ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

Human Health Risks of Heavy Metal Exposure from Eight Popular Cultured Fish Species in Jashore, Bangladesh

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Publication Date: 2025/02/25

Abstract: The current study sought to determine the levels of seven heavy metals—lead, cadmium, chromium, arsenic, copper, nickel, and mercury—and the possible health concerns to humans in eight common cultured fish species from Monirampur Upazila, Jashore, Bangladesh. This study employed a completely randomized laboratory experimental design with three replications. Using ICP-MS technology, the experiment was carried out from May to July 2024 at Jashore University of Science and Technology's Centre for Sophisticated Instrumentation and Research Laboratory (CSIRL). Five percent of daily calories are obtained from fish. Eight common cultured freshwater fishes—Pangas, *Pangasius pangasius*; Tilapia, *Oreochromis mossambicus*; Rui, *Labeo rohita*; Silver Carp, Hypophthalmichthys molitrix; Mrigal, *Cirrhinus cirrhosis*; Catla, *Catla catla*; Koi, *Anabas testudineus*; and Kalibaus, *Labeo calbasu*—were gathered from a commercial fish farm in Monirampur Upazila, Jashore, Bangladesh in order to measure the metal levels in the edible portion (flesh) and evaluate the risk to human health. Copper and arsenic were below detection limits, but the following amounts were measured: cadmium (0.1365-0.2235 mg/kg), lead (1.225 mg/kg), chromium (1.435 mg/kg), mercury (0.202-3.105 mg/kg), and nickel (1.09 mg/kg). Mercury from *Pangasius pangasius* may present non-carcinogenic concerns, even if the Target Hazard Quotient (THQ) values for individual metals (apart from mercury) were less than 1, suggesting no substantial health risk. Additionally, the Target Carcinogenic Risk (TRs) for chromium and nickel surpassed acceptable limits, suggesting chronic exposure to these metals may result in both carcinogenic and non-carcinogenic health effects.

Keywords: *Heavy metals, Human Health Risks, Cultured Fish Species, Mercury Contamination, Target Hazard Quotient (THQ).*

How to Cite: Ahasan Habib; Md. Shazzad Hossain; Pulakesh Basak; Md. Moklesur Rahman; Most. Rabeya Sultana Setu; Mridul Kanti Das; Rezaul Karim; S. M. Shamiul Alam. (2025). Human Health Risks of Heavy Metal Exposure from Eight Popular Cultured Fish Species in Jashore, Bangladesh. *International Journal of Innovative Science and Research Technology*, 10(1), 2863-2870. https://doi.org/10.5281/zenodo.14928738.

I. INTRODUCTION

Bangladesh is often called "land of rivers," due to its broad network of waterways that bear its rich fishery resources [1]. Fish acquires a special place in the Bengali culture and diet of the country, as condensed in the popular adage, "Fish and Rice make a Bengali." This schmaltziness reflects the critical role of fish in the daily lives of the Bangladeshi population. In recent years, Bangladesh has recognized as one of the top fish-producing nations in the world. It has a notable production of 4.85 million metric tons in the fiscal year 2022–2023 [2]. The fisheries sector contributes 2.12% to the country's GDP and accounting for 22.1% of the agricultural sector's total output during the same period [3].

Fish is a primary source of animal protein due to its nutritional importance. Fish contributes over 60% of the animal protein intake in Bangladesh, with the average per

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

capita daily consumption providing around 50 grams of protein [4, 5]. This dependency, however, places a substantial responsibility on ensuring the safety and sustainability of fish as a food source. Despite its importance, the fisheries sector faces significant challenges, with environmental pollution emerging as a critical threat to the sustainability and safety of fish resources.

Heavy metals have a significant impact on aquatic ecosystems [6, 7]. Because they are not biodegradable, these harmful substances linger in the environment and frequently build up in aquatic life, such as fish, through processes called bioaccumulation and bio magnification [6, 7]. The increasing contamination of water bodies in Bangladesh can be attributed to rapid urbanization, unregulated industrial activities, and agricultural runoff, which have collectively exacerbated heavy metal pollution in aquatic environments [6, 7].

Different type's health risks to humans occur due to consumption of contaminated fish by heavy metals [8]. Numerous researches and the WHO have emphasized the negative consequences of prolonged exposure to these hazardous metals [8]. For instance, lead can impair cognitive development in children and contribute to cardiovascular problems, while cadmium is linked to kidney dysfunction and hormonal imbalances [9, 10]. Chromium and mercury also pose significant risks, including carcinogenic and non-carcinogenic effects, making their presence in commonly consumed fish species a matter of grave concern.

According to recent research conducted in Bangladesh, fish contained higher levels of heavy metals especially those rose in contaminated waters [11]. According to a study by Akter et al. (2021), for example, concentrations of heavy metals were higher in wild fish than in fish raised in captivity [11]. The study highlighted the need for continuous monitoring by pointing out that metals including Cr, Ni, and Cd may cause cancer, even though these levels were below worldwide safety criteria [11]. In a similar vein, Hossain et al. (2022) examined the levels of heavy metals in Bangshi River fish and discovered that Corica soborna had lead (Pb) levels beyond safety thresholds, underscoring the need for stricter control [12]. Together, these results highlight how critical it is to monitor and control heavy metal pollution in order to protect public health and guarantee food safety. Given the importance of fish in the Bangladeshi diet, customers may suffer serious long-term health effects if appropriate measures are not taken.

In order to address this urgent problem, this study assessed the levels of eight commonly consumed cultured fish species that were gathered from Monirampur Upazila, Jashore, Bangladesh for heavy metals. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technology was used in this study, offers a thorough evaluation of the possible health hazards related to eating fish. This study aims to measure the dangers to human health that are not carcinogenic as well as those that are by using metrics like the Target Hazard Quotient (THQ) and Target Carcinogenic Risk (TR).

The study's importance lies in its emphasis on the possible health hazards associated with eating fish tainted with heavy metals, a significant dietary issue in Bangladesh. Understanding the level of heavy metal pollution in fish and its consequences for public health is greatly aided by the research findings. The study offers valuable insights for policymakers, regulatory bodies, and stakeholders in the fisheries sector to implement effective measures for mitigating contamination, ensuring food safety, and promoting sustainable aquaculture practices in Bangladesh. This work also serves as a foundation for future research aimed at improving environmental health and protecting the well-being of fish consumers in the country.

II. METHODOLOGY

A. Sampling Site

Fig 1: Map of Sampling Site

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

The sample for this study was undertaken in Monirampur Upazila, located in Jashore district, Bangladesh. This region is well-known for its aquaculture operations and offers a variety of fish species that the people of Bangladesh frequently eat.

B. *Sample Collection*

Eight species of cultured fish, locally name, Tilapia/Nilotica, Rui, Silver Carp, Mrigal, Catla, Koi, and Kalibaus, were collected from Monirampur Upazila. These species were chosen for their economic value and high consumption rates in Bangladesh. After being gathered, the fish samples were promptly cleaned with fresh water to get rid of any pollutants or surface dirt. After that, the samples were put in sterile polyethylene bags and taken to Jashore University of Science and Technology's Department of Agro Product Processing Technology lab for additional examination.

C. *Sample Preparation*

The fish samples were brought to room temperature and rinsed with distilled water when they arrived at the lab. Prior to dissection, each fish's total length (cm) and weight (g) were precisely measured. A stainless steel knife that had been steam-cleaned was used to remove the fish's edible section, or muscle tissues. The muscle tissues were further cleaned with distilled water, then cut into 2-4 cm pieces and dried to eliminate any remaining moisture. After preparation, the samples were kept for examination of heavy metals.

D. *Determination of Heavy Metals by ICP-OES*

Prior to analysis, all lab equipment was pre-treated by immersing it in 20% HNO_3 for 48 hours, then washing it with distilled water and drying it in an oven set at 150°C [13]. Prior to being digested with 10 mL of a 4:1 (v/v) HNO_3-$HClO_4$ solution at 150°C on a hot plate, 10 g of fish muscle tissue was dried at 110°C to a constant weight for each sample [13]. The digested samples were allowed to cool to room temperature before being diluted with 50 milliliters of double-distilled water and filtered using Whatman No. 42 filter paper [13]. Using inductively coupled plasma optical emission spectrometry (ICP-OES), the concentrations of As, Cd, Cr, Hg, Ni, Cu, and Pb were determined [13]. To guarantee accuracy, every sample was examined three times [13].

E. *Calculation*

➢ *Estimated Daily Intake (EDI)*

The EDI of heavy metals was calculated to assess the risk posed by fish consumption. EDI was expressed in mg/kg body weight/day, using the following equation 1 [14]:

$$EDI = \frac{MC \times FIR}{BW} \times 10^{-3} \quad (1)$$

Where: MC = Concentration of heavy metals in the fish samples (mg/kg wet weight), BW = Average adult body weight (70 kg), and FIR = Fish ingestion rate (49.5 g/day) [15].

➢ *Target Hazard Quotient (THQ)*

The non-carcinogenic risk posed by heavy metals in fish was assessed by the THQ using equation 2, which was supplied by [16,17]:

$$THQ = \frac{EF \times ED \times FIR \times MC}{BW \times ATn \times RfD} \times 10^{-3} \quad (2)$$

Where: MC = Concentration of heavy metals in the fish (mg/kg dry weight), EF = Exposure frequency (350 days/year), ED = Exposure duration (30 years), FIR = Fish ingestion rate (49.5 g/day) [15], BW = Average adult body weight (70 kg), ATn = Average exposure time for non-carcinogens (EF × ED), RfD = Oral reference dose for each heavy metal [18,19].

There is little chance of negative health effects if THQ is less than 1. On the other hand, THQ ≥ 1 suggests a possible health concern that calls for precautions [20].

➢ *Hazard Index (HI)*

Equation 3 is used to generate the Hazard Index (HI), which is the total of the individual THQ values for each of the metals under analysis (USEPA, 2011):

$$HI = THQ(As) + THQ(Cd) + THQ(Cr) + THQ(cu) + THQ(Ni) + THQ(Hg) + THQ(Pb) \quad (3)$$

While HI > 1 indicates possible health risks, HI < 1 indicates that eating the fish species is safe.

➢ *Target Cancer Risk (TCR)*

The incremental lifetime risk of acquiring cancer as a result of exposure to carcinogenic heavy metals is estimated by Target Cancer Risk (TCR). Equation 4 was utilized to compute TCR [21]:

$$TCR = \frac{EF \times ED \times FIR \times MC \times CPSo}{BW \times ATc} \times 10^{-3} \quad (4)$$

Where: CPSo = Carcinogenic potency slope (mg/kg bw/day), ATc = Average exposure time for carcinogens (365 days/year for 70 years). TCR values were calculated for As, Pb, and Cr as these metals have known carcinogenic potency slopes [22].

III. RESULTS AND DISCUSSION

A. *Concentration of Heavy Metals in Fish Species*

Fish is an important part of the Bangladeshi cuisine. Almost 60% of Bangladesh's population consumes cultivated fish on a regular basis, accounting for approximately 5% of their diet [23]. Fish flesh is an essential and important dietary component for human being which is main source of protein. The current study estimated the degree of seven heavy metals (Cd, Pb, Cu, Cr, Hg, Ni, and As) pollution in eight popular cultured fish species of Monirampur Upzila in Jashore district, as shown in Table 1 below. Heavy metal concentrations were measured using wet weight as the unit. Metal concentrations varied significantly among fish species due to their eating habits and metal accumulation capacity.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

The heavy metal concentrations were determined to be as follows: Cd (0.132-0.292), Pb (1.35), Cr (1.55), Hg (0.227-3.605), Ni (1.12) in mg/kg unit, while Cu and As were under the detection limits listed in Table 1. The ranking of the average concentration heavy metals in fish flesh was Cd > Hg> Ni > Pb > Cr.

Even at low doses, cadmium (Cd) is a very poisonous metal that can seriously harm human health. It has been linked to cancer, reproductive toxicity, liver, kidney, lung, and skeletal damage [24]. All eight of the common cultivated fish species in the current study included Cd, with amounts ranging from 0.132 mg/kg in Anabas testudineus to 0.292 mg/kg in *Pangasius pangasius*, as indicated in Table 1. These concentrations exceeded the FAO/WHO limit of 0.1 mg/kg, but remained within the Bangladeshi regulatory standard of 0.5 mg/kg for Cd in fish [25]. This is significant because, although the levels are within the national standard, they still pose potential risks if consumed in large quantities over time. These findings are consistent with the results of [26], who also detected Cd in fish species from Dhaka, although concentrations in Jashore's Monirampur Upazila were found to be higher, highlighting the need for continued monitoring and stricter regulations.

A harmful metal that is not necessary for human health, lead (Pb) can enter the body through food, water, and the air. In addition to causing kidney damage and other health problems, lead exposure is especially detrimental to the neurological system [27]. The greatest Pb concentration in this study was found in Pangasius pangasius, where it was 1.35 mg/kg, as shown in Table 1. This is far higher than the 0.5 mg/kg allowable limit established by the Bangladeshi government and the FAO/WHO. This finding poses potential health risks to consumers, especially considering the neurotoxic effects of Pb. Consuming fish that has Pb concentrations over the legal limits can result in cumulative exposure, which is especially dangerous for pregnant women and children.

A vital trace element, copper (Cu) is necessary for many biological processes, such as cellular respiration and enzyme activity. But at high concentrations, Cu can be harmful to aquatic life and people [28]. In this study, Cu was found to be below detection limits in all the fish species analysed that is stated in Table 1, indicating no associated health risks from Cu exposure in the sampled fish. This implies that there is very little chance of metal toxicity in the investigated fish species and that the amounts of Cu in these fish are far within safe consumption limits. The lack of Cu contamination emphasizes even more the necessity of keeping an eye on other heavy metals that can be more harmful to health.

Although chromium (Cr) is a necessary trace metal involved in insulin and lipid metabolism, too much of it can have harmful effects [29]. According to Table 1, *Pangasius pangasius* had the highest concentration of Cr in this study, at 1.55 mg/kg, which is higher than the WHO/FAO recommendation of 1 mg/kg for safe fish consumption. Prolonged exposure to elevated Cr levels, especially in *Pangasius pangasius*, may have carcinogenic effects in addition to possible health problems such as liver and kidney damage. These results imply that in order to reduce the health concerns associated with prolonged exposure to high concentrations of this metal, fish levels of Cr should be monitored, particularly in high-consumption species like *Pangasius pangasius*.

When mercury (Hg), a very poisonous non-essential element, builds up in the body, it can seriously harm the nervous system and development [30]. Pangasius pangasius had the highest Hg concentration in the study, with a level of 3.605 mg/kg, as shown in Table 1. This is significantly higher than the FAO/WHO limit of 0.5 mg/kg. This high concentration of mercury indicates a significant health risk for consumers, especially considering the neurological and developmental effects of Hg exposure, which can be particularly harmful to children and pregnant women. The results emphasize the need for regulatory measures to limit mercury contamination in fish, as the consumption of such contaminated species could lead to long-term health issues for consumers.

Humans can absorb nickel (Ni), a metal that is frequently present in the environment, through their diet and exposure to the environment [31]. According to Table 1, *Pangasius pangasius* had the highest Ni concentration in this investigation, 1.12 mg/kg, above the FAO/WHO recommendation of 0.8 mg/kg. Although the levels found in the fish under study are not very high, they raise the possibility of health issues for customers who may frequently eat fish species with high Ni concentrations. Prolonged exposure to high Ni levels can cause respiratory and kidney issues. This emphasizes how crucial it is to keep an eye on Ni levels in aquaculture in order to safeguard public health.

Arsenic (As) is considered one of the most lethal environmental contaminants, known for its carcinogenic properties and significant health risks [32]. For every fish species examined in this study, As was found to be under the detection limit, as indicated in Table 1, indicating that the fish in this area are not exposed to levels of arsenic that are cause for concern. Arsenic levels in fish near Dhaka, however, have been documented in the literature to range from 0.091 to 0.53 mg/kg, which is less than the WHO recommendation of 1 mg/kg. Even though the current study did not find measurable amounts of As, the low levels of arsenic in some fish species in the surrounding areas call for on-going monitoring to make sure that arsenic poisoning does not endanger human health in the future.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

Table 1: Average (± SD) Heavy Metal Content (mg/kg) in Eight Cultured Fish Species

Fish varities (Local name)	**Heavy Metal Concentration (mg/kg)**						
	Cd	**Pb**	**Cu**	**Cr**	**Hg**	**Ni**	**As**
Rui *(Labeo rohita)*	0.165±0.003	BMR	BMR	BMR	0.252±0.002	BMR	BMR
Catla *(Catla catla)*	0.154±0.002	BMR	BMR	BMR	0.262±0.004	BMR	BMR
Silver carp*(H. molitrix),*	0.156±0.005	BMR	BMR	BMR	0.277±0.008	BMR	BMR
Pangas *(Pangasius pangasius)*	0.292±0.008	1.35±0.014	UDL	1.55±0.067	3.605±0.006	1.12±0.003	BMR
Koi *(Anabas testudineus)*	0.132±0.003	BMR	BMR	BMR	0.227±0.003	BMR	BMR
Tilapia (*O. niloticus)*	0.149±0.003	BMR	BMR	BMR	0.243±0.012	BMR	BMR
Mrigal *(Cirrhinus cirrhosus)*	0.138±0.002	BMR	BMR	BMR	0.254±0.004	BMR	BMR
Kalibaus *(Labeo calbasu)*	0.143±0.004	BMR	BMR	BMR	0.827±0.005	BMR	BMR

(***Guideline Limits (mg/kg):** FAO/WHO: Cd (0.1), Pb (0.5), Cu (4.5), Cr (1.0), Hg (0.5), Ni (0.8), As (1.0) FAO/WHO (2002). **EU:** Cd (0.1), Pb (0.3), Hg (1.0) EU (2006). **Bangladesh:** Cd (0.25), Pb (0.3), Cu (5), Cr (1.0), Hg (0.5) MOFL (2014). **BMR** = Beyond Measurable Range)

B. Estimated Daily Intake (EDI)

Table 2 shows the Hg and Cd concentrations found in the majority of the fish species tested. Among the fish species, Pangas (*Pangasius pangasius*) exhibited the highest EDI for Mercury (Hg), with a value of 2.30E-03 mg/kg b.w./day, far exceeding other metals. This concentration aligns with concerns over the neurotoxic effects of mercury exposure through regular fish consumption.

Overall, the EDI values for the discovered heavy metals were determined to be significantly lower than the Recommended Daily Allowance (RDA) and Maximum Tolerable Daily Intake (MTDI) thresholds for human consumption. However, certain metals like mercury and cadmium still require monitoring due to their potential for bioaccumulation and long-term health effects. The table is a valuable tool for assessing the danger of heavy metal exposure from fish consumption and emphasizes the significance of regulatory actions to protect public health.

Table 2: Estimated Daily Intake (EDI) of Heavy Metals from Eating Eight Species of Cultured Fish

Fish Varities (Local Name)	**Estimated daily intake (EDI) (mg/kg b.w./day)**						
	Cd	**Pb**	**Cu**	**Cr**	**Hg**	**Ni**	**As**
Rui *(Labeo rohita)*	8.95E-05	BMR	BMR	BMR	1.53E-04	BMR	BMR
Catla *(Catla catla)*	1.12E-04	BMR	BMR	BMR	1.61E-04	BMR	BMR
Silver carp *(H. molitrix)*	1.23E-04	BMR	BMR	BMR	1.70E-04	BMR	BMR
Pangas *(Pangasius pangasius)*	1.68E-04	9.61E-04	BMR	1.11E-03	2.30E-03	7.61E-04	BMR
Koi *(Anab$_t$as testudineus)*	8.74E-05	BMR	BMR	BMR	1.56E-04	BMR	BMR
Tilapia (*O. niloticus)*	9.90E-05	BMR	BMR	BMR	1.66E-04	BMR	BMR
Mrigal *(Cirrhinus cirrhosus)*	9.50E-05	BMR	BMR	BMR	1.30E-04	BMR	BMR
Kalibaus *(Labeo calbasu)*	9.83E-05	BMR	BMR	BMR	1.83E-04	BMR	BMR
RDA	8.57E-04[a]	3.00E-03[a]		2.86E-03[a]	4.28E-04[a]		1.86E-03[a]
MTDI	7.142E-03[c]	4.2E-02[d]	0.428[c]	2.85E-03[b]		4.28E-03[e]	1.8E-03[f]

- (*BMR = Beyond Measurable Range
- *RDA = Recommended daily dietary allowance (mg/day/person) [c](FAO, 1983)*
- *MTDI= Maximum tolerable daily intake [d] (JECFA, 2000)*
- *[a](JECFA, 2009) [e](WHO, 1996)*
- *[b](RDA, 1989) [f](FAO, 2006))*

C. Health Risk Assessment

Exposure to heavy metals through the consumption of fish can significantly affect human health. Therefore, conducting a health risk assessment is essential for consumers who consume fish on a daily basis.

➢ *Target Hazard Quotient (THQ)*

Table 3 shows the estimated THQ for Cd, Pb, Cu, Cr, Hg, Ni, and As from the diet of farmed fish species. The United States Environmental Protection Agency (USEPA) defines an acceptable THQ value as 1[33]. The results show that the THQ value for each metal is less than one, implying that consumers will not face major non-carcinogenic health concerns. However, ingestion of mercury (Hg) from cultured fish may offer a non-carcinogenic health risk, as indicated by a THQ greater than one. The Hazard Index (HI) also takes into account the combined impacts of all metals. The HI value for Pangasius pangasius above the allowed limit of one, whereas the HI values for all other fish species were less than this threshold. These findings suggest that excessive and long-term use of Pangasius pangasius may result in chronic non-carcinogenic health concerns.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

Table 3: Individual Metals' Target Hazard Quotient (THQ) and Hazard Index (HI) Based on Eight Cultured Fish Species' Ingestion

Fish varities (Local name)	Target Hazard Quotient (THQ)							Hazard Index (HI)
	Cd	Pb	Cu	Cr	Hg	Ni	As	
Rui *(Labeo rohita)*	0.09756	BMR	BMR	BMR	0.472	BMR	BMR	0.57526
Catla *(Catla catla)*	0.10235	BMR	BMR	BMR	0.569	BMR	BMR	0.67135
Silver carp*(H. molitrix)*	0.08769	BMR	BMR	BMR	0.589	BMR	BMR	0.67669
Pangas *(Pangasius pangasius)*	0.15785	0.223	BMR	0.334	7.128	0.046	BMR	7.88885
Koi *(Anabas testudineus)*	0.09856	BMR	BMR	BMR	0.489	BMR	BMR	0.58756
Tilapia (*O. niloticus)*	0.09534	BMR	BMR	BMR	0.512	BMR	BMR	0.60734
Mrigal *(Cirrhinus cirrhosus)*	0.09456	BMR	BMR	BMR	0.465	BMR	BMR	0.55956
Kalibaus *(Labeo calbasu)*	0.08923	BMR	BMR	BMR	0.430	BMR	BMR	0.51923

(*BMR = Beyond Measurable Range)

- *Target Cancer Risk (TCR)*

Carcinogenic potency slope factors are given for Pb, Cr, and Ni. Inorganic As is classed as a known carcinogen (USEPA Group A), whereas lead is deemed a potential carcinogen based on animal research (USEPA Group B) [34]. Nickel and chromium are classified as Group 1 by the International Agency for Research on Cancer (IARC, 2014), suggesting substantial evidence of carcinogenicity in humans. Table 4 shows the lifetime Target Cancer Risk (TCR) values for Pb, Cr, and Ni resulting from fish consumption. The TCR values for Pb, Cr, and Ni in *Pangasius pangasius* were 2.99E-06, 2.05E-04, and 5.45E-04, respectively. In general, a cancer risk less than 10-6 is considered minimal, whereas a risk greater than 10-4 is deemed undesirable. A risk that falls between 10-6 and 10-4 is deemed tolerable [35]. The carcinogenic risk for Pb was within the acceptable range for *Pangasius pangasius* fish, but the TCR for Cr and Ni exceeded the acceptable risk limit (10-4), indicating an increased risk of cancer due to chromium and nickel exposure from long-term consumption of *Pangasius pangasius*.

Table 4: Target Cancer Risk (TCR) of Heavy Metals

Fish varities (Local name)	Target cancer risk (TCR)			
	Pb	Cr	Ni	As
Rui *(Labeo rohita)*	BMR	BMR	BMR	BMR
Catla *(Catla catla)*	BMR	BMR	BMR	BMR
Silver carp*(H. molitrix)*	BMR	BMR	BMR	BMR
Pangas *(Pangasius pangasius)*	2.99E-06	2.05E-04	5.45E-04	BMR
Koi *(Anabas testudineus)*	BMR	BMR	BMR	BMR
Tilapia (*O. niloticus)*	BMR	BMR	BMR	BMR
Mrigal *(Cirrhinus cirrhosus)*	BMR	BMR	BMR	BMR
Kalibaus *(Labeo calbasu)*	BMR	BMR	BMR	BMR

(* BMR = Beyond Measurable Range)

IV. CONCLUSION

A concise investigation was conducted to determine heavy metal content along with their potential consumer health risks in eight widely consumed farmed fish species from the Jashore district of Bangladesh. The findings outline remarkable differences in heavy metal concentrations across the examined species, with *Pangasius pangasius* shows remarkable higher levels of Cd, Pb, Ni, Cr and Hg.

This study showed that the THQ for most metals remained under the acceptable threshold of 1, suggesting a minimal risk of non-carcinogenic effects for most fish species. However, the THQ for mercury in *Pangasius pangasius* above this threshold, suggesting possible health hazards related to ingestion.

Additionally, this species' Hazard Index (HI) revealed a combined danger from several metals that should be taken seriously, especially for consumers that consume a lot of fish. While the cancer risk for lead was within tolerable bounds, the hazards related to nickel and chromium were alarming, according to the Target Cancer Risk (TCR) research. Given the substantial role that fish play in Bangladeshi diets, our findings highlight the need of strict monitoring policy.

To maintain food safety and protect the public's health, the study's findings generally support the adoption of stronger laws and frequent testing of fish for heavy metal concentrations. In order to reduce possible health risks and encourage customers to adopt safer eating habits, public awareness efforts on the dangers of eating infected fish—especially species like *Pangasius pangasius*—are essential. To guarantee the safety of fish products in Bangladesh, future studies should concentrate on identifying the sources of contamination and investigating mitigating techniques.

ISSN No:-2456-2165 https://doi.org/10.5281/zenodo.14928738

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of individuals who assisted in the preparation of this manuscript. No funding was received for this research.

COMPETING INTERESTS

It is clearly declared that there are no contradictory interests among the authors.

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