ISSN: 2644-2981

DOI: 10.33552/GJNFS.2021.03.000566

Global Journal of Nutrition & Food Science

Iris Publishers

Research Article

Health Risk Assessment of Heavy Metals Through Ten Common Foodstuffs Collected from an Area of Ruppur Nuclear Power Plant, Pabna, Bangladesh

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Received Date: April 08, 2021

Published Date: April 28, 2021

Abstract

This study has been designed to assess the levels of selected toxic metals (V, Pb, Cr, Mn, Co, Fe, As, Ni, Cu and Zn) in some common foodstuff's samples, collected from the RNPP (Ruppur Nuclear Power Plant) area, Pabna District, Bangladesh. Therefore, ten different types of foodstuffs samples from RNPP site, and to measure the heavy metals concentration in the collected foodstuff samples using energy dispersive X-ray florescence (XRF) technique. The results of this study showed that the concentrations for Mn, Cu, Zn, Pb and Fe were ranged from 100.88 to 75.46, 123.02 to 36.78, 49.75 to 11.99, 10.79 to 6.32 and 1533.09 to 132.39 mg/kg respectively. This study revealed that the concentrations of Fe and Cu in foodstuffs were found to be higher than the maximum permissible limit set by WHO/FAO. Reversely, this study showed that the level of Mn, Zn and Pb in foodstuffs samples were below the maximum permissible limit set by WHO/FAO. However, V, Cr, Ni, Co and as were found to be below the detection limit of XRF. Thereafter, the experimental data for Mn, Cu, Zn, Pb and Fe was used for identifying MPI (metal pollution index) and HRI (health risk index) in the selected foodstuffs samples. The decreasing sequence for metal pollution index was found to be as Bitter Gourd (BG) > Pawpaw (PP) > Ceylon Spinach (CS) > Red Amaranth (RA) > Guava (GU) > Mango (MN) > Lady's Finger (LF) > Brinjal (BR) > Jackfruit (JAC) > Banana (BA) respectively. The studied foodstuff samples were found to be within the safe limit considering the health risk index values. Considering the results of health risk index, it has been suggested that the people in the study area might not be at risk for V, Pb, Cr, Mn, Co, Fe, As, Ni, Cu and Zn at this moment. However, a continuous monitoring should be carried on.

Keywords: Daily Intake of Heavy Metal; Metal Pollution Index; Health Risk Index; Ruppur Nuclear Power Plant; Oral Reference Doses

Introduction

Foodstuffs have been recognized as good sources of vitamins and minerals, and for their role in preventing vitamin C and vitamin A deficiencies. People who eat fruits and vegetables as part of an overall healthy diet generally have a reduced risk of chronic diseases. Fruits and vegetables are edible plant products that are good for health. Precise qualitative and quantitative analyses of heavy metals present in them are important for accurate nutritional labeling, determination of compliance with the standard of identification and in ensuring that the products meet manufacturer's specification. Heavy metals, such as cadmium, copper, lead, chromium, arsenic, iron, zinc and nickel are important environmental pollutants, particularly in areas with high anthropogenic pressure. Their presence in the atmosphere, soil and water, even in trace amount can cause serious problems to all, and organism's heavy metal bioaccumulation in the food chain especially can be highly dangerous to human health. Heavy metals intake by human populations through food chain has been reported in many countries. The heavy metals are potential environmental contaminants with the capability of causing human health problems if present in excess in the food we take every day. There may be no visible sign of an unacceptable level of residue, especially for toxic elements (e.g., Cd, Pb, Co etc.). At higher concentrations these metals may poison their host. At lower but still unacceptable levels of exposure, effects may be restricted to physiological or biochemical level. Heavy metals have damaging effects on humans and animals because of their non-biodegradable nature, long biological half-lives and potential to accumulate in different body parts as there is inadequate mechanism for their elimination from the body [1]. Accumulation of heavy metals has been reported to exhibit carcinogenic, mutagenic and teratogenic effects [2]. Pb and Cd are the most abundant heavy metals, and their excessive intake is associated with cardiovascular, kidney, nervous and bone diseases [2,3]. Children are at particular risk to the harmful side effects of food adulteration, which may lead to serious liver and kidney diseases including various forms of cancer and hepatitis [4]. Many countries including Bangladesh have now set legal or at least provisional guideline level for maximum permitted concentrations for one or more heavy metals. In recent years, heavy metal pollution is a matter of great interest for researchers and environmental agencies because of its hazard and toxicity to ecosystems, reactivity and mobility in foodstuffs. Many countries including Bangladesh have now set legal or at least provisional guideline level for maximum permitted concentrations for one or more heavy metals. Bangladeshi foodstuffs showed relatively high concentration of heavy metals grown in different regions of Bangladesh [5]. Having reliable database on contamination levels in commonly consumed fruits for elucidating the present status of heavy metal contamination and ensuring food safety is very important. Bangladesh is going to establish the first ever Ruppur Nuclear Power Plant (RNPP), Pabna district, Bangladesh, which has schedule for commissioning in 2023. A huge construction work is going on at RNPP site. Therefore, it is important to assess the pollution level in local foodstuffs in the study area. However, the present work was designed and carried out for determining some of toxic metal concentrations in some selected foodstuffs, which were mostly common in around the study area of RNPP. The health risk assessment associated with heavy metals (V, Cr, Mn, Fe, Co, Ni, Cu Zn, As, and Pb) of foodstuffs were also targeted for this study.

Material and Methods

Study area

The study area is situated at the Ruppur Nuclear Power Plant (RNPP) site, which is under construction and has been scheduled for power production in 2023. This study area is 200 km northwest of Dhaka, at Paksey union on the bank of Padma River, Pabna District, Bangladesh. It is located at 24°3′36″N, 89°2′24″E Figure 1. The study area is well connected with Rajshahi and other districts by means of national highway and railway. Communication systems of the study area are also well developed. So, the accessibility of this area is fairly easy.

Collection and preparation of foodstuffs samples

Ten (10) different species of foodstuffs samples Figure 2 were collected from the field around the RNPP area. A detailed description (English name, scientific name, local name, types of foodstuffs etc.) has been presented in Table 1. However, the foodstuffs were thoroughly washed with double distilled water (DDW) and then cut and separated into different parts where applicable (leaf, stalks and roots). These were then dried in air for a week and dried in Gallenkamp Hotbox oven overnight at 80 °C until constant weight. The samples were homogenized by grinding and stored in desiccators in the dark until analysis, usually with the same week [6] (Figure 1&2 and Table 1).

Figure 1: Study area (Ruppur Nuclear Power Plant) in Bangladesh map.

Figure 2: Studied foodstuffs: (a) Bitter Gourd, (b) Brinjal, (c) Red Amaranth, (d) Ceylon Spinach, (e) Lady's Finger, (g) Banana, (h) Mango, (i) Jackfruit and (j) Guava.

Table 1: English names and scientific names of analyzed fruits samples.

English Name	Scientific Name	Local Name	Vegetable ID	Vegetable Type/Fruit
Bitter gourd	Momordica charantia	Korola	BG	Vegetable
Brinjal	Solanum melongena	Begoon	BR	Vegetable
Red amaranth	Amaranthus gangeticus	Lalshak	RA	Vegetable
Ceylon spinach	Basella alba	Pui shak	CS	Vegetable
Lady's finger	Abelmoschus esculentus	Dherosh	LF	Vegetable
Papaw	Carica papaya	Papaya	PA	Vegetable
Banana	Musa Acuminata	Kola	BA	Fruit
Mango	Mangifera Indica	Amm	MA	Fruit
Jackfruit	Artocarpus Heterophllus	Kathal	JAC	Fruit
Guava	Psidium Guajava	Peyara	GU	Fruit

Analysis of samples

The Energy Dispersive X-ray Fluorescence (Panalytical Epsilon 5, The Netherland) was used as major analytical technique for carrying out elemental analysis in the samples. For irradiation of the sample with X-ray beam 2 g of each powdered material was pressed into a pellet of 25 mm diameter with a pellet maker (Specac) and loaded into the X-ray excitation chamber with the help of automatic sample changer system. The irradiation of samples was performed by assigning a time-based program, controlled by a software package provided with the system. The standard materials were also irradiated under similar experimental conditions for construction of the calibration curves for quantitative elemental determination in the respective samples [7]. The generated X-ray spectra of the materials were stored into the computer. The X-ray intensities of the elements in sample spectrum were calculated using the system software by integration of area of the respective X-ray peak areas using peak fitting deconvolution software.

Concentration calibration

A direct comparison method based on EDXRF technique was used for elemental concentration measurement. As the analysis is based on direct comparison, the standards of similar matrices were used for the construction of the calibration curve in order to avoid the matrix effect. Five plant standards (Apple Leaf/NIST 1516, Spinach/NIST 1570a, Orchard Leaf/NIST 1571, Tomato Leaf/NIST 1573a, and Peach Leaf/NIST 1574) were used for the construction of calibration curves for carrying out elemental analysis in plant samples. The calibration curve for each element was constructed based on the K X-ray or L X-ray intensities calculated for the respective elements present in standard samples. The curves were constructed by plotting the sensitivities of the elements as a function of their atomic number. The validation of calibration curves constructed for elements present in the standards was checked through analysis of standard reference materials.

Data analysis

Metal pollution index: The MPI (metal pollution index) was determined overall heavy metal concentration in all foodstuffs analyzed. This index was obtained by calculating the geometrical mean of concentrations of all the metals in the foodstuffs [8].

MPI = (Cf1 Cf2 ……… Cfn)1/n ------------------(1)

Where Cfn = concentration of metal in the samples.

Health risk assessment: The HRI (Health Risk Index) was calculated as the ratio of estimated exposure of test vegetables and oral reference dose [9]. Oral reference doses were 7.00E-01, 3.00E-01, 4.00E-02, 4.00E-03 and 1.4E-02 mg kg-1 day-1 for Fe, Zn, Cu, Pb and Mn respectively [10]. Estimated exposure is obtained by dividing daily intake of heavy metals (DIM) by their safe limit. An index more than 1 is considered as not safe for human health [11]. Daily intake of heavy metal was calculated by the following equation [12].

$$DIM = \frac{C_{metal} \times C_{factor} \times C_{foodintake}}{B_{average\ weight}} \quad \text{.........(2)}$$

Where, C metal is the heavy metal conc. in vegetables (mg/kg), Cfactor is the conversion factor; C food intake is the daily intake of vegetables. The conversion factor of 0.085 is to convert fresh vegetable weight to dry weight [13], daily vegetable intake of 65 g/day while the average body weight used was 65 kg for this study [14]. The health risk index (HRI) was calculated using the formula below [12].

HRI= DIM/RFD --------------------------------- (3)

Result and Discussion

Concentration of heavy metals in foodstuffs samples

The elemental concentration (i.e., Mn, Cu, Zn, Pb, Fe, V, Cr, Ni, Co and as) in ten species (i.e., Bitter Gourd, Pawpaw, Ceylon Spinach, Red Amaranth, Guava, Mango, Lady's Finger, Brinjal, Jackfruit and Banana) of most common local foodstuffs were measured by XRF technique and presented in Table 2. This study revealed that the ranking order of mean metal concentration (mg/kg as dry wt. basis) in ten species of foodstuffs were found to be Fe (525.06 ± 415.89 mg/kg) > Mn (85.71 ± 8.34 mg/kg) > Cu (64.91 ± 31.0 mg/kg) > Zn (24.07 ± 11.37 mg/kg) > Pb (7.49 ± 1.32 mg/kg) respectively. Therefore, a variation for the concentration of Fe, Mn, Cu, Zn and Pb was observed. Subsequently, ANOVA test ($\alpha = 0.05$, $p < 0.0001$) also revealed that each metal concentration in different types of foodstuffs collected from the RNPP site was significantly different (Fcal > Fcritic = 13.65 > 2.63) at a 95% confidence level Table 3. A detailed description for each mental concentration in different foodstuffs has been discussed below (Table 2 & 3).

Table 2: Concentration of heavy metals in foodstuffs from RNPP.

Sample ID	Heavy metal concentration in foodstuffs samples (mg/kg)									
	Mn	Cr	Co	Cu	Ni	V	Zn	As	Pb	Fe
BG	89.34	BDL	BDL	123.02	BDL	Nd	32.79	BDL	10.79	509.04
BR	75.46	BDL	BDL	47.87	BDL	Nd	15.72	BDL	6.32	311.59
RA	100.88	BDL	BDL	41.39	BDL	Nd	21.19	BDL	7.54	1533.09
CS	93.61	BDL	BDL	53.92	BDL	Nd	49.75	BDL	8.11	714.24
LF	91.78	BDL	BDL	36.78	BDL	Nd	21.17	BDL	7.18	269.32
PA	87.52	BDL	BDL	79.09	BDL	Nd	32.69	BDL	8.12	817.85
BA	82.58	BDL	BDL	45.51	BDL	Nd	11.99	BDL	6.54	132.39
MN	79.36	BDL	BDL	56.23	BDL	Nd	22.59	BDL	6.91	383.68
JAC	81.02	BDL	BDL	49.18	BDL	Nd	15.36	BDL	6.92	182.88
GU	75.55	BDL	BDL	116.07	BDL	Nd	17.44	BDL	6.46	396.49

BDL= Below Detection Limit

Table 3: Two-way ANOVA for different metal ions concentration and different types of foodstuffs.

Source of Variation	SS	DF	MS	F	P-value	F crit
Between foodstuffs	328151.7	9	36461.3	1.059	0.41491	2.152
Between Heavy Metals	1878440	4	469610	13.65	7.25E-07	2.633
Error	1238971	36	34415.8			
Total	3445563	49				

Manganese: Total manganese concentration in all the foodstuffs studied through EDXRF are shown in Table 2. The concentrations are reported as milligrams of total manganese per kilogram of edible parts of foodstuffs as dry weight basis. From the results, it has been seen that the concentrations of manganese in foodstuffs samples varied 100.87 – 75.46 mg/kg with an average value of 85.71 ± 8.34 mg/kg Figure 3, which was in line with the WHO recommended values (15 to 100 mg/kg) in food stuffs [15]. Finding of this study was consistent with the reported result in literature [16-18]. Jolly, et al. [16] found maximum concentration for Mn in Turmeric (149.45 mg/kg) and minimum concentration in Bottle gourd leaves (3.34 mg/kg). Mohamed, et al. [17] found concentration of manganese in different vegetables collected from main city of Kingdom of Saudi Arabia varied from 4.16-94.16 mg/kg. The presents results shows that the concentration of total manganese in collected foodstuffs samples are within the normal limit than the world average value. The world average value (WAV) of manganese is 30-300 mg/kg [18]. The sequence for Mn concentration in the studied foodstuffs was found as Brinjal (75.46 mg/kg) < Guava (75.55 mg/kg) < Mango (79.36 mg/kg) < Jackfruit (182.88 mg/kg) < Banana (82.58 mg/kg) < Pawpaw (87.52 mg/kg) < Bitter Gourd (89.34 mg/kg) < Lady's Finger (91.78 mg/kg) < Ceylon Spinach (93.6 mg/kg) < Red Amaranth (100.88 mg/kg) respectively Table 2. ANOVA test (α = 0.05, p = 0.415) also revealed that Mn concentration in different foodstuffs was not significantly different (Fcal > Fcritic = 1.06 > 2.15) at a 95% confidence level Table 3 (Figure 3).

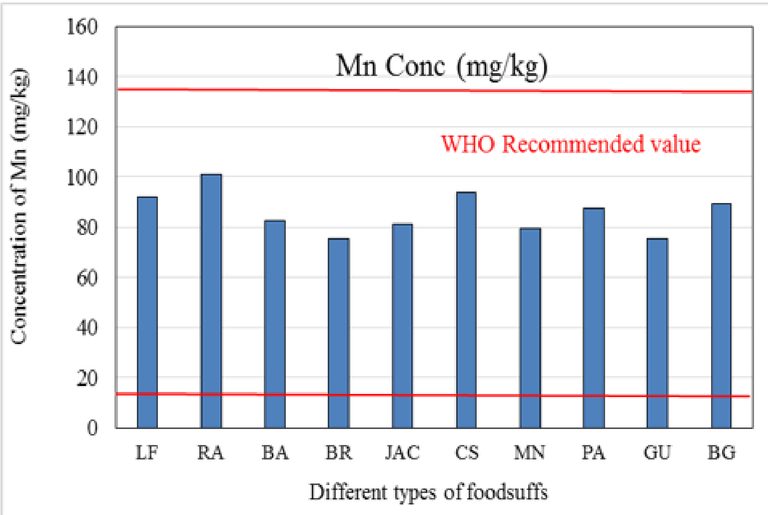

Figure 3: Concentration of manganese (Mn) in mg/kg for different foodstuffs.

Copper (Cu): Copper (Cu) is an essential trace element for normal biological activities of aminoxide and tryosinase enzymes, but excessive intake of copper may cause haemolysis, hepatotoxic and nephrotoxic effects [19]. This study revealed that the total copper (Cu) concentration in the studied foodstuffs samples remain in the range of 123.018 – 36.784 mg/kg with an average value of 64.91 ± 31 mg/kg. However, the sequence for Cu concentration in the studied foodstuffs was found as Lady's finger < red amaranth < Banana < Brinjal < Jackfruit < Ceylon spinach < Mango < Pawpaw < Guava < Bitter gourd respectively Table 2. The standard limit of Cu in foodstuffs is 30 mg/kg and 40 mg/kg set by world health organization [10]. It has been observed that the Cu concentrations in all studied foodstuffs were above than that of the recommended values set by WHO/FAO [10] Figure 4 and higher than that of the reported results (WAV of copper is 05-30 mg/kg) in literature [16,18]. Pendias [18] found copper concentration of 05-30 mg/kg in WAV, while Jolly, et al. [16] found Cu ranges between 3.62 (Basil) and 8.91(Sponge gourd) mg/kg respectively. However, a detailed result for this study revealed that the Cu concentration in BG, BR, RA, CS, PA, BA, MA, JAC and GU were found to be 123.02, 47.87, 41.39, 53.92, 79.09, 45.51, 56.23, 49.18 and 116.07 mg/kg respectively, which were really higher than the acceptable limit for human consumption of copper (10 ppm of Cu) [20]. According to an estimate 1.5 to 3.0 mg/day of dietary copper has been determined to be safe and adequate for human consumption [21]. It is obvious that, the concentrations of Cu in foodstuffs samples are higher than the standard value accepted sample LF. So, it has been suggested that the collected foodstuffs samples in RNPP area might be contaminated with Cu.

Zinc: Zinc is an essential element for human body. The obtained results on total zinc concentration from all foodstuffs samples are summarized in Table 2, which is expressed as milligram of total zinc per kilogram. From the table, it is seen that the concentrations of zinc in foodstuffs samples were varied from 49.75 – 11.99 mg/kg with an average value of 24.07 ± 11.37 mg/kg Figure 5, which was bellow than the maximum permissible limit of 50 to 60 mg/kg for Zn set by WHO/FAO [10]. Similar results for Zn concentration in food stuffs have also been found in literature [12,16,18,22]. The world average value (WAV) of zinc is 27-150 mg/kg [18] investigated Zn, maximum concentration was found in Bottle gourd leaves

(149.18 mg/kg) and minimum concentration was found in papaya (6.19 mg/kg). Ratul et al. [23] found the mean concentration of Zn 45.73 mg/kg. Garba, et al. (2018) found in the vegetables, Zn has the highest level of 2.21 µg/g observed in tomato, 2.118 µg/g in sorrel, and 1.330 µg/g observed in cucumber. The lower levels: 0.72, 0.78, 0.81, and 0.85 µg/g were observed in onion, watermelon, lettuce, and guava respectively. Abdelkareem, et al. found the concentration of zinc in the selected vegetables in range 4.21 – 20.80 mg/kg. From these results one can infer that the foodstuffs are free from zinc contamination and are safe for human consumption. So the foodstuffs samples from the study area are no contaminated with Zn. However, the sequence for Zn concentration in the studied foodstuffs was found as Banana < Jackfruit < Brinjal < Guava < Lady's Finger < Red Amaranth < Mango < Pawpaw < Bitter Gourd < Ceylon Spinach respectively Table 2 (Figure 4-6).

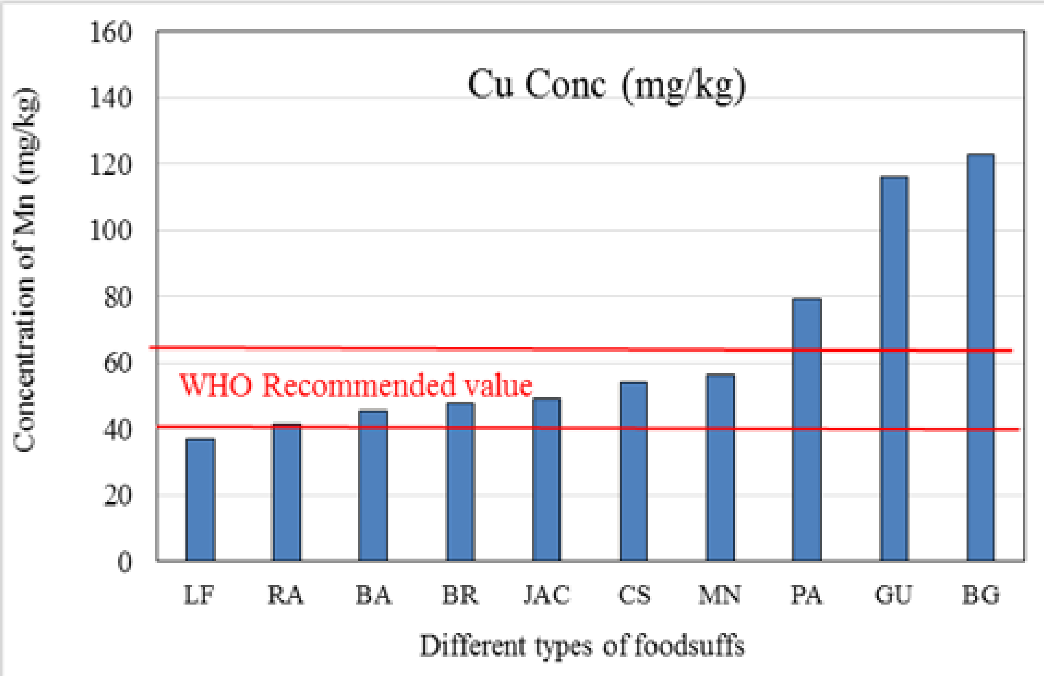

Figure 4: Concentration of copper (Cu) in mg/kg for different foodstuffs.

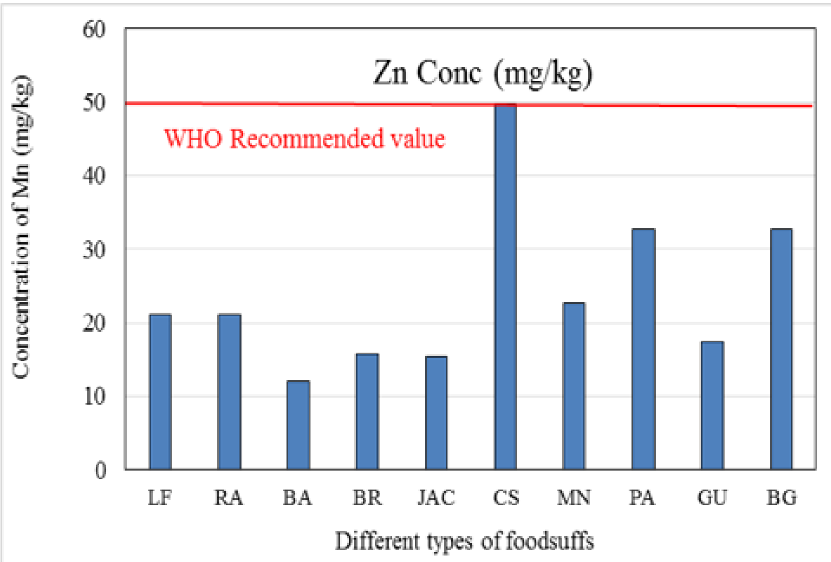

Figure 5: Concentration of zinc (Zn) in mg/kg for different foodstuffs.

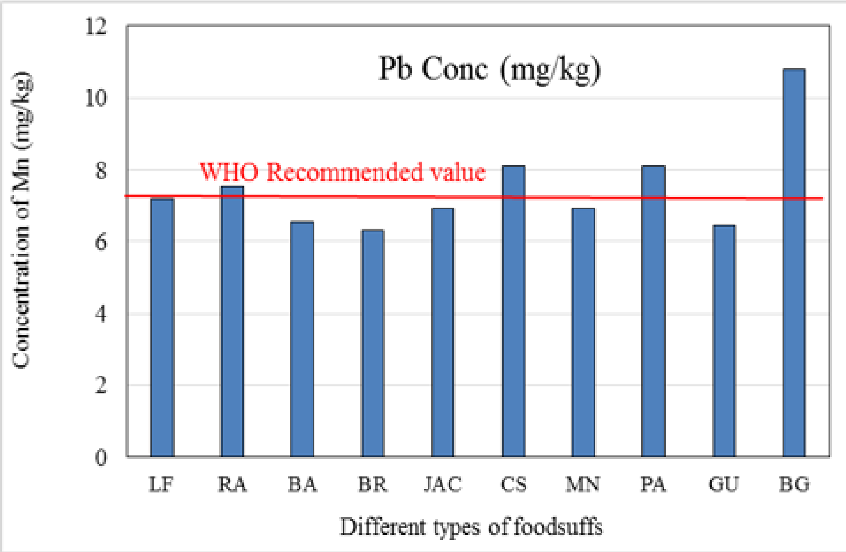

Figure 5: Concentration of zinc (Zn) in mg/kg for different foodstuffs.

Lead: Pb is a serious cumulative body poison, which can affect every organ and system in the body. Exposure to its high levels can severely damsage the brain, kidneys and ultimately cause death [24]. The total lead concentrations in all foodstuff's samples studied through EDXRF are shown in Table 2. The concentrations are reported as milligram of total lead per kilogram of foodstuffs samples. The maximum (10.79 mg/kg) and minimum (6.32 mg/kg) concentration of Pb was found in BG and BR respectively with an average value of 7.49 ± 1.32 mg/kg Figure 6. The sequence for Pb concentration in the studied foodstuffs was found as Brinjal (6.32 mg/kg) < Guava (6.46 mg/kg) < Banana (6.54 mg/kg) < Mango (6.91 mg/kg) < Jackfruit (6.92 mg/kg) < Lady's Finger (7.18 mg/kg) < Red Amaranth (7.54 mg/kg) < Ceylon Spinach (8.12 mg/kg) < Pawpaw (8.12 mg/kg) < Bitter Gourd (10.79 mg/kg) respectively Table 2. This study revealed that Pb concentration in 40% of the total studied foodstuffs were lower than the maximum permissible of Pb (7.2 mg/kg) set by world health organization [25]. However, finding from this study was in line with the reported result in literature [16]. Jolly, et al. [16] found concentration of lead maximum and minimum concentration were 0.13 (Tomato) and 1.57 (Bottle gourd leaves) mg/kg respectively.

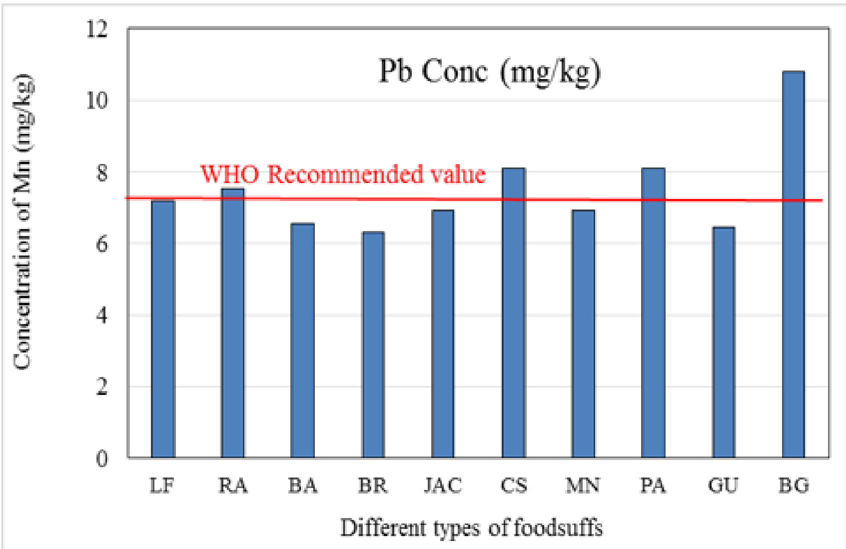

Figure 6: Concentration of lead (Pb) in mg/kg for different foodstuffs.

Iron (Fe): The total iron concentrations in all foodstuff's samples studied through EDXRF are shown in Table 2. The concentrations are reported as milligram of total iron per kilogram of foodstuffs samples as dry wt basis. The maximum permissible limit of iron in foodstuffs samples is 425 mg/kg and 720 to 990 mg/kg (as dry wt) recommended by WHO/FAO [25] and ATSDR [26] respectively. This study revealed that 40% of the total studied foodstuffs had higher Fe content than the recommended value set by WHO/FAO [25], and Fe content in maximum studied foodstuffs were in line with the recommended value set by ATSDR [26]. Similar findings are reported in literature [16,17]. Jolly, et al. [16] measured Fe concentration in different foodstuffs and found maximum concentration of Fe in bottle gourd leaves (748.70 mg/kg) and minimum concentration was found in radish (40.89 mg/kg). Mohamed, et al. [17] found concentration iron in different vegetables varied 31.96–543.2 mg/kg. However, this study revealed that Fe content in the studied foodstuffs samples were ranged from 1533.09 – 132.39 mg/kg with average value of 525.06 ± 415.89 mg/kg Figure 7. The sequence for Pb concentration in the studied foodstuffs was found as Banana (132.39 mg/kg) < Jackfruit (182.88 mg/kg) < Lady's Finger (269.32 mg/kg) < Brinjal (311.59 mg/kg) < Mango (383.68 mg/kg) < Guava (396.49 mg/kg) < Bitter Gourd (509.04 mg/kg) < Ceylon Spinach (714.24 mg/kg) < Pawpaw (817.85 mg/kg) < Red Amaranth (1533.09 mg/kg) respectively Table 2 (Figure 7).

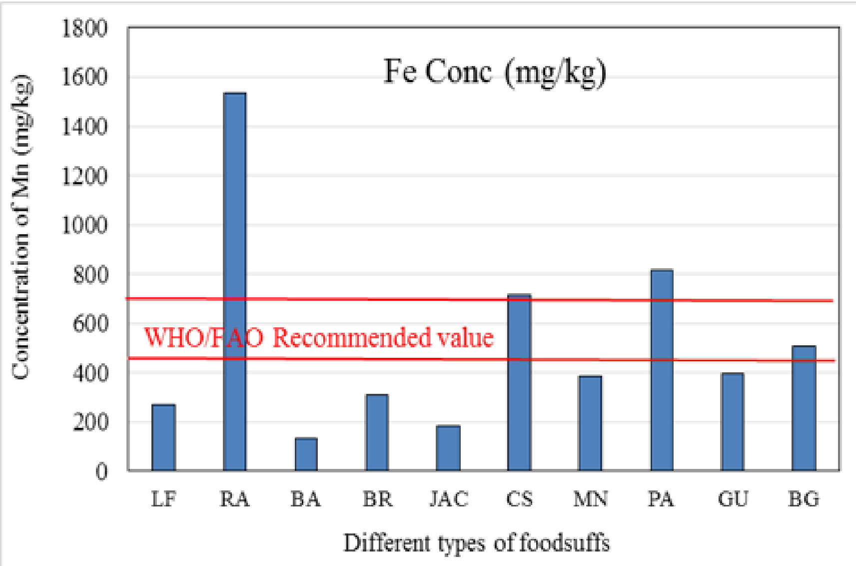

Figure 7: Concentration of iron (Fe) in mg/kg for different foodstuffs.

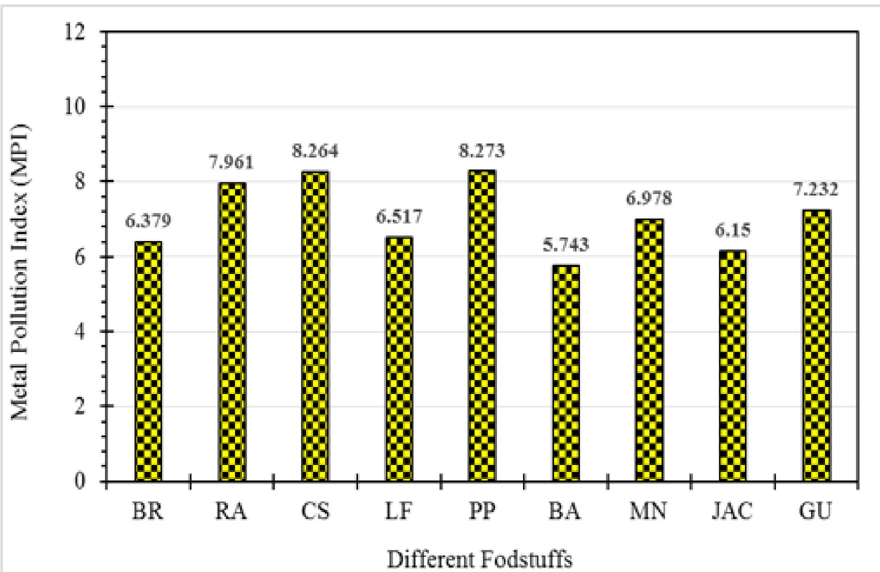

Figure 8: Metal pollution index of foodstuffs samples in RNPP.

Metal pollution index (MPI)

Calculate metal pollution index (MPI) in different foodstuffs samples as shown in Fig. 8 followed a decreasing sequence of Bitter gourd (BG) > Pawpaw (PP) > Ceylon Spinach (CS) > Red Amaranth (RA) > Guava (GU) > Mango (MN) > Lady's Finger (LF) > Brinjal (BR) > Jackfruit (JAC) > Banana (BA) respectively. Jolly et al. (2013) calculate metal pollution index (MPI) in different vegetables from Ruppur Nuclear Power plant site in Pabna district, Bangladesh and found the sequence of BGL > WS > LF > SP > TM > BN > BA > LR > WG > AM > SG > BG > CA > BR > RA > PL > PP > CF > TO respectively. However, higher MPI of bitter gourd, pawpaw, ceylon spinach and red amaranth suggested that these foodstuffs may cause many human health risk due to the higher accumulation of heavy metals (Figure 8).

Health risk index

The health risk assessment associated with heavy metal (Mn, Fe, Cu, Zn, Pb) of vegetables locally grown, estimated exposure and health risk index were calculated following the equations (2) and (3). The obtained results on health risk index for all foodstuffs samples are summarized in Table 4. From the Table 4, it is seen that the HRI in foodstuffs samples varied for Mn (0.49 – 0.61), Fe (0.02 – 0.19), Cu (0.01 – 0.26), Zn (0.013 – 0.009) and Pb (0.13 – 0.23) respectively. The sequence of the average health risk index for the studied foodstuffs was found as Zn (0.005 ± 0.002) < Fe (0.06 ± 0.05) < Cu (0.13 ± 0.08) < Pb (0.16 ± 0.03) < Mn (0.52 ± 0.05) respectively. This study revealed that the highest health risk index was observed for Mn considering the studied foodstuffs. This study also revealed that health risk index for all the studied metal and for all the studied foodstuffs were below than 1, which indicating that there is no significant health risk for the studied element in the studied foodstuffs at this moment in the study area. Finding of this study is consistent with the previously reported result in the same study area [16] and in the different country [9,27-29]. In a previous study Jolly, et al. [16] reported that Cr, Mn, Fe, Co, Ni and Cu for all type of vegetables are lower than 1 indicating safe for the consumer and Pb, Cd and Zn found to show HRI value greater than 1 in some vegetables in the area of RNPP. Singh, et al. [27] found that, Cu, Zn and Cr were not found to cause any risk to the people by consuming vegetables and cereals grown in the area around Dinapur Sewage treatment plant, India. In a study Cui, et al. [9] reported that local residents of an area near a smelter in Nanning, China have been exposed to Cd and Pb through consumption of vegetables. It is obvious that, the population is therefore at no risk of Mn, Fe, Cu, Zn and Pb. A two-way ANOVA test revealed that the health risk index for different metals (Fcal > Fcritic = 208.89 > 2.63 and p = 2.24E-24) are significantly different at 95% confidence level (Table 5). Similar finding was also observed for the health risk index in between different types of foodstuffs (Fcal > Fcritic = 2.156 > 2.153 and p = 0.049) collected from the study area (Table 4&5).

Table 4: Health risk index (HRI) of heavy metals via intake of foodstuffs analysed, RNPP site, Pabna, Bangladesh.

English Name	Sample ID	HRI				
		Mn	Fe	Cu	Zn	Pb
Bitter gourd	BG	0.54	0.06	0.26	0.01	0.23
Brinjal	BR	0.46	0.04	0.01	0	0.13
Red amaranth	RA	0.61	0.19	0.09	0.01	0.16
Ceylon spinach	CS	0.57	0.09	0.11	0	0.17
Lady's finger	LF	0.56	0.03	0.08	0.01	0.15
Pawpaw	PP	0.53	0.1	0.17	0.01	0.17
Banana	BA	0.5	0.02	0.1	0	0.14
Mango	MN	0.48	0.05	0.12	0.01	0.15
Jackfruit	JAC	0.49	0.02	0.1	0	0.15
Guava	GU	0.46	0.05	0.25	0	0.14

Table 5: Two-way ANOVA on health risk index (HRI) for different types of foodstuffs and different metals.

Source of Variation	SS	DF	MS	F	P-value	F crit
Between foodstuffs	0.038	9	0.0042	2.156	0.0497	2.153
Between Heavy Metals	1.624	4	0.406	208.9	2.24E-24	2.634
Error	0.07	36	0.0019			
Total	1.732	49				

Conclusions

Concentration of Mn, Zn and Pb elements in foodstuffs was found to be lower than that of the world average value, while the concentrations of Fe and Cu in foodstuffs were higher than the world average value. On the other hand, the concentration of the five metals (V, Cr, Ni, Co) and as were found less than the method of detection limit. Therefore, these five metals were not counted for the metal pollution index. Subsequently, the metal pollution index (MPI) values were found to be higher for Bitter Gourd, Pawpaw, Ceylon Spinach and Red Amaranth compared than other foodstuffs analyzed in this study. Health risk index (HRI) for Mn, Cu, Zn, Fe and Pb was found to be less than 1.0 for all varieties of foodstuffs samples around the area of Ruppur Nuclear Power Plant (RNPP) site. Therefore, it has been suggested that the people in the study area was at no risk for Mn, Fe, Cu, Zn and Pb through the studied foodstuffs. Moreover, the results of this study can be used as base-line values, which would be highly important as Ruppur Nuclear Power Plant undergoing power production cycle. The data would also be useful in possible human health risks assessment of local dwellers and those who consume fruits and vegetables grown in adjacent soil.

Acknowledgement

The authors deeply thankful to the Bangladesh Atomic Energy Commission (BAEC), for providing all necessary research facilities. Special thanks go to Dr Jolly YN, Chief Scientific Officer, Dr Akhter S, Principal Engineer, Jamiul Kabir M, Principal Scientific Officer of Atomic Energy Centre, Dhaka, Bangladesh for providing technical and logistic supports to complete this PhD project.

Conflict of Interest

None.

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