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Evaluating Heavy Metal Levels in Commercial Fish Feeds in Khulna, Bangladesh: Implications for Aquaculture Safety

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ABSTRACT

The present study aims to assess the levels of selected heavy metals—zinc (Zn), chromium (Cr), cadmium (Cd), lead (Pb), and arsenic (As)—in commercial fish feeds obtained from 17 different feed companies in Khulna district, Bangladesh. The collected feed samples were analyzed at the Interdisciplinary Institute for Food Security (IIFS) Laboratory using Graphite Furnace Atomic Absorption Spectrometry (GFAAS) to determine the concentrations of the targeted heavy metals. The results showed that zinc concentrations varied among the feeds, ranging from 52.73 ppm in Aman Feed Grower to 95.20 ppm in Mega Grower Feed. All values were below the maximum permissible limit of 100 ppm set by the WHO and FAO. In contrast, chromium concentrations were of greater concern. The highest level was found in Agroho Grower Feed (6.33 ppm), while the lowest was in Lily Starter Feed (0.43 ppm). Chromium was not detected in Mega Grower Feed. Cadmium, lead, and arsenic were not detected in any of the samples, indicating a relatively low risk from these toxic metals in the feeds tested. Zinc levels in the tested feeds are within safe limits; however, chromium concentrations substantially exceed international safety standards, highlighting the need for continuous monitoring to ensure fish and public health safety.

INTRODUCTION

Bangladesh's southwestern districts, including Khulna, Satkhira, and Bagerhat, are well-known for brackish water aquaculture (**Hossain *et al*., 2025**). Satkhira and Bagerhat are specialized in shrimp (*Penaeus monodon*) and other brackish water fish farming due to their proximity to the Sundarbans, the world's largest mangrove forest. Khulna supports both shrimp and prawn (*Macrobrachium rosenbergii*) culture, benefiting from its favorable geography and water resources (**Mahmud *et al*., 2021; Biswas *et al*., 2021; Mou *et al*., 2023; Rahman *et al*., 2025**). Shrimp has become the second-largest export of Bangladesh, after ready-made garments, generating millions of dollars annually. Coastal aquaculture, encompassing shrimp, prawn, and finfish farming in enclosed ponds or ghers, has grown steadily (**Sohidullah *et al*., 2025**). Farmers practicing good aquaculture practices (GAP) are increasingly adopting sustainable methods and cluster farming approaches (**Baroi *et al*., 2019; Hossain *et al*., 2021; Murshed *et al*., 2023**). The government has also introduced initiatives to increase shrimp and prawn production, contributing to a rise in total production from 100,000 MT in 2002–03 to 258,000 MT in 2018–19 (**DoF, 2020; Nasrin *et al*., 2021; Noor *et al*., 2024, Biswa *et. al*., 2025**). Heavy metals are dense metallic elements that can be toxic even at low concentrations. Metals such as cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), and zinc (Zn) are commonly found in aquatic environments and pose risks to both fish and humans when accumulated above safe levels (**Abdel-Baki *et al*., 2011**). While some metals are essential in trace amounts, excessive exposure can be toxic or carcinogenic (**Gupta *et al*., 2014**). Industrial activities, urbanization, and modern agricultural practices contribute significantly to environmental contamination. For example, chromium in natural waters usually ranges from 1 to 10µg/ L, while the EPA allows up to 50– 100µg/ L to protect aquatic life. Elevated chromium can harm fish gills and blood chemistry and may cause skin and respiratory issues in humans (**Karadede *et al*., 2004**). Cadmium is highly toxic and can damage kidneys, reproductive organs, and the nervous system. Lead accumulates in fish tissues and affects neurological health, while arsenic exposure can trigger oxidative stress and organ damage, potentially causing chronic diseases. Zinc, though essential, can cause gastrointestinal and cardiovascular problems when present in excess (**Olaifa *et al*., 1998**).

Commercial aquaculture depends heavily on formulated feeds, primarily based on fishmeal. Raw materials in these feeds may carry heavy metal contaminants, which can accumulate in fish and indirectly affect human health. Although it is challenging to eliminate all contamination, controlling heavy metal levels in feeds is crucial for sustainable and safe aquaculture. Recent studies in Bangladesh have reported the presence of heavy metals in commercial fish feeds, underscoring potential health risks for both cultured fish and consumers (**Alam, 2023; Rakib, 2024**). Considering these concerns, monitoring heavy metal levels in fish feeds is essential. This study aims to evaluate the concentrations of zinc (Zn), chromium (Cr), cadmium (Cd), lead (Pb), and arsenic (As) in commercial fish feeds collected from Khulna district, Bangladesh, providing updated information on feed safety and potential risks to aquatic animals and human health.

MATERIALS AND METHODS

Selection of the study area

The study was carried out in different areas of Khulna region (Fig. 1)

Fig. 1. Selected study area (Khulna region)

Sample collection

A total of 17 commercial fish feed samples were collected from different feed companies in Khulna district. The sampled feeds included Aman Feed Grower, Victory Grower, Agroho Grower, Tongwei Grower Freshwater Fish Feed, Nourish Grower, Quality Grower, Suguna Grower, Boishakhi Grower, Anchor Grower, Paragon Feed Grower, Saudi-Bangla Special Shrimp Feed Grower, K. N. B. Finisher, Titas Grower, Quality Starter, Lily Starter-I, and Mega Grower. Following collection, the samples were placed in airtight polythene bags and stored in the refrigerator of the BAU Fish Nutrition Laboratory, until further analysis (Fig. 2).

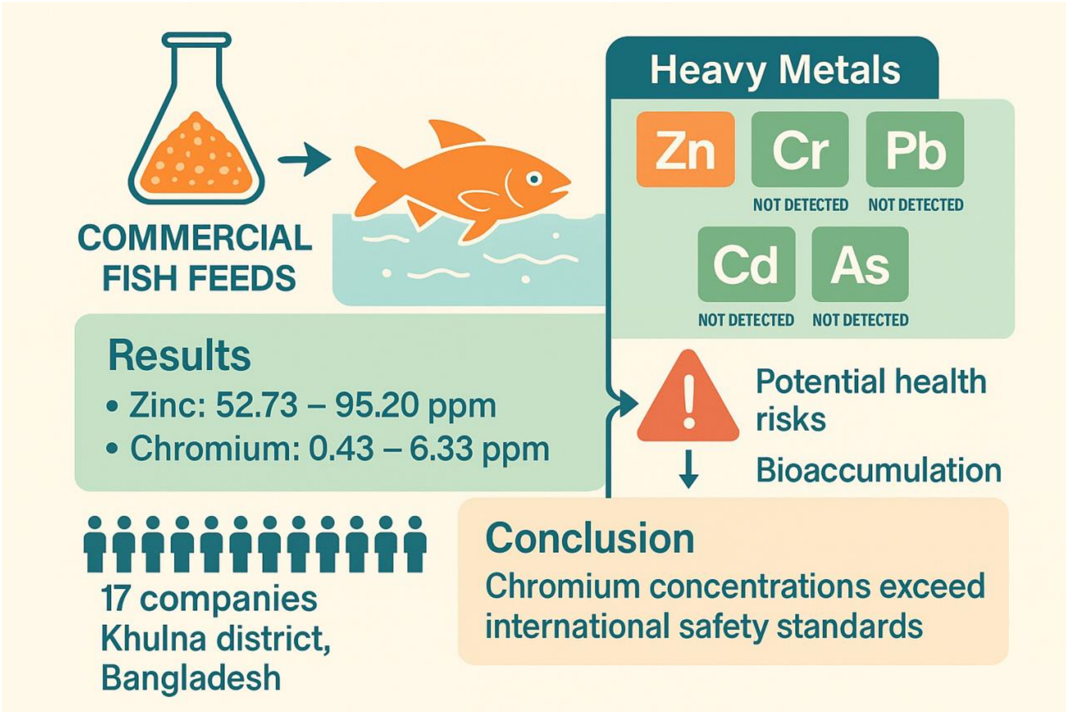

Fig. 2. Graphical presentations of 17 company's heavy metals summary

Laboratory facilities

Sample preparation, acid addition, and electro-thermal digestion were conducted in the Fish Nutrition Laboratory, Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh. The concentrations of heavy metals were subsequently analyzed at the Interdisciplinary Institute for Food Security (IIFS) Laboratory, BAU, Mymensingh.

Sample preparation

Fish feed samples were removed from refrigeration and allowed to reach room temperature prior to analysis.

Reagent preparation

Analytical grade nitric acid and perchloric acid were used. Each sample was accurately weighed (1 g) using an electronic balance before digestion.

Electro-thermal digestion

Ten millilitres of nitric acid and five millilitres of perchloric acid were added to a digestion tube containing 1.0g of each sample for the digestion process. After that, the tubes were heated for 25 to 30 minutes at 80°C using an electro-thermal heater. After cooling, the digested solutions were transferred into acid-washed 100mL volumetric flasks, diluted to the mark with double-distilled water, filtered using Whatman No. 42 filter paper, and stored in airtight, properly labeled bottles. Electro-thermal digestion was chosen over conventional methods because it requires less acid, reduces processing time, and better preserves volatile compounds.

Blank preparation

Acid blanks were prepared alongside each set of samples to monitor contamination. These blanks contained the same reagents but no feed sample. The values obtained from blanks were subtracted from the sample readings to ensure accurate measurement of heavy metals.

Atomic absorption spectroscopy (AAS)

Heavy metals were analyzed using a Shimadzu AA-7000 flame atomic absorption spectrophotometer. The instrument uses a hollow cathode lamp as the radiation source, a flame or electro-thermal atomizer to convert metals into atomic form, a monochromator to isolate analytical wavelengths, and a photomultiplier tube (PMT) detector to measure light absorption. The samples were introduced into an acetylene–air flame, and the concentrations of metals were determined using calibration curves derived from standard solutions. Each measurement was performed in triplicate to ensure accuracy.

Contamination prevention

All glassware and bottles were cleaned with 10% (v/v) acidic solution and deionized water before use. Samples were stored in airtight bags and refrigerated to prevent microbial growth and contamination during preparation.

Data processing

All results were recorded and processed using Microsoft Excel for further analysis.

RESULTS AND DISCUSSION

The primary aim of this study was to determine the concentration of selected heavy metals, including zinc (Zn), chromium (Cr), lead (Pb), cadmium (Cd), and arsenic (As), in fish feeds obtained from various feed companies in the Khulna district. The findings of the study are summarized below.

Fish feed used in aquaculture may act as a potential source of heavy metal contamination in cultured fish. In this study, feed samples were collected from different companies within the Khulna district and analyzed in the laboratory to quantify the levels of Zn, Cr, Pb, Cd, and As. The results, presented as averages in Table (1), are expressed on a dry weight basis in mg/kg (ppm).

Table 1. Average Zn, Cr, Pb, Cd and As concentrations (ppm) in fish feed collected from different feed market in Khulna region compared to the maximum recommended limits of the **FAO (1983**) and **WHO (1989)**

Serial No.	Company Name		Zn	Cr	Pb	Cd	As
1.	Aman Feed Grower	Max.	54.7358	7.2490	NF	NF	NF
		Min	50.7268	4.7594			

		Av.	52.7313	6.0042			
2.	Victory Grower	Max.	63.4436	5.2591	NF	NF	NF
		Min	60.3234	5.2479			
		Av.	61.8835	5.2535			
3.	Agroho Grower	Max.	62.9767	6.5711	NF	NF	NF
		Min	60.4871	6.0815			
		Av.	61.7319	6.3263			
4.	Tongwei Grower Freshwater Fish Feed	Max.	91.3150	7.6152	NF	NF	NF
		Min	91.2140	4.9552			
		Av.	91.2645	6.2852			
5.	Nourish Grower	Max.	77.8284	6.2004	NF	NF	NF
		Min	72.7284	6.0994			
		Av.	75.2784	6.1499			
6.	Quality Grower	Max.	94.2956	6.2993	NF	NF	NF
		Min	91.4154	601983			
		Av.	92.8555	6.2488			
7.	Suguna Grower	Max.	63.7889	6.1062	NF	NF	NF
		Min	59.0689	5.9862			
		Av.	61.4289	6.0462			
8.	Boishakhi Grower	Max.	58.6985	6.2855	NF	NF	NF
		Min	58.2497	6.2743			
		Av.	58.4741	6.2799			
9.	Quality Grower	Max.	94.9268	6.1130	NF	NF	NF
		Min	93.9107	6.1046			
		Av.	94.9163	6.1088			
10.	Anchor Grower	Max.	59.4019	6.0387	NF	NF	NF
		Min	56.6675	5.3043			
		Av.	58.0347	5.6715			
11.	Paragon Feed Grower	Max.	65.0073	5.1767	NF	NF	NF
		Min	64.5177	4.3403			
		Av.	64.7625	4.7585			
12.	Saudi-bangla Special Shrimp Feed Grower	Max.	64.2687	1.7854	NF	NF	NF
		Min	59.9831	1.2958			
		Av.	62.1259	1.5406			
13.	K. N. B. Finisher	Max.	67.2966	6.6297	NF	NF	NF
		Min	66.5620	5.5187			
		Av.	66.9293	6.0742			

14.	Titas Grower	Max.	57.1581	6.0793	NF	NF	NF
		Min	54.6685	5.5693			
		Av.	55.9133	5.8243			
15.	Quality starter	Max.	89.9602	0.6832	NF	NF	NF
		Min	89.1442	0.4180			
		Av.	89.5522	0.5506			
16.	Lily starter-I	Max.	77.5260	0.6507	NF	NF	NF
		Min	75.0614	0.2019			
		Av.	76.2937	0.4263			
17.	Mega Grower	Max.	95.3368	NF	NF	NF	NF
		Min	95.0716				
		Av.	95.2042				

Av. = Average, Max. = Maximum, Min = Minimum, NF= Not Found,
Maximum Allowable limit: Zn= 100 ppm, Cr= 0.05 ppm, Pb= 2.0 ppm, Cd=1.0 ppm, and As= 0.05 ppm (**FAO, 1983; WHO, 1989**)

The study aimed to assess the concentration of various metals in fish feed samples collected from different markets in the Khulna region. The results revealed distinct patterns for zinc (Zn), chromium (Cr), lead (Pb), cadmium (Cd), and arsenic (As) concentrations across different feed types, with notable differences observed between brands.

Zinc (Zn) concentration

The average zinc concentration in the various feed samples ranged from 52.73 ppm in Aman Feed Grower to 95.20 ppm in Mega Grower feed. All of the observed zinc concentrations were below the maximum permissible limit of 100 ppm set by the Food and Agriculture Organization **(FAO, 1983)** and the World Health Organization **(WHO, 1989)**. Among the samples, Mega Grower feed had the highest concentration of zinc at 95.20 ppm, while Aman Feed Grower had the lowest concentration at 52.73 ppm. The concentrations of zinc in Victory Grower (61.88 ppm), Agroho Grower (61.73 ppm), Tongwei Grower Freshwater Fish Feed (91.26 ppm), and Quality Grower (92.86 ppm) were also significantly below the maximum recommended limit. Titas Grower (55.91 ppm) and Boishakhi Grower (58.47 ppm) contained zinc concentrations that were well within safe limits (Table 1). The data show that while there is some variation in zinc levels across brands, all values fall well within the internationally accepted safety range. This suggests that the zinc concentrations in the analyzed feeds are generally safe for consumption, with no immediate concerns related to zinc toxicity in the feed available in the Khulna region.

Chromium (Cr) concentration

The chromium concentrations, however, exhibited a different pattern. Unlike zinc, many of the samples exceeded the maximum recommended limit of 0.05 ppm set by the WHO and FAO. Agroho Grower had the highest chromium concentration at 6.33 ppm, followed by Tongwei Grower Freshwater Fish Feed (6.29 ppm) and Boishakhi Grower (6.28 ppm). Other notable concentrations included Victory Grower (5.25 ppm) and Nourish Grower (6.15 ppm).

In contrast, some feeds such as Quality Starter (0.55 ppm) and Lily Starter-I (0.43 ppm) exhibited chromium concentrations that were closer to the acceptable limit, but still above the recommended threshold. Interestingly, Mega Grower was the only feed sample where chromium was not detected, with a concentration recorded at 0.00 ppm (Table 1). The data indicate that while chromium levels in most samples were significantly above the permissible limit, Mega Grower exhibited a surprisingly low concentration of chromium, raising questions about the consistency of chromium levels across different feed brands and their manufacturing processes.

Cadmium (Cd), arsenic (As) and lead (Pb) concentrations

A key finding of this study was that lead (Pb), cadmium (Cd), and arsenic (As) were not detected in any of the fish feed samples collected from the Khulna region. The detection limits of the analytical methods employed did not identify any traces of these toxic metals in the samples. This result suggests that either these heavy metals were absent from the feeds or present in concentrations too low to be detected by the methodology used. While the absence of these heavy metals is reassuring, further studies with more sensitive detection methods could help ensure that these potentially harmful substances are not present in higher quantities in other feed samples in the region.

Summary of findings

To summarize, the maximum zinc concentration was found in Mega Grower feed at 95.20 ppm, which was below the WHO and FAO's recommended limit of 100 ppm. The minimum zinc concentration was observed in Titas Grower feed at 55.91 ppm, also well below the recommended threshold. In contrast, the maximum chromium concentration was found in Agroho Grower at 6.33 ppm, significantly exceeding the acceptable limit of 0.05 ppm. The minimum chromium concentration was found in Lily Starter-I feed at 0.43 ppm, still above the permissible limit. The data further revealed that no lead, cadmium, or arsenic were detected in the samples, indicating that these heavy metals were absent or present in undetectable quantities. These findings highlight the need for closer monitoring of chromium concentrations in fish feeds, as well as a continued focus on ensuring the absence of harmful substances such as lead, cadmium, and arsenic in feed products across the region.

This study evaluated the concentrations of heavy metals—zinc (Zn), chromium (Cr), lead (Pb), cadmium (Cd), and arsenic (As)—in commercial fish feeds from various companies in Khulna district. The presence of heavy metals in fish feed is a significant concern, as these elements can bioaccumulate in fish tissues and potentially transfer to humans through the food chain **(Ayas, 2007)**. Rapid industrialization, urban expansion, and agricultural practices contribute to elevated heavy metal levels in the environment, posing a growing threat to aquatic ecosystems and aquaculture **(Abdel-Baki *et al.*, 2011)**. Among the metals analyzed, zinc is essential for fish health but can be toxic at high levels. In the present study, zinc concentrations ranged from 52.73 ppm in Aman Feed Grower to 95.20 ppm in Mega Grower, remaining below the WHO and FAO recommended limit of 100 ppm. These levels indicate that zinc in the tested feeds does not pose immediate risks to fish. Chromium, although necessary in trace amounts, was detected at levels far exceeding the safe limit of 0.05 ppm in most feed samples. The highest concentration was found in Agroho Grower Feed (6.33 ppm), while Mega Grower Feed showed no detectable chromium. These results suggest variability in feed manufacturing processes, possibly due to differences in raw materials, additives, and coloring agents used during production **(Cohen *et al.*, 1993)**. Elevated chromium can cause genotoxic effects in fish, including DNA damage, and may have potential carcinogenic impacts if bioaccumulated over time **(Baruthio, 1992; Dayan & Paine, 2001)**. Lead, cadmium, and arsenic were not detected in any sample, which is a positive outcome for aquaculture safety. This finding indicates that feeds from reputable brands in Khulna are generally free from these highly toxic metals. Similarly, arsenic absence reduces the posing risks to food safety, supporting safer aquaculture practices in the region **(Biswas *et al.*, 2021**). Comparisons with international studies show that heavy metal contamination in fish feeds is a common concern. Research from Turkey and Saudi Arabia has reported elevated chromium and zinc levels in commercial feeds, consistent with our findings **(Karadede *et al.*, 2004; Abdel-Baki *et al*., 2011)**. These parallels highlight the global relevance of monitoring heavy metals in aquaculture feeds. In summary, while zinc levels were within safe limits, excessive chromium in most feeds underscores the need for stricter quality control and continuous monitoring. The variability observed among brands suggests differences in sourcing and manufacturing practices, emphasizing the importance of standardized feed production and regulatory oversight. Regular screening of heavy metals in feeds will help protect fish health, ensure food safety, and support sustainable aquaculture development in Bangladesh.

CONCLUSION

Environmental pollution remains a major global concern, with heavy metals being among the most critical contaminants in aquatic systems due to their toxicity, persistence, and potential for bioaccumulation and biomagnification in marine organisms. Aquatic ecosystems are highly sensitive to such pollutants, and the gradual increase in heavy metal concentrations has become a pressing environmental issue. Fish, as primary inhabitants of aquatic environments, are particularly vulnerable to heavy metal contamination. This not only poses significant risks to human health and nutrition but can also disrupt the natural balance of aquatic ecosystems. The present study revealed that fish feed samples collected from various feed companies in the Khulna district contained substantial levels of zinc (Zn) and chromium (Cr), whereas cadmium (Cd), lead (Pb), and arsenic (As) were not detected. These findings highlight the need for careful consideration in the formulation of fish feeds, avoiding ingredients with high heavy metal concentrations. It is essential that fish feeds available in the region undergo regular screening for heavy metal contamination. Feed manufacturers should periodically assess their products to ensure safety, while local, state, and national authorities must implement continuous monitoring and enforcement to maintain heavy metal levels within acceptable limits. Non-compliance should be met with appropriate sanctions.

Furthermore, basic and applied research on fish feed formulations should be expanded to establish stricter safety standards. While complete elimination of contaminants like cadmium from the environment may not be feasible, proactive measures can significantly reduce risks. Training and awareness programs for farmers, toll millers, and small-scale producers are critical, emphasizing proper storage and handling of feed ingredients. Such practices can minimize the presence of toxic heavy metals in fish feeds, ultimately protecting the health of both cultured fish and human consumers.

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