QUANTIFICATION OF HEAVY METALS AND RELATED HEALTH RISKS THROUGH CONSUMPTION OF DIFFERENT FOODSTUFFS COLLECTED FROM FIVE DIFFERENT MARKETPLACES OF DHAKA CITY

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CERTIFICATE

*This is to certify that the thesis entitled, **"QUANTIFICATION OF HEAVY METALS AND RELATED HEALTH RISKS THROUGH CONSUMPTION OF DIFFERENT FOODSTUFFS COLLECTED FROM FIVE DIFFERENT MARKETPLACES OF DHAKA CITY"** was submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the degree of **MASTER OF SCIENCE IN AGRICULTURAL CHEMISTRY** embodies the result of a piece of bona fide research work carried out by **AOLAD HOSSAIN,** Registration No. 19-10245 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institutes.*

I further certify that any help or sources of information, as have been availed during this investigation have duly been acknowledged.

Dated: Oct 2022
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DEDICATED TO MY BELOVED PARENTS

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ABSTRACT

This study was designed to determine the concentrations of iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), manganese (Mn), lead (Pb), and cadmium (Cd) status in commonly consumed foodstuffs such as, various parts of boiler and cock chicken (breast meat, leg meat, bone, liver, and brain), as well as some common foods (egg albumin, yolk, raw rice, black gram, fine and coarse lentil) collected from five different marketplaces of Dhaka city and to assess potential human health risks through the consumption of those foodstuffs. A total of 70 food samples were analyzed for Fe, Zn, Cu, Cr, Pb, Mn, and Cd contents by an atomic absorption spectrophotometer. The contents of Cu, Pb, and Cd, were found in most of the analyzed foodstuff samples that exceeded the FAO/WHO maximum allowable concentration (MAC) value. The estimated daily intake (EDI) for all heavy metals was below the corresponding maximum tolerable daily intake (MTDI). The incremental lifetime cancer risk (ILCR) values of Cd in egg, rice, black gram, coarse, and fine lentil samples exceeded the threshold limit (ILCR > 10^{-4}) for both adults and children, indicating lifetime cancer risk due to the consumption of contaminated foods. Although the threshold limit (ILCR > 10^{-4}) for selected body parts of both boiler and cock chicken was lower except bone sample. The target hazard quotient (THQ) of each heavy metal was THQ < 1.0 in all chicken and egg samples but THQ > 1.0 was observed in rice and coarse lentil samples for Fe, Pb, and Cd, indicating that consumers have potential non-cancer risk when exposed to a single heavy metal. However, hazard index (HI) values of heavy metals were greater than one in contaminated rice and coarse lentil for adults and children. Meanwhile, rice and coarse lentil samples for children emerged as potential health risks for inhabitants in the studied areas. Among the individual metals, Cu was the most dominant metal present in different foodstuffs collected from different marketplaces of Dhaka city and contributed to significant risk to the people.

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LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	FULL MEANING	ABBREVIATION	FULL MEANING
AAS	Atomic Absorption Spectrophotometer	HNO_3	Nitric Acid
ILCR	Indicating Life Time Cancer Risk	WHO	World Health Organization
Fe	Iron	IPCS	International Program on Chemical Safety
Zn	zinc	Kg	Kilogram
Cu	Copper	L	Liter
Cr	Chromium	$Mg(NO_3)_2$	Magnesium Nitrate
Mn	Manganese	Mg	Magnesium
Pb	Lead	MAC	Maximum Allowable Concentration
Cd	Cadmium	M.S.	Master of science
SD	Standard deviation	mL	Milliliter
HI	Hazard Index	mm	Millimeter
cm	Centimeter	$NH_4H_2PO_4$	Ammonium Monobasic Phosphate
cm^2	Square centimeter	ppm	Parts per million
LDV	Locally Developed Variety	RDA	Recommended Daily Allowance
Alb	Albumin	SAU	Sher-e-Bangla Agricultural University
et al.	And others/Associates	SE	Standard Error
Etc.	And the other things	THQ	Target Hazard Quotient
EU	European Union	TTHQ	Total Target Hazard Quotient
LT	Lentil	EDI	Estimated Daily Intake
FAO	Food and Agriculture Organization	MTDI	Maximum Tolerable Daily Intake
PI	Pollution Index	HIES	Household Income and Expenditure Survey
g	Gram	RfD	Reference Doses
HCl	Hydrochloric Acid	ILCR	Incremental Lifetime Cancer Risk

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATION	FULL MEANING	ABBREVIATION	FULL MEANING
H_2O_2	Hydrogen Peroxide	USEPA	United States Environmental Protection Agency
HM	Heavy Metals	BR	Brain
LM	Leg Meat	BN	Bone
BM	Breast Meat	LV	Liver

LIST OF SYMBOLS

SYMBOLS	FULL MEANING
@	At the rate of
+	Plus
-	Minus
<	Less than
>	Greater than
°C	Degree Celsius
%	Percentage
&	And
/	Per

CHAPTER 1

INTRODUCTION

Heavy metals are defined as metallic elements with a density greater than that of water (Tchounwou *et al*., 2012). Heavy metals also include metalloids, such as arsenic, that can cause toxicity at low levels of exposure, based on the notion that heaviness and toxicity are linked (Cui *et al*., 2005). Essential biological components are used by the body for a variety of biochemical and physiological activities. For some types of creatures, some components are necessary, but not for others. Mn, Fe, Co, Cu, and Zn are a few examples of necessary heavy metals (Eqani *et al*., 2016). According to Sauliute and Svecevicius (2015), essential heavy metals might be hazardous if present in excess. Due to the small gap between their toxicity and necessity, critical heavy metals including Mn, Fe, Cu, and Zn have attracted environmental and eco-toxicological interest (Yousafzai and Shakoor, 2007). Among the most hazardous heavy metals in the environment are the elements Cu and Zn (Burba., 1999; Gao *et al*., 2013). Ingestion of these metals over a long period is harmful to human health (Afrin *et al*., 2015). The four heavy metals and metalloids that are most harmful to the environment, namely Cd, Pb, Hg, and As, are typically known as non-essential heavy metals (Fraga, 2005).

Environmental contamination by these metals has been a growing problem for the environment and worldwide public health in recent years. Furthermore, as a result of an exponential expansion in their usage in a variety of industrial, agricultural, residential, and technical applications, human exposure has increased drastically (Ahmed *et al*., 2018). Geogenic, industrial, agricultural, pharmaceutical, home effluents, and atmospheric sources have all been reported as sources of heavy metals in the environment (Ahmed *et al*., 2019). Although heavy metals are naturally occurring elements found throughout the earth's crust, anthropogenic activities such as mining and smelting, industrial production and use, and domestic and agricultural use of metals and metal-containing compounds cause most of the environmental contamination and human exposure (Ahmed *et al*., 2019; Ara *et al*., 2018; Divrikli *et al*., 2003).

The most important resource for life's existence is unquestionably food. Foodstuffs (meat, grains, cereals, and eggs) are the most significant portion of the human diet because they offer protein, vitamins, carbohydrates, calcium, iron, and other critical micronutrients (such as Cu, Zn) to the body (Afrin *et al.*, 2021; Ahmed and Goni., 2010). As a result, eating various foods has become a primary source of nutrition as well as a pathway for contaminants to enter the human body (Ahmed *et al*., 2018). As a result, in the recent decade, food safety has become not only a significant food quality trait but also a major societal concern (Ahmed *et al*., 2019;).

Now-a-days heavy metals in the food chain have become a matter of concern for developing countries most likely Bangladesh. Due to their mobility in the air and soil, heavy metals are easily absorbed by plants in the environment (Khairiah *et al*., 2004). Heavy metals behave in the environment in a way that is both exceedingly persistent and cumulative. Due to their thermostability and lack of biodegradability, they can easily accumulate excessively (Sharma *et al*., 2007). Due to municipal and industrial activities (textile, garment, pharmaceutical, and cosmetics) as well as effective use of agrochemicals, hazardous metal contamination of soil is common in urban and peri-urban regions (Afrin *et al*., 2021; Meftaul *et al*., 2021). Additionally, one of the primary causes of soil pollution in crop fields are wastewater irrigation (Mahmood and Malik, 2014). Due to unchecked industrialization, wastewater and industrial effluents are carelessly discharged into nearby rivers in Bangladesh without adequate treatment (Majumder *et al*., 2021). As a result, in many industrial locations in Bangladesh, heavy metals do pollute a river or canal water (Afrin *et al*., 2021). Furthermore, industrial wastewater includes N, P, Mg, and K, farmers prefer to irrigate their agricultural fields with it (Haque *et al*., 2021). Besides numerous pathways exist for heavy metals to infiltrate the poultry production system. These include atmospheric deposition (caused by burning fossil fuels), the use of inorganic fertilizers on land, the application of biosolids and agrochemicals, and animal manures (Ahmed *et al*., 2010). Batteries, dyes, alloys, chemical compounds, pharmaceuticals, and cosmetic goods all contain heavy metals in large quantities, which suggests that the danger of contamination is quite significant and that stronger controls are required along the whole food chain.

Rice, pulses, chicken meat, and eggs are the primary consumables that the population in Asian nations including Bangladesh, India, Thailand, China, and Vietnam consumes regularly (Islam *et al*., 2014a). Even at low concentrations throughout a lifetime, toxic metal contamination of agricultural crops and subsequent accumulation in people through interactions with the food chain may cause a variety of cancerous and non-cancerous health issues, including neurological, immunological, cardiovascular, renal, and reproductive disorders (Anyanwu *et al*., 2018, Mohammadi *et al*., 2019). By eating contaminated foods, metals often aggregate in the human body's major organs including the kidneys, bones, and liver.

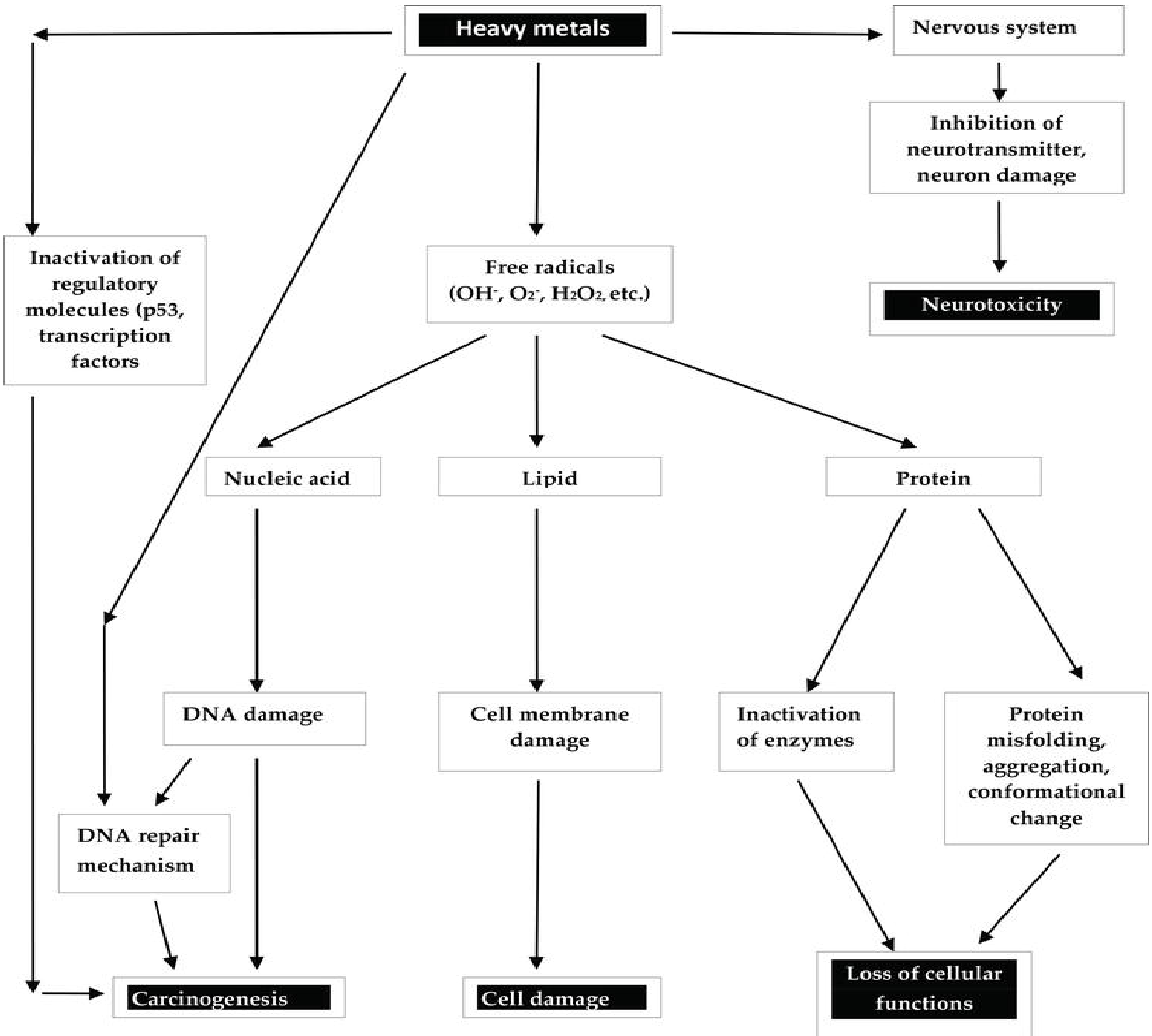

Figure: Heavy metals and its harmful effect on human health. (Engwa *et al*., 2019)

This causes the body to lose certain important nutrients and results in significant health issues (Duruibe *et al*., 2007, Zhuang *et al*., 2009, Islam *et al*., 2014a). For instance, high concentrations of Cu, Cd, and Pb in foods like rice, pulses, meat, fruits, and other foods are associated with a high prevalence of upper gastrointestinal cancer (Turkdogan *et al.*, 2003), whereas toxic metals like Pb and As have demonstrated carcinogenic effects (Khan *et al.*, 2012). Due to rising levels of toxic metals in agricultural soils and their transfer to agricultural products including rice, pulses, vegetables, fruits, and other food crops, a severe health concern has drawn significant attention in the Asian area, especially in emerging nations (Williams *et al.*, 2006).

In Dhaka city, it is essential to estimate their daily dietary intake of toxic metals and health hazards based on studies of people's normal food consumption (Williams *et al*., 2006., Islam *et al*., 2015b). The number of harmful metals in Bangladeshi rice, vegetables, and fruits has been the subject of several research (Bo *et al*., 2009, Hu *et al*., 2013). More research is necessary on different foodstuffs in Dhaka city because it is not just one of the world's most populous cities, but also the metropolis with the highest population in Bangladesh. In the center of Bangladesh, near to the Burighanga River, sits the multicultural metropolis of Dhaka. If the foodstuffs of Dhaka city are contaminated with heavy metals, a large population will be affected. For that, I selected five different marketplaces in Dhaka city and tried to asses about heavy metal contamination in different foodstuffs and future uses this knowledge to save the people who are living in Dhaka city from heavy metals toxicity.

Therefore the objectives of the present research work were:

- To quantify the amount of Cu, Cr, Zn, Fe, Pb, and Mn in different foodstuffs.
- To compare with the WHO/FAO standards of these heavy metals present in foodstuffs.
- To assess human health risk.

CHAPTER 2

REVIEW OF LITERATURE

This chapter's focus is to review earlier research studies that are connected to the current discussion. An attempt has been made in this chapter to represent a brief review of research information to assess different heavy metals in some common foodstuffs collected from different marketplaces of Dhaka city. Since a review of the literature creates a connection between the current and previous research on an issue, it aids in drawing a satisfying conclusion from an investigation. The most pertinent research works which have been done in the previous studies related to the present research work, are presented below-

According to Kormoker *et al*. (2021), heavy metals in food pose a serious threat to the public's health and they stated that consuming grains, pulses, and other commodities cultivated on soil polluted with harmful metals exposes people to these metals daily. The ranges of Cr, Ni, Cu, As, Cd, and Pb were 1.57-12.52, 1.71-37.78, 1.97-16.67, 0.36-3.72, 0.00-4.02, and 1.04-10.88mg/kg dw, respectively, in the meals that were the subject of the study. Their investigation showed that the foodstuffs had considerable anthropogenic inputs of Cr, Cu, As, and Pb. Except for Cu, all metals' estimated daily intake (EDI) levels are above the maximum allowable daily consumption (MTDI). All the tested metals' target hazard quotients (THQs), except Cr, were higher than 1, indicating that consuming these meals might increase a person's risk of exposure to the analyzed metals. Indicating a greater risk of cancer for both adults and children in the research location, the calculated target carcinogenic risk of As was higher than the United States Environmental Protection Agency United States Environmental Protection (USEPA) threshold.

Proshad *et al.* (2021) Conducted a study on 250 samples of food (25 species) and 315 samples of soil in Bangladesh's Jhenidah and Kushtia districts. The range of Pb, Cd, As, Cu, Ni, and Cr contents (mg/kg) in soils was discovered to be 0.97-114.72, 0.11-7.51, 1.07-23.38, 0.89-122.91, 0.91-77.32, and 0.7-23.03 mg/kg, respectively, whereas those in foodstuff samples were shown to be 0.46-11.48, 0.30-11.54, 0.47-921, 0.20-3.59, 0.001-1. According to the PMF model, Cu (81.4%) in the study area soils was primarily caused by the combustion of motor vehicle fuel, while Cr (84.9%)

was primarily of natural origin, Pb (73%) was caused by traffic emissions, Cd (74.3%), and As (63.4%) primarily came from agricultural practices, and Ni (70.9%) was primarily caused by industrial pollution. Cu, As, and Pb EF> 1.5 indicate moderate contamination. Most of the crops under study had BCF values for Cr that were more than 1, indicating that it is absorbed more readily than other metals. The cancer risk estimates for Cr, Ni, As, and Pb was higher than the threshold range, indicating possible cancer hazards.

Tchounwou *et al.* (2012) designed a research to look at the levels of toxic metals in various foods (cereals, and meat), and then calculate the possible health hazards of consuming toxic metals in Beijing, China, people. They discovered that the THQ values of the meals varied and were 0.00-0.04 for Hg, 0.03-0.29 for Cr, 0.02-0.23 for Pb, 0.01-0.33 for Cd, and 0.01-0.06 for As, all of which did not surpass the maximum threshold of 1. The TTHQ values for Cr, Pb, Cd, As, and Hg were 0.96, 0.54, 0.50, 0.19, and 0.09 respectively. This indicates that Cr was a significant risk factor (41.7%) for Beijing inhabitants, which warrants considerable concern.

Toxic metal concentrations (Cd, Pb, Cr, As, and Hg) in various foods (cereals, and meat) were investigated in a study designed by Liang *et al*. (2019), and the study's results were used to calculate the potential health risks of consuming toxic metals for Beijing, China, residents. They discovered that the majority of the chosen harmful metal levels in the meals were below the Pb, Cr, Cd, As, and Hg maximum permissible values for Chinese foodstuffs suggested in the China National Food Safety Standard. The target hazard quotients (THQs) for the various meals ranged from 0.00-0.04 for Hg to 0.03-0.29 for Cr, 0.02-0.23 for Pb, 0.01-0.33 for Cd, and 0.01-0.06 for As, all of which did not surpass the maximum threshold of 1. Vegetables had a total THQ (TTHQ) value of 0.88, grains of 0.57, meat of 0.46, fish of 0.32, and fruits of 0.07. This shows that, compared to other diets, consuming vegetables (38.8%) had a substantial risk impact. According to the TTHQ values of 0.96 for Cr, 0.54 for Pb, 0.50 for Cd, 0.19 for As, and 0.09 for Hg, Cr was a significant risk factor (41.7 percent). The THQ/TTHQ ratios, however, were all below 1, indicating that there were no health hazards associated with intake for the local population. Dietary weekly intakes (WIs) levels were all below the World Health

Organization (WHO) and Food and Agriculture Organization (FAO) of the United Nations suggested limit of Provisional Tolerable Weekly Intakes (PTWI).

Pirsaheb *et al*. (2021) studied a research that the market of Kermanshah city's seven varieties of high-consumption cereals, including lentils, peas, maize, split peas, beans, rice, and wheat (a total of 48 brands), was studied in Iran. Three samples from each brand made up the total of 144 that were examined for Cd, Cr, Ni, Pb, Zn, Cu, As, and Hg. Cd, Cr, Pb, Zn, Ni, Cu, Hg, and As were all present in concentrations of 6.85–12.0, 27.3–15.5, 86.7–136, 459–146, 21.2–34.8, 147–86.3, 2.03–2.26, and 0.62–1.80 g/kg dry weight, respectively. While the total carcinogenic risks (TCR) for virtually all cereals are greater than the permissible limit (=10^{-4}), the total non-carcinogenic risks (TTHQ) of heavy metals are less than the permitted threshold (=1).

Various rice, pulses, and grass pea were sampled in the study conducted by Alam E.T. AU3 - Tanaka, A., (2003) and analyzed for As, Cd, Cu, Pb, and Zn using inductively coupled plasma atomic emission spectrometry and inductively coupled plasma mass spectrometry in Samta village, Jessore district, Bangladesh. They claim that the bulk of the local population's nutritional needs is met by native food crops, which are also crucial to their general health. They found that some plants might potentially collect heavy metals with Pb values larger than Cd. In comparison to rice and lentils, veggies had greater As and Cd contents. In general, rice had a greater Pb content than pulses and vegetables. With an average daily intake of just 260 g of rice per person per day, only Pb is at amounts that would pose a health risk for human consumption in the rice farming in Samta.

The high dietary structure of cereals, legumes, and their products (CLPs) has been linked to heavy metal pollution, dietary exposure, and health risk assessment was found by Wei and Cen, (2020). This research was conducted in 16 Beijing neighborhoods using atomic spectrometry and the Nemerow pollution index method (NPIM). Finally, they evaluated the dietary exposure and health risk based on the HM contents and dietary composition of the population of Beijing. The findings showed that the CLPs offered for sale in Beijing were secure and that the daily exposure doses (DEDs) for Cd, Cr, Pb, Cu, Fe, Mn, and Zn were, respectively, 0.0772, 0.2251, 0.3350 µg kg/d, 0.0119, 0.0417, 0.0367, and 0.0505 mg kg/d. The HMs described above had hazard quotients (HQs) of 0.08, 0.08, 0.24, 0.32, 0.06, 0.22, and 0.17, respectively. They discovered that the integrated hazard index (HI) was more than 1 but less than 10, showing that Beijing residents may experience non-carcinogenic negative side effects from consuming these CLP samples over an extended period. Additionally, this study indicated that, in comparison to the other HMs, the dietary consumption of Cr, Mn, and Cu may harm the health of Beijing inhabitants.

Despite the global importance of atmospheric heavy metal input into agricultural soils, Zhou *et al*. (2020) research has primarily focused on the amount of the depositions with limited attention given to the risk of the newly deposited heavy metals. To understand the remobilization of the newly deposited copper (Cu) and lead (Pb) from the atmosphere and explore the metals’ mobility and bioavailability in rice (Oryza sativa L.), a soil transplant experiment was conducted in three areas along with a gradient Journal Pre-proof 3 of atmospheric depositions. Approximately 61% of the Cu and 76% of the Pb depositions tended to be present in potentially mobile fractions. The soil retention of newly deposited Cu and Pb presented as higher mobile fractions than those in the original soil. The newly deposited Cu and Pb in soils only accounted for 0.34-8.7% and 0.07-0.29% of the total soil Cu and Pb pools, but they contributed 30-84% and 6-41% in rice tissues, respectively. A major implication of these findings is that once the heavy metal is deposited, it may be reactivated in soils and transported to aerial parts or foliar uptake into plant tissues, emphasizing the important role of the newly deposited Cu and Pb in contributing to the edible parts of crops.

Zhou *et al.* (2020) gave mostly concentrated on the volume of depositions with little attention paid to the danger of freshly deposited heavy metals in a study, despite the significance of atmospheric heavy metal access into agricultural soils on a worldwide scale. A soil transplant experiment was carried out in three locations along with a gradient Journal Pre-proof 3 of atmospheric depositions to comprehend the remobilization of the recently deposited Cu and Pb from the atmosphere and investigate the metals' mobility and bioavailability in rice (Oryza sativa L.). Potentially mobile fractions tended to contain around 61% of the Cu and 76% of the Pb depositions. Higher mobile fractions than those in the original soil were present in the soil retention of recently deposited Cu and Pb. Although freshly deposited Cu and Pb in soils only made up 0.34–8.7% and 0.07–0.29 percent of the total soil Cu and Pb pools, respectively, they were responsible for 30-84 and 6-41 percent of the Cu and Pb in rice tissues. These results have significant ramifications, including the possibility that heavy metals may be reactivated in soils and transferred to aerial portions or foliar absorption into plant tissues, highlighting the significant contribution of recently deposited Cu and Pb to the edible sections of crops.

A pot trial experiment was carried out by Miaz and Wilke, (1997) to determine how irrigated sewage affects soil and plant absorption of heavy metals. They discovered that when soil pollution rose, crop concentrations of Cd, Cu, Pb, and Zn increased. However, Cd and Zn absorption increased substantially more than those of Cu and Pb. Cd levels in leaves varied from 0.1 to 8.2 mg kg^{-1}, depending on the dry matter.

According to O'Neill *et al*. (1992), most plants' edible sections normally had modest levels of arsenic buildup. For grass species about plant development, organic arsenicals and As (Ill) were the most phototoxic substances. Arsenic absorption and translocation were species-specific, and the concentration of arsenic in photosynthetic organisms generally followed the trend of As (V) and As (Ill). Regardless of the As chemical forms, as application rate Rosen greatly led to an increase in arsenic content in root and shoot (Carbonell et al., 1999).

A study was undertaken by Islam *et al*. (2014b) in Bangladesh to assess the levels of seven major heavy metals (Cr, Ni, Cu, Zn, As, Cd, and Pb) in grains and pulses, as well as any potential health effects. They discovered that the Total THQ values for As and Pb were more than 1, indicating that consuming As and Pb from grains and pulses has serious health concerns. The projected HI value of 1.7×10^{1} (>1) does, however, highlight a possible non carcinogenic danger to consumers. Additionally, the assessment revealed that As (5.8×10^{-3}) and Pb (4.9×10^{-5}) had carcinogenic risks that were higher than the USEPA-accepted risk limit of (1×10^{-6}).

According to Islam *et al*. (2015c) study, they looked at the concentrations of Cr, Ni, Cu, As, Cd, and Pb in a variety of meals, including cereals, pulses, meat, and eggs. The ranges of Cr, Ni, Cu, As, Cd, and Pb were 0.18–4.8, 0.008–10, 0.47–22, 0.003-0.98, and 0.0003-0.85 mg/kg fw, respectively, and 0.005–3.7 mg/kg fw for Cd. The daily intakes (EDIs) of Cr, Ni, As, Cd, and Pb exceeded the maximum tolerated daily intake (MTDI), suggesting that dietary consumption may be one of their probable sources. The total P HQs (metal hazard quotients) from rice, beef, and eggs exceeded 1.

The quantities of heavy metals (As, Cd, and Pb) in rice, pulses, and various agricultural products were examined by Park *et al.*, (2011). The findings indicated that Transfer Factor (TF) was examined on average at 0.0060.309 for As, 0.0026.185 for Cd, and 0.0030.602 for TF (Pb). The three grains of rice (0.309 in As, 0.308 in Cd, and 0.602 in Pb) had the greatest mean TF values.

To compare the levels of heavy metals (As, Pb, Cd, and Hg) in various grains, Samal and Garg, (2012) conducted research in Uttar Pradesh, India. Of the four heavy metals, they discovered that rice had the greatest concentrations. According to Bhattacharya *et al*. (2010), the Boro rice has substantially greater amounts of As (451 ppb). In the samples of Assamese rice that were gathered, the amount of Pb was extremely low (1.5 g/kg) (Haloi et al., 2010). The average amount of As found in grains, according to (Roychowdhury et al. 2003), was 130 ppb. Similar amounts of lead (1310.02 g/kg) were found in the grains on the Egyptian market, according to Salama and Mohamedm (2005).

Zakir *et al.* (2021) conducted a study on the heavy metal analysis of various meals from Bangladesh's divisional cities of Chottogram and Mymensingh. They discovered that in both locations, the estimated per capita per day dietary intakes of Cu and Mn from rice-eating were greater than the RDA for an adult person. As a result of consuming rice gathered from Mymensingh city, the computed daily metal intake (DMI) values of Pb for both males and females were likewise greater than the upper tolerable intake level (UTIL). In Chottogram city and Mymensingh city, the average computed hazard index (HI) values for males and females attributable to dietary consumption of rice were 47.67 and 93.30 and 97.98 and 192.04, respectively.

A study on the consumption of foods polluted with heavy metals and related dangers in Bangladesh was undertaken by Real *et al*., (2017). In contrast to the EPA's suggested carcinogenic risk threshold of 1.0 106, they discovered that all pollutants contained in each food item, except Cd and Pb, posed substantial levels of carcinogenic hazards up to 2.99 103. When compared to the EPA's recommended non-carcinogenic risk threshold of 1.0, the dietary intake of cadmium and arsenic from rice-eating likewise posed dangerous levels of non-carcinogenic hazards of 4.587 and 6.648, respectively.

Shaheen *et al*. (2016) attempted to determine the quantities of six trace elements—Cr, Ni, Cu, Cd, Pb, and As in "non-piscine protein source" meals (meat and eggs) to assess contamination levels and potential dangers to human health in Bangladesh. They discovered that majority of the elements' estimated mean levels exceeded the dietary items' maximum permissible concentration (MAC). Children are more vulnerable to harmful substances through food consumption, as shown by the estimated daily intakes (EDIs) of Cr and Cd being greater than the maximum tolerated daily intake (MTDI) for children. Their findings indicated that for both adults and children, As had target hazard quotients (THQs) and target carcinogenic risks (TCR) (THQ > 1 and TCR > 104).

Liang *et al.* (2017) carried out a study on the evaluation of heavy metals in various Chinese meals. To their findings, Pb had the highest level of the metals, with an average concentration of 1.557 0.779 mg/kg, followed by Cr (0.782 0.394), Hg (0.284 0.094), As (0.127 0.078), and Cd (0.071 0.032), in that order (in decreasing order)—all of which were below the upper limit of normal values in China.

A research was done on the probabilistic health risk assessment of toxic metals in chickens from Bangladesh's biggest production sites in Dhaka (Haque *et al*., 2021a). They discovered that the hazardous metals (As, Ni, Cr, Hg, and Pb) were often present in very high amounts in various chicken body sections, particularly the livers, which had concentrations that were several times higher than the permitted maximum (MAC). Their analytical findings revealed that some feed and water contain significant amounts of As and Cr, which may bioaccumulate in chicken. Except for As and Fe on a few farms, all metals' estimated daily intakes (EDI) were below the PTDI's (provisional tolerable daily intakes). Most metals had target hazard quotients (THQs) below 1, however, several farms had THQs of As and Cr over 1.

An investigation into the assessment of trace metals in Bangladeshi consumer chickens was done by Mottalib *et al*., (2018). According to their research, the concentrations of As, Cd, Co, Cr, Cu, and Ni in broiler, layer, and LDV chickens were 0.728, 0.232, 0.392; 0.595, 0.245, 0.271; 0.058, 0.016, 0.096; 5.275, 1.562, 22.180;

3.571, 2.269, 4.241, and 0.332, 0.211, 0.433 mg/kg, respectively. The findings show that As, Cr, and Cu concentrations in the examined samples surpassed the upper limits that were permitted, although Cd and Ni amounts were within acceptable bounds. Cr > Cu > As > Cd > Ni > Co was the sequence in which metal concentrations declined. Due to the intake of various varieties of chicken, the goal hazard quotient and cancer risk values for each metal were computed.

Ansar and Durham, (2019) examined if heavy metals may be present in poultry products and, as a result, what impact they might have on Bangladeshi citizens. According to their research findings, the main factor causing the food-borne disease was the amount of Cr contamination, which was beyond the regulatory limits advised by the World Health Organization. The primary causes of heavy metal contamination in Bangladesh's environment were the tanning and textile industries.

Jothi *et al*. (2017) Conducted study on the presence of heavy metals in Bangladeshi commercial chicken diets. The average amount of heavy metals in protein meal feed ranged from 10.63 to 218.10 mg kg^{-1} for Cr and from 7.37 to 52.25 mg kg^{-1} for Pb. In feed samples including meat and bone meal, Cr levels ranged from 9.15 to 40.59 mg kg^{-1} while Pb levels ranged from 5.0 to 61.42 mg kg^{-1}. Results, however, indicated that Pb and Cr were found in worrying amounts in the majority of the feed samples, with both metals present in all feed samples. To assess the health risks and safeguard the end-user from potentially dangerous foods, they recommended routine heavy metal screening, particularly for Cr and Pb.

Research by Islam *et al*. (2014a) attempts to measure the number of heavy metals (Cd, Cu, Cr, Pb, and Zn) present in edible chicken eggs in Peshawar, Khyber Pakhtunkhwa, which have a direct impact on human health. Atomic absorption spectrophotometer was used to calculate the combined concentration of egg components, including egg white, egg yolk, and entire egg. The study's findings showed that the levels of Cd, Zn, and Pb in whole eggs were 2-3 times higher than the recommended daily consumption. The Cr was nonetheless undetectable, whereas the Cu was within the consumable limit.

Fe, Cu, Zn, Ni, Mn, Cd, Pb, and Cr were discovered in southern Nigerians' consumption of chicken flesh and chicken gizzard Iwegbue *et al*., (2008). The elements in chicken flesh and gizzard were found in the following order: Fe>Zn>Ni>Cu>Cr>Pb>Cd>Mn. The elements' concentrations ranged from 23.59 to 97.72 mg kg^{-1} of Fe, 0.01 to 5.15 mg kg^{-1} of Cu, 4.95 to 48.23 mg kg^{-1} of Zn, 0.13 to 7.93 mg kg^{-1} of Ni, 0.01 to 1.37 mg kg^{-1} of Mn, 0.01 to 5.68 mg kg^{-1} of Cd, 0.01-4.60 mg kg^{-1} of Pb, and 0.01-3.43 mg kg^{-1} of Cr. While the quantities of cadmium, nickel, chromium, and lead in certain samples were at levels over the permitted limits, those of iron, manganese, copper, and zinc were within the legal limits.

To establish the potential danger given to consumers of Saudi Arabia by consuming chicken products, the concentrations of Fe, Cu, Zn, Mn, Se, Co, Cr, Pb, Cd, and Ni in eggs and chicken meat products, as well as those in the feed of chickens was evaluated (Korish and Attia., 2020) and their findings showed that the amounts of Cd, Pb, and Se in chicken meat products and eggs were below detectable levels, indicating that hazardous heavy metals are not a danger. On the other hand, broiler liver had the highest level of heavy metals, except Cr, Co, and Ni. When compared to raw meat and table eggs, meat products had greater amounts of Cd, Cu, Mn, Ni, Pb, and Co. Overall, the results showed that the intake of chicken meat products posed a health risk to people since the levels of Pb and Ni were four and seven times higher, respectively than the permissible maximum limit.

Atomic absorption spectrometry was used in Liaoning, China to measure the amounts of copper and zinc in feed and chicken flesh reerted by Jiang *et al*., (2011). The typical copper levels in chickens were higher than the upper limit values allowed by Chinese standard GB15199-94.

The purpose of the study by Kalu *et al.*, (2021) was to identify the presence and concentrations of manganese (Mn), zinc (Zn), and iron (Fe) in the broiler's kidney, liver, and gizzard offals and thigh muscle. They discover that more Mn (5.105 0.053 mg/kg) accumulated in the thigh muscle than any other organ, although the liver had the greatest concentration of Fe (6.256 0.246 mg/kg), which was over the MPL set by FAO/WHO. Mn, Zn, and Fe in eggs had mean concentrations of 5.081 0.033, 5.092 0.021, and 7.102 0.146 (mg/kg), respectively. The amount of Mn in eggs was only a little bit higher than the 5.0 mg/kg maximum residual limit.

To examine several trace metals that are troublesome with neutron activation analysis, such as Cu, Fe, Mn, Zn, Pb, and Cd, atomic absorption spectrophotometry was used to measure the amount of harmful metals variation in domestic and farm-raised chicken eggs by Khalid *et al*., (2007). In the yolk of chicken farm eggs, median concentrations of Cu, Fe, Mn, and Zn were determined to be 3.6, 101.2, 1.7, and 42.3 µg g^{-1}, respectively. As may be predicted, egg albumen had substantially lower amounts of these components. On the other hand, egg albumen had greater median Pb (0.130 µg g^{-1}) and Cd (0.049 µg g^{-1}) values than egg yolk.

Atamaleki *et al*. (2020) conduct a study to find out the concentration of heavy metals in poultry eggs as well as health risk assessment of these metals. Fe (44.11 mg/kg), Zn (25.45 mg/kg), Cu (2.100 mg/kg), Pb (0.797 mg/kg), Ni (0.781 mg/kg), Se (0.633 mg/kg), Cr (0.368 mg/kg), As (0.148 mg/kg), Cd (0.028 mg/kg), and Hg (0.0027 mg/kg) were the results of their study. Additionally, compared to the white of the egg, the yolk had a larger content of trace metals. On the other hand, there was no discernible variation in the PTE concentration between commercial and local eggs. As a result of ingesting heavy metals by eating eggs, consumers in some nations face severe non-carcinogenic and carcinogenic hazards.

According to Ullah *et al*. (2022), the levels of Pb, Cd, Cr, As, Hg, Mn, Fe, and Zn in samples of chicken meat and eggs that were taken from across the country were measured and were found to be between 0.03-2.73, 0.01-0.015, 0.025-0.67, 0.04-0.06, 0.01-0.015, 0.15-0.63, 2.50-38.6, and 1.02-19.4 mg/kg- The maximum acceptable concentration (MAC) for dietary food was shown to be surpassed by just Pb, according to their findings. The primary source of heavy metals in the foodstuffs under investigation, according to them, was human activity. The ingestion of chicken meat and eggs, which both contain these metals, was analyzed for human health hazards, and the results show that there are no dangers connected with doing so.

The largest amount of chromium discovered in the solid waste was determined to be 3.2% in chicken feed, according to Hossain *et al*., (1970). Chromium concentrations as high as 2.49 percent and 1.94 percent were found in two distinct locations in Dhaka. All feed sample amounts for cadmium, lead, arsenic, and mercury were also measured. The greatest and minimum levels of these elements that could be identified were determined to be 3.888 ppm and 0.991 ppm for cadmium, 30.114 ppm and 7.577 ppm for lead, 2.212 ppm, and 0.099 ppm for arsenic, and 13.916 ppm and 0.166 ppm for mercury. The pollution of chicken feed with heavy metals, they added, was caused by the chemical industry.

According to Rahman *et al*. (2022) the levels of As and Pb in the various chicken parts and Cr exceeded the upper limits permitted by various regulations. For all species, the metal concentrations found in the various samples produced target hazard quotients (THQ) values greater than 1, indicating health hazards associated with eating chicken. However, when all the factors were taken into account, there was a non-target cancer risk. Their research revealed that eating fowl carries a risk of As, Pb, and Cr cancer in people.

Akter *et al*. (2020) conduct research in Hazaribagh, a region with a thriving leather processing industry and the primary location in Bangladesh for the production and distribution of fish and poultry feed. Proteinaceous materials include sliced-cut bits of skin and hide and solid tannery trash. Without any suitable treatment, these wastes are transformed into protein concentrate that is utilized in chicken feed. Three distinct types of samples were taken at various points around the sampling site. Their sample reflects the numerous steps in the manufacturing of protein concentrates, from solid waste to finished goods, such as components for poultry feed. Their findings show that all heavy metals were not only found in all sample types but also considerably above the MAC value for components in chicken feed and went beyond the human tolerable limit.

Shahnur - Alam *et al*. (2021) lead a study on poultry samples that were collected from five different farms in Dhaka city. The main aim of the study was to find out the concentration of arsenic and chromium from these collected samples. Their research showed that certain locally produced chicken diets are seriously chromium polluted. There is no arsenic contamination in fowl meat.

Suleman et al., (2022) found out that the global poultry market is substantial and expanding. There was a need to make poultry feed on an industrial scale due to the significant commercialization of poultry farms and the growth in the number of birds on poultry farms. There are substantially increased chances that chicken feed may become contaminated with some harmful substances during the preparation process as a result of industrialization and rising environmental contamination. Animal feed might have physical, chemical, or biological risks. Feed for chickens may get contaminated when being handled, stored, or transported, either accidentally or on purpose. Risk management should focus more on prevention than reaction after a problem has been identified.

In the Namakkal district of Tamil Nadu, Raghavan *et al*. (2021) attempted to determine the lead concentration in poultry feed and its byproducts, i.e., chicken egg and meat. In the Namakkal area, 90 poultry farms provided samples for this study. The study's findings revealed that the Namakkal district's lead levels in chicken feed and egg/meat samples vary from 0.68 0.12 to 5.46 0.53 ppm and 0.28 0.05 to 1.06 0.36 ppm, respectively.

By comparing the concentration of metals in their feed intake, research by Kabeer *et al*. (2021) attempted to quantify heavy metals (Ni, Pb, Zn, Mn, Cr, Cu, and Se) in eggs retrieved from chicken farms. In all, 90 egg samples and 12 samples of chicken feed six each with food and water were gathered from three distinct peri-urban Lahore poultry farms and backyards. The results demonstrated that the levels of Pb, Cr, and Se in feed (Pb = 2.585, Cr = 1.3039, and Se = 0.9411) and egg white (Pb = 0.6578, Cr = 0.18, and Se = 0.2161) were higher than allowed in chicken farms. The presence of more metals in chicken farm eggs, such as Pb, Mn, Cr, Cu, and Se, may be related to the consumption of tainted feed.

In Markazi Province, Iran, Karimi *et al*. (2020) examined the amounts of harmful heavy metals (As, Cd, Hg, and Pb) in agricultural goods such as pulses, rice, and beans. The country's most industrialized region is the Markazi Province. There are lead mines and other industrial facilities there, therefore the soil likely contains heavy metals. The analysis's results revealed that the carcinogenic risk index for the samples was within permissible bounds. However, due to its large consumption relative to the other crops, such as earthlings and legumes, rice was discovered to be the most significant source of harmful metal exposure.

Heavy metal levels of copper (Cu), zinc (Zn), cadmium (Cd), lead (Pb), nickel (Ni), and chromium (Cr) in muscle tissues, livers, kidneys, and a staple of livestock were examined at conventional farms in central Greece. According to the study, there was little danger of heavy metal transmission from feed to animal products. In experiment 2, feed for poultry kept under various feeding regimens and seasons on various farms was examined. According to the results, there were relatively high quantities of Cu (155 9.13) and Zn (144.56 5.78) in the liver, respectively admitted by Makridis *et al*., (2012).

Imran *et al*. (2014) conducted research to identify the contamination of chicken feed with heavy metals (arsenic, cadmium, copper, chromium, mercury, iron, lead, manganese, nickel, and zinc). All the samples were gathered in Kasur since it is the center of the tanning industry in Punjab and there is a significant amount of environmental pollution coming from the tanneries there. Without any treatment, the tanneries' wastewater is dumped into the sewers. All of the examined samples contained heavy metals, according to the results. Except for mercury, none of the other metals were detected in concerning quantities. In every sample, mercury levels were higher than those permitted by the National Research Council and the European Union.

Heavy metal buildup can be excessive in poultry, especially in backyard-raised birds. Landfills (agricultural waste), animal waste, and polluted roadside ditches are all hazards to poultry. It could consume plants, geohelminths, and polluted soil. According to Kopacz *et al*. (2007) study's excess Pb levels were found in chicken muscles in 20% of samples and chicken eggs in 4.3% of samples from chickens maintained in the Lower Silesia region. For Cd, there were exceedances of I4.8 and 7.9 percent, but for Hg, there were exceedances of 45.5 and 64.5 percent, respectively. In hen eggs, there was a rather substantial buildup of mercury, with averages frequently surpassing the 0.02 mg Hg kg1 national allowed limit. The level of heavy metal bioaccumulation (Cd, Cu, Hg, Pb, and Zn) in the muscles and livers of free-range hens in the copper Belt region was evaluated by (Kopacz et al., 2007). The findings indicated that chicken liver, where the permitted quantity of Pb and Cd was exceeded was the organ collecting the highest quantities of heavy metals. However, the Pb concentration was surpassed in the muscles.

In the Sharkia Governorate of Egypt, Raslan *et al.* (2018) took a total of 60 fresh egg samples randomly from 20 of each over June and October 2016. The obtained data showed that commercial, organic, and poultry chicken eggs had the greatest metal loads of all the samples. All analyzed elements had residual amounts that were higher than the FAO/maximum WHO's acceptable levels, particularly in the balance of Pb (0.340.03), Cd (0.180.02), As (0.140.017), Zn (23.170.88), Ni (1.310.08), and Cu (11.470.66), followed by commercial and then organic eggs. High levels of metals in chicken eggs pose serious risks to both human and chicken embryos and may have serious toxicological effects.

To determine the presence of heavy metals, particularly arsenic (As), lead (Pb), and chromium, Rashid *et al*. (2018) collected a total of 360 elemental samples of chicken feed, meat, and egg samples from the main poultry growing areas of the nation (Cr). All the examined samples' heavy metal contents (As, Pb, and Cr) were discovered to be positive. However, in the majority of instances, the levels were below the Maximum Permitted Concentration (MPC). On the other hand, the "Cr" and "Pb" levels in the 14 percent and 11 percent loose feed samples were 7-70 and 3 times, respectively, higher than that of MPC. The layer and broiler-ready feed samples were found to be free of such elements. It's important to note that the egg samples were also confirmed to be free of those dangers. Of the analyzed samples, 14% of the broiler meat samples had levels of "As" and "Cr" that were 4-6 significantly greater than the MPC.

The purpose of Hossain et al., (2022) study was to assess the quality of ready-made broiler feed (starter and grower) purchased from seven various feed mills located throughout five distinct administrative regions of Bangladesh. In this investigation, the heavy metal concentrations, specifically Pb and Cd, were determined by purchasing broiler starter and grower feed from each of the feed mills. The laboratory tests of broiler starter and grower feed samples from five divisions of seven feed mills revealed no differences in the heavy metal data (Pb, Cd) across treatments ($P>0.05$). Although there was no significant difference in the Pb and Cd concentrations of the broiler feed samples from the five divisions of the seven feed mills when compared as a whole ($P>0.05$), there was a significant difference (P0.01) in the feed samples from the individual divisions (Dhaka, Chittagong). The study's findings indicated that, despite variations in the harmful metal concentrations of separate division's feed samples, the quality of broiler feed at various feed mills seemed to be satisfactory based on chemical examination. The broiler chicken had no chance of posing a public health risk to the consumer globe since the feed's assessed content of harmful metals was within the range of limitations of the allowed level.

Ifie et al., (2022) conducted a study to measure the levels of total aflatoxin and heavy metals (lead, cadmium, chromium, and copper) in chicken feed and components from two different parts of Delta State, Nigeria (north and center). Moisture content, total aflatoxin, and heavy metal (lead, cadmium, chromium, and copper) concentrations were examined in a total of 120 samples that were gathered directly from chicken farms, feed mills, and poultry feed merchants. In samples from the north and central regions, the concentrations of total aflatoxins varied from 12.0 to 20 g/kg and 21 to 31 g/kg, respectively. Aflatoxin levels in other samples from the north, except maize, were just a little bit lower (18–20 g/kg) than the allowed values. Aflatoxin levels, however, were all above acceptable levels in samples from the center. The samples had copper content within the allowable level, while the quantities of lead, cadmium, and chromium were higher in 44.4, 29.1, and 21% of the samples, respectively. Aflatoxin and lead levels in poultry diets that are higher than the allowed limits of 20 g/kg and 5 mg/kg, respectively, may be dangerous to the health of both animals and people.

According to Hasan *et al.* (2022), heavy metals were found in rice samples from Bangladesh's three main industrial areas Savar, Gazipur, and Ashulia in the following order: Zn >Cu >Cr > Co > Fe >Cd > Pb > Ni >As. The findings of their analysis revealed that the discovered quantities of Zn, Cd, Cr, and Co are above the maximum tolerance levels advised by the WHO and FAO. They discovered heavy metals transferred from the soil to the rice in the following order: Zn > Cu > Cr > Co >Cd > Pb > Fe > As > Ni. The buildup of heavy metals in rice is a significant public health issue.

According to Guadie et al., (2022) the average metal contents (mg/kg) in samples of Ethiopian and imported rice were found to be within FAO/WHO guidelines, falling within the ranges of 4.82-17.04 for Cr, 11.30-18.30 for Cu, 6.04-9.22 for Mn, and 17.15-27.37 for Zn. Pb was not found in any of the rice samples, either. When compared to White rice, Red rice had greater amounts of metals. In comparison to imported rice, Ethiopian rice has greater metal levels. They discovered that the

anticipated daily consumption (mg/kg-day) was below the acceptable daily intake limit. Except for Cr, all samples' levels of the target hazard quotient (THQ) were within the acceptable range, eliminating any potential health hazards from eating rice. Except for Jimma Red, the hazard index values (HI) for the metals in Ethiopian rice indicated the warning threshold level and probable health hazards for rice eaters. As a result, the concentrations of these metals were below the FAO/WHO maximum limits, and the majority of THQ and HI values were below unity. According to their research, consuming these grains did not provide a significant non-carcinogenic danger to human health in terms of exposure to metals.

According to Bielecka *et al*., (2020), all rice products sold in Poland had average As, Cd, Pb, and Hg concentrations of 123.5 77.1 g/kg, 25.7 26.5 g/kg, 37.5 29.3 g/kg, and 2.8 2.6 g/kg, respectively. One sample of the As concentration was above the limit set by the Polish National Food Safety Level, while two samples of the Hg content exceeded the standard set by the European Commission. Statistically, the As content of the food samples imported from European markets (n = 27) was greater (p 0.05) than that of the food samples imported from Asian nations (n = 53). Health risk indicator readings for the adult population in Poland did not indicate an elevated risk. However, the benchmark dosage lower confidence limit (BMDL) for Pb is equal to 55 g of rice consumed each day.

Bilo *et al*. (2015) made research to identify trace metals in rice grown in India's industrial districts. According to their research, the concentration of heavy metals found in rice samples falls in the following order: Mn is followed by Zn, then Cu, then Ni, then Pb, and finally Cr. In comparison to rice, and rice husk has a greater mental concentration. This study makes a first-ever suggestion on the potential use of rice husk as a heavy metals filter. The potential of rice husk to sequester metals may encourage the adoption of novel management techniques for rice farming to protect it from contamination.

Researchers Sharafi *et al*. (2019) lead a study to identify the levels of several harmful metals (arsenic, lead, and cadmium) in popular rice brands in Iran and the health concerns associated with them. According to the findings, almost 88 percent of the rice consumed in Iran (including rice from Iran, Pakistan, and India) does not adhere

to national standards or WHO/FAO guidelines, posing unacceptable health hazards. In comparison to other types of rice, the hazards of arsenic, lead, and cadmium in Indian rice were much greater.

CHAPTER 3

MATERIALS AND METHODS

A study was conducted from November 2020 to March 2022 to determine the status of heavy metals in selected foodstuffs collected from five different markets places of Dhaka city. The details of materials used, and methods applied for the collection and analysis of samples are presented in this chapter.

3.1 Sampling sites

All samples were collected from five selected sites in Dhaka district, Bangladesh. The location of the sites are shown in Table 3.1 from where samples were collected in clean polyethylene bags and brought to the laboratory for analysis.

Table 3.1 Location of the sampling sites in Dhaka city.

Sl No:	Market Name	Location
1	Kawran Bazar	23°42′37″N
2	Camper Bazar	23°33′18″N
3	Taltola Bazar	23°29′56″N
4	Kochukhet Bazar	23°45′42″N
5	Agargaon Bazar	23°12′50″N

3.2 Collection of samples:

In the case of poultry, three chickens were collected from each market (a total of 15 broiler chickens and 6 LDV chickens) randomly. Five different body parts like- leg meat, leg bone, breast meat, liver, and brain were selected as samples. After collecting these selected parts, samples were put into the individual polythene bag with distinct marking and tagging and brought to the Agro-environmental laboratory of Sher-e Bangla Agricultural University (SAU) and freeze at low temperature till further use. In the laboratory, the fresh weight of the collected chicken was taken by a weighing balance and cut into small pieces using a sharp knife. After that, the individual cutting sample was put into a paper bag with proper marking. In the case of poultry eggs, the same as the chicken total of 15 eggs were collected from five selected markets and boiled at high temperatures. After boiling, albumin and yolk were separated and weighted through an electrical weighing balance and put into an individual paper bag with proper tagging. In the case of rice the samples were collected from each marketplaces. Three types of pulses samples like lentil (fine), lentil (coarse), and black gram were collected, weighed, and put into paper bags. A total of 165 samples were collected and then oven-dried at 65 °C for 72 hours or until constant weight achieved. The samples were then grounded using a grinding mill and stored in plastic containers for analysis.

Table 3.2 Types of collected samples from five selected marketplaces of Dhaka city.

Sl No	Sample	Analyzed parts
01	Broiler chicken	Breast meat
		Leg meat
		Bone
		Liver
		Brain
02	Locally developed variety (LDV) chicken	Breast meat
		Leg meat
		Bone
		Liver
		Brain
03	Chicken egg	Albumin
		Yolk
04	Raw rice	
05	Lentil (Fine)	
06	Lentil (Coarse)	
07	Black gram	

3.3 Digestion of samples

Exactly 1 g ground foodstuff sample was taken in a digestion tube. About 10 mL di-acid mixture (HNO_3 and $HClO_4$ = 2:1) was added to the digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 100°C. The temperature was increased from 180 to 200°C gradually and left to digest until the solution turned to whitish colour, which is used for the determination of different heavy metals (Islam *et al.*, 2022). Afterward the digest was removed and allowed to cool, diluted to 100 ml volumetric flask with deionized water, and filtered through Whatman No. 42 filter paper and volume up to the mark. Then the sample was poured into a plastic bottle and preserved in the refrigerator until further use to avoid evaporation.

3.4 Determination of different metals

Concentrations of Zn, Fe, Cu, Pb, Cd, Cr, and Mn were determined by using the Atomic Absorption Spectrophotometer (Analytik Jena novAA 400P) (Welsh *et al.*, 1990). The analytical procedure was checked against a known concentration of the standard reference material. The percentage recovery was between 94-105%. All chemicals used were analytical grade, including standard stock solutions of known concentration for each metal. Blank samples were regularly analyzed after every seven samples. Standard solutions of these heavy metals were purchased from Sigma Aldrich. The standards were prepared from the individual 1000 mg/L standards.

3.5 Statistical analysis: The concentration of heavy metals, including the mean, median, minimum, maximum, and standard deviation in the selected foodstuffs were analyzed using an excel computer package.

3.6 Risk assessment:

The content of heavy metals in foodstuffs was determined. Apart from content, the following parameters were assessed to estimate the risk associated with the accumulation of metals:

3.6.1 Single Factor Pollution Index (PI):

The Pollution Index (PI) is the ratio of heavy metal content in a sample and the permissible limits imposed by international organizations such as the WHO, FAO, and US Environmental Protection Agency (US EPA) (Afrin *et al*., 2021, Kowalska *et al*., 2018):

PI = CV/CL …………………………………………………(1)

Where CV is the concentration of heavy metal in foodstuffs sample (mg kg^{-1}) and CL is the regulatory limit by FAO/ WHO (mg kg^{-1}). PI < 1 indicates samples have not yet been polluted, whereas a value of PI > 1 suggests contamination, and PI = 1 indicates critical condition (require environmental monitoring) (Kowalska *et al*., 2018):

3.6.2 Sum of pollution index

The sum of pollution index (PI) previously described by (Qingjie *et al*., 2008) was used for the present application.

SPI = PiFe +PiCr + PiPb + PiCd……………………………………………….. (2)

Where Pi = single factor pollution index of heavy metals

3.6.3 Average Pollution Index (PIA)

The average pollution index (PIA) of different foodstuffs samples was calculated as follows (Afrin *et al*., 2021):

$$PI_{Avg.} = \frac{1}{n}\sum_{i=1}^{n} PI \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where PI is the single-factor pollution index and n is the number of heavy metal species studied. PIA > 1.0 suggests higher heavy metal contamination is evident in the sample (Qingjie *et al*., 2008)

3.6.4 Metal Pollution Index (MPI)

To examine the overall heavy metal concentrations of selected foodstuffs, the metal pollution index (MPI) was computed (Usero *et al*., 1997). This index was obtained by calculating the geometrical mean of concentrations of all the metals in the foodstuffs.

$$MPI\ (mg\ kg^{-1}) = (C_1 \times C_2 \times \ldots\ldots \times C_n)\ 1/n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where C_n = concentration of metal n in the sample

3.6.5 Estimated Daily Intake of Heavy Metal

The consumer health risk is assessed by obtaining the estimated daily intake (EDI) value and comparing it with the maximum tolerable daily intake (MTDI) set by regulatory bodies. According to the US EPA, the EDI values of different heavy metals were estimated as follows (Parven *et al*., 2021):

$$EDI = \frac{IR \times C}{BW} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where IR = Foodstuffs ingestion rate (in kg) of Bangladesh, C = mean concentration of heavy metal in the sample (mg kg^{-1}), and BW = body weight (kg). The average foodstuffs ingestion rate in Bangladesh was considered to be (0.0174 for chicken, 0.0136 for egg, 0.3672 for rice, and 0.0049 for pulses) kg person^{-1} day^{-1} and BW values of 60 and 32 kg for adults and children, respectively (Afrin *et al.*, 2021, Hossain *et al.*, 2015).

3.7 Cancer Risk Assessment

Both carcinogenic and non-carcinogenic risks of heavy metals in foodstuffs samples were estimated using the US EPA models (US EPA, 2015).

3.7.1 Carcinogenic Risk

The Incremental Lifetime Cancer Risk (ILCR) is determined to evaluate the possibility of cancer risk through the intake of carcinogenic heavy metals via foodstuffs which were estimated as follows (Kasozi *et al.*, 2021):

$$\text{ILCR} = \text{CDI} \times \text{CSF} \quad \dots\dots\dots(5)$$

Where CDI = chronic daily intake of heavy metal (mg kg^{-1} BW day^{-1}) and CSF = cancer slope factor (mg kg^{-1} day^{-1}). According to OEHHA, the oral CSF values of Pb and Cd are 0.0085 and 15 (mg kg^{-1} day^{-1}), respectively. The CDI value for each heavy metal was calculated using the following equation:

$$\text{CDI} = \frac{EDI \times EF \times TED}{AT} \quad \dots\dots\dots(6)$$

Where EDI = estimated daily intake of heavy metal (mg kg^{-1} day^{-1}); EF = exposure frequency (365 days year^{-1}); TED = total exposure duration (70 years), which is the average lifetime of Bangladeshi people; and AT = average exposure time (365 days × 70 years = 25,550 days). The cumulative ILCR (ΣILCR) is used to assess total cancer risk due to ingestion of multiple heavy metals by a specific type of food:

$$\sum_{i=1}^{n} ILCR = ILCR1 + ILCR2 \dots\dots\dots \cdots + ILCRn \quad \dots\dots\dots(7)$$

where i (= 1, 2…..n) is the individual heavy metal present in the same sample. If the estimated ILCR < 10^{-6}, the exposure to people is considered as safe (negligible/ accepted risk), whereas ILCR > 10^{-4} is considered as the threshold risk limit (risk requires remedial measures), and ILCR > 10^{-3} is reflected as moderate risk (concerning public health) (Haque *et al*., 2021):

3.7.2 Non-carcinogenic Risk

The target hazard quotient (THQ) is used to assess the non-carcinogenic risks of specific heavy metals detected in the sample, which was calculated following the formula (Parven *et al*., 2021, Sultana *et al*., 2017):

$$THQ = \frac{CDI}{RfD} \quad \text{………………………………………..(8)}$$

where CDI = chronic daily intake of heavy metals (mg kg^{-1} BW day^{-1}) and RfD = oral reference doses of heavy metals (mg kg^{-1} day^{-1}). The standard RfD values of Fe, Zn, Mn, Pb, Cd, Cr, and Cu are 0.7, 0.3, 0.14, 0.0035, 0.003, 1.5, and 0.07 mg kg^{-1} day^{-1}, respectively (Afrin *et al*., 2021, Hossain *et al*., 2015, Shaheen *et al*., 2016).

3.7.3 Hazard Index

The chronic hazard index (HI) is the cumulative target hazard quotient of each heavy metal present in a sample. According to USEPA, HI is obtained as follows:

$$HI = \sum_{i=1}^{n} THQ \quad \text{………………………………………..(9)}$$

where i (= 1, 2……., n) = individual heavy metal present in the sample. The exposed population is deemed safe when HI < 1, whereas HI > 1 indicates a potential risk of ingesting contaminated food items. Thus, control measures should be applied (Shahriar *et al*., 2021).

3.7.4 Hazard quotient

The screening level risk associated with the consumption of contaminated food can be assessed using the hazard quotient (US EPA, 1989). The hazard quotient for adults and children (below 3 years) associated with the intake of metals along with foodstuffs from experimental sites was assessed using the following formula:

$$HQ = (D) \times (C\ metal)\ Rf\ D \times BO \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

where, D = daily intake of food (kg/day),

Cmetal = concentration of metal (mg/kg),

RfD = reference oral dose of metal (mg/kg of body weight/day) and

BO = Body weight (kg).

CHAPTER 4

RESULT AND DISCUSSION

Concentrations of heavy metals (Iron, Zinc, Copper, Manganese, Chromium, Lead, and Cadmium) were analyzed in different foodstuffs collected from five selected marketplaces in Dhaka city in Bangladesh. This chapter reported on the status of heavy metals concentrations in different body parts (breast meat, leg meat, bone, liver, and brain) of two types of chicken (broiler and locally developed variety), and other common foods like egg albumin, egg yolk, raw rice, black gram, Lentil (fine) and Lentil (coarse) and these metals' health risks for adult and children.

4.1. Concentration of Heavy metals in foodstuffs

4.1.1. Heavy Metals in Broiler Chicken:

Table 4.1 shows the concentration of Fe, Zn, Cu, Cr, Mn, Cd, and Pb present in broiler breast meat, leg meat, bone, liver, and brain collected from five different marketplaces. In the case of Kawran bazar, the highest amount of iron was found in the liver and the lowest amount was present in the brain. The concentration of zinc was highest in bone of chicken collected fromm Camper bazar and lowest in the brain of broiler chicken collected from Agargaon bazar. The amount of copper found was 44.56 mg/kg in the bone which was the highest but in the case of breast meat and brain samples concentration of copper was not found. Chromium was found in all collected samples except the liver, among them the amount was high in bone. Manganese was present in leg meat and bone. The concentration of cadmium was detected in bone, but the lead was absent in all samples.

In the case of the Taltola bazar the highest amount of Fe, Zn, Cu, Cr, Mn, Cd, and Pb was present in broiler bone and the lowest amount of these metals was present in the brain sample. Mn, Cd, and Pb concentrations were not found in breast meat, leg meat, liver, and brain.

Table 4.1 Concentration of Fe, Zn, Cu, Cr, Mn, Pb, and Cd in collected broiler chicken body parts according to marketplaces.

Market Name	Sample Name	Heavy Metals (mg/kg)						
		Fe	**Zn**	**Cu**	**Cr**	**Mn**	**Cd**	**Pb**
Kawran Bazar	Breast Meat	20.8±0.06	6.6±0.08	0.00	0.27±0.06	0.00	0.00	0.00
	Leg Meat	78.1±0.91	17.7±0.03	0.2±0.08	0.58±0.02	1.46±0.07	0.00	0.00
	Bone	76.4±1.11	67.3±1.2	44.6±0.03	3.9±.62	4.37±0.17	0.3±0.06	2.21±0.03
	Liver	102.5±0.08	36.2±0.33	3.6±0.09	0.00	0.00	0.00	0.00
	Brain	3.2±0.38	3.5±0.13	0.00	0.6±0.08	0.00	0.00	0.00
Taltola Bazar	Breast Meat	20.5±.99	9.04±0.11	0.2±0.42	2.5±0.92	0.00	0.00	0.00
	Leg Meat	16.9±0.68	22.1±0.21	0.4±0.05	0.4±0.13	0.00	0.00	0.00
	Bone	58.9±0.06	65.3±0.42	2.9±0.17	3.9±0.02	4.5±0.41	0.4±.07	1.18±.48
	Liver	58.3±0.13	18.4±0.23	3.9±0.23	0.5±0.17	0.00	0.00	0.00
	Brain	1.8±0.15	2.2±0.05	0.4±0.1	0.1±0.1	0.00	0.00	0.00
Camp Bazar	Breast Meat	14.6±0.29	7.5±0.03	0.00	0.3±0.17	0.00	0.00	0.00
	Leg Meat	16.9±0.46	18.3±0.12	1.5±0.12	0.02±.01	0.3±.01	0.00	0.00
	Bone	91.87±0.7	91.31±0.7	5.06±0.32	5.97±0.15	2.61±0.3	0.71±0.13	1.22±0.13
	Liver	65.22±0.15	24.49±0.04	5.61±0.11	0.04±.04	2.38±.31	0.00	0.00
	Brain	1.05±0.73	2.64±0.12	0.6±.015	0.67±0.24	0.00	0.00	0.00
Agargaon Bazar	Breast Meat	64.04±0.92	9.07±0.07	1.4±0.14	0.9±0.03	0.00	0.00	0.00
	Leg Meat	24.8±0.38	15.02±0.13	0.004±0.04	0.21±0.41	1.03±0.03	0.00	0.00
	Bone	48.9±.86	68.85±0.13	5.58±0.14	4.27±.01	3.92±0.39	0.34±0.14	0.00
	Liver	86.1±0.86	14.9±0.24	3.03±0.02	0.4±0.12	0.00	0.00	0.00
	Brain	2.06±0.56	2.1±0.1	0.4±0.1	0.5±0.21	0.00	0.00	0.00
Kochukhet Bazar	Breast Meat	25.16±0.61	10±0.22	0.00	0.8±0.06	0.00	0.00	0.00
	Leg Meat	38.9±0.14	9.9±0.17	0.00	0.13±0.08	1.02±0.05	0.00	0.00
	Liver	53±1.86	9.9±0.04	2.5±0.09	0.00	0.6±0.13	0.00	0.00
	Brain	1.65±0.37	2.29±0.09	0.00	0.00	0.00	0.00	0.00

In the camp bazar the amount of Fe, Zn, Cr, Mn, Cd, and Pb was higher in the bone sample, but the highest amount of Cu was found in the liver sample. The lowest concentration of these metals was found in the brain sample. Cd and Pb were only present in the bone sample

The concentration of Zn, Cu, Cr, Mn, and Cd was highest in a bone sample of Agargaon bazar, but the highest amount of Fe was found in the liver sample. The lowest amount was found in brain samples. Pb was absent in all samples.

In the case of Kochukhet Bazar, the highest amount of Fe and Cu in the liver; Zn and Cr in breast meat; and Mn in leg meat were found. Cd and Pb were not found in any sample of this market.

4.1.2. Heavy Metals in locally developed variety (LDV) chicken:

Table 4.2 shows the concentration of Fe, Zn, Cu, Cr, Mn, Cd, and Pb present in LDV chicken breast meat, leg meat, bone, liver, and brain in Kawran bazar and Taltola bazar different marketplaces. In the case of Kawran bazar, the highest amount of iron and zinc were found in the bone and the lowest amount of iron was present in the brain of collected chicken sample. The descending order iron concentration was followed as bone > liver > leg meat > breast meat > brain. The concentration of zinc was highest in bone and lowest in the brain similar to iron concentration. The amount of copper was 7.9 mg/kg in the liver, which was the highest, and the lowest concentration of copper was found in brain sample. The highest chromium concentration was found in the bone sample and the lowest in leg meat samples. The descending order of chromium concentration was followed as bone > breast meat > brain > liver > leg meat.

In case Taltola bazar the highest amount of Fe found in bone sample and lowest amount in brain sample. The descending order was followed as bone > liver > breast meat > leg meat > brain. Zn concentration was also highest in bone and lowest in brain. Highest amount of Copper was found in liver sample and lowest in leg meat and the descending order was liver > bone > brain > breast meat > leg meat. The highest amount of Chromium concentration was found in the bone sample and the lowest in liver samples. The descending order of chromium concentration was followed as bone > leg meat > breast meat > liver > brain. The concentrations of Cd, Pb, and Mn were absent in all the collected samples of both Kawran bazar and Taltola bazar.

Table 4.2 Concentration of Fe, Zn, Cu, Cr, Mn, Pb, and Cd in collected LDV chicken body parts according to marketplaces.

Market Name	Sample Name	Heavy Metals (mg/kg)						
		Fe	Zn	Cu	Cr	Mn	Cd	Pb
Kawran Bazar	BM	28.3±0.38	10.9±0.28	1.3±0.16	1.2±0.07	0.0	0.00	0.00
	LM	55.6±0.46	25.4±0.56	4.2±.05	0.4±0.06	0.0	0.00	0.00
	Bone	84.2±0.38	74.2±0.28	3.6±0.16	4.03±0.07	0.0	0.00	0.00
	Liver	80.1±0.44	21.5±0.37	7.9±0.07	0.59±0.01	0.0	0.00	0.00
	Brain	5.9±0.00	3.2±0.04	0.7±0.24	0.59±0.13	0.0	0.00	0.00
Taltola Bazar	BM	34.1±0.78	8.9±0.15	1.5±0.13	0.49±0.04	0.0	0.00	0.00
	LM	32.2±0.79	52.4±0.11	1.04±0.07	2.08±0.2	0.0	0.00	0.00
	Bone	61.5±0.41	69.5±0.76	4.4±0.00	4.48±0.26	0.0	0.00	0.00
	Liver	47.4±1.55	21.2±0.09	8.8±0.05	0.41±0.05	0.0	0.00	0.00
	Brain	5.1±0.32	3.2±0.06	2.1±0.00	0.34±0.09	0.0	0.00	0.00

BM = Breast meat

LM = Leg meat

4.1.3. Heavy metals in other common foods:

The concentration of Fe, Zn, Cu, Cr, Mn, Cd, and Pb present in some common foods like egg (albumin), egg(yolk), raw rice, black gram, lentil (fine), and lentil (coarse) were shown in Table 4.3 according to marketplaces. The concentrations of Fe in kawran bazar foodstuffs are quite variable, ranging from (6.41 – 251.48) mg/kg. The lowest value was analyzed in egg (Albumin), while the highest was in Raw rice. However, the order of the foodstuffs' containing Fe was raw rice > egg (yolk) > black gram > lentil (coarse) > lentil (fine) > egg (albumin). The results showed a big difference in Fe contained between two different parts of the poultry egg. The highest amount of Zn is present in lentils (fine) and the lowest in eggs (albumin). Besides the order of Cu containing foods was lentil (coarse) > lentil (fine) > black gram > raw rice > egg (yolk) > egg (albumin). The result showed a high amount of Cu present in the pulses sample. Cr concentration only determined in egg (yolk) at 0.32 mg/kg. In the case of Cd, the highest amount was present in black grams and the lowest in egg (albumin). Besides the highest amount of Pb contained in the lentil (coarse) sample and the lowest in egg (albumin) and no Pb was found in raw rice, black gram, lentil (fine).

In Taltola bazar the highest concentration of Fe has discovered in raw rice and lowest in egg (albumin), Zn followed the descending order of lentil (fine) > egg (yolk) > black gram > lentil (coarse) > raw rice > egg (albumin). Cu followed the descending order of lentil (coarse) >lentil (fine) > black gram > raw rice > egg (yolk) > egg (albumin). Only black gram had 0.18 mg/kg Cr among the dietary samples from the Taltola bazar. Cd showed a range of (0.81-1.99) mg/kg. Highest concentration of Cd in Lentil (coarse) and lowest in Egg (yolk). In rice and lentil (fine) no Pb was found.

The greatest concentrations of Fe, Zn, and Cu in fine lentil samples, as well as Cd and Pb in rice samples, were found in samples taken from Camp bazar. Egg (albumin) has the least amount of these elements. Only the egg sample was found to contain any Cr concentration.

Table 4.3 Concentration of Fe, Zn, Cu, Cr, Mn, Pb, and Cd in collected common foods according to marketplaces.

Market Name	Sample Type	Heavy Metals (mg/kg)					
		Fe	**Zn**	**Cu**	**Cr**	**Cd**	**Pb**
Kawran Bazar	Egg (Alb)	6.41±0.03	0.86±0.02	0.52±0.15	0.00	0.32±0.01	0.71±0.09
	Egg (Yolk)	101.2±0.91	26.18±0.23	0.7±0.11	0.32	0.93±0.12	0.86±0.45
	Black gram	73.13±0.45	20.59±0.05	6.65±0.14	0.00	1.45±0.4	0.00
	Raw Rice	251.5±0.53	4.05±0.09	2.13±0.04	0.00	1.41±0.17	0.00
	Lentil (Fine)	62.92±1.47	31.64±0.00	8.02±0.00	0.00	0.53±0.29	0.00
	Lentil (Coarse)	67.44±1.67	25.26±0.23	12.53±0.16	0.00	1.3±0.28	12.04±0.38
Taltola Bazar	Egg (Alb)	6.89±0.93	0.17±0.03	0.68±0.42	0.00	1.08±.032	3±1.82
	Egg (Yolk)	77.19±0.34	23.67±0.01	0.85±0.02	0.00	0.81±0.12	0.25±0.38
	Black gram	71.49±0.25	23.36±0.16	5.23±0.13	0.18±0.4	1.69±0.18	0.81±0.06
	Raw Rice	142.1±1.37	10.22±0.1	3.78±0.24	0.00	1.04±0.24	0.00
	Lentil (Fine)	100.5±0.01	33.29±0.26	9.24±0.37	0.00	1.03±0.22	0.00
	Lentil (Coarse)	70.59±1.04	22.93±0.17	10.63±0.28	0.00	1.99±0.23	11.75±0.24
Camp Bazar	Egg (Alb)	7.19±0.02	0.72±0.00	0.14±0.01	1.19±0.2	0.26±0.03	0.93±0.03
	Egg (Yolk)	73.07±0.25	24.27±0.16	1.14±0.13	0.42±0.4	0.85±0.18	0.97±0.06
	Black gram	45.52±0.11	19.29±0.05	5.14±0.91	0.00	1.43±0.11	0.00
	Raw Rice	32.95±0.21	9.13±0.07	2.72±0.42	0.00	1.59±0.26	1.55±0.04
	Lentil (Fine)	100.49±0.4	33.29±0.17	9.24±0.19	0.00	1.03±0.34	0.00
	Lentil (Coarse)	49.84±1.01	23.12±0.13	6.3±0.09	0.00	0.95±0.14	0.00
Agargaon Bazar	Egg (Alb)	3.54±0.01	0.03±0.00	0.04±0.01	0.00	0.17±0.01	0.00
	Egg (Yolk)	100.3±1.77	26.59±0.39	0.73±0.25	0.17±0.0	0.92±0.19	1.56±0.02
	Black gram	57.28±0.12	18.77±0.44	7.65±0.08	0.00	1.65±0.26	0.00
	Raw Rice	71.54±0.38	2.53±0.03	1.1±0.18	0.00	1.42±0.25	0.00
	Lentil (Fine)	109.72±2.5	28.86±0.61	7.73±0.61	0.00	1.29±0.08	0.00
	Lentil (Coarse)	83.33±0.38	23.49±0.2	12.71±0.26	0.00	1.16±0.15	6.79±0.63
Kochukhet Bazar	Egg (Alb)	4.31±0.02	0.06±0.01	0.36±0.09	0.13±0.1	0.27±0.01	0.28±0.02
	Egg (Yolk)	74.74±0.08	23.15±0.58	1.54±0.04	0.00	0.53±0.04	1.51±0.35
	Black gram	74.13±1.49	22.28±0.12	9.03±0.87	0.00	1.97±0.09	0.84±0.53
	Raw Rice	32.08±0.05	9.32±0.15	5.51±0.66	0.00	1.31±0.17	0.11±0.1
	Lentil (Fine)	62.92±1.47	31.51±0.00	10.07±0.00	0.00	0.91±0.29	0.00
	Lentil (Coarse)	94.02±0.31	33.81±0.47	13.17±0.25	0.00	1.4±0.14	10.7±0.63

Egg (albumin) has the lowest content of Fe, Zn, and Cu among all the foods collected from the Agargaon market, whereas lentil (fine) has the highest concentration. Except for egg (yolk), practically all samples had no Cr. The Cadmium was detected in concentrations between 0.92 and 1.65 mg/kg. In egg (yolk) and lentil (coarse) sample, concentrations of Pb were detected.

Egg (albumin) samples in the kochukhet bazar had the lowest levels of Fe, Zn, Cu, and Pb whereas lentil (coarse) samples had the highest levels. The Cd concentrations vary from 0.27 to 1.97 mg/kg. The Cr was found only in egg (albumin).

4.2. Mean concentration of heavy metals in foodstuffs compared with the WHO/FAO standard:

4.2.1 Mean concentration of metals in chicken body parts:

Meat is the most important and common protein source in the regular diet worldwide. The mean concentrations of Cu, Zn, Fe, Pb, Mn, Cr, and Cd in broiler and LDV chicken (leg meat, breast meat, liver, and brain), were presented in Table 4.4 and 4.5. Among the meat proteins, now-a-days, broilers captured the lion's share in the Bangladeshi diet due to their price difference from beef, mutton, and others, and according to Household Income and Expenditure Survey (HIES) (2017), in Bangladesh per capita per day consumption rate of chicken is 17.33 g.

Table 4.4 and Figure 4.1 shows the mean concentration of Fe, Zn, and Cu in different parts of the broiler and LDV chicken with Maximum, Minimum, and standard deviation. Fe concentrations in breast meat, leg meat, bone, liver, and brain are 29.01, 35.11, 69.02, 73.03, 1.95 mg/kg of broiler and 31.2, 37.45, 72.86, 63.7, and 5.52 mg/kg of LDV chicken respectively. The result shows that all the body parts of the broiler and LDV chicken sample contain Fe. Whereas in the case of broiler the greatest amount of Fe was in liver and the lowest amount was found in brain and in LDV chicken the highest amount was present in bone and the lowest amount in brain. Similar kind of result was reported by Alturiqi and Albedair (2012) and Hashish *et al.* (2012).

Table 4.4 Concentrations of Fe, Zn, and Cu in Collected Chicken Samples Compared with World Health Organization Standards.

Sample	**Part**	**Fe(mg/kg)**				**Zn(mg/kg)**				**Cu(mg/kg)**			
		Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Broiler Chicken	BM	64.04	14.6	29.01	19.94	10.00	6.61	8.44	1.37	1.44	0.00	0.33	0.63
	LM	78.01	16.9	35.11	25.61	22.09	9.97	16.60	4.49	1.54	0.00	**0.54**	0.69
	BN	91.87	48.9	69.02	18.99	91.31	65.3	**73.20**	12.2	44.6	2.96	**14.6**	20.1
	LV	102.5	53.0	73.03	20.72	36.19	9.85	20.80	10.2	5.61	2.46	**3.74**	1.19
	BR	3.17	1.05	1.95	0.78	3.48	2.06	2.53	0.58	0.6	0.00	0.28	0.27
LDV Chicken	BM	34.08	28.3	31.2	4.07	10.99	8.89	9.94	1.48	1.46	1.34	**1.42**	0.08
	LM	55.56	24.3	37.45	16.21	52.35	25.4	37.4	13.7	4.15	1.04	**2.21**	1.69
	BN	84.21	61.5	72.86	16.09	74.15	69.5	**71.80**	3.31	4.43	3.62	**4.02**	0.57
	LV	80.06	47.4	63.72	23.13	21.52	21.2	21.31	0.27	8.78	7.87	**8.32**	0.64
	BR	5.95	5.09	5.52	0.61	3.23	3.18	3.211	0.04	2.13	0.73	**1.41**	0.99
WHO/FAO Standards		**NA**				**60.00**				**0.4**			

WHO = World Health Organization **BM** = Breast meat **Max** = Maximum

FAO = Food and Agriculture Organization **LV** = Liver **Min** = Minimum

NA = Not Available **BN** = Bone **SD** = Standard

LM = Leg meat **BR** = Brain

The Zn was present in all the selected body parts of the broiler and LDV chicken. In broiler chicken, Zn was present at a range of (2.53-73.20) mg/kg and in LDV chicken (3.2-71.81) mg/kg respectively. However, a lower value of Zn in chicken meat was reported by (Oforka *et al*. 2012). WHO recommended the maximum allowable concentration (MAC) of Zn was 60 mg/kg. The mean concentration of Zn in all the collected samples of broiler and LDV chicken was lower than the WHO recommended maximum allowable concentration except bone of both chicken types.

According to Table 4.4 among the different parts of the broiler, the accumulation pattern of Cu followed the sequence as bone > liver > leg meat > breast meat > brain. Where the largest amount was found in bone and the lowest in brain. The accumulation pattern of Cu in LDV chicken different parts in a sequence of liver > bone > leg meat > breast meat = brain. The mean concentration of analyzed toxic metals in all the LDV chicken and broiler bone and leg meat samples exceeded the maximum allowable concentration (FAO/WHO, 2011; JECFA, 2005). All the analyzed metal concentrations were a significant level higher than in previous work in Bangladesh (Islam *et al.,* 2015b; Shaheen *et al*., 2016), India (Giri and Singh, 2019), Pakistan (Mariam *et al.,* 2004), Turkey (Uluozlu *et al.*, 2009), and Saudi Arabia (Alturiqi and Albedair, 2012).

Table 4.5 revels the mean concentration of Cr, Mn, Cd and Pb in different parts of the broiler and LDV chicken with Maximum, Minimum, and standard deviation. Among the different parts of the broiler, the accumulation pattern of Cr followed the sequence as bone > breast meat > brain >liver > leg meat. Where the largest amount is found in bone and the lowest in leg meat. The accumulation pattern of Cr in LDV chicken different parts in a sequence of bone > leg meat > breast meat> liver > brain. The mean concentration of Cr in LDV chicken and broiler bone samples exceeded the maximum allowable concentration (FAO/WHO, 2002; JECFA, 2005). The Cr concentrations were significant level lower than in previous work in Bangladesh (Islam *et al.*, 2015c; Shaheen *et al*., 2016), India (Giri and Singh, 2019), Pakistan (Mariam *et al*., 2004), Turkey (Uluozlu *et al.*, 2009), and Saudi Arabia (Alturiqi and Albedair, 2012).

Only the liver, bone, and meat from the broiler leg were discovered to have Mn. According to (FAO/WHO, 2011 and JECFA, 2005), the mean concentration of Mn is lower than the maximum permissible limit. Mn has a MAC value of 6.5 mg/kg. Mn concentration was not detected in the brain and breast flesh of broiler chicken. No Mn was detected in the LDV chicken body parts. Previous studies have discovered a greater concentration of Mn in Bangladesh (Islam *et al.*, 2015b; Shaheen *et al.*, 2016), India (Giri and Singh, 2019), Pakistan (Mariam *et al*., 2004), Turkey (Uluozlu *et al.*, 2009), and Saudi Arabia (Alturiqi and Albedair, 2012).

In broiler and LDV chicken the Cd and Pb concentrations were below detectable level except for broiler bone sample. The mean concentration of Cd in broiler bone sample was analyzed at 0.44mg/kg (fw). Which is higher than the MAC value of Cd (0.04mg/kg) recommended by (FAO/WHO, 2002 and JECFA, 2005). The average concentration of Pb in broiler bone sample was 1.15mg/kg (fw). Which was several times higher than the MAC value of Pb (0.1mg/kg) recommended by (FAO/WHO, 2011 and JECFA, 2005). No Pb was found in all LDV chicken samples the concentration. So the result indicate that consumption of broiler bone has pernicious effect on human health.

Table 4.5 Concentrations of Cr, Mn, Cd and Pb in Collected Chicken Samples Compared with World Health Organization Standards.

Sample	Part	Cr(mg/kg)				Mn(mg/kg)				Cd(mg/kg)				Pb(mg/kg)			
		Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Broiler Chicken	BM	2.53	0.27	**1.01**	0.88	0	0	0	0	0	0	0	0	0	0	0	0
	LM	0.54	0.02	0.26	0.21	1.46	0	0.76	0.59	0	0	0	0	0	0	0	0
	BN	5.97	3.89	**4.52**	0.98	4.51	2.61	3.85	0.87	0.71	0.3	**0.44**	0.19	2.21	0.00	**1.15**	0.90
	LV	0.53	0	0.27	0.26	2.38	0	0.6	1.03	0	0	0	0	0	0	0	0
	BR	0.67	0	0.37	0.31	0	0	0	0	0	0	0	0	0	0	0	0
LDV Chicken	BM	1.14	0.49	0.82	0.46	0	0	0	0	0	0	0	0	0	0	0	0
	LM	2.08	0.41	**1.52**	0.96	0	0	0	0	0	0	0	0	0	0	0	0
	BN	4.83	4.03	**4.43**	0.57	0	0	0	0	0	0	0	0	0	0	0	0
	LV	0.59	0.41	0.5	0.13	0	0	0	0	0	0	0	0	0	0	0	0
	BR	0.59	0.34	0.47	0.18	0	0	0	0	0	0	0	0	0	0	0	0
WHO/FAO Standards		**1.00**				**6.5**				**0.05**				**0.1**			

WHO = World Health Organization
BM = Breast meat
Max = Maximum

FAO = Food and Agriculture Organization
LV = Liver
Min = Minimum

NA = Not Available
BN = Bone
SD = Standard

LM = Leg meat
BR = Brain
LDV= Locally Developed Variety

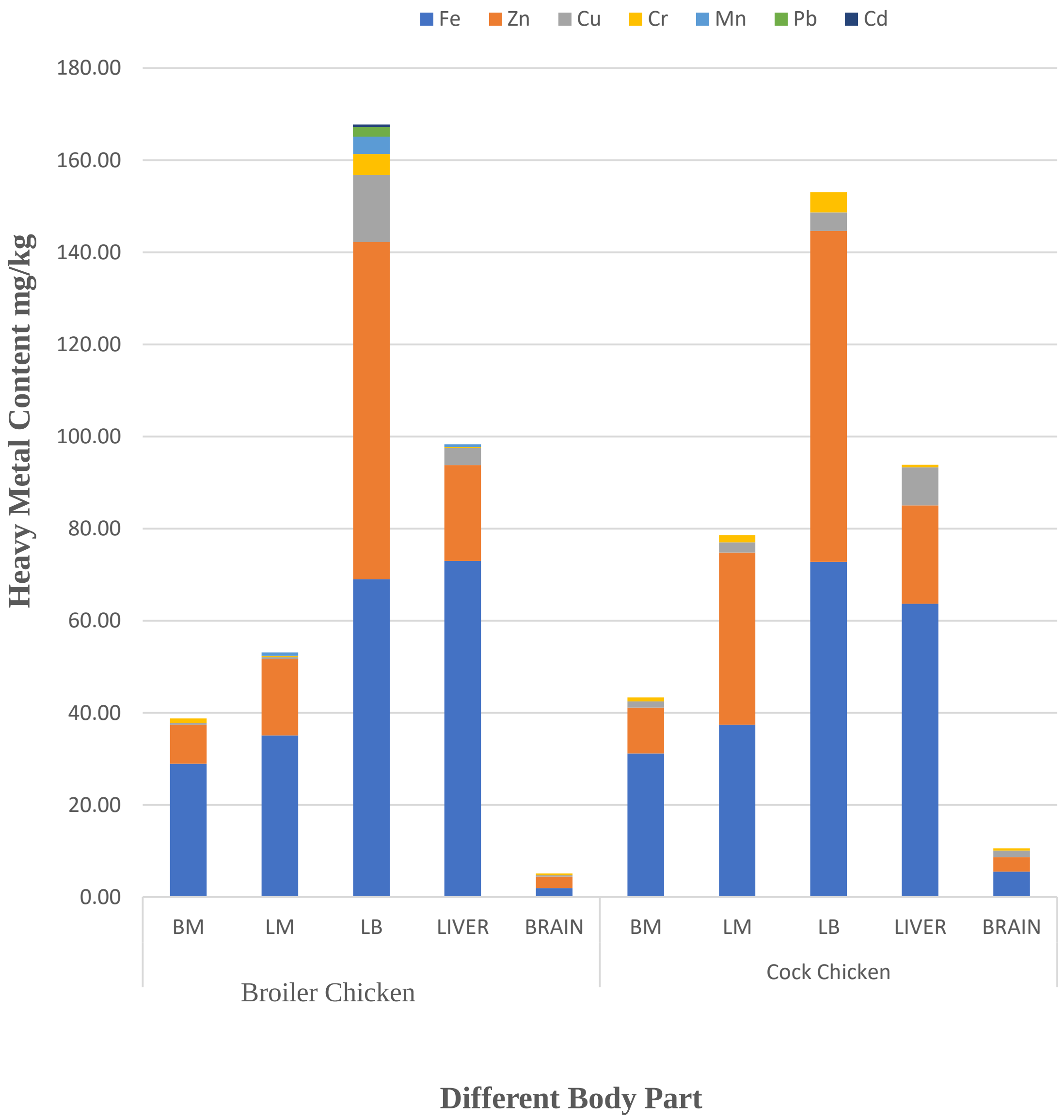

Figure 4.1 The mean concentrations of Cu, Zn, Fe, Pb, Mn, Cr, and Cd in chicken samples (leg meat, breast meat, liver, and brain)

4.2.2 Mean concentration of metals in common foods:

The mean concentrations of Cr, Fe, Cu, Zn, Cd, and Pb (mg/kg fw) were determined in some commonly consumed foodstuffs in Bangladesh such as egg (albumin), egg (yolk), raw rice, black gram, lentil (fine), lentil (coarse) were presented in Table 4.6 and Figure. 4.2 with Maximum, Minimum and standard deviation. Average concentrations of trace metals among the food groups showed the descending order of rice > lentil (fine) > lentil (coarse) > egg (yolk) > black gram > egg (albumin). For all types of foods, relatively large variability in metal concentrations was observed, even within the same kind of food. The observed variation in metal concentrations in foodstuffs could be due to variation in absorption and accumulation capabilities (Pandey and Pandey., 2009), growth period, and stages of food crops (Saha and Zaman., 2013), or climatic differences in the study areas (Santos *et al*., 2004).

From the Table 4.6 it is illustrated that Fe concentration was found in these common foods at various ranges of (5.7-106.1) mg/kg. Where the highest concentration was discovered in raw rice samples and the lowest in egg albumin. Although egg yolk sample contains sixteen times higher Fe than egg albumin. Fe content in poultry eggs was lower than those reported by (Alturiqi and Albedair, 2012) and (Hashish *et al.,* 2012), respectively. Pulse samples contain at a range of 64.31-79.09 mg/kg where black gram contain 64.31mg/kg, lentil coarse 73.04mg/kg and lentil fine contain 79.09mg/kg.

The mean Zn concentrations (mg/kg, fw) followed the descending order of lentil fine (30.6)> lentil coarse (25.72)> egg yolk (24.77) > black gram (20.86) > rice (7.05) >egg albumin (0.37) mg/kg. The measured values were like the values reported by (Dogheim *et al.,* 2004). All the analyzed Zn concentrations are lower than the WHO/FAO recommended dose which is 60 mg/kg fw.

Among the food items, the mean Cu concentrations followed the descending order of lentil coarse > lentil fine > black gram > rice > egg yolk > egg albumin. The highest mean concentration of Cu was found in lentil coarse (mean: 11.07 mg/kg) and the lowest in egg albumin (0.35 mg/kg). The recommended concentration of Cu which is given by WHO is 0.4 mg/kg. in this study except for egg albumin all food samples contained Cu higher concentration than the WHO/FAO recommended value. This heavy metal can easily enter the human body through the food chain. That's why it is a great threat to human health.

Table 4.6 Concentrations of Fe, Zn, and Cu in Common Food Samples Compared with World Health Organization Standards.

Sample	Fe(mg/kg)				Zn(mg/kg)				Cu(mg/kg)			
	Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Egg (Alb)	7.19	3.5	5.7	1.64	0.86	0.03	0.37	0.39	0.68	0.1	0.35	0.3
Egg (Yolk)	101.2	73.1	85.3	14.2	26.6	23.2	24.77	1.53	1.5	0.7	**0.99**	0.4
Rice	251.5	32.1	106.1	92.8	10.22	2.53	7.05	3.5	5.51	1.1	**3.05**	1.7
Black gram	74.13	45.5	64.31	12.5	23.36	18.8	20.86	1.95	9.03	5.1	**6.74**	1.7
LT (Fine)	109.7	59.4	79.09	24.0	33.29	27.7	30.6	2.27	10.1	7.7	**8.77**	.95
LT (Coarse)	94.02	49.8	73.04	16.8	33.81	22.9	25.72	4.62	13.2	6.3	**11.07**	2.8
WHO/FAO Standards	**NA**				**60.00**				**0.4**			

Alb = Albumin

LT = Lentil

WHO =World Health Organization

FAO = Food and Agriculture Organization

Table 4.7 and Figure. 4.2 showed mean concentrations of Cr, Mn, and Cd Maximum, Minimum, and standard deviation in common foodstuffs. Chromium (Cr) contamination occurs due to the untreated wastewater coming from various industries such as dying and tanning, photography, textile, manufacturing green varnish, paints, and inks around Dhaka Export Processing Zone (DEPZ), and river run-off from upstream agricultural fields (Kashem and Singh, 1999; Islam *et al.*, 2009, 2014a; Bhuiyan *et al.*, 2010; Rahman *et al.*, 2013). The mean concentration of Cr in foodstuffs followed the descending order of: egg albumin > egg yolk > black gram.

The highest mean concentration of Cr was observed in egg albumin (0.26 mg/kg) and the lowest was found in black gram (0.04 mg/kg fw). The Cr contained in rice and lentil samples was not found. The concentrations of Cr in most of these foodstuffs were lower than the maximum allowable concentration (MAC) of Cr in foods given by WHO.

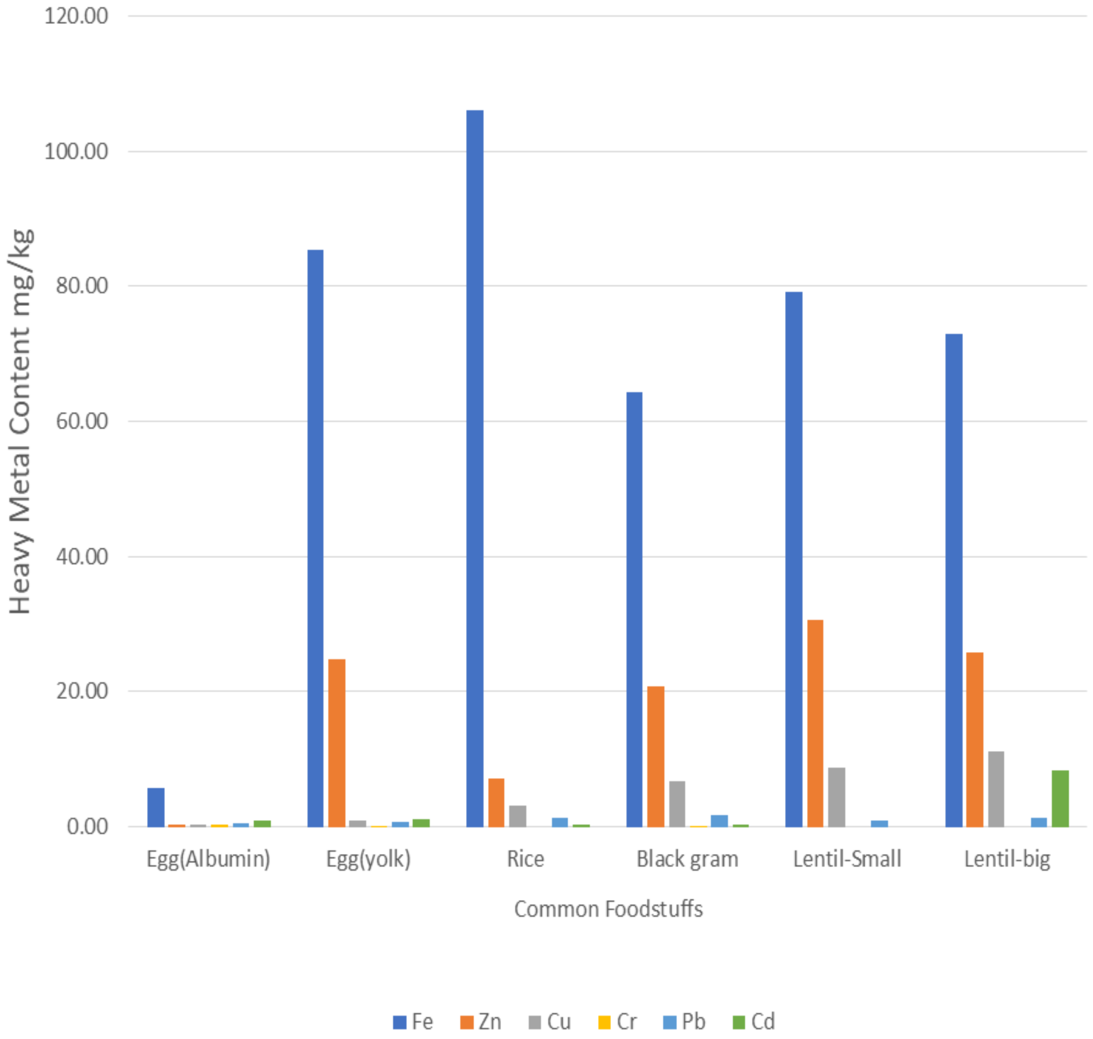

Figure 4.2 The mean concentrations of Cu, Zn, Fe, Pb, Cr, and Cd in some common foods (egg albumin, egg yolk, rice, black gram, fine lentil, and coarse lentil)

Table 4.7 Concentrations of Cr, Pb, and Cd in Collected Common Food Samples Compared with WHO/FAO Standards.

Sample	Type	Cr(mg/kg)				Pb(mg/kg)				Cd(mg/kg)			
		Max	Min	Mean	SD	Max	Min	Mean	SD	Max	Min	Mean	SD
Egg	Albumin	1.19	0	0.26	0.52	1.08	0.17	**0.42**	0.37	3.00	0	**0.99**	1.2
	Yolk	0.42	0	0.18	0.19	0.93	0.53	**0.81**	0.16	1.56	0.25	**1.02**	0.5
Rice	Raw Rice	0	0	0	0	1.59	1.04	**1.36**	0.2	1.55	0	**0.33**	0.7
Pulse	Black gram	0.18	0	0.04	0.08	1.97	1.43	**1.63**	0.22	0.84	0	**0.33**	0.5
	Lentil (Fine)	0	0	0	0	1.29	0.53	**0.95**	0.27	0	0	0	0
	Lentil (Coarse)	0	0	0	0	1.99	0.95	**1.36**	0.39	12.04	0	**8.25**	5.1
WHO/FAO Standards		**1.00**				**0.1**				**0.05**			

Lead (Pb) is a toxic metal that enters the body system through the air, water, and food and cannot be removed by washing and LDV chickening foods (Sharma *et al.*, 2007). The mean Pb concentrations (mg/kg) followed the descending order of: Black gram (1.63) > lentil coarse (1.36) = rice (1.36) > lentil fine (0.95) > egg yolk (0.81) > egg albumin (0.42). The highest mean concentration of Pb was found in black grams. The elevated concentration of Pb in cereal and pulses could probably be due to the lead smelting activity in the study area. The concentrations of Pb in collected foodstuffs were higher than the recommended permissible levels in foods, indicating severe contamination.

Cadmium is a metallic element that occurs naturally at low levels in the environment (Rahman et al., 2014). Food, rather than air or water, represents the major source of cadmium exposure (FSANZ, 2003). The mean Cd concentrations (mg/kg) followed the descending order of : lentil coarse (8.25) > egg yolk (1.02) > egg albumin (0.99) > rice (0.33) = black gram (0.33). Among common foods, the highest Cd concentration was observed in lentil coarse (8.25mg/kg). In the present study, concentrations of Cd in collected common foods were slightly higher than in some of the studies on Bangladesh by Alam *et al*. (2003) (range: 0.012–0.22 mg/kg), Rahman *et al*. (2013) (mean: 0.13 mg/kg, range: 0.006–0.43 mg/kg) and Rahman *et al*. (2014) (mean: 0.14 mg/ kg, range: 0.009–0.43 mg/kg). Among the foodstuffs, Cd exceeded the MAC, indicating that collected common foods are contaminated by Cd.

4.3: Health Risk Assessment for consumption of poultry chicken

4.3.1: Pollution Index for broiler chicken:

Diverse bodily sections of broiler chicken have various values of the single factor pollution index (PI) of Fe (Table 4.8). The liver and bones have greater PI of Fe than other organs. While the PI of Fe value was less than 1 over the entire Table 4.8 Fe had PI values between (0.00 - 0.17). Additionally, the PI of Zn differed throughout the broiler body components examined in this study (Table 4.8). The PI of Zn for bone was 1.22, and for liver was 0.35. The PI of Cu was 36.52 for bone, 9.36 for liver, 1.36 for leg meat, 0.84 for breast meat, and 0.71 for brain. The liver was found to have the lowest PI of Cr. In the current study, the single factor pollution index of Cr varied amongst the various body parts. For bone, the PI of Cr was the greatest (4.52), followed by breast flesh (1.01). For bone, breast flesh, and liver, the PI values Mn were 0.59, 0.12, and 0.09, respectively. Only the PI values of Pb and Cd, 21.03 and 8.7, for bone were observed. The World Health Organization (WHO), the United States Environmental Protection Agency (USEPA), and other international organizations have regulatory standards for metal content in biotic and abiotic media.

Table 4.8 Single factor pollution index, metal pollution index, and the sum of pollution index of five different body parts of broiler chicken collected from five different sites.

Sample	Single Factor Pollution Index							Sum of PI	Avg. PI
	Fe	Zn	Cu	Cr	Mn	Pb	Cd		
Breast meat	0.07	0.14	0.84	**1.01**	0.00	0	0	2.1	0.3
Leg meat	0.08	0.28	**1.36**	0.26	0.12	0	0	2.1	0.3
Bone	0.16	**1.22**	**36.52**	**4.52**	0.59	**21.03**	**8.7**	72.7	10.4
Liver	0.17	0.35	9.36	0.20	0.09	0	0	10.2	1.5
Brain	0.00	0.04	0.71	0.37	0.00	0	0	1.1	0.2

This ratio is known as the single factor pollution index (PI) (Jamali *et al*., 2007). PI values below 1 show that the sample is not yet polluted, whereas PI values over 1 show contamination. However, PI=1 shows a critical condition, making the sample involved important for environmental monitoring (Chukwuma, 1993). The study showed that bone, which has a PI value greater than 1 for all heavy metals except Fe, has the greatest PI value. The order of PI_{Avg} bone, liver, leg meat, breast meat, and brain are downward.

4.3.2: Estimated Daily Intake (EDI) of Heavy Metal

The most typical way for a person to be exposed to heavy metals in their body is through eating. The number of heavy metals consumed through contaminated foods determines how serious the risk is. In this study, the maximum tolerable daily intake (MTDI) values for Fe, Zn, Cu, Cr, Mn, Pb, and Cd were calculated for both adults and children (Table 4.9). Broiler chicken meat consumption rates were obtained from a preliminary study on the household income and expenditure survey (HIES) of Bangladesh and used in the EDI calculation. This study found that adults consumed

17.4g of broiler meat daily on average, while children consumed 8.3g. Adults had total EDI values for Fe, Zn, Cu, Cr, Mn, Pb, and Cd of 0.061, 0.035, 0.006, 0.002, 0.002, 0.001, and 0.0001 mg $kg^{-1}day^{-1}$, whereas children had total EDI values of 0.113, 0.066, 0.011, 0.003, 0.003, 0.001, and 0.0002 mg $kg^{-1}day^{-1}$ respectively. Fe and Zn have the highest EDI values for both adults and children's populations when compared to all other heavy metals. The computed EDI values of any heavy metal in all the examined samples, however, were lower than the corresponding MTDI. These findings lead us to the conclusion that eating broiler meat in the research region in Dhaka city has no health risk for these heavy metals. Haque *et al*., (2021); Islam *et al*., (2015a) found the same result in the case of the different parts of broiler consumption in Bangladesh.

Table 4.9 Estimated daily intake (EDI) (mg/kg/day) of heavy metals in collected broiler chicken and corresponding maximum tolerable daily intake (MTDI)

Sample	Fe		Zn		Cu		Cr		Mn		Pb		Cd	
	Adult	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**	**Adult**	**Child**
BM	8.41E-03	1.58E-02	2.45E-03	4.59E-03	9.69E-05	1.82E-04	2.92E-04	5.48E-04	0.00E+00	0.00E+00	0.00E+0	0.00E+00	0.00E+0	0.00E+0
LM	1.02E-02	1.91E-02	4.82E-03	9.03E-03	1.57E-04	2.95E-04	7.48E-05	1.40E-04	2.22E-04	4.16E-04	0.00E+0	0.00E+00	0.00E+0	0.00E+0
BN	2.00E-02	3.75E-02	2.12E-02	3.98E-02	4.24E-03	7.94E-03	1.31E-03	2.46E-03	1.12E-03	2.09E-03	6.10E-04	6.10E-04	1.26E-04	2.37E-04
LV	2.12E-02	3.97E-02	6.02E-03	1.13E-02	1.09E-03	2.03E-03	5.86E-05	1.10E-04	1.75E-04	3.27E-04	0.00E+0	0.00E+00	0.00E+0	0.00E+0
BR	5.66E-04	1.06E-03	7.33E-04	1.37E-03	8.18E-05	1.53E-04	1.08E-04	2.03E-04	0.00E+00	0.00E+00	0.00E+0	0.00E+00	0.00E+0	0.00E+0
Total EDI	0.061	0.113	0.035	0.066	0.006	0.011	0.002	0.003	0.002	0.003	0.001	0.001	0.0001	0.0002
MTDI	**8-10**		**0.3-1**		**30**		**0.04-0.2**		**1.8-2.3**		**0.21**		**0.02-0.07**	

EDI = Estimated Daily Intake

MTDI = Maximum Tolerable Daily Intake

4.3.3: Cancer risk Assessment:

Pb and Cd are classified as carcinogenic heavy metals as their chronic exposure causes different types of cancer (Haque *et al*., 2021). The calculated incremental lifetime cancer risks (ILCRs) of Pb and Cd via consuming contaminated broiler body parts are presented in Table 4.10. The calculated ILCRs for Pb in broiler bone were (5.19×10^{-6}, 9.72×10^{-6}) and Cd (1.89×10^{-3}, 3.55×10^{-3}) for adults and children, respectively. These findings demonstrated that the cancer risk of Cd in broiler bone is higher than the threshold value (ILCR > 10^{-4}), which poses a potential cancer risk to both target groups (children and adults). In contrast, the least cancer risk was observed from Pb, which exceeded the safe limit (ILCR > 10^{-6}) but within the acceptable limit (ranged between 10^{-6} and 10^{-4}). The sum ILCR values of Pb and Cd for children and adults are 1.9×10^{-3} and $3.56\times10^{-3.}$ In the case of leg, breast meat, liver, and brain the ILCR are zero. So, the study concluded that consumption of broiler chicken bone from the research area had an incremental lifetime cancer risk but other parts did not show any incremental lifetime cancer risk

4.3.4: Non-cancer Risk Assessment:

The non-cancer risk of heavy metals in five different parts of broiler chicken for adults and children was estimated based on target hazard quotient (THQ) and hazard index (HI = ΣTHQ). The THQ is the ratio of the investigated dose of a metal to a reference dose level of the same metal and if the ratio is greater than 1, then the exposed population is likely to experience obvious adverse non-carcinogenic health effects (Wang *et al*., 2005). The THQ values for different body parts of broiler chicken are displayed in Table 4.10 and Fig. 3. The value of THQ < 1.0 was observed for all heavy metals in the investigated five different parts of broiler samples for adults and children, respectively, indicating no non-cancer risk to both consumer groups. The highest TTHQ was obtained for Pb (0.17 in adults, 0.327 in children), and the trend that emerged was Pb > Zn > Fe > Cu > Cd > Mn > Cr for both aged groups.

Table 4.10 Non-cancer risk as total target hazard quotient (THQ) and incremental lifetime cancer risks (ILCR) of adults and children through consumption of collected broiler chicken.

	Non-cancer risk (THQ)														Incremental Lifetime Cancer Risk (ILCR)					
Sample	**For Adult**							**For Children**							**For Adult**			**For Children**		
	Fe	**Zn**	**Cu**	**Cr**	**Mn**	**Pb**	**Cd**	**Fe**	**Zn**	**Cu**	**Cr**	**Mn**	**Pb**	**Cd**	**Pb**	**Cd**	**Sum**	**Pb**	**Cd**	**Sum**
BM	0.012	0.008	0.002	0.001	0	0	0	0.023	0.015	0.003	0	0	0	0	0	0	0	0	0	0
LM	0.015	0.016	0.002	4.99E-05	0.002	0	0	0.027	0.030	0.004	0	0.003	0	0	0	0	0	0	0	0
Bone	0.029	0.071	0.061	0.001	0.008	0.17	0.04	0.054	0.133	0.113	0.002	0.015	0.327	0.079	5.19E-06	1.89E-03	1.90E-03	9.72E-06	3.55E-03	3.56E-03
Liver	0.03	0.02	0.016	3.91E-05	0.001	0	0	0.057	0.038	0.029	0	0.002	0	0	0	0	0	0	0	0
Brain	0.001	0.002	0.001	7.23E-05	0	0	0	0.002	0.005	0.002	0	0	0	0	0	0	0	0	0	0
TTHQ	**0.086**	**0.117**	**0.081**	**0.001**	**0.011**	**0.17**	**0.04**	**0.16**	**0.22**	**0.15**	**0.01**	**0.02**	**0.33**	**0.08**						

BM = Breast meat

LM = Leg meat

TTHQ = Total Target Health Quotient (∑THQ)

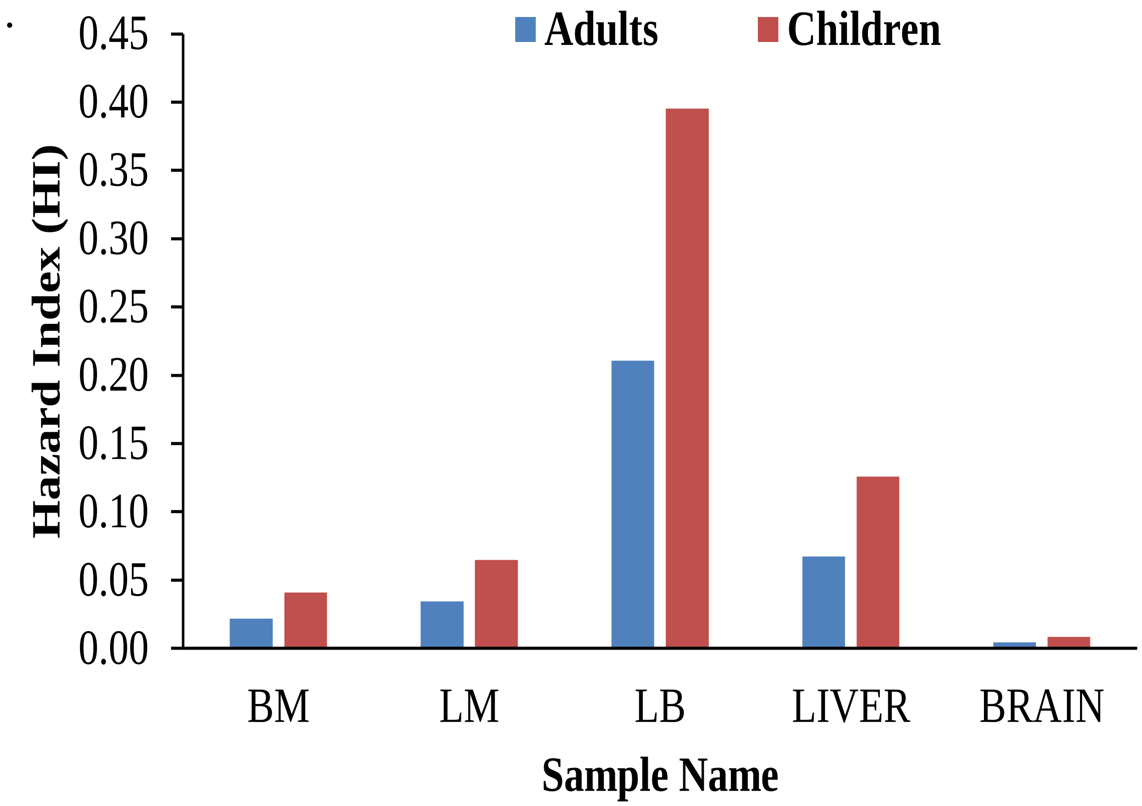

Figure 4.3 Hazard Index (HI) among both adults and children through consumption of different parts of collected broiler chicken.

4.3.5: Hazard Index:

The cumulative non-cancer risk of all studied heavy metals was expressed as hazard index (HI). All samples revealed the HI < 1.0 for adults and children. The highest hazard index was found for bone samples and the lowest for brain. For all samples, children showed higher HI than adults. Therefore, the current investigation reveals no potential non-carcinogenic health risk through ingestion of broiler chicken in selected marketplaces of Dhaka.

4.4: Health Risk Assessment for Consumption of LDV Chicken

4.4.1: Pollution Index for LDV Chicken:

PI value of Fe was below 1 in all the body parts of LDV chicken where the highest value was for bone 0.17 followed by 0.15 for liver. Zn had a diverse range of PI values which is (1.20-0.05) highest for bone and lowest for brain. Diverse bodily sections of broiler chicken had various values of the single factor PI of Cu (Table 4.11).

Table 4.11 Single factor pollution index, average pollution index, and the sum of pollution index of five parts of collected LDV chicken.

Sample	Single Factor Pollution Index (PI)							Sum of PI	Avg. PI
	Fe	Zn	Cu	Cr	Mn	Pb	Cd		
BM	0.07	0.17	3.50	0.82	0.00	0.00	0	4.6	0.7
LM	0.09	0.62	5.53	1.52	0.00	0.00	0	7.8	1.1
Bone	0.17	1.20	10.06	4.43	0.00	0.00	0	15.9	2.3
Liver	0.15	0.36	20.81	0.50	0.00	0.00	0	21.8	3.1
Brain	0.01	0.05	3.58	0.47	0.00	0.00	0	4.1	0.6

The liver and bones have greater PI of Cu than other organs. While the PI of Cu value was greater than 1 over the entire body. Cu had PI values between (3.50- 20.81). The PI of Cr was 0.82 for breast meat, 1.52 for leg meat, 4.43 for bone, 0.50 for liver, and 0.47 for brain. Here the PI of Cr for bone and leg meat was higher than 1. The PI of Mn, Cd, and Pb was zero for all body parts. The descending order of the sum of pollution index was liver > bone > leg meat > breast meat > brain. Average pollution index of the study illustrated that PI_{Avg} was greater in liver (3.1) and followed the descending order bone (2.3)>leg meat (1.1) which suggested the potential pollution hazard is due to the accumulation of heavy metals.

Table 4.12 Estimated daily intake (EDI) of heavy metals in collected LDV chicken and corresponding maximum tolerable daily intake (MTDI).

EDI value for Adults							
Sample	**Fe**	**Zn**	**Cu**	**Cr**	**Mn**	**Pb**	**Cd**
BM	9.05E-03	2.88E-03	4.06E-04	2.36E-04	0.00E+00	0.00E+00	0.00E+00
LM	1.09E-02	1.08E-02	6.42E-04	4.42E-04	0.00E+00	0.00E+00	0.00E+00
Bone	2.11E-02	2.08E-02	1.17E-03	1.28E-03	0.00E+00	0.00E+00	0.00E+00
Liver	1.85E-02	6.19E-03	2.41E-03	1.45E-04	0.00E+00	0.00E+00	0.00E+00
Brain	1.60E-03	9.29E-04	4.15E-04	1.35E-04	0.00E+00	0.00E+00	0.00E+00
Total EDI	0.061	0.042	0.005	0.002	0	0	0
MTDI	8-10	0.3-1	30	0.04-0.2	1.8-2.3	0.21	0.02-0.07
EDI value for Children							
BM	1.70E-02	5.40E-03	7.61E-04	4.43E-04	0.00E+00	0.00E+00	0.00E+00
LM	2.04E-02	2.03E-02	1.20E-03	8.28E-04	0.00E+00	0.00E+00	0.00E+00
Bone	3.96E-02	3.90E-02	2.19E-03	2.41E-03	0.00E+00	0.00E+00	0.00E+00
Liver	3.46E-02	1.16E-02	4.53E-03	2.72E-04	0.00E+00	0.00E+00	0.00E+00
Brain	3.00E-03	1.74E-03	7.78E-04	2.53E-04	0.00E+00	0.00E+00	0.00E+00
Total EDI	0.115	0.078	0.009	0.004	0	0	0
MTDI	8-10	0.3-1	30	0.04-0.2	1.8-2.3	0.21	0.02-0.07

EDI = Estimated Daily Intake **MTDI** = Maximum Tolerable Daily Intake

4.4.2: Estimated Daily Intake of Heavy Metal

In this study, the maximum tolerable daily intake values and predicted estimated daily intake values for Fe, Zn, Cu, Cr, Mn, Pb, and Cd were compared after intake of five distinct LDV chicken body parts by both adults and children (Table 4.12). To calculate the estimated daily intake consumption rates of LDV chicken meat were acquired from a preliminary investigation of the household income and expenditure survey of Bangladesh. According to this study, children only ate 8.3g of meat per day on average, compared to adults who ate 17.4g. Total EDI values for adults Fe, Zn, Cu, Cr, Mn, Pb, and Cd were 0.61, 0.042, 0.005, 0.002, 0.00, and 0.00 mg $kg^{-1}day^{-1}$, whereas for children, these values were 0.115, 0.078, 0.009, 0.004, 0.00, and 0.00 mg $kg^{-1}day^{-1}$. When compared to all other heavy metals, Fe and Zn have the highest EDI values for both adult and pediatric populations. However, the estimated EDI values of any heavy metal in any or all the samples under examination were lower than the equivalent MTDI. These results led us to the conclusion that there is no health risk associated with consuming LDV chicken meat from the study area in Dhaka. A similar conclusion was reached by Haque *et al.*, (2021); Islam *et al.*, (2014a) in cases involving various portions of broiler usage in Bangladesh.

4.4.3: Cancer Risk Assessment:

Pb and Cd are categorized as carcinogenic heavy metals, because they induce many forms of cancer when exposed repeatedly. In the case of LDV chicken Pb and Cd were undetectable in all the body sections, and the target health quotient (THQ) value for Pb and Cd was zero. The conclusion is that eating LDV chicken flesh has no cancer risk.

4.4.4: Non-cancer Risk Assessment:

Based on target hazard quotient (THQ) and hazard index (HI = THQ), the non-cancer danger of heavy metals in five distinct portions of LDV chicken for adults and children was assessed in Table 4.13. The THQ is the ratio of metal's examined dosage to its reference dose level, and if the ratio is less than 1, the exposed population is likely to have overtly negative, non-cancerous health impacts (Wang et al. 2005).

Table 4.13 Non-cancer risk as total target hazard quotient (THQ) of adults and children through consumption of heavy metal-contaminated LDV chicken.

			THQs for Adult				
Sample	**Fe**	**Zn**	**Cu**	**Cr**	**Mn**	**Pb**	**Cd**
BM	0.01	0.01	0.01	0.0002	0.00	0.00	0.00
LM	0.02	0.04	0.01	0.0003	0.00	0.00	0.00
Bone	0.03	0.07	0.02	0.0009	0.00	0.00	0.00
Liver	0.03	0.02	0.03	0.0001	0.00	0.00	0.00
Brain	0.00	0.00	0.01	0.0001	0.00	0.00	0.00
TTHQ	0.09	0.14	0.07	0.0015	0.00	0.00	0.00
			THQs for Children				
BM	0.02	0.02	0.01	0.0003	0.00	0.00	0.00
LM	0.03	0.07	0.02	0.0006	0.00	0.00	0.00
Bone	0.06	0.13	0.03	0.0016	0.00	0.00	0.00
Liver	0.05	0.04	0.06	0.0002	0.00	0.00	0.00
Brain	0.00	0.01	0.01	0.0002	0.00	0.00	0.00
TTHQ	0.16	0.26	0.14	0.0028	0.00	0.00	0.00

TTHQ = Total Target Health Quotient (∑THQ)

HI = Hazard Index

Table 4.13 and Fig. 4 show the THQ values for several chicken broiler body sections. Zn had the greatest TTHQ (0.14 in adults and 0.26 in children), whereas Mn, Pb, and Cd had TTGQ of 0. For both age groups, the pattern was Zn > Fe > Cu > Cr. All heavy metals in the five distinct broiler samples under investigation for adults and children had THQ values below 1.0, suggesting no non-cancer danger to any consumer group.

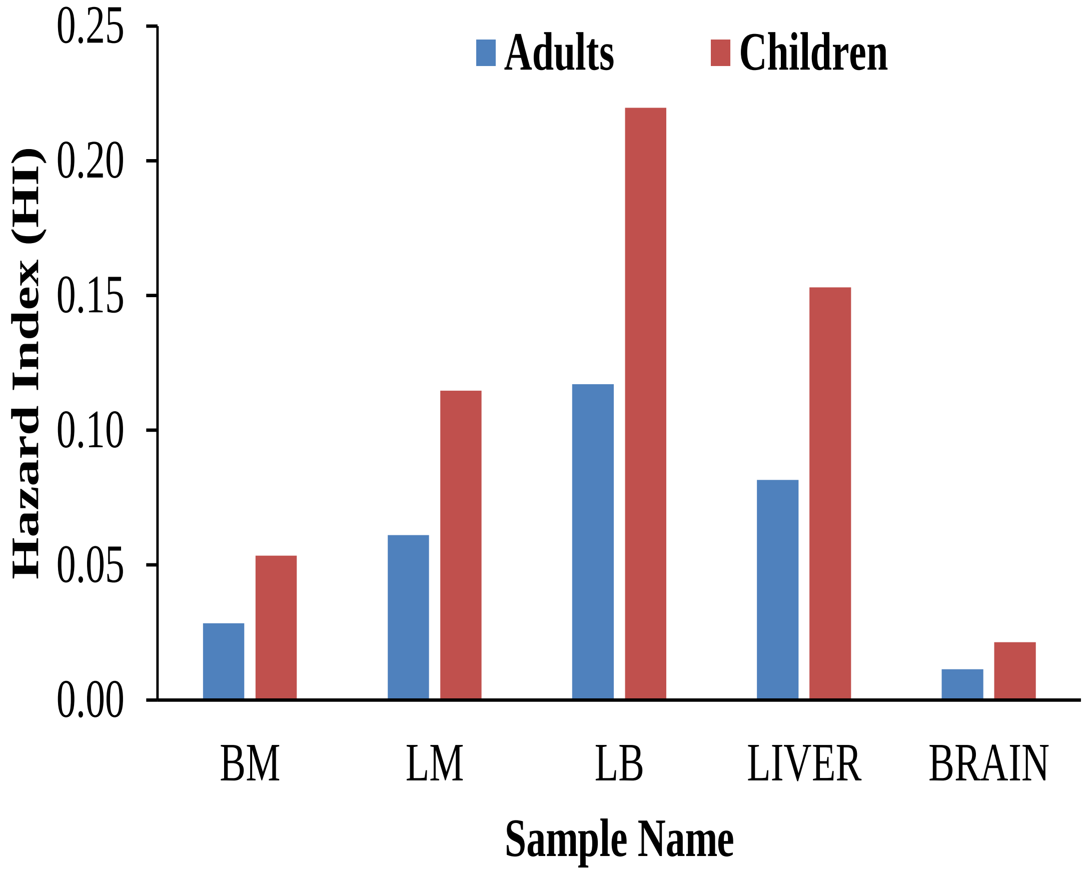

Figure 4.4 Hazard Index (HI) among both adults and children through consumption of different parts of collected LDV chicken.

4.4.5: Hazard Index:

The hazard index was used to reflect the overall non-cancer danger of all heavy metals under investigation (HI). All LDV chicken samples for both adults and children showed HI <1.0. As a result, the current analysis finds no non-carcinogenic health risk associated with consuming LDV chicken in particular markets of Dhaka city.

4.5: Health Risk Assessment for Consumption of Egg, Rice, Black gram and Lentil

4.5.1: Pollution Index for Common foods:

Different foodstuffs have various values of the single factor Pollution index of Fe (Table 4.14). Rice and egg (yolk) have greater PI of Fe than other foods. While the PI of Fe value was less than 1 in all selected common foods. Fe had PI values between (0.01-0.25). Additionally, the PI of Zn differed throughout the common food components examined in this study (Table 4.14).

Table 4.14 Single factor pollution index, average pollution index, and the sum of pollution index of collected common foods.

Sample	Single Factor Pollution Index						Sum of PI	Avg. PI
	Fe	Zn	Cu	Cr	Pb	Cd		
Egg (Albumin)	0.01	0.01	0.86	0.26	9.93	8.39	19.5	3.2
Egg(yolk)	0.20	0.41	2.48	0.18	10.22	16.17	29.7	4.9
Rice	0.25	0.12	7.62	0.00	3.32	27.04	38.4	6.4
Black gram	0.15	0.35	16.85	0.04	3.30	32.70	53.4	8.9
Lentil-fine	0.19	0.51	21.93	0.00	0.00	19.03	41.7	6.9
Lentil-coarse	0.17	0.43	27.67	0.00	82.50	27.21	138.0	23.0

The highest PI of Zn for lentil-fine was 0.51, and the lowest PI of Zn for egg-albumin was 0.01. The PI of Cu was 27.67 for lentil-coarse, 21.93 for lentil-fine, 16.85 for black gram, 7.62 for rice, 2.48 for egg yolk and 0.86 for egg albumin. The black gram was found to have the lowest PI of Cr which is 0.04. In the current study, the single factor pollution index of Cr varied amongst the various foodstuffs. PI value for Cr was in the range of (0.00-0.26). The highest amount of Cr was found in egg albumin. No pollution index was found for Cr in rice and lentil samples. For lead (Pb) the Table 4.14 showed a diverse result. The findings for listed common food were in a range of (0.00-82.50) and the decreasing order was coarse lentil (82.50)> egg yolk (10.22)> egg albumin (9.93)>rice (3.32)>black gram (3.30)> fine lentil (0.00). For Cd, all the common foods samples showed a pollution index where highest for black gram (32.50) and lowest for egg albumin (8.39). For all heavy metals, the pollution index was lowest in egg albumin sample but for Cr, it was highest. The World Health Organization (WHO), the United States Environmental Protection Agency (USEPA), and other international organizations have regulatory standards for metal content in biotic and abiotic media. This ratio is known as the single factor pollution index (PI) (Jamali *et al*., 2007). PI values below 1 show that the sample is not yet polluted, whereas PI values over 1 show contamination. However, PI=1 shows a critical condition, making the sample involved important for environmental monitoring (Chukwuma, 1993). The study showed PI>1 for Cu in all common foods except egg albumin. For lead (Pb) without fine lentil, all common foods showed PI>1 and for Cd PI>1 in all foodstuffs. So, from this study, it is concluded that through the consumption of common foodstuffs people have high health risks. The order of PI_{Avg} lentil (coarse), black gram, lentil (fine), rice, egg (yolk), and egg (albumin) are downward.

4.5.2: Sum of pollution index (SPI)

In foodstuffs of five different markets of the Dhaka city, the sum of pollution index (SPI) of the six heavy metals in popular meals was calculated and is shown in Table 4.14. The pollution index's total revealed a broad range of disparities. The sum of the pollution index was 138.0, the highest estimated in coarse lentils, and 19.5 the lowest in egg albumin. Additionally, source regions, pest control measures, post-harvest processing procedures, and other anthropogenic activities may contribute to the difference across the various commodities (El-Ramady *et al.*, 2015). Agricultural fields are being inundated by industrial effluents through irrigation water. Soil and crops are becoming poisoned with heavy metals as a result (Naser *et al*., 2011).

Table 4.15 Estimated daily intake (EDI) of heavy metals in collected LDV chicken and corresponding maximum tolerable daily intake (MTDI).

			EDI value for Adults			
Sample	Fe	Zn	Cu	Cr	Pb	Cd
Egg (Albumin)	1.28E-03	8.36E-05	7.82E-05	5.97E-05	2.25E-04	9.51E-05
Egg(yolk)	1.93E-02	5.61E-03	2.25E-04	4.11E-05	2.32E-04	1.83E-04
Rice	6.49E-01	4.31E-02	1.87E-02	0.00E+00	2.03E-03	8.28E-03
Black gram	5.25E-03	1.70E-03	5.50E-04	3.01E-06	2.70E-05	1.34E-04
Lentil-fine	6.46E-03	2.50E-03	7.16E-04	0.00E+00	0.00E+00	7.77E-05
Lentil-coarse	5.97E-03	2.10E-03	9.04E-04	0.00E+00	6.74E-04	1.11E-04
Total EDI	0.687	0.055	0.021	0.0001	0.003	0.009
MTDI	8-10	0.3-1	30	0.04-0.2	0.21	0.02-0.07
			EDI value for Children			
Egg (Albumin)	2.41E-03	1.57E-04	1.47E-04	1.12E-04	4.22E-04	1.78E-04
Egg(yolk)	3.63E-02	1.05E-02	4.21E-04	7.71E-05	4.34E-04	3.44E-04
Rice	1.22E+00	8.09E-02	3.50E-02	0.00E+00	3.81E-03	1.55E-02
Black gram	9.85E-03	3.19E-03	1.03E-03	5.65E-06	5.05E-05	2.50E-04
Lentil-fine	1.21E-02	4.69E-03	1.34E-03	0.00E+00	0.00E+00	1.46E-04
Lentil-coarse	1.12E-02	3.94E-03	1.69E-03	0.00E+00	1.26E-03	2.08E-04
Total EDI	1.289	0.103	0.039	0.0002	0.006	0.017
MTDI	8-10	0.3-1	30	0.04-0.2	0.21	0.02-0.07

4.5.3: Estimated Daily Intake of Heavy Metal

Estimated daily intake was calculated to measure human health risks associated with different heavy metals via commonly consumed foodstuffs. In the calculation of EDI, different food ingestion rates were taken from a preliminary report on the household income and expenditure survey of Bangladesh. According to this report, per capita per day consumption rates were-367.19 g for rice, 13.6g of egg 4.9 g for lentil, and black gram (HIES 2017). The calculated EDI values for different foodstuffs for adults and children are presented in Table 4.15, along with the MTDI and oral reference doses (RfD) of heavy metals. It can be seen from Table 4.15 that the EDI values obtained for Fe, Cu, Zn, Cr, Pb, and Cd are due to the consumption of foodstuffs in five different marketplaces of Dhaka city. Here we see the EDI value for rice is higher than other foodstuffs, because the consumption rate of rice is high. Adults had total EDI values for Fe, Zn, Cu, Cr, Pb, and Cd of 0.687, 0.055, 0.021, 0.0001, 0.003, and 0.009 mg $kg^{-1}day^{-1}$, whereas children had total EDI values of 1.289, 0.103, 0.039, 0.0002, 0.006, and 0.017 mg $kg^{-1}day^{-1}$ respectively. Fe and Zn have the highest EDI values for both adults and children's populations when compared to all other heavy metals. The computed EDI values of any heavy metal in all the examined samples, however, were lower than the corresponding MTDI.

4.5.4: Cancer risk Assessment:

Pb and Cd are classified as carcinogenic heavy metals as their chronic exposure causes different types of cancer (Haque *et al.*, 2021). The calculated incremental lifetime cancer risks (ILCRs) of Pb and Cd via consuming contaminated foodstuffs are presented in Table 4.16. The calculated Pb ILCRs were 1.9×10^{-6} for egg albumin, 2.0×10^{-6} for egg yolk 1.7×10^{-5} for rice 2.3×10^{-7} for black gram, and 1.9×10^{-6} for coarse lentil for adults and 3.6×10^{-6}, 3.7×10^{-6}, 3.2×10^{-5}, 4.3×10^{-7}, 3.6×10^{-6} for children. The calculated Cd ILCR values were 1.4×10^{-3}, 2.7×10^{-3}, 1.2×10^{-1}, 2.0×10^{-3}, 1.2×10^{-3}, and 1.4×10^{-3} for adults, and 2.7×10^{-3}, 5.2×10^{-3}, 2.3×10^{-1}, 3.8×10^{-3}, 2.2×10^{-3}, 2.7×10^{-3} for children respectively.

Table 4.16 Non-cancer risk as total target hazard quotient (THQ) of adults and children through consumption of collected LDV chicken.

Sample	**Non-cancer risk (THQ)**						**Incremental Lifetime Cancer Risk (ILCR)**		
	For Adults						**For Adults**		
	Fe	Zn	Cu	Cr	Pb	Cd	Pb	Cd	Sum
ALB	1.8E-03	2.8E-04	1.1E-03	4.0E-05	6.4E-02	3.2E-02	1.9E-06	**1.4E-03**	1.4E-03
YK	2.8E-02	1.9E-02	3.2E-03	2.7E-05	6.6E-02	6.1E-02	2.0E-06	**2.7E-03**	2.8E-03
RR	9.3E-01	1.4E-01	2.7E-01	0.0E+00	5.8E-01	**2.8E+0**	1.7E-05	**1.2E-01**	1.2E-01
BG	7.5E-03	5.7E-03	7.9E-03	2.0E-06	7.7E-03	4.5E-02	2.3E-07	**2.0E-03**	2.0E-03
LT-Fine	9.2E-03	8.3E-03	1.0E-02	0.0E+00	0.0E+00	2.6E-02	0.0E+0	**1.2E-03**	1.2E-03
LT-coarse	9.7E-01	1.8E-01	2.9E-01	6.9E-05	7.2E-01	**2.9E+0**	1.9E-06	**1.4E-03**	1.4E-03
TTHQ	**1.947**	0.354	0.578	0.0001	**1.437**	**5.843**			
Sample	**Non-cancer risk (THQ)**						**Incremental Lifetime Cancer Risk (ILCR)**		
	For Children						**For Children**		
ALB	3.4E-03	5.2E-04	2.1E-03	7.5E-05	1.2E-01	5.9E-02	3.6E-06	**2.7E-03**	2.7E-03
YK	5.2E-02	3.5E-02	6.0E-03	5.1E-05	1.2E-01	1.1E-01	3.7E-06	**5.2E-03**	5.2E-03
RR	**1.7E+0**	2.7E-01	5.0E-01	0.0E+00	**1.1E+00**	**5.2E+0**	3.2E-05	**2.3E-01**	2.3E-01
BG	1.4E-02	1.1E-02	1.5E-02	3.8E-06	1.4E-02	8.3E-02	4.3E-07	**3.8E-03**	3.8E-03
LT-Fine	1.7E-02	1.6E-02	1.9E-02	0.0E+00	0.0E+00	4.9E-02	0.0E+0	**2.2E-03**	2.2E-03
LT-Coarse	**1.8E+00**	3.3E-01	5.4E-01	1.3E-04	**1.3E+00**	**5.5E+00**	3.6E-06	**2.7E-03**	2.7E-03
TTHQ	**3.649**	0.663	1.083	0.0002	**2.695**	**10.956**			

TTHQ = Total Target Health Quotient (∑THQ) **ALB** = Albumin **YK** = Yolk
RR = Raw Rice **BG** = Black Gram **LT** = Lentil

These findings demonstrated that the cancer risk of Cd in all foodstuffs is higher than the threshold value (ILCR > 10^{-4}), which poses a potential cancer risk to both target groups (children and adults). In contrast, the least cancer risk was observed from Pb, which exceeded the safe limit (ILCR > 10^{-6}) but within the acceptable limit (ranged between 10^{-6} and 10^{-4}). The sum ILCR values of Pb and Cd for adults are 1.4×10^{-3}, 2.8×10^{-3}, 1.2×10^{-1}, 2.0×10^{-3}, 1.2×10^{-3}, 1.4×10^{-3} and for children 2.7×10^{-3}, 5.2×10^{-3}, 2.3×10^{-1}, 3.8×10^{-3}, 2.2×10^{-3}, 2.7×10^{-3} respectively. So, the study concluded that consumption of common foodstuffs, especially rice from the research area has an incremental lifetime cancer risk. Moreover, the cancer risk of some common foodstuffs grown in some industrial areas of Bangladesh has been reported in the literature, which exceeded the threshold value. Islam, (2014b); Kormoker *et al*., (2021) revealed that consumption of cereal and pulse items would pose carcinogenic health risks to its consumers through the combined effects of toxic metals.

4.5.5: Non-cancer Risk Assessment:

The non-cancer risk of heavy metals in six different foodstuffs for adults and children was estimated based on the target hazard quotient (THQ) and hazard index (HI = ΣTHQ). The THQ is the ratio of the investigated dose of a metal to a reference dose level of the same metal and if the ratio is greater than 1, then the exposed population is likely to experience obvious adverse non-carcinogenic health effects (Wang *et al.,* 2005). The THQ values for foodstuffs are displayed in Table 4.16 and Fig. 5. In rice and coarse lentil, the value of THQ >1.0 was observed for Cd for adults; Fe, Pb, and Cd for children within the investigated six foodstuffs samples, indicating potential non-cancer risk to both consumers groups. The highest TTHQ was obtained for Cd (TTHQ =5.843 in adults, 10.956 in children), and the trend that emerged was Cd > Fe > Pb > Cu > Zn > Cr for both aged groups.

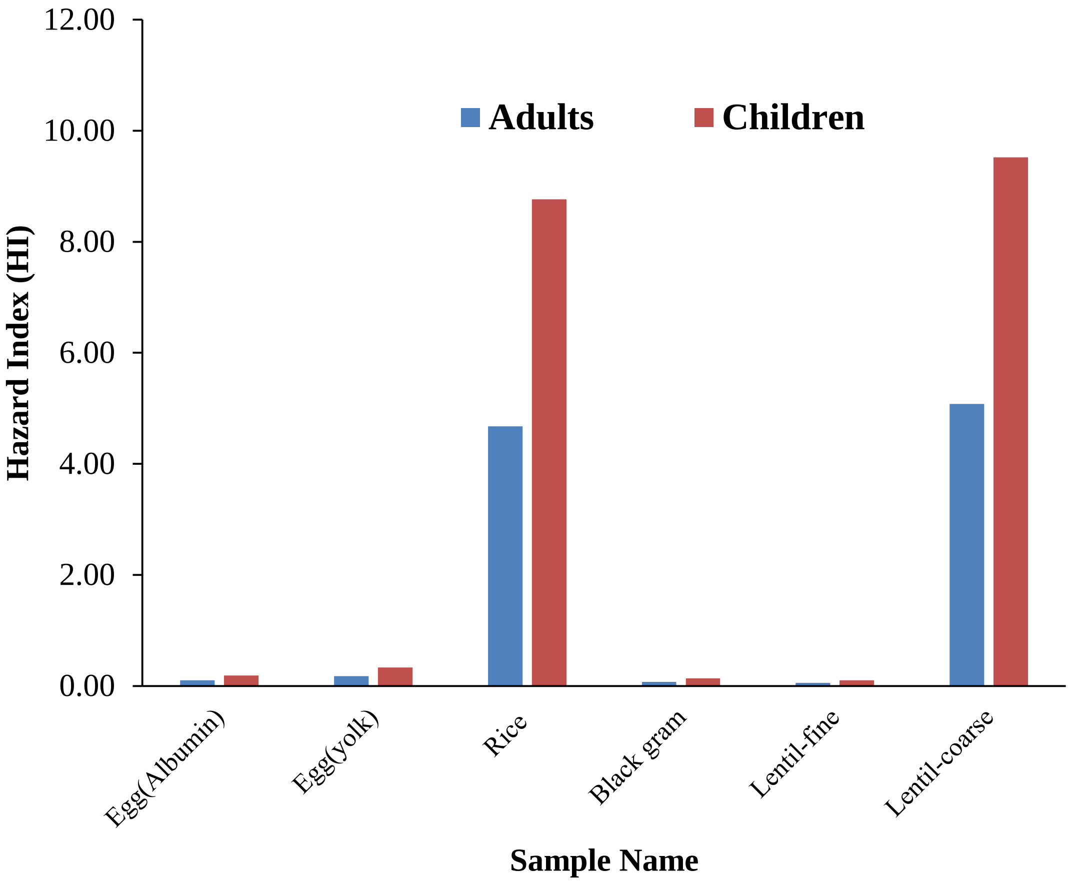

Figure 4.5 Hazard Index (HI) among both adults and children through consumption of collected foods.

4.5.6: Hazard Index for common foods:

The cumulative non-cancer risk of all studied heavy metals was expressed as hazard index (HI). Rice and coarse lentil revealed the HI > 1.0 for adults and children (Figure: 4.5). Therefore, the current investigation reveals the severe non-carcinogenic health risk through ingestion of rice and coarse lentil in selected marketplaces of Dhaka city. Islam et al., (2014a, 2015b); Kormoker et al., (2021) find HI>1 in rice and they recommended that people would be subjected to considerable non-carcinogenic risks from trace metals if they ingest rice.

CHAPTER 5

SUMMARY AND CONCLUSION

An investigation was conducted to assess the levels of iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), manganese (Mn), lead (Pb), and cadmium (Cd) in various parts of broiler and LDV chicken (breast meat, leg meat, bone, liver, and brain) and some common foods (egg albumin, yolk, raw rice, black gram, and fine and coarse lentil) collected from Kawran Bazar, Taltola Bazar, Camper Bazar by using the Atomic Absorption Spectrophotometer (AAS).

Fe was found in broiler and LDV chicken at quantities ranging from (1.95-72.86 mg/kg). The liver and bone contained most of it. The brain established the lowest. Fe concentrations ranged from (5.7-106.1) mg/kg in some common foods, with raw rice samples having the highest concentrations and egg albumin having the lowest. Although egg yolk sample contains sixteen times higher Fe than egg albumin

Zn was present at a range of (2.53-73.20) mg/kg in broiler and (3.2-71.81) mg/kg in LDV chicken respectively. Where highest was found in bone and lowest in brain. The mean Zn concentrations (mg/kg, fw) followed the descending order of lentil fine (30.6)> lentil coarse (25.72)> egg yolk (24.77) > black gram (20.86) > rice (7.05) >egg albumin (0.37) mg/kg. All the collected samples were shown lower than the maximum permissible limit except poultry bone samples.

Among the different parts of the broiler, the accumulation pattern of Cu followed the sequence as bone > liver > leg meat > breast meat > brain. The mean concentration of analyzed toxic metals in all the LDV chicken and broiler bone and leg meat samples exceeded the maximum allowable concentration (MAC).The recommended concentration of Cu which is given by FAO/WHO is 0.4mg/kg. In this study except for egg albumin, all collected food samples contained Cu higher concentration than the FAO/WHO recommended value. This heavy metal can easily enter the human body through the food chain. That’s why it is a great threat to human health.

Among the different parts of the broiler LDV chicken, the Cr was present at a range of (0.02-4.03) mg/kg. The mean concentration of Cr in broiler and LDV chicken bone samples exceeded the maximum allowable concentration. The mean concentration of Cr in foodstuffs followed the descending order of: egg albumin > egg yolk > black gram. The highest mean concentration of Cr was observed in egg albumin (0.26 mg/kg) and the lowest was found in black gram (0.04 mg/kg fw). The Cr contained in rice and lentil samples was not found. The concentrations of Cr in most of the foods were lower than the maximum allowable concentration.

Only the liver, bone, and flesh from the broiler leg were discovered to have Mn. The mean concentration of Mn is lower than the maximum permissible limit. Mn has a MAC value of 6.5 mg/kg. The concentration was below the detectable level (< 0.01mg/kg) in the brain or breast flesh. Mn levels in all the bodily sections of the LDV chicken were below what could be detected.

In broiler and LDV chicken no Cd concentration was found except for broiler bone sample. The mean concentration of Cd in broiler bone sample was analyzed at 0.44 mg/kg. The mean Cd concentrations (mg/kg) followed the descending order of : lentil coarse (8.25) > egg yolk (1.02) > egg albumin (0.99) > rice (0.33) = black gram (0.33). Among common foods, the highest Cd concentration was observed in lentil coarse (8.25mg/kg).

The mean Pb concentrations (mg/kg) followed the descending order of: Black gram > lentil (coarse) = rice > lentil (fine) > egg yolk > egg albumin. The highest mean concentration of Pb was found in black grams. The elevated concentration of Pb in cereal and pulses could probably be due to the lead smelting activity in the study area. The concentrations of Pb in foodstuffs were higher than the recommended permissible levels in foods, indicating severe contamination.

The study showed that bone, which has a pollution index (PI) value greater than 1 for all heavy metals except Fe, has the greatest pollution index value. Other parts of broiler like breast and leg meat, liver and brain had Pi values lower than 1. The order of $PI_{Avg.}$ bone, liver, leg meat, breast meat, and brain are downward. All LDV chicken samples for both adults and children showed HI <1.0. As a result, the current analysis finds no non-carcinogenic health risk associated with consuming LDV chicken in particular Dhaka market locations. Rice and coarse lentil revealed the HI > 1.0 for adults and children. Therefore, the current investigation reveals the severe non-carcinogenic health risk through ingestion of rice and coarse lentil in selected marketplaces of Dhaka city.

It can be concluded that Breast meat, leg meat, liver and brain of broiler and LDV chicken have no non-cancer and incremental lifetime cancer health risk. Egg (albumin, yolk), rice, black gram, fine lentil, coarse lentil and broiler bone from the research area have an incremental lifetime cancer risk for both adult and child group. The non-carcinogenic health risk was detected in case of rice and coarse lentil ingestion in selected marketplaces of Dhaka city.

The present study produced an important result as human health is directly affected by ingestion of foodstuffs (rice and lentil), so the bio monitoring of trace elements in common foodstuffs needs to be continued because these foodstuffs are highly consumed in Bangladesh and around the world.

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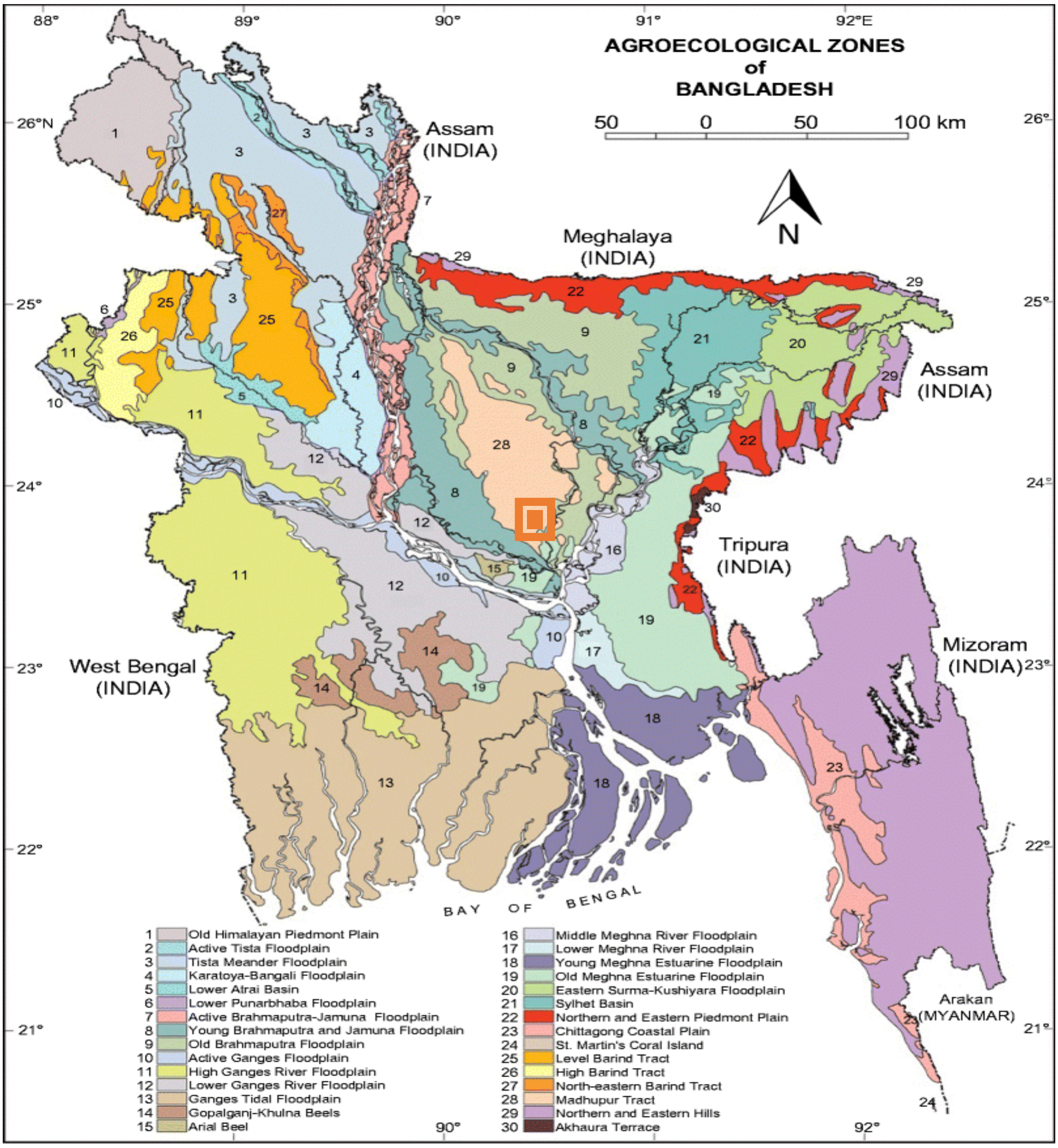
APPENDICES

Appendix I Map showing the experimental site under the study



The experimental site under study

Appendix II The mean concentrations of Cu, Zn, Fe, Pb, Mn, Cr, and Cd in collected chicken samples (leg meat, breast meat, liver, and brain)

Sample		**Heavy Metals**						
		Fe	**Zn**	**Cu**	**Cr**	**Pb**	**Cd**	**Mn**
Broiler Chicken	BM	29.01	8.44	0.33	1.01	0.00	0.00	0.00
	LM	35.11	16.61	0.54	0.26	0.76	0.00	0.00
	Bone	69.02	73.20	14.61	4.52	3.85	0.44	0.00
	Liver	73.03	20.76	3.74	0.20	0.60	0.00	0.00
	Brain	1.95	2.53	0.28	0.37	0.00	0.00	0.00
LDV Chicken	BM	31.205	9.94	1.4	0.815	0	0	0
	LM	37.45	37.40	2.21	1.52	0.00	0.00	0.00
	Bone	72.83	71.81	4.025	4.43	0	0	0
	Liver	63.705	21.33	8.325	0.5	0	0	0
	Brain	5.52	3.205	1.43	0.465	0	0	0

Appendix III The mean concentrations of Cu, Zn, Fe, Pb, Cr, and Cd in some collected common foods (egg albumin, egg yolk, rice, black gram, fine lentil, and coarse lentil)

Sample	Heavy Metals					
	Fe	Zn	Cu	Cr	Pb	Cd
Egg(Albumin)	5.67	0.37	0.35	0.26	0.42	0.99
Egg(yolk)	85.30	24.77	0.99	0.18	0.81	1.02
Rice	106.05	7.05	3.05	0.00	1.35	0.33
Black gram	64.31	20.86	6.74	0.04	1.63	0.33
Lentil-Small	79.09	30.60	8.77	0.00	0.95	0.00
Lentil-big	73.04	25.72	11.07	0.00	1.36	8.25

Appendix IV Hazard Index (HI) among both adults and children through consumption of different parts of broiler chicken

Sample	Adults	Children
BM	0.02	0.04
LM	0.03	0.06
LB	0.21	0.40
LIVER	0.07	0.13
BRAIN	0.00	0.01

Appendix V Hazard Index (HI) among both adults and children through consumption of different parts of LDV chicken.

Sample	Adults	Children
BM	0.03	0.05
LM	0.06	0.11
Bone	0.12	0.22
Liver	0.08	0.15
Brain	0.01	0.02

Appendix VI Hazard Index (HI) among both adults and children through consumption of common foods.

Sample	Adults	Children
Egg(Albumin)	0.10	0.19
Egg(yolk)	0.18	0.33
Rice	4.68	8.77
Black gram	0.07	0.14
Lentil-Small	0.05	0.10

PLATES

Plate 1: Collected chicken samples.

Plate 2: Weighing of samples

Plate 3: Putting samples in oven

Plate 4: Grinding of Oven dry samples

Plate 5: Digestion of sample

Plate 6: Standard preparation