).

Rahman et al. (2014) reported the mean concentrations of Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn in Australian grown rice as 7.5 mg/kg, 21 mg/kg, 144 mg/kg, 2.9 mg/kg, 24.4 mg/kg, 166 mg/kg, 375 mg/kg, and 17.1 mg/kg dry weight, respectively. Except Cd, heavy metal concentrations in Australian grown rice were higher than Bangladeshi rice on sale in Australia while the concentrations of Cd, Cr, Cu, and Ni in Indian rice on sale in Australia were higher than Australian grown rice. The concentrations of Cu and Ni in Vietnamese rice, and that of Cd, Cr, Cu, Ni, and Pb in Thai rice on sale in Australia were also higher than Australian grown rice. Heavy metal concentrations in Pakistani rice on sale in Australia were substantially lower than that in Australian grown rice. In Australian grown rice varieties, the concentrations of heavy

metals were considerably higher in brown rice varieties than white rice varieties, indicating Australian brown rice as a potential source of dietary heavy metals for Australian consumers.

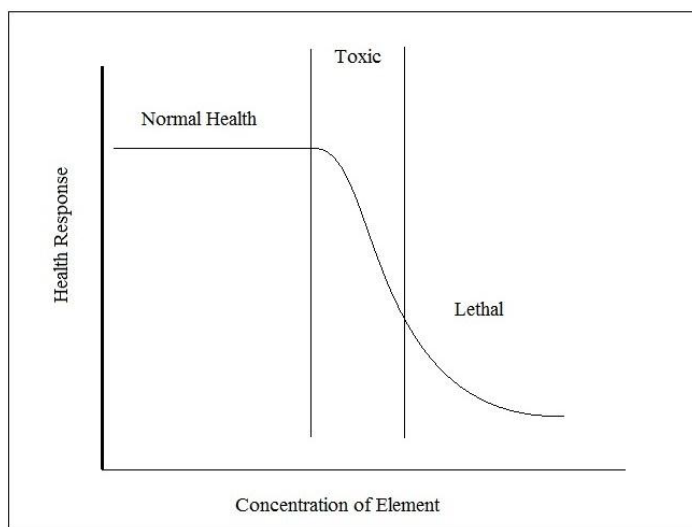
Some of the Australian grown and Bangladeshi vegetables contained heavy metals higher than Australian standard maximum limits indicating them as potential sources of dietary heavy metals for Australian consumers.

From a pot culture study Zakir et al. (2018) reported that accumulation of heavy metals and major nutrients in spinach leaves was in the sequence of  $\text{Fe} > \text{Zn} > \text{Cr} > \text{Mn} > \text{Cu} > \text{Pb}$  and  $\text{K} > \text{S} > \text{Ca} > \text{Mg} > \text{P}$ , respectively for industrial contaminated soil, while the order was  $\text{Fe} > \text{Mn} > \text{Cr} > \text{Zn} > \text{Cu} > \text{Pb}$  and  $\text{S} > \text{K} > \text{Ca} > \text{Mg} \geq \text{P}$ , respectively for farm soil. The sequence of Zn, Mn, Ca, K and S accumulation in spinach was leaf > root, while in case of Fe, Cr and P the order was reverse. The calculated THQ (target hazard quotient) value for Cr surpassed 1, and the values for male were 2.85 and 6.86 and for female were 4.47 and 10.75 due to consumption of spinach grown in farm and industrial contaminated soils, respectively. The study results inferred that Cr health risk through consumption of spinach is unsafe in industrial contaminated sites; and in both places female is more vulnerable than male.

Shi et al. (2020) have done an extensive review on cadmium concentrations in rice grain globally. The concentrations of cadmium in the global polished (white), market rice supply-chain were assessed in 2270 samples, purchased from retailers across 32 countries, encompassing 6 continents. It was found on a global basis that East Africa had the lowest cadmium with a median for both Malawi and Tanzania at 4.9  $\mu\text{g}/\text{kg}$ , an order of magnitude lower than the highest country, China with a median at 69.3  $\mu\text{g}/\text{kg}$ . The Americas were typically low in cadmium, but the Indian sub-continent was universally elevated. In particular certain regions of Bangladesh had high cadmium, that when combined with the high daily consumption rate of rice of that country, leads to high cadmium exposures. Concentrations of cadmium were compared to the European Standard for polished rice of 200  $\mu\text{g}/\text{kg}$  and 5% of the global supply-chain exceeded this threshold. For the stricter standard of 40  $\mu\text{g}/\text{kg}$  for processed infant foods, for which rice can comprise up to 100% by composition (such as rice porridges, puffed rice cereal and cakes), 25% of rice would not be suitable for making pure rice baby foods. Given that rice is also elevated in inorganic arsenic, the only region of the world where both inorganic arsenic and cadmium were low in grain was East Africa.

### 2.3 Heavy metal contamination and health implications

Heavy metals are very harmful because of their non-biodegradable nature, long biological half lives and their potential to accumulate in different body parts (Sharma et al., 2007). Furthermore, the consumption of heavy metal-contaminated food can seriously deplete some essential nutrients in the body causing a decrease in immunological defenses, intrauterine growth retardation, impaired psycho-social behaviour, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer and negative health responses (Figure 2.1).



**Fig. 2.1** Health response for toxic element (adapted from Fergusson, 1990).

Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Jarup, 2003).

Intake of heavy metals through the food chain by human populations has been widely reported throughout the world (Muchuweti et al., 2006). Due to the non-biodegradable and persistent nature, heavy metals are accumulated in vital organs in the human body such as the kidneys, bones and liver and are associated with numerous serious health disorders (Duruibe et al., 2007). The nature of effects can be toxic (acute, chronic or sub-chronic), neurotoxic, carcinogenic, mutagenic or teratogenic (European Union, 2002).

Lead is a cumulative toxin that can primarily affect the blood, nervous system and kidneys. In the blood at high concentrations, lead inhibits red blood cell formation and eventually results in anaemia (WHO, 2010a). The effects of high concentrations of lead on the nervous system can vary from hyperactive behaviour and mental retardation to seizures and cerebral palsy. As the kidneys are the primary route for lead excretion, lead tends to accumulate in these organs, causing irreversible damage. There is currently no reference health standard for lead, so the risk assessment has been based on the MOE approach. For adults, there is consistent evidence that the first significant effect seen at lower blood lead concentrations is an increase in systolic blood pressure (WHO 2010b).

Human exposure to inorganic arsenic (Asi), a class 1, non-threshold carcinogen, for non industrially exposed cohorts, is primarily from food and water (Mondal and Polya, 2008). Acute toxicity as a result of high exposure to inorganic arsenic can result in gastrointestinal disturbances such as vomiting (WHO, 2001). Chronic toxicity from high exposure to inorganic arsenic from drinking water has been associated with arsenicosis, characterized by hyperpigmentation (melanosis) of the torso and keratoses of the planer portions of hands and feet. In the extreme, cancer of the skin, liver, lungs and bladder may occur (WHO, 2001; Yu et al, 2006). People who consume large amounts of seafood may ingest significant amounts of arsenic; however, the arsenic in seafood is primarily in the organic, less toxic form (Borak and Hosgood, 2007).

The intake of heavy metal can lead to illness of humans and animals. Thus, the carcinogenic effects generated by continuous consumption of fruits and vegetables loaded with heavy metals such as Cd, Pb or even Cu and Zn are known. This may be related to the incidence of gastrointestinal cancer (Turkdogan et al., 2002) and cancer of the pancreas, urinary bladder or prostate (Waalkes and Rehm, 1994). The sad thing about the pollution of the environment with heavy metals is that they can only be transformed from one oxidation state or organic complex to another (Jing et al., 2007; Lone et al., 2008;).

Sharma et al. (2009) have generated data on heavy metal pollution in and around Varanasi city of India and associated health risk assessment for the consumer's exposure to the heavy metals. They proposed the hypothesis that the transportation and marketing of vegetables in contaminated environment may elevate the levels of heavy metals in vegetables through surface

deposition. Heavy metals have a toxic impact but detrimental impacts become apparent only when long-term consumption of contaminated vegetables occurs.

An assessment was done on the daily consumption by adults of As and other elements in drinking water and home-grown vegetables in As-contaminated area of Bangladesh (Rahman et al., 2013). Most of the examined elements in drinking water were below the World Health Organization (WHO) guideline values except As. Potential health risk was estimated comparing with the FAO/WHO values of metals. Vegetables alone contribute the elemental intake below the PMTDI values. The median concentrations of As, Cd, Cr, Co, Cu, Pb, Mn, Ni, and Zn in vegetables were 90 g/kg, 111 g/kg, 0.80 mg/kg, 168 g/kg, 13 mg/kg, 2.1 mg/kg, 65 mg/kg, 1.7 mg/kg, and 50 mg/kg, respectively. Daily intakes of As, Cd, Cr, Co, Cu, Pb, Mn, Ni, and Zn from vegetables and drinking water for adults were 839 g, 2.9 g, 20.8 g, 5.5 g, 0.35 mg, 56.4 g, 2.0 mg, 49.1 g, and 1.3 mg, respectively. Vegetables alone contribute 0.05 g of As and 0.008 mg of Cu per kg of body weight (bw) daily; 0.42 g of Cd, 8.77 mg of Pb, and 0.03 mg of Zn per kg bw weekly. Other food sources and particularly dietary staple rice need to be evaluated to determine the exact health risks from such foods.

Islam et al. (2014) investigated the concentration of Cr, Ni, Cu, Zn, As, Cd, and Pb in cereals and pulses and associated health implications in Bangladesh. USEPA deterministic approaches were followed to assess the carcinogenic risk (CR) and noncarcinogenic risk which was measured by target hazard quotient (THQ) and hazard index (HI). Total THQ (target hazard quotient) values for As and Pb were higher than 1, suggesting that people would experience significant health risks. However, the estimated HI (hazard index) value of  $1.7 \times 10^1$  ( $>1$ ) elucidates a potential noncarcinogenic risk to the consumers. The estimation also showed that the carcinogenic risk of As ( $5.8 \times 10^{-3}$ ) and Pb ( $4.9 \times 10^{-5}$ ) exceeded the USEPA accepted risk level of  $1 \times 10^{-6}$ . Thus, the carcinogenic risk of As and Pb with nutritional deficiency of essential elements for Bangladeshi people is a great concern.

An extensive number (965) of rice samples collected by household survey from 73 upazilas (sub-districts) in Bangladesh was analyzed to determine regional variation, distribution and associated health risks from As (Islam et al., 2017). Total As levels of aromatic rice were significantly lower (average 58  $\mu\text{g/kg}$ ) than nonaromatic rice (average 150  $\mu\text{g/kg}$ ). The variation in As content was dominated by the location (47% among the upazilas, 71% among districts) and

rice variety (14%). Inorganic As content in rice grain ranged between 11 and 502  $\mu\text{g/kg}$  ( $n=162$ ) with the highest fraction being 98.6%. The daily intake of inorganic As from rice ranged between 0.38 and 1.92  $\mu\text{g/kg BW}$  in different districts. The incremental lifetime cancer risk (ILCR) for individuals due to the consumption of rice varied between  $0.57 \times 10^{-3}$  to  $2.88 \times 10^{-3}$  in different districts, and  $0.54 \times 10^{-3}$  to  $2.12 \times 10^{-3}$  in different varieties, higher than the US EPA threshold. The hazard quotient of iAs suggests very high potential non-carcinogenic risk. The 2–10 age group experiences higher carcinogenic risks than others and females are more susceptible than males.

Jahiruddin et al. (2017) determined the levels of As, Cd, Pb and Cr in 71 irrigated and rain-fed rice and assessed dietary (rice) exposure to the heavy metals. The heavy metal in irrigated and rain-fed rice were as follows: As  $0.153 \pm 0.112$  and  $0.140 \pm 0.080$  mg/kg, Cd  $0.073 \pm 0.069$  and  $0.038 \pm 0.032$  mg/kg, Pb  $0.264 \pm 0.125$  and  $0.147 \pm 0.077$  mg/kg and Cr  $1.208 \pm 0.913$  and  $0.986 \pm 0.796$  mg/kg, respectively which indicates an elevated concentration in boro rice (dry season) grown with contaminated irrigation water. Higher concentrations of Cd, Pb and Cr were noted for industrial effluent contamination areas. Daily intake of As and heavy metals from rice is estimated as 18.6–214  $\mu\text{g}$  for As, 2.6–119  $\mu\text{g}$  for Cd, 25.0–241  $\mu\text{g}$  for Pb and 59.0–1846  $\mu\text{g}$  for Cr, based on 400g daily rice consumption for 60 kg Bangladeshi adult people. The rice component of the diet alone may contribute up to 46%, 57%, 50% and 60% of the Maximum Tolerable Daily Intake (MTDI) for As, Cd, Pb and Cr, respectively, making it a more important factor in the dietary intake for these elements than other food stuffs and drinking water.

As observed by Islam (2018), the ranges of Cr, Ni, Cu, As, Cd and Pb concentrations in the meat samples (beef, mutton, chicken and duck) were 0.533–6.55, 0.005–7.70, 0.581–15.99, 0.080–11.34, 0.001–0.22 and 0.061–13.52 mg/kg (on fresh weigh basis), respectively. The estimated levels of most of the heavy metals were higher than the maximum allowable concentration (MAC) for dietary foods. The target hazard quotients (THQ) and carcinogenic risk (TR) of As for both adults and children suggest that the consumers are exposed chronically to metal contamination with carcinogenic and non-carcinogenic health diseases.

Currently Kulathunga et al. (2021) performed a human health risk assessment to identify if there is any link between heavy metal(loid) exposure from vegetable consumption and the prevalence of chronic kidney disease of unknown aetiology (CKDu). It was noted that potato and bitter

gourd accumulated Pb to a greater extent than other vegetables and exceeded the permissible concentration for foodstuffs. The Cd content of Brinjal also exceeded permissible levels, while the As content was below permissible levels for all the vegetables tested. Estimated Daily Intake (EDI) from the consumption of vegetables follows the decreasing order of  $Mn > Zn > Cu > Pb > As > Cd$ . Health risks from individual metal(loid) exposure were assessed by calculating hazard quotients. All the measured heavy metal(loid) HQ values were less than 1, confirming that the health risk from consuming metal(loid)s present in vegetables was minimal. Since, few vegetables showed marked heavy metal(loid) accumulation, periodical monitoring of heavy metal(loid) concentrations in vegetables will be beneficial for avoidance of future possible health risks.

#### **2.4 Reduction of dietary exposure of heavy metals**

There are several options to reduce dietary exposure of heavy metals which include reduction of the sources of soil pollution, cultivation of crop plants that translocate less amount of heavy metals to the edible portion (mainly to seeds or grains), water management practices, cooking rice with excess water and draining the gruels, some micro-organism-based remediation techniques, such as bioremediation, show potential for their ability to degrade and detoxify certain contaminants.

Hyper accumulators store metals in their tissues at concentrations far exceeding those in the environment. Heavy metal contents in hyper accumulators are more or less 100 times those found in non-hyper accumulator plants grown in soil under the same conditions (Brooks, 1998).

There exists wide variation among rice genotypes with respect to grain-As contents of rice. Among the HYV of rice, BRRI dhan47 and BR 3 showed lowest grain-As contents than the other Bangladesh rice varieties. Uruguchi et al. (2011) reported that knock-down of OsLCT1 reduced rice grain Cd by 50% (Norton et al., 2009).

Arao et al. (2009) reported that flooding the rice field before and after heading drastically reduced grain Cd concentrations, but on contrary, this treatment increased As concentration in grains.

It was observed by Khan et al. (2010) reported that washing rice with water before cooking reduced the concentration of arsenic in raw rice by 13-15%. Rice, when cooked with excess

water discarded, showed a significant decrease in As concentration compared to that cooked without discarding the water. In contrast, concentration of Cd did not decrease in cooked rice after discarding water. Similar results were also observed by (Bae et al., 2005).

Uraguchi and Fujiwara (2012) reviewed that Cd is a toxic heavy metal which harms human health. In Japan contamination of paddy soils by Cd and accumulation of Cd in rice grains are the serious agricultural issues. There also exists Cd contamination of rice and its toxicity in several populations in countries including China and Thailand. Understanding the Cd transport mechanisms in rice can be a basis for regulating rice Cd transport and accumulation by molecular engineering and marker-assisted breeding.

Phytoremediation is considered a clean, cost-effective and non-environmentally disruptive technology, to remove heavy metals from polluted lands. However, one major disadvantage of phytoremediation is that it requires a long-term commitment as the process is dependent on plant growth, tolerance to toxicity and bioaccumulation capacity. Sarma (2011) has reviewed the recent advances of phytoremediation technology. Different plants have been identified for phytoremediation of heavy metals. Chinese Brake fern (*Pteris vittata*) for As, Willow (*Salix viminalis*) for Cd, Zn & Cu, and Indian Mustard (*Brassica juncea*) and sunflower for Pb (Raskin and Ensley, 2000; USEPA, 2000).

## **2.5 Vitamins in vegetables and fruits**

Though there are beneficial mineral elements in the Bangladeshi diets, vitamins are reportedly deficient in the rice based diets, and this requires a detailed understanding in order to address the resultant micronutrient deficiencies due to such diets. There has been a dramatic reduction in the prevalence of night blindness among preschool children from the 1980s to 2004, which is attributed to the successful programme of vitamin A supplementation launched in 1973 (IPHN and HKI, 2005). Keratomalacia, the most severe form of VAD, is now seen occasionally among children hospitalized. However, a previous study in rural Bangladesh, sub-clinical VAD (serum retinol <0.7 µg/dL) was found in 18.5% of 200 pregnant women (Lee et al, 2008). The vitamin A intake by nearly half of pregnant women was less than the recommended dietary allowance. Available estimates from the national micronutrient survey 2011/12 have shown that vitamin A deficiency was 20.5%, 20.9% and 5.4% respectively in preschool age children, school age children and the non-pregnant non-lactating women. Potatoes also provide a substantial portion



of daily requirement values (DRV) of essential nutrients e.g. potassium (plays role in acid-base equilibrium, also promotes Na elimination; 26% of DRV), vitamin C (needed for the growth and repair of tissues and in antioxidant functions; 28% of DRV), vitamin B<sub>6</sub> (needed for almost every enzymatic functions; 27% of DRV) and dietary fiber (essential for gastro intestinal peristalsis and body weight management; 15% of DRV), magnesium (constituent of several metalloenzymes with role in cellular functions; 12% of DRV) and iron (cofactor with several enzyme metabolism, 10% of DRV) and others (Zaheer & Akhtar 2016).

Analysis of potatoes from the Pacific Northwest's TriState Breeding Program found a range of different locations and especially during different years (Love et al., 2004; Love & Pavek, 2008). Vitamin C content in 33 cultivars grown in three European locations ranged from 13 to 31 mg vitamin C/100 g FW, assuming the potatoes were 80% water (Dale et al., 2003). Folate (vit. B<sub>9</sub>) concentrations have been screened in cultivars, with over a 3-fold range between 12 and 41 µg/100 g FW and 0.5–1.4 µg/g DW; the wild species *S. boliviense* contained 115 µg/100 g FW (Goyer & Navarre, 2007; Goyer & Sweek, 2011; Kuhn et al., 1984). In a study of mature and immature tubers, vitamin B<sub>6</sub> ranged from 16 to 27 µg/g DW (Mooney et al., 2013). Finally, thiamine (vitamin B<sub>1</sub>) in potatoes has been measured at concentrations of 0.06–0.23 µg/100 g FW (Augustin et al., 1978; Goyer & Sweek, 2011).

Raw banana contains vitamin A (RAE) 3 µg, total folate 20 µg, thiamin 0.031mg, riboflavin 0.073 mg, niacin 0.665 mg, pantothenic acid 0.218mg, vit.B<sub>6</sub>0.367mg, vit. C 8.7 mg in per 100 g fresh weight (USDA, 2020a). Raw mango contains vit. A (RAE) 54 µg, total folate 43 µg, thiamin 0.028mg, riboflavin 0.038 mg, niacin 0.669 mg, vit.B<sub>6</sub>0.119mg, vit. C 36.4 mg in per 100gm fresh weight (USDA, 2020b). Raw jackfruit contains vitamin A (RAE) 5 µg, total folate 24 µg, thiamin 0.105 mg, riboflavin 0.055 mg, niacin 0.92 mg, pantothenic acid 0.235 mg, vitamin B<sub>6</sub>0.329 mg, vit. C 13.7 mg in per 100 g fresh weight (USDA, 2019a). Papaya contains vitamin A . A (RAE) 18.7–88.7µg, folate 37–63µg, thiamin 0.021–0.036mg, riboflavin 0.024–0.058 mg, niacin 0.227–0.338 mg, pantothenic acid 0.218mg, vit.B<sub>6</sub> 0.019mg, vit. C 35.5–142.0 mg in per 100gm edible fresh weight (Wall & Tripathi, 2014). Guava contains vit. A (RAE) 31 µg, folate 49 µg, thiamin 0.067 mg, riboflavin 0.04 mg, niacin 1.084 mg, vit.B<sub>6</sub>0.11 mg, vit. C 228.3 mg in per 100gm edible fresh weight (USDA, 2020d). Raw pineapple contains vit. A (RAE) 3 µg, total folate 18 µg, thiamin 0.079 mg, riboflavin 0.032 mg, niacin 0.5 mg, vit. B<sub>6</sub>0.112 mg, vit. C 47.8 mg in per 100 g fresh weight (USDA, 2020e). Raw apple contains vit. A

(RAE) 3 µg, total folate 3 µg, thiamin 0.017mg, riboflavin 0.026 mg, niacin 0.091 mg, vit.B<sub>6</sub>0.041 mg, vit. C 4.6 mg in per 100 g fresh weight (USDA, 2020c).

## **2.6 Food coloring agents, food preservatives**

As reported earlier, the use of harmful chemicals is seen across the food chain, from the farm to the fork (Ali, 2013 and Islam and Hoque, 2013). Poisonous colouring agents like Auramine, Rhodamine-b, Malachite green, Yellow-g, Allura red, and Sudan red are applied on food items for colouring, rightness, and freshness (Galvin-King et al., 2018). Juice and fruit drinks could be unsafe by the presence of toxic chemicals like Chrome, Tartazine, and Erythrosine. Copper, Zinc or indigo dye, etc. are mixed with soft drinks (Cola beverages, fruit juice). Though the effects of these dyes are not apparent but they may cause cancer in the long run (Rao and Sudershan, 2008; Doell et al., 2016). Amylum is one kind of complex starch (indigestible) which is used as a food thickener.

Sarower (2013) conducted a study to determine the adulteration and assess the quality of jelly and squash commercially available in the local market of Mymensingh. Analysis was done in laboratories of BAU, BSTI, BCSIR and SGS. Physico-chemical characteristics of jelly and squash samples were tested in BAU laboratory. In commercial brand jellies juice content was 13-33% where the reference value was 45%. Commercial brands squash had 19% juice where it should contain at least 25%. The jelly and squash samples were also analyzed in BSTI laboratory to determine acidity as citric acid (% m/m) and sodium benzoate (mg/kg). Saini et al. (1997) reported that the taste of sweetened fruit juice depends upon the sugar/juice/ acid ratio. Minimum sugar content should be 18%, acidity 0.8- 1.5% and the sugar/ acid ratio 20-29. The preservation of the flavor, aroma, color and vitamin content of the fresh juice was dependent on the degree of destruction of enzymes or inhibition of their activity. Enzymes could be destroyed and their activity could be inhibited by pasteurization.

Falco et al. (1993) tested Sodium benzoate and potassium sorbate for their ability to preserve for 3 months concentrated jam (pH 3.7, water activity 0.87) stored in non-hermetic containers, and for their effect on *Penicillium italicum* and *Aspergillus ochraceus*. Although both compounds reduced the microbial count in samples of the jam, potassium sorbate was more effective than sodium benzoate. Periodic counts of aerobic mesophiles, moulds and yeasts, and osmophilic yeasts in jam treated with 500 ppm. Potassium sorbate confirmed its

effectiveness. *A. ochraceus* was significantly ( $P < 0.05$ ) more resistant to the treatments than *P. italicum*. Implovo *et al.* (2000) described an isocratic HPLC technique for the determination of benzoic acid and ascorbic acid in industrial quince jam. The preparation procedure was optimized. Precipitation of proteins and fat by the addition of methanol, followed by centrifugation and/or filtration provided extract suitable for chromatographic analysis. The chromatographic separation was achieved with a C18 column and acetate buffer ( $\text{pH} = 4.4$ ) - methanol (65:35) as the mobile phase. The effluent was monitored at 235 nm. Effective separation and quantification was achieved in less than 7 min. Specificity of the method was checked against common food additives added to industrial quince jam, such as L-ascorbic acid and citric acid. Diode array detection was used for confirmation of the preservatives. Mean recoveries of 95-104% were obtained with a precision less than 2.6%, mie detection limits of 25 and 6.25 mg/kg were obtained for benzoic and ascorbic acids, respectively. Results were in good agreement with the reference methods. The presence of benzoic and ascorbic acids in quince jams available on the Portuguese market, was also determined. Eleven commercial brands of quince jam were analyzed. All contained benzoic acid. The concentration ranged from  $413.9 \pm 10.4$  to  $1501 \pm 4.2$  mg of benzoic acid/ kg of quince jam. Only two brands also contained sorbic acid. The concentrations were  $515.0 \pm 7.0$  and  $908.3 \pm 5.3$  mg of sorbic acid/kg of quince jam. Oplatowska *et al.* (2011) conducted a study on sudan dyes have been found to be added to chilli and chilli products for illegal colour enhancement purposes. Due to the possible carcinogenic effect, they are not authorized to be used in food in the European Union or the USA. However, over the last few years, many products imported from Asian and African countries have been reported via the Rapid Alert System for Food and Feed in the European Union to be contaminated with these dyes. In order to provide fast screening method for the detection of Sudan I (SI), which is the most widely abused member of Sudan dyes family, a unique (20 min without sample preparation) direct disequilibrium enzyme-linked immunosorbent assay (ELISA) was developed and used. The assay was used to screen a range of products (85 samples) collected from different retail sources within and outside the European Union. Three samples were found to contain high amounts (1,649, 722 and 1,461 ng/g) of SI by ELISA. These results were confirmed by liquid chromatography-tandem mass spectrometry method. The innovative procedure allows for the fast, sensitive and high throughput screening of different foodstuffs for the presence of the illegal colorant SI. Ferrer *et al.* (2007) conducted a study on illegal dyes used

in spices powder in the United Kingdom. A sensitive and accurate methodology was developed for the analysis of seven illegal dyes (Sudan I, Sudan II, Sudan III, Sudan IV, Sudan Orange G, Sudan R and Para Red) used as additives in food products, such as chili powder and steak sauces. Kayshar (2012) carried out a research in two phases.

In the current study, jam samples of selected commercial brands were collected from local market of Mymensingh for chemical analysis and sensory evaluation. The base line survey pointed to consumers' opinions, that all commercial jam products were adulterated by harmful food colors, low grade fruits and harmful preservatives and these are harmful to health. The consumers expressed that the color of the jam was too bright and did not appear to be natural. However, it was heartening to note, that upon analysis in the laboratories of BAU, BSTI and BCSIR it was found that there were no harmful chemicals and heavy metals in commercial brands of jam. But every commercial brand jam sample had scanty amount of pulp. Pulp content in jam samples varied widely from 13% to 22.5%, which is likely to decrease the quality and added provided from the products. Miguel and Belloso (2000) evaluated the quality of peach jams with peach dietary fiber (DF) used as a thickener. Peach jams with soluble solids contents of up to 40, 45, 50 and 55 degrees Brix with total or partial substitution of commercial amidated pectin by peach DF were studied. The uronic acid contents (pectin substances) in the jam formulations were 0, 25, 50, 75 and 100% from peach DF with the residue from the commercial pectin. Jam color was not affected by the incorporation of DF because both the DF and the puree came from peach.. From a sensorial point of view, high peach DF jams were as acceptable as conventional jams. Anjum et al. (2000) prepared dried apricot jam by incorporating a suitable combination of sorbitol, cyclamate and aspartame instead of sucrose and glucose syrup on the equivalent solid basis. The treatments were analyzed of physico-chemical and sensory evaluation fortnightly for two months. Significant results were obtained for TSS, pH, acidity and reducing sugars with regard to treatments and storage periods. All the sensory characteristics affected significantly due to the differences in sweetener combinations while the effect of storage period was found to be non-significant. There was no effect of treatment and storage period on ash contents of apricot jam. The total soluble solids increased gradually in all treatments during storage periods.

## 2.7 Aflatoxins in cereals

Aflatoxins were first discovered in the 1960s following an outbreak of so-called "turkey X ... common and affect the agricultural industry and consumers' health (Richard. 2008). In considering toxicity and carcinogenicity, the presence of aflatoxin in rice is a serious public health concern especially in developing countries where people are at risk of aflatoxin exposure. Rice and other staple foods are susceptible to aflatoxin contamination (Ali, 2019). Low aflatoxin awareness, food insecurity and lack of regulatory limits enforcement are the significant contributors to high aflatoxin exposure of these populations. In China, AFB1 was found in 235 of 370 samples with an average of 0.06 µg/kg (Lai et al., 2015). In another study, AFB1 detected in all 29 samples with an average contamination level of around 0.5-0.6 µg/kg (Sun et al., 2011). A previous study reported the presence of AFB1 in 16 out of 84 samples with a range between 0.15-3.22 µg/kg (Wang et al., 2007). The presence of aflatoxins has been reported in rice from India. A study covering rice from 12 states of India reported that about 38.5% out of 1511 samples were contaminated by AFB1 (Toteja et al., 2006). Another survey covered 20 states of India, reported that AFB1 was present in 814 of 1200 samples ranging from 0.1 to 308 µg/kg (Reddy et al., 2009). In Indonesia, AFB1 was detected in 2 of 2 rice samples with a range between 2.0-7.0 µg/kg (Noviandi et al., 2001).

Roy et al. (2013) conducted a rapid cross-sectional study to investigate the extent of aflatoxin contamination among common Bangladeshi foods viz. rice, lentils, wheat flour, dates, betelnut, red chili powder, ginger and groundnuts and poultry feed samples from two large markets in each of three cities in Bangladesh. Aflatoxin levels were highest in dates and groundnuts (maximum 623 and 423 ng/g), respectively. Samples of betelnut (mean 30.6 ng/g), lentils (mean 21.2 ng/g) and red chili powder (>20 ng/g) also had elevated levels. The mean aflatoxin level among poultry feed samples was 73.0 ng/g. Aflatoxin levels were above the US maximum regulatory levels of 20 ng/g in five of eight commonly ingested human food commodities tested.

Hye et al. (2008) studied on the aflatoxins contamination in spices and processed spice products commercialized in Korea. This survey for total aflatoxins was conducted on 88 spices and processed spice products commercialized in Korea. The presence of aflatoxins was determined by high-performance liquid chromatography (HPLC) with fluorescence detector using immunoaffinity column clean-up. Total aflatoxins (AFs) are detected in 12 samples (13.6% of

incidence) including seven red pepper powder, two red pepper pastes (Kochujang), two curry and one ginger product. The contamination levels are 0.08-4.45 micro g/kg as aflatoxin B<sub>1</sub> and 0.08-4.66 micro g/kg as AFS. The liquid chromatography-tandem mass spectrometry (LC-MS/MS) analysis on contaminated samples was conducted for the confirmation of detected aflatoxins. The 12 samples which showed aflatoxins by HPLC/FLD were confirmed as aflatoxins by LC-MS/MS.

O'Riordan *et al.* (2008) studied on the incidence and level of aflatoxin contamination in a range of imported spice preparations in Irish retail markets. Aflatoxin content was detected in 130 commercial spice preparations, including pepper, chilli, curry powder, cayenne, paprika, cinnamon, coriander, turmeric and cumin. Aflatoxin B<sub>1</sub> gave the highest incidence of contamination in spice preparations and was found in 20 of the 130 samples. The highest concentration of aflatoxin, 27.5 micro g/kg, was detected in chilli powder followed by cayenne pepper ( ). Five samples (3.8%), consisting of chilli, cayenne pepper and turmeric pepper, were above the regulatory limits of the EU. Aflatoxin contamination was not detected in cumin or cinnamon samples

## **2.8 Pesticide residues in vegetables**

Pesticides used to protect the crops from pest attack in the agricultural fields have harmful effects on non-target organisms such as human and many other aquatic and terrestrial organisms either directly or indirectly through food chain. Organophosphorous pesticides (OP) may affect sperm chromosome segregation and augment the risk for genetic syndromes. Alam et al. (2015) reported that almost 50% of the egg plants and 60% of tomatoes from Narayanganj, Dhaka were contaminated with pesticides at levels exceeding the EU maximum residual limits (MRL). In this regard, it is worth noting that eggplant and tomatoes are widely used in the Bangladesh diet, and this aspect needs further study.

Among the pesticide residues tested, diazinon was the most commonly detected (35%) pesticide in the vegetable samples. The highest concentration for diazinon was 4.514 mg/kg in an eggplant sample. This level is approximately 450 times higher than the MRL, which is alarming. The highest diazinon level detected in tomatoes was 3.612 mg/kg, which is approximately 360 times higher than the MRL. This result is alarming, in that tomatoes which are a good source of lycopene, other valuable carotenoids and vitamin C are usually consumed raw in salads. Hasan

et al. (2017) on their study of country bean collected from Mohammadpur, two samples (DMB22 and DMB28) contained residue of dimethoate at 0.093 mg/kg and 0.019 mg/kg, respectively. Considering the maximum residue limit (0.02 mg/kg), the level of detected residue of DMB22 was above the MRL and DMB28 was below the MRL.

Witczak et al. (2018) studied both local and imported vegetables for the presence of organophosphorus residue, where, potato contained 0.926 ng/g ethoprophos, 1.98 ng/g diazinon, 1.478 ng/g parathion-methyl, 31.728 ng/g chlorpyrifos, and 0.088 ng/g merfos, wet weight basis, tomato contained 0.296 ng/g ethoprophos, 0.919 ng/g diazinon, 0.818 ng/g parathion-methyl, 2.541 ng/g chlorpyrifos, and 0.035 ng/g merfos, wet weight basis, and eggplant contained 0.035 ng/g ethoprophos, 0.146 ng/g diazinon, 0.586 ng/g parathion-methyl, 2.65 ng/g chlorpyrifos, and 0.09 ng/g merfos, wet weight basis.

Chowdhury et al. (2012) studied the presence of different pesticides in vegetables collected from several regions of Bangladesh and found 0.008-0.040 mg/kg malathion, 0.005-0.700 mg/kg diazinon, 0.005-0.050 mg/kg carbofuran in eggplant, 0.040-0.700 mg/kg chlorpyrifos, 0.010-0.060 mg/kg malathion, 0.004-0.050 mg/kg carbofuran in tomato, 0.062-0.080 mg/kg chlorpyrifos, 0.020-0.100 mg/kg carbaryl in cauliflower, 0.020-0.100 mg/kg carbaryl in cabbage, 0.013-0.240 mg/kg diazinon, 0.012-0.300 mg/kg carbaryl, 0.031-0.140 mg/kg dimethoate in potato.

Chowdhury et al. (2014) found organophosphate and organo-carbamate residues were detected in 50% of the 16 eggplant samples collected from four different markets of Dhaka, Bangladesh, and approximately 19% of the total samples exceeded the MRL level provided by WHO or FAO. In Bangladesh, 0.420 mg/kg chlorpyrifos in brinjal, 0.406 mg/kg chlorpyrifos and 0.143 mg/kg quinalphos in cabbage, 0.443 mg/kg chlorpyrifos in tomato, 0.302 mg/kg chlorpyrifos in pointed gourd, 0.160 mg/kg quinalphos and 0.090 mg/kg chlorpyrifos in okra were reported also (Ahmed et al., 2016a). Brinjal, Lady's finger, tomato, red amaranth, cucumber, yard long bean, country bean, cabbage and pointed gourd are vital source of nutrient and are highly valuable for fitness in Bangladesh. It is necessary to control the insect pests and diseases through bio-rational based pest management. However, the farmers are using chemical pesticides as it is the most convenient, economic and easy way to control the insect pests and diseases and to increase the production. This leads to the contamination of food with different chemical pesticide

residues which have been reported by several researchers in Bangladesh (Prodhan et. al., 2021a,b; Ahmed et al., 2019; Hasan et al., 2017; Aktar et. al., 2017; Ahmed et al., 2016 a,b,c; Prodhan et al., 2010; Prodhan et al., 2009).

Pesticides belonging to the group of synthetic pyrethroids are widely used in Bangladesh. Four commonly used synthetic pyrethroids pesticides (cypermethrin, deltamethrin, lambda-cyhalothrin and fenvalerate) were selected for this study. Previous analysis has been conducted for the quantification of pesticide residues in different vegetables in Bangladesh (Nahar et al., 2020; Ahmed et al., 2019; Islam et al., 2019a,b,c; Prodhan et al., 2018a,b; Hasan et al., 2017; Aktar et. al., 2017; Ahmed et al., 2016a,b, c; Islam et. al., 2014; Hossain et al., 2014; Kabir et al., 2008).



### 3. METHODOLOGY

#### 3.1 Preparation of a Total Dietary Study (TDS) food list

The commonly consumed foods and representing 85% of the total weight of the food intake as reported in the Household Income Expenditure Survey (HIES, 2016) were selected to form the key food list (Islam et al, 2013). In addition, traditional foods that contribute to dietary diversity (Greenfield and Southgate, 2003) and foods that are potentially contaminated by heavy metal exposure were also taken into account in the food list. Foods were purchased in the raw and uncooked form. Food samples were collected from three markets representing an upazila of a division and the samples from three shops of each market were pooled to form a composite sample. The sampling divisions and corresponding upazilas are given below:

Division	Upazila
Mymensingh	Sadar, Trisal, Muktagacha
Rajshahi	Sadar, Puthia, Poba
Khulna	Jashoresadar, Chowgacha, Sarsha
Chattogram	Sadar, Shitakudo, Hathazari



**Fig. 3.1** Map showing the sampling divisions of Bangladesh

The list below includes the 15 different food items under study and the number of samples for analysis from each of Mymensingh, Rajshahi, Khulna and Chattogram divisions (Table 3.1). For determining organic contaminants 22 food samples of five food groups from different markets and hubs were brought under analysis (Table 3.2).

**Table 3.1** List of food samples for analysis of trace elements, vitamins and heavy metals (numbers in parentheses indicates foods in the food group)

Food groups	Food items	English name	Scientific name
1. Cereals (4)	Chaal	Rice	<i>Oryza sativa</i>
	Ata	Wheat flour	<i>Triticumaestivum</i>
	Muri	Puffed rice	<i>Oryza sativa</i>
	Chira	Rice flakes	<i>Oryza sativa</i>
2. Pulses (2)	Masur	Lentil	<i>Lens culinaris</i>
	Mung	Mungbean	<i>Vignaradiata</i>
3. Fish (6)	Ilish	Hilsa	<i>Tenualosailisha</i>
	Golda chingri	Prawn	<i>Farfantepena eusaztecus</i>
	Rohu	Indian major carp	<i>Labeorohita</i>
	Silver carp	Silver carp	<i>Hypophthalm ichthysmolitrix</i>
	Pangas	Irridefpren shark	<i>Pangasius pangasius</i>
	Tilapia	Tilapia	<i>Oreochromis niloticus</i>
4. Eggs (2)	Murgir deem	Chicken egg	<i>Gallus gallus domesticus</i>
	Hasher deem	Duck egg	<i>Anasplaty rhynchos</i>
5. Meat (3)	Gorurgosth	Beef	<i>Bostauras</i>
	Khasirgosth	Mutton	<i>Capra aegagrus</i>
	Murgirgosth	Farm chicken	<i>Gallus gallusdomesticus</i>
6. Vegetables (11)	Alu	Potato	<i>Solanum tuberosum</i>
	Begun	Brinjal	<i>Solanum melongena</i>
	Kacha papaya	Green papaya	<i>Carica papaya</i>
	Patal	Pointed gourd	<i>Trichosanthes dioica</i>
	Misthikumra	Pumpkin	<i>Cucurbita maxima</i>
	Lau	Water gourd	<i>Lagenariasiceraria</i>
	Okra	Lady's finger	<i>Abelmoschus esculentus</i>
	Tomato	Tomato	<i>Lycopersicon esculentum</i>
	Lalsak	Red amaranth	<i>Amaranthus cruentus</i>
	Phul kopi	Cauliflower	<i>Brassica oleracea varbotrytis</i>
	Badha kopi	Cabbage	<i>Brassica oleracea varcapitata</i>
7. Milk and dairy (2)	Liquid milk	Cattle milk	
	Powder milk	Cattle milk powder	
8. Sweetmeat (2)	Rasogolla	Rasogolla	-
	Jilapi	Jilapi	-
9. Oils (2)	Sarishatel	Mustard oil	<i>Brassica juncea</i>
	Soybean tel	Soybean oil	<i>Glycine max</i>
10. Fruits (7)	Paka Kala	Ripe banana	<i>Musa sapientum</i>
	Aam	Mango	<i>Mangifera indica</i>

Food groups	Food items	English name	Scientific name
	Kanthal	Jackfruit	<i>Artocarpus heterophyllus</i>
	Peyara	Guava	<i>Psidium guajava</i>
	Anaras	Pineapple	<i>Ananas comosus</i>
	Apple	Apple	<i>Malus pumila</i>
	Papay	Papaya	<i>Carica papaya</i>
11. Drinks (5)	Chaa/Coffee	Tea/Coffee	<i>Camellia sinensis/ Coffea arabica</i>
	Orange rosh	Orange juice	<i>Citrus aurantium</i>
	Aamerrosh	Mango juice	<i>Mangifera indica</i>
	Pepsi	Pepsi	-
	Drinking water	Drinking water	-
12. Sugar and Molasses (2)	Sugar	Cane sugar	<i>Saccharum officinarum</i>
	Gur	Cane molasses	<i>Saccharum officinarum</i>
13. Processed foods (3)	Pickles	Mango pickle	-
	Jam	Orange jam	-
	Jelly	Orange jelly	-
14. Spices (5)	Suknamarich	Dried chilli	<i>Capsicum annum</i>
	Halud	Turmeric	<i>Curcuma longa</i>
	Peyanj	Onion	<i>Allium cepa</i>
	Ada	Ginger	<i>Zingiber officinale</i>
	Dhoneya	Coriander Seed	<i>Coriandrum sativum</i>
15. Bakery (4)	Biscuits	-	
	Bon ruti	Wheat ruti	
	Cake	-	
	Chips	Potato chips	

**Table 3.2** List of food samples for analysis of organic contaminants (aflatoxin, food colour, food preservatives and pesticide residues) (numbers in parentheses indicates foods in the food group)

<b>Food groups</b>	<b>Food items</b>	<b>English name</b>	<b>Name of contaminant</b>
1. Cereals and pulses (4)	Chal	Rice	Aflatoxin
	Ata	Wheat flour	Aflatoxin
	Masur dal	Lentil	Aflatoxin
	Mung dal	Mungbean	Aflatoxin
2. Fruit juice (2)	Orange rosh	Orange juice	Preservatives & colouring agents
	Aamerrosh	Mango juice	Preservatives & colouring agents
3. Vegetables (10)	Begun	Brinjal	Pesticide residue
	Patal	Pointed gourd	Pesticide residue
	Okra	Lady's finger	Pesticide residue
	Tomato	Tomato	Pesticide residue
	Lalshak	Red amaranth	Pesticide residue
	Shosha	Cucumber	Pesticide residue
	Borboti	Yard long bean	Pesticide residue
	Bean	Country bean	Pesticide residue
	Phul kopi	Cauliflower	Pesticide residue
	Badha kopi	Cabbage	Pesticide residue
4. Processed foods (3)	Aachar	Mango pickles	Preservatives & colouring agents
	Jam	Orange jam	Preservatives & colouring agents
	Jelly	Orange jelly	Preservatives & colouring agents
5. Bakery (2)	Biscuits	Biscuits	Preservatives & colouring agents
	Cake	Cake	Preservatives & colouring agents
	Chips	Chips	Preservatives & colouring agents

### 3.2 Analysis of trace elements and heavy metals

Food samples as listed in Table 3.1 were analyzed for trace elements (Fe, Zn, Cu & Se) and heavy metals (As, Cd, Pb & Cr). Food samples were collected in the raw/uncooked form. Each of the food samples were collected from three different shops from three different markets from each of the four divisions. The GPS locations of the sampling points were noted. Proper labeling was done for each of the collected food items. Vegetables and fruits were collected tender and fresh. The collected samples were kept in a new High Density Polyethylene bags (Poly bags). Water was sprayed on the vegetable samples during packing in poly bags to keep the samples moist during transportation from the market to the laboratory. The meat and fish samples were kept in the icebox to avoid decay and prevent nutrient losses as much as possible, during transportation.

### 3.3 Processing and cooking of food samples

Standard operating procedures were followed for the processing of food samples. Hand gloves were used to process the samples to avoid any contamination. The inedible parts of the food samples were discarded and the ratio of edible and inedible parts was calculated. Fresh food samples were cooked with known amount of tap water collected from the respective locations that are locally used for cooking. The following procedures were followed for processing and/cooking the different food items.

**Cereals:** Rice was cooked by standard procedure practiced in Bangladesh, by the absorption method (rice to water ratio 1:3) without draining out excess water. Wheat flour (Atta) was made into dough with the required quantity of water. The dough was then rolled into roti and cooked on hot a plate. Both boiled rice and roti were then dried in the oven.

**Pulses:** Two hundred and fifty grams of each of the pulses in Table 3.1 were boiled with known amount of water and then heated to dryness.

**Fish:** The fresh weight of all fish samples collected from the market was recorded. The scales, fins and viscera of fish were removed and the weight of the cleaned fish was recorded again. The fishes were cut into pieces. A sub-sample weighing 250g was boiled with known amount of water. The weight of the cooked fish was recorded. The bones from the boiled fishes were removed and its weight was noted.

**Eggs:** Five of each egg varieties, notably chicken eggs and duck eggs were collected from three different shops of each market. Eggs were hard-boiled and crushed together to make composite samples for both types of egg. The composite samples were then dried in the oven.

**Meats:** Meat samples (beef and mutton) were collected from all different body parts and from three different butcher shops of each market. The meat samples from all shops were mixed together. A sub-sample weighing one kilogram was boiled with water until they became soft. The weight of the boiled meat was recorded. The bones from the meat were removed and its weight was taken. In case of farm chicken, three live birds were purchased, slaughtered, dressed and cut into pieces. A sub-sample of one kilogram was boiled and the weight of the boiled meat was noted. The bones of all the meat samples, beef, mutton and chicken were removed and the weight of the boneless meat was noted. One hundred gram of boneless meat was placed in the oven at 65<sup>0</sup>C to obtain the dry weight.

**Vegetables:** Weight of a whole amount of a specific vegetable was taken. The vegetable was washed, peeled and cut into pieces with a stainless steel knife. Edible coefficient of the vegetables was calculated by taking weight before and after peeling. A sub-sample of 250g vegetable was boiled with water collected from the respective locality. The weight of the boiled vegetables was recorded to calculate the yield factor.

**Milk:** Liquid milk was boiled. Powder milk was reconstituted with water (in the ratio of milk powder to milk as 1:4) from the respective markets and boiled for 10 minutes. Both milk samples were then heated to dry.

**Sweetmeats:** Weight of the collected samples of roshogolla and jilapi was recorded. The sub-samples (100g) of each of the two types of samples were put in the oven to get dry weight.

**Fruits:** Fresh weight of all the fruit samples was recorded. The fruits were peeled and sliced. The weight of the sliced fruit was noted. A sub-sample of 250g was dried in the oven and the weight loss was calculated.

**Molasses:** Weight of collected molasses sample was recorded. A sub-sample was placed in the oven to get dry weight.

**Drinks:** The drink items in Table 3.1 were heated to dryness.

**Processed foods:** Processed foods like pickles, jam and jelly were dried in the oven to get dry weight.

**Spices:** Weight of individual spices samples was recorded. A sub-sample was placed in the oven to get dry weight.

### **3.4 Drying and storage of samples**

An amount of 50 g each of the prepared samples as described above was placed on a clean Petri dish in an oven at 65°C until a constant weight was obtained. The oven dried samples of different food items were ground to powder in a ball mill. The homogenized mixture of each food sample amounting to 20g was kept in polyethene zipper bags labeled with a specific code number. The samples were stored in desiccators.

### **3.5 Procedure for chemical analysis**

An amount of 200 mg of each powdered sample was weighed out using Shimadzu digital weighing scales into labelled 100 mL quartz digestion tubes and 3mL of Trace element grade 69% nitric acid (or similar) was added to each tube. The same volume of nitric acid was added to 1 tube designated as blank and 1 tube designated for certified reference materials (CRM) for each batch of digestion. Tubes were shaken briefly and left overnight to soak. Following this period, 2 mL of 30% hydrogen peroxide was added to each tube via pipette. Tubes were then left open for 15 minutes to allow the gases out. Tubes were then placed into the digestion block (VELP digestion system) and the temperature was gradually raised to 120 °C through a 2-stage process. If brown fumes were generated, indicating incomplete oxidation of the sample by HNO<sub>3</sub>; then heating was continued until no brown fumes were given off by the sample indicating the complete reaction with HNO<sub>3</sub>. After cooling, the digest was transferred into a 50 mL falcon tube and the final weight (50 g) was made using deionized water. Eight standards in a range of 0-50 ppb were made up including one blank. The standard tubes were then made up to final weight (50g) with 1% HNO<sub>3</sub> aq. 10 mL from the final digest was poured into 15mL polypropylene tubes placed into the auto-sampler in predetermined random run order. Analysis of the samples was carried out using ICP-MS (Shimadzu 2300 ICP-MS) which was connected with auto-sampler. The ICP-MS operating conditions were Forward RF power- 1550W; Nebuliser sample flow rate- 0.35mL/min. Helium was used as collision gas at a flow rate of 5 mL/min. Samples were analysed by comparison to the standards previously mentioned.

### **3.6 Analysis of vitamins**

#### **Sample preparation**

Upon arrival, the fresh and healthy vegetables were immediately washed under tap water and excessive water was dripped off. Edible portions (100 g) of the vegetables were cut into small pieces and homogenised using a blender for 2 min. The homogenised sample were transferred into an air-tight container and kept at -20°C before vitamin analysis. All procedures were carried out carefully without much exposure to light.

After washing with tap water and draining, the fruits were sliced into 10 mm thick transverse slices using a fruit slicer. Subsequently, they were dried under direct sunlight in the dry season with an overall maximum day time air temperature of approximately at 37°C and a minimum

night temperature of approximately 20°C. The samples were weighed at various intervals over the entire drying period until obtaining a constant weight. The dried slices were milled into a coarse powder by using a laboratory mill (D-6072, Germany) and stored in polyethylene bags at room temperature.

### **Determination of $\beta$ carotene**

Frozen samples were thawed overnight in a refrigerator at 4°C. Non-edible portions of fruits and vegetables were removed, and remaining portions were sliced. The components so obtained were then ground separately into a spice grinder until become fine paste. For extraction, a representative portion of this sample (1 g) was accurately weighed in a glass test tube. Then 5 ml of chilled acetone was added to it, and the tube was held for 15 min with occasional shaking at 4°C, vortexed at high speed for 10 min, and finally centrifuged at 1370 x g for 10 min. Supernatant was collected in to a separate test tube, and the compound was re-extracted with 5 ml of an acetone followed by centrifugation once again as above. Both of the supernatants were pooled together and then passed through the Whatman filter paper No. 42. The absorbance of the extract was determined at 449 nm wavelength in a uv-vis spectrophotometer (Biswas et al. 2011).

### **Determination of vitamin C**

Vitamin C from fruit and vegetable samples was determined by dichlorophenol Indophenol dye reduction method (Khattak and Rahman, 2017). About 0.5 g of the sample was weighed and macerated with 12 ml of 0.4% oxalic acid in a test tube for 30 minutes. Afterward it was centrifuged for 5 minutes and the solution was filtered using filter paper. One ml of the filtrate was transferred into a dry test tube and 9 ml of 2,6-dichlorophenol indophenol solution was added to it. The absorbance was taken at 15- and 30-seconds interval at 520 nm.

### **Determination of Riboflavin (B2)**

Riboflavin was assessed by taking 5 g dried and powdered vegetable samples, mixed with 120 ml of ethanol and was kept for 2 hours. The extract then was filtered and 10 ml of this was mixed with 10 ml of 5% potassium permanganate and 10 ml of 30% hydrogen peroxide solutions. This mixture was allowed to stand on hot water bath for 30 minutes. After that, 2 ml of 40% sodium



sulphate was added and the volume was made up to 50 ml. The absorbance of the solution was recorded at 510nm.

### **3.7 Analysis of food colours and preservatives**

Fruit juices (mango and orange) and jam/jelly that available at the local market under the popular brand were analyzed to detect the commonly used preservatives and synthetic colors. The preservatives generally used in these products were Na-benzoate and sulphur dioxide. Both are permitted according to the Additive Regulation of Bangladesh Food Safety Authority (BFSA) at a certain limit depending on the types of products.

#### **Analysis of Na-benzoate**

Na-benzoate, an ether extractable organic preservative widely used in fruit and vegetable products, was determined in the collected samples adopting the method of AOAC, USA. The benzoic acid present in the sample is converted into water-soluble sodium benzoate by the addition of NaOH, acidified with excess HCl to form insoluble benzoic acid and then is extracted with chloroform. The chloroform is removed by evaporation and the residue containing benzoic acid is dissolved in alcohol and then titrated with standard NaOH.

The sample preparation technique was slightly modified to fit it with our collected samples. In the case of jam/jelly and sauce/pickle, 100g of sample was mixed in 300ml of saturated NaCl solution. A 15g of NaCl was added in excess and checked its alkalinity with a litmus paper, then transferred to a 500ml volumetric flask and diluted to mark with a saturated salt solution. The solution was allowed to stand for at least 2 hr shaking frequently and then filtered. The filtrate was used to determine the sodium benzoate.

For the case of preparing mango and orange juice samples, the primary samples were sonicated and then filtered through 0.45 $\mu$ m membrane filters.

The sodium benzoate content in the filtrate was finally determined as per the procedure described in the method. The final content of sodium benzoate was expressed as mg per 1000g of samples taken for the analysis.

### **Analysis of Sulphur Dioxide**

Ripper Titration Method was used to estimate total SO<sub>2</sub> in the fruit-based food products. In the case of sample preparation, a similar procedure used for the sodium benzoate was used for the total SO<sub>2</sub> estimation.

In case of estimation, about 700 mL of distilled was taken in a round-bottomed flask and allowed to boil. A 25 g of the material was taken into the Kjeldahl flask and connected to the apparatus. A 200 mL of HCl was added through the funnel. It was allowed the CO<sub>2</sub> to bubble through. The distillate was allowed to pass the condenser and collect in a vessel containing 0.1N iodine solution. Generally, all the SO<sub>2</sub> was evolved within 5 min. Distillation was continued for another 5 min and the excess iodine was titrated with 0.1N sodium thiosulphate. Blank determination was done with none of the food material in the flask. Then the content was calculated.

### **Analysis of synthetic food colours**

Tartrazine (102) and Brilliant blue (133) and sunset yellow are commonly used food permitted synthetic colours used in fruit drinks. The method as reported by Dilrukshi et al. (2019) was used for determining them.

In the case of fruit drinks, liquid samples were directly used for color extraction. In the case of solid and semi-solid samples, 5.0 g of ground sample was weighed and oil was removed using petroleum ether. Then, 10 mL of 2% ammonia in 70% alcohol was added to the oil-removed sample, and the mixture was warmed in a water bath for 2-3 minutes for starch to settle down. The resulting coloured liquid was centrifuged at 30,000 rpm for 15 minutes. The separated liquid evaporated on the water bath. Extraction of colour from the treated sample is a critical part. This part has been carried out following the method of Farzianpour et al. (2013) and William (2005). In brief, each pre-treated sample was acidified by 2 mL of 2M glacial acetic acid, an equal amount of distilled water and 5 cm length conditioned pure sheep wool thread. This was kept in a water bath for 1 hour for the colour to be adsorbed onto the wool. The wool thread was then removed from the solution and washed with running tap water. It was resoaked in 2 mL of 2M ammonia solution with an equal amount of distilled water and kept in a water bath until the wool thread decolourized. The wool thread was removed, and the solution was concentrated by evaporation in a water bath.

Extracted colours were identified by thin-layer chromatography (Zahra *et al.*, 2015). Extracted colour samples and colour standards were dissolved in a few drops of distilled water with one drop of ethanol. Mobile phases were prepared using distilled water: butanol: glacial acetic acid (6:10: 5) and propanol: ammonia (4: 1) for colour identification.  $R_f$  value calculated (Eq. 1) after TLC was used to identify the colour compounds.

$$R_f = \frac{\text{distance of the color spot travelled from the baseline}}{\text{distance of the solvent travelled from the baseline}}$$

Finally, quantification of the identified colour compounds was carried out using the spectrophotometric method as reported by Rao *et al.* (2005).

### **3.8 Analysis of Mycotoxin**

Total aflatoxin in the collected samples was determined by using Total Aflatoxin Elisa Kit (Sigma-Aldrich) according to the method described by Leszczynska *et al.*, (2018). For the sample preparation, a finely ground, representative, laboratory sample weighing 50 - 200g was prepared. 5g sample was taken and blended to a powdered form. The powder was mixed with 70% methanol. Mixed well by using a vibrator for 1-1.5 min. and filtered and collected the filtrate as a sample.

To analyze total aflatoxin using Total Aflatoxin Elisa Kit, 100  $\mu$ l extract was taken in a dilution well and 100  $\mu$ l conjugate was added to the well. The mixer was taken in a micro-well and kept in an incubator for 15 min. After the incubation period, the well was washed 5 times thoroughly with distilled water. A 120  $\mu$ l substrate was added to the microwell and 100  $\mu$ l stop solution was added. The reading was taken from the Elisa analyzer.

### **3.9 Analysis of pesticide residues**

#### **Sample extraction and clean up**

For pesticide residue analysis in selected vegetables and fruits, collected samples were carried in iceboxes to the laboratory from the selected locations. Sample clean up and preparation was carried out using the AOAC Official Method 2007.01 (AOAC, 2007) and QuEChERS kit with modifications (Prodhan *et al.*, 2015). A representative 10 g portion of the thoroughly homogenized sample was weighed in a 50 mL polypropylene centrifuge tube. Then 10 mL of acetonitrile (MeCN) was added into the centrifuge tube and was shaken vigorously for 30

seconds using a vortex mixer. Then, 4 g of anhydrous  $\text{MgSO}_4$  and 1 g of NaCl was added into the centrifuge tube and shaken immediately by the vortex mixer for 1 minute to prevent the formation of magnesium sulfate aggregates. Afterwards, the extract was centrifuged for 5 min at 5000 rpm. An aliquot of 3 mL of the acetonitrile layer was transferred into a 15 mL microcentrifuge tube containing 600 mg anhydrous  $\text{MgSO}_4$  and 120 mg primary secondary amine (PSA). Then it was thoroughly mixed by vortex for 30 seconds and centrifuged for 5 minutes at 4000 rpm. After centrifuge, a 1 mL supernatant was filtered by a 0.2  $\mu\text{m}$  PTFE filter to a clean HPLC vial for injection.

### **Detection and quantification of pesticide residue in samples**

The concentrated extracts were subjected to analysis by GC-2010 (Shimadzu) with flame thermionic detector (FTD) for the detection for selected pesticides (acephate, dimethoate, diazinon, fenitrothion, malathion, chlorpyrifos and quinalphos).

### **3.10 Estimating dietary exposures**

Food consumption data for the households was collected from the food consumption data sets as outlined in the HIES (2016). Stratified sampling was followed to select 100 households from each of the four administrative divisions (representing the geographical locations of Bangladesh).

Dietary risk exposure to a specific contaminant is dependent on the quantity of food consumed, which varies with age. A dietary exposure assessment is the process of estimating how much of a food chemical a population, or population subgroup, consumes. This assessment considers the potential exposure of the population to chemicals like food additives, pesticide residues, chemical contaminants, nutrients, food ingredients and other substances that have a nutrition or health implication. Dietary exposure to (or intake of) food chemicals is estimated by combining food consumption data with food chemical concentration data. On the other had, ‘dietary intake assessment’ is used to refer to nutrients and other substances that have a nutrition or health purpose.

To this end, the estimated dietary exposure to a contaminant or potentially harmful substance or a nutrient with a known health-based guidance value, for example, an acceptable daily intake (ADI) for the substance, is the amount of that substance that can be consumed daily without

adverse health effects. Comparing estimated dietary exposures to these values is done to work out the level of risk to the population (<https://www.foodstandards.gov.au/science/exposure>).

The dietary intake of contaminants was calculated as per capita food intake in Mymensingh, Rajshahi, Khulna and Chattogram divisions based on consumption data from the HIES, 2016 survey. Daily intake of heavy metals and trace elements from different food items was determined using the total weight of food consumed each day multiplied by the concentrations of heavy metals and trace elements in that food.

### **Comparison to the reference health standards**

The intakes of trace elements were calculated and compared with the RDA which reflects the average daily level of intake sufficient to meet the nutrient requirements of nearly all (97%-98%) healthy people. For trace elements, the recommended daily intakes (RDI) of trace elements for adult male are presented in Table 3.3.

**Table 3.3** RDA<sup>2</sup> of trace elements and vitamins for adult male

Trace elements	Recommended Daily Intake (RDI) (per day)
Iron	19 mg
Zinc	17 mg
Copper	2.0 mg
Selenium	40 µg
Vitamin C	80 mg
β-carotene	6 mg
Riboflavin	2.5 mg

### **Food contribution calculation**

The percentage contribution of each food group to the total estimated nutrient intake was calculated by dividing the sum of the individual's intake from one food group by the sum of all individuals' intakes from all foods containing the elements assessed, and multiplying this by 100.

### **Exposure assessment of heavy metals from food exposure**

The estimated cancer risks due to exposure to a specified dose of heavy metal through food intake were computed using the Incremental life cancer risk<sup>3</sup> (ILCR) threshold ( Means, 1989). The ILCR is defined as the incremental probability of a person developing any type of cancer over a lifetime as a result of twenty-four hours per day exposure to a given daily amount of a carcinogenic element for the whole life.

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<sup>2</sup> Adapted from Revised RDA for Indians, 2020, National Institute of Nutrition (NIN), Indian Council of Medical Research (ICMR)

<sup>3</sup> Estimate of potential Incremental Lifetime Cancer Risk (ILCR) associated with that exposure.

The following equation was used for the calculation of the lifetime cancer risk (Means, 1989)

$$AvDI = \frac{DI}{BW} \times \frac{EF \times ED}{AT}$$

Where

AvDI is the average daily intake of a heavy metal (µg/day),

DI is the daily intake of a heavy metal (µg/day),

BW is body weight (kg),

EF is the exposure frequency (days/year),

ED is the exposure duration (year) and

AT is the averaging time (day).

$$ILCR = AvDI \times CSF$$

Where, SF is the slope factor of As (µg/kg/d).

The ILCR determinate factors are presented in Table 3.4

**Table 3.4** Variables used in the calculation of cancer risk determination

Variables	Parameter characteristics
Exposure duration (ED)-year	Constant=70
Exposure frequency (EF)-day	Constant=365
Ingestion of toxicants in mg/day	From the intake data of this project
Life expectancy (LE)in days	Constant=25,550
Body weight (BW) in kg	Male=65, Female=55, Boy=34.9, Girl=36.4 (NIN/ICMR, 2020)
Cancer slope factor <sup>4</sup> (CSF) mg/kg/day	As=1.50 (IRIS, 2013) Cd=15.0 (USEPA 2011) Cr=0.50 (USDOE 2011) Pb=0.0085 (USEPA 2011)

<sup>4</sup> pathway-specific slope factors or unit risks that exist

## 4. RESULTS AND DISCUSSION

This study was done to know the concentration of trace elements, vitamins, heavy metals, colours, preservatives, aflatoxins and pesticide residues in foods, to estimate their daily intake and to perform dietary exposure analysis of each chemical. Seven hundred and eight ( $59 \times 3 \times 4$ ) food samples representing 15 different food groups were collected from Mymensingh, Rajshahi, Khulna and Chattogram divisions. The food samples, where applicable, were processed and cooked/boiled in water collected from the respective area, with no salt addition. The edible coefficient and dry weight of the food samples were recorded. All food samples were digested with ultrapure nitric acid and hydrogen peroxide for determination of trace elements and heavy metals, and analysis was done by ICP-MS. The daily intake of trace elements, heavy metals and others by the people over four divisions was calculated from the food consumption data, as recorded in HIES (2016).

### 4.1 Edible coefficient and yield factor of foods

A total of 31 food items from 10 food groups were cooked and their edible coefficient and/yield factor were determined. The edible coefficient of fresh fishes varied from 0.39 in Prawn to 0.88 in Hilsa (Table 4.1). This variation was due to removal of scales, fins and viscera from the fishes. The yield factor of the fresh fishes was in a range of 0.59 (Tilapia) - 0.65 (Silver carp, Hilsa) and the dry matter (DM %) was 26.4 (Rohu) - 39.9 (Hilsa). The yield factors for cereals and pulses increased due to absorption of water during cooking showing a range of 1.97 (rice flakes) - 2.29 (rice) and 1.75 (mung) - 2.12 (lentil). The edible coefficient of the different vegetables varied widely, it ranged from 0.41 in cauliflower to 0.96 in tomato, the yield factors varied from 0.46 (tomato) to 0.91 (potato) and the DM % from 7.00 (pointed gourd) to 13.2 (pumpkin). Next to potato, the higher yield factors were noted with okra (0.89) followed by cauliflower (0.88), green papaya and pointed gourd (both 0.79) and pumpkin (0.74). For the case of fruits, the edible coefficient values ranged between 0.36 (jackfruit) - 0.94 (guava) and the DM% between 9.4 (guava) - 26.7 (banana).



**Table 4.1** Edible coefficient, yield factor and dry weight of different food items

Food group	Food items	Edible Coefficient	Yield Factor	Dry weight (%)
1. Cereals (3)	Rice	-	2.29 ± 0.03	91.42±0.66
	Wheat flour	-	1.71±0.09	77.25±0.95
	Rice flakes	-	1.97±0.01	89.83±0.38
2. Pulses (2)	Lentil	-	2.12±0.04	85.41±0.95
	Mung	-	1.75±0.07	86.66±2.49
3. Vegetables (11)	Potato	0.88±0.02	0.91±0.02	18.49±0.68
	Brinjal	0.95±0.01	0.66±0.05	7.15±0.56
	Green papaya	0.75±0.02	0.79±0.03	5.69±0.61
	Pointed gourd	0.74±0.02	0.79±0.03	7.00±0.59
	Pumpkin	0.75±0.02	0.74±0.04	13.18±1.63
	Bottle gourd	0.80±0.02	0.56±0.01	7.11±1.21
	Okra	0.82±0.03	0.89±0.03	7.05±0.46
	Tomato	0.96±0.01	0.46±0.03	8.98±0.37
	Red Amaranth	0.64±0.03	0.63±0.03	10.97±0.58
	Cauliflower	0.41±0.02	0.88±0.02	9.01±0.49
	Cabbage	0.79±0.01	0.65±0.02	8.38±0.49
4. Fish (6)	Hilsa	0.88±0.01	0.65±0.01	39.94±0.55
	Prawn	0.39±0.03	0.61±0.01	30.83±2.30
	Rohu	0.73±0.02	0.63±0.01	26.43±0.55
	Silver carp	0.81±0.02	0.65±0.02	28.09±1.10
	Pangas	0.82±0.02	0.63±0.01	31.21±0.94
	Tilapia	0.78±0.01	0.59±0.02	26.37±0.89
5. Meats (3)	Beef	0.48±0.02	0.47±0.02	44.94±2.21
	Mutton	0.44±0.04	0.44±0.03	37.17±2.13
	Chicken	0.67±0.02	0.54±0.02	38.39±1.46
6. Eggs (2)	Chicken	0.86±0.02	1.01±0.02	23.83±2.4
	Duck	0.84±0.03	1.01±0.02	28.06±2.17
7. Fruits (7)	Banana	0.75±0.01	-	26.68±1.67
	Mango	0.63±0.02	-	15.99±1.29
	Jackfruit	0.36±0.03	-	18.11±0.86
	Guava	0.94±0.01	-	9.94±0.38
	Pineapple	0.59±0.02	-	14.89±1.75
	Apple	0.92±0.01	-	16.23±1.67
	Papaya	0.68±0.01	-	12.78±0.48
8. Sweetmeat (2)	Rosogolla	-	-	67.71±8.53
	Jilapi	-	-	78.83±2.46
9. Sugar and Molasses (2)	Gur (Cane molasses)	-	-	87±2.36
10. Spices (2)	Onion	0.88±0.1	-	19.75±1.57
	Ginger	0.77±0.14	-	8.88±0.39
11. Bakery (2)	Chips	-	-	65.67±0.37
	Biscuits	-	-	96.08±0.96

## **4.2 Trace elements**

### **4.2.1 Concentration of trace elements**

The concentration of trace elements (Zn, Fe, Cu and Se) greatly varied between food groups, between items within a food group and between locations of food items collection. Indeed, the concentration of these elements and their consumption through each of the food items have significant value considering the health implications.

#### **Zinc concentration**

Pulses, among the food groups, showed the highest zinc (Zn) concentration (36.6 mg/kg) and the next highest value (19.3 mg/kg) was noted for meats (Table 4.2). The Zn levels for the other food groups were sequentially 18.1 mg/kg (spices), 14.2 mg/kg (cereals), 13.6 mg/kg (egg), 12.8 mg/kg (milk and dairy), 11.4 mg/kg (sweetmeats), 8.16 mg/kg (biscuits, chips), 6.88 mg/kg (fish), 2.81 mg/kg (vegetables) and 2.29 mg/kg (fruits). Oils and soft drinks had very low level of Zn, the values being 0.78 and 0.11 mg/kg, respectively.

When the food items in a group are considered, rice and wheat flour (17.4-17.9 mg/kg) from the cereal group, mungbean (40.9 mg/kg) from the pulse group, prawn (10.0 mg/kg) from fish group, beef and mutton (23.4-26.5 mg/kg) from meat group, potato (7.15 mg/kg) from vegetables (roots and tubers) group, powder milk (21.4 mg/kg), pineapple (4.17 mg/kg) from fruit group, pickles (5.24 mg/kg) from processed food group and coriander (39.0 mg/kg) from spice group demonstrated the highest Zn concentration (Table 4.2). In particular, coriander and mungbean had the highest content of Zn.

Considering location variation, the Zn concentration of cereals differed from 13.7-14.8 mg/kg, pulses from 31.4-39.2 mg/kg, fishes from 6.59-7.19 mg/kg, eggs from 11.1-15.3 mg/kg, meats from 17.1-23.6 mg/kg, vegetables from 2.33-3.11 mg/kg, fruits from 2.22-2.84 mg/kg and spices from 14.9-19.5 mg/kg (Table 4.2). Food samples from Khulna and Chattogram had the highest Zn concentration. Among the four sampling locations, Rajshahi samples showed the lowest Zn values.

The earlier study by Islam et al (2013) showed that the Zn concentration of food samples from three markets of Dhaka city (Hazaribagh, Kawran bazar and Gulshan) ranged from 13.7-17.2 mg/kg for rice, 19.4-25.6 mg/kg for wheat flour, 1.87-27.7 mg/kg for fishes, 1.58-35.2 mg/kg for

vegetables, 2.26-29.6 mg/kg for fruits and 3.45-483 mg/kg for spices. It was noted that coriander leaves and coriander seeds recorded the highest Zn value.

**Table 4.2** Concentration of Zn (mg/kg fresh weight) in different food items from four divisions (results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	19.32±0.24	15.78±0.80	14.89±0.47	19.57±0.40	<b>17.39</b>
	Wheat flour	19.83±0.65	17.61±2.06	17.57±2.63	16.69±4.70	<b>17.93</b>
	Bon ruti	3.15±1.01	5.58±1.33	7.62±1.71	3.81±0.52	<b>5.04</b>
	Puffed rice	13.58±2.36	13.10±0.78	13.69±1.29	16.51±5.30	<b>14.22</b>
	Rice flakes	12.82±4.03	19.70±5.10	20.17±3.78	17.10±4.02	<b>16.31</b>
	<b>Average</b>	<b>13.74</b>	<b>14.35</b>	<b>14.79</b>	<b>14.33</b>	<b>14.18</b>
Pulses	Lentil	29.37±1.84	31.44±0.85	30.76±0.77	37.79±0.71	<b>32.34</b>
	Mung	33.40±0.76	44.45±0.50	47.57±0.95	38.23±1.09	<b>40.91</b>
	<b>Average</b>	<b>31.39</b>	<b>37.95</b>	<b>39.17</b>	<b>38.01</b>	<b>36.63</b>
Fish	Hilsa	4.72±1.96	6.75±0.54	6.44±2.70	7.63±0.95	<b>6.39</b>
	Giant prawn	10.37±0.82	9.37±1.22	11.48±1.53	8.83±1.89	<b>10.01</b>
	Rohu	8.75±1.98	9.07±0.95	7.22±0.27	9.38±1.96	<b>8.61</b>
	Silver carp	5.03±0.57	4.91±1.06	4.70±1.14	6.19±0.99	<b>5.21</b>
	Pungus	4.78±1.34	4.58±0.65	4.33±2.44	5.15±1.20	<b>4.71</b>
	Tilapia	5.91±0.56	5.86±0.73	7.66±2.67	5.93±2.52	<b>6.34</b>
	<b>Average</b>	<b>6.59</b>	<b>6.76</b>	<b>6.97</b>	<b>7.19</b>	<b>6.88</b>
Egg	Chicken	10.35±2.40	10.77±1.51	14.49±4.35	13.92±0.53	<b>12.38</b>
	Duck	11.79±1.10	14.72±3.80	16.17±3.54	16.58±0.92	<b>14.82</b>
	<b>Average</b>	<b>11.07</b>	<b>12.75</b>	<b>15.33</b>	<b>15.25</b>	<b>13.60</b>
Meat	Beef	20.94±0.65	20.08±0.50	25.86±1.50	26.67±0.83	<b>23.39</b>
	Mutton	21.63±0.85	25.29±0.68	24.01±3.53	34.99±1.14	<b>26.48</b>
	Chicken	8.78±1.94	7.23±0.62	6.79±0.84	9.20±0.99	<b>8.00</b>
	<b>Average</b>	<b>17.12</b>	<b>17.53</b>	<b>18.89</b>	<b>23.62</b>	<b>19.29</b>
Vegetables	Potato	4.67±0.94	7.31±0.60	7.99±2.03	8.61±1.44	<b>7.15</b>
	Brinjal	2.99±1.07	3.24±0.88	3.10±0.50	3.05±0.78	<b>3.10</b>
	Green papaya	1.55±0.82	1.69±1.59	1.58±1.59	1.75±0.77	<b>1.64</b>
	Pointed gourd	2.92±0.66	2.69±0.56	3.10±0.50	3.45±0.52	<b>3.04</b>
	Pumpkin	2.08±0.56	3.40±0.63	1.87±0.62	3.34±0.31	<b>2.67</b>
	Bottle gourd	0.53±0.18	0.95±0.59	1.02±0.49	1.84±0.57	<b>1.09</b>
	Okra	3.27±0.66	3.71±0.71	3.45±1.14	3.52±0.62	<b>3.49</b>
	Tomato	1.36±0.07	2.09±0.08	1.60±1.01	1.29±0.60	<b>1.59</b>
	Red amaranth	1.96±0.76	2.56±0.11	4.28±1.82	3.03±1.77	<b>2.96</b>
	Cauliflower	2.18±1.05	2.02±0.44	1.93±0.32	2.59±0.58	<b>2.18</b>
	Cabbage	2.14±0.10	2.07±0.19	2.04±0.32	1.77±0.18	<b>2.01</b>
	<b>Average</b>	<b>2.33</b>	<b>2.88</b>	<b>2.91</b>	<b>3.11</b>	<b>2.81</b>
Milk and Dairy	Liquid milk	4.56±0.03	4.30±0.67	4.04±0.09	4.03±0.59	<b>4.23</b>
	Powder milk	21.53±4.73	25.67±1.93	20.77±2.88	17.41±0.84	<b>21.35</b>
	<b>Average</b>	<b>13.05</b>	<b>14.99</b>	<b>12.41</b>	<b>10.72</b>	<b>12.79</b>
Sweetmeat	Roshogolla	12.95±0.73	11.04±1.20	10.41±0.66	15.32±1.29	<b>12.43</b>
	Jilapi	10.53±1.95	11.28±1.61	9.11±2.45	10.41±1.85	<b>10.33</b>

	<b>Average</b>	<b>11.74</b>	<b>11.16</b>	<b>9.76</b>	<b>12.87</b>	<b>11.38</b>
Oil	Mustard oil	1.96±0.59	1.47±0.17	1.10±0.41	0.84±0.12	<b>1.34</b>
	Soybean oil	0.22±0.13	0.22±0.13	0.24±0.04	0.16±0.01	<b>0.21</b>
	<b>Average</b>	<b>1.09</b>	<b>0.85</b>	<b>0.67</b>	<b>0.50</b>	<b>0.78</b>
Fruits	Banana	1.22±0.51	0.86±0.07	1.15±0.30	1.15±0.07	<b>1.10</b>
	Mango	2.08±0.02	1.17±0.72	0.81±0.04	1.23±0.29	<b>1.32</b>
	Jackfruit	3.78±0.60	2.24±0.10	5.63±0.52	2.48±0.68	<b>3.53</b>
	Guava	1.30±0.54	3.40±0.53	3.05±1.00	1.49±0.56	<b>2.31</b>
	Pineapple	2.99±1.07	4.79±0.54	5.52±0.81	3.37±0.63	<b>4.17</b>
	Apple	1.79±0.26	1.21±0.56	0.99±0.40	1.35±1.12	<b>1.34</b>
	Papaya	2.37±0.73	1.88±0.57	2.72±0.97	2.14±0.04	<b>2.28</b>
	<b>Average</b>	<b>2.22</b>	<b>2.22</b>	<b>2.84</b>	<b>1.89</b>	<b>2.29</b>
Drinks	Tea/Coffee	0.31±0.07	0.29±0.03	0.15±0.06	0.16±0.04	<b>0.23</b>
	Orange Juice	0.09±0.02	0.05±0.06	0.05±0.01	0.03±0.04	<b>0.06</b>
	Mango juice	0.09±0.02	0.07±0.07	0.04±0.01	0.03±0.02	<b>0.06</b>
	Pepsi	0.16±0.02	0.15±0.03	0.13±0.04	0.13±0.01	<b>0.14</b>
	Drinking water	0.07±0.02	0.08±0.00	0.05±0.01	0.06±0.04	<b>0.07</b>
	<b>Average</b>	<b>0.14</b>	<b>0.13</b>	<b>0.08</b>	<b>0.08</b>	<b>0.11</b>
Sugar and Molasses	Cane sugar	1.17±0.40	0.81±0.45	1.30±0.82	1.25±0.32	<b>1.13</b>
	Gur	9.83±0.33	6.41±4.64	6.86±1.74	6.35±4.76	<b>7.36</b>
	<b>Average</b>	<b>5.50</b>	<b>3.61</b>	<b>4.08</b>	<b>3.80</b>	<b>4.25</b>
Processed food	Pickles	5.36±1.62	4.05±1.79	6.98±1.54	4.58±1.72	<b>5.24</b>
	Jam	2.73±0.72	3.21±0.98	4.73±0.26	2.43±0.82	<b>3.28</b>
	Jelly	4.81±0.42	3.32±0.23	3.67±0.21	4.71±0.58	<b>4.13</b>
	<b>Average</b>	<b>4.30</b>	<b>3.53</b>	<b>5.13</b>	<b>3.91</b>	<b>6.63</b>
Spices	Dried chilli	21.52±1.92	25.43±3.23	21.38±1.78	33.67±1.18	<b>25.50</b>
	Turmeric	18.50±1.47	24.30±8.56	25.31±10.36	16.47±2.71	<b>21.15</b>
	Onion	3.14±0.22	3.32±0.79	3.01±0.76	3.18±0.18	<b>3.16</b>
	Ginger	1.45±0.20	1.05±1.06	2.30±0.44	2.13±1.51	<b>1.73</b>
	Coriander	29.69±1.60	40.55±2.62	43.80±2.43	41.91±3.00	<b>38.99</b>
	<b>Average</b>	<b>14.86</b>	<b>18.93</b>	<b>19.16</b>	<b>19.47</b>	<b>18.11</b>
Bakery	Chips	7.88±1.10	6.86±3.19	9.46±1.32	8.38±1.23	<b>8.15</b>
	Biscuits	9.32±0.64	9.82±2.05	6.27±1.62	7.28±0.31	<b>8.17</b>
	<b>Average</b>	<b>8.60</b>	<b>8.34</b>	<b>7.87</b>	<b>7.83</b>	<b>8.16</b>

## Iron concentration

The iron (Fe) concentration in cereals (Table 4.3) was 16.16 mg/kg (average between the items across four locations). The other food groups followed the order of pulse (average 25.2 mg/kg) > eggs (22.17 mg/kg) > spices (10.2 mg/kg) > fishes (6.93 mg/kg) > meats (7.46 mg/kg) > vegetables (4.49 mg/kg) > fruits (4.12 mg/kg). The other group of foods such as milk & dairy products had 6.55, sweetmeats 8.97, sugars and molasses 6.63, prickles/jam/jelly 3.28, and bakeries 6.05 mg/kg Fe. Oil and drinks was found to have almost zero amount of Fe.

Comparing food items in a group, the Fe concentration of cereals (Table 4.3) varied chronologically puffed rice (mean 23.5 mg/kg) > rice flakes (21.13 mg/kg) > wheat flour (19.88 mg/kg) > plain rice (10.4 mg/kg) > bon ruti (5.91 mg/kg). The two pulse items lentil and mungbean showed similar amount of Fe, 25.7 and 24.8 mg/kg, respectively. The fishes showed Fe in a range of 6.06-8.68 mg/kg, the highest value observed with prawn and the lowest value noted with rohu. Next to prawn, hilsa demonstrated the highest Fe concentration (7.20 mg/kg). The Fe concentration of egg and meat samples showed a narrow range of 21.9-22.5 and 6.49-8.87 mg/kg, respectively. The Fe concentration of vegetables varied from 2.25 mg/kg (bottle gourd) to 8.04 mg/kg (green papaya). The second highest Fe value was noted for brinjal (6.25 mg/kg) which followed potato (5.34 mg/kg), pointed gourd (5.34 mg/kg), okra (4.30 mg/kg) and the others had Fe concentration below 4 mg/kg. In case of fruits, pineapple exhibited the highest Fe value (6.22 mg/kg) followed by apple 4.25 mg/kg, jackfruit 4.30 mg/kg, papaya 3.77 mg/kg and mango 3.58 mg/kg, and banana did the lowest (2.28 mg/kg) (Table 4.3).

The Fe concentration of different food groups differed significantly with locations. Depending on the locations, the cereals Fe concentration ranged from 15.5-17.8 mg/kg, pulses 24.8-26.3 mg/kg, fishes 6.37-7.52 mg/kg, vegetables from 4.04-5.43 mg/kg, fruits from 3.60 – 4.86 mg/kg and spices 8.26-13.1 mg/kg. Khulna division recorded the highest Fe value for cereals, fishes, vegetables, fruits and spices. Food samples from Mymensingh had the lowest Fe level (Table 4.3).

As previously observed by Islam et al. (2013), the Fe concentration of food samples from Hazaribagh, Kawran bazar and Gulshan market of Dhaka city varied from 10.0-18.6 mg/kg for rice, 24-35 mg/kg for pulses, 3.35-15.7 mg/kg for fishes, 0.79-9.28 mg/kg for vegetables, 0.85-8.76 mg/kg for fruits and wheat flour, 1.87-27.7 mg/kg for fishes, 1.58-35.2 mg/kg for

vegetables, 2.26-29.6 mg/kg for fruits and 3.45-483 mg/kg for spices. Arum (kachu), among the vegetables and coriander seed, among the spices, recorded the highest Fe values.

**Table 4.3** Concentration of Fe (mg/kg fresh weight) in different food items from four divisions (results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	10.13±0.80	10.77±0.80	10.26±0.47	10.28±0.40	<b>10.36</b>
	Wheat flour	18.25±2.06	21.87±2.06	19.59±2.63	19.82±4.70	<b>19.88</b>
	Bon ruti	5.05±1.01	4.56±1.33	11.21±7.71	2.83±0.52	<b>5.91</b>
	Puffed rice	23.73±2.36	20.54±0.78	26.37±1.29	23.44±5.30	<b>23.52</b>
	Rice flakes	20.07±4.03	20.73±5.10	21.59±3.78	22.13±4.02	<b>21.13</b>
	<b>Average</b>	<b>15.45</b>	<b>15.69</b>	<b>17.80</b>	<b>15.70</b>	<b>16.16</b>
Pulses	Lentil	28.11±1.84	24.72±0.85	25.11±0.77	24.75±0.71	<b>25.67</b>
	Mung	24.42±0.76	24.86±0.50	24.94±0.95	24.79±1.09	<b>24.75</b>
	<b>Mean</b>	<b>26.27</b>	<b>24.79</b>	<b>25.03</b>	<b>24.77</b>	<b>25.21</b>
Fishes	Hilsa	7.73±1.96	7.43±0.54	6.20±2.70	7.42±0.95	<b>7.20</b>
	Giant Prawn	9.35±0.82	8.02±1.22	9.01±1.53	8.34±1.89	<b>8.68</b>
	Rohu	5.51±1.98	6.03±0.95	7.44±0.27	5.24±1.96	<b>6.06</b>
	Silver carp	5.89±0.57	5.49±1.06	8.22±1.14	6.74±0.99	<b>6.59</b>
	Pungus	6.02±1.34	5.12±0.65	7.18±2.44	6.62±1.20	<b>6.24</b>
	Tilapia	7.04±0.56	6.14±0.73	7.04±2.67	7.09±2.52	<b>6.83</b>
	<b>Average</b>	<b>6.92</b>	<b>6.37</b>	<b>7.52</b>	<b>6.91</b>	<b>6.93</b>
Egg	Chicken	23.03±2.40	22.53±1.51	21.18±4.35	23.08±0.53	<b>22.46</b>
	Duck	23.54±1.10	25.13±3.80	16.09±3.54	22.76±0.92	<b>21.88</b>
	<b>Average</b>	<b>23.29</b>	<b>23.83</b>	<b>18.64</b>	<b>22.92</b>	<b>22.17</b>
Meat	Beef	7.62±0.65	7.49±0.50	12.01±1.50	8.34±0.83	<b>8.87</b>
	Mutton	6.48±0.85	5.93±0.68	8.55±3.53	7.11±1.14	<b>7.02</b>
	Chicken	5.80±1.04	6.74±0.62	7.05±0.84	6.36±0.99	<b>6.49</b>
	<b>Average</b>	<b>6.63</b>	<b>6.72</b>	<b>9.20</b>	<b>7.27</b>	<b>7.46</b>
Vegetables	Potato	5.07±0.94	5.02±0.60	6.85±2.03	5.93±1.44	<b>5.72</b>
	Brinjal	5.16±1.07	5.54±0.88	7.69±0.42	6.61±0.78	<b>6.25</b>
	Green papaya	8.23±1.82	8.08±1.59	8.52±1.59	7.31±0.77	<b>8.04</b>
	Pointed gourd	5.02±0.66	4.71±0.56	6.77±0.50	4.87±0.52	<b>5.34</b>
	Pumpkin	3.41±0.56	2.59±0.63	3.93±0.62	2.93±0.31	<b>3.22</b>
	Bottle gourd	1.83±0.85	1.86±0.59	2.64±0.49	2.66±0.57	<b>2.25</b>
	Okra	4.02±0.66	3.91±0.71	5.45±1.14	3.80±0.62	<b>4.30</b>
	Tomato	2.24±0.07	2.47±0.08	3.49±1.01	2.85±0.60	<b>2.76</b>
	Red amaranth	3.51±0.76	3.43±0.11	5.56±1.82	2.53±1.77	<b>3.76</b>
	Cauliflower	4.40±1.05	3.11±0.44	4.13±0.32	3.99±0.58	<b>3.91</b>
	Cabbage	3.61±0.10	3.77±0.19	4.69±0.32	3.39±2.18	<b>3.87</b>

	<b>Average</b>	<b>4.23</b>	<b>4.04</b>	<b>5.43</b>	<b>4.26</b>	<b>4.49</b>
Milk and Dairy	Liquid milk	3.25±0.03	3.45±0.67	3.24±0.09	3.63±0.59	<b>3.39</b>
	Powder milk	7.74±1.84	9.75±1.93	7.30±2.88	14.00±0.84	<b>9.70</b>
	<b>Average</b>	<b>5.50</b>	<b>6.60</b>	<b>5.27</b>	<b>8.82</b>	<b>6.55</b>
Sweetmeat	Roshogolla	8.99±0.73	8.11±1.20	10.84±0.66	7.07±1.29	<b>8.75</b>
	Jilapi	11.99±1.95	7.73±1.61	8.37±2.45	8.64±1.85	<b>9.18</b>
	<b>Average</b>	<b>10.49</b>	<b>7.92</b>	<b>9.61</b>	<b>7.86</b>	<b>8.97</b>
Oil	Mustard oil	1.23±0.59	1.23±0.17	1.00±0.41	0.99±0.12	<b>1.11</b>
	Soybean oil	0.37±0.13	0.51±0.13	0.52±0.03	0.84±1.01	<b>0.56</b>
	<b>Average</b>	<b>0.80</b>	<b>0.87</b>	<b>0.76</b>	<b>0.92</b>	<b>0.84</b>
Fruits	Banana	2.59±0.51	2.34±0.97	1.57±0.30	2.61±0.07	<b>2.28</b>
	Mango	4.15±0.02	4.15±0.72	3.14±156	2.87±0.29	<b>3.58</b>
	Jackfruit	4.92±0.60	3.17±0.10	6.14±0.52	2.98±0.68	<b>4.30</b>
	Guava	3.38±0.54	2.93±0.53	5.81±1.00	4.37±0.56	<b>4.22</b>
	Pineapple	6.31±1.07	6.54±0.54	6.81±0.81	5.02±0.63	<b>6.22</b>
	Apple	5.73±0.26	5.89±1.56	6.44±0.40	5.29±1.12	<b>4.47</b>
	Papaya	3.59±0.73	3.90±0.57	4.09±0.97	3.49±0.04	<b>3.77</b>
	<b>Average</b>	<b>3.60</b>	<b>4.13</b>	<b>4.86</b>	<b>3.89</b>	<b>4.12</b>
Drinks	Tea/Coffee	0.28±0.07	0.28±0.03	0.19±0.06	0.23±0.04	<b>0.25</b>
	Orange Juice	0.24±0.02	0.24±0.06	0.20±0.07	0.20±0.05	<b>0.22</b>
	Mango juice	0.21±0.02	0.19±0.07	0.20±0.01	0.19±0.02	<b>0.20</b>
	Pepsi	0.10±0.02	0.11±0.03	0.12±0.04	0.12±0.01	<b>0.11</b>
	Drinking water	0.08±0.02	0.06±0.00	0.05±0.01	0.05±0.04	<b>0.06</b>
	<b>Average</b>	<b>0.18</b>	<b>0.18</b>	<b>0.15</b>	<b>0.16</b>	<b>0.17</b>
Sugar and Molasses	Cane sugar	2.91±0.40	1.84±0.45	2.81±0.82	2.86±0.32	<b>2.61</b>
	Gur	12.71±0.33	11.15±4.64	8.41±5.74	10.34±4.76	<b>10.65</b>
	<b>Average</b>	<b>7.81</b>	<b>6.50</b>	<b>5.61</b>	<b>6.60</b>	<b>6.63</b>
Processed food	Pickles	5.88±1.62	5.12±1.79	7.13±1.91	5.87±1.72	<b>6.00</b>
	Jam	1.98±0.72	2.16±0.98	2.79±0.26	1.98±0.82	<b>2.23</b>
	Jelly	1.65±0.42	1.62±0.23	1.49±0.21	1.70±0.58	<b>1.62</b>
	<b>Average</b>	<b>3.17</b>	<b>2.97</b>	<b>3.80</b>	<b>3.18</b>	<b>3.28</b>
Spices	Dried chilli	7.46±1.92	9.43±3.23	10.19±1.78	8.38±1.18	<b>8.87</b>
	Turmeric	24.65±1.47	19.19±8.56	26.56±10.36	16.57±2.71	<b>21.74</b>
	Onion	1.98±0.22	1.97±0.79	4.87±0.76	0.85±0.18	<b>2.42</b>
	Ginger	7.02±0.20	5.68±1.06	11.08±4.36	5.09±1.51	<b>7.22</b>
	Coriander	10.83±1.60	8.49±2.62	12.88±2.43	10.39±3.00	<b>10.65</b>
	<b>Average</b>	<b>10.39</b>	<b>8.95</b>	<b>13.12</b>	<b>8.26</b>	<b>10.18</b>
Bakery	Chips	6.62±1.10	7.10±3.19	6.77±1.32	5.79±1.23	<b>6.57</b>
	Biscuits	4.49±0.64	6.95±2.05	6.30±1.62	4.41±0.31	<b>5.54</b>
	<b>Average</b>	<b>5.56</b>	<b>7.03</b>	<b>6.54</b>	<b>5.10</b>	<b>6.05</b>

### **Copper concentration**

The copper (Cu) concentration differed markedly with various food groups. On an average, the highest Cu concentration of 8.77 mg/kg was observed with spices that was followed by cereals (4.53 mg/kg), pulses (3.43 mg/kg), fruits (1.71 mg/kg), eggs (1.39 mg/kg), fishes (1.21 mg/kg), meats (0.76 mg/kg) and vegetables (0.38 mg/kg) (Table 4.4). Among others bakery products (chips and biscuits) had higher Cu level (6.62 mg/kg), then sugar & molasses (4.94 mg/kg), pickles, jam & jelly (3.90 mg/kg), sweetmeats (3.77 mg/kg) and powder milk (4.73 mg/kg). Liquid milk, oils and various drinks did not contain Cu.

There was a marked variation between the items within a food group. The Cu content in cereals was in a range of 3.11(wheat flour) - 6.53 (rice) mg/kg, in pulses 0.20 (lentil) – 6.67 (mungbean) mg/kg, in fishes 0.77 (rohu) - 2.16 (hilsa) mg/kg, in meats 0.52 (chicken) – 0.89 (beef) mg/kg, in vegetables 0.11 (cauliflower) – 0.54 (tomato) mg/kg, in fruits 0.30 (papaya) - 2.43 (banana) mg/kg and in spices 0.83 (ginger) - 17.7 (coriander) mg/kg. Between two bakery items, chips (7.11 mg/kg) had little higher Cu content than biscuits (6.14 mg/kg) (Table 4.4).

Location variation in food Cu concentration is also remarkable; however samples from the same location did not show always higher or lower values. For pulses, eggs, meats, fruits, powder milk, sweetmeat and spices, the highest Cu value was observed in samples from Khulna and the values were 5.37, 1.48, 1.10, 2.57, 4.22, 2.43 9.45 mg/kg, respectively (Table 4.4). The samples from Rajshahi location exhibited the maximum Cu level for cereals (5.21 mg/kg), vegetables (0.44 mg/kg and for pickles, jam & jelly (3.86 mg/kg). Fishes had minimum Cu contamination (1.07-1.35 mg/kg), the elevated level for samples from Mymensingh.

The results of this study are in good agreement with the previous study done by Islam et al. (2013) over Dhaka city markets. For example, rice had Cu content from 3.14-6.38 mg/kg, meats below 1.0 mg/kg, vegetables from 0.14-1.40 mg/kg, fruits from 0.16-2.73 mg/kg and spices from 0.53-11.8 mg/kg.



**Table 4.4** Concentration of Cu (mg/kg fresh weight) in different food items from four divisions (results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	6.34±1.12	6.65±0.22	7.53±1.47	5.60±1.83	<b>6.53</b>
	Wheat flour	4.34±0.28	5.86±0.21	0.49±0.16	1.76±0.34	<b>3.11</b>
	Bon ruti	3.86±0.22	3.09±0.68	3.77±0.99	3.18±0.29	<b>3.48</b>
	Puffed rice	0.19±0.02	2.43±0.22	5.77±0.57	7.16±1.53	<b>3.89</b>
	Rice flakes	0.12±0.02	8.01±2.18	7.67±0.56	6.81±1.57	<b>5.65</b>
	<b>Average</b>	<b>2.97</b>	<b>5.21</b>	<b>5.05</b>	<b>4.90</b>	<b>4.53</b>
Pulses	Lentil	0.04±0.01	0.27±0.03	0.38±0.05	0.09±0.01	<b>0.20</b>
	Mung	0.11±0.01	6.47±2.62	10.35±0.27	9.75±0.44	<b>6.67</b>
	<b>Average</b>	<b>0.08</b>	<b>3.37</b>	<b>5.37</b>	<b>4.92</b>	<b>3.43</b>
Fishes	Hilsa	2.87±0.29	1.85±0.84	1.75±0.15	2.15±0.35	<b>2.16</b>
	Giant Prawn	1.30±0.31	1.61±0.55	2.43±0.81	1.39±0.15	<b>1.68</b>
	Rohu	1.03±0.36	0.62±0.14	0.48±0.01	0.93±0.01	<b>0.77</b>
	Silver carp	0.92±0.03	0.77±0.13	1.19±0.18	1.28±0.16	<b>1.04</b>
	Pangas	1.21±0.29	0.75±0.06	0.95±0.12	0.88±0.13	<b>0.95</b>
	Tilapia	0.76±0.08	0.80±0.07	0.90±0.06	0.85±0.17	<b>0.83</b>
	<b>Average</b>	<b>1.35</b>	<b>1.07</b>	<b>1.28</b>	<b>1.25</b>	<b>1.24</b>
Egg	Chicken	1.27±0.13	1.16±0.16	1.42±0.13	1.32±0.08	<b>1.29</b>
	Duck	1.46±0.21	1.35±0.16	1.53±0.01	1.60±0.20	<b>1.49</b>
	<b>Average</b>	<b>1.37</b>	<b>1.26</b>	<b>1.48</b>	<b>1.46</b>	<b>1.39</b>
Meat	Beef	0.63±0.19	0.59±0.01	1.07±0.31	1.27±0.24	<b>0.89</b>
	Mutton	0.42±0.06	0.49±0.01	1.56±0.15	0.99±0.03	<b>0.87</b>
	Chicken	0.44±0.06	0.45±0.06	0.66±0.07	0.51±0.03	<b>0.52</b>
	<b>Average</b>	<b>0.50</b>	<b>0.51</b>	<b>1.10</b>	<b>0.92</b>	<b>0.76</b>
Vegetables	Potato	0.63±0.09	0.86±0.16	0.66±0.03	0.89±0.14	<b>0.76</b>
	Brinjal	0.34±0.06	0.58±0.14	0.54±0.07	0.51±0.11	<b>0.49</b>
	Green Papaya	0.17±0.08	0.17±0.04	0.14±0.02	0.11±0.02	<b>0.15</b>
	Pointed Gourd	0.49±0.15	0.25±0.01	0.43±0.09	0.33±0.06	<b>0.38</b>
	Pumpkin	0.54±0.08	0.89±0.10	0.26±0.04	0.43±0.04	<b>0.53</b>
	Bottle Gourd	0.45±0.051	0.23±0.06	0.23±0.07	0.34±0.05	<b>0.31</b>
	Okra	0.64±0.12	0.59±0.09	0.49±0.04	0.38±0.03	<b>0.53</b>
	Tomato	0.35±0.06	0.41±0.05	0.32±0.02	0.29±0.02	<b>0.34</b>
	Red amaranth	0.41±0.07	0.45±0.08	0.45±0.09	0.24±0.04	<b>0.39</b>
	Cauliflower	0.13±0.03	0.14±0.01	0.08±0.02	0.10±0.03	<b>0.11</b>
	Cabbage	0.22±0.02	0.27±0.01	0.28±0.02	0.19±0.01	<b>0.24</b>
	<b>Average</b>	<b>0.40</b>	<b>0.44</b>	<b>0.35</b>	<b>0.35</b>	<b>0.38</b>
Milk and Dairy	Liquid milk	0.16±0.03	0	0	0	<b>0.04</b>
	Powder milk	4.41±0.12	4.62±0.14	5.14±0.24	4.75±0.54	<b>4.73</b>
	<b>Average</b>	<b>2.29</b>	<b>2.31</b>	<b>2.57</b>	<b>2.38</b>	<b>2.39</b>

Sweetmeat	Roshogolla	3.05±0.47	3.33±0.24	2.80±0.18	3.22±0.18	<b>3.10</b>
	Jilapi	4.38±2.35	3.91±0.22	5.63±0.66	3.81±0.09	<b>4.43</b>
	<b>Average</b>	<b>3.72</b>	<b>3.62</b>	<b>4.22</b>	<b>3.52</b>	<b>3.77</b>
Oil	Mustard	0.75±0.03	0	0	0	<b>0.19</b>
	Soybean	0.75±0.11	0	0	0	<b>0.19</b>
	<b>Average</b>	<b>0.75</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.19</b>
Fruits	Banana	1.99±0.40	2.37±0.23	2.80±0.24	2.55±0.36	<b>2.43</b>
	Mango	1.83±0.31	4.53±0.12	2.21±0.35	0.97±0.06	<b>2.39</b>
	Jackfruit	1.43±0.97	0.66±0.07	6.34±0.23	0.53±0.06	<b>2.24</b>
	Guava	0.90±0.14	1.58±0.19	1.77±0.15	0.70±0.05	<b>1.24</b>
	Pineapple	1.21±0.09	4.56±0.14	2.32±0.18	0.57±0.07	<b>2.17</b>
	Apple	1.35±0.76	1.57±0.06	1.27±0.37	0.76±0.09	<b>1.24</b>
	Papaya	0.39±0.15	0.21±0.01	0.27±0.05	0.34±0.01	<b>0.30</b>
	<b>Average</b>	<b>1.30</b>	<b>2.21</b>	<b>2.43</b>	<b>0.92</b>	<b>1.71</b>
Drinks	Tea/Coffee	0	0.28	0	0	<b>0.00</b>
	Orange Juice	0.29±0.01	0	0	0	<b>0.07</b>
	Mango juice	0.25±0.05	0	0	0	<b>0.06</b>
	Pepsi	1.35±0.14	0.11	0	0	<b>0.34</b>
	Drinking water	0.08±0.01	0.09±0.01	0	0	<b>0.02</b>
	<b>Average</b>	<b>0.39</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.10</b>
Sugar and Molasses	Cane sugar	6.24±0.96	3.76±0.15	5.46±0.32	5.41±0.31	<b>5.22</b>
	Gur	3.54±0.64	6.23±0.16	4.35±0.35	4.55±0.62	<b>4.67</b>
	<b>Average</b>	<b>4.89</b>	<b>5.00</b>	<b>4.91</b>	<b>4.98</b>	<b>4.94</b>
Processed food	Pickles	4.87±0.29	3.73±0.29	4.51±0.41	3.64±0.24	<b>4.19</b>
	Jam	3.72±0.64	4.71±0.21	4.53±0.34	3.38±0.04	<b>4.09</b>
	Jelly	2.45±0.12	3.15±0.22	3.65±0.22	4.44±0.31	<b>3.42</b>
	<b>Average</b>	<b>3.68</b>	<b>3.86</b>	<b>4.23</b>	<b>3.82</b>	<b>3.90</b>
Spices	Dried chilli	14.33±0.82	13.56±0.44	16.42±0.45	15.25±0.42	<b>14.89</b>
	Turmeric	10.56±1.55	11.79±0.17	10.32±0.44	1.00±0.17	<b>8.42</b>
	Onion	3.12±0.28	1.71±0.35	1.62±0.24	1.71±0.24	<b>2.04</b>
	Ginger	0.79±0.12	0.91±0.12	0.91±0.10	0.70±0.08	<b>0.83</b>
	Coriander	17.50±1.87	16.84±0.33	17.96±0.59	18.46±0.98	<b>17.69</b>
	<b>Average</b>	<b>9.26</b>	<b>8.96</b>	<b>9.45</b>	<b>7.42</b>	<b>8.77</b>
Bakery	Chips	6.87±0.86	5.77±0.50	8.67±0.25	7.13±0.36	<b>7.11</b>
	Biscuits	6.58±1.18	6.97±1.44	4.60±0.71	6.40±1.91	<b>6.14</b>
	<b>Average</b>	<b>6.73</b>	<b>6.37</b>	<b>6.64</b>	<b>6.77</b>	<b>6.62</b>

### Selenium concentration

The selenium (Se) concentration of food stuffs is small over the locations, however variation was found between food groups, between food items within a group and between locations. On an average, cereal foods had Se of 0.23 mg/kg, pulses 0.42 mg/kg, fishes 0.36 mg/kg, eggs 0.24 mg/kg, meats 0.12 mg/kg, vegetables 0.09 mg/kg, fruits 0.22 mg/kg and spices 0.39 mg/kg. The other groups of food such as milk, sweetmeats, sugar & molasses, processed foods (pickles, jam

& jelly) and bakeries possessed 0.22, 0.19, 0.61, 0.11 and 0.52 mg/kg Se, respectively. Oils (mustard and soybean) and various drinks did not contain detectable amount of Se (Table 4.5).

Although Se content is small, variation in Se value between the food items in a group was found wide, showing a range of 0.09-0.46 mg/kg for cereals, 0.20-0.65 mg/kg for pulses, 0.16-0.61 mg/kg fishes, 0.16-0.32 for eggs, 0.03-0.16 mg/kg for meats, 0.01-0.25 mg/kg for vegetables, 0.05-0.43 mg/kg for fruits, 0.44-0.78 mg/kg for sugar & molasses, 0.06-0.16 mg/kg for processed foods, 0.04-0.90 mg/kg for spices and 0.50-0.54 mg/kg for bakeries (Table 4.5). Among the cereals wheat flour exhibited the highest Se content (0.46 mg/kg), for the pulse group mungbean showed the higher Se value (0.65 mg/kg), among fishes hilsa topped the list (0.61 mg/kg). For the vegetables group, potato ranked the top (0.25 mg/kg), banana and mango among the fruits had the highest value (0.43 mg/kg) and for spices coriander had exceedingly high value (0.90 mg/kg).

There was a considerable variation between locations for Se content of food samples. For cereals this element concentration was from 0.13-0.35 mg/kg, pulses from 0.09-0.81 mg/kg, fishes from 0.30-0.39 mg/kg, eggs from 0.17-0.29 mg/kg, meats from 0.09-0.13 mg/kg, vegetables from 0.07-0.12 mg/kg, milk 0.16-0.32 mg/kg, sweetmeats from 0.17-0.20 mg/kg, fruits from 0.18-0.30 mg/kg, sugar & molasses 0.45-0.73 mg/kg, processed foods from 0.08-0.14 mg/kg, spices from 0.34-0.45 mg/kg and bakeries from 0.27-0.65 mg/kg (Table 4.5).

In a previous study conducted by Islam et al (2013) on samples obtained from Dhaka city markets Se was not traceable in cereals, pulses, vegetables and fruits. In the present study, fishes and spices showed some amount of Se, the values being 0.16 (Rohu) - 0.36 (prawn) mg/kg and 0.01 (ginger) -0.38 (coriander) mg/kg, respectively (Table 4.5).

Schwarz and Foltz (1957) first discovered the importance of selenium as a nutrient. It has three interconnected roles in humans as antioxidants, vitamin E, and components of selenoprotein. It was reported that trace Se supplementation prevents nutritional liver necrosis in vitamin E deficient rats. 'Keshan' (cardiomyopathy) and 'KashinBeck' (osteoarthritis) the two childhood/adolescent endemic diseases in China were found to be associated with Se deficiency.

**Table 4.5** Concentration of Se (mg/kg fresh weight) in different food items from four divisions  
(results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	0.12±0.01	0.10±0.00	0.46±0.03	0.36±0.02	<b>0.26</b>
	Wheat flour	0.23±0.03	0.84±0.02	0.59±0.03	0.17±0.01	<b>0.46</b>
	Bon ruti	0.23±0.05	0.23±0.03	0.38±0.01	0.43±0.01	<b>0.32</b>
	Puffed rice	0.01±0.00	0.11±0.01	0.02±0.00	0.11±0.01	<b>0.04</b>
	Rice flakes	0.06±0.01	0.04±0.01	0.24±0.01	0.07±0.00	<b>0.09</b>
	<b>Average</b>	<b>0.13</b>	<b>0.26</b>	<b>0.35</b>	<b>0.23</b>	<b>0.23</b>
Pulses	Lentil	0.14±0.01	0.08±0.04	0.37±0.02	0.21±0.00	<b>0.20</b>
	Mung	0.03±0.01	0.49±0.04	1.24±0.00	0.80±0.04	<b>0.65</b>
	<b>Average</b>	<b>0.09</b>	<b>0.28</b>	<b>0.81</b>	<b>0.51</b>	<b>0.42</b>
Fishes	Hilsa	0.81±0.08	0.52±59.42	0.61±0.05	0.50±0.02	<b>0.61</b>
	Giant Prawn	0.08±0.01	0.12±33.55	0.26±0.04	0.16±0.01	<b>0.16</b>
	Rohu	0.28±0.02	0.34±14.52	0.20±0.03	0.20±0.01	<b>0.26</b>
	Silver carp	0.49±0.07	0.31±16.68	0.30±0.04	0.31±0.02	<b>0.35</b>
	Pangas	0.43±0.01	0.24±7.11	0.30±0.02	0.29±0.03	<b>0.31</b>
	Tilapia	0.28±0.02	0.30±68.92	0.67±0.06	0.55±0.01	<b>0.45</b>
	<b>Average</b>	<b>0.39</b>	<b>0.30</b>	<b>0.39</b>	<b>0.33</b>	<b>0.36</b>
Egg	Chicken	0.31±0.02	0.33±0.01	0.29±0.06	0.34±0.06	<b>0.32</b>
	Duck	0.28±0.01	0.20±0.01	0.05±0.00	0.09±0.00	<b>0.16</b>
	<b>Average</b>	<b>0.29</b>	<b>0.27</b>	<b>0.17</b>	<b>0.22</b>	<b>0.24</b>
Meat	Beef	0.18±0.01	0.17±0.00	0.13±0.00	0.15±0.01	<b>0.16</b>
	Mutton	0.06±0.01	0.01±0.00	0.21±0.00	0.04±0.00	<b>0.03</b>
	Chicken	0.11±0.01	0.18±0.00	0.12±0.00	0.21±0.00	<b>0.15</b>
	<b>Average</b>	<b>0.12</b>	<b>0.12</b>	<b>0.09</b>	<b>0.13</b>	<b>0.12</b>
Vegetables	Potato	0.07±0.01	0.48±0.03	0.26±0.03	0.21±0.04	<b>0.25</b>
	Brinjal	0.05±0.01	0.07±0.02	0.05±0.00	0.05±0.00	<b>0.06</b>
	Green Papaya	0.03±0.00	0.05±0.01	0.01±0.00	0.01±0.00	<b>0.02</b>
	Pointed Gourd	0.03±0.01	0.04±0.02	0.05±0.00	0.05±0.00	<b>0.04</b>
	Pumpkin	0.04±0.01	0.07±0.02	0.04±0.01	0.06±0.01	<b>0.05</b>
	Bottle Gourd	0.03±0.00	0.02±0.00	0.03±0.00	0.04±0.00	<b>0.03</b>
	Okra	0.16±0.01	0.14±0.01	0.16±0.04	0.14±0.02	<b>0.15</b>
	Tomato	0.13±0.02	0.14±0.01	0.11±0.02	0.11±0.01	<b>0.12</b>
	Red amaranth	0.16±0.02	0.17±0.03	0.16±0.04	0.09±0.00	<b>0.15</b>
	Cauliflower	0.08±0.02	0.10±0.01	0.06±0.01	0.05±0.02	<b>0.05</b>
	Cabbage	0.03±0.00	0.01±0.00	0.01±0.00	0.01±0.00	<b>0.01</b>
	<b>Average</b>	<b>0.07</b>	<b>0.12</b>	<b>0.09</b>	<b>0.08</b>	<b>0.09</b>
Milk and Dairy	Liquid milk	0	0	0	0	<b>0.00</b>
	Powder milk	0.42±0.07	0.39±0.04	0.65±0.04	0.32±0.01	<b>0.44</b>
	<b>Average</b>	<b>0.21</b>	<b>0.20</b>	<b>0.32</b>	<b>0.16</b>	<b>0.22</b>

Sweetmeat	Roshogolla	0.18±0.02	0.18±0.02	0.14±0.01	0.20±0.04	<b>0.17</b>
	Jilapi	0.12±0.02	0.07±0.01	0.61±0.01	0.01±0.00	<b>0.20</b>
	<b>Average</b>	<b>0.15</b>	<b>0.13</b>	<b>0.37</b>	<b>0.10</b>	<b>0.19</b>
Oil	Mustard oil	0	0	0	0	<b>0.00</b>
	Soybean oil	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>00.00</b>
Fruits	Banana	0.31±0.01	0.37±0.00	0.43±0.04	0.59±0.06	<b>0.43</b>
	Mango	0.26±0.01	1.02±0.04	0.30±0.05	0.13±0.03	<b>0.43</b>
	Jackfruit	0.30±0.01	0.02±0.00	0.33±0.03	0.02±0.00	<b>0.17</b>
	Guava	0.04±0.00	0.10±0.01	0.13±0.05	0.06±0.01	<b>0.08</b>
	Pineapple	0.09±0.01	0.39±0.08	0.21±0.08	0.04±0.00	<b>0.19</b>
	Apple	0.17±0.01	0.19±0.02	0.19±0.03	0.13±0.03	<b>0.17</b>
	Papaya	0.06±0.01	0.03±0.00	0.04±0.01	0.06±0.01	<b>0.05</b>
	<b>Average</b>	<b>0.18</b>	<b>0.30</b>	<b>0.24</b>	<b>0.15</b>	<b>0.22</b>
Drinks	Tea/Coffee	0	0	0	0	<b>0.00</b>
	Orange juice	0.01±0.00	0	0	0.01±0.00	<b>0.01</b>
	Mango juice	0.01±0.00	0	0	0.01±0.00	<b>0.01</b>
	Pepsi	0.01±0.00	0	0	0.03±0.00	<b>0.01</b>
	Drinking water	0.03±0.00	0	0	0.04±0.00	<b>0.02</b>
	<b>Average</b>	<b>0.01</b>	<b>0.00</b>	<b>0.00</b>	<b>0.02</b>	<b>0.01</b>
Sugar and Molasses	Cane sugar	0.13±0.01	0.57±0.01	0.55±23.76	0.50±0.01	<b>0.44</b>
	Gur	0.78±0.01	0.89±0.01	0.58±53.94	0.86±0.02	<b>0.78</b>
	<b>Average</b>	<b>0.45</b>	<b>0.73</b>	<b>0.57</b>	<b>0.68</b>	<b>0.61</b>
Processed food	Pickles	0.07±0.01	0.15±0.01	0.12±24.62	0.11±0.02	<b>0.12</b>
	Jam	0.20±0.01	0.17±0.08	0.10±8.76	0.17±80.01	<b>0.16</b>
	Jelly	0.04±0.00	0.10±0.01	0.04±0.00	0.05±0.01	<b>0.06</b>
	<b>Average</b>	<b>0.10</b>	<b>0.14</b>	<b>0.08</b>	<b>0.11</b>	<b>0.11</b>
Spices	Dried chilli	0.34±0.01	0.58±0.01	0.15±0.02	0.77±0.02	<b>0.46</b>
	Turmeric	0.21±0.01	0.51±0.01	0.47±0.04	0.41±0.07	<b>0.40</b>
	Onion	0.46±0.02	0.09±0.00	0.07±0.00	0.07±0.00	<b>0.17</b>
	Ginger	0.03±0.00	0.05±0.01	0.04±0.00	0.03±0.00	<b>0.04</b>
	Coriander	0.83±0.01	0.84±0.03	0.98±0.05	0.94±0.05	<b>0.90</b>
	<b>Average</b>	<b>0.37</b>	<b>0.41</b>	<b>0.34</b>	<b>0.45</b>	<b>0.39</b>
Bakery	Chips	0.52±0.04	0.64±0.02	0.02±0.00	0.79±0.03	<b>0.50</b>
	Biscuits	0.63±0.01	0.50±0.02	0.52±0.01	0.51±0.02	<b>0.54</b>
	<b>Average</b>	<b>0.57</b>	<b>0.57</b>	<b>0.27</b>	<b>0.65</b>	<b>0.52</b>

#### **4.2.2 Intake of trace elements**

##### **Zinc intake**

Dietary intake of Zn by the adult male of different divisions of Bangladesh ranged from 4.6-21.96 mg/d, in Mymensingh division, from 5.61-28.2 mg/d in Rajshahi division, from 0.93-24.2 mg/d in Khulna division and from 9.19-27.5 mg/d in Chittagong division (Table 4.6). All the adult male of Mymensingh division had lower dietary intake of Zn than the RDA of 17 mg/d. Only 7%, 3% and 15% of the adults of Rajshahi, Khulna and Chattogram division had dietary intake of Zn more than the RDA (Table 4.6).

The contribution of cereals was the highest (68-71%) to the dietary Zn intake followed by vegetables (5.38-14.16%), pulses (3.13-6.85%), meat (4.67-8.45% and fishes (2.85-5.48%) in adults across the four divisions (Table 4.7).

##### **Iron intake**

Dietary intake of Fe by the adult male varied widely among the four divisions of Bangladesh with the highest mean Fe intake (11.02 mg/d) observed in Khulna division followed by Rajshahi division (10.61 mg/d), Chittagong division (10.24 mg/d) and the lowest in Mymensingh division (9.94 mg/d) (Table 4.6). The RDA of Fe for an adult is 19.0 mg/d (NIN, 2020). Only 2% adults of Rajshahi division and 1% adults of Khulna and Chittagong divisions had dietary intake of Fe more than the RDA. All the adults of Mymensingh division had Fe intake below 100% RDA. In Mymensingh division, 5%, 55% and 40% of the population had Fe intake within 75-100% RDA, 50-74% RDA and <50% RDA, respectively (Table 4.7). In Rajshahi division, 7%, 48% and 43% of the population had Fe intake within 75-100% RDA, 50-74% RDA and <50% RDA, respectively. In Khulna division, 8%, 70% and 21% of the population had Fe intake within 75-100% RDA, 50-74% RDA and <50% RDA. The percentage of adult of Chittagong division had 3%, 43% and 53% Fe intake within 75-100% RDA, 50-74% RDA and <50% RDA, respectively (Table 4.7).

The contribution of cereals to the dietary intake of Fe for the population of four divisions of Bangladesh was in the range of 57.4-71.5%, followed by vegetables (12.3-24.2%), fishes (3.0-7.74%), pulses (2.56-10.4%) and meat (3.5-5.16%) (Table 4.8).

### **Copper intake**

Dietary copper (Cu) intake by the adult male of four divisions varied widely among the four divisions of Bangladesh (Table 4.6). The highest mean intake (4.13 mg/d) was observed in Mymensingh division followed by Khulna division (3.02 mg/d), Rajshahi division (2.63 mg/d) and Chattogram division (2.31 mg/d) (Table 4.6). The RDA of Cu for an adult is 2.0 mg/d (NIN,, 2020). A 97%, 84%, 98% and 68% adult of Mymensingh, Rajshahi, Khulna and Chattogram division, respectively had Cu intake more than 100% RDA (Table 4.7). Only 3%, 11%, 2% and 30% of the population of Mymensingh, Rajshahi, Khulna and Chattogram divisions had Cu intake in the range of 75-99% of the RDA.

In all the four divisions, the contribution of cereals was the highest (54-91%) followed by vegetables (3.6-4.4%) , molasses (1.02-3.0% ) and fishes (1.01-3.25%) (Table 4.9).

### **Selenium intake**

Almost all the adult male of Mymensingh, Khulna and Chattogram divisions had higher dietary Se than the RDA intake of 55 µg/d (Table 4.6). Only 1% of the population of Rajshahi division had dietary intake of Se below 100%RDA (Table 4.7). Cereal crops contributed to the highest dietary intake of Se (46.71-68.54%) followed by vegetables (9.41-25.43%) and fishes (6.61-23.62%) (Table 4.10).

**Table 4.6** Statistics for intake of trace elements (mg/d) by the population of Mymensingh, Rajshahi, Khulna and Chattogram divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Iron</b>				
Minimum	3.28	10.6	14.23	6.34
Maximum	16.55	28.55	25.09	20.31
Mean±SD	9.94±2.43	10.61±3.3	11.02±2.7	10.24±2.3
<b>Zinc</b>				
Minimum	4.60	5.61	7.93	9.19
Maximum	21.96	28.2	24.2	27.5
Mean±SD	14.0±3.24	12.42±3.26	12.07±2.4	14.6±3.2
<b>Copper</b>				
Minimum	1.52	1.08	1.86	1.97
Maximum	7.09	5.93	4.83	4.76
Mean±SD	4.13±1.31	2.63±0.74	3.02±0.58	2.31±0.61
<b>Selenium</b>				
Minimum	0.10	0.04	0.16	0.27
Maximum	0.22	0.59	0.64	0.44
Mean±SD	0.17±0.03	0.16±0.08	0.25±0.06	0.29±0.05



**Table 4.7** Percentage of dietary intake of trace elements adapted from the latest estimates of RDA<sup>5</sup> for an adult in four divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Iron</b>				
100% RDA	0	2	1	1
75-99% RDA	5	7	8	3
50-74% RDA	55	48	70	53
<50%RDA	40	43	21	43
<b>Zinc</b>				
100% RDA	0	7	3	15
75-99% RDA	51	34	26	55
50-74% RDA	26	51	66	22
<50%RDA	23	8	5	8
<b>Copper</b>				
100% RDA	97	84	98	68
75-99% RDA	3	11	2	30
50-74% RDA	0	5	0	2
<50%RDA	0	0	0	0
<b>Selenium</b>				
100% RDA	100	99	100	100
75-99% RDA	0	1	0	0
50-74% RDA	0	0	0	0
<50%RDA	0	0	0	0

<sup>5</sup> RDA for Indians (2020), ICMR, NIN.

**Table 4.8** Contribution (%) of each food group to dietary exposure to Fe and Zn for an adult of four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram	Mymensingh	Rajshahi	Khulna	Chattogram
	<b>Iron</b>				<b>Zinc</b>			
1. Cereals	62.1	71.5	57.4	62.6	69.86	71.55	68.73	71.83
2. Pulses	10.4	4.4	2.56	5.03	6.85	4.66	3.13	5.08
3. Fish	5.3	3.0	6.84	7.74	3.38	2.85	5.48	5.47
4. Eggs	0.1	0.12	0.09	0.08	0.04	0.05	0.06	0.03
5. Meat	3.5	5.16	3.51	4.18	4.72	8.45	4.67	5.20
6. Vegetables	12.3	11.74	24.2	13.4	5.38	9.03	14.16	8.47
7. Milk and dairy	1.6	0.94	0.79	2.22	1.37	1.00	0.93	1.70
8. Sweatmeat	0.4	0	0.38	0.11	0.27	0.00	0.31	0.16
9. Oil and fats	0.2	0.30	0.28	0.46	0.08	0.11	0.11	0.06
10. Fruits	0.8	0.69	2.17	1.87	0.25	0.26	1.08	0.52
11. Drinks	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00
12. Sugar & Molasses	0.5	0.29	0.22	0.58	0.14	0.10	0.09	0.17
13. Jam & Jelly	0.03	0.01	0	0.13	0.02	0.01	0.00	0.07
14. Drinking water	2.58	1.80	1.43	1.57	1.41	1.93	1.24	1.24

**Table 4.9** Contribution (%) of each food group to dietary exposure to Cu and Se for an adult of four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram	Mymensingh	Rajshahi	Khulna	Chattogram
	<b>Copper</b>				<b>Selenium</b>			
1. Cereals	84.23	91.10	88.43	85.41	46.71	55.10	68.54	63.54
2. Pulses	0.02	0.40	0.68	0.29	3.46	0.87	1.72	1.58
3. Fish	1.44	1.01	1.88	3.25	23.62	6.61	10.35	13.18
4. Eggs	0.01	0.02	0.01	0.01	0.12	0.07	0.03	0.03
5. Meat	0.41	0.96	0.79	1.12	4.85	4.95	1.32	3.93
6. Vegetables	6.68	3.70	4.04	3.95	14.73	25.43	12.21	9.41
7. Milk and dairy	0.14	0.06	0.10	0.75	0.11	0.08	0.15	0.60
8. Sweat meat	0.16	0.00	0.22	0.14	0.41	0.00	0.13	0.11
9. Oil and fats	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10. Fruits	0.71	1.22	2.82	1.87	4.40	3.12	4.31	4.33
11. Drinks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12. Sugar & Molasses	1.74	1.52	1.02	3.00	1.56	3.75	1.23	3.21
13. Jam & Jelly	0.04	0.02	0.00	0.00	0.03	0.01	0.00	0.08
14. Drinking water	3.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00

### **4.2.3 Health implications for trace elements**

Dietary intake of Zn in all four divisions of Bangladesh is low. All the household adults of Mymensingh division, 93% household adult from Rajshahi division, 97% household adults of Khulna division and 85% household adult of Chattogram division had the dietary intake of Zn below RDA. All the household adults of Mymensingh division, 98% household adult from Rajshahi division, 99% household adults of Khulna and Chattogram divisions had the dietary intake of Fe below RDA. The adult of all these divisions might manifest the symptoms of Fe like anaemia. Trace elements (that are in the group of micronutrients) are required by the body in minimal amounts and are usually available from a diverse range of foods that should be taken in a balanced diet, to ensure micronutrient adequacy.

## **4.3. Heavy metals**

### **4.3.1 Concentration of heavy metals**

#### **Arsenic concentration**

The concentration of arsenic (As) in the different food groups (Table 4.10) varied markedly showing the following order: fish (average 395  $\mu\text{g/kg}$ ) > pulses (165  $\mu\text{g/kg}$ ) > cereals (121  $\mu\text{g/kg}$ ) > spices (66.2  $\mu\text{g/kg}$ ) > meat (28.0  $\mu\text{g/kg}$ ) > fruits (11.7  $\mu\text{g/kg}$ ) > vegetables (9.32  $\mu\text{g/kg}$ ) > egg (7.37  $\mu\text{g/kg}$ ). Milk and dairy products contained 14.0, sweetmeats 20.3, oils 10.3, chips & biscuits (dry) 45.5  $\mu\text{g/kg}$ , drinking water 2.39  $\mu\text{g/kg}$  As; drinks, sugar, molasses, pickles, jam & jelly had nil or negligible amount of As.

Numerous works in the past have reported significant variation in As concentration of cereals, vegetables and spices. The previous market basket study (Islam et al., 2013) in Dhaka city demonstrated a significant variation of arsenic (As) levels in the different food groups showing chronologically fishes (mean 572  $\mu\text{g/kg}$ ), cereals (157  $\mu\text{g/kg}$ ), spices (86  $\mu\text{g/kg}$ ), eggs (31  $\mu\text{g/kg}$ ), meats (18  $\mu\text{g/kg}$ ), fruits (0.12  $\mu\text{g/kg}$ ) and vegetables (0.003  $\mu\text{g/kg}$ ). Roychowdhury et al. (2003) from West Bengal, India, reported the mean As levels as 130 and 179  $\mu\text{g/kg}$  in cereals & bakery goods, 20.9 and 21.2  $\mu\text{g/kg}$  in vegetables and 133 and 202  $\mu\text{g/kg}$  in spices for the Jalangi and Domkal blocks. Thus, the values in the present study are in line with the reported values.

Since rice is the staple food of Bangladeshi people and As contamination of groundwater is a severe problem in Bangladesh (Rahman et al., 2003), thus the As level of rice has the greatest implication. There were variable amounts of As in rice and rice products from the four locations (Table 4.10). Puffed rice (bangla name ‘muri’, 187 µg/kg) and plain rice (184 µg/kg) had similar As concentration which was higher compared to wheat flour (33.5 µg/kg) and bon ruti (bangla name ‘ata’, 25.8 µg/kg). As reviewed by Williams et al. (2006), the rice As levels in Asia-Pacific regions are 0.06-0.14 µg/g for Thailand, 0.00-0.25 µg/g for Philippines, 0.02-0.04 µg/g for Australia, 0.07-0.19 µg/g for China, 0.03-0.07 µg/g (Basmati) for India and 0.08-0.36 µg/g (Transplant Aman rice) and 0.09-0.51 µg/g (Boro rice) for Bangladesh. Thus, results of the present study are in considerable agreement with the reported values.

Arsenic concentration of fish (Table 4.10) was found to vary with the order of Hilsa (mean 1677 µg/kg) > Prawn (346 µg/kg) > Tilapia (µg/kg) > Silver carp (152 µg/kg) > Rohu (54.4 µg/kg) > Pangas (24 µg/kg). Arsenic concentration of egg samples showed a narrow range, 0.029-0.034 µg/g. Very little amount of As was recorded with meat (42.9 µg/kg for beef, 28.7 µg/kg for chicken and 12.3 µg/kg for mutton) and egg (5.21 µg/kg for chicken and 9.54 µg/kg for duck).

The As level in vegetables was found generally very low (Table 4.10). It varied from 1.46 µg/kg (cauliflower) to 15.9 µg/kg (red amaranth). Gourd (bottle gourd, pointed gourd and pumpkin) had As content from 9.02 - 10.8 µg/kg. Potato, brinjal (egg plant) and green papaya contained 1.5, 12.8 and 9.69 µg/kg As, respectively. Among the fruits, the highest level was measured for jackfruit (21.1 µg/kg) followed by pineapple (17.6 µg/kg) and apple (11.1 µg/kg), mango 10.0 µg/kg, guava (9.24 µg/kg) and banana (7.09 µg/kg). The lowest amount was noted with papaya (2.74 µg/kg).

Between two pulses, As level was detected higher with lentil (198 µg/kg) than with mungbean (132 µg/kg). The As concentration quite varied with kinds of spices, with the highest value for coriander (168 µg/kg) followed by turmeric (87.9 µg/kg) and dried chilli (67.6 µg/kg). Insignificant value was noted with ginger (4.78 µg/kg) and onion (2.44 µg/kg) (Table 4.10).

Bakery items like biscuits (39.5 µg/kg) and chips (51.5 µg/kg) had considerably higher As contamination which could be due to dry condition. Powder milk (dry) contained 26.4 µg As/kg while liquid milk had only 1.73 µg As/kg. Sweetmeat like roshogolla and jilapi had similar As level (20.0 and 20.5 µg/kg, respectively). Between two oils, soybean had relatively higher As

(12.1 µg/kg) compared to mustard oil (8.53 µg/kg). Soft drinks (orange juice, mango juice and pepsi) and sugar & molasses had no As. Drinking water had also very minimum As content (3.03 µg/kg) (Table 4.10).

Looking at the locations comparisons (Table 4.10), the As concentration of different food groups over the four locations varied considerably, showing for cereals from 85.3- 143.8 µg/ kg, pulses from 2.96 - 580 µg/kg, fishes from 306-463 µg/kg, vegetables from 3.22-19.7 µg/kg and fruits from 5.76 – 18.5 µg/g; the highest level was always detected in case of Chattogram except for fruits where Khulna recorded the highest level and the lowest level noted mostly with Rajshahi.

Williams et al. (2006) reported elevated concentration of As in rice grain in the southwest Bangladesh, recognized as As contaminated region, the values varied from 0.29 µg/g (Meherpur district) to 0.51 µg/g(Faridpur district). There is a number of evidences of elevated rice grain As in Bangladesh and West Bengal, India where paddy fields are irrigated with As contaminated water (Meharg and Rahman, 2003; Islam et al.,2004). Thus, point source of rice marketing i.e. location of rice cultivation can better explain the As variation.

**Table 4.10** Concentration of As ( $\mu\text{g/kg}$  fresh weight) in different food items from four divisions (results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	48.79 $\pm$ 8.74	108.01 $\pm$ 41.90	292.03 $\pm$ 12.7	286.62 $\pm$ 13.73	<b>183.86</b>
	Wheat flour	33.37 $\pm$ 9.44	34.19 $\pm$ 7.91	31.95 $\pm$ 13.14	34.56 $\pm$ 7.77	<b>33.52</b>
	Bon ruti	31.12 $\pm$ 1.10	24.48 $\pm$ 2.76	24.07 $\pm$ 3.46	23.34 $\pm$ 0.82	<b>25.75</b>
	Puffed rice	188.36 $\pm$ 19.71	192.50 $\pm$ 14.39	165.17 $\pm$ 37.88	201.39 $\pm$ 2.55	<b>186.86</b>
	Rice flakes	124.72 $\pm$ 21.52	210.42 $\pm$ 6.15	183.89 $\pm$ 17.44	173.26 $\pm$ 13.79	<b>173.07</b>
	<b>Average</b>	<b>85.27</b>	<b>113.92</b>	<b>139.42</b>	<b>143.83</b>	<b>120.61</b>
Pulses	Lentil	6.28 $\pm$ 0.48	3.48 $\pm$ 0.63	72.00 $\pm$ 11.0	712.20 $\pm$ 271.22	<b>198.49</b>
	Mung	3.80 $\pm$ 1.91	2.43 $\pm$ 0.42	72.23 $\pm$ 12.2	448.38 $\pm$ 42.6	<b>131.71</b>
	<b>Average</b>	<b>5.04</b>	<b>2.96</b>	<b>72.12</b>	<b>580.29</b>	<b>165.10</b>
Fish	Hilsa	1821.78 $\pm$ 51.05	1531.10 $\pm$ 102.64	1621.34 $\pm$ 74.04	1733.29 $\pm$ 133.43	<b>1676.88</b>
	Giant Prawn	22.84 $\pm$ 2.97	34.30 $\pm$ 9.55	751.90 $\pm$ 53.97	576.58 $\pm$ 16.64	<b>346.41</b>
	Rohu	66.75 $\pm$ 10.04	32.74 $\pm$ 6.87	35.84 $\pm$ 13.32	82.21 $\pm$ 13.39	<b>54.39</b>
	Silver carp	100.71 $\pm$ 34.86	158.97 $\pm$ 9.54	95.27 $\pm$ 17.75	251.18 $\pm$ 61.68	<b>151.53</b>
	Pangas	21.00 $\pm$ 7.06	13.45 $\pm$ 5.20	24.95 $\pm$ 8.55	34.49 $\pm$ 10.33	<b>23.47</b>
	Tilapia	88.08 $\pm$ 21.81	64.86 $\pm$ 11.64	220.27 $\pm$ 24.45	102.45 $\pm$ 15.16	<b>118.92</b>
	<b>Average</b>	<b>353.53</b>	<b>305.90</b>	<b>458.26</b>	<b>463.37</b>	<b>395.26</b>
Egg	Chicken	3.96 $\pm$ 1.13	3.16 $\pm$ 0.86	6.63 $\pm$ 2.80	7.07 $\pm$ 1.04	<b>5.21</b>
	Duck	12.40 $\pm$ 3.62	10.78 $\pm$ 0.63	6.51 $\pm$ 1.93	8.45 $\pm$ 3.12	<b>9.54</b>
	<b>Average</b>	<b>8.18</b>	<b>6.97</b>	<b>6.57</b>	<b>7.76</b>	<b>7.37</b>
Meat	Beef	17.31 $\pm$ 0.95	24.22 $\pm$ 3.93	89.15 $\pm$ 30.75	41.01 $\pm$ 3.89	<b>42.92</b>
	Mutton	2.08 $\pm$ 0.63	4.81 $\pm$ 2.86	22.41 $\pm$ 4.73	19.68 $\pm$ 9.68	<b>12.25</b>
	Chicken	17.49 $\pm$ 6.64	13.22 $\pm$ 6.59	41.66 $\pm$ 18.45	42.48 $\pm$ 3.61	<b>28.71</b>
	<b>Average</b>	<b>12.29</b>	<b>14.08</b>	<b>51.07</b>	<b>34.39</b>	<b>27.96</b>
Vegetables	Potato	3.23 $\pm$ 0.68	3.62 $\pm$ 0.69	17.36 $\pm$ 2.20	29.65 $\pm$ 4.49	<b>13.47</b>
	Brinjal	3.02 $\pm$ 1.21	5.12 $\pm$ 0.80	13.01 $\pm$ 3.98	29.93 $\pm$ 4.28	<b>12.77</b>
	Green papaya	4.41 $\pm$ 0.52	4.06 $\pm$ 0.75	7.62 $\pm$ 3.12	22.68 $\pm$ 5.86	<b>9.69</b>
	Pointed Gourd	3.06 $\pm$ 1.63	4.28 $\pm$ 1.98	15.14 $\pm$ 3.31	20.85 $\pm$ 7.68	<b>10.83</b>
	Pumpkin	1.99 $\pm$ 0.32	2.41 $\pm$ 0.59	6.33 $\pm$ 1.34	32.13 $\pm$ 5.26	<b>10.72</b>
	Bottle gourd	3.27 $\pm$ 1.11	1.28 $\pm$ 0.08	6.05 $\pm$ 0.76	25.48 $\pm$ 4.98	<b>9.02</b>
	Okra	3.56 $\pm$ 0.75	3.17 $\pm$ 1.33	11.20 $\pm$ 2.53	17.71 $\pm$ 2.97	<b>8.91</b>
	Tomato	2.74 $\pm$ 1.55	1.31 $\pm$ 0.11	5.91 $\pm$ 2.83	18.13 $\pm$ 7.12	<b>7.02</b>
	Red amaranth	4.74 $\pm$ 1.75	22.92 $\pm$ 7.12	20.57 $\pm$ 3.15	15.47 $\pm$ 3.58	<b>15.93</b>
	Cauliflower	1.45 $\pm$ 0.51	1.11 $\pm$ 0.44	1.34 $\pm$ 0.38	1.94 $\pm$ 0.28	<b>1.46</b>
	Cabbage	3.91 $\pm$ 2.93	1.40 $\pm$ 0.22	2.34 $\pm$ 0.35	2.96 $\pm$ 0.21	<b>2.65</b>
	<b>Average</b>	<b>3.22</b>	<b>4.61</b>	<b>9.72</b>	<b>19.72</b>	<b>9.32</b>
Milk and Dairy	Liquid milk	2.42 $\pm$ 0.28	2.66 $\pm$ 0.67	1.83 $\pm$ 0.05	0	<b>1.73</b>
	Powder milk	23.74 $\pm$ 4.34	26.34 $\pm$ 7.79	27.72 $\pm$ 10.43	27.63 $\pm$ 10.20	<b>26.36</b>
	<b>Average</b>	<b>13.08</b>	<b>14.50</b>	<b>14.78</b>	<b>13.82</b>	<b>14.04</b>
Sweetmeat	Roshogolla	18.33 $\pm$ 4.11	21.24 $\pm$ 4.84	22.74 $\pm$ 9.86	17.86 $\pm$ 5.82	<b>20.04</b>
	Jilapi	11.43 $\pm$ 2.84	18.11 $\pm$ 5.92	28.37 $\pm$ 6.37	24.22 $\pm$ 4.18	<b>20.53</b>
	<b>Average</b>	<b>14.88</b>	<b>19.68</b>	<b>25.56</b>	<b>21.04</b>	<b>20.29</b>

Oil	Mustard oil	10.51±1.61	9.55±1.63	7.55±1.68	6.51±1.66	<b>8.53</b>
	Soybean oil	8.21±1.79	12.12±1.68	19.10±3.13	9.12±1.21	<b>12.14</b>
	<b>Average</b>	<b>9.36</b>	<b>10.84</b>	<b>13.33</b>	<b>7.82</b>	<b>10.33</b>
Fruits	Banana	4.93±0.48	4.95±1.94	8.62±3.12	9.84±1.12	<b>7.09</b>
	Mango	5.57±0.82	22.48±3.94	8.07±1.55	3.92±0.99	<b>10.01</b>
	Jackfruit	5.29±3.41	6.45±2.00	67.50±8.36	5.10±0.83	<b>21.09</b>
	Guava	5.28±0.55	11.34±2.27	14.17±2.37	6.16±1.11	<b>9.24</b>
	Pineapple	8.74±1.76	42.69±12.47	14.96±4.07	4.16±1.46	<b>17.64</b>
	Apple	12.06±3.09	11.53±0.18	13.11±2.08	7.72±2.37	<b>11.11</b>
	Papaya	3.26±0.52	1.32±0.21	2.93±1.01	3.45±0.53	<b>2.74</b>
	<b>Average</b>	<b>6.45</b>	<b>14.39</b>	<b>18.48</b>	<b>5.76</b>	<b>11.27</b>
Drinks	Tea/Coffee	0	10.98±1.28	5.87±0.15	9.87±2.09	<b>6.68</b>
	Orange Juice	0	0	0	0	<b>0.00</b>
	Mango juice	0	0	0	0	<b>0.00</b>
	Pepsi	0.68±0.30	0	0	0	<b>0.17</b>
	Drinking water	3.20±0.50	5.10±0.22	14.5±1.38	10.4 ±1.23	<b>2.39</b>
	<b>Average</b>	<b>0.78</b>	<b>3.22</b>	<b>4.07</b>	<b>4.05</b>	<b>3.03</b>
Sugar and Molasses	Cane sugar	0	0	0	0	<b>0.00</b>
	Gur	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Processed food	Pickles	0	0	0	0	<b>0.00</b>
	Jam	0	0	0	0	<b>0.00</b>
	Jelly	0	0	0	2.04±0.24	<b>0.51</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.68</b>	<b>0.17</b>
Spices	Dried chilli	51.13±7.96	60.97±10.53	81.13±6.76	76.97±10.95	<b>67.55</b>
	Turmeric	109.07±7.87	73.92±13.07	125.48±25.36	42.97±4.65	<b>87.86</b>
	Onion	4.24±0.58	2.55±1.46	1.57±0.54	1.40±0.69	<b>2.44</b>
	Ginger	8.88±0.67	3.94±0.56	3.48±1.40	2.83±1.25	<b>4.78</b>
	Coriander	360.79±50.6	97.93±14.77	181.86±9.25	32.47±8.13	<b>168.26</b>
	<b>Average</b>	<b>106.82</b>	<b>47.86</b>	<b>78.70</b>	<b>31.33</b>	<b>66.18</b>
Bakery	Chips	49.04±10.56	77.11±8.43	35.44±9.69	44.49±7.53	<b>51.52</b>
	Biscuits	42.41±4.39	43.07±8.93	30.46±11.58	42.23±7.15	<b>39.54</b>
	<b>Average</b>	<b>45.73</b>	<b>60.09</b>	<b>32.95</b>	<b>43.36</b>	<b>45.53</b>

## Cadmium concentration

There was a significant variation in cadmium (Cd) concentration of the different food groups from the four locations in Bangladesh (Table 4.11). Spices exhibited the highest Cd concentration showing the order as spices (average 68.0 µg/kg) > cereals (59.0 µg/kg) > pulses (43.3 µg/kg) > fruits (22.6 µg/kg) > fishes (16.5 µg/kg) > vegetables (9.98 µg/kg) > meat (6.45 µg/kg) > egg (3.83 µg/kg). Bakery items (dry chips & biscuits) contained fairly high amount of Cd (66.1 µg/kg). Milk had 11.0 and sweetmeat (rashogolla and jilapi) 22.1 µg Cd/kg. The other items such as oils, pickles, jam, jelly, drinks, and sugar & molasses were free from Cd contamination.

The Cd concentration of the different food items under a group considerably varied over the locations (Table 4.11). Comparing cereal items, puffed rice had the highest Cd content (78.9 µg/kg) followed by plain rice (73.4 µg/kg), wheat flour (52.1 µg/kg), rice flakes (49.9 µg/kg) and Bon ruti (40.7 µg/kg). Meharg et al. (2013) reported Cd levels over 260 rice samples across 12 districts of Bangladesh in the range of <5-1310 µg/kg, with the mean of 990 µg/kg. Al-Rmalli et al. (2012) observed higher value of Cd in puffed rice (67.9 µg/kg) compared to uncooked rice (37.2 µg/kg) in the Bangladeshi shops in the United Kingdom which showed that some amount of Cd contamination occurred during preparing puffed rice.

Cadmium was detectable in all vegetables, except cauliflower from Chattogram (Table 4.11). Of the vegetables, red amaranth showed the highest amount (29.4 µg/kg) followed by potato (26.0 µg/kg), okra (12.9 µg/kg) and tomato (12.8 µg/kg). The other vegetables viz. brinjal, pumpkin, bottle gourd, pointed gourd, pumpkin, cauliflower, cabbage and green papaya had minimum; the lowest value (0.57 µg/kg) noted with green papaya. Al-Rmalli et al. (2012) noted Cd Content for leafy vegetables as 31.0 µg/kg and non-leafy vegetables 7 µg/kg. Naser et al. (2009) reported the Cd concentration of spinach, tomato and cauliflower in the industrial areas of Bangladesh as 559-1400 µg/kg, 630-1303 µg/kg and 506-782 µg/kg, respectively. Such results indicate that location of vegetables cultivation is the point for variation in heavy metal contents in vegetables.

Between two pulses, lentil (45.8 µg/kg) had little higher amount of Cd than mungbean (40.8 µg/kg). All the spices contained some amount of Cd, with the highest value (149 µg/kg) for coriander followed by turmeric (115 µg/kg). The mean Cd level of different fruits were in the



order of pineapple (60.4 µg/kg)> jackfruit (40.4 µg/kg)> apple (16.2 µg/kg)> guava (13.8 µg/kg)> mango (13.7 µg/kg)> banana (10.6 µg/kg) > papaya (3.37 µg/kg) (Table 4.11).

Considerable variation in Cd content occurred between the locations. The Cd content depending on the locations ranged from 48.6-74.7 µg/kg for cereals, from 11.7-22.4 µg/kg for fishes, from 51.4-95.0 µg/kg for spices, from 7.25-13.3 for vegetables and from 8.10-35.7 µg/kg for fruits. For other food groups, the range of Cd content was very small. Generally higher Cd values were noted for the food stuffs from Chattogram and Khulna (Table 4.7).

The previous market study in Dhaka city (Islam et al., 2013) demonstrated the highest Cd values for cereals, vegetables and meats for the samples from Hazaribagh market (near tannery industry) and for others such as spices, pulses, fishes and fruits the Kawran bazar (whole sale market) recorded the maximum Cd content. Gulshan super market samples had relatively lower Cd concentration for all types of food indicating that in these markets the supply of different types of food comes from the less contaminated areas (e.g. non-industrial areas).

**Table 4.11** Concentration of Cd ( $\mu\text{g/kg}$  fresh weight) in different food items from four divisions  
(results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	27.34 $\pm$ 8.74	79.07 $\pm$ 0.29	80.67 $\pm$ 13.76	106.42 $\pm$ 20.99	<b>73.38</b>
	Wheat flour	96.46 $\pm$ 9.44	64.66 $\pm$ 7.91	18.07 $\pm$ 3.14	29.15 $\pm$ 7.77	<b>52.09</b>
	Bon ruti	47.92 $\pm$ 6.10	37.43 $\pm$ 0.89	38.58 $\pm$ 9.22	38.95 $\pm$ 6.86	<b>40.72</b>
	Puffed rice	75.25 $\pm$ 22.33	59.50 $\pm$ 4.39	54.79 $\pm$ 7.88	126.11 $\pm$ 24.53	<b>78.91</b>
	Rice flakes	40.22 $\pm$ 3.45	35.83 $\pm$ 6.31	50.75 $\pm$ 6.97	72.87 $\pm$ 13.62	<b>49.92</b>
	<b>Average</b>	<b>57.44</b>	<b>55.30</b>	<b>48.57</b>	<b>74.70</b>	<b>59.00</b>
Pulses	Lentil	56.04 $\pm$ 5.41	8.48 $\pm$ 0.63	76.46 $\pm$ 11.0	42.14 $\pm$ 2.22	<b>45.78</b>
	Mung	56.96 $\pm$ 5.85	36.53 $\pm$ 7.42	14.20 $\pm$ 2.2	55.50 $\pm$ 6.50	<b>40.80</b>
	<b>Average</b>	<b>56.50</b>	<b>22.51</b>	<b>45.33</b>	<b>48.82</b>	<b>43.29</b>
Fishes	Hilsa	22.71 $\pm$ 1.48	14.24 $\pm$ 3.56	52.04 $\pm$ 4.04	37.01 $\pm$ 13.61	<b>31.50</b>
	Giant Prawn	5.88 $\pm$ 3.43	7.66 $\pm$ 1.55	18.34 $\pm$ 3.97	4.22 $\pm$ 0.87	<b>9.03</b>
	Rohu	2.25 $\pm$ 0.64	3.08 $\pm$ 1.85	7.96 $\pm$ 1.41	7.78 $\pm$ 1.63	<b>5.27</b>
	Silver carp	19.00 $\pm$ 3.86	15.09 $\pm$ 2.54	25.04 $\pm$ 7.75	21.03 $\pm$ 5.65	<b>20.04</b>
	Pangas	30.58 $\pm$ 5.99	17.76 $\pm$ 2.20	18.65 $\pm$ 6.11	15.97 $\pm$ 4.63	<b>20.74</b>
	Tilapia	10.79 $\pm$ 1.19	12.51 $\pm$ 2.36	12.57 $\pm$ 0.54	12.87 $\pm$ 1.95	<b>12.19</b>
	<b>Average</b>	<b>15.20</b>	<b>11.72</b>	<b>22.43</b>	<b>16.48</b>	<b>16.46</b>
Egg	Chicken	2.27 $\pm$ 0.13	1.31 $\pm$ 0.86	4.68 $\pm$ 0.50	5.52 $\pm$ 2.68	<b>3.45</b>
	Duck	4.24 $\pm$ 1.64	4.34 $\pm$ 0.63	3.99 $\pm$ 1.92	4.31 $\pm$ 1.10	<b>4.22</b>
	<b>Average</b>	<b>3.26</b>	<b>2.83</b>	<b>4.34</b>	<b>4.92</b>	<b>3.83</b>
Meat	Beef	4.73 $\pm$ 0.95	8.88 $\pm$ 1.73	4.71 $\pm$ 1.03	9.51 $\pm$ 3.89	<b>6.96</b>
	Mutton	2.83 $\pm$ 0.63	5.52 $\pm$ 1.86	11.35 $\pm$ 4.73	9.99 $\pm$ 1.68	<b>7.42</b>
	Chicken	4.55 $\pm$ 1.64	5.32 $\pm$ 1.59	6.16 $\pm$ 0.45	3.87 $\pm$ 0.25	<b>4.98</b>
	<b>Average</b>	<b>4.04</b>	<b>6.57</b>	<b>7.41</b>	<b>7.79</b>	<b>6.45</b>
Vegetables	Potato	15.05 $\pm$ 0.86	27.98 $\pm$ 6.69	35.81 $\pm$ 2.20	25.18 $\pm$ 4.49	<b>26.01</b>
	Brinjal	8.14 $\pm$ 1.21	12.45 $\pm$ 2.80	8.67 $\pm$ 3.79	8.89 $\pm$ 1.04	<b>9.54</b>
	Green Papaya	0.35 $\pm$ 0.02	0.84 $\pm$ 0.05	0.43 $\pm$ 0.04	0.67 $\pm$ 0.06	<b>0.57</b>
	Pointed Gourd	0.60 $\pm$ 0.03	1.76 $\pm$ 0.48	1.12 $\pm$ 0.31	3.46 $\pm$ 1.68	<b>1.74</b>
	Pumpkin	5.26 $\pm$ 0.32	7.14 $\pm$ 0.59	2.76 $\pm$ 0.34	5.92 $\pm$ 1.26	<b>5.27</b>
	Bottle Gourd	5.87 $\pm$ 1.11	2.51 $\pm$ 0.08	2.10 $\pm$ 0.76	4.10 $\pm$ 0.98	<b>3.65</b>
	Okra	13.63 $\pm$ 1.00	13.83 $\pm$ 1.33	13.51 $\pm$ 4.89	10.52 $\pm$ 2.97	<b>12.87</b>
	Tomato	14.75 $\pm$ 1.95	13.24 $\pm$ 0.11	18.14 $\pm$ 2.60	4.98 $\pm$ 1.12	<b>12.78</b>
	Red amaranth	21.95 $\pm$ 5.41	35.25 $\pm$ 7.12	48.57 $\pm$ 3.15	11.84 $\pm$ 3.23	<b>29.40</b>
	Cauliflower	1.73 $\pm$ 0.78	2.23 $\pm$ 0.82	1.34 $\pm$ 0.38	0	<b>1.33</b>
	Cabbage	3.95 $\pm$ 1.95	4.05 $\pm$ 0.86	14.340 $\pm$ 0.90	4.21 $\pm$ 1.21	<b>6.64</b>
	<b>Average</b>	<b>8.30</b>	<b>11.03</b>	<b>13.34</b>	<b>7.25</b>	<b>9.98</b>
Milk and Dairy	Liquid milk	0	0	0	0	<b>0.00</b>
	Powder milk	17.89 $\pm$ 4.34	16.38 $\pm$ 2.79	27.82 $\pm$ 10.89	26.54 $\pm$ 4.11	<b>22.16</b>
	<b>Average</b>	<b>8.95</b>	<b>8.19</b>	<b>13.91</b>	<b>13.27</b>	<b>11.08</b>
Sweetmeat	Roshogolla	29.91 $\pm$ 4.11	5.30 $\pm$ 0.84	9.13 $\pm$ 1.86	6.69 $\pm$ 2.82	<b>12.76</b>
	Jilapi	25.95 $\pm$ 2.84	21.37 $\pm$ 1.31	43.98 $\pm$ 6.75	34.15 $\pm$ 4.18	<b>31.36</b>

	<b>Average</b>	<b>27.93</b>	<b>13.34</b>	<b>26.56</b>	<b>20.42</b>	<b>22.06</b>
Oil	Mustard oil	0	0	0	0	<b>0.00</b>
	Soybean oil	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Fruits	Banana	9.81±0.54	6.36±1.93	17.53±3.12	8.69±1.12	<b>10.60</b>
	Mango	8.61±0.82	23.24±3.37	13.75±1.55	9.01±2.74	<b>13.65</b>
	Jackfruit	37.51±3.41	2.99±0.80	113.12±8.36	8.02±2.40	<b>40.41</b>
	Guava	7.38±0.55	15.56±3.49	24.13±2.37	8.11±2.20	<b>13.80</b>
	Pineapple	17.28±1.76	178.45±12.47	38.66±4.07	7.05±1.46	<b>60.36</b>
	Apple	14.43±3.09	21.36±2.78	18.18±2.08	10.96±1.81	<b>16.23</b>
	Papaya	3.77±0.52	1.96±0.21	2.93±1.01	4.83±1.22	<b>3.37</b>
	<b>Average</b>	<b>14.11</b>	<b>35.70</b>	<b>32.61</b>	<b>8.10</b>	<b>22.63</b>
Drinks	Tea/Coffee	0	0	0	0	<b>0.00</b>
	Orange Juice	0	0	0	0	<b>0.00</b>
	Mango juice	0	0	0	0	<b>0.00</b>
	Pepsi	6.74±2.31	0	0	0	<b>1.69</b>
	Drinking water	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>1.35</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.34</b>
Sugar and Molasses	Cane sugar	0	0	0	0	<b>0.00</b>
	Gur	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Processed food	Pickles	0	0	0	0	<b>0.00</b>
	Jam	0	0	0	0	<b>0.00</b>
	Jelly	0	0	0	25.27±8.26	<b>6.32</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>8.42</b>	<b>2.11</b>
Spices	Dried chilli	8.55±0.96	0	153.33±6.76	0	<b>40.47</b>
	Turmeric	112.07±7.87	149.02±13.07	105.31±25.36	91.95±1.10	<b>114.59</b>
	Onion	30.99±6.94	19.94±1.46	12.28±1.87	18.57±3.64	<b>20.45</b>
	Ginger	26.54±5.67	7.79±1.28	14.37±1.40	12.08±1.25	<b>15.20</b>
	Coriander	147.50±17.86	124.52±14.77	189.69±9.25	134.53±6.54	<b>149.06</b>
	<b>Average</b>	<b>65.13</b>	<b>60.25</b>	<b>95.00</b>	<b>51.43</b>	<b>67.95</b>
Bakery	Chips	59.61±4.25	73.78±13.88	62.84±9.22	66.02±7.24	<b>65.56</b>
	Biscuits	72.41±3.53	64.58±7.51	59.77±11.58	69.78±12.91	<b>66.64</b>
	<b>Average</b>	<b>66.01</b>	<b>69.18</b>	<b>61.31</b>	<b>67.90</b>	<b>66.10</b>

## Lead concentration

The lead (Pb) concentration markedly varied between different food groups. Relatively pulses, cereals and spices had higher Pb concentration, with the average values of 1993, 635 and 752 µg/kg, respectively (Table 4.12). Next to them, egg samples (261 µg/kg), fruits (205 µg/kg), fishes (181 µg/kg) and meats (161 µg/kg) exhibited higher Pb level. The other type of food groups such as sugar & molasses (676 µg/kg), processed foods viz. pickles, jam & jelly (640 µg/kg), sweetmeats (962 µg/kg) and bakeries e.g. chips, biscuits (1485 µg/kg) showed considerably higher Pb value. Edible oils (mustard, soybean) and drinks (pepsi, fruit juice, water) had no Pb contamination.

There was a wide variation in Pb content between the items within a food group (Table 4.12). For cereal group, the food items followed the order: bon ruti (1248 µg/kg) > rice flakes (640 µg/kg) > wheat flour (573 µg/kg) > puffed rice (520 µg/kg) > plain rice (193 µg/kg). For pulses, mungbean had higher Pb content (2207 µg/kg) than lentil (1781 µg/kg). Among the vegetables, pumpkin (94.87) displayed the highest Pb value followed by red amaranth (80.2 µg/kg), potato (73.4 µg/kg), tomato (68.4 µg/kg) and brinjal (54.4 µg/kg); the others had below 50 µg/kg Pb.

The Pb content of fish samples varied with the species, hilsa fish demonstrated the highest Pb content (206 µg/kg) and prawn did the lowest (81.5 µg/kg). The other fishes such as pangas, silver carp, tilapia and rohu had Pb levels of 206, 190, 160 and 123 µg/kg, respectively. For the case of spice items, turmeric and coriander had an elevated level of Pb, the values being 1289 and 1270 µg/kg, respectively. Next to it, dried chilli showed higher Pb value, 926 µg/kg. Ginger and onion showed low Pb concentrations of 144 and 129 µg/kg, respectively (Table 4.12).

Comparing fruit samples, jackfruit, banana, mango, pineapple and apple had Pb level in a range of 144-419 µg/kg, the highest value noted for jackfruit. Guava and papaya had the minimum Pb contamination, showing 84.2 and 19.1 µg/kg, respectively. Regarding sweetmeats, roshogolla (1310 µg/kg) possessed higher Pb contamination than jilapi (614 (84.2 µg/kg). Concerning bakery items, biscuits contained 1716 µg Pb/kg and chips 1254 µg Pb/kg (Table 4.12).

**Table 4.12** Concentration of Pb ( $\mu\text{g/kg}$  fresh weight) in different food items from four divisions  
(results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	367.56 $\pm$ 58.48	136.50 $\pm$ 0.51	115.17 $\pm$ 18.04	152.01 $\pm$ 12.95	<b>192.81</b>
	Wheat flour	141.80 $\pm$ 51.30	116.43 $\pm$ 19.99	1031.03 $\pm$ 41.94	1003.76 $\pm$ 73.77	<b>573.26</b>
	Bon ruti	3357.20 $\pm$ 1983.90	456.49 $\pm$ 60.89	720.43 $\pm$ 59.22	457.67 $\pm$ 86.00	<b>1247.95</b>
	Puffed rice	953.83 $\pm$ 22.33	0	354.32 $\pm$ 15.56	770.86 $\pm$ 102.56	<b>519.75</b>
	Rice flakes	397.42 $\pm$ 34.45	635.36 $\pm$ 4.65	746.35 $\pm$ 155.05	780.44 $\pm$ 83.62	<b>639.89</b>
	<b>Average</b>	<b>1043.56</b>	<b>268.96</b>	<b>593.46</b>	<b>632.95</b>	<b>634.73</b>
Pulses	Lentil	1753.01 $\pm$ 138.82	1495.62 $\pm$ 43.63	2429.37 $\pm$ 432.02	1444.11 $\pm$ 122.22	<b>1780.53</b>
	Mung	4256.66 $\pm$ 436.14	2260.41 $\pm$ 107.42	1071.67 $\pm$ 342.60	1239.06 $\pm$ 220.82	<b>2206.95</b>
	<b>Average</b>	<b>3004.84</b>	<b>1878.02</b>	<b>1750.52</b>	<b>1341.59</b>	<b>1993.74</b>
Fish	Hilsa	471.72 $\pm$ 38.48	275.17 $\pm$ 59.97	274.49 $\pm$ 64.04	274.48 $\pm$ 10.61	<b>323.97</b>
	Giant Prawn	70.51 $\pm$ 18.33	86.64 $\pm$ 16.55	102.08 $\pm$ 14.84	66.78 $\pm$ 11.87	<b>81.50</b>
	Rohu	138.12 $\pm$ 2.30	126.87 $\pm$ 26.52	112.28 $\pm$ 9.02	113.97 $\pm$ 13.63	<b>122.81</b>
	Silver carp	191.10 $\pm$ 3.86	152.34 $\pm$ 32.54	208.81 $\pm$ 57.50	206.15 $\pm$ 29.65	<b>189.60</b>
	Pangas	273.90 $\pm$ 63.85	166.11 $\pm$ 16.11	209.46 $\pm$ 36.11	173.02 $\pm$ 45.63	<b>205.62</b>
	Tilapia	113.71 $\pm$ 6.70	204.80 $\pm$ 52.36	163.45 $\pm$ 41.68	157.29 $\pm$ 29.95	<b>159.81</b>
	<b>Average</b>	<b>209.84</b>	<b>168.66</b>	<b>178.43</b>	<b>165.28</b>	<b>180.55</b>
Egg	Chicken	230.45 $\pm$ 15.13	242.19 $\pm$ 18.86	334.83 $\pm$ 14.50	212.98 $\pm$ 46.75	<b>255.11</b>
	Duck	212.43 $\pm$ 14.64	336.72 $\pm$ 79.63	275.07 $\pm$ 57.82	240.60 $\pm$ 7.35	<b>266.21</b>
	<b>Average</b>	<b>221.44</b>	<b>289.46</b>	<b>304.95</b>	<b>226.79</b>	<b>260.66</b>
Meat	Beef	111.27 $\pm$ 5.95	200.72 $\pm$ 47.59	184.41 $\pm$ 61.03	250.12 $\pm$ 43.89	<b>186.63</b>
	Mutton	77.67 $\pm$ 6.63	166.46 $\pm$ 36.87	200.68 $\pm$ 25.73	265.83 $\pm$ 45.68	<b>177.45</b>
	Chicken	98.46 $\pm$ 7.64	131.01 $\pm$ 57.08	145.39 $\pm$ 40.45	101.87 $\pm$ 9.25	<b>119.18</b>
	<b>Average</b>	<b>95.80</b>	<b>166.06</b>	<b>176.83</b>	<b>205.66</b>	<b>161.09</b>
Vegetables	Potato	58.12 $\pm$ 13.61	94.78 $\pm$ 6.69	75.22 $\pm$ 14.20	65.43 $\pm$ 9.49	<b>73.39</b>
	Brinjal	36.30 $\pm$ 4.66	80.75 $\pm$ 7.80	54.65 $\pm$ 4.95	45.95 $\pm$ 12.04	<b>54.41</b>
	Green Papaya	48.71 $\pm$ 7.02	52.33 $\pm$ 14.99	36.93 $\pm$ 6.44	22.20 $\pm$ 6.44	<b>40.04</b>
	Pointed Gourd	43.23 $\pm$ 13.00	62.13 $\pm$ 9.48	48.88 $\pm$ 14.83	34.70 $\pm$ 11.26	<b>47.24</b>
	Pumpkin	104.09 $\pm$ 7.32	145.26 $\pm$ 7.59	84.10 $\pm$ 48.87	46.04 $\pm$ 3.26	<b>94.87</b>
	Bottle Gourd	20.70 $\pm$ 9.68	24.96 $\pm$ 7.08	18.03 $\pm$ 3.32	17.56 $\pm$ 0.98	<b>20.31</b>
	Okra	37.56 $\pm$ 14.32	53.83 $\pm$ 7.33	7.31 $\pm$ 1.89	27.67 $\pm$ 9.67	<b>31.59</b>
	Tomato	32.19 $\pm$ 4.95	111.46 $\pm$ 44.11	81.51 $\pm$ 14.55	48.30 $\pm$ 7.12	<b>68.37</b>
	Red amaranth	62.76 $\pm$ 5.41	159.67 $\pm$ 9.95	52.93 $\pm$ 16.66	45.77 $\pm$ 3.23	<b>80.28</b>
	Cauliflower	29.31 $\pm$ 3.78	28.09 $\pm$ 9.95	0	0	<b>14.35</b>
	Cabbage	35.34 $\pm$ 4.15	62.27 $\pm$ 7.92	57.22 $\pm$ 13.90	35.03 $\pm$ 2.21	<b>47.47</b>
	<b>Average</b>	<b>46.21</b>	<b>79.59</b>	<b>46.98</b>	<b>35.33</b>	<b>52.03</b>
Milk and Dairy	Liquid milk	0	0	0	0	<b>0.00</b>
	Powder	575.04 $\pm$ 94.62	1033.69 $\pm$ 12.79	562.55 $\pm$ 134.73	1149.25 $\pm$ 54.11	<b>830.13</b>

	milk					
	<b>Average</b>	<b>287.52</b>	<b>516.85</b>	<b>281.28</b>	<b>574.63</b>	<b>415.07</b>
Sweetmeat	Roshogolla	2792.39±54.11	869.06±45.84	775.90±15.86	802.01±140.82	<b>1309.84</b>
	Jilapi	551.62±42.84	452.24±21.31	898.07±86.75	554.79±64.18	<b>614.18</b>
	<b>Average</b>	<b>1672.01</b>	<b>660.65</b>	<b>836.99</b>	<b>678.40</b>	<b>962.01</b>
Oil	Mustard oil	0	0	0	0	<b>0.00</b>
	Soybean oil	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Fruits	Banana	236.42±17.95	236.40±63.61	315.19±46.12	312.06±56.12	<b>275.02</b>
	Mango	139.07±7.05	599.04±43.37	210.10±52.73	123.34±45.76	<b>267.89</b>
	Jackfruit	520.25±53.41	2.99±0.80	1074.07±184.99	78.60±28.40	<b>418.98</b>
	Guava	84.91±13.55	0	175.38±22.37	76.48±10.96	<b>84.19</b>
	Pineapple	138.10±14.76	467.45±52.47	247.92±34.07	58.69±11.46	<b>228.04</b>
	Apple	139.53±13.09	180.21±25.78	155.00±44.34	103.11±20.81	<b>144.46</b>
	Papaya	34.57±5.52	15.69±3.21	0	26.19±7.22	<b>19.11</b>
	<b>Average</b>	<b>184.69</b>	<b>214.54</b>	<b>311.09</b>	<b>111.21</b>	<b>205.38</b>
Drinks	Tea/Coffee	0	0	0	0	<b>0.00</b>
	Orange Juice	0	0	0	0	<b>0.00</b>
	Mango juice	0	0	0	0	<b>0.00</b>
	Pepsi	0	0	0	0	<b>0.00</b>
	Drinking water	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Sugar and Molasses	Cane sugar	262.23±61.37	270.39±61.37	660.18±61.00	455.38±21.46	<b>412.05</b>
	Gur	2353.84±88.02	577.54±15.59	434.37±13.94	397.41±20.81	<b>940.79</b>
	<b>Average</b>	<b>1308.04</b>	<b>423.97</b>	<b>547.28</b>	<b>426.40</b>	<b>676.42</b>
Processed food	Pickles	2467.74±61.37	1148.43±41.37	830.20±194.62	496.91±61.46	<b>1235.82</b>
	Jam	876.31±61.37	529.52±77.11	349.31±96.55	342.63±40.81	<b>524.44</b>
	Jelly	0	0	0	637.45±68.26	<b>159.36</b>
	<b>Average</b>	<b>1114.68</b>	<b>559.32</b>	<b>393.17</b>	<b>492.33</b>	<b>639.88</b>
Spices	Dried chilli	459.73±50.96	570.37±61.37	1128.31±216.76	1547.30±121.46	<b>926.43</b>
	Turmeric	872.57±72.87	739.24±92.49	2786.13±235.36	758.21±1890.81	<b>1289.04</b>
	Onion	177.51±27.59	91.35±23.06	146.62±64.82	98.72±13.64	<b>128.55</b>
	Ginger	272.96±25.67	198.82±14.28	46.53±5.14	57.26±11.25	<b>143.89</b>
	Coriander	1820.73±170.86	1355.63±54.77	983.93±79.08	919.85±179.54	<b>1270.04</b>
	<b>Average</b>	<b>720.70</b>	<b>591.08</b>	<b>1018.30</b>	<b>676.27</b>	<b>751.59</b>
Bakery	Chips	709.19±84.25	1797.15±143.88	1521.89±155.05	987.30±81.24	<b>1253.88</b>
	Biscuits	2010.72±303.28	1605.21±278.97	2252.18±131.58	997.83±178.91	<b>1716.49</b>
	<b>Average</b>	<b>1359.96</b>	<b>1701.18</b>	<b>1887.04</b>	<b>992.57</b>	<b>1485.18</b>

When the Pb contents of different food groups for different locations are looked into (Table 4.12), the Pb variation was relatively narrow for fishes (165-210  $\mu\text{g/kg}$ ) and spices (591-1018  $\mu\text{g/kg}$ ) while it was wide for cereals (269-1044  $\mu\text{g/kg}$ ), pulses (1342-3005  $\mu\text{g/kg}$ ), vegetables (35.3-79.6  $\mu\text{g/kg}$ ), fruits (111-311  $\mu\text{g/kg}$ ) and spices (591-1018  $\mu\text{g/kg}$ ). As reported by Islam et al. (2013) on Dhaka market survey, Hazaribagh market showed the highest value and the Gulshan supermarket did the lowest. The Pb values in most cases were similar with the present study. The range of Pb variation for cereal group was 638-680  $\mu\text{g/kg}$ , for vegetables 13-65  $\mu\text{g/kg}$ , for pulses 329-711  $\mu\text{g/kg}$ , for spices 173-1324  $\mu\text{g/kg}$  and for fishes it was 12-140  $\mu\text{g/kg}$ .

### **Chromium concentration**

The chromium (Cr) concentration significantly differed between the food groups. Comparatively higher values were detected for cereals (724  $\mu\text{g/kg}$ ), spices (491  $\mu\text{g/kg}$ ) and fruits (170  $\mu\text{g/kg}$ ). Next to them were vegetables (74.6  $\mu\text{g/kg}$ ), pulses (69.4  $\mu\text{g/kg}$ ), fishes (64.5  $\mu\text{g/kg}$ ), meats (51.7  $\mu\text{g/kg}$ ), eggs (61.2  $\mu\text{g/kg}$ ). Among other groups of food, gur contained Cr of 953  $\mu\text{g/kg}$ , sweetmeat (roshogolla and jilapi) 205.8  $\mu\text{g/kg}$  and processed foods (pickles, jam & jelly) 140  $\mu\text{g/kg}$ . It's a striking note that bakery foods (chips and biscuits) had the highest Cr value (1439  $\mu\text{g/kg}$ ). Oils, drinks and cane sugar had no detectable Cr contamination (Table 4.13).

Among cereals, rice flakes recorded the maximum Cr value (977  $\mu\text{g/kg}$ ) that was followed by puffed rice (727  $\mu\text{g/kg}$ , zero for Rajshahi samples), plain rice (718  $\mu\text{g/kg}$ ), bon ruti (630  $\mu\text{g/kg}$ ) and wheat flour (568  $\mu\text{g/kg}$ ) (Table 4.13). Between two pulses, mungbean (84.2  $\mu\text{g/kg}$ ) showed higher Cr value over lentil (54.7  $\mu\text{g/kg}$ ). For different types of vegetables, the highest value was noted with potato (269  $\mu\text{g/kg}$ ) and then chronologically pumpkin (122  $\mu\text{g/kg}$ ), okra (85.4  $\mu\text{g/kg}$ ), brinjal (85.1  $\mu\text{g/kg}$ ), pointed gourd (62.4  $\mu\text{g/kg}$ ), green papaya (60.9  $\mu\text{g/kg}$ ), bottle gourd (56.6  $\mu\text{g/kg}$ ), tomato (27.6  $\mu\text{g/kg}$ ) and cabbage (2.20  $\mu\text{g/kg}$ ).

Concerning fruits, the highest value (652  $\mu\text{g/kg}$ ) was detected for pineapple followed by banana (283  $\mu\text{g/kg}$ ) and the lowest for papaya (5.11  $\mu\text{g/kg}$ ). The other types of fruits (mango, jackfruit, guava and apple) had Cr level in a range of 40.8-89.9  $\mu\text{g/kg}$ . Of the different types of spices, coriander produced the highest value (1037  $\mu\text{g/kg}$ ) which followed turmeric (866  $\mu\text{g/kg}$ ), dried chilli (401  $\mu\text{g/kg}$ ), onion (85.3  $\mu\text{g/kg}$ ) and ginger 65.0  $\mu\text{g/kg}$ ) (Table 4.13).

Referring fishes, silver carp had the highest Cr contamination (144 µg/kg) and the next highest was noted for pangas (93.9 µg/kg) followed by hilsa (50.1 µg/kg). The other fish species such as prawn, rohu and tilapia had lower Cr level with a range of 18.1- 48.5 µg/kg (Table 4.13). As far spices are concerned, coriander followed by turmeric and dried chilli showed higher Cr values, the values being 1037, 866 and 401 µg/kg, respectively. Quite a high amount of Cr was detected for bakery items with the values of 1573 µg/kg for chips and 1304 µg/kg for biscuits (Table 4.13).

For two types of egg, chicken egg (99.0 (144 µg/kg) contained higher level than duck egg (23.3 (144 µg/kg). Meat samples followed the order of beef (98.2 µg/kg), mutton (39.9 µg/kg) and chicken (17.1 µg/kg). It is noted that liquid milk did not contain detectable Cr while powder milk had a lot of Cr (62.3 µg/kg). Regarding sweetmeat, roshogolla (272 µg/kg) contained more Cr than jilapi (139 µg/kg). Gur was highly contaminated with Cr, the value being 953 µg/kg. Between processed foods, pickles had higher Cr contamination (220 µg/kg) followed by jelly (156 µg/kg) and jam (45.4 µg/kg) (Table 4.13).

Considering location variation for Cr level in foods (Table 4.13), it reveals that the variation for cereals was 638-780 µg/kg, pulses 23-106 µg/kg, vegetables 66.0-85.7 µg/kg, fruits 28.1-485 µg/kg, pulses 23-106 µg/kg, spices 372-667 µg/kg, 29.4 97.6 µg/kg, meats 18.7-105.7 µg/kg and eggs 8.02-147 µg/kg).



**Table 4.13** Concentration of Cr ( $\mu\text{g/kg}$  fresh weight) in different food items from four divisions  
(results are the means of 3 upazilas)

Food items		Locations				
Group	Name	Mymensingh	Rajshahi	Khulna	Chattogram	Average
Cereals	Rice	230.28 $\pm$ 12.00	881.90 $\pm$ 3.28	925.99 $\pm$ 74.24	833.45 $\pm$ 118.83	<b>717.91</b>
	Wheat flour	1128.19 $\pm$ 53.30	870.46 $\pm$ 23.99	11.42 $\pm$ 2.76	261.22 $\pm$ 7.77	<b>567.82</b>
	Bon ruti	736.21 $\pm$ 17.50	558.03 $\pm$ 105.52	1031.42 $\pm$ 59.22	196.20 $\pm$ 16.00	<b>630.47</b>
	Puffed rice	1027.10 $\pm$ 132.01	0	797.52 $\pm$ 189.56	1083.37 $\pm$ 164.33	<b>727.00</b>
	Rice flakes	779.08 $\pm$ 69.48	987.99 $\pm$ 88.18	1323.99 $\pm$ 155.05	816.11 $\pm$ 28.57	<b>976.79</b>
	<b>Average</b>	<b>780.17</b>	<b>659.68</b>	<b>818.07</b>	<b>638.07</b>	<b>724.00</b>
Pulses	Lentil	70.66 $\pm$ 8.82	61.16 $\pm$ 9.63	46.05 $\pm$ 8.68	40.73 $\pm$ 9.22	<b>54.65</b>
	Mung	88.61 $\pm$ 17.96	77.33 $\pm$ 7.42	0	170.81 $\pm$ 20.82	<b>84.19</b>
	<b>Average</b>	<b>79.64</b>	<b>69.25</b>	<b>23.03</b>	<b>105.77</b>	<b>69.42</b>
Fish	Hilsa	140.36 $\pm$ 38.48	13.48 $\pm$ 5.97	40.06 $\pm$ 4.04	6.50 $\pm$ 0.00	<b>50.10</b>
	Giant Prawn	26.88 $\pm$ 8.33	3.20 $\pm$ 0.55	21.15 $\pm$ 7.22	21.17 $\pm$ 8.87	<b>18.10</b>
	Rohu	12.62 $\pm$ 2.30	18.81 $\pm$ 6.52	16.09 $\pm$ 2.02	81.04 $\pm$ 7.63	<b>32.14</b>
	Silver carp	129.67 $\pm$ 13.86	43.99 $\pm$ 21.54	158.30 $\pm$ 7.50	244.26 $\pm$ 29.65	<b>144.06</b>
	Pangas	231.83 $\pm$ 6.85	26.51 $\pm$ 1.11	37.47 $\pm$ 3.35	79.57 $\pm$ 5.63	<b>93.85</b>
	Tilapia	44.42 $\pm$ 6.70	70.21 $\pm$ 2.36	28.25 $\pm$ 4.68	51.20 $\pm$ 9.95	<b>48.52</b>
	<b>Average</b>	<b>97.63</b>	<b>29.37</b>	<b>50.22</b>	<b>80.62</b>	<b>64.46</b>
Egg	Chicken	261.96 $\pm$ 15.13	53.66 $\pm$ 6.86	16.04 $\pm$ 4.50	64.35 $\pm$ 6.75	<b>99.00</b>
	Duck	32.48 $\pm$ 2.64	27.77 $\pm$ 4.63	0	33.06 $\pm$ 7.35	<b>23.33</b>
	<b>Average</b>	<b>147.22</b>	<b>40.72</b>	<b>8.02</b>	<b>48.71</b>	<b>61.17</b>
Meat	Beef	54.89 $\pm$ 2.555	32.60 $\pm$ 7.59	50.61 $\pm$ 6.03	254.86 $\pm$ 44.89	<b>98.24</b>
	Mutton	13.95 $\pm$ 3.44	14.56 $\pm$ 1.87	93.68 $\pm$ 12.73	37.19 $\pm$ 13.68	<b>39.85</b>
	Chicken	31.96 $\pm$ 6.44	9.04 $\pm$ 0.08	2.50 $\pm$ 0.45	25.02 $\pm$ 1.25	<b>17.13</b>
	<b>Average</b>	<b>33.60</b>	<b>18.73</b>	<b>48.93</b>	<b>105.69</b>	<b>51.74</b>
Vegetables	Potato	215.03 $\pm$ 32.19	297.94 $\pm$ 37.69	276.70 $\pm$ 29.20	286.02 $\pm$ 30.49	<b>268.92</b>
	Brinjal	73.30 $\pm$ 4.66	84.34 $\pm$ 2.78	89.91 $\pm$ 13.42	92.83 $\pm$ 14.04	<b>85.10</b>
	Green Papaya	82.52 $\pm$ 7.02	64.54 $\pm$ 14.27	48.02 $\pm$ 3.25	48.35 $\pm$ 0.97	<b>60.86</b>
	Pointed gourd	86.70 $\pm$ 13.00	50.54 $\pm$ 6.12	55.66 $\pm$ 4.83	56.13 $\pm$ 14.26	<b>62.26</b>
	Pumpkin	106.28 $\pm$ 7.32	184.10 $\pm$ 47.59	115.64 $\pm$ 8.87	81.81 $\pm$ 21.67	<b>121.96</b>
	Bottle Gourd	96.13 $\pm$ 9.68	39.59 $\pm$ 1.56	30.50 $\pm$ 3.32	60.29 $\pm$ 9.98	<b>56.63</b>
	Okra	112.29 $\pm$ 14.34	97.03 $\pm$ 17.91	51.19 $\pm$ 4.89	80.88 $\pm$ 5.01	<b>85.35</b>
	Tomato	77.48 $\pm$ 13.95	10.01 $\pm$ 2.11	8.63 $\pm$ 1.55	14.06 $\pm$ 4.50	<b>27.55</b>
	Red amaranth	20.52 $\pm$ 5.41	112.33 $\pm$ 7.95	47.33 $\pm$ 4.66	17.25 $\pm$ 3.53	<b>49.36</b>
	Cauliflower	1.34 $\pm$ 0.49	0	0	0	<b>0.34</b>
	Cabbage	1.19 $\pm$ 0.15	1.73 $\pm$ 0.12	2.41 $\pm$ 0.90	3.46 $\pm$ 1.21	<b>2.20</b>
	<b>Average</b>	<b>79.34</b>	<b>85.65</b>	<b>66.00</b>	<b>67.37</b>	<b>74.59</b>
Milk and Dairy	Liquid milk	0	0	0	0	<b>0.00</b>
	Powder	80.06 $\pm$ 9.62	62.33 $\pm$ 16.36	24.60 $\pm$ 4.73	166.72 $\pm$ 5.11	<b>1875.49</b>

	milk					
	<b>Average</b>	<b>40.03</b>	<b>31.17</b>	<b>12.30</b>	<b>83.36</b>	<b>937.75</b>
Sweetmeat	Roshogolla	756.24±46.11	230.43±14.84	11.42±1.86	91.42±14.82	<b>272.38</b>
	Jilapi	6.42±2.84	52.42±2.31	459.83±16.75	38.44±4.18	<b>139.28</b>
	<b>Average</b>	<b>381.33</b>	<b>141.43</b>	<b>235.63</b>	<b>64.93</b>	<b>205.83</b>
Oil	Mustard oil	0	0	0	0	<b>0.00</b>
	Soybean oil	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Fruits	Banana	42.21±1.95	592.55±63.61	310.48±41.12	185.51±6.12	<b>282.69</b>
	Mango	42.46±5.05	177.41±43.37	99.52±5.73	40.29±6.76	<b>89.92</b>
	Jackfruit	80.49±5.41	5.99±0.80	141.44±14.99	13.60±2.40	<b>60.38</b>
	Guava	11.88±3.55	58.94±5.80	142.26±18.37	17.70±1.96	<b>57.70</b>
	Pineapple	16.40±1.76	2516.04±306.47	57.77±3.07	17.41±1.46	<b>651.91</b>
	Apple	0	38.55±2.78	65.38±4.34	59.44±3.81	<b>40.84</b>
	Papaya	3.12±0.52	5.21±3.21	0	12.09±1.22	<b>5.11</b>
	<b>Average</b>	<b>28.08</b>	<b>484.96</b>	<b>116.69</b>	<b>49.43</b>	<b>169.79</b>
Drinks	Tea/Coffee	0	0	0	0	<b>0.00</b>
	Orange Juice	0	0	0	0	<b>0.00</b>
	Mango juice	0	0	0	0	<b>0.00</b>
	Pepsi	0	0	0	0	<b>0.00</b>
	Drinking water	0	0	0	0	<b>0.00</b>
	<b>Average</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>	<b>0.00</b>
Sugar and Molasses	Cane sugar	0	0	0	0	<b>0.00</b>
	Gur	0	2971.96±165.59	87.99±13.94	751.95±20.81	<b>952.98</b>
	<b>Average</b>	<b>0.00</b>	<b>1485.98</b>	<b>44.00</b>	<b>375.98</b>	<b>476.49</b>
Processed food	Pickles	714.99±61.37	111.66±4.37	33.36±4.62	18.67±1.46	<b>219.67</b>
	Jam	129.81±19.30	0	0	51.86±9.81	<b>45.42</b>
	Jelly	0	0	0	623.68±60.26	<b>155.92</b>
	<b>Mean</b>	<b>281.60</b>	<b>37.22</b>	<b>11.12</b>	<b>231.40</b>	<b>140.34</b>
Spices	Dried chilli	89.73±20.96	234.20±16.37	845.69±126.76	434.91±21.46	<b>401.13</b>
	Turmeric	1210.73±72.87	791.84±92.49	862.89±135.36	597.87±98.81	<b>865.83</b>
	Onion	154.55±27.59	37.84±10.06	95.91±6.82	52.84±11.64	<b>85.29</b>
	Ginger	53.12±21.67	56.24±18.28	113.64±5.14	36.95±10.06	<b>64.99</b>
	Coriander	1828.66±170.86	623.24±24.77	958.90±45.08	737.74±19.54	<b>1037.14</b>
	<b>Average</b>	<b>667.36</b>	<b>348.67</b>	<b>575.41</b>	<b>372.06</b>	<b>490.88</b>
Bakery	Chips	1558.94±208.63	1519.49±221.88	1647.84±220.34	1564.33±136.24	<b>1572.65</b>
	Biscuits	1275.84±118.61	1570.62±290.97	1120.46±131.58	1250.61±201.91	<b>1304.38</b>
	<b>Average</b>	<b>1417.39</b>	<b>1545.06</b>	<b>1384.15</b>	<b>1407.47</b>	<b>1438.52</b>

### 4.3.2 Intake of heavy metals

#### Arsenic intake

Arsenic intake due to consumption of different foods by the people of different districts varied widely (Table 4.14a). The lowest dietary mean As intake by the adult male was observed in Mymensingh division (37.7 µg/d) and the highest value (159 µg/d) was noted in Khulna division, followed by Chattogram (144 µg/d). Similar trend was noticed for As intake by female and by boys or girls since

Female intake = Male intake  $\times$  0.90 and boy and girl intake (10-12 yrs) = Male intake  $\times$  0.50. So, the As intake by female was lower than that by male and it ranged from 34.0 µg/d in Rajshahi division to 143 µg/d in Khulna division. For the case of both boys and girls, the As intake range was between 18.8 and 79.6 µg/d.

The higher dietary intake of As by the population of Khulna division was probably due to high As in irrigation water and soils which ultimately enters into the food chain (Alam et al., 2003; Islam et al., 2005, Williams et al., 2006). The contribution of cereals was the highest (59.5-70.5%) for the dietary intake of As across the four divisions (Table 4.15). Drinking water contributed 14.4-20.6% of the total dietary intake of As over the populations studied. The contribution of fishes was 5.5-18.9%, while vegetables contributed to 2.02-3.09% of the dietary intake of As, in four divisions of Bangladesh.

#### Cadmium intake

Dietary cadmium intake by the people of different divisions varied widely with the lowest mean value of 15.9 µg/d in Mymensingh division to the highest value of 48.1 µg/d in Chattogram division (Table 4.14b). The trend of dietary mean Cd intake was in the order: Chattogram > Khulna > Rajshahi > Mymensingh. The dietary intake of Cd by the adult male of Mymensingh, Rajshahi, Khulna and Chattogram divisions was on an average 15.9, 32.4, 37.6 and 48.1 µg/d, respectively. The mean Cd intake by the adult female was 14.3, 29.2, 33.8 and 43.3 µg/d for the four divisions, respectively. This element intake by boys & girls was found as 7.95, 16.2, 18.8 and 24.0 µg/d, respectively. The Cd content of food items depend on fertilizers (Roberts, 2014), bedrock geology, soil formation and weathering, plant types and soil management practices (Hu et al. 2016; Zhao and Wang 2020).

Cereals were the main sources of dietary intake of Cd (69.53-76.46%) followed by vegetables (5.79-16.53%), pulses (0.13-15.58%) and fishes (0.96-2.56%) for the population of different divisions of Bangladesh (Table 4.14b). The contribution of cereals was the highest (69.5-86.0%) for the dietary intake of As across the four divisions, the highest value being for Rajshahi and the lowest value for Mymensingh (Table 4.15). Pulses contributed 0.13-15.6% dietary intake across the four divisions with the highest value noted for Chattogram and the lowest for Rajshahi. For the case of vegetables, Khulna had the highest (16.5%) and Chattogram showed the lowest contribution (4.79%).

**Table 14.4a** Statistics for intake of **arsenic** ( $\mu\text{g/d}$ ) by the different groups of people of Mymensingh, Rajshahi, Khulna and Chattogram divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Adult Male</b>				
Minimum	18.87	34.07	110.5	100.88
Maximum	72.42	106.91	289.56	309.3
Mean $\pm$ SD	37.74 $\pm$ 9.17	59.2 $\pm$ 12.85	159.2 $\pm$ 28.78	144.03 $\pm$ 34.68
<b>Adult Female</b>				
Minimum	16.983	30.663	99.45	90.792
Maximum	65.178	96.219	260.604	278.37
Mean $\pm$ SD	33.97 $\pm$ 8.25	53.28 $\pm$ 11.57	143.28 $\pm$ 25.90	129.63 $\pm$ 31.21
<b>Boys</b>				
Minimum	9.435	17.035	55.25	50.44
Maximum	36.21	53.455	144.78	154.65
Mean $\pm$ SD	18.87 $\pm$ 4.59	29.6 $\pm$ 6.42	79.6 $\pm$ 6.43	72.02 $\pm$ 14.39
<b>Girls</b>				
Minimum	9.435	17.035	55.25	50.44
Maximum	36.21	53.455	144.78	154.65
Mean $\pm$ SD	18.87 $\pm$ 4.59	29.6 $\pm$ 6.42	79.6 $\pm$ 6.43	72.02 $\pm$ 14.39

Calculation: Female intake = Male intake  $\times$  0.90

Boy and girl (10-12 yr) intake = Male  $\times$  0.50

Previous studies have also pointed to the variation in arsenic concentrations in rice and this has only been partially consistent with the pattern of arsenic concentrations in drinking water tube wells. There was no evidence from yield or panicle sterility data of arsenic toxicity to rice. Processing of rice (parboiling and milling) reduced arsenic concentrations in rice by an average of 19% in rice samples collected from households (Duxbury JM et al 2003).

**Table 14.4b** Statistics for intake of **cadmium** ( $\mu\text{g/d}$ ) by the different groups of people of

Mymensingh, Rajshahi, Khulna and Chattogram divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Adult Male</b>				
Minimum	5.55	12.67	23.15	37.62
Maximum	24.75	68.07	63.25	92.77
Mean± SD	15.90±3.81	32.42±8.59	37.55±6.74	48.06±11.78
<b>Adult Female</b>				
Minimum	4.995	11.403	20.835	33.858
Maximum	22.275	61.263	56.925	83.493
Mean± SD	14.31±1.09	29.18±7.73	33.80±6.07	43.25±10.66
<b>Boys</b>				
Minimum	2.775	6.335	11.575	18.81
Maximum	12.375	34.035	31.625	46.385
Mean± SD	7.95±1.90	16.21±4.29	18.78±3.37	24.03±5.81
<b>Girls</b>				
Minimum	2.775	6.335	11.575	18.81
Maximum	12.375	34.035	31.625	46.385
Mean± SD	7.95±1.90	16.21±4.29	18.78±3.37	24.03±5.81

### Lead intake

The dietary Pb intake by the adult male differed markedly with the four divisions (Table 4.14c). The Pb mean intake value for adult male was the highest in Mymensingh division (228 µg/d) followed by Chattogram (147 µg/d), Khulna (131 µg/d) and Rajshahi (113 µg/d) division. For the adult female, these values were 206, 133, 118 and 102 µg/d, respectively. The Pb intake by boys & girls was chronologically 114, 73.6, 65.4 and 56.5 µg/d.

The contribution of cereals was the highest (31.0-65.1%) for the dietary intake of Pb across the four divisions (Table 4.16). Pulses contributed to a wide range from 6.35 to 19.24% % of the total dietary intake of Pb over the populations studied. The contribution of vegetables was from 3.74-14.19% of the dietary intake of Pb in four divisions of Bangladesh.

**Table 14.4c** Statistics for intake of **lead** ( $\mu\text{g/d}$ ) by the different groups of people of Mymensingh, Rajshahi, Khulna and Chattogram divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	83.72	43.33	54.50	114.69
Maximum	417.24	390.50	339.48	358.76
Mean $\pm$ SD	228.43 $\pm$ 71.50	113.03 $\pm$ 43.22	130.73 $\pm$ 60.04	147.26 $\pm$ 54.21
<b>Female</b>				
Minimum	75.348	38.997	49.05	103.221
Maximum	375.516	351.45	305.532	322.884
Mean $\pm$ SD	205.587 $\pm$ 64.35	101.727 $\pm$ 38.89	117.657 $\pm$ 54.03	132.534 $\pm$ 48.78
<b>Boy</b>				
Minimum	41.86	21.665	27.25	57.345
Maximum	208.62	195.25	169.74	179.38
Mean $\pm$ SD	114.215 $\pm$ 35.75	56.515 $\pm$ 21.61	65.365 $\pm$ 30.02	73.63 $\pm$ 27.10
<b>Girl</b>				
Minimum	41.86	21.665	27.25	57.345
Maximum	208.62	195.25	169.74	179.38
Mean $\pm$ SD	114.215 $\pm$ 35.75	56.515 $\pm$ 21.61	65.365 $\pm$ 30.02	73.63 $\pm$ 27.10

### Chromium intake

There was a significant variation in dietary intake of Cr by the people of the four divisions (Table 4.14d). The lowest dietary mean Cr intake ( $67.1 \mu\text{g/d}$ ) by adult male was recorded in Rajshahi division and the highest ( $370 \mu\text{g/d}$ ) was noted for Khulna division. The trend of mean dietary Cr intake was in the order: Khulna>Chattogram>Mymensingh>Rajshahi. The dietary intake of Cr by adult female was calculated as 333, 297, 121 and  $60.4 \mu\text{g/d}$  for the four divisions, respectively. Similarly for the boys and girls, the Cr intake followed the order: 185, 165, 67.0 and  $33.5 \mu\text{g/d}$  over the divisions.

Cereals are the main contributor to dietary intake of Cr (76.3%-89.3%) by the population of four divisions of Bangladesh (Table 4.16). Next to cereals, fishes, vegetables and meat had contribution to the Cr intake by the population of four divisions.

**Table 14.4d** Statistics for intake of **chromium** ( $\mu\text{g/d}$ ) by the different groups of people of Mymensingh, Rajshahi, Khulna and Chattogram divisions

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	49.45	27.07	209.37	277.93
Maximum	233.03	121.68	522.94	678.04
Mean $\pm$ SD	133.99 $\pm$ 35.24	67.06 $\pm$ 19.00	370.42 $\pm$ 71.42	330.22 $\pm$ 88.18
<b>Female</b>				
Minimum	44.505	24.363	188.43	250.13
Maximum	209.72	109.51	470.64	610.23
Mean $\pm$ SD	120.59 $\pm$ 31.71	60.35 $\pm$ 17.1	333.37 $\pm$ 64.27	297.19 $\pm$ 79.01
<b>Boy</b>				
Minimum	24.72	13.53	104.68	138.96
Maximum	116.51	60.84	261.47	339.02
Mean $\pm$ SD	66.99 $\pm$ 17.62	33.53 $\pm$ 9.50	185.21 $\pm$ 35.71	165.11 $\pm$ 40.58
<b>Girl</b>				
Minimum	24.72	13.53	104.68	138.96
Maximum	116.51	60.84	261.47	339.02
Mean $\pm$ SD	66.99 $\pm$ 17.62	33.53 $\pm$ 9.50	185.21 $\pm$ 35.71	165.11 $\pm$ 40.58

As an essential trace element, chromium is found in many kinds of food. We must get from our diets, though our bodies only require small amounts. Chromium plays an important role in blood sugar regulation, brain function, and breaking down fats and carbohydrates. Chromium is also useful in type 2 diabetes, helping diabetics control their blood sugar and play a role in its management. Chromium supplements given are like medications. They can interact with other substances, and too much can be harmful.

**Table 4.15** Contribution (%) of each food group to dietary exposure to arsenic and cadmium for an adult of four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram	Mymensingh	Rajshahi	Khulna	Chattogram
	<b>Arsenic</b>				<b>Cadmium</b>			
1. Cereals	59.57	66.60	70.5	66.47	69.53	86.34	76.01	76.46
2. Pulses	0.46	0.07	0.2	5.04	8.11	0.13	1.06	15.58
3. Fish	18.93	9.64	5.5	9.32	5.76	0.96	2.56	2.01
4. Eggs	0.01	0.00	0.0	0.00	0.01	0.00	0.00	0.00
5. Meat	1.75	1.67	0.6	1.16	0.94	1.06	0.43	0.41
6. Vegetables	2.02	2.20	2.1	3.09	14.23	10.55	16.53	4.79
7. Milk and dairy	0.25	0.10	0.0	0.07	0.03	0.02	0.04	0.21
8. Sweet meat	0.00	0.00	0.0	0.01	0.41	0.00	0.06	0.01
9. Oil and fats	0.78	0.00	0.3	0.00	0.0	0.00	0.00	0.00
10. Fruits	0.29	0.31	0.2	0.16	0.99	0.93	2.24	0.54
11. Drinks	0.00	0.02	0.0	0.00	0.00	0.00	0.00	0.00
12. Sugar & Molasses	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
13. Jam & Jelly	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00
14. Drinking water	20.37	19.40	20.6	14.40	0.00	0.00	1.06	0.00

**Table 4.16** Contribution (%) of each food group to dietary exposure to lead and chromium for an adult of four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram	Mymensingh	Rajshahi	Khulna	Chattogram
	<b>Lead</b>				<b>Chromium</b>			
1. Cereals	65.09	51.34	31.03	59.11	76.25	89.07	89.25	88.68
2. Pulses	19.24	16.38	6.35	12.60	1.25	0.05	0.06	0.18
3. Fish	4.67	4.72	4.45	7.65	4.63	7.51	0.84	1.81
4. Eggs	0.04	0.07	0.04	0.03	0.02	0.00	0.00	0.00
5. Meat	1.47	7.16	2.00	3.49	1.00	1.32	0.20	0.74
6. Vegetables	3.74	14.19	6.51	5.75	14.99	1.78	7.49	6.50
7. Milk and dairy	0.06	0.31	0.14	2.83	0.01	0.01	0.00	0.18
8. Sweet meat	2.68	0.00	0.82	0.56	1.24	0.00	0.10	0.03
9. Oil and fats	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10. Fruits	1.34	3.16	4.08	3.57	0.44	0.25	2.00	0.85
11. Drinks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12. Sugar and Molasses	1.32	2.55	1.62	3.95	0.00	0.00	0.14	0.00
13. Jam and Jelly	0.35	0.12	0.00	0.47	0.17	0.00	0.00	0.01
14. Drinking water	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01



### **4.3.3 Health Implications due to consumption of heavy metals**

#### **Carcinogenic risk of arsenic**

Enough evidence exists for arsenic to be classified as a human carcinogen of group 1. Exposure to inorganic arsenic via ingestion is associated with multiple types of cancer, such as lung, bladder, and skin; and potentially with cancers of the kidney, liver, and prostate (IARC, 2012). Dietary intake of As poses incremental life cancer risk (ILCR) for all the populations of all four divisions (Table 4.17a). The lowest mean ICLR of  $6.9 \times 10^{-4}$  adult male was found in Mymensingh division and the highest ICLR of  $29.4 \times 10^{-4}$  was observed in Khulna division which was followed by chattogram division ( $22.7 \times 10^{-4}$ ) and then Rajshahi division ( $10.9 \times 10^{-4}$ ). Similar trend was noticed for adult female, boys and girls: Khulna > Chattogram > Rajshai > Mymensingh. It was also noted that the ICLR was the highest for female followed by male, boys and girls. Islam et al. (2017) state that females compared to males are more susceptible to non-carcinogenic As risk.

All the observed ICLR values were higher than the USEPA threshold level ( $1 \times 10^{-6}$ ) or residual level ( $1 \times 10^{-4}$ ) for causing cancer. Islam et al (2014) reported the ICLR value due to dietary intake of As by the male adult population of Bogra district were  $4.7 \times 10^{-3}$ ,  $3.4 \times 10^{-4}$ ,  $3.8 \times 10^{-4}$ ,  $2.1 \times 10^{-4}$ , and  $2.0 \times 10^{-4}$  for rice, wheat, maize, lentil, and black gram, respectively. Islam et al. (2017) calculated ICLR for individuals due to the consumption of rice varied between  $0.57 \times 10^{-3}$  to  $2.88 \times 10^{-3}$  in different districts, and  $0.54 \times 10^{-3}$  to  $2.12 \times 10^{-3}$  in different rice varieties, higher than the US EPA threshold.

#### **Carcinogenic risk of cadmium**

The International Agency for Research on Cancer (IARC) has classified Cd as being of carcinogenic risk to humans (Group 1) (IARC, 1993). The renal cortex appears to be the most sensitive target tissue in humans, with implications for chronic kidney failure. Toxicity is in part due to Cd's extremely long half-life in mammalian systems, being about 15 years in human kidneys, so a steady state would be achieved in 45–60 years of exposure (Honda et al., 2010; WHO, 2010b).

The ICLR values due to dietary intake of Cd varied widely with food sampling divisions (Table 4.17b), Chattogram division showed the highest carcinogenic risk of Cd. Like As risk exposure,

the Cd risk exposure followed the same order: female > male > boys > girls. The lowest ILCR of  $36.7 \times 10^{-4}$  was found in adult male of Mymensingh division and the highest ILCR value of  $111 \times 10^{-4}$  was observed in adult male of Chattogram division. The mean ILCR values due to dietary intake of Cd for adult male in Rajshahi and Khulna divisions were  $74.8 \times 10^{-4}$  and  $86.7 \times 10^{-4}$ , respectively. Meharg et al. (2009) reported the ILCR value of 22.1 in 10,000 due to consumption of rice alone by Bangladeshi people.

### **Carcinogenic risk of lead**

Lead is a potential carcinogen (Group 2B) that primarily affects the blood, nervous system and kidneys. In the blood at high concentrations, lead inhibits red blood cell formation and eventually results in anaemia (WHO, 2000b). The effects of high concentrations of lead on the nervous system can vary from hyperactive behaviour and mental retardation to seizures and cerebral palsy. As the kidneys are the primary route for lead excretion, lead tends to accumulate in these organs, causing irreversible damage.

The ILCR values due to dietary intake of Pb varied about two-fold among the divisions of Bangladesh (Table 4.17c). The population of Mymensingh division had the highest mean ILCR value ( $299 \times 10^{-4}$ ) whereas the lowest mean ILCR value ( $148 \times 10^{-4}$ ) was found among the population of Rajshahi division. The second highest cancer risk was recorded in the population of Chattogram division ( $193 \times 10^{-4}$ ) followed by the population of Khulna division ( $171 \times 10^{-4}$ ). Similar to As and Cd risk exposure, adult male had the highest cancer to Pb exposure which followed adult male and then boys and girls. All these values were higher than the USEPA threshold level ( $10^{-6}$ ) or residual level ( $10^{-4}$ ) for causing cancer. Islam et al (2014) reported the ILCR value due to dietary intake of Pb were  $4.5 \times 10^{-5}$ ,  $1.1 \times 10^{-6}$ ,  $1.1 \times 10^{-6}$ ,  $1.2 \times 10^{-6}$ , and  $1.1 \times 10^{-6}$  for rice, wheat, maize, lentil, and black gram, respectively indicating carcinogenic risks for the male adults of Bogra district.

### **Carcinogenic risk of chromium**

The ILCR values due to dietary intake of Cr were very low over the divisions and population groups showing a range from  $0.5 \times 10^{-4}$  (for all groups in Rajshahi division) to  $2.7 \times 10^{-4}$  (female adult in Khulna and Chattogram divisions (Table 4.17d). The population group showed the same ILCR pattern with the other heavy metals (As, Cd and Pb) i.e. female > male > boys > girls. The ILCR values due to dietary Cr intake by adult male were  $0.52 \times 10^{-4}$ ,  $1.03 \times 10^{-4}$ ,  $2.56 \times 10^{-4}$ , and

$2.85 \times 10^{-4}$  in Rajshahi, Mymensingh, Chattogram and Khulna divisions, respectively. All these values fall within the residual level ( $10^{-4}$ ) for causing cancer. Therefore, dietary intake of Cr would not impose any cancer effect on human body.

Thus, the people of different divisions of Bangladesh are taking an elevated level of arsenic, cadmium and lead through different food items and the level is exceedingly high for Pb (148-299 adult male per 10,000 populations). Between As and Cd risk exposure, the value is higher for Cd (36.7 – 111 adult male per 10,000 populations) than for As (6.9-29.4 adult male per 10,000 populations). It is noted that among the four divisions, the population of Khulna is most affected by As contaminants, that of Chattogram by Cd and the population of Mymensingh division by Pb. Nevertheless, health impacts may be compounded by consuming a cocktail of all these three heavy toxic metals (Pb, Cd and As) which might find their way into the food system. Given their wide occurrence and distribution in the environment, their entry into the food system raises concern and attention over their potential effects on human health and the environment.

**Table 4.17a** Incremental Life Cancer Risk (ILCR) of the population (per 10,000 populations) of Mymensingh, Rajshahi, Khulna and Chattogram divisions due to dietary intake of **arsenic**

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	3.4	6.3	20.4	18.6
Maximum	13.4	19.7	53.5	57.1
Mean± SD	6.9±1.7	10.9±2.4	29.4±5.3	22.7±6.4
<b>Female</b>				
Minimum	3.70	6.69	21.70	19.81
Maximum	14.22	20.99	56.86	60.74
Mean± SD	7.41±1.8	11.62±2.52	31.26±5.65	28.28±6.69
<b>Boys</b>				
Minimum	3.24	6.89	8.33	8.41
Maximum	12.45	21.67	21.83	25.77
Mean± SD	6.49± 1.58	10.18 ±1.86	27.37±0.97	24.76±2.40
<b>Girls</b>				
Minimum	3.11	5.61	18.21	16.63
Maximum	11.94	17.62	47.73	50.98
Mean± SD	6.22±1.51	9.76±2.12	26.24±2.12	23.74±4.74

**Table 4.17b** Incremental Life Cancer Risk (ILCR) of the population (per 10,000 populations) of Mymensingh, Rajshahi, Khulna and Chattogram divisions due to dietary intake of **cadmium**

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	12.8	29.2	53.4	86.8
Maximum	57.1	157.1	146.0	214.1
Mean± SD	36.7±8.8	74.8±19.8	86.7±15.6	110.9±27.2
<b>Female</b>				
Minimum	13.6	31.1	56.7	92.3
Maximum	60.7	167.1	155.2	227.7
Mean± SD	39.0±3.0	79.6±21.1	92.2±16.6	117.9±29.2
<b>Boys</b>				
Minimum	11.9	27.2	49.9	80.8
Maximum	53.2	146.3	135.8	199.4
Mean± SD	34.2±8.2	69.7 ±18.4	80.7±14.5	103.3±25.0
<b>Girls</b>				
Minimum	11.5	26.1	47.7	77.5
Maximum	51.0	140.1	130.3	107.0
Mean± SD	32.8±7.8	26.1±17.7	77.4 ±13.9	99.0±13.4

**Table 4.17c** Incremental Life Cancer Risk (ILCR) of the population (per 10,000 populations) of Mymensingh, Rajshahi, Khulna and Chattogram divisions due to dietary intake of **lead**

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	193.2	100.0	125.8	264.7
Maximum	962.9	901.2	783.4	828.0
Mean± SD	298.7±165.0	147.8 ±99.7	171.0 ±138.6	192.6 ±125.1
<b>Female</b>				
Minimum	205.4	106.4	133.6	281.5
Maximum	1024.1	957.3	831.8	880.6
Mean± SD	317.7 ±175.5	157.3 ±106.1	181.9 ±147.3	204.8 ±133.3
<b>Boys</b>				
Minimum	179.7	93.3	117.3	246.3
Maximum	896.6	839.4	729.4	771.1
Mean± SD	278.1 ±153.4	125.5 ±92.8	159.3 ±128.9	179.3 ±116.5
<b>Girls</b>				
Minimum	172.3	89.4	112.5	236.1
Maximum	859.6	804.8	699.3	739.3
Mean± SD	266.7±147.1	120.3 ±89.0	152.7 ±123.6	171.9 ±65.5

Benefo et al (2019) determined chronic daily intake (CDI) of lead and estimated the risks in terms of the margin of exposure (MoE) and incremental lifetime cancer risk (ILTCR). Across the three age groups, the modal CDI ranged between 0.007 and 0.06 µg/kg bw-day. Significantly low modal MoEs (0.009-0.05) were recorded for developmental neurotoxicity, nephrotoxicity and cardiovascular toxicity. De minimis (<10<sup>-6</sup>) modal lifetime cancer risks were recorded, with the 95th percentile risks showing that some consumers are still at risk (>10<sup>-6</sup>). These findings suggest serious public health concerns.

**Table 4.17d** Incremental Life Cancer Risk (ILCR) of the population (per 10,000 populations) of Mymensingh, Rajshahi, Khulna and Chattogram divisions due to dietary intake of **chromium**

Parameter	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Male</b>				
Minimum	0.4	0.2	2.1	2.1
Maximum	1.8	0.9	5.2	5.2
Mean± SD	1.0±0.3	0.5±0.1	2.5±0.7	2.5±0.7
<b>Female</b>				
Minimum	0.4	0.2	2.3	2.3
Maximum	1.9	0.9	5.5	5.5
Mean± SD	1.1±0.3	0.5±0.1	2.7±0.7	2.7±0.7
<b>Boys</b>				
Minimum	0.2	0.2	2.0	2.0
Maximum	1.1	0.9	4.9	4.9
Mean± SD	0.6±0.2	0.5±0.1	2.4±0.6	2.4±0.6
<b>Girls</b>				
Minimum	0.3	0.2	1.9	1.9
Maximum	1.6	0.9	4.7	4.7
Mean± SD	0.9±0.2	0.5±0.1	2.3±0.5	2.3±0.6

## 4.4 Vitamins

### 4.4.1 Concentration of vitamins

#### $\beta$ Carotene

Beta carotene contents were determined from major fruits and vegetables collected from 12 locations of four divisions of Bangladesh and the results are presented in Table 18. Although the amount of beta carotene in fruits and vegetable samples varies widely, the location variation for each item was not statistically significant. Among the sampled fruits, irrespective of all divisions, the highest amount of beta carotene was found in papaya (823, 815, 780 and 723  $\mu\text{g}$  per 100g fresh weight in samples from Mymensingh, Khulna, Chattogram and Rajshahi, respectively) which is followed by guava samples (Table 18). The lowest amount of beta-carotene was observed in banana from Rajshahi (18  $\mu\text{g}$  per 100g fresh weight). In case of vegetables, brilliant orange coloured pumpkin contained the highest amount of beta carotene (4625, 4125, 3825, and 3750  $\mu\text{g}$  per 100g fresh weight in samples from Mymensingh, Rajshahi, Khulna, and Chattogram, respectively). On the other hand, the lowest amount was observed in water gourd samples from Chattogram and Rajshahi divisions (22  $\mu\text{g}$  per 100g fresh weight) (Table 18).

#### Vitamin C

The vitamin C content was determined from fresh fruits and vegetables collected from four divisions of Bangladesh (Table 19). Expectedly, vitamin C content was highest in guava among other fruits and the highest amount was found in guava samples collected from Mymensingh division ( $224.36 \pm 46.92 \text{mg}$  per 100g fresh weight) (Table 19). The lowest amount of vitamin C was recorded in apple from Khulna ( $5.12 \pm 1.32 \text{mg}$  per 100g fresh weight). Among vegetable samples, vitamin C content was the highest in pointed gourd samples and the highest was found in samples collected from Khulna division ( $120.78 \pm 18.00 \text{mg}$  per 100g fresh weight) (Table 19). Brinjal, among the tested vegetables, contained the lowest amount of vitamin C.

In general, fruits have naturally occurring high content of Vitamin C, compared to vegetables, though some vegetables like cabbage, broccoli, capsicum, potatoes, leafy vegetables and fresh herbs are also good sources. Upon cooking, vitamin C largely gets destroyed. It is therefore important to consume fruits and vegetables fresh, either as such or as salads to obtain vitamin C.

**Table 4.18** Beta-carotene contents in vegetables and fruits of four Divisions of Bangladesh

Food items	Mymensingh	Rajshahi	Khulna	Chattogram
<b>a)Vegetables</b>	<b>β-carotene (μg/100g)</b>			
Apple	25±9	35±11	33±11	28±8
Banana	45±19	18±6	30±6	20±6
Guava	425±80	349±59	378±45	400±78
Papaya	823±136	738±124	815±110	780±125
Pineapple	86±24	47±15	68±13	75±17
<b>b)Vegetables</b>				
Bean	280±0	200±0	220±0	250±0
Brinjal	65±18	42±18	25±12	52±8
Cabbage	70±0	55±0	62±0	55±0
Cauliflower	15±0	18±0	9±0	8±0
Cucumber	60±0	44±0	31±0	55±0
Green papaya	28±0	41±0	18±0	30±0
Lady's finger	220±42	187±39	159±35	205±22
Pointed gourd	90±0	70±0	78±0	70±0
Potato	48±0	25±0	42±0	30±0
Pumpkin	4625±425	4125±380	3825±275	3750±328
Tomato	110±0	110±0	145±0	125±0
Water gourd	33±9	22±8	30±11	22±5



**Table 4.19.** Vitamin C contents in fruits and vegetables of four Divisions of Bangladesh

Food Types	Mymensingh	Rajshahi	Khulna	Chattogram
<b>a)Fruits</b>	<b>Vitamin C (mg/100g)</b>			
Apple	7.86±1.67	9.88±0.95	5.12±1.32	6.41±2.04
Banana	4.98±1.53	11.35±0.73	10.07±2.04	11.35±1.83
Guava	224.36±46.92	175.68±20.78	161.04±31.75	127.19±31.47
Papaya	42.74±7.97	53.99±8.13	68.63±8.39	78.69±9.55
Pineapple	31.66±0.91	30.38±1.75	56.36±1.28	38.25±5.05
<b>b) Vegetables</b>				
Bean	14.64±0.92	11.90±0.91	16.47±3.17	9.15±0.92
Brinjal	6.13±2.00	5.49±2.48	5.86±1.63	4.21±0.80
Cabbage	15.53±7.72	28.00±1.58	43.92±9.96	40.63±1.38
Cauliflower	73.60±22.43	120.78±0.00	80±8.78	75±13.80
Cucumber	6.41±1.32	5.67±1.20	15.01±1.94	8.05±2.95
Green papaya	16.10±4.61	56.73±18.23	62.22±3.30	69.17±3.74
Lady's finger	9.15±3.30	16.47±2.75	10.07±0.91	16.47±1.58
Pointed gourd	79.93±4.24	73.75±18.21	72.78±18.00	75.43±4.64
Potato	17.06±3.99	9.88±1.98	18.67±1.76	29.28±0.66
Pumpkin	12.46±2.21	12.81±0.92	10.98±1.58	10.98±1.58
Tomato	9.20±0.88	9.15±0.92	12.81±1.83	26.54±10.31
Water gourd	6.71±3.85	8.24±2.48	9.52±1.11	12.26±1.75

**Riboflavin**

The riboflavin (vitamin B2) content was determined from fresh fruits and vegetables collected from four divisions of Bangladesh (Table 20). In general, the riboflavin content in observed fruits and vegetables was very low. However, among fruits it was found the highest in pineapple samples collected from Mymensingh division (0.45mg per 100g fresh weight) (Table 20). Among vegetable samples, riboflavin content was the highest in lady's finger samples and the highest was found in samples collected from Chattogram division (0.38mg per 100g fresh weight) (Table 20).

**Table 4.20** Riboflavin content in fruits and vegetables of four Divisions of Bangladesh

Food types	Mymensingh	Rajshahi	Khulna	Chattogram
<b>a)Fruits</b>	<b>Vitamin B2 (riboflavin) (mg/100g)</b>			
Apple (n=1)	0.00±0.00	0.00±0.00	0.20±0.00	0.13±0.00
Banana	0.25±0.00	0.20±0.00	0.25±0.00	0.25±0.00
Guava	0.38±0.00	0.25±0.00	0.30±0.00	0.25±0.00
Papaya	0.13±0.00	0.25±0.00	0.13±0.00	0.13±0.00
Pineapple	0.45±0.00	0.25±0.00	0.25±0.00	0.38±0.00
<b>b) Vegetables</b>				
Bean	0.30±0.00	0.20±0.00	0.25±0.00	0.25±0.00
Brinjal	0.30±0.00	0.13±0.00	0.13±0.00	0.25±0.00
Cabbage	0.13±0.00	0.13±0.00	0.00±0.00	0.13±0.00
Cauliflower	0.18±0.00	0.08±0.00	0.00±0.00	0.00±0.00
Cucumber	0.13±0.00	0.08±0.00	0.13±0.00	0.25±0.00
Green papaya	0.20±0.00	0.08±0.00	0.13±0.00	0.13±0.00
Lady's finger	0.13±0.00	0.08±0.00	0.13±0.00	0.38±0.00
Pointed gourd	0.13±0.00	0.13±0.00	0.13±0.00	0.08±0.00
Potato	0.18±0.00	0.00±0.00	0.00±0.00	0.13±0.00
Pumpkin	0.38±0.00	0.25±0.00	0.13±0.00	0.25±0.00
Tomato	0.25±0.00	0.13±0.00	0.13±0.00	0.13±0.00
Water gourd	0.13±0.00	0.00±0.00	0.00±0.00	0.05±0.00

#### 4.4.2 Vitamin intake

$\beta$ -carotene intake from the selected vegetables and fruits varied widely among the four divisions of Bangladesh (Table 4.21). The highest mean intake (0.142 mg/d) was observed in Khulna division followed by Mymensingh division (0.093 mg/d), Chattogram division (0.092 mg/d) and Rajshahi division (0.071 mg/d) (Table 4.21). The RDA of  $\beta$ -carotene for an adult is 6mg/d (NIN, 2020). Vegetables and fruits contribute only 1.2-2.4% of the RDA of  $\beta$ -carotene for an adult among the four divisions. Whereas, in Southern India, vegetables contribute 40% of the daily recommended intake of beta carotene (Belanger et al. 2010). According to Lee et al. (2013), in Korea, individuals consuming greater amount of fruits and vegetables obtain their recommended amount of carotenoids and other phytonutrients. They also observed that fruit and vegetable consumption is lower among young adults.

Vitamin-C intake by the adult male from the selected vegetables and fruits varied widely among the four divisions of Bangladesh (Table 4.21). The highest mean intake (67 mg/d) was observed in Khulna division followed by Chattogram division (51 mg/d), Rajshahi division (35 mg/d) and Mymensingh division (32 mg/d). The RDA of Vitamin-C for an adult is 80 mg/d (NIN, 2020). The vegetables and fruits we selected contribute 40-84% of the RDA of Vitamin-C for an adult among the four divisions.

Riboflavin (B2) intake by the adult male from the selected vegetables and fruits also varied widely among Mymensingh, Rajshahi, Khulna and Chattogram divisions of Bangladesh (Table 21). The highest mean intake (0.32 mg/d) was observed in Mymensingh division followed by Chattogram division (0.27 mg/d), Khulna division (0.21 mg/d) and Rajshahi division (0.09 mg/d). The RDA of Riboflavin for an adult is 2.5 mg/d (NIN, 2020). Vegetables and fruits contributed 3.6-12.8% of the RDA of Riboflavin for an adult among the four divisions.

Apparently, principal share of the consumed vitamins from fruits and vegetables were obtained from few vegetables (potato, brinjal and pointed gourd for  $\beta$ -carotene and vitamin C; potato and brinjal for riboflavin) and fruits (ripe banana and guava). This indicates that there is lack of food (especially fruits) diversity in the sampled population which ultimately results in the poor dietary intake of vitamins.

Although we calculated the daily intake of three vitamins ( $\beta$ -carotene, Vitamin-C, Riboflavin), there are some limitations to interpret the results of our study for vitamins in vegetables and fruits. The number of samples for each district was very low and daily consumption rate was not available in the HIES 2016 dataset for some vegetables e.g.  $\beta$ -carotene content in pumpkin was 3.7-4.6 mg/100g among the four divisions but the consumption data by the households were absent. On the other hand, some seasonal vegetables and fruits were not available fresh for vitamin analysis which needs to be considered for a complete picture.

**Table 4.21** Beta-carotene, Vitamin C and Riboflavin intake by the household adult in four Divisions of Bangladesh

Vitamins	Mymensingh	Rajshahi	Khulna	Chattogram
<b>β-carotene</b>				
Total Intake (mg/day/Adult male)	0.093	0.071	0.142	0.092
% RDA	1.6	1.2	2.4	1.6
<b>Vitamin-C</b>				
Total Intake (mg/day/Adult male)	32	35	67	51
% RDA	40	44	84	64
<b>Riboflavin</b>				
Total Intake (mg/day/Adult male)	0.32	0.10	0.21	0.27
% RDA	13	4	8	11

RDA for β-carotene= 6 (mg/day/Adult male)

RDA for Vitamin C=80 (mg/day/Adult male)

RDA for Riboflavin=2.5 (mg/day/Adult male)

#### 4.4.3 Health Implications of vitamins

All the households of all the four divisions in Bangladesh had lower intake of beta carotene, riboflavin, and vitamin C in relation to the RDA. Hence, all the households of all four divisions may suffer from all these vitamins. Human body converts beta carotene into vitamin A (retinol) – beta carotene is a precursor of vitamin A. Vitamin A deficiency may show fat malabsorption, or liver disorders. Deficiency impairs immunity, haematopoiesis and causes rashes and typical ocular effects (eg, xerophthalmia, night blindness). Low intakes of intake of riboflavin may show the symptoms like fatigue, red gums, easy bruising and bleeding, joint pain and rough, bumpy skin. As the deficiency progresses, bones may become brittle, nail and hair deformities can develop and wounds may take longer to heal. Vitamin C deficiency include fatigue, depression, and connective tissue defects (eg, gingivitis, rash, internal bleeding, impaired wound healing).

Overall, vitamins and minerals are considered essential nutrients and as antioxidants —because they perform multiple roles in the body. They help and maintain skeletal systems, heal wounds and bolster the immune system. They also convert food into energy, and repair cellular damage.

## 4.5. Preservatives, food colours and aflatoxins

### 4.5.1 Concentration of reservatives, food colours and aflatoxins

#### Preservatives

In order to study the concentration of preservatives, food colours and aflatoxins, popular fruit-based processed products like jam/jelly, pickle/chutney, mango and orange juices were collected from three locations of each of four divisions namely Mymensingh, Rajshahi, Khulna and Chattogram. Different brands of each category products were blended and carefully sampled for the analysis of commonly used preservatives. The analysis results for total SO<sub>2</sub> and sodium benzoate are presented in Table 4.22. Irrespective of sampling locations, fruit chutney contained about five times more SO<sub>2</sub> compared to jelly and mango juice samples and SO<sub>2</sub> content in jelly and mango juice samples from four different locations varied slightly from each other. The SO<sub>2</sub> content in jam samples from different divisions was similar. Regarding SO<sub>2</sub> content of chutney, the highest amount (about 106 mg/kg) was noted in Mymensingh samples, followed by about 98 mg/kg in Rajshahi samples and the lowest 85 mg/kg in Khulna and Chattogram samples.

**Table 4.22** Amount of SO<sub>2</sub> and Na-benzoate in different processed foods from four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram
	<b>Total SO<sub>2</sub> (mg/kg)</b>			
Jelly/Jam	14.93±3.30	14.81±3.42	13.87±2.61	13.5±2.31
Pickle/Chutney	105.96±9.11	97.64±4.71	85.33±5.91	85.58±4.91
Mango juice	19±1.91	18.77±1.32	18.56±2.23	17.55±2.32
Orange juice	ND*	ND	ND	ND
	<b>Na-benzoate (mg/kg)</b>			
Jelly/Jam	1088±121	1000±56	922±115	984±51
Pickle/chutney	992±94	999±60	979±39	946±65
Mango juice	373±72	419±43	370±54	378±81
Orange juice	360	ND	288	ND

\*ND = Not Detected

Concerning Na-benzoate content, jelly and chutney showed similar amount which was about three times higher than that of mango and orange juices. Orange juices were available only in two locations and showed similar amount with mango juice sample. Mango juice from Rajshahi was found quite higher (419 mg/kg) compared to the other three locations.

### Food colors

Mango and orange juices were only analyzed for measuring food color content. The results for color analysis of the collected samples are presented in Table 4.23. No spot was observed on the TLC paper for tartrazine, brilliant blue and sunset yellow in mango juice. The nutrient labeling on mango juice declaring beta-carotene content is justified by TLC analysis.

**Table 4.23** Food colours in fruit juices from four divisions

Food groups	Mymensingh	Rajshahi	Khulna	Chattogram
<b>Tartrazine (mg/kg)</b>				
Mango juice	NP	NP	NP	NP
Orange juice	NP	NP	NP	NP
<b>Brilliant blue (mg/kg)</b>				
Mango juice	NP	NP	NP	NP
Orange juice	NP	NP	NP	NP
<b>Sunset yellow (mg/kg)</b>				
Mango juice	NP	NP	NP	NP
Orange juice	186±3	221±1	169±1.6	167±2.5

\*NP = Not Present

Tartrazine and brilliant blue were also not detectable in orange juice samples as revealed by TLC analysis. However, sunset yellow was detected in orange juice and hence went for its quantification. The highest content of 221 mg/kg was observed in Rajshahi samples, followed by 186 mg/kg in Mymensingh, 169 mg/kg in Khulna and the lowest 167 mg/kg was noted in Chattogram samples.

### Aflatoxin

The presence of aflatoxin in different pulse samples was observed and the results are presented in Table 4.24. It was gratifying to note that no aflatoxin was detected in any sample of Atta

collected from different geographical regions. Among the detected samples, some variation was found between food groups and between locations.

**Table 4.24** Concentration of aflatoxins in different pulses from four divisions

Food groups	Concentration ( $\mu\text{g/kg}$ )			
	Mymensingh	Rajshahi	Khulna	Chattogram
Rice	ND	ND	$8.26 \pm 12$	$6 \pm 0.1$
Ata	ND	ND	ND	ND
Masur	$13.1 \pm 15$	$0.47 \pm 0.02$	$0.37 \pm 0.01$	ND
Mug	$3.21 \pm 01$	$5.58 \pm 03$	$9.56 \pm 05$	ND

\*ND = Not detected

Rice samples from Khulna had the highest ( $8.26 \mu\text{g/kg}$ ) amount of aflatoxins, followed by  $6 \mu\text{g/kg}$  in Chattogram samples whereas the Mymensingh and Rajshahi samples were free from aflatoxins. Comparatively, Masur (lentil) samples that collected from Mymensingh contained the highest amount of aflatoxins ( $13.1 \mu\text{g/kg}$ ) among the food groups analyzed. Masur samples from Chattogram division were found aflatoxin-free whereas a negligible amount was estimated in the samples from Rajshahi and Khulna. In the case of Mug (mungbean), samples from Khulna division showed the highest amount ( $9.56 \mu\text{g/kg}$ ), followed by Rajshahi samples containing  $5.58 \mu\text{g/kg}$  and the lowest content ( $3.21 \mu\text{g/kg}$ ) was recorded for Mymensingh samples.

#### 4.5.2 Intake of preservatives, food colours and aflatoxins

An exposure assessment of the aflatoxins, Na-benzoate and  $\text{SO}_2$  was carried out among 100 households individuals of each division using HIES-2016 data sets. The mean intake, estimated daily intake (EDI) and acceptable daily intake (ADI) are presented in Table 4.25. A noticeable variation was observed in the mean intake of total aflatoxins among division wise household individuals. The highest total aflatoxins intake ( $2.89 \mu\text{g/day}$ ) was observed in Khulna HH individuals followed by Chattogram ( $2.11 \mu\text{g/day}$ ) and then Mymensingh ( $0.29 \mu\text{g/day}$ ) and the lowest ( $0.012 \mu\text{g/day}$ ) by the Rajshahi individuals. In the case of  $\text{SO}_2$  and Na-benzoate, the mean Na-benzoate intake was about 10 times higher than that of the mean  $\text{SO}_2$  intake. However, division-wise intake of  $\text{SO}_2$  and Na-benzoate among HH individuals was found quite close.



In the case of the mean intake expressed in estimated daily intake (EDI), both Khulna and Chattogram HH's exposure largely exceeded allowable daily intake. This exposure of aflatoxins was mostly from rice. Exposure of the Mymensingh division HHs was also marginally exceeded the allowable daily intake which was from pulses. The estimated daily intake of SO<sub>2</sub> and Na-benzoate among different divisional HHs was far below the allowable daily intake. Hence, the HHs of Khulna and Rajshahi are under acute dietary exposure to total aflatoxin due to its excess presence in the rice samples.

**Table 4.25** Intake of food preservatives and aflatoxins by the adult of four divisions

Compounds	Exposure summary			
	Mymensingh	Chattogram	Rajshahi	Khulna
Aflatoxin (µg/day)	0.29	2.11	0.012	2.89
SO <sub>2</sub> (µg/day)	34.23	27.78	31.65	27.46
Na-benzoate (µg/day)	320.74	305.88	322.68	316.22
<b>EDI ( for avg body weight 60 Kg)</b>				
Aflatoxin (ng/ Kg BW/day)	4.83	35.17	0.20	48.17
SO <sub>2</sub> (µg/day)	0.57	0.46	0.53	0.46
Na-benzoate (µg/Kg BW/day)	5.35	5.10	5.38	5.27
<b>ADI (WHO/JECFA)</b>				
	SO <sub>2</sub> (mg/Kg BW/day)	Na-benzoate (mg/Kg BW/day)	Aflatoxin* (ng/Kg BW/day)	
	0-0.7	0-5	0.4-3.7	

\*Provisional maximum tolerable daily intake (PMTDI) of aflatoxins=0.4ng/KgBW/day for carriers of hepatitis B-virus (Ref.: Food Additives and Contaminants: Part B (2011), 4(2))

### 4.5.3 Health implications of aflatoxins

Total aflatoxins are the combination of AFB1, AFB2, AFG1 and AFG2. The most frequently found aflatoxins in contaminated food samples are AFB1 and the three others are generally not reported in the absence of AFB1 (FAO/WHO, 2018). Aflatoxins are genotoxic and the critical effect of aflatoxins in all the previous assessments was found to be liver cancer. The mortality from liver cancer associated with exposure to aflatoxins both in HBsAg-positive and negative individual was reported by JECFA. According to JECFA (FAO/WHO, 1999, 2018), the estimated AFB1 potencies are 0.3 cancer cases/year per 100,000 subjects per ng AFB1/kg body weight (bw) per day in HBsAg-positive individuals and 0.01 cancer cases/year per 100,000 subjects per ng AFB1/kg bw per day for HBsAg-negative individuals (Table 4.26).

**Table 4.26** Mortality from liver cancer associated with exposure to AFB1 Associated risk (cases/100000/year)

Individual types	Mymensingh	Chattogram	Rajshahi	Khulna
HBsAg-negative individuals	0.05	0.35	0.00	0.48
HBsAg-positive	1.45	10.55	0.06	14.45

According to Table 4.26 HBsAg-negative individuals are almost riskless at its current exposure of total aflatoxins. If total aflatoxins are assumed to AFB1, 11 to 15 cases per 100000 HBsAg-positive individuals per year are at estimated risk of cancer.

## 4.6 Pesticide residues

### 4.6.1 Concentration of pesticide residues

The pesticide analysis results have been summarized in Table 4.27. A total of 8 among 99 tested samples were found contaminated with cypermethrin and lambda-cyhalothrin residues. One brinjal sample from Mymensingh was contaminated with cypermethrin residue (0.535 mg/kg) which was above the EU-MRLs (0.50 mg/kg). Three amaranth samples were found contaminated with pesticide residue which were collected from Mymensingh (0.297 mg/kg with lambda-cyhalothrin), Rajshahi (0.112 mg/kg with cypermethrin) and Khulna (0.141 mg/kg with

cypermethrin). Along with these, two yard long bean were found contaminated with lambda-cyhalothrin residue, which were collected from Khulna (0.027 mg/kg) and Chattogram districts (0.420 mg/kg). Cypermethrin and lambda-cyhalothrin residue were also detected in three country bean samples collected from Rajshahi and Khulna. None of the analyzed samples of okra, tomato, cabbage and pointed gourd contained any residues of the tested pesticides collected from Mymensingh, Rajshahi, Khulna and Chattogram.

#### **4.6.2 Pesticide residue intake**

The average daily intakes of pesticides have been estimated and presented in Table 4. 28. The range of daily intake of cypermethrin varied from 0.491 µg/day in Rajshahi division to 2.473 µg/day found in Mymensingh. The daily intake of lambda-cyhalothrin through vegetable consumption was only estimated for Mymensingh division which was 1.494 µg/day. Although we estimated the daily intake of pesticides, there are some limitations to interpret the results of this study for pesticide residues in vegetables. Organophosphorous pesticides are also used widely in vegetable cultivation which was not determined due to lack of facilities now in Bangladesh.

**Table 4.27** Concentration of insecticides (mg/kg) in vegetables from four divisions of Bangladesh

Food items	Locations			
	Mymensingh	Rajshahi	Khulna	Chattogram
Potato	ND	ND	ND	ND
Pointed gourd	ND	ND	ND	ND
Okra	ND	ND	ND	ND
Tomato	ND	ND	ND	ND
Cucumber	ND	ND	ND	ND
Pointed gourd	ND	ND	ND	ND
Cabbage	ND	ND	ND	ND
Red amaranth	0.297 mg/kg; (Lambda-cyhalothrin)	0.112 mg/kg; (Cypermethrin)	0.141 mg/kg; (Cypermethrin)	ND
Yard long bean	ND	ND	0.027 mg/kg; (Lambda-cyhalothrin)	0.420 mg/kg; (Lambda cyhalothrin)
Country bean	ND	0.043 mg/kg; (Cypermethrin)	0.021 mg/kg; 0.044 mg/kg (Lambda-cyhalothrin)	ND

\*ND = Not detected

**EU-MRLs (mg/kg):** Cypermethrin - 0.50 mg/kg

: Lambda-cyhalothrin - 0.40 mg/kg

**Table 28:** Daily intake of insecticides (µg/day) from vegetables by an adult in four divisions

Insecticides	Locations			
	Mymensingh	Rajshahi	Khulna	Chattogram
Cypermethrin	2.473	0.491	1.137	-
Lambda-cyhalothrin	1.494	-	*ND	*ND

\*Not Detected (Daily consumption value not available)

## 5. CONCLUSIONS

Contamination in the food chain by heavy metals, pesticides, preservatives, and coloring agents is a major concern for safe food intake in Bangladesh. The main objectives of this research study were to determine the levels of trace elements and heavy metals, vitamins, pesticide residues, food color, food preservatives and aflatoxins in major foods consumed by the households of four divisions of Bangladesh and to assess the dietary exposure to trace elements, heavy metals, pesticide residues, food color, food preservatives and aflatoxins, and potential health implications as well as recommendations for action. The Total diet study (TDS) methodology was used to assess the contamination and calculate the dietary risk exposure.

The following conclusions are drawn from the research results.

1. The concentration of trace elements (Zn, Fe, Cu and Se) and heavy metals (As, Cd, Pb and Cr) varied widely among the four divisions of Bangladesh. The reason of this variation can be attributed to the location where the foods were grown, transport processes, environmental distribution of the minerals and heavy metals, persistence in the soil and bio-accumulative nature of the heavy metals where they have been grown.

Leaching of metals from different sources such as landfills, waste dumps, excretion, livestock and chicken manure are also some of the causes of heavy metal distribution in the food chain.

2. All the household adults of Mymensingh division, 93% household adults of Rajshahi division, 97% household adults of Khulna division and 85% household adults of Chattogram division had the dietary intake of Zn below RDA.
3. All the household adults of Mymensingh division, 98% household adults of Rajshahi division, 99% household adults of Khulna and Chattogram divisions showed the dietary intake of Fe below RDA.
4. The populations of all four divisions indicate sufficient dietary intake of Cu and Se indicating adequacy of intake.
5. The dietary intake of As, Cd and Pb in the studied population of four divisions, based on dietary risk exposure calculation, pointed to a dietary exposure implicated with estimated

disease risks, notably cancer. The population of Mymensingh division has the lowest estimated cancer risk from As and Cd, but the highest estimated cancer risk due to dietary Pb intake. The population of Khulna exhibits the highest estimated cancer risk due to dietary intake of As while the population of Chittagong division showed the highest estimated risk to Cd intake.

6. Cereals, especially rice is the major food component determining the dietary intake of the trace elements and heavy metals by the population of all four division. All the households of the four divisions of Bangladesh have low intake of beta carotene, riboflavin and vitamin C than the RDA. In plant based diets it is expected that carotenoids meet 80 % or more of requirements for vitamin A. Population based studies have shown correlations of carotene deficiencies with high prevalence of ocular disease such as cataracts and macular degeneration, as well as non-ocular conditions such as certain forms of cancer (Johra et al., 2020).
7. A population of 11 to 15 per 100000 HBsAg-positive individuals per year is under estimated risk of cancer due to dietary intake of aflatoxins.

## **6. POLICY IMPLICATIONS AND RECOMMENDATIONS**

The following policy options and recommendations are suggested from this study.

1. High variation in the concentration of trace elements and heavy metals was noted in food items among all the four divisions of Bangladesh due to the variation in soil as well as local agricultural practices for crop production.
2. Arsenic gets entry into the human body mainly through rice irrigated with arsenic-contaminated STW water, cultivation of rice with arsenic-free water (DTW or surface water) need to be promoted to reduce arsenic levels in the food chain.
3. There is a need to screen out rice varieties as well as develop rice varieties for lower uptake of As, Cd, and Pb by grains in order to decrease the risks of As, Cd, and Pb intake by the Bangladesh people.
4. The contribution of cereals, especially rice to the intake of heavy metals (As, Pb and Cd) by the adults of four divisions is the highest compared to other food items. Decreased consumption of rice and increased consumption of wheat, potato and vegetables may help reduce the dietary risk exposure from heavy metals.
5. Biofortification strategy with micronutrients (Zn, Fe) for major food crops (rice, lentil) by either varietal development or use of micronutrient fertilizers could be adopted to enhance the micronutrient level in crop produce.
6. Promote awareness campaigns for decreasing the intake of aflatoxins by preserving the food items after proper drying and storage in airtight containers
7. Enforcing regulation and conducting regular surveillance by BFSA in different market hubs for assessing storage conditions and storage time of rice and pulses.
8. Campaigns encouraging the intake of diversified food items, especially fruits and vegetables could be done to increase the people's dietary intake of vitamins and minerals.

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