HEAVY METAL CONTENT IN BEEF COLLECTED FROM LOCAL MARKETS OF DHAKA AND ASSESSING THE HEALTH RISK

Bioresearch Communications
Volume 9, Issue 1, January 2023

DOI:
doi.org/10.3329/brc.v9i1.63599

Rubel Akanda[1], Shamshad B. Quraishi[2] and Sumaiya Mamun[1]*

[1] *Institute of Nutrition and Food Science, University of Dhaka, Dhaka -1000, Bangladesh.*
[2] *Atomic Energy Centre, Dhaka, Bangladesh Atomic Energy Commission, Dhaka-1000, Bangladesh.*

ABSTRACT

Around the world, beef is consumed as a healthy source of protein, fat, niacin, vitamins B6, B12, iron, zinc, and phosphorus. There is mounting evidence that beef is becoming increasingly contaminated with heavy metals, particularly lead (Pb) and chromium (Cr). The purpose of this study was to determine the amounts of the lead (Pb) and chromium (Cr) in beef. Five large markets in Dhaka city—Mirpur-1, New Market, Karwan Bazar, Kaptan Bazar, and town hall market of Mohammadpur—were chosen to gather samples of beef. In this study, the Pb and Cr content in beef was estimated by the Zeeman method using graphite furnace atomic absorption spectrophotometer (GFAAS). The microwave digester finished the digestion of beef. The Pb and Cr content in beef were estimated in mg/kg. Total lead (Pb) content in a beef sample of Mirpur-1, New Market, Karwan Bazar, Kaptan Bazar and Mohammadpur was found to be 0.563±0.084, 0.845±0.127, 0.159±0.024, 0.063±0.009 and 0.143±0.021 mg/kg respectively (Minimum detection limit is 0.06 mg/kg). On the other hand, total chromium (Cr) content in beef sample from Mirpur-1 was found below the detection limit of the method (Minimum detection limit is 0.05 mg/kg). The Cr content in beef from New market, Karwan Bazar, Kaptan bazaar and Mohammadpur was found to be 0.05±0.007, 0.052±0.008, 0.121±0.018 and 0.053±0.008 mg/kg respectively. According to Codex Alimentarium Commission (CAC), the acceptable limit of lead content in beef is 0.1 mg/kg and there is no standard for chromium set by international organization like WHO/FAO, CAC. Brazil has set 0.1 mg/kg as permissible chromium content in beef (Ihedioha et al., 2014). Except for Kaptan Bazar, the chromium content was found to be within Brazil's permissible limit. Surprisingly, only Kaptan Bazar had acceptable lead content that was within the CAC limit.

KEYWORDS: Lead (Pb); Chromium (Cr); GFAAS; Microwave digestion; Permissible limit; TR; THQ

Received: 19 August 2022, Accepted: 26 November 2022

Type: Original Research

***Corresponding Author: Dr. Sumaiya Mamun, Associate Professor, Institute of Nutrition and Food Science, University of Dhaka, Dhaka-1000, Bangladesh. Email: sumaiya.mamun@du.ac.bd**

Introduction

Heavy metals are found in the earth's crust. The bioaccumulation of heavy metals can be toxic. These metals were employed for a variety of reasons thousands of years ago, but the expansion of both agricultural and industrial fields considerably increased the concentration of these metals in the environment (Nour et al. 2020; Liu et al. 2020; Kahal et al.2020). In most cases, eating is seen as the primary way that people are exposed to heavy metals. The World Health Organization (WHO) has found that even low quantities of particular metals, such as lead and cadmium, can have a negative effect or disease in people after extensive evaluation research on food additives and their toxicity. (WHO 2000, WHO 2001). Continuous releases of heavy metals from man-made pollution affect both terrestrial and aquatic ecosystems. They can acutely and permanently impact the human body through the food chain and can disrupt the natural ecosystem also (Weber et al. 2020; Ali et al. 2020). As a result, people are becoming more concerned about how pollution caused by humans is affecting ecosystems. Because of their toxicity and irreversible nature, heavy metal contamination is a severe danger. (Demirezen and Uruc, 2006; Islam et al, 2018).

Despite being widely employed for many different purposes, heavy metals are nonetheless recognized to be harmful. Living things are exposed to heavy metals both dietarily and non-dietarily. A heavy metal's concentration can rise or fall along the trophic levels of a food chain. Heavy metal retention in an organism's body is influenced by a number of variables, including the speciation of the metal in question and the physiological systems the organism has set up for heavy metal regulation, homeostasis, and detoxification. (Ali et al. 2021). Meat is a crucial component of the food we eat and is mostly made of protein, fat, and a few other vital nutrients (Akan et al., 2010). Niacin, vitamins B6 and B12, iron, zinc, and phosphorus are also found in abundance (Williams 2007). Due to its high protein content, minerals, lipid-soluble vitamins, and omega fatty acids, which are known to support excellent health, red meat (beef) is popularly consumed throughout much of the world (Tuzen and Soylak2007). In addition to being an essential component of the human diet and a significant source of many different nutrients, meat and meat products may also include some heavy metals that are harmful to health (Fathy et al., 2011). Copper, nickel, chromium, and iron, among others, are essential for the survival of all life forms in extremely low concentrations. In addition to being a significant source of human food, it may accumulate toxic minerals and be one of the sources of heavy metals for humans. Vanadium, tungsten, and cadmium are examples of elements that are normally toxic to some organisms under certain conditions. Metabolic anomalies can only occur when they are in greater quantities. Human health had been a major concern due to the danger posed by eating foods high in heavy metals. (Santhi et at. 2008). According to UNEP (2008a), even modest levels of exposure to lead (Pb) may have an impact on a child's neurodevelopment. Other side effects include those on the heart, kidneys, gastrointestinal system, hematology, and reproductive system. Chromium (Cr), on the other hand, can cause numerous cellular injuries, such as the activation of the nuclear transcription factor (NF)-KB, DNA single and double strand breaks, base modifications like the formation of 8-hydroxy-deoxyguanosine (8-OHdG), and other DNA adducts through hexavalent chromium-mediated in vitro and in vivo reactions (Shi et al., 2007).1999). Cr(VI) disrupted ionic homeostasis, resulting in cell death, calcium overabundance, MPTP opening, mitochondrial damage, and AIF movement (Zhang et al. 2021). Consumption of red meat is linked to the transmission of toxic heavy metals to humans (Sen et al.,2011).

As a result, the purpose of this study was:1) to determine whether meat sold in Dhaka city's local markets contained lead (Pb) and chromium (Cr). 2) To investigate the health risk assessment made with the aid of the estimated daily intake (EDI), the hazardous index (HI), and the target hazard quotient (THQ). Information on the degree of heavy metal contamination in emerging nations is hard to come by. As a result, policymakers in the food business lack the knowledge essential to take the appropriate action to protect consumers. Therefore, it is necessary to start disseminating this crucial information to protect public safety. In this study, we begin to close the knowledge gap by determining the heavy metal content of beef consumed in a typical developing nation community.

Materials and Methods

Collection of sample

Sample of beef was collected from 5 major markets; Mirpur-1, New Market, Karwan Barzar, Kaptan Bazar and Mohammadpur (Town Hall Market) area of Dhaka city. Sampling was done by taking Three (3) individual samples were collected and a f 500gm composite sample was made. Samples were collected in air tied zipper bag and labeled appropriately according to market name, shop identification and collection date. Samples were stored in refrigerator below -20°C until further use in the laboratory.

Sample preparation

1 gram of pest sample was weighed into a clean, dry microwave-safe Teflon vessel with a spatula to avoid contamination from hands. Then 7.0 ml of 69% nitric acid was added to the weighed sample in the vessel. In a fume hood, the weighed samples were pre-digested for 15 minutes. A seal-forming tool was used to expand the lip-seal on the lids that were placed in each vessel following pre-digestion. The vessels were positioned correctly in the support module. And inserted into the microwave system (Closed Vessel Acid Digestion Microwave digester, Model No.:MARS'5/907511, ID of the Instrument: ACL/E/MO/02) and a digestion program that was optimized (at 175°C for 20 minutes).The vessels were taken out of the microwave system after the microwave digestion step was finished. The lids and screw were slowly removed under a fume hood, allowing the nitrogen oxides to escape slowly. Quantitative transfer of the samples into volumetric flasks of 10 milliliters followed. The transparent sample solution was then stored in small vials. Clear was made by comparative interaction without expansion of test.4 ml of original sample solution was taken and made 20 ml in 10ml vial. Then samples were ready for atomic absorption spectrophotometric analysis. The GF AAS (Varian Graphite Furnace Atomic Absorption Spectrophotometer (GFAAS) Model No.: AA280Z, Instrument ID: ACL/E/AAS-03, Australia) was used to determine the Cr and Pb contents using the respective wavelengths of 357.9 nm and 217 nm.

Health risk assessment

For each adult male and female, the values of heavy metal accumulation in muscle were used to calculate the hazard index (HI), target hazard quotients (THQ), and estimated daily intake of metals (EDI).

Estimated daily intake (EDI)

The estimated daily intake (EDI) The following equation was used for EDI:

$$EDI = \frac{(C \times F_{IR})}{BWa}$$

Where C is the concentration of the element in the food in mg/kg, F_{IR} is the daily food ingestion rate in gm/day and BWa is the average body weight of Bangladeshi male which is taken as 56 kg and that of a female as 50 kg.

Target hazard quotient (THQ)

The ratio of the toxic element's exposure to the reference dose, which is the highest level at which no expected adverse health effects are expected, is the target hazard quotient (THQ). The reference dose is unique to the analysed trace element. The non-carcinogenic health risk posed by exposure to the specific toxic element is outlined in the THQ. Non-carcinogenic health effects are unlikely if the THQ is less than 1. However, if the THQ is greater than 1, there is a possibility of negative health effects. A THQ surpassing 1 is certainly not a likelihood that unfriendly non-cancer-causing wellbeing impacts will happen. Based on the Region III risk-based concentration table, the United States Environmental Protection Agency's (US EPA) methodology was utilized to estimate the THQ.

$$THQ = \frac{(EFR \times Ed \times F_{IR} \times C)}{(RfD \times BWa \times ATn)} \times 10^{-3}$$

Where E_{FR} = exposure frequency to the trace element,
Ed = exposure duration (71 yrs for male; 75 yrs for female),
F_{IR} = food ingestion rate in gms/day for beef,

C = concentration in wet weight of the trace element in beef,
R*f*D = oral reference dose of the trace element,
BWa = reference body weight of (56 kg for male and 50 kg for female)
ATn = averaged exposure time (365 days*71yrs for male; 365 days*75yrs for female)
10^{-3} is the unit conversion factor.

Hazard index (HI)

The sum of the individual target hazard quotients of the elements evaluated for each food type is the hazard index (HI). The HI makes the assumption that consuming a particular kind of food would simultaneously expose one person to several potentially harmful elements .Even if the individual THQs of the ingredients in the food item are lower than unity, their combined consumption may have negative effects on health. There is a possibility of adverse non-carcinogenic health effects if the HI is greater than 1. The equation for HI is:

$$HI = \sum_{N=1}^{i} THQ_n$$

Results

The highest Pb content of 0.845 (±0.127) mg/kg was found in New Market and the lowest 0.063 (±0.009) was found in Kaptan Bazar. Pb content expressed in mg/kg was found to be 0.563 (±0.084), 0.159± (0.024), 0.143±(0.021) in Mirpur-1, Kaptan Bazar and Mohammadpur respectively. Cr content was found to range from 0.05 (±0.007) in New Market to 0.121 (±0.018) mg/kg in Kaptan Bazar. 0.052 (±0.008), 0.053 (±0.008) mg/kg were found in Karwan Bazar and Mohammadpur, respectively. Sample from Mirpur-1 contain Cr below the minimum detection limit (0.05 mg/kg) for the method. According to Codex Alimentarius Commission, Joint FAO/WHO Standard Program, Codex Committee on Contaminants on Food (Fifth Edition), Held in the Hague, Netherlands on 22-25 March 2011 the acceptable limit of Pb in beef is 0.1 mg/kg.

Table 1. Pb and Cr content (mg/kg) in beef collected from 5 markets of Dhaka city

Market Name	Pb content (mg/kg)	CAC Limit for Pb (mg/kg)	Cr content (mg/kg)	Permissible limit for Cr (mg/kg)
Mirpur-1	0.563±0.084	0.1	< 0.05*	0.1
New Market	0.845±0.127		0.05±0.007	
Karwan Bazar	0.159±0.024		0.052±0.008	
Kaptan Bazar	0.063±0.009		0.121±0.018	
Mohammadpur	0.143±0.021		0.053±0.008	

*Minimum Detection limit of Cr by Zeeman method using GFAAS is 0.05mg/kg

In table 1, Pb content in beef collected from Mirpur-1, New Market, Karwan Bazar and Mohammadpur exceed 0.1 mg/kg the limit set by Codex Alimentarius Committee. According to Brazilian standard, beef collected from Kaptan Bazar only found to have Cr content higher than the acceptable limit.

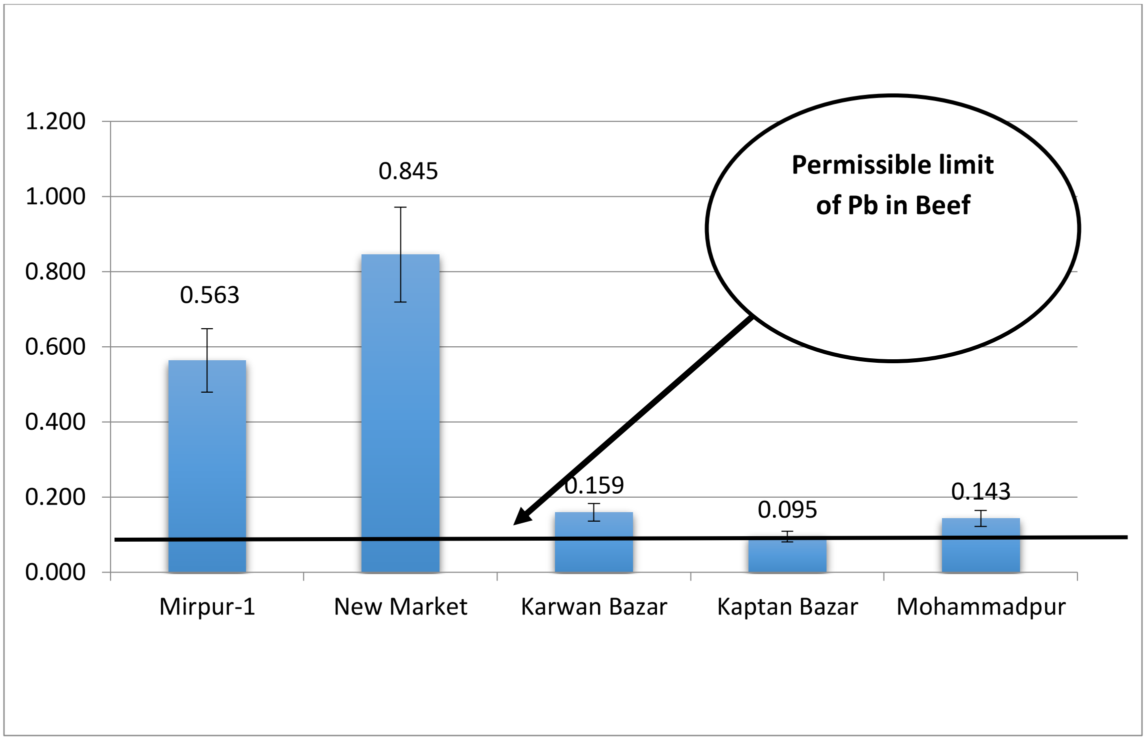


Figure 1. Pb content (mg/kg) in beef collected from 5 major market of Dhaka city

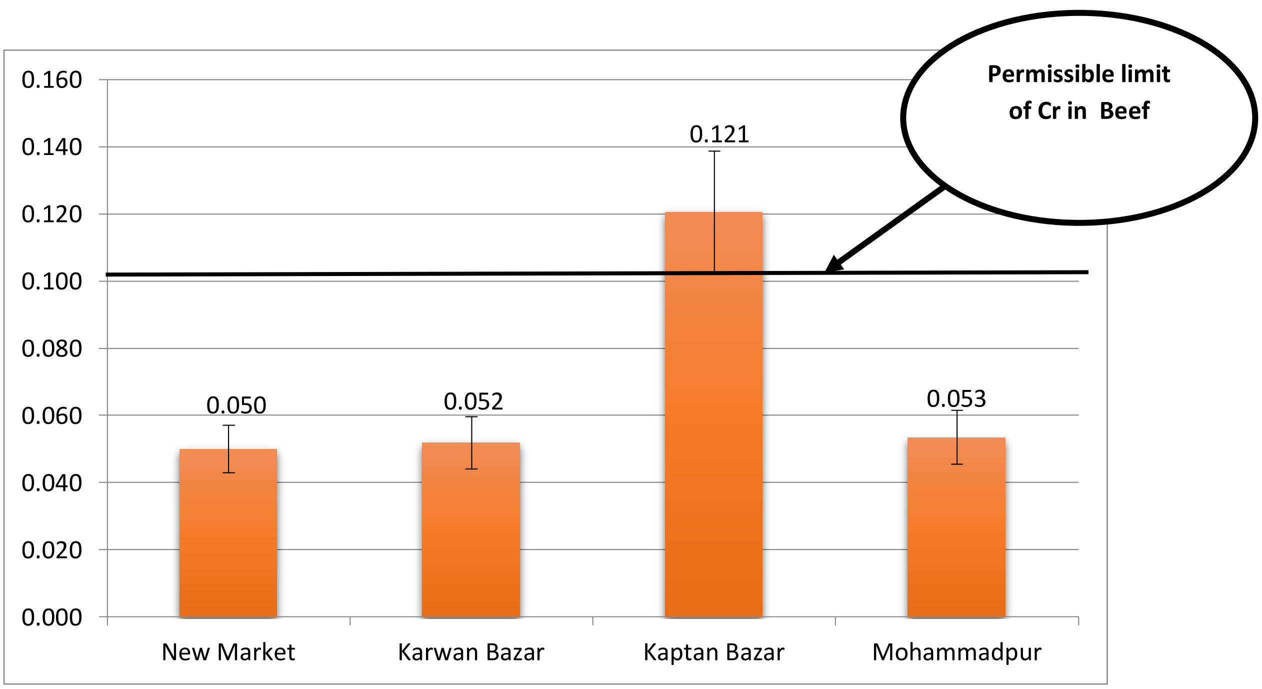
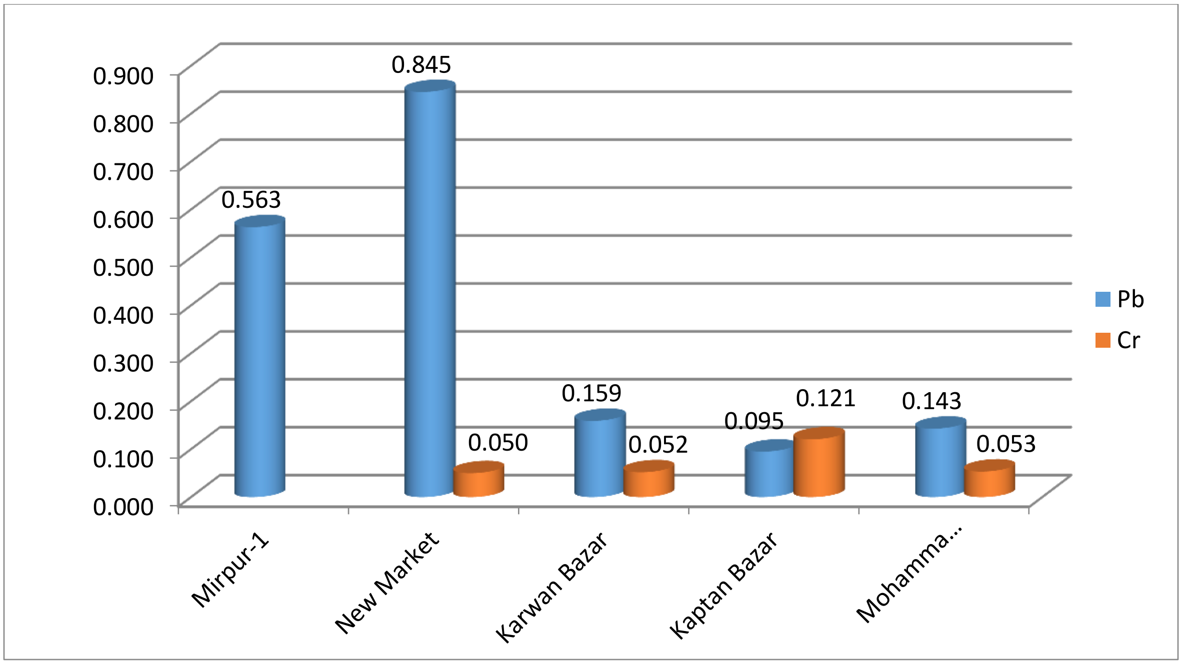


Figure 2. Cr content (mg/kg) in beef collected from 5 major markets of Dhaka city



*Cr content in beef collected from Mirpur-1 was found below the detection limit of the method

Figure 3. Marketwise comparison of Pb and Cr content (both in mg/kg)

Health Risk Assessment

To determine the risk to human health posed by eating the heavy metal-contaminated beef; The US EPA Region III Risk-Based Concentration Table [USEPA (United States Environmental Protection Agency) 2011] was used to calculate the target hazard quotient (THQ) for Pb and Cr. The THQ is an estimate of the pollutant exposure risk level that is not cancer-causing.

The Target Hazard Quotient is calculated for lifetime exposure to metals. THQ for Pb (Figure ?) was highest in New Market for both males and females. However, the THQ values for beef samples collected from five different markets were less than 1.00, indicating that the THQ for Pb was within the safe range, despite the fact that the Pb content in the beef sample was found to be above the acceptable range. THQ for Cr was found in the safe range (below 1.00) for beef collected from Mirpur-1, New Market, Karwan Bazar, Kaptan Bazar and Mohammadpur.

To evaluate the general potential wellbeing risk presented by more than one metal, THQ of each and every metal is summarized and is known as danger file (Greetings).The total of each metal's target hazard quotients can be used to calculate the HI [USEPA (United States Environmental Protection Agency) 2011].The Hazard Index is a summed-up expression of the impact of metal THQ values. New Market > Mirpur-1 >Karwan Bazar > Mohammadpur > Kaptan Bazar was the descending order for Hazar Index for beef both for male and female. But Hazard Index (HI) for beef collected from the stated markets was below 1.00 which means it was within the permissible limit (Table-2).

Table 2. Target Hazard Quotient (THQ), and Hazard Index (HI) of Pb and Cr analysed in beef.

Markets	THQ for Pb		THQ for Cr		HI	
	Male	Female	Male	Female	Male	Female
Mirpur 1	0.011	0.013	BDL*	BDL*	0.011	0.013
New Market	0.017	0.020	0.0006	0.0007	0.017	0.021
Karwan Bazar	0.003	0.003	0.0007	0.0008	0.003	0.004
Kaptan Bazar	0.001	0.001	0.001	0.001	0.002	0.003
Mohammadpur	0.002	0.003	0.0007	0.0008	0.003	0.004

**BDL=Below Detection Level*

EDI is an index to calculate metal ingestion and is measured in µg/kg body weight/day. According to FAO/WHO Expert Committee on Food Additives permissible Pd intake is 3.5 µg/kg body weight/day. The calculated EDI of Pb for both male and female groups was far below the permissible limit. Recommended Cr intake is upto 200 µg/kg body weight/day. The calculated EDI was far below the acceptable limit. Pb and Cr levels in beef were found to be within acceptable limits.

Table 3. Estimated Daily Intake (EDI) of Pb and Cr via the consumption of beef.

Markets	EDI for Pb		EDI for Cr	
	Male	Female	Male	Female
Mirpur 1	0.022822	0.02556	BDL*	BDL*
New Market	0.034253	0.038363	0.002027	0.00227
Karwan Bazar	0.006445	0.007219	0.002108	0.002361
Kaptan Bazar	0.002554	0.00286	0.004905	0.005493
Mohammadpur	0.005797	0.006492	0.002148	0.002406

**BDL=Below Detection Level*

Discussion and Conclusion

Chromium is essential for our bodies in small amounts. As our environment is getting polluted by waste products rich in chromium day by day, it is important to be concern about keeping our foods away from chromium accumulation. Cattle are exposed to toxic levels of Cr through contaminated soil, water, and air.. In this study, total five major markets of Dhaka city were investigated for getting a picture about toxic Cr content in beef. Beef sample collected from Kaptan Bazar was found to have total Cr content (0.121±0.018 mg/kg) above the permissible limit. The remaining four markets had total Cr content below the permissible limit (The permissible limit for Cr in beef is 0.1mg/kg, set by Brazil ((Ihedioha et al., 2014 Other studies have found that the Cr content of beef is within acceptable limits (Danieli et al. 2012). On the other hand, lead (Pb) a heavy metal was found in beef above the permissible limit set by CAC. The highest Pb content (0.845±0.127 mg/kg) was found in New Market and lowest (0.063 (±0.009 mg/kg) was found in Kaptan Bazar. Total Pb contents 0.563±0.084, 0.159±0.024, 0.143±0.021 mg/kg were found in Mirpur-1, Kaptan Bazar and Mohammadpur respectively. All of the values for total Pb content in beef exceed the permissible limit set by CAC. Beef samples with high levels of Pb content are found to have low Cr content (0.854 vs 0.05, 0.159 vs 0.052, 0.095 vs 0.143 vs 0.053). According to the findings of a study that was carried out in Bangladesh, poultry contained both lead and chromium, and the majority of the samples contained alarming levels of both metals (Jothi et al.).2016). Conversely, According to the findings of another study that was carried out in the city of Masul, Pb had the highest levels, followed by Cr, while Co had the lowest levels in both domestic and imported cattle and buffalo meat (Al-Naemi et al., 2020).

Pb is poisonous to our bodies. And the presence of Pb in beef raises concerns about its accumulation in the animal.It needs to identify the source of Pb in beef. Pesticides, fertilizers, industries may be sources of Pb. So, for the sake of our health, our government, as well as private and international NGOs, should work together to reduce the accumulation of pb in beef, as beef is widely consumed throughout the country. Cattle from areas polluted with Pb (air, water, soil, etc) have a greater risk of accumulating Pb as a result of chronic exposure to Pb in the environment.

Acknowledgement

This paper is part of Rubel Akanda's MS thesis, which is being supervised by Dr Sumaiya Mamun. The technical part was supported by Bangladesh Atomic Energy Commission, Dhaka.

References

1. Ali MM, Ali ML, Proshad R, Islam S, Rahman Z, Tusher TR, et al. Heavy metal concentrations in commercially valuable fishes with health hazard inference from Karnaphuli river, Bangladesh. Human and ecological risk assessment: an international journal 2020;26:2646-62
2. Ali, M. M., Hossain, D., Al-Imran, M., Khan, S., Begum, M., & Osman, M. H. (2021). Environmental Pollution with Heavy Metals: A Public Health Concern. In *Heavy Metals-Their Environmental Impacts and Mitigation*. IntechOpen.
3. Al-Naemi, H. S., Al-Sanjary, R. A., & Faraj, R. A. (2020). Detection of lead, chromium and cobalt in meats of cattle and buffalo from retails of Mosul city. *Iraqi Journal of Veterinary Sciences*, *34*(2), 447-451.
4. Danieli PP, Serrani F, Primi R, Ponzetta MP, Ronchi B, Amici A. Cadmium, lead, and chromium in large game: a local-scale exposure assessment for hunters consuming meat and liver of wild boar. Arch Environ Contam Toxicol. 2012 Nov;63(4):612-27. doi: 10.1007/s00244-012-9791-2. Epub 2012 Aug 22. PMID: 22911061.
5. Hashem, M. A., Kamal, M. T., Al-Mamun, M., Hossain, M. M., & Razzaque, M. A. (2022). Assessment of heavy metals in feed and beef in Bangladesh: A safety issues. *Meat Research*, *2*(1).
6. Islam MS, Proshad R, Ahmed S. Ecological risk of heavy metals in sediment of an urban river in Bangladesh. Human and ecological risk assessment: an international journal 2018;24:699-720.
7. Jothi, J. S., Yeasmin, N., Anka, I. Z., & Hashem, S. (2016). Chromium and lead contamination in commercial poultry feeds of Bangladesh. *International Journal of Agricultural Research, Innovation and Technology*, *6*(2), 57-60.
8. Kahal A, El-Sorogy AS, Qaysi S, Almadani S, Kassem OM, Al-Dossari A. Contamination and ecological risk assessment of the Red Sea coastal sediments, southwest Saudi Arabia. Marine Pollution Bulletin 2020;154:111125.
9. Liu P, Hu W, Tian K, Huang B, Zhao Y, Wang X, et al. Accumulation and ecological risk of heavy metals in soils along the coastal areas of the Bohai Sea and the Yellow

Sea: A comparative study of China and South Korea. Environment International 2020;137:105519.

10. Nour HE, El-Sorogy AS, Abd El-Wahab M, Mohamaden M, Al-Kahtany K. Contamination and ecological risk assessment of heavy metals pollution from the Shalateen coastal sediments, Red Sea, Egypt. Marine pollution bulletin 2019;144:167-72.
11. Shi X, Chiu A, Chen CT, Halliwell B, Castranova V, Vallyathan V. Reduction of chromium(VI) and its relationship to carcinogenesis. J Toxicol Environ Health B Crit Rev. 1999 Jan-Mar;2(1):87–104. [PubMed] [Google Scholar]
12. U.S Environmental Protection Agency (EPA) information on lead, http://www.epa.gov/lead/
13. Weber AA, Sales CF, de Souza Faria F, Melo RMC, Bazzoli N, Rizzo E. Effects of metal contamination on liver in two fish species from a highly impacted neotropical river: A case study of the Fundão dam, Brazil. Ecotoxicology and Environmental Safety 2020;190:110165.
14. Zhang, X., Wang, Y., Chen, M., & Zeng, M. (2021). Hexavalent chromium-induced apoptosis in Hep3B cells is accompanied by calcium overload, mitochondrial damage, and AIF translocation. *Ecotoxicology and Environmental Safety*, *208*, 111391.