Scientific Research Publishing

American Journal of Analytical Chemistry, 2025, 16(5), 69-105
https://www.scirp.org/journal/ajac
ISSN Online: 2156-8278
ISSN Print: 2156-8251

Status of Heavy Metals in Naturally Grown Native Fish in Bangladesh and Its Consequences on Human Health: A Comprehensive Review

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How to cite this paper: Akter, R., Rahman, M.A., Bijly, R.A., Akhter, M.S., Khatun, M.C.S., Ferdiousi, N., Khandaker, G. and Rafiquzzaman, M. (2025) Status of Heavy Metals in Naturally Grown Native Fish in Bangladesh and Its Consequences on Human Health: A Comprehensive Review. *American Journal of Analytical Chemistry*, **16**, 69-105.
https://doi.org/10.4236/ajac.2025.165005

Received: March 19, 2025
Accepted: May 27, 2025
Published: May 30, 2025

Abstract

Background: Heavy metals are well-known environmental contaminants due to their harmful effects, persistence in the natural environment, and tendency to bioaccumulate. Hazardous heavy metal pollution in terrestrial and aquatic ecosystems poses a serious threat to the environment and human health due to food chain contamination and bioaccumulation. **Objective:** This study aimed to provide a comprehensive review of the accumulation of heavy metals, such as lead (Pb), chromium (Cr), arsenic (As), and others, in various species of naturally grown native fish in Bangladesh. **Methods:** For this study, various electronic databases were carefully searched using appropriate keywords for papers on the concentrations of toxic heavy metals accumulation in naturally grown native fish in Bangladesh from January 2010 to January 2020. **Results:** The literature review revealed the presence of lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), iron (Fe), and manganese (Mn) in 33 varieties of naturally grown native fish in Bangladesh. Heavy metals were detected in over 90% of the reported fish samples. Among all the reported fish and heavy metals, the Shingi fish contained the highest concentration of heavy metals, specifically Pb at 63.63 mg/kg, while the highest concentration of Mn was found in Bacha fish at 1.69 mg/kg. In contrast, the Puti and Tank goby (or Bele) fish had the lowest concentration of Cd among all the cited fish varieties, with only 0.002 mg/kg. The highest concentrations (mg/kg) of specific heavy metals among all the observed fish, regardless of fish type, followed this order: Pb (63.63) > Cu (26.60) > Zn (14.37) > Cr (6.42) > Cd (6.22) > As (5.26) > Fe (3.02) > Mn (1.69). Owing to the high variability of heavy metal content in fish, the comparison is made based on median values (mg/kg), which followed the decreasing order: Cu (5.31) > Fe (2.20) > As (0.99) > Zn (0.91) > Pb (0.67) > Cr (0.65) > Mn (0.26) > Cd (0.11). The percentages (%) of fish samples that exceeded the safety limit of specific heavy metal content followed this order: 63.04 (Pb) > 52.17 (Cu) > 37.50 (Cd) > 25.00 (Mn) > 9.68 (As) > 0% (Cr = Fe = Zn). **Conclusion:** Eight heavy metals were reported in 33 varieties of naturally grown native fish in Bangladesh. The concentrations of Pb, Cd, As, Mn and Cu exceeded the safe limits in varieties of naturally grown native fish in Bangladesh and Pb, Cd and Cu in almost all of the fish from the Karnaphuli River and the sea exceeded the recommended values for safe consumption among other sources. During the winter, the concentration of heavy metals in all types of fish was higher than in the summer. The incorporation of heavy metals into aquatic food chains leads to human exposure pathways and is associated with various pathological conditions and health hazards.

Keywords

Heavy Metals, Bioaccumulation, Naturally Grown Fish, Toxicity, Seasonal Impact, Bangladesh

1. Introduction

Heavy metals, typically defined as metallic elements and metalloids with densities exceeding 5 g/cm^3 [1] [2], have emerged as a significant environmental and public health challenge worldwide. These persistent contaminants raise particular concern due to their toxicological properties, including environmental persistence, bioaccumulation potential, and capacity for biomagnification through food chains [3] [4]. Their non-degradable nature and bioavailability contribute to widespread ecosystem contamination and pose substantial risks to living organisms [2]. Heavy metals such as Hg, Ni, Cr, Pb, and Cd are classified as potentially hazardous because they are toxic even at low concentrations [5]. Although some of these elements-like zinc and copper, are essential to biological processes, high concentrations of them can be harmful. Among the 51 heavy metals [2], eight heavy metals, namely lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni), are listed as the most widespread heavy metals in the environment [6]. These toxic metals are naturally found in aquatic environments in low concentrations, but their concentration levels have risen due to anthropogenic activities over time [7]. Through industrial, residential, agricultural, and atmospheric deposition, heavy metals can find their way into aquatic environments [8].

The rapid industrial modernization and increased agricultural practices in Bangladesh have significantly heightened the pollution of heavy metals, particularly in aquatic environments such as lakes, rivers, and estuaries, which are recognized as crucial reservoirs for these contaminants [9]. Metallic pollutants entering these aquatic ecosystems exhibit alarming ecotoxicological profiles [4] and contribute to the contamination of aquatic organisms, including fish species that show particularly high levels of bioaccumulation [3]. The incorporation of heavy metals into aquatic food chains culminates in human exposure pathways through the consumption of contaminated fish, posing significant public health risks [10].

In 2026, Bangladesh is expected to transition from being classified as a least developed country to a developing country. To achieve this upgrade, Bangladesh aims to meet 17 targets of the Sustainable Development Goals (SDGs). Among these targets, SDG 14 (Life Below Water) and SDG 3 (Good Health and Well-being) are directly or indirectly related to the presence of heavy metals in fish. Therefore, gathering data on heavy metals in fish is crucial for effectively working towards achieving the SDGs in Bangladesh by implementing immediate measures to control heavy metal exposure in its fisheries.

Bangladesh is a developing country with approximately 180 million people, and most of them have a strong fondness for native and naturally grown fish. In Bangladesh, fish alone accounts for 60% of the total animal protein consumption [11] and Bangladesh is ranked third in inland open-water capture production [12]. Although review papers have been published on heavy metals in commercial edible fish [13] and aquatic animals [14] in Bangladesh, there has been no literature review on the status of heavy metals in native and naturally grown fish species of the country and their associated implications for human health. Consequently, there is a lack of collective data on heavy metal accumulation in indigenous fish from rivers, lakes, and floodplains. Therefore, it is essential to compile data on heavy metals in native and naturally grown fish in Bangladesh and discuss their implications for human health.

The existing research on heavy metal contamination in Bangladesh's naturally grown fisheries has several limitations. First, studies are often geographically fragmented, focusing disproportionately on specific river systems (e.g., Buriganga, Karnaphuli). They also lack information regarding the impact of seasonal variation (monsoon vs. dry season) on heavy metal bioaccumulation and tend to selectively examine certain metallic elements (notably arsenic and lead). This leads to an incomplete assessment of nationwide contamination patterns. Furthermore, current studies insufficiently address critical public health issues, including emerging toxicological threats related to chronic metal exposure through fish consumption.

It is thus essential to compile data from these geographically fragmented studies to identify the heavy metals contaminating naturally grown native fish in Bangladesh in general, along with their levels and patterns of contamination. Such a compilation is also necessary to account for the impact of seasonal variation on heavy metal levels in fish. Moreover, it is crucial to discuss the implications of heavy metal exposure to humans through fish consumption to raise public awareness and attract the attention of relevant authorities.

Therefore, this study aims to conduct a comprehensive review of the accumulation of different heavy metals in a variety of naturally grown native fish from various water bodies in Bangladesh. The authors primarily intend to compile and analyze data on the concentration of heavy metal accumulation reported in naturally grown native fish varieties of Bangladesh to identify the heavy metals, along with their levels and patterns of contamination. Additionally, the authors aim to evaluate the variation in heavy metal concentrations in naturally grown fish due to seasonal changes. They also aim to compare the concentrations of heavy metals with recommended levels set by various standard organizations, report their findings, and discuss their impact on human health in this review.

2. Materials and Methods

2.1. Research Design and Database Search Strategy

This is a comprehensive review of reported concentrations of heavy metals in naturally grown, native fish in Bangladesh. A comprehensive literature search was conducted following the proper guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). Relevant articles on the concentrations of heavy metals in a variety of naturally grown fish in Bangladesh were searched on various electronic databases, namely ScienceDirect, PubMed, and Google Scholar, using various mesh terms such as "heavy metal", "trace metals", "toxic metal", "bioaccumulation", Boolean operators AND", "naturally grown" "native fish", "freshwater fish", "wild fish" and "Bangladesh" to find published papers and reports associated with the subject of this study published between January 2010 to January 2020.

2.2. Inclusion Criteria

Original research articles that were written in the English language reporting the concentration of heavy metals in naturally grown native fish in Bangladesh were included in the present study. The research articles published between January 2010 and January 2020, and were available as full-text articles with the desired information, were considered to be fit for inclusion in this study. Following adherence to the inclusion criteria, reports containing the necessary information were incorporated into this study (**Figure 1**).

2.3. Exclusion Criteria

The study did not include review papers, conference proceedings, abstracts, duplicate publications, articles written and published in non-English languages, articles that were published with relevant information from countries other than Bangladesh, studies on farmed or imported fish species, or articles reporting the concentration of heavy metals in non-native fish or those cultured, or cultivated, or farmed in traps and closed water systems in Bangladesh (**Figure 1**).

2.4. Eligibility and Quality Assessment

The articles were downloaded, applying the inclusion and exclusion criteria, reviewed, and shortlisted for further analysis. Two independent reviewers from our research team initially screened the titles and abstracts for the relevance of articles retrieved from the databases to ensure transparency, reprehensibility of results, and rigor in reviewing evidence about heavy metal contamination in naturally grown Bangladeshi fish. Full texts of eligible studies were assessed against inclusion and exclusion criteria. Discrepancies were resolved through discussion or consultation with a third reviewer.

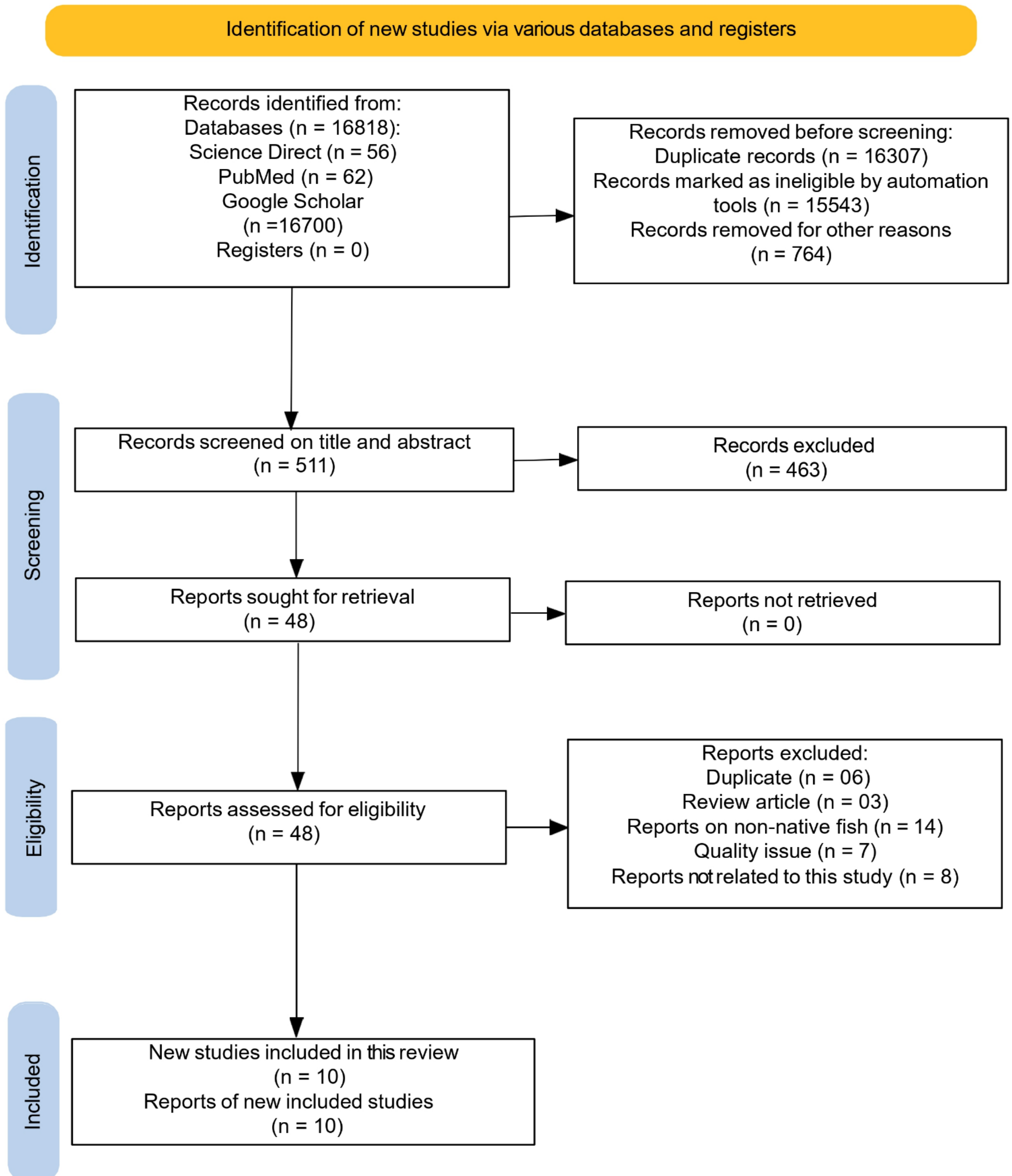


Figure 1. PRISMA flow diagram representing the process of literature searching, screening, and inclusion of reports in the study.

2.5. Records Screening and Data Extraction

The screening phases were conducted independently, and the decision was finalized by consensus through discussion. Rigorous checking was performed to ensure eligibility, and any differences in opinion were finalized through a consensual agreement from a senior author of the team. We excluded studies reporting the concentration of heavy metals in non-native and cultured or cultivated species in traps and closed water systems. Multiple publications from similar centers, facilities, author names, and periods of the outbreaks were cross-checked to avoid duplication and were excluded appropriately. Finally, 10 studies were included in this review. A PRISMA flow diagram of the literature screening and inclusion of the present study is shown in **Figure 1**. All shortlisted articles were carefully studied and reviewed further, and several findings about heavy metals and fish were extracted and presented in this review. The data were tabulated regarding the source of data, including local and scientific names of fish, so that readers can trace back the original work and data and also can recognize the fish easily. Concentration units were harmonized wherever applicable.

3. Results and Discussion

3.1. Scenarios of Heavy Metal Content in Various Naturally Grown Native Fish Studied in Bangladesh

The findings related to heavy metal accumulation in fish were extracted from reviewed papers and presented in **Tables 1-4** of this research report. Naturally grown native freshwater fish are organized in **Tables 1-3**, and those saltwater fish in **Table 4** based on their habitat and the depth of water where they roam and take food most of the time [15]-[21].

Based on various criteria cited in literature [1] [2], Ali & Khan (2018) stated in their article that 51 elements of the periodic table are to be recognized as heavy metals [2]. Among these, eight heavy metals, namely lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg), and nickel (Ni), are listed as the most widespread heavy metals in the environment [6]. The literature review indicated that among the eight aforementioned common heavy metals found in the environment, Ni and Hg in fish were hardly assessed (**Tables 1-4**). Instead, many researchers examined the content of Mn and Fe heavy metals in fish (**Tables 1-4**). Furthermore, some studies reported a maximum of six heavy metals in a small number of fish (**Tables 1-4**). All researchers evaluated the levels of Pb and Cr in naturally grown freshwater native fish (**Tables 1-3**), while the content of Pb, Cd, and Cr in saltwater or sea fish (**Table 4**). Based on this review, it can be concluded that the status of eight heavy metals, namely lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), iron (Fe), and manganese (Mn) in 22 naturally grown native freshwater fish varieties (**Tables 1-3**) and 11 types of saltwater or sea fish in Bangladesh were studied and reported (**Table 4**) in the reviewed literature. The total number of fish types assessed was found to be 33; however, for certain heavy metals (e.g., Pb), the total number of fish samples evaluated was found as 46. The variation in the total number of fish was because multiple scientists assessed the same type of fish (**Tables 1-4**). The concentration of heavy metals varied greatly among the different types of fish. For example, the concentration of Pb was 63.63 mg/kg in Shingi fish, whereas it was only 0.018 mg/kg in Tank goby or Bele-1 fish **Table 5(A) & (last column)**. Similar wide variation in heavy metal content was noted across the reports for the same fish, too. For example, Khanom *et al.* (2020) reported the concentration of Cu in Chapila fish as 12.63 mg/kg, while Samad *et al.* (2015) reported it as only 0.13 (**Table 1**) [22] [23]. These differences could be due to various factors, including the level of heavy metal contamination in the water bodies where the fish live and the process by which each fish absorbs heavy metals from its environment [24].

Table 1. Heavy metal content in naturally grown freshwater surface-feeder fish in Bangladesh.

Fish Name		Concentration of heavy metals (mean ± SD) in fish (mg/kg)								References
Local name	Scientific name	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
1. Chapila	*Gudusia chapra*	-	0.375 ± 0.156	0.031 ± 0.026	0.645 ± 0.149	12.632 ± 2.939	-	14.367 ± 3.851	1.391 ± 1.232	[22]
		-	0.027 ± 0.013	-	0.022 ± 0.008	0.133 ± 0.037	2.34 ± 0.67	1.162 ± 0.173	0.178 ± 0.035	[23]
		1.73 (1.5 - 1.83)	0.82 (0.6 - 1.0)	0.11 (0.09 - 0.13)	0.84 (0.7 - 0.97)	-	-	-	-	[25]
2. Puti	*Puntius puntio*	0.059 ± 0.001	0.164 ± 0.051	0.002 ± 0.000	0.112 ± 0.024	-	-	-	-	[26]
3. Kachki	*Corica soborna*	0.37	0.58	0.20	0.44	-	-	-	-	[27]
4. Tank goby/Bele	*Glossogobius giuris*	-	0.018 ± 0.015	-	0.017 ± 0.009	0.124 ± 0.045	3.02 ± 0.70	0.713 ± 0.134	0.20 ± 0.057	[23]
		-	9.91	0.87	6.42	5.03	-	-	-	[28]
		-	0.06	0.002	0.38	0.62	-	-	-	[29]
5. Kholisha	*Colisa fasciata*	0.18	0.52	0.019	0.70	-	-	-	-	[27]
6. Trout barb	*Barilius bola*	-	0.09 ± 0.016	-	0.012 ± 0.008	0.102 ± 0.066	1.68 ± 0.36	0.690 ± 0.034	0.123 ± 0.047	[23]
7. Phasa	*Setipinna phasa*	1.9 (1.8 - 1.94)	0.95 (0.9 - 0.99)	0.22 (0.05 - 0.3)	0.85 (0.7 - 0.89)	-	-	-	-	[25]

-: Not analyzed.

Table 2. Heavy metal content in naturally grown freshwater mid-feeder fish in Bangladesh.

Fish name		Content of heavy metals (mean ± SD) in fish (mg/kg)								References
Local name	Scientific name	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
1. Rui	*Labeo rohita*	*BDL	BDL	BDL	BDL	26.60	-	-	-	[30]
2. Boal	*Wallago attu*	BDL	3.28	1.00	BDL	BDL	-	-	-	[30]
3. Tengra	*Mystus vittatus*	0.022 ± 0.004	0.218 ± 0.068	0.011 ± 0.002	0.102 ± 0.016	-	-	-	-	[26]

*BDL: Below Detection Level, -: not analyzed.

Table 3. Heavy metal content in naturally grown freshwater mixed-feeder (*i.e.*, Surface or mid & bottom-feeder) fish in Bangladesh.

Fish name		Content of heavy metals in fish (Mean ± SD) in (mg/kg)								References
Local name	Scientific name	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
1. Chewa	*Apocryptes bato*	4.65 ± 1.06	15.22 ± 1.32	0.60 ± 0.13	3.54 ± 0.54	15.29 ± 3.82	-	-	-	[31]
2. Shingi	*Heteropneustes fossilis*	BDL	63.63	6.22	4.52	BDL	-	-	-	[20]
		0.27	0.92	0.016	0.97	-	-	-	-	[27]
3. Shing	*Amblyceps mangois*	0.031 ± 0.005	0.178 ± 0.055	0.061 ± 0.010	0.076 ± 0.016	-	-	-	-	[26]
4. Lesser spiny eel	*Macrognathus aculeatus*	-	0.036 ± 0.014	-	0.022 ± 0.010	0.126 ± 0.033	1.76 ± 0.43	0.796 ± 0.230	0.341 ± 0.107	[23]
5. Baim	*Mastacembelus armatus*	0.780	0.92	0.05	0.26	-	-	-	-	[32]
		0.018 ± 0.003	0.092 ± 0.029	0.006 ± 0.001	0.107 ± 0.033	-	-	-	-	[26]
6. Bacha	*Eutropiichthys vacha*	-	0.193 ± 0.073	0.014 ± 0.008	0.525 ± 0.228	11.180 ± 1.684	-	11.892 ± 1.039	1.688 ± 1.266	[22]
7. Koi	*Cyprinus carpio*	0.25	0.81	0.025	0.78	-	-	-	-	[27]
8. Shoil	*Channa striata*	0.25	0.78	0.020	0.69	-	-	-	-	[27]
9. Foli	*Notopterus notopterus*	0.24	0.82	0.022	1.1	-	-	-	-	[27]
10. Shrimp	*Peneaus monodon*	-	0.033 ± 0.019	-	0.024 ± 0.020	1.054 ± 0.182	2.05 ± 0.82	1.023 ± 0.211	0.318 ± 0.074	[23]
		-	0.13	0.05	0.53	11.59	-	-	-	[33]

Continued

		-	9.11	0.88	5.66	5.31	-	-	-	[28]
		-	0.03	0.006	0.25	0.44	-	-	-	[29]
11. Taki	*Channa punctatus*	-	0.024 ± 0.009	-	0.016 ± 0.017	0.134 ± 0.056	2.65 ± 0.54	0.743 ± 0.245	0.174 ± 0.066	[23]
		0.013 ± 0.002	0.130 ± 0.040	0.011 ± 0.002	0.028 ± 0.006	-	-	-	-	[26]
12. Taposi	*Polynemus paradiseus*	2.16 (1.9 - 2.33)	1.52 (1.4 - 1.66)	0.86 (0.81 - 0.91)	0.98 (0.85 - 123)	-	-	-	-	[25]

*BDL: Below Detection Level, -: not analyzed.

Table 4. Heavy metal content of saltwater or sea fish (Estuarine and Tidal River, and the Sea) in Bangladesh.

Fish name		Content of heavy metals in fish (Mean ± SD) in (mg/kg)								References
Local	**Scientific**	**As**	**Pb**	**Cd**	**Cr**	**Cu**	**Fe**	**Zn**	**Mn**	
				Only surface-feeder fish						
1. Ek Thuitta	*Hyporhamphus limbatus*	5.14 ± 0.86	13.77 ± 1.54	0.35 ± 0.08	3.52 ± 0.48	12.52 ± 1.40	-	-	-	[31]
				Only bottom-feeder fish						
1. Bagda	*Penaeus monodon*	*NA	0.46	0.05	0.15	-	-	-	-	*[34]*
2. Chingri	*Metapenaeus spinulatus*	0.118 ± 0.020	0.261 ± 0.089	0.005 ± 0.001	0.102 ± 0.021	-	-	-	-	[26]
3. Bata	*Liza parsia*	4.36 ± 0.93	13.98 ± 1.93	0.34 ± 0.09	3.30 ± 0.40	9.50 ± 1.16	-	-	-	[31]
		-	0.17	0.04	0.38	0.78	-	-	-	[33]
				Mixed-feeder (surface & bottom feeder)						
1. Rup Chanda	*Pampus chinensis*	5.03 ± 0.86	14 ± 1.79	0.44 ± 0.14	3.59 ± 0.55	13.9 ± 2.49	-	-	-	[31]
		1.2 (0.9 - 1.32)	0.95 (0.8 - 1.03)	0.69 (0.53 - 0.8)	0.81 (0.7 - 0.85)	-	-	-	-	[25]
2. Flathe-ad bata	*Mugil cephalus*	4.89 ± 0.48	12.70 ± 1.72	0.31 ± 0.09	3.14 ± 0.36	11.48 ± 1.27	-	-	-	[31]
3. Chand-ana Ilish	*Tenualosa toil*	5.26 ± 0.49	13.61 ± 0.82	0.31 ± 0.07	3.11 ± 0.54	10.72 ± 1.47	-	-	-	[31]
4. Hilsha	*Tenualosa ilisha*	0.51	0.49	0.17	0.48	-	-	-	-	[27]
		1.22 (1.2 - 1.24)	0.67 (0.6 - 0.7)	0.15 (0.14 - 0.17)	0.65 (0.6 - 0.67)	-	-	-	-	[25]

Continued

5. Poa	*Otolithoides pama*	1.75 (1.6 - 1.85)	1.67 (1.66 - 1.84)	0.41 (0.3 - 0.49)	0.85 (0.7 - 0.97)	-	-	-	-	[35]
6. Loitta	*Harpadon nehereus*	2.1 (1.9 - 2.23)	2.0 (1.9 - 2.08)	0.44 (0.39 - 0.48)	1.02 (0.9 - 1.15)	-	-	-	-	[25]
7. Tular danti	*Sillaginopsis panijus*	2.13 (1.9 - 2.33)	2.64 (2.5 - 2.78)	1.11 (0.94 - 1.53)	1.19 (1.1 - 1.33)	-	-	-	-	[25]

*NA or -: Not Analyzed.

3.2. Potential Factors Influencing Heavy Metal Bioaccumulation and Their Implications

The bioaccumulation of heavy metals in fish is influenced by several confounding factors, such as the life span of fish, fishes' body size (*i.e.*, length and weight), adaptation ability to metals load, feeding habits and habitats preferences, growth dilution factor, and the physical and chemical characteristics of aquatic environment necessitating careful consideration in risk assessments. Age and size demonstrate complex relationships with metal concentrations in fish. Generally, older fish tend to exhibit higher levels of metal accumulation. However, certain fast-growing species may experience growth dilution effects [36]-[40]. Larger fish often accumulate higher levels of heavy metals, while smaller fish exhibit little metal deposition due to their reduced body size, which limits metal uptake through surface interactions. The dietary habits of fish play a crucial role in metal uptake, with carnivorous species frequently demonstrating elevated levels of mercury accumulation due to biomagnification, whereas herbivorous species tend to accumulate higher levels of cadmium from sediments [41]-[44].

Humans are frequently exposed to several metals during their lifetimes, and the health consequences of multiple heavy metal exposures may be synergistic, additive, antagonistic, or manifest additional consequences [45]-[47]. The combined effects of various heavy metals can greatly enhance their toxicity relative to exposure to each metal individually. This phenomenon transpires when the cumulative impact of many metals surpasses their individual implications, resulting in intensified health and ecological repercussions. Studies indicate that even minimal concentrations of many metals can have unforeseen synergistic effects, thereby resulting in detrimental outcomes at levels previously deemed safe for particular metals [48] [49]. In another case, the dose-response relationships for heavy metal combinations are frequently complicated and nonlinear, compromising the prediction of outcomes based on single-metal toxicity data. Variables including metal divergence, bioavailability, and interactions with the biological networks might affect these connections [50]-[52]. Comprehending these synergistic interactions and their dose-response relationships is essential for precise risk evaluations and the formulation of suitable regulatory standards for heavy metal exposure in diverse environmental and occupational domains.

3.3. The Influence of Fish Habitats on the Heavy Metal Content in Naturally Grown Native Fish in Bangladesh

The concentration of heavy metals in naturally occurring native fish in Bangladesh was highly variable (Tables 1-4). The authors wanted to determine whether there is a correlation between the fish habitats and the concentration of heavy metals in naturally occurring native fish. When the authors examined Tables 1-4, they noticed that the influence of fish habitat on the heavy metal content in fish was not remarkable/pronounced (Tables 1-4). However, it can be said that bottom-feeder fish accumulate more heavy metals than other types of feeders.

3.4. Extent and Trends of Heavy Metals in Naturally Grown Native Fish in Bangladesh

To compare and gain insight into the results compiled in Tables 1-4, the authors harmonized and organized the accumulated heavy metals in fish in a certain order (high to low) and tabulated them in Tables 5(A)-(D). The data for various heavy metals in Tables 5(A)-(D) have been analyzed, and the summarized results have been recorded for each heavy metal in the bottom part of Tables 5(A)-(D).

Table 5. (A) Harmonized and ordered data of heavy metals (As & Pb) observed in naturally grown native fish in Bangladesh; (B) Harmonized and ordered data of heavy metals (Cd & Cr) observed in naturally grown native fish in Bangladesh; (C) Harmonized and ordered data of heavy metals (Cu & Fe) observed in naturally grown native fish in Bangladesh; (D) Harmonized and ordered data of heavy metals (Zn & Mn) observed in naturally grown native fish in Bangladesh.

(A)

Local name	Scientific name	As (mg/kg)	Local name	Scientific name	Pb (mg/kg)
Shingi-1	*Heteropneustes fossilis*	BDL	Rui	*Labeo rohita*	BDL
Boal	*Wallago attu*	BDL	Shingi-1	*Heteropneustes fossilis*	63.63
Bagda	*Penaeus monodon*	*NA	Chewa	*Apocryptes bato*	15.22
Rui	*Labeo rohita*	*BDL	Rup Chanda	*Pampus chinensis*	14
Tank goby /Bele-2	*Glossogobius giuris*	-	Bata	*Liza parsia*	13.98
Taki-1	*Channa punctatus*	-	Ek Thuitta	*Hyporhamphus limbatus*	13.77
Chapila-1	*Gudusia chapra*	-	Chandana Ilish	*Tenualosa toil*	13.61
Bacha	*Eutropiich thysvacha*	-	Flathead bata	*Mugil cephalus*	12.7
Bata	*Liza parsia*	-	Tank goby/Bele-2	*Glossogobius giuris*	9.91
Shrimp-2	*Peneaus monodon*	-	Taki-1	*Channa punctatus*	9.11
Trout barb	*Barilius bola*	-	Boal	*Wallago attu*	3.28
Tank goby /Bele-3	*Glossogobius giuris*	-	Tular danti	*Sillaginopsis panijus*	2.64
Lesser spiny eel	*Macrognathus acule*	-	Loitta	*Harpadon nehereus*	2
Shrimp-1	*Peneaus monodon*	-	Poa	*Otolithoides pama*	1.67
Taki-2	*Channa punctatus*	-	Taposi	*Polynemus paradiseus*	1.52

Continued

Chapila-2	*Gudusia chapra*	-	Rup Chanda	*Pampus chinensis*	0.95
Taki-3	*Channa punctatus*	-	Phasa	*Setipinna phasa*	0.95
Tank goby/Bele-1	*Glossogobius giuris*	-	Shingi-2	*Heteropneustes fossilis*	0.92
Chandana Ilish	*Tenualosa toil*	5.26	Baim	*Mastacembelus armatus*	0.92
Ek Thuitta	*Hyporhamphus limbatus*	5.14	Chapila-3	*Gudusia chapra*	0.82
Rup Chanda	*Pampus chinensis*	5.03	Foli	*Notopterus notopterus*	0.82
Flathead bata	*Mugil cephalus*	4.89	Koi	*Cyprinus carpio*	0.81
Chewa	*Apocryptes bato*	4.65	Shoil	*Channa striata*	0.78
Bata	*Liza parsia*	4.36	Hilsha	*Tenualosa ilisha*	0.67
Taposi	*Polynemus paradiseus*	2.16	Kachki	*Corica soborna*	0.58
Tular danti	*Sillaginopsis panijus*	2.13	Kholisha	*Colisa fasciata*	0.52
Loitta	*Harpadon nehereus*	2.1	Hilsha	*Tenualosa ilisha*	0.49
Phasa	*Setipinna phasa*	1.9	Bagda	*Penaeus monodon*	0.46
Poa	*Otolithoides pama*	1.75	Chapila-1	*Gudusia chapra*	0.375
Chapila-3	*Gudusia chapra*	1.73	Chingri	*Metapenaeus spinulatus*	0.261
Hilsha	*Tenualosa ilisha*	1.22	Tengra	*Mystus vittatus*	0.218
Rup Chanda	*Pampus chinensis*	1.2	Bacha	*Eutropiich thysvacha*	0.193
Baim	*Mastacembelus armatus*	0.78	Shing	*Amblyceps mangois*	0.178
Hilsha	*Tenualosa ilisha*	0.51	Bata	*Liza parsia*	0.17
Kachki	*Corica soborna*	0.37	Puti	*Puntius puntio*	0.164
Shingi-2	*Heteropneustes fossilis*	0.27	Shrimp-2	*Peneaus monodon*	0.13
Koi	*Cyprinus carpio*	0.25	Taki-4	*Channa punctatus*	0.13
Shoil	*Channa striata*	0.25	Baim	*Mastacembelus armatus*	0.092
Foli	*Notopterus notopterus*	0.24	Trout barb	*Barilius bola*	0.09
Kholisha	*Colisa fasciata*	0.18	Tank goby/Bele-3	*Glossogobius giuris*	0.06
Chingri	*Metapenaeus spinulatus*	0.118	Lesser spiny eel	*Macrognathus aculeatus*	0.036
Puti	*Puntius puntio*	0.059	Shrimp-1	*Peneaus monodon*	0.033
Shing	*Amblyceps mangois*	0.031	Taki-2	*Channa punctatus*	0.03
Tengra	*Mystus vittatus*	0.022	Chapila-2	*Gudusia chapra*	0.027
Baim	*Mastacembelus armatus*	0.018	Taki-3	*Channa punctatus*	0.024
Taki-4	*Channa punctatus*	0.013	Tank goby/Bele-1	*Glossogobius giuris*	0.018
Summarized results:					
Arsenic was detected in fish (%).	Fish (%) that exceeded the safe limit of Arsenic (5 mg/kg).	Median value of Arsenic (mg/kg).	Lead was detected in fish (%).	Fish (%) that exceeded the safe limit of Lead (0.3 mg/kg).	Median value of Lead (mg/kg).
90.32	9.68	0.99	97.81	63.04	0.67

Continued

(B)

Local name	Scientific name	Cd (mg/kg)	Local name	Scientific name	Cr (mg/kg)
Rui	*Labeo rohita*	BDT	Rui	*Labeo rohita*	BDL
Chapila-2	*Gudusia chapra*	-	Boal	*Wallago attu*	BDL
Tank goby/Bele-1	*Glossogobius giuris*	-	Tank goby/Bele-2	*Glossogobius giuris*	6.42
Trout barb	*Barilius bola*	-	Taki-1	*Channa punctatus*	5.66
Lesser spiny eel	*Macrognathus aculeatus*	-	Shingi-1	*Heteropneustes fossilis*	4.52
Taki-3	*Channa punctatus*	-	Rup Chanda-1	*Pampus chinensis*	3.59
Shrimp-1	*Peneaus monodon*	-	Chewa	*Apocryptes bato*	3.54
Shingi-1	*Heteropneustes fossilis*	6.22	Ek Thuitta	*Hyporhamphus limbatus*	3.52
Tular danti	*Sillaginopsis panijus*	1.11	Bata-1	*Liza parsia*	3.3
Boal	*Wallago attu*	1	Flathe-ad bata	*Mugil cephalus*	3.14
Taki-1	*Channa punctatus*	0.88	Chand-ana Ilish	*Tenualosa toil*	3.11
Tank goby/Bele-2	*Glossogobius giuris*	0.87	Tular danti	*Sillaginopsis panijus*	1.19
Taposi	*Polynemus paradiseus*	0.86	Foli	*Notopterus notopterus*	1.1
Rup Chanda-2	*Pampus chinensis*	0.69	Loitta	*Harpadon nehereus*	1.02
Chewa	*Apocryptes bato*	0.6	Taposi	*Polynemus paradiseus*	0.98
Rup Chanda-1	*Pampus chinensis*	0.44	Shingi-2	*Heteropneustes fossilis*	0.97
Loitta	*Harpadon nehereus*	0.44	Phasa	*Setipinna phasa*	0.85
Poa	*Otolithoides pama*	0.41	Poa	*Otolithoides pama*	0.85
Ek Thuitta	*Hyporhamphus limbatus*	0.35	Chapila-3	*Gudusia chapra*	0.84
Bata-1	*Liza parsia*	0.34	Rup Chanda-2	*Pampus chinensis*	0.81
Flathe-ad bata	*Mugil cephalus*	0.31	Koi	*Cyprinus carpio*	0.78
Chandana Ilish	*Tenualosa toil*	0.31	Kholisha	*Colisa fasciata*	0.7
Phasa	*Setipinna phasa*	0.22	Shoil	*Channa striata*	0.69
Kachki	*Corica soborna*	0.2	Hilsha-2	*Tenualosa ilisha*	0.65
Hilsha-1	*Tenualosa ilisha*	0.17	Chapila-1	*Gudusia chapra*	0.65
Hilsha-2	*Tenualosa ilisha*	0.15	Shrimp-2	*Peneaus monodon*	0.53
Chapila-3	*Gudusia chapra*	0.11	Bacha	*Eutropiich thysvacha*	0.525
Shing	*Amblyceps mangois*	0.061	Hilsha-1	*Tenualosa ilisha*	0.48
Baim-1	*Mastacembelus armatus*	0.05	Kachki	*Corica soborna*	0.44
Shrimp-2	*Peneaus monodon-2*	0.05	Tank goby/Bele-3	*Glossogobius giuris*	0.38
Bagda	*Penaeus monodon*	0.05	Bata-2	*Liza parsia*	0.38
Bata-2	*Liza parsia-2*	0.04	Baim-1	*Mastacembelus armatus*	0.26
Chapila-1	*Gudusia chapra-1*	0.031	Taki-2	*Channa punctatus*	0.25

Continued

Koi	*Cyprinus carpio*	0.025	Bagda	*Penaeus-monodon*	0.15
Foli	*Notopterus notopterus*	0.022	Puti	*Puntius puntio*	0.112
Shoil	*Channa striata*	0.02	Baim-2	*Mastacembelus armatus*	0.107
Kholisha	*Colisa fasciata*	0.019	Tengra	*Mystus vittatus*	0.102
Shingi-2	*Heteropneustes fossilis*	0.016	Chingri	*Metapenaeus spinulatus*	0.102
Bacha	*Eutropiich thysvacha*	0.014	Shing	*Amblyceps mangois*	0.076
Tengra	*Mystus vittatus*	0.011	Taki-4	*Channa punctatus*	0.028
Taki-4	*Channa punctatus*	0.011	Shrimp-1	*Peneaus monodon*	0.024
Baim-2	*Mastacembelus armatus*	0.006	Chapila-2	*Gudusia chapra*	0.022
Taki-2	*Channa punctatus*	0.006	Lesser spiny eel	*Macrognathus aculeatus*	0.022
Chingri	*Metapenaeus spinulatus*	0.005	Tank goby/Bele-1	*Glossogobius giuris*	0.017
Puti	*Puntius puntio*	0.002	Taki-3	*Channa punctatus*	0.016
Tank goby/Bele-3	*Glossogobius giuris*	0.002	Trout barb	*Barilius bola*	0.012

Summarized results:

Cadmium was detected in fish (%).	Fish (%) that exceeded the safe limit of Cadmium (0.25 mg/kg).	Median value of Cadmium (mg/kg).	Chromium was detected in fish (%).	Fish (%) that exceeded the safe limit of Chromium (13 mg/kg).	Median value of Chromium (mg/kg).
97.5	37.5	0.11	95.65	0	0.65

(C)

Local name	Scientific name	Cu (mg/kg)	Local name	Scientific name	Fe (mg/kg)
Boal	*Wallago attu*	BDL	Chapila-1	*Gudusia chapra*	-
Shingi-1	*Heteropneustes fossilis*	BDL	Chapila-3	*Gudusia chapra*	-
Chapila-3	*Gudusia chapra*	-	Puti	*Puntius puntio*	-
Puti	*Puntius puntio*	-	Kachki	*Corica soborna*	-
Kachki	*Corica soborna*	-	Tank goby/Bele-2	*Glossogobius giuris*	-
Kholisha	*Colisa fasciata*	-	Tank goby/Bele-3	*Glossogobius giuris*	-
Phasa	*Setipinna phasa*	-	Kholisha	*Colisa fasciata*	-
Tengra	*Mystus vittatus*	-	Phasa	*Setipinna phasa*	-
Shingi-2	*Heteropneustes fossilis*	-	Rui	*Labeo rohita*	-
Shing	*Amblyceps mangois*	-	Boal	*Wallago attu*	-
Baim-1	*Mastacembelus armatus*	-	Tengra	*Mystus vittatus*	-
Baim-2	*Mastacembelus armatus*	-	Chewa	*Apocryptes bato*	-
Koi	*Cyprinus carpio*	-	Shingi-1	*Heteropneustes fossilis*	-
Shoil	*Channa striata*	-	Shingi-2	*Heteropneustes fossilis*	-
Foli	*Notopterus notopterus*	-	Shing	*Amblyceps mangois*	-

Continued

Taki-4	*Channa punctatus*	-	Baim-1	*Mastacembelus armatus*	-
Taposi	*Polynemus paradiseus*	-	Baim-2	*Mastacembelus armatus*	-
Bagda	*Penaeus monodon*	-	Bacha	*Eutropiich thysvacha*	-
Chingri	*Metapenaeus spinulatus*	-	Koi	*Cyprinus carpio*	-
Rup Chanda-2	*Pampus chinensis*	-	Shoil	*Channa striata*	-
Hilsha-1	*Tenualosa ilisha*	-	Foli	*Notopterus notopterus*	-
Hilsha-2	*Tenualosa ilisha*	-	Shrimp-2	*Peneaus monodon*	-
Poa	*Otolithoides pama*	-	Taki-1	*Channa punctatus*	-
Loitta	*Harpadon nehereus*	-	Taki-2	*Channa punctatus*	-
Tular danti	*Sillaginopsis panijus*	-	Taki-4	*Channa punctatus*	-
Rui	*Labeo rohita*	26.6	Taposi	*Polynemus paradiseus*	-
Chewa	*Apocryptes bato*	15.29	Ek Thuitta	*Hyporhamphus limbatus*	-
Rup Chanda-1	*Pampus chinensis*	13.1	Bagda	*Penaeus-monodon*	-
Chapila-1	*Gudusia chapra*	12.632	Chingri	*Metapenaeus spinulatus*	-
Ek Thuitta	*Hyporhamphus limbatus*	12.52	Bata-1	*Liza parsia*	-
Shrimp-2	*Peneaus monodon*	11.59	Bata-2	*Liza parsia*	-
Flathe-ad bata	*Mugil cephalus*	11.48	Rup Chanda-1	*Pampus chinensis*	-
Bacha	*Eutropiich thysvacha*	11.18	Rup Chanda-2	*Pampus chinensis*	-
Chand-ana Ilish	*Tenualosa toil*	10.72	Flathe-ad bata	*Mugil cephalus*	-
Bata-1	*Liza parsia*	9.5	Chand-ana Ilish	*Tenualosa toil*	-
Taki-1	*Channa punctatus*	5.31	Hilsha-1	*Tenualosa ilisha*	-
Tank goby/Bele-2	*Glossogobius giuris*	5.03	Hilsha-2	*Tenualosa ilisha*	-
Shrimp-1	*Peneaus monodon*	1.054	Poa	*Otolithoides pama*	-
Bata-2	*Liza parsia*	0.78	Loitta	*Harpadon nehereus*	-
Tank goby/Bele-3	*Glossogobius giuris*	0.62	Tular danti	*Sillaginopsis panijus*	-
Taki-2	*Channa punctatus*	0.44	Tank goby/Bele-1	*Glossogobius giuris*	3.02
Taki-3	*Channa punctatus*	0.134	Taki-3	*Channa punctatus*	2.6
Chapila-2	*Gudusia chapra*	0.133	Chapila-2	*Gudusia chapra*	2.34
Lesser spiny eel	*Macrognathus aculeatus*	0.126	Shrimp-1	*Peneaus monodon*	2.05
Tank goby/Bele-1	*Glossogobius giuris*	0.124	Lesser spiny eel	*Macrognathus aculeatus*	1.76
Trout barb	*Barilius bola*	0.102	Trout barb	*Barilius bola*	1.68

Summarized results:

Copper was detected in fish (%).	Fish (%) that exceeded the safe limit of Copper (5 mg/kg).	Median value of Copper (mg/kg).	Iron was detected in fish (%).	Fish (%) that exceeded the safe limit of Iron (100 mg/kg).	Median value of Iron (mg/kg).
91.3	52.17	5.31	100	0	2.12

Continued

(D)					
Local name	**Scientific name**	**Zn (mg/kg)**	**Local name**	**Scientific name**	**Mn (mg/kg)**
Chapila-3	*Gudusia chapra*	-	Chapila-3	*Gudusia chapra*	-
Puti	*Puntius puntio*	-	Puti	*Puntius puntio*	-
Kachki	*Corica soborna*	-	Kachki	*Corica soborna*	-
Tank goby/Bele-2	*Glossogobius giuris*	-	Tank goby/ Bele-2	*Glossogobius giuris*	-
Tank goby/Bele-3	*Glossogobius giuris*	-	Tank goby/ Bele-3	*Glossogobius giuris*	-
Kholisha	*Colisa fasciata*	-	Kholisha	*Colisa fasciata*	-
Phasa	*Setipinna phasa*	-	Phasa	*Setipinna phasa*	-
Rui	*Labeo rohita*	-	Rui	*Labeo rohita*	-
Boal	*Wallago attu*	-	Boal	*Wallago attu*	-
Tengra	*Mystus vittatus*	-	Shingi-1	*Heteropneustes fossilis*	-
Chewa	*Apocryptes bato*	-	Shingi-2	*Heteropneustes fossilis*	-
Shingi-1	*Heteropneustes fossilis*	-	Shing	*Amblyceps mangois*	-
Shingi-2	*Heteropneustes fossilis*	-	Baim-1	*Mastacembelus armatus*	-
Shing	*Amblyceps mangois*	-	Baim-2	*Mastacembelus armatus*	-
Baim-1	*Mastacembelus armatus*	-	Koi	*Cyprinus carpio*	-
Baim-2	*Mastacembelus armatus*	-	Shoil	*Channa striata*	-
Koi	*Cyprinus carpio*	-	Foli	*Notopterus notopterus*	-
Shoil	*Channa striata*	-	Shrimp-2	*Peneaus monodon*	-
Foli	*Notopterus notopterus*	-	Taki-1	*Channa punctatus*	-
Shrimp-2	*Peneaus monodon*	-	Taki-2	*Channa punctatus*	-
Taki-1	*Channa punctatus*	-	Taki-4	*Channa punctatus*	-
Taki-2	*Channa punctatus*	-	Taposi	*Polynemus paradiseus*	-
Taki-4	*Channa punctatus*	-	Ek Thuitta	*Hyporhamphus limbatus*	-
Taposi	*Polynemus paradiseus*	-	Bagda	*Penaeus-monodon*	-
Ek Thuitta	*Hyporhamphus limbatus*	-	Chingri	*Metapenaeus spinulatus*	-
Bagda	*Penaeus-monodon*	-	Bata-1	*Liza parsia*	-
Chingri	*Metapenaeus spinulatus*	-	Bata-2	*Liza parsia*	-
Bata-1	*Liza parsia*	-	Rup Chanda-1	*Pampus chinensis*	-
Bata-2	*Liza parsia*	-	Rup Chanda-2	*Pampus chinensis*	-
Rup Chanda-1	*Pampus chinensis*	-	Flathe-ad bata	*Mugil cephalus*	-
Rup Chanda-2	*Pampus chinensis*	-	Chand-ana Ilish	*Tenualosa toil*	-
Flathe-ad bata	*Mugil cephalus*	-	Hilsha-1	*Tenualosa ilisha*	-
Chandana Ilish	*Tenualosa toil*	-	Hilsha-2	*Tenualosa ilisha*	-

Continued

Hilsha-1	*Tenualosa ilisha*	-	Poa	*Otolithoides pama*	-
Hilsha-2	*Tenualosa ilisha*	-	Loitta	*Harpadon nehereus*	-
Poa	*Otolithoides pama*	-	Tular danti	*Sillaginopsis panijus*	-
Loitta	*Harpadon nehereus*	-	Tengra	*Mystus vittatus*	-
Tular danti	*Sillaginopsis panijus*	-	Chewa	*Apocryptes bato*	-
Chapila-1	*Gudusia chapra*	14.367	Bacha	*Eutropiich thysvacha*	1.688
Bacha	*Eutropiich thysvacha*	11.892	Chapila-1	*Gudusia chapra*	1.391
Chapila-2	*Gudusia chapra*	1.162	Lesser spiny eel	*Macrognathus aculeatus*	0.341
Shrimp-1	*Peneaus monodon*	1.023	Shrimp-1	*Peneaus monodon*	0.318
Lesser spiny eel	*Macrognathus aculeatus*	0.796	Tank goby/Bele-1	*Glossogobius giuris*	0.2
Taki-3	*Channa punctatus*	0.743	Chapila-2	*Gudusia chapra*	0.178
Tank goby/Bele-1	*Glossogobius giuris*	0.713	Taki-3	*Channa punctatus*	0.174
Trout barb	*Barilius bola*	0.690	Trout barb	*Barilius bola*	0.123

Summarized results:

Zinc was detected in fish (%).	Fish (%) that exceeded the safe limit of Zinc (100 mg/kg).	Median value of Zinc (mg/kg).	Manganese was detected in fish (%).	Fish (%) that exceeded the safe limit of Manganese (1 mg/kg).	Median value of Manganese (mg/kg).
100	0	0.91	100	25	0.26

The following aspects are immediately apparent from Tables 5(A)-(D). Heavy metals were detected in over 90% of the reported fish samples. One can verify this fact by looking into the summarized results in the bottom part of Tables 5(A)-(D) (1st & 4th columns). Among all the observed fish and heavy metals, the Shingi fish contained the highest concentration of heavy metals, specifically Pb (63.63 mg/kg, Table 5(A) **& (last column**). While for Mn, the highest concentration was 1.69 mg/kg in Bacha fish Table 5(A) **& (last column**), which was the lowest among the highest concentrations of heavy metals in the various fish varieties Tables 5(A)-(D). In contrast, the Puti and Tank goby (or Bele) fish had the lowest concentration of heavy metals among all observed fish varieties, with only 0.002 mg/kg and the heavy metal was Cd Table 5(B) **& (3rd column**). Based on the review, among the heavy metals observed, Pb had the highest content (63.63 mg/kg), followed by Cu (26.6 mg/kg) in various fish Tables 5(A)-(D). The heavy metal content (mg/kg) in naturally grown native fish in Bangladesh, regardless of fish type reported Tables 5(A)-(D), followed this order:

$$\mathrm{Pb}(63.63) > \mathrm{Cu}(26.60) > \mathrm{Zn}(14.37) > \mathrm{Cr}(6.42) > \mathrm{Cd}(6.22) > \mathrm{As}(5.26) > \mathrm{Fe}(3.02) > \mathrm{Mn}(1.69) \quad (1)$$

As the content of heavy metals in fish was found to be highly variable, comparing the heavy metal content in fish in terms of the median value (mg/kg) is preferable. Based on the median values (summarized results of Tables 5(A)-(D)), the heavy metal content (mg/kg), regardless of the type of fish, decreased in the following order:

$$\mathrm{Cu}(5.31) > \mathrm{Fe}(2.20) > \mathrm{As}(0.99) > \mathrm{Zn}(0.91) > \mathrm{Pb}(0.67) > \mathrm{Cr}(0.65) > \mathrm{Mn}(0.26) > \mathrm{Cd}(0.11) \quad (2)$$

Both sequences are meaningful, depending on the perspective you are interested in. For instance, if one wants to determine the highest concentration of each heavy metal observed in naturally grown fish in Bangladesh, then the first sequence (Equation (1)) is useful. On the other hand, if one is interested in the typical trend of heavy metal concentrations in naturally grown fish in Bangladesh, then the second sequence (Equation (2)) is important.

In the recent advances in scientific research book, Shantosh *et al.* (2024) discussed the heavy metal concentration of small indigenous fishes of Manipur in India [53]. It was reported that the concentration of Cd was in the range of 0.036 mg/kg to 0.16 mg/kg, which showed the highest concentration in *P. pangia* (0.16 mg/kg), followed by *T. burmanicus* (0.14 mg/kg), and the lowest was found in *L. guntea* (0.009 mg/kg). The concentration of Pb was found only in *S. berdmorei* (0.07 mg/kg) and *T. burmanicus* (0.10 mg/kg), whereas other fishes were not detected [53].

The study of cadmium uptake and relationship to feeding habits of freshwater fish from the Ayeyarwady River, Mandalay, Myanmar by Myint Mar K (2020) has reported that in herbivorous fish species, Cd content ranged from 0.07 mg/kg (*Catla catla*) to 0.086 mg/kg (*Osteobrama belangeri*). In carnivorous fish species, Cd ranged from 0.060 mg/kg (*Mystus leucophasis*) to 0.083 mg/kg (*Wallago attu*). In omnivorous fish species, Cd ranged from 0.07 mg/kg (*Botia histrionica*) to 0.084 mg/kg (*Gudusia variegata*) [54].

In 2016, Munir *et al.* (2016) made a similar study on Toxic Metals Analysis in Zabi Dam Fishes Collected from District Karak, Khyber Pakhtunkhwa, Pakistan, and reported that Cu was in the range of 0.001 ± 0.013 mg/kg (*Cyprinus carpio*) to 0.104 ± 0.016 mg/kg (*Labeo rohita*). Fe content ranged from 1.630 ± 0.002 mg/kg (in the tail of *Cyprinus carpio*) to 20.82 ± 0.052 mg/kg (in the abdomen of Cyprinus carpio). Zn was found in the range of 2.425 ± 0.103 mg/kg (in the abdomen of Cyprinus carpio) to 4.965 ± 0.004 mg/kg (Golden fish). The highest and lowest concentration of Pb was found in *Cyprinus carpio* (26.28 ± 0.493 mg/kg) and *Labeo rohita* (4.746 ± 0.736 mg/kg), respectively. Cd was not detected in all fish studied [55].

It is challenging to compare the heavy metal content data of naturally grown fish from neighboring countries with that of Bangladesh. This difficulty arises mainly from the limited collection of heavy metal and fish sample data from those countries, as well as inconsistencies in the collected fish varieties. However, the comparison clearly indicates that the levels of heavy metals such as cadmium (Cd), copper (Cu), and zinc (Zn) in naturally grown fish from India, Myanmar, and Pakistan are in the lower range for each heavy metal when compared to those found in naturally grown fish from Bangladesh. The iron content is significantly higher in naturally grown fish from Pakistan (20.82 - 1.63 mg/kg) compared to that of Bangladesh (3.02 - 1.68 mg/kg, **Table 5(C) & (last column)**), while the lead content falls in a middle range (26.26 - 4.74 mg/kg) when compared to Bangladesh (63.63 - 0.018 mg/kg, **Table 5(D) & (3rd column)**).

3.5. The Highest Concentration of Heavy Metals in Naturally Grown Individual Native Fish in Bangladesh

It is straightforward to identify the highest and lowest concentrations of heavy metals in a specific fish. For example, in Bacha fish, the highest concentration of heavy metals is 11.89 mg/kg for Zn and the lowest concentration is 0.014 mg/kg for Cd (**Table 3**). The data in **Tables 1-4** were used to identify the highest concentration of heavy metals in a specific naturally grown native fish species in Bangladesh. The results are presented in **Table 6.**

Table 6. The highest concentration of heavy metals in a specific naturally grown native fish in Bangladesh.

Fish name		Highest content of heavy metals in fish (mean) in mg/kg								References
Local name	Scientific name	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
1. Shingi	*Heteropneustes fossilis*		63.63							[30]
2. Rui	*Labeo rohita*					26.60				[30]
3. Chewa	*Apocryptes bato*					15.29				[31]
4. Chapila	*Gudusia chapra*							14.37		[22]
5. Rup-chanda	*Pampus chinensis*		14.00							[31]
6. Bata	*Liza parsia*		13.98							[31]
7. Ek Thuitta	*Hyporhamphus limbatus*		13.77							[31]
8. Chandana Ilish	*Tenualosa toil*		13.61							[31]
9. Flathead bata	*Mugil cephalus*		12.70							[31]
10. Bacha	*Eutropiich thysvacha*							11.89		[22]
11. Shrimp	*Peneaus monodon*					11.59				[33]
12. Tank goby/Bele	*Glosso-gobius giuris*		9.91							[28]
13. Taki	*Channa punctatus*		9.11							[28]
14. Boal	*Wallago attu*		3.28							[30]
15. Foli	*Notopterus- notopterus*				1.1					[27]
16. Koi	*Cyprinus carpio*		0.81							[27]
17. Lesser spiny eel	*Macrognathus aculeatus*						1.76			[23]
18. Baim	*Mastacem belusar-matus*		0.92							[32]
19. Kholisha	*Colisa fasciata*				0.70					[27]
20. Shoil	*Channa striata*		0.78							[27]
21. Trout barb	*Barilius bola*						1.68			[23]
22. Kachki	*Corica soborna*		0.58							[27]
23. Bagda	*Penaeus-monodon*		0.46							[34]

Continued

24. Tengra	*Mystus vittatus*		0.22	[26]
25. Puti	*Puntius puntio*		0.16	[26]
26. Poa	*Otolithoides pama*	1.75		[25]
27. Hilsa	*Tenualosa ilisha*	1.22		[27]
28. Loitta	*Harpadon nehereus*	2.1		[25]
29. Tular danti	*Sillaginopsis panijus*		2.64	[25]
30. Chingri	*Metapenaeus spinulatus)*		0.26	[26]
31. Taposi	*Polynemus paradiseus*	2.16		[25]
32. Phasa	*Setipinna phasa*	1.9		[25]
33. Shing	*Amblyceps mangois*		0.18	[26]

When considering fish individually, out of all the fish (33 fish varieties) studied and reported by various researchers for heavy metals, the majority, *i.e.*, 19 fish samples or 57.58% of the fish samples, contained the highest levels of Pb (**Table 6**). In Bangladesh, the percentage of naturally grown native fish with the highest concentration of heavy metals in individual fish decreased in the following order (**Table 6**):

$$\text{Pb}(57.58\%) > \text{As}(15.15\%) > \text{Cu}(9.09\%) > \text{Cr} \approx \text{Fe} \approx \text{Zn}(6.06\%) > \text{Cd} \approx \text{Mn}(0\%) \quad (3)$$

Among the heavy metals found in fish, Pb can be released from a relatively higher number of sources, despite occurring in trace quantities on Earth [56]. The primary sources of environmentally harmful Pb are $Pb(C_2H_5)_4$, widely used as an additive material for vehicle fuel, and Pb-based home paint, until recently [57]-[59]. The release of Pb into drinking water due to pipeline corrosion has recently caused significant concerns worldwide [60]-[62]. As a result, most fish may contain high levels of lead (Equation (3) & Equation (1)).

3.6. Differences in Heavy Metal Content Between Freshwater and Saltwater Fish

Noman (2020) reported in the Bangladesh Post that "Salinity grips Karnaphuli" River [63]. Usually, the salinity of the Karnaphuli River water is low during the monsoon season, but in recent years, it has been high during both the monsoon and dry seasons. Some points of the Karnaphuli River have had a salinity level of nearly 5800 PPM, while the tolerable level of salinity in water for human consumption is 5 PPM [63]. This suggests that the water in the Karnaphuli River is now saline water, similar to that of the sea, rather than freshwater. The data presented in this review indicate that the content of all heavy metals was higher in the Karnaphuli River and sea or saltwater fish (**Table 4**) than in fish from other freshwater sources (**Tables 1-3**). Determining whether the difference in heavy metal content in fish is due to variations in water salinity is very difficult. The authors suggest that the issue may be caused by water pollution in the Karnaphuli River, which is surrounded by an industrial area. As a result, it receives large quantities of untreated effluents rich in various heavy metals and their contents from industries such as spinning mills, dyeing, cotton textiles, oil refineries, and others. The contamination from these industries is responsible for the high levels of heavy metals found in the river [25]. Fish in this river may have absorbed heavy metals from the contaminated water, resulting in a higher content of heavy metals observed in their bodies (Table 4).

3.7. The Impact of Seasonal Changes on Heavy Metals Accumulation in Naturally Grown Native Fish in Bangladesh

The authors of this review found that some researchers reported heavy metal content of As, Pb, Cd, and Cr in fish during different seasons, but they did not report Cu, Fe, Zn, and Mn. The collected data is presented in Table 7 below. The authors included the unreported heavy metals in Table 7 to maintain consistency with the other tables in this paper. Note that for a few fish (serial numbers 1 to 4), data were only available for the summer season and not for both seasons.

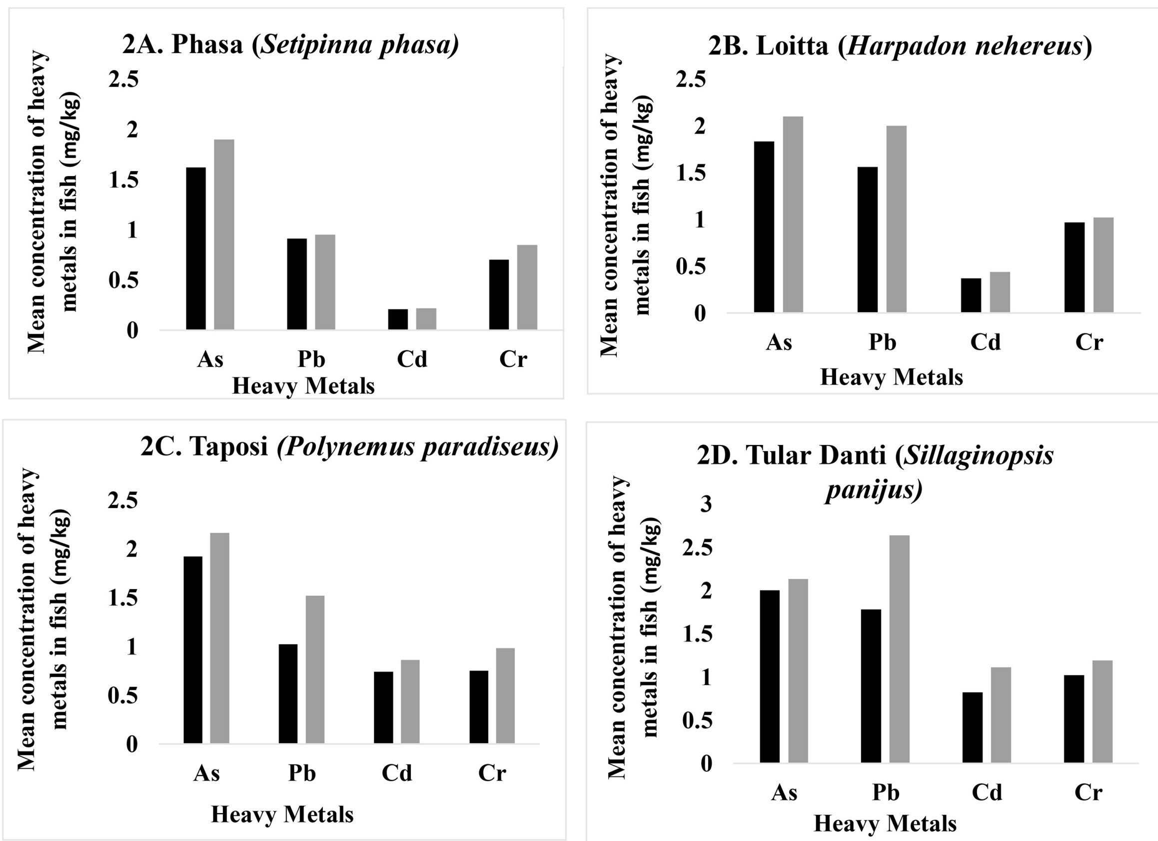
Table 7. Heavy metal content of naturally grown native fish by season in Bangladesh.

SL No. & Name of fish		Habitat	Seasons	Concentrations of heavy metals in fish (Mean ± SD) in mg/kg								References
Local	Scientific			As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
1. Taki	*Channa punctatus*	Freshwater surface and bottom feeders	**Summer** (average of various months)	0.013 ± 0.002	0.130 ± 0.040	0.011 ± 0.002	0.028 ± 0.006					[26]
2. Baim	*Mastacembelus armatus*	Freshwater bottom feeder	**Summer** (average of various Months)	0.018 ± 0.003	0.092 ± 0.029	0.006 ± 0.001	0.107 ± 0.033					[26]
3. Shing	*Amblyceps mangois*	Freshwater bottom feeder	**Summer** (average of various months)	0.031 ± 0.005	0.178 ± 0.055	0.061 ± 0.010	0.076 ± 0.016					[26]
4. Chingri	*Metapenaeus spinulatul*	Saltwater bottom feeder	**Summer** (average of various months)	0.118 ± 0.020	0.261 ± 0.089	0.005 ± 0.001	0.102 ± 0.021					[26]
5. Ilish	*Tenualosa ilisha*	Dual habitat surface and bottom feeder	Summer	**1.07** (1.0 - 1.08)	**0.57** (0.5 - 0.58)	**0.09** (0.0 - 0.13)	**0.27** (0.2 - 0.29)					[25]
			Winter	1.22 (1.2 - 1.24)	**0.67** (0.6 - 0.7)	**0.15** (0.14 - 0.17)	**0.65** (0.6 - 0.67)					
6. Chaplia	*Gudusia chapra*	Freshwater surface feeder	Summer	**1.57** (1.4 - 1.68)	**0.74** (0.6 - 0.92)	**0.11** (0.09 - 0.12)	**0.71** (0.6 - 0.86)					[25]
			Winter	**1.73** (1.5 - 1.83)	**0.82** (0.6 - 1.0)	**0.11** (0.09 - 0.13)	**0.84** (0.7 - 0.97)					
7. Phasa	*Setipinna phasa*	Freshwater surface-feeder	Summer	**1.62** (1.5 - 1.77)	**0.91** (0.8 - 0.94)	**0.21** (0.15 - 0.27)	**0.7** (0.6 - 0.72)					[25]
			Winter	**1.9** (1.8 - 1.94)	**0.95** (0.9 - 0.99)	**0.22** (0.05 - 0.3)	**0.85** (0.7 - 0.89)					
8. Loitta	*Harpadon nehereus*	Saltwater surface & bottom feeder	Summer	**1.83** (1.6 - 2.02)	**1.56** (1.5 - 1.66)	**0.37** (0.34 - 0.41)	**0.97** (0.8 - 1.11)					[25]
			Winter	**2.1** (1.9 - 2.23)	**2.0** (1.9 - 2.08)	**0.44** (0.39 - 0.48)	**1.02** (0.9 - 1.15)					

Continued

9. Taposi	*Polynemus paradiseus*	Freshwater mixed-feeder	Summer	**1.92** (1.7 - 2.05)	**1.02** (0.9 - 1.05)	**0.74** (0.65 - 0.82)	**0.75** (0.5 - 0.89)	[25]
			Winter	**2.16** (1.9 - 2.33)	**1.52** (1.4 - 1.66)	**0.86** (0.81 - 0.91)	**0.98** (0.85 - 123)	
10. Tular-danti	*Sillaginopsis panijus*	Saltwater surface & bottom feeder	Summer	**2.0** (1.9 - 2.03)	**1.78** (1.6 - 1.87)	**0.82** (0.77 - 0.86)	**1.02** (0.9 - 1.11)	[25]
			Winter	**2.13** (1.9 - 2.33)	**2.64** (2.5 - 2.78)	**1.11** (0.94 - 1.53)	**1.19** (1.1 - 1.33)	
11. Rup-chada	*Pampus chinensis*	Saltwater surface & bottom feeder	Summer	**0.97** (0.9 - 1.06)	**0.74** (0.63 - 0.82	**0.54** (0.33 - 0.75)	**0.75** (0.5 - 0.88)	[25]
			Winter	**1.2** (0.9 - 1.32)	**0.95** (0.8 - 1.03)	**0.69** (0.53 - 0.8)	**0.81** (0.7 - 0.85)	

In this review, the authors attempt to determine and demonstrate the impact of seasonal variations on the accumulation of heavy metals in naturally occurring native fish in Bangladesh. The data in Table 7 indicate that fish accumulate higher levels of heavy metals during winter than in summer, except for certain heavy metals (serial numbers 5 to 11). However, to have a vivid picture of the impact of seasonal changes on the accumulation of heavy metals in naturally grown native fish in Bangladesh, the authors presented the data in different bar charts in Figures 2(A)-(G).



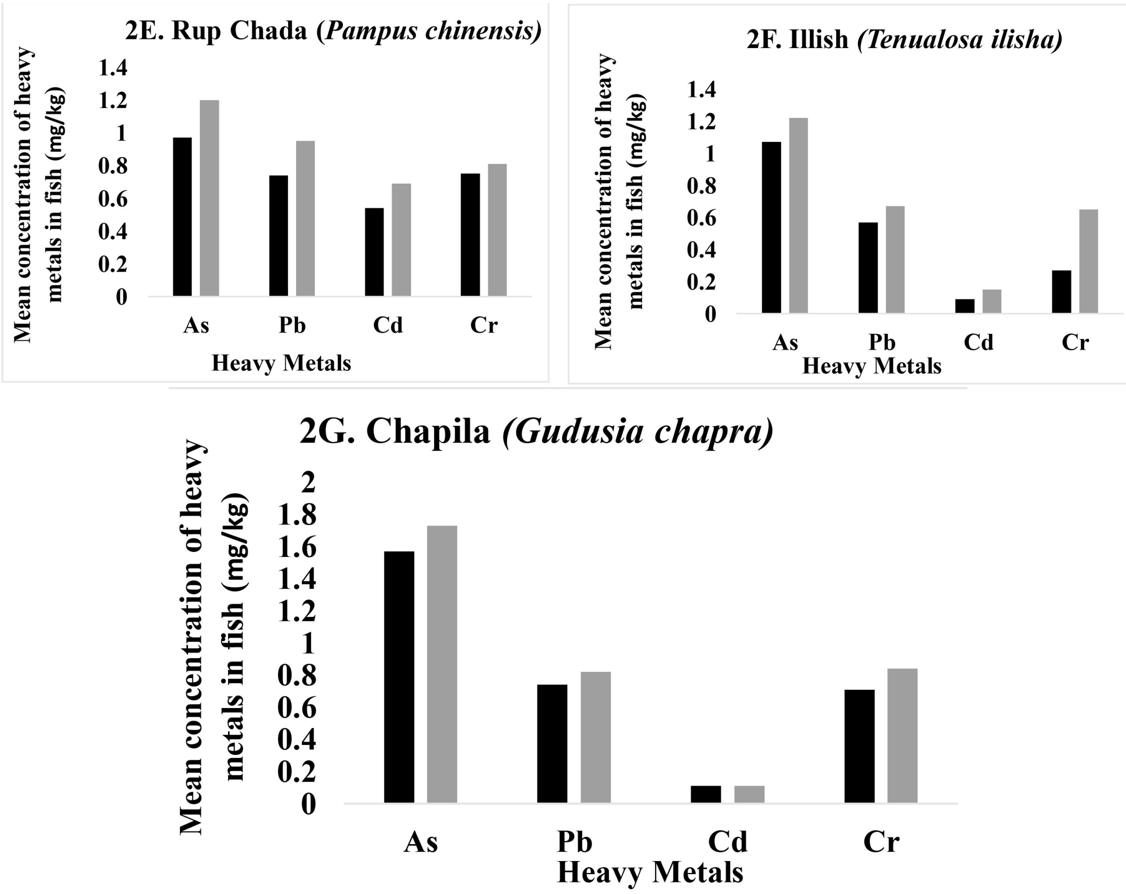


Figure 2. A-G. Concentrations of certain heavy metals in specific fish during summer (dark black bars) and winter (light black bars) seasons in Bangladesh.

It is evident that all the observed naturally grown native fish in Bangladesh had higher concentrations of all four types of accumulated heavy metals in them during the winter season compared to the summer Figures 2(A)-(G), except for the cadmium concentration in Chapila or *Gudusia chapra* Figure 2(G). During the summer in Bangladesh, natural water bodies contain large amounts of water due to rain, which dilutes the concentration of heavy metals. In contrast, during the winter season, the water content in the water bodies is a lesser amount, which concentrates heavy metals in the water. These patterns of heavy metal concentration in the water and sediments may explain why heavy metal accumulation in fish is higher in the winter than in the summer.

3.8. Insight on Content of Heavy Metals in Naturally Grown Native Fish in Bangladesh in the Light of Safe Concentration Limits for Heavy Metals in Fish

This review indicates that natural water bodies in Bangladesh were contaminated with heavy metals during the period 2010 to 2020, otherwise, fish would not have been found to contain high levels of heavy metals. The probable sources and causes of contamination may include the use of inorganic fertilizers in agricultural fields, less efficient management of effluent treatment plants in different industries, and the lack of proper initiative and promptness in taking action by national environmental protection agencies against identified specific anomalies. If contamination continues at levels higher than the accepted limits in fish, it could be detrimental to the public health of the nation and hinder Bangladesh's targets to achieve the SDGs. Therefore, the authors of this review compiled acceptable limits of heavy metals for fish and tabulated the data in **Table 8**, so that it facilitates the authors' discussion of the concentration levels of heavy metals in fish in terms of safety limits (**Table 8**).

Table 8. Safe concentrations for heavy metals in fish cited and set by various organizations.

Organization/Cited by	Safe concentrations (mg/kg) of heavy metals in fish								References
	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
FAO	1	2.5	0.2	1	10	-	-	-	[64]
	-	0.30	0.5	1.0	30.0	-	30.0	-	[65]
	0.1	0.5	0.05	0.15	-		-	-	[66]
WHO	0.01	2	–	0.15	3	-	-	-	[67]
	1.00	0.50	0.10	0.10	-	-	-	-	[68]
	0.014	-	-	-	0.3		1	-	[69]
	-	0.5	30	-	30	100	100	1.0	[70]
EC	-	0.02	-	-	-		0.4-1	-	[71]
EU	–	0.1	0.05	1	3	-	-	-	[72]
FAO/WHO/USFDA/EC	-	2/1.5	0.5	12-13	30	-	30	1	[64] [73]-[75]
Bangladesh Gazette	5	0.30	0.25	–	5.00	-	-	-	[76]

The authors found it challenging to compare heavy metal concentrations in fish to guideline values because the limits set in the guidelines varied considerably among organizations or references (**Table 8**). Similarly, the safe concentrations for heavy metals in fish cited and set by various organizations varied from year to year when enacted or considered (**Table 8**). Therefore, the authors of this study considered the latest guidelines and references for limits on heavy metal concentrations (mg/kg) in fish. If the guideline value is missing in the latest version, the authors of this paper advise using the guideline value from the previous version, regardless of the organization or reference, resulting in **Table 9**.

Surprisingly, the *Bangladesh Gazette* sets the limit for arsenic (As) in fish at 5 (**Table 8**) [76], whereas other organizations set it much lower (**Table 8**). However, with the exception of some fish in **Table 4**, none of the fish studied in **Tables 1-4** exceeded the safe limit value of 5 mg/kg (**Table 9**) for arsenic (As). Similarly, USFDA in 1993 set the safe limit for Cr in fish far higher (12 - 13 mg/kg) than the limit set by other organizations (**Table 8**) [73]. Consequently, no naturally grown native fish in Bangladesh was found to exceed (bottom part of **Table 5**) the safe limit for chromium 12 - 13 mg/kg (Table 9) in fish.

Table 9. Safe concentrations for heavy metals in fish cited and set by various organizations.

Organization/Cited by	Safe concentrations (mg/kg) of heavy metals in fish								References
	As	Pb	Cd	Cr	Cu	Fe	Zn	Mn	
Bangladesh Gazette	5	0.30	0.25	–	5.00	-	-	-	[76]
WHO						100	100	1.0	[70]
FAO/WHO/USFDA/EC				12-13					[64] [73]-[75]

It was found that the concentrations of Pb, Cd, and Cu in most of the fish in the Karnaphuli River and sea (Table 4) exceeded the guideline values (Table 9) set by various organizations and researchers. In general, the levels of at least one of the heavy metals, such as As, Pd, Cd, Cu, and Mn exceeded the safe limit (Table 9) in naturally grown native fish (Tables 1-4) observed in Bangladesh except for Puti, Trout barb, Lesser spiny eel, Tengra, Bagda, Bain, and Chingri fish (Tables 1-4). It is important to mention that the maximum number of heavy metals found to exceed the safe limit in a single fish is four (heavy metals), and this was found in Rup Chanda, Ek Thuitta, and Chandana Ilish (Table 4). It is concerning that a significant percentage (63.04%, given in the lower part of Table 5(A) under summarized results) of fish have exceeded the safe limit of 0.3 mg/kg (Table 9) for the toxic heavy metal lead. The percentage (%) of fish samples that exceeded the safe limit for specific heavy metal content followed this order (values of percentage can be seen from the bottom parts of Tables 5(A)-(D) under summarized results):

$$63.04(\text{Pb}) > 52.17(\text{Cu}) > 37.50(\text{Cd}) > 25.00(\text{Mn}) > 9.68(\text{As}) > 0\%(\text{Cr} = \text{Fe} = \text{Zn}) \quad (4)$$

Iron and zinc are essential heavy metals, and naturally, their safe limit in fish is very high (100 mg/kg). As a result, zero percent (values are under summarized results in the bottom parts of Tables 5(C)-(D) of naturally grown native fish in Bangladesh were found to contain either of the heavy metals beyond the set safe limit of 100 mg/kg (Table 9). The safe limit for chromium is also set relatively to a high value, 12 - 13 mg/kg (Table 9), compared to the other toxic heavy metals and hence none of the fish samples exceeded the safe limit for it.

3.9. Impact of the Heavy Metals (Pd, Cu, Cd, Mn, and As) That Exceeded Safety Limits in Naturally Grown Native Fish in Bangladesh on Human Health

The pollution of the aquatic environment by heavy metals and their subsequent bioaccumulation in fish has become a significant public health concern [77]. If someone consumes fish that have exceeded the safe limit of heavy metals, he/she might become a victim of the deleterious effects of the respective heavy metals. Accumulation of different heavy metals in human beings through the food chain, such as fish, can cause various diseases and toxicities in humans. For example, significant exposure to lead can lead to cognitive deficits in children [78]. Lead poisoning over an extended period can result in thrombosis, atherosclerosis, and hypertension [79]. Cadmium poisoning stimulates neurological defects along with Parkinson's disease, Alzheimer's disease, Amyotrophic lateral sclerosis, and multiple sclerosis [80]. Exposure to cadmium through fish consumption can lead to kidney, bone, and cardiovascular diseases [81]. Exposure to low to moderate levels of cadmium causes diabetes [82], myocardial infarction [83], heart failure, and stroke [84]. Exposure to heavy metals, including lead and cadmium, puts women at risk of infertility [85]. Arsenic exposure increases the risk of cancer by adhering to DNA-binding proteins and delaying DNA repair [86]. Arsenic exposure is also responsible for reproductive and developmental toxicity [79]. Inorganic arsenic exposure not only influences sperm production but also modifies gonadotropin and testosterone levels and tampers with the steroidogenesis process [87]. Manganese and copper are essential heavy metals necessary for a variety of physiological activities. Although these are crucial for normal physiological functions, excessive exposure to manganese and copper leads to significant toxicity [82] [88] [89]. Excessive use of copper may occasionally result in the development of a clinical condition such as inexplicable liver cirrhosis [90]. Acute exposure to manganese reduces cardiac contraction and induces vasodilation, which lowers blood pressure [91]. Parkinson's disease-like, but distinct, signs and symptoms are induced by exposure to manganese [92] [93]. High levels of manganese in water sources have been linked to infant mortality [89]. A similar impact is expected from high levels of manganese in fish.

3.10. Specific Measures for Heavy Metals Pollution Control

The serious consequences of heavy metal contamination demonstrate inadequacies in environmental management by both the private sector and government agencies. Efficient management of heavy metal contamination necessitates a multifaceted strategy. Coordination of individuals, markets, and government actions is required to regulate heavy metal discharges to the environment and address this issue.

3.10.1. Growing the Green GDP

Public health and human settlements in polluted areas; conservation and sustainable use of natural resources; pollution control technology for waste gas, waste water, and solid wastes; cleaner production and environmental protection industry; clean energy, green transportation, and green buildings; and a few other priority research programs should be implemented by the authorities to boost green GDP [94].

3.10.2. Cutting Down on Heavy Metals in Fuel

The use of heavy metals needs to be drastically reduced in a few industries, including manufacturing, metallurgy, power generation, transportation, etc. For instance, when gasoline is consumed in an engine, the heavy metals in it may release toxins into the air. Since lead also harms the catalytic converter, which regulates other pollutants from vehicle exhaust, new automobiles should be forced to use gasoline with less lead [94] [95].

3.10.3. Ensuring the Use of Renewable Energy

Three fundamental actions need to be performed to accomplish this strategic objective: enacting laws that encourage the production and marketing of renewable energy; lowering the cost of renewable energy by giving power producers access to new technologies; and creating financial support structures to boost the use of clean and renewable energy sources, particularly shale gas, wind, and solar [94].

3.10.4. Using Market-Based Strategies to Cut Down on Pollution

To reduce pollution, some market-based incentives are required. Pollution taxes and fees are the two main types of market incentives [96].

3.10.5. Interventions in Regulation and Policy

Stringent emission standards should be enforced, such as putting laws into place to restrict the amount of heavy metals released by mining, smelting, and industrial processes. Utilization of harmful metals in products should be prohibited or restricted. For instance, to lessen environmental release, phase out lead-based paints. We should keep an eye out for legacy contamination, such as utilizing sediment management and remediation initiatives to address past pollution from industrial sites, mining waste, and landfills [97] [98].

3.10.6. Adaptation of the Best Practices for Industry and Agriculture

Cleaner production technologies should be resorted. For this purpose, antiquated industrial processes should be replaced with closed-loop systems to reduce waste. To control agricultural runoff, we should reduce the use of fertilizers and pesticides containing metals and encourage organic farming and buffer zones to keep heavy metals out of water systems. Industrial effluents should be treated by using chemical precipitation, ion exchange, or membrane filtration to remove metals like chromium and cadmium from wastewater before discharge [97] [98].

3.10.7. Community Engagement and Public Health Awareness Building

Awareness initiatives should be raised. For instance, inform local populations living close to industrial or mining areas about the dangers of heavy metals and safe precautions (such as avoiding tainted water). Food safety testing should be promoted such as to stop cadmium, lead, and arsenic from bioaccumulating in the food chain, and screen seafood and crops for these elements. Populations who are in high-exposure areas should have regular health examinations to identify early indicators of metal poisoning, such as cadmium-induced kidney impairment [97] [99].

4. Conclusion

Based on this review, it was concluded that the status of eight heavy metals, namely lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), iron (Fe) and manganese (Mn) in thirty-three naturally grown native fish of Bangladesh has been studied. No study assessed the aforementioned eight heavy metals in any fish. The maximum number of heavy metals reported in a single study for a fish was six. It was found that the level of heavy metal content in naturally grown native fish in Bangladesh varied depending on the fish species, the seasons during which the fish were in their habitat, and the types of heavy metals to which they were exposed. The concentration of heavy metals varied among both the fish and the heavy metals themselves and was highly variable. Heavy metals were detected in over 90% of the fish samples studied. Among all the observed fish and heavy metals, the Shingi fish contained the highest concentration of heavy metals, specifically Pb (63.63). In contrast, the Puti and Tank goby (or Bele) fish had the lowest concentration of heavy metals among all observed fish varieties, with only 0.002 of Cd. The heavy metal content (mg/kg) in the fish samples, regardless of fish type, followed this order: Pb (63.63) > Cu (26.60) > Zn (14.37) > Cr (6.42) > Cd (6.22) > As (5.26) > Fe (3.02) > Mn (1.69). The Karnaphuli River and the sea had a higher level of heavy metal content than other sources. During winter, the concentrations of heavy metals in all types of fish were higher than during summer. Based on median values, the heavy metal content (mg/kg) in the fish samples decreased in the following order: Cu (5.31) > Fe (2.20) > As (0.99) > Zn (0.91) > Pb (0.67) > Cr (0.65) > Mn (0.26) > Cd (0.11). The percentages (%) of fish samples that exceeded the safe limit of specific heavy metal content followed this order: 63.04 (Pb) > 52.17 (Cu) > 37.50 (Cd) > 25.00 (Mn) > 9.68 (As) > 0% (Cr = Fe = Zn). A significant percentage (63.04%) of naturally grown native fish in Bangladesh have exceeded the safe limit for the toxic heavy metal lead. It is concerning for human health that several heavy metals have exceeded safe limits in naturally grown native fish in Bangladesh. Through bioaccumulation via the fish food chain, they can have deleterious effects on human beings. Finally, the authors want to draw the attention of the responsible government authorities in Bangladesh to address the issue of heavy metal contamination in water and, hence, in naturally grown native fish in Bangladesh to ensure the sustainable development of natural water bodies and fisheries sectors in the country.

5. Limitations and Recommendations

Nowadays, there is an abundance of secondary data available across various fields, which researchers are studying and analyzing. However, secondary data analysis is susceptible to apophenia—the tendency to see patterns in random data—and confirmation bias, which is the inclination to focus only on evidence that supports one's existing beliefs [100]. These biases can lead to selective reporting of findings and particular analytical choices [101]-[103]. In the current study, variability in the secondary data has been noted and analyzed from different perspectives. It would be better if the researchers considered the potential biases due to data variability from the very beginning of the study and addressed them accordingly. Therefore, the authors of the present study recommend adhering to the practices outlined by Baldwin [100] from the outset to mitigate researcher bias in secondary data analysis and enhance the robustness of research based on existing data.

Acknowledgements

The authors are grateful to the valued faculty members of the Department of Pharmacy, Jahangirnagar University, and Mawlana Bhashani Science and Technology University for providing the facilities and valuable insights to conduct this study and publish the paper.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

Funding Source Declaration

All authors herein affirm that this research did not receive any funds, research grants, or any other financial support from any public, private, or nonprofit organization throughout the study and preparation, and publication of the manuscript.

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Graphical Abstract