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Heavy Metals Accumulation in Different Cultivated Fish Tissues through Commercial Fish Feeds and Health Risk Estimation in Consumers in Bangladesh

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ABSTRACT

Cultivated fishes are major protein and microelement sources for all sorts of people in Bangladesh due to its availability and affordability. Since heavy metals are persistent in the aquatic environment, these metals can accumulate in the food chain. Cultivated fishes containing heavy metals can cause a carcinogenic and non-carcinogenic risk to human as it biologically accumulates heavy metals from commercial feeds. In this study, seven types of cultivated fishes and their respective commercial feeds were collected from different cultivation farms based on different physical characteristics and after taking dry weight, 1g of each sample was digested with an acid mixture. Data analysis was carried out using ICP-OES (Optima-7000DV) software. This study was designed to access the content of heavy metals in the flesh of fish species through feeds available in Bangladesh and potential health risk calculation for consumers due to intake daily. The concentration (mg/kg, dry weight) range of heavy metals like; Pb (4.56- 7.08), Cd (0.23- 1.28), Cr (4.00-7.08), Cu (11.23- 20.62), As (0.08- 0.34), Hg (0.05- 0.34) in selected commercial fish feeds and Pb (4.35-8.03), Cd (0.87- 1.35), Cr (4.71-8.98), Cu (14.00- 31.80), As (0.17-0.28), Hg (0.08- 0.41) in collected fishes. Statistical analysis was interpreted to show data variability and coherence. The recorded concentration value for selected metals in fish tissues and feeds was also compared with the safe limit proposed by World Health Organization (WHO, 1995), Food and Agricultural Organization (FAO, 1983), European Union (EU, 2001). This study also estimated the carcinogenic and non- carcinogenic risk due to the daily consumption of these cultivated fishes for a certain age.

1. Introduction

Environment Pollution due to heavy metals along with food safety is a burning issue worldwide recently. Toxic metals may have adverse health impacts on all living organisms, especially to humans if the consumption level exceeded the allowable limit [1]. Moreover, heavy metal contamination and toxicity are increasing at an alarming rate in the aquatic environment in recent days. Waterbody such as; rivers, ponds, streams can be contaminated by toxic metals as a result of an increase in atmospheric deposition and the rapid development of industrialization and agricultural activities [2]. Fish is a vital food source and

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its demand and intake rate is increasing globally as it contains high nutritional values and health benefits. However, despite its nutritional benefits, fish can accumulate non-essential metals such as; Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu), Arsenic (As), Mercury (Hg) through its diet and from the water body and sediment [3, 4]. Heavy metals may deposit in sediment by ion exchange reaction, precipitation, absorption, and finally contamination in fish may cause a potential health risk to men since metals can bio-accumulate in the food chain [5, 6]. In the eye of public health, it is necessary to have good quality control for fish and fish made products to prevent health pollution.

Fish farming is one of the most valuable parts of the agriculture sector in Bangladesh contributing largely to fulfill the protein demand of the rising population through cultivated fish. Bangladesh has settled a landmark in aquaculture in 2014 and stood 6th in world farm fish production. Fish cultivation largely depends on commercial fish feed production as the chemical composition and the quality of fish are influenced by feeding ingredients [7-9]. Commercial fish feeds are generally made of vegetables, proteins, cereal grains, vitamins, minerals in the form of pellets or granules enabling fish to consume efficiently [10]. Fish feed producing industries failed to control the feed quality as the source of feed ingredients tends to be polluted with toxic metals in many ways [11]. However, commercial feeds might be a source of toxic metal contamination in cultured fish tissues and different organs. Heavy metal contamination can do the imbalance of the mental and central nervous system, declining energy levels, adverse effects on the blood constitution, lungs, liver, kidneys and different vital body organs [12].

Physical, muscular and neurological degenerative processes may be also affected due to long-period exposure to toxic metals [13]. Lead (Pb) can cause disruption of the biosynthesis of hemoglobin and raise blood pressure in men [14]. Long exposure to Cadmium (Cd) may be responsible for kidneys dysfunction, skeletal damage, prostate cancer and mutation [15-17]. Chromium (Cr) has different oxidation states, but the hexavalent state of Cr is considered carcinogenic and may lead to bronchial cancer [18]. Acute Copper (Cu) and Arsenic (As) contamination in food cause physical illness like; nausea, vomiting, abdominal pain, and severe diarrhea [19, 20]. Mercury (Hg) consumption may cause significant neurological disorder and kidney toxicity in humans [21]. However, little studies focused to investigate heavy metal in freshwater fishes in Bangladesh [7, 8, 22, 23]. Although it is not possible to keep away completely from the toxic metal contamination in cultivated fishes, there is a need for such toxicity to be minimized with a view to reducing both carcinogenic and non- carcinogenic risk in humans. Though several studies were done on heavy metal analysis in fishes or feeds separately, our study focused only on cultivated fishes and their respective commercial feeds. We observed the selected fishes up to certain ages and their consumed foods. We established a chain of heavy metal translocation from feeds to fishes and determined their probable impacts on humans related to health risk which was not done before. Therefore, the study was concerned to access the heavy metal concentration in different commercial fish feeds and their bioaccumulation in different types of cultivated fishes with probable health impacts on the human body.

2. Materials and Methods

Fishes that are generally cultured in freshwater in a closed area by providing commercial fish feeds are called cultivated fish. Cultivated fishes are cheap and available in the local market in Bangladesh. Seven types of fish with their respective commercial feeds were collected from the different cultivated fish farms in the southern part of Bangladesh. A summary of the age, weight, length of different types of cultivated fishes with their respective feed names were presented in Table 1. A total of 14 samples (7 types of fishes and 7 types of feeds) was collected and analyzed for heavy metal concentration in the present study.

Sample Digestion

Once the fishes were cut with a sharp stainless-steel knife, samples (fish tissues) were kept in plastic boxes, stored at -18ºC, and digested as soon as possible. All collected fish samples were cut into small pieces and dried them in an oven at 105ºC until a constant weight was achieved and finally powdered. Feed samples were also dried similarly. 1g (dry weight) of the homogenate of each sample (Fish and Feed) was taken into a quick fit round bottom flask and 15 mL mixture of concentrated HNO_3, H_2SO_4 and $HClO_4$ in (4:1:1; v/v) was into the flask. A condenser was set up added with the flask and the mixture was stirred at 85°C for 3 hours until the proper digestion was completed and the solution became colorless [6, 24, 25].

Then, the sample was removed and allowed to cool. Filtration of all digested samples was done with Whitman no. 42 filter paper and the filtrated was transferred into the volumetric flask and finally diluted to 50 mL with deionized water. Samples were kept in a refrigerator to avoid evaporation until metal analysis. All knives, glassware (round bottom flask, condenser and magnet) were rinsed with dilute HNO_3 solution and then was washed several times with tap water and finally with deionized water. All were dried in an oven at 110°C to remove moisture.

Sample Analysis

All samples were analyzed by Inductive Coupled Plasma Optical Spectroscopy (Optima- 7000DV, USA). The precision and analytical accuracy of the analyses were checked by the analysis of standard reference material C.P.A Chem., Bulgaria. The percent recovery was between 96.3-104.8% as shown in Table 2.

Table 1: Age, Weight and Length of Different Types of Fishes with their Respective Feeds

Feed Sample ID	Names of Cultivated Fishes (Scientific Name)	Cultivated fish (Local Name)	Age (Month)	Length (cm)	Weight (gm)
FF1	*Labeo rohita*	Rui Fish	8	58.42	2300
FF2	*Hypophthalmichthys molitrix*	Silver Carp	8	55.88	2000
FF3	*Puntius sarana*	Sarpunti	6	26.67	350
FF4	*Labeo calbasu*	Kaalibaus	7	43.18	1500
FF5	*Anabas testudineus*	Koi	6	19.05	200
FF6	*Ctenopharyngodon idella*	Grass Carp	8	60.96	2500
FF7	*Oreochromis niloticus*	Tilapia	8	33.02	1100

Table 2: Wavelength, Detection Limit and Percent Recovery of each Heavy Metal

Metals	Wavelength (nm)	Detection limit (mg/kg)	Assigned Value (mg/kg)	Obtained Value (mg/kg)	Percent Recovery (%)
Pb	220.35	0.01	0.50	0.4815	96.3
Cd	228.80	0.001	0.50	0.4923	98.5
Cr	267.71	0.001	0.50	0.4693	93.4
Cu	327.39	0.001	0.50	0.5235	104.7
As	193.69	0.01	0.50	0.5132	102.6
Hg	253.65	0.01	0.50	0.5242	104.8

All chemicals used were Merck, Germany analytical grade, including standard stock solutions of known concentrations of different Metals. Concentration was calculated on a dry weight basis. The present study used equation 1 to calculate metal concentration (in mg/kg, dry weight):

Equation 1:

$$\textbf{Element, (mg/kg)} = \mathbf{R \times D/W}$$

R = Reading of the metal concentration in mg/kg from the digital scale of the instrument

D = Dilution factor of the prepared sample
W = Weight of the sample

Calculation of accumulation level

Biological accumulation factor (BAF) was calculated from the ratio of heavy metals in fish tissues to that in fish feed according to the formula [26] as presented in equation 2:

Equation 2:

$$\mathbf{BAF = C_{fish} / C_{feed}}$$

C_{fish} = Concentration of metal in fish
C_{feed} = Concentration of metal in feed

Health risk estimation

The estimated daily intake of the metals considered in this study was determined based on the concentration in each fish species in mg/kg. The EDI value of each metal was determined by the formula [27] as given in equation 3:

Equation 3

$$\mathbf{EDI = (EF \times ED \times FIR \times CM \times CF \times 0.001) / (WAB \times ATn)}$$

Where, EF is the exposure frequency (365 days/year), ED is the exposure duration (70 years for adult), FIR is the fish ingestion rate (49.5 g/person/day), CF is the conversion factor (0.208) to convert fresh weight (Fw) to dry weight (Dw) considering 79 % of moisture content in fish, CM is the heavy metal concentration in fish (mg/kg, dry weight), WAB is the average body weight (bw) (70 Kg), ATn is the average exposure time for non-carcinogens (365 days x 70 years) i.e., ATn= 25,550 days and 0.001 is unit conversion factor [28,29] The overall data employed for the calculation of EDI and finally to calculate the target hazard quotient (THQ) by using the formula [28] as presented in equation 4:

Equation 4:

$$\mathbf{THQ = EDI / RfD}$$

Where EDI is estimated daily intake and RfD is the reference dose of the metal an estimate of the daily exposure to which the human population may be continuously exposed over a lifetime without an appreciable risk of deleterious effects.

Hazard index

The hazard index from THQ is expressed as the sum of the hazard quotients [28].

Equation 5:

$$\boldsymbol{HI = THQ(Pb) + THQ(Cd) + THQ(Cr) + THQ(Cu) + THQ(As) + THQ(Hg)}$$

Target Cancer Risk

TCR calculated by multiplying the oral carcinogenic potency slope of metal by its estimated daily intake was used to estimate the carcinogenic risk of metals for a lifetime [28].

Equation 6:

$$\mathbf{TCR = (CPSo \times EDI)}$$

Where, CPSo is the oral carcinogenic potency slope values (mg/kg/day) are 0.0085, 0.08, 0.5, 1.5, and 1.5 for Pb, Cd, Cr, Cu, As respectively and CPSo values for Hg was not established yet [28, 30].

3. Results

Table 3 summarizes the concentration (mg/kg, dry weight) of Pb, Cd, Cr, Cu, As and Hg in different types of commercial fish feeds which are commonly used in fish cultivation in Bangladesh.

The highest concentration of Pb was 7.08 mg/kg found in Mega fish feed and the lowest concentration was 4.56 mg/kg in Fresh fish feed. The mean concentration of Pb in analyzed feeds was 5.79 mg/kg, which was beyond the permissible limit 2.0, 1-5 and 5.0 mg/kg proposed by WHO, FAO [32] and EU respectively [31-33]. The concentration of Cd ranged from 0.23-1.28 mg/kg in different types of fish feeds. The mean concentration of Cd was 0.82 mg/kg in feeds which was within the allowable level stated by the different international organizations [31-33]. Chromium (Cr) was traced in all feed samples in this study.

Table 3: Concentration of Heavy Metals (mg/kg- dry weight) in Commercial Fish Feeds

No	Feed Sample ID	Brand of Fish Feeds	Pb	Cd	Cr	Cu	As	Hg
01	FF1	Fresh Fish Feed	4.56	0.74	5.13	14.74	0.15	0.08
02	FF2	Teer Fish Feed	4.79	0.23	4.00	11.23	0.21	0.05
03	FF3	ACI Fish Feed	5.43	0.62	4.56	20.62	0.09	0.16
04	FF4	Quality Fish Feed	6.54	1.01	6.09	20.21	0.17	0.19
05	FF5	Saudi Bangla Feed.	5.37	0.80	5.98	12.80	0.14	0.34
06	FF6	Mega Fish Feed	7.08	1.28	7.08	18.68	0.08	0.09
07	FF7	Mesh Fish Feed	6.74	1.07	5.63	17.29	0.34	0.15
Mean Value			5.79	0.82	5.50	16.51	0.17	0.15
Safe Limit (mg/kg)		WHO [31]	2.0	1.0	1.0	30	---	0.1
		FAO [32]	1-5	2.0	1.0	30	---	0.1
		EU [33]	5.0	2.0	1.0	30	1.0	---

The highest amount of Cr was 7.08 mg/kg recorded in Mega fish feed and the least value was 4.00 mg/kg found in Teer fish feed. The safe limit of Cr is 1.0 mg/kg for animal feed stated by WHO [31] whereas the mean value of Cr in feeds recorded 5.50 mg/kg. Copper is an essential metal but its high concentration can lead to various health diseases. The maximum permissible limit of Cu is 30 mg/kg by FAO and EU [32, 33] but the average concentration in fish feeds was recorded as 16.51 mg/kg. The highest concentration of Cu was 20.62 mg/kg in ACI fish feed whereas the lowest concentration was 11.23 mg/kg in Teer fish feed. Arsenic (As) and Mercury (Hg) was recorded 0.08-0.34 mg/kg and 0.05-0.34 mg/kg in analyzed feeds. The recorded mean value of As was 0.17 mg/kg in feeds which was below the safe limit of 1.0 mg/kg proposed by EU but the analyzed mean value of Hg was 0.15 mg/kg exceeded the safe limit of 0.1 mg/kg of WHO and FAO [31, 32].

Table 4: Concentration of Heavy Metals (mg/kg- dry weight) in Cultivated Fishes

No	Fish Sample ID	Scientific Name of Fish Samples	Pb	Cd	Cr	Cu	As	Hg
01	F1	*Labeo rohita*	4.74	1.02	5.49	20.00	0.21	0.17
02	F2	*Hypophthalmichthys molitrix*	4.35	0.87	5.47	24.67	0.24	0.08
03	F3	*Puntius sarana*	5.96	1.08	4.71	31.80	0.17	0.27
04	F4	*Labeo calbasu*	7.43	1.31	8.46	22.50	0.18	0.33
05	F5	*Anabas testudineus*	6.67	0.96	8.98	14.00	0.24	0.41
06	F6	*Ctenopharyngodon idella*	6.65	1.26	7.58	21.70	0.28	0.19
07	F7	*Oreochromis niloticus*	8.03	1.35	8.03	28.60	0.28	0.17
Mean Value			6.26	1.12	6.96	23.32	0.23	0.23
Safe Limit (mg/kg)		WHO [31]	2.0	1.0	1.0	30	---	0.1
		FAO [32]	1-5	2.0	1.0	30	---	0.1
		EU [33]	5.0	2.0	1.0	30	1.0	---

The concentration (mg/kg, dry weight) of Pb, Cd, Cr, Cu, As and Hg in fish tissues were presented in Table 4. The mean concentration of Pb was 6.26 mg/kg in analyzed fish samples. The highest concentration was 8.03 mg/kg found in *Oreochromis niloticus* and the least concentration was 4.35 mg/kg in *Hypophthalmichthys molitrix.* Most of the fish samples exceeded the safe limit of 1-5 mg/kg stated by FAO [32]. The highest concentration of Cd was 1.35 mg/kg in *Oreochromis niloticus* whereas the lowest concentration, 0.87 mg/kg found in *Hypophthalmichthys molitrix*. The mean concentration of Cd was 1.12 mg/kg which was in acceptable limit according to WHO and FAO [31, 32]. In the present study, the highest amount of Cr was 8.98 mg/kg in *Anabas testudineus* and the lowest value was 4.71 mg/kg in *Puntius sarana.* According to the international safe limit for Cr in edible fish, all analyzed fish samples in this study exceeded the allowable limit of 1.0 mg/kg [31-33]. Copper (Cu) was ranged from 14.40 mg/kg to 31.80 mg/kg in analyzed fish tissues which was within the safe limit of 30 mg/kg [31-33]. The highest amount of As was 0.28 mg/kg recorded in *Ctenopharyngodon idella* and *Anabas testudineus* whereas the least value was 0.17 mg/kg recorded in *Puntius sarana.* The recorded values of As in each fish samples were within the safe limit proposed by EU [33]. Mercury (Hg) was traced in all analyzed fish samples and ranged from 0.08 mg/kg to 0.41 mg/kg. The mean concentration of Hg was 0.23 mg/kg in fish tissues which was higher than the safe limit of 0.1 mg/kg sated by WHO [31].

Accumulation of metal

Biological accumulation factor (BAF) represents the tendency of the fish to accumulate metal from its diet. Depending on this value fish can be hyperaccumulator (BAF > 1) or excluder (BAF < 1) [26]. In the present study, BAF was observed > 1 for all metals in all analyzed fish species which suggested that that analyzed all fish species had a strong tendency to accumulate metals from the diet (Table 5). Besides, other environmental factors like; water and sediment may be also responsible for high bioaccumulation.

Table 5: Bioaccumulation Factor Value of Analyzed Metals in Different Fishes

Fish Samples ID	**Bioaccumulation Factor (BAF)**					
	Pb	Cd	Cr	Cu	As	Hg
F1	1.03	1.30	1.07	1.46	1.4	2.10
F2	0.92	3.70	1.30	1.13	1.14	0.53
F3	1.09	1.74	1.03	1.18	1.80	1.60
F4	1.10	1.20	1.40	1.29	1.05	1.70
F5	1.20	1.20	1.50	1.03	1.71	1.20
F6	0.94	0.98	1.07	1.20	1.50	1.20
F7	1.19	1.26	1.42	1.09	1.16	1.0

Result of Statistical Analysis

The correlation coefficient is calculated by using MS Word (Redmond, WA, 2007) denoted by r, which helps to measure the strength and direction of two variables by establishing a linear relationship. The value stands between +1 and -1 where +1 indicates a positive relationship and -1 indicates a negative relationship Positive relationship means one variable rise in value, the other value also increases. In addition, a negative relationship means one variable in value increases, the other value decreases. If the correlation value is greater than 0.8 indicating a strong correlation and less than 0.5 suggesting weak correlation [34].

Table 6: Correlation Matrix between Metal Concentrations in Fish Feeds

	Pb	**Cd**	**Cr**	**Cu**	**As**	**Hg**
Pb	1					
Cd	0.85	1				
Cr	0.76	0.93	1			
Cu	0.17	-0.11	-0.21	1		
As	0.14	-0.02	-0.21	0.52	1	
Hg	0.10	0.19	0.31	0.41	-0.07	1

Table 7: Correlation Matrix between Metal Concentrations in Fishes

	Pb	Cd	Cr	Cu	As	Hg
Pb	1					
Cd	0.84	1				
Cr	0.76	0.48	1			
Cu	0.40	0.08	0.08	1		
As	0.47	0.55	0.37	0.15	1	
Hg	0.48	0.10	0.57	0.12	-0.35	1

Table 6 shows a strong positive correlation between Pb-Cd (r2= 0.85), Pb-Cr (r2= 0.76) and Cd-Cr (r2= 0.93) in fish feed. Table 7 shows also a strong positive correlation between Pb-Cd (r2= 0.84) and Pb-Cr (r2= 0.76) in fish samples. The strong positive correlation suggested that these metals had similar sources and levels of pollution. In contrast, both types of samples showed a strong negative correlation for As-Hg.

Table 8: Analysis of Variance for analyzed metals (mg/kg, dry weight) in feed and fishes.

Metals	P -value	F-value
Pb	0.06	0.52
Cd	0.03*	3.51
Cr	0.08	2.38
Cu	0.001*	0.71
As	0.44	0.24
Hg	0.008*	0.71

*Significant at $P< 0.05$

Table 8 interpreted the result of analysis of variance (ANOVA) where there was no significant variance in the recorded concentration of Pb (0.06), Cr (0.08) and As (0.44) in the selected fish species and feeds but a substantial variance was found for Cd (0.03), (0.001) and Hg (0.008).

Health Risk Estimation

The estimated THQ values for selected metals due to the daily consumption of these analyzed fishes were presented in Table 9. According to USEPA, if THQ>1, the risk of a non-carcinogenic effect is considered high [28]. The recorded THQ values were lower than 1 for each analyzed metals in the studied fish species. As a result, it was clear that the consumption of these toxic metals via the consumption of these cultivated fishes should have no potential non-carcinogenic health risk. In contrast, total THQ or HI in all species was higher than 1 except L. rohita and H. molitrix indicating potential non-carcinogenic risk but HI might overestimate the potential for non-cancer health effects. Table 10 shows the target cancer risk (TCR) values for humans due to the consumption of the analyzed fish samples. If TCR value exceeds 1x10-4 is considered as intolerable, the values lower than 1x10-6 is considered as safe.

Table 9: Target Hazard Quotient of Heavy Metals from the consumption of Different Types of Cultivated Fishes

Metal	**RfD (mg/kg/day)**	**Target Hazard Quotient (THQ)**						
		F1	F2	F3	F4	F5	F6	F7
Pb	0.002	0.35	0.32	0.44	0.55	0.49	0.49	0.59
Cd	0.001	0.15	0.13	0.16	0.19	0.14	0.19	0.20
Cr	1.5	0.001	0.001	0.001	0.002	0.002	0.002	0.002
Cu	0.04	0.13	0.20	0.23	0.17	0.21	0.15	0.25
As	0.0003	0.10	0.11	0.08	0.08	0.11	0.23	0.23
Hg	0.0001	0.25	0.11	0.39	0.48	0.60	0.27	0.24
Total THQ or HI		0.981	0.871	1.301	1.472	1.552	1.332	1.512

Table 10: Target Cancer Risk of Heavy Metals from the consumption of Different Types of Cultivated Fishes

Metal	CPS_o (mg/kg/ day)	Target Cancer Risk (TCR)						
		F1	F2	F3	F4	F5	F6	F7
Pb	0.0085	4.0×10^{-6}	3.6×10^{-6}	5.0×10^{-6}	6.3×10^{-6}	5.6×10^{-6}	5.5×10^{-6}	6.8×10^{-6}
Cd	0.38	3.8×10^{-5}	3.3×10^{-5}	4.1×10^{-5}	4.9×10^{-5}	3.6×10^{-5}	4.7×10^{-5}	5.1×10^{-5}
Cr	0.5	2.7×10^{-5}	2.6×10^{-5}	2.3×10^{-5}	4.2×10^{-5}	4.5×10^{-5}	3.8×10^{-5}	4.0×10^{-5}
Cu	1.5	5.1×10^{-4}	8.0×10^{-4}	9.3×10^{-4}	6.8×10^{-4}	8.4×10^{-4}	6.1×10^{-4}	9.3×10^{-4}
As	1.5	3.1×10^{-5}	3.6×10^{-5}	2.1×10^{-5}	2.3×10^{-5}	3.6×10^{-5}	4.2×10^{-5}	4.2×10^{-5}

USEPA stated that TCR values between 1x10-4 and 1x10-6 are permissible [28]. The present study recorded that TCR values within the permissible limit for each analyzed fish samples indicating no cancer risk via the ingestion of these cultivated fish species. Accumulation of heavy metals in fish species may be happened by feed contamination, water and sediment. The limitation of this present study was that toxic metals in water and sediment should be assessed

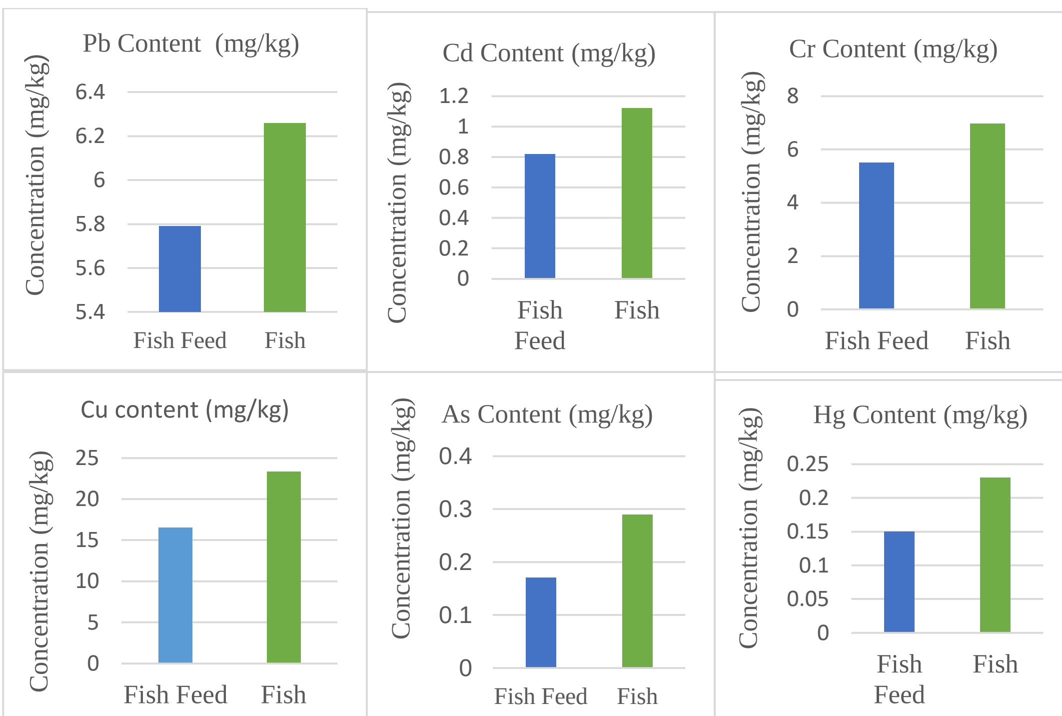

Fig 1: Mean Concentration (mg/kg, dry weight) comparison of each analyzed metal from fish feed to fish

Discussion

In the present study, Pb concentration was recorded in all feed and fish samples with no significant variance, P> 0.05 (Table 8). The mean concentration of Pb recorded in fish feeds was higher than 0.36 mg/kg reported by Munshi et al [35]. In addition, the average Pb content in cultivated fish samples recorded also higher than 1.45 mg/kg recorded by Mohammad et al [36]. Pb content in the analyzed samples decreased in the order of fish > feed and the increased rate of Pb in fishes was 8.1% from their respective feeds on average due to high bioaccumulation.

The range of Cd concentration in feed (0.23-1.28 mg/kg) and fish (0.87-1.35 mg/kg) with significant difference ($P < 0.05$) was recorded in this study. The concentration range of Cd in commercial feeds was higher than the levels reported by Mannan et al. (0.02-0.03 mg/kg) and in the case of fish samples, the found range of Cd was also higher than 0.09-0.87 mg/kg recorded by Rahman et al [24,37]. The mean concentration of Cd in fish samples was 36.5% more than their consumed fish feeds (Fig 1). Cadmium content found in the current study was higher than those reported by Abalaka et al. (0.04-0.26 mg/kg) and D. Qin et al. (ND- 0.130 mg/kg) [38,39].

Chromium (Cr) was traced in all analyzed samples in this study without any significant difference, $P> 0.05$ (Table 8). The Chromium concentrations in analyzed feed samples recorded in the present study were lower than those reported by Munshi et al. (15.03 mg/kg) [35]. In addition, the mean Cr content in fish samples was also lower than 7.58 mg/kg reported in Nigeria by Abalaka et al [38]. Due to the high bioaccumulation rate, Cr content increased by about 26.54% in fish compared to feed (Fig 1). Few studies recorded Cr concentration in different fish species was higher than the present study by Hossain et al. (9.29-11.73 mg/kg) Koleleni et. al. (16.1–20.7 µg/g) [8, 40].

A significant amount of Copper (Cu) was recorded in all analyzed fish and feed samples with significant metal concentration variation, $P< 0.05$ (Table 8). The mean concentration of Cu in analyzed fish samples was about 41.24% more compared with their respective feeds. The found range of Cu content in analyzed feed samples was lower than reported by Fatema et al. (8.21-18.25 mg/kg) and similar to Hossain et al. (4.85-33.84 mg/kg) [8, 23]. In addition, Cu concentration found in fish samples was also close to comparing with previous studies in different countries by Aladesanmi et al. (132.23-302.02 µg/kg) and Abalaka et al. (0.23-21.33 mg/kg) [2, 38].

A little amount of arsenic (As) was recorded in each cultivated fish samples and their respective feed samples without any significant difference, $P> 0.05$. The concentration ranges of As in the analyzed feed and fish were 0.08- 0.34 mg/kg and 0.17-0.28 mg/kg respectively but the As content reported below the detection limit in both fish and fish feed by Aladesanmi et al., Sabbir et al [2, 22]. Inorganic As can lead to various diseases in the lung, bladder and skin as well as decrease IQ scores of Children [20]. Since the As bioaccumulation rate was high in this study, 35% more As was accumulated in fish than feed.

This study observed a noticeable amount of Hg was accumulated in cultivated fish samples from the feed with significant variation ($P<0.05$) due to the high bioaccumulation rate. Mercury was recorded in feed from 0.05 mg/kg to 0.34 mg/kg which was similar to the value reported by Berntssen et al. (0.03- 0.63 mg/kg) [41]. The concentration range of Hg in the analyzed fish samples was 0.08- 0.41 mg/kg was higher than the values reported in Northeast China (ND- 0.175 mg/kg) [39]. In contrast, Koleleni found As concentration in fish muscles between the range of 1.2-2.4 mg/kg which was substantially bigger than the present study [40].

Conclusion

A significant amount of analyzed metal translocated in analyzed all fish species from fish feeds due to the high bioaccumulation rate. The recorded results revealed that the content of Pb, Cr, Hg in the selected fish feeds and fish samples was beyond the acceptable level, though the Cd, Cu and As content in these selected samples was below the maximum acceptable limit of the different international organization. Industrial development and anthropogenic activities may be responsible to contaminate the food chain. The presence of a high amount of toxic metals in selected fish species may pose a significant risk to human health. However, the concentration of few selected metals exceeded the safe limit, the calculated target hazard quotient and target cancer risk for each selected metals in all analyzed fish species within the tolerable limit of USEPA, indicating no carcinogenic and non-carcinogenic risk to humans due to daily ingestion. It is not fully possible to avoid toxic metal pollution in the aquatic food chain but the food quality control authority, policymakers and fish farm owners should take necessary steps to monitor the feed quality to prevent major heavy metal pollution in cultivated fishes in Bangladesh.

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