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BIOACCUMULATION OF HEAVY METAL IN FARMED TILAPIA AND SHRIMP IN SATKHIRA DISTRICT, SOUTHWEST BANGLADESH

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Abstract

Fish farmers in the Satkhira district, southwest Bangladesh, are progressively moving towards intensive aquaculture, and heavy metal contamination of the feed may frequently occur. This study explores the bioaccumulation of heavy metal in farmed tilapia *(Oreochromis mossambicus)* and shrimp species such as bagda *(Penaeus monodon)*, golda *(Macrobrachium rosenbergii)*, randomly collected from 3 *gheer* at Assasuni and Debhata Upazilla in Satkhira, Bangladesh from December 2020 to March 2021. The levels of elements including Fe, Mn, Zn, Cu, Cr, Cd, Pb, and As were evaluated using the flame-AAS and HG-AAS methods followed by Nitric Acid (HNO_3)-Perchloric Acid ($HClO_4$) digestion. The results revealed that the concentrations of Fe, Mn, Cr, and As were higher than the WHO and FAO recommended levels. Maximum concentrations (mg/kg) of Fe, Mn, Cr, and As were observed as 104.00 ± 8.30 in Tilapia (*O. mossambicus*) from *gheer* #3, 3.40 ± 1.71 in Tilapia (*O. mossambicus*) of *gheer* #3, 12.80 ± 1.45 in golda (*M. rosenbergii*) of *gheer* #1, and 1.96 ± 0.09 in Tilapia (*O. mossambicus*) from *gheer* #3, respectively. But on average, *M. rosenbergii* was discovered to contribute more to the maximum level of almost every metal compared to the other two species, whereas species from *gheer* #3 were found to be more contaminated. Overall, tilapia and shrimp from all three *gheer* were considered unsafe for consumption. More research is recommended for estimating the levels of heavy metal accumulation in fish and shrimp over a longer time period and across a wider geographic range.

Keywords: Heavy metal, bioaccumulation, shrimp, Tilapia, fish feed, Satkhira.

Introduction

Bioaccumulation is the process of deposition of a pollutant with increasing concentration inside the tissue of living organisms as a result of rapid consumption or unambiguous absorption from the water rather than excretion (Fatema et al. 2019 and Nyamete *et al.* 2020). According to Ali and Khan (2018), naturally formed elements having an atomic number higher than 20 as well as an elemental density higher than 5 g/cm^3 are referred to as heavy metals, while the bioaccumulation of heavy metals in biological tissues is the transmission of contaminants through different hierarchical levels in an ecosystem (Fatema *et al.* 2019). Bangladesh is one of the countries with the densest populations in the world, and the majority of its population depends either directly or indirectly on agriculture. According to the FAO report, *The State of World Fisheries and Aquaculture 2020*, Bangladesh has achieved a significant milestone in the development of aquaculture and is ranked 3rd in inland open water capture production and 5th in world aquaculture production (FAO 2020). Fish is a vital component of many natural food webs and a valuable source of protein for humans, as well as being high in biologically important proteins, fats, and fat-soluble vitamins. Shrimp consumption has grown as people have come to recognize the need for a balanced diet and the nutritional significance of elements like high protein content, vitamin D, vitamin B_3, and zinc, all of which are advantageous to one's health (Aremu and Ekunode 2008 and Copat et al. 2011). However, pollutants in aquatic environments have grown to be a serious problem because they may accumulate in aquatic food acquired from the adjoining environment (Ahmed et al. 2019).

Impetuous industrial expansion and economic advancement have led to the continuous discharge of several synthetic and geogenic substances into aquatic environments. Heavy metals are assigned higher precedence as contaminants among the potentially harmful components that enter these systems because of their toxic effects, endurance, and ability to enter the food webs through bioaccumulation and biomagnification. As a result, they constitute a significant global public health issue that endangers both aquatic life and human health as well as the environment as a whole (Sun et al. 2018 and Raknuzzaman et al. 2016). Health hazards from ingesting tainted aquatic foods are growing globally at an alarming rate, especially in poor third-world nations like Bangladesh (Ahmed et al.

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2019). An accumulation of these trace elements can have severely adverse effects on the liver, kidneys, central nervous system, mucosal tissues, digestive tract, and reproductive systems. Aside from their poisonous and cancer-causing effects on people and animals, several metals are crucial for maintaining appropriate cell function (Fatema et al. 2015). Fish farmers in Bangladesh are gradually transitioning from no feed to factory-made feeds by using farm-made feeds, while the use of suitable feeds is essential for the success of both exaggerated and semi-exaggerated fish production (Nasim et al. 2012). Some feed manufacturers those who produce feed commercially have fallen short to meet the required standard needed for fish meal. The raw materials used to make the feeds, such as tannery and poultry wastes, which are regularly employed as an affordable source of fish food, are frequently contaminated with heavy metals. The usage of these kinds of feed sources might potentially raise the amounts of hazardous components like Pb, Cd, and Cr in farmed fish and endanger public health (Shamshad et al. 2009 and Kundu et al. 2017).

Certain authors in Bangladesh have examined the aquatic species, water, and sediment (Sarkar et al. 2016, Bhuyan et al. 2016, Kundu et al. 2017, Das et al. 2017, Ahmed et al. 2019, and Akter et al. 2020) to find the levels of some heavy metal in specific rivers for a number of certain organisms. Information on the contamination of metal in farmed shrimp and tilapia in the Satkhira region, which are produced using contaminated water and other artificial feeds, is scarce. This important gap forced us to find the heavy metal contamination in the farm-reared tilapia and shrimp. The present investigation was therefore designed to determine the degree of metal contamination in farm-produced bagda shrimp *(P. monodon)*, golda shrimp *(M. rosenbergii)*, and tilapia *(O. mossambicus)* regarding bioaccumulation of metals such as Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Arsenic (As).

Materials and Methods

Study area

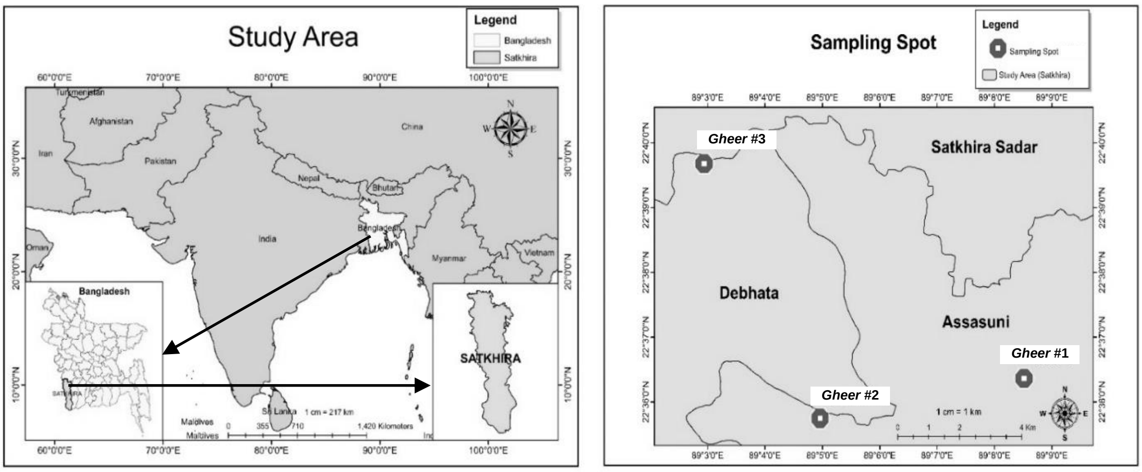

Figure 1. Location of the Study Area

Three different *gheer* such as *gheer* #1 (22° 36' 21.79" N and 89° 08' 30.78" E), *gheer* #2 (22° 35' 42.76" N and 89° 04' 57.42" E) and *gheer* #3 (22° 39' 47.05" N and 89° 03' 03.42" E) situated at Assasuni and Debhata Upazilla of Satkhira District, were randomly selected for sample collection to perform this study.

Collection and preservation of sample

Cultivated fish and shrimp sample collection, preparation, and storage were conducted by following Islam et al. (2016), Sarkar et al. (2016), Bhuyan et al. (2016), Kundu et al. (2017), Das et al. (2017), and Ahmed et al. (2019). Samples of fish and shrimp were properly cleansed with distilled water straight immediately following collection. And the edible parts of the fish and shrimp (muscle tissues) were diced and oven dried at (70-80) °C to get a consistent weight. Prior to laboratory testing, the dried fish and shrimp samples were crushed and powdered before being screened through a 2 mm nylon mesh and preserved in sterile, sealed plastic containers in the refrigerator.

Preparation and digestion of sample
Digestion of fish and shrimp samples was done by following the Nitric Acid (HNO_3)-Perchloric Acid ($HClO_4$) digestion method (APHA 1998). Further treatment was conducted with 3 ml of Sulfuric Acid (H_2SO_4) and 3 ml of 30% H_2O_2 until adequate digestion was completed and the solution turned colorless (Islam et al. 2016). After being digested, the solution was poured into immaculate volumetric flasks. To precisely create 100 ml of each solution, double-distilled water was added. The solutions were filtered with Whatman Filter Paper No. 42. All experimental supplies and equipment were subsequently washed by immersing them overnight in a 10% nitric acid solution, followed by a deionized water rinse.

Determination of heavy metal concentration
By using the flame-AAS technique (AA-7000, Shimadzu, Japan), the concentrations of Fe, Mn, Zn, Cu, Cr, Cd, and Pb were directly measured, while the hydride vapor generation (HG-AAS) method was employed to determine the level of As (APHA 1998). The average findings of the triple analyses of each sample were utilized to represent the data. In order to determine the concentrations of heavy metal, the formula shown below was utilized (Ali *et al.* 2012):
Metal concentration in a sample (mg/kg) =

$$\frac{Concentration\ observed\ (ppm) \times Final\ volume\ of\ sample\ (ml)}{Weight\ of\ sample\ tissue\ taken\ (g)}$$

Results and Discussion
A diverse variety of concentrations of heavy metal were recorded in the 3 tested species. The level of heavy metal (Fe, Mn, Zn, Cu, Cr, Cd, Pb and As) bioaccumulation (mg/kg) in bagda shrimp (*P. monodon*), golda shrimp (*M. rosenbergii*), and tilapia (*O. mossambicus*) collected from three different fish farms (*gheer*) is presented in Table 1.

Iron (Fe)
Iron (Fe) is essential for most life on Earth, including humans, since it plays a part in a number of metabolic functions, including the production of red blood cells, transportation of oxygen, DNA synthesis, and electron transport but excess intake of Fe may affect the human body in various ways such as DNA damage, gastrointestinal problems (Gupta 2014). On a dry weight basis, the highest Fe content was (104 ± 8.30) mg/kg in tilapia (*O. mossambicus*) from the *gheer* #3 and the minimum value was recorded (39.40 ± 2.75) mg/kg in bagda shrimp (*P. monodon*) of the *gheer* #2 (Figure 2). Except for two species from *gheer* #3 like *O. mossambicus* and *M. rosenbergii*, the average concentrations of Fe in all the species from all the *gheer* were reasonable and not particularly dreadful.

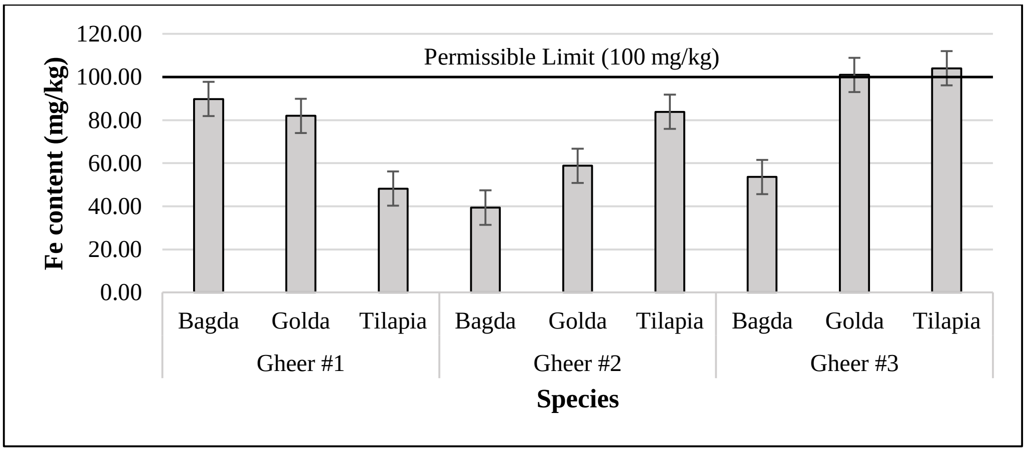

Figure 2. Fe bioaccumulation (mg/kg) in species

The recommended guideline value for Fe concentration in food by the WHO (1989), as mentioned in Mokhtar et al. (2009), is 100 mg/kg. Golda shrimp (*M. rosenbergii*) contributed to the uppermost concentration level of Fe (80.60 ± 21.13 mg/kg) which is still below the highest allowable level, whereas the lowest value of Fe (60.93 ± 25.99 mg/kg) went to bagda shrimp *(P. monodon)* (Table 1). Iron content in fish fluctuated between (136.241 - 200.26) mg/kg in an investigation carried out in Mymensingh by Kundu *et al.* (2017), which is higher than our findings. Variations in the physicochemical state of the water, sediment, and feeding practices of various regions may also be responsible for the

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concentration variance observed in this research and other investigations. Kundu et al. (2017) reported the level of Fe (475.878 - 10004.855 mg/kg), which seems higher than the outcome of the present investigation. According to Mokhtar et al. (2009), intensive agricultural activities may contribute to higher concentration of Fe in species in this study.

Manganese (Mn)

Mn, a trace metal, is a crucial element for human life, and the typical human body has roughly 12 mg of Mn (Teodorovic et al. 2000). While Mn insufficiency causes skeletal and fertility issues, excessive Mn consumption can lead to psychiatric and neurological ailments (Ahmed et al. *2016*). In this investigation, Mn levels in several samples of farmed species exceeded the WHO and FAO-recommended maximum allowable limit of 1 mg/kg (WHO 1989, FAO 1983), as mentioned in Mokhtar et al. (2009) and Ahmed et al. (2016), respectively. Mn concentration was measured and ranged from 0.60 ± 0.38 to 3.40 ± 1.71 mg/kg (Fig. 3). The highest (3.40 ± 1.71 mg/kg) and lowest (0.60 ± 0.38 mg/kg) Mn content were recorded in tilapia (*O. mossambicus*) collected from the *gheer* #3 and bagda shrimp *(P. monodon)* collected from the *gheer* #2, respectively.

The findings denote that the maximum Mn level (2.27 ± 1.21 mg/kg) was determined in tilapia (*O. mossambicus*), and golda shrimp *(M. rosenbergii)* represented the lowest Cd concentration (1.27 ± 0.46 mg/kg) (Table 1). Consumption of fish having an excess amount of Mn may cause harm to the human body. In the earlier studies conducted by Bhuyan et al. (2016), the highest concentration of Mn was recorded in *Tetraodon cutcutia* (19.07 mg/kg) and the lowest was found in *Ctenopharyngodon idella* (0.96 mg/kg) collected from the Meghna river in Narsingdi district, and it was concluded that the area around the Meghna River was contaminated by numerous heavy metal released from diverse manufacturing, municipal, and agricultural activities. Mn exists instinctively in nature as mentioned by Ahmed et al. (2016) that can enter into aquatic systems while extensive use of agrochemicals may contribute to the higher recorded level of Mn in this study.

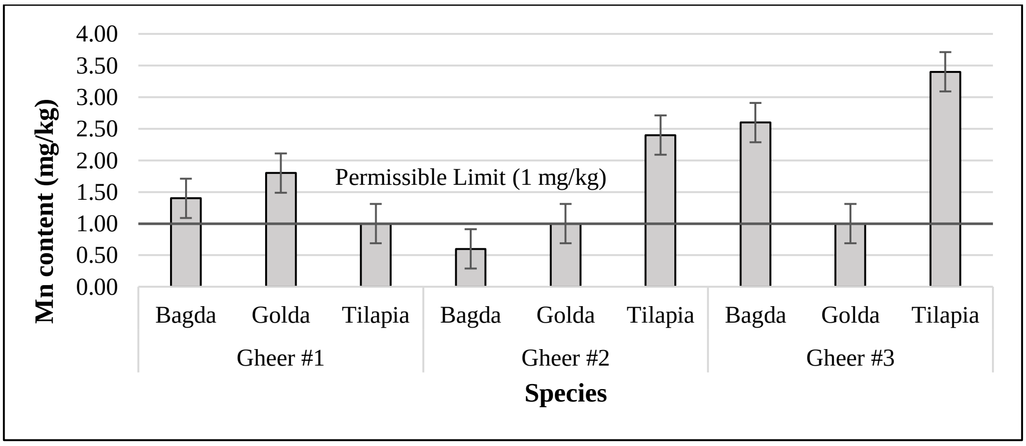

Figure 3. Mn bioaccumulation (mg/kg) in species

Table 1. Metal content (mg/kg) in selective species from *gheer* in Satkhira area, guideline values and literature review

	Species		**Metal concentration (mg/kg)**							
	Local Name	**Scientific Name**	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Copper (Cu)	Chromium (Cr)	Cadmium (Cd)	Lead (Pb)	Arsenic (As)
Present Study	Bagda	*P. monodon*	60.93 ± 25.99	1.53 ± 1.01	25.27 ± 0.50	10.37 ± 5.61	8.53 ± 4.45	0.03 ± 0.01	0.15 ± 0.04	0.84 ± 0.41
	Golda	*M. rosenbergii*	80.60 ± 21.13	1.27 ± 0.46	25.33 ± 0.31	16.60 ± 9.17	9.47 ± 3.89	0.04 ± 0.01	0.18 ± 0.07	0.91 ± 0.17
	Tilapia	*O. mossambicus*	78.67 ± 28.25	2.27 ± 1.21	21.80 ± 0.53	1.87 ± 0.42	9.13 ± 5.15	0.04 ± 0.01	0.16 ± 0.02	1.39 ± 0.65
Guidelines										
FAO Standard (FAO 1983) as mentioned in Ahmed *et al.* (2016), Ahmed *et al.* (2019)			-	1	30	70	0.15	0.10	0.50	1
WHO Standard (WHO 1989) as mentioned in Mokhtar *et al.* (2009)			100	1	100	30	50	1	2	-
Bangladesh Standard (Fish) (MOFL 2014) as mentioned in Ahmed *et al.* (2019)			-	-	-	5	1	0.25	0.30	5
New Zealand (CEPA 1995-97) as mentioned in Raknuzzaman *et al.* (2016), Ahmed *et al.* (2019)			-	-	40	30	-	1	2	1
Turkey Standard (TFC 2002) as mentioned in Raknuzzaman *et al.* (2016), Ahmed *et al.* (2019)			-	-	50	20	-	0.10	0.30	-
Literature										
Fish farm, Noakhali (Das *et al.* 2017)			-	-	-	1.77 ± 0.74 - 2.70 ± 0.38	1.29± 0.54 - 0.42 ± 0.22	0.28 ± 0.16- 0.42 ± 0.22	2.76 ± 0.42 - 4.98 ± 1.27	-
Fish farm, Mymensingh (Kundu *et al.* 2017)			136.2-200.3	-	-	19.08-25.34	< 0.0001	9.08-10.45	-	-
Fish farm, Tala, Satkhira (Sarkar *et al.* 2016)			-	-	-	-	0.19 ± 0.01	0.96 ± 0.38	<0.1	<0.1
Fish farm, Tala, Satkhira (Fatema *et al.* 2017)			-	-	-	-	<0.1	<0.1	<0.1	<0.1
Fish market, Satkhira and Bagherhat (Islam *et al.* 2016)			-	-	-	-	<0.54	0.42-0.67	4.57-4.60	<0.30

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Zinc (Zn)

Zn being an integral part of various enzymes (Ahmed et al. 2016), the majority of human metabolic activities are known to require such as synthesis of several metallo-enzymes and physiological development (Akter et al. 2020), while its shortage can cause lack of appetite, delayed puberty, skin abnormalities, and immunological irregularities (Tuzen 2009). Akter et al. (2020) mentioned that after Fe (approximately 4 g), Zn (about 2.5 g) is the next element found in every system of the human body, with muscle tissue containing half of it. The levels of Zn in analysed farmed species ranged from (21.4 ± 3.69 to 25.8 ± 2.45) mg/kg (Figure 4).

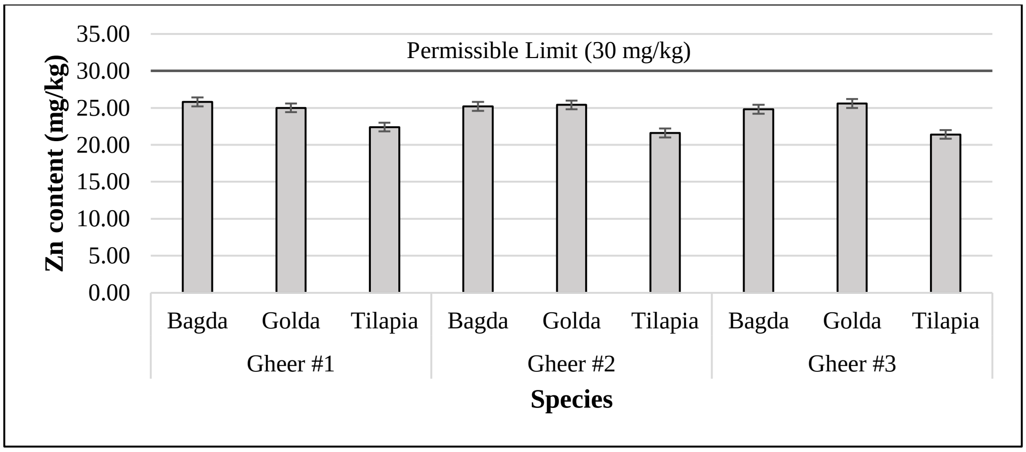

Figure 4. Zn bioaccumulation (mg/kg) in species

Moreover, the mean Zn concentrations (mg/kg) for golda shrimp (*M. rosenbergii*), bagda shrimp *(P. monodon)*, and tilapia (*O. mossambicus*) were (25.33 ± 0.31), (25.27 ± 0.50) and (21.80 ± 0.53), respectively (Table 1), which means that the Zn concentration of all the species under the current study is still below the maximum permissible limit (100 mg/kg, 30 mg/kg) recommended by WHO (1989) and FAO (1983) as mentioned in Mokhtar et al. (2009) and Ahmed et al. (2016), respectively. The highest Zn content (25.8 ± 2.45 mg/kg) was found in bagda shrimp (*P. monodon*) collected from the *gheer* #1 while the lowest (21.4 ± 3.69 mg/kg) was determined in tilapia *(O. mossambicus)* collected from the *gheer* #3. Regarding the Zn content, none of the species falling under this investigation were discovered to be frightful.

Copper (Cu)

Despite being a necessary component for maintaining health, particularly in the production of hemoglobin and a few necessary enzymes, Copper overdose can impair the activities of the liver and kidneys (Vu et al. 2017 and Baki et al. 2018). Copper (Cu) concentration was varied on a dry weight basis from (1.40 ± 0.21 to 24.00 ± 2.91) mg/kg. The highest and lowest value were measured in golda *(M. rosenbergii)* collected from the *gheer* #3 and tilapia *(O. mossambicus)* collected from the *gheer* #1, respectively. The variation of Copper (Cu) concentration (mg/kg) in studied species from different fish farms is shown in Figure 5.

The mean Cu content for all of the specimens were rational and not overly alarming. The fact is that they met the minimum level, which was less than the suggested level (30 mg/kg) given by WHO (WHO 1989) as mentioned in Mokhtar et al. (2009). It is clear that the maximum contamination level of Cu (16.60 ± 9.27) mg/kg was observed in golda shrimp (*M. rosenbergii*) and the minimal level (1.87 ± 0.42 mg/kg), was detected in tilapia (*O. mossambicus*) (Table 1). The MOFL (2014)-established acceptable value of 5 mg/kg is exceeded by the species bagda shrimp (*P. monodon*) and golda shrimp (*M. rosenbergii*), as mentioned in Ahmed et al. (2019). TFC (2002) and CEPA (1995–1997) established further acceptable limits of 30 mg/kg and 20 mg/kg for Cu, respectively (Raknuzzaman et al. 2019 and Ahmed et al. 2019).

According to ATSDR (2004), Cu has a maximum suggested level of 1.0 mg/day for children (1–3 years old) and 10 mg/day for males and females (19–70 years old) due to its status as a trace metal, while the liver and kidneys may be damaged if the dose is exceeded. In the prior research, the mean Cu concentration (4.97 ± 1.13 mg/kg) was measured in fish collected from the Meghna river, conducted by Ahmed et al. (2019), and a range of 1.77 ± 0.74 to 2.70 ± 0.38 mg/kg was estimated in fish collected from different fish farms in Noakhali (Das et al. 2017), were less than our readings. In contrast, a range, 19.073–25.343 mg/kg was estimated for the fish farms in the Mymensingh district of Bangladesh (Kundu et al. 2017), which was higher than our results.

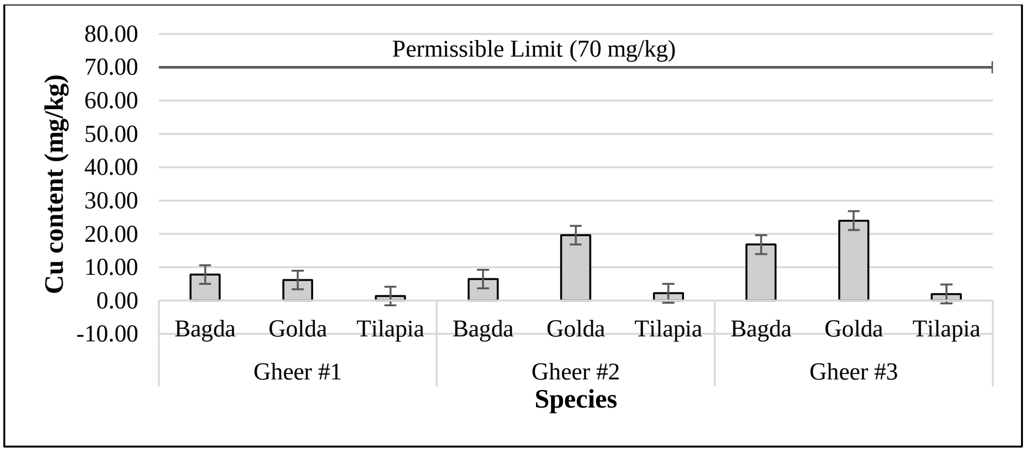

Figure 5. Cu bioaccumulation (mg/kg) in species

Chromium (Cr)

Dietary Cr is inevitable to properly metabolise lipids and glucose (Mertz 1969 and Velusamy et al. 2014). Cr insufficiency can impede growth and hinder the synthesis of lipids, proteins, and glucose and on the other hand, excessive ingestion of Cr has been linked to acute respiratory problems as well as organ damage in the liver, lungs, and kidneys (Forti et al. 2011). Each of the studied species surpassed the acceptable values of 0.15 mg/kg (FAO 1983), and 1.0 mg/kg MOFL (2014) as mentioned in Ahmed *et al.* (2019) and Mokhtar et al. (2009), respectively. The level of Cr content (mg/kg) was measured on a dry weight basis and ranged from 3.20 ± 0.18 to 12.80 ± 1.45 (Figure 6).

For species, golda shrimp (*M. rosenbergii*) contributed to the uppermost concentration level of Cr (9.47 ± 3.89) mg/kg), which is almost 9 times higher than the maximum allowable limit, in contrast to the minimum Cr concentration level (8.53 ± 4.45 mg/kg) went to bagda shrimp *(P. monodon)* (Table 1). The golda shrimp *(M. rosenbergii)* collected from the *gheer* #1 led to the highest degree of Cr content (12.80 ± 1.45 mg/kg), while the tilapia *(O. mossambicus)* collected from the *gheer* #1 had the lowest value (3.20 ± 0.18 mg/kg). According to Ahmed *et al.* (2019), the level of Cr content was recorded between 0.62 - 1.19 mg/kg in fish species from the Meghna river and Das *et al.* (2017) observed (1.29 ± 0.54 - 1.93 ± 1.50) mg/kg of Cr content in fish specimens from fish farms in Noakhali district, Bangladesh. According to Fatema et al. (2015), shrimp species from the river and shrimp farms of Tala Upazilla, Satkhira have Cr concentrations ranging from 0.156 - 0.338 mg/kg in bagda and harina shrimp. Thus, our finding surpassed the Cr concentration observed by Ahmed et al. (2019), Das et al. (2017), and Fatema et al. (2015) (Table 1). The application of chemical fish feed contaminated with hazardous metals, as indicated by Shamshad et al. (2009), may be responsible for the elevated level of Cr in the species under this research.

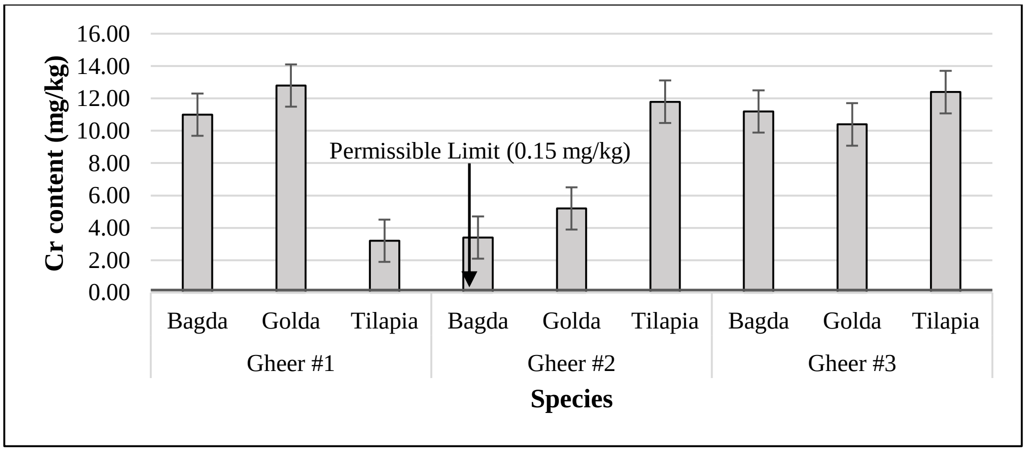

Figure 6. Cr bioaccumulation (mg/kg) in species

Cadmium (Cd)

Usually available at a degree of just 1 mg/kg, Cd can cause persistent poisoning (Roels et al. 1981). As a result of prolonged or excessive contact, Cd may have been linked to collapse of the renal system, skeletal weakening, and prostate carcinoma (Ahmed *et al.* 2016). According to Ahmed *et al.* (2019) the highest allowable limit of Cadmium (Cd) in fish is 0.25 mg/kg MOFL (2014), and 0.10 mg/kg FAO (1983). The content (mg/kg) of Cd in shrimp and tilapia was varied from 0.02 ± 0.002 to 0.06 ± 0.003, which is shown in Figure 7. This research documented that the Cd in the tested species from all fish farms were still lower than the permissible limits suggested by the Codex Committee on Food Additives (FAO 1983). The permitted level (0.05 mg/kg) specified by the regulations of the European Community was surpassed each of the examined species (EC 2001).

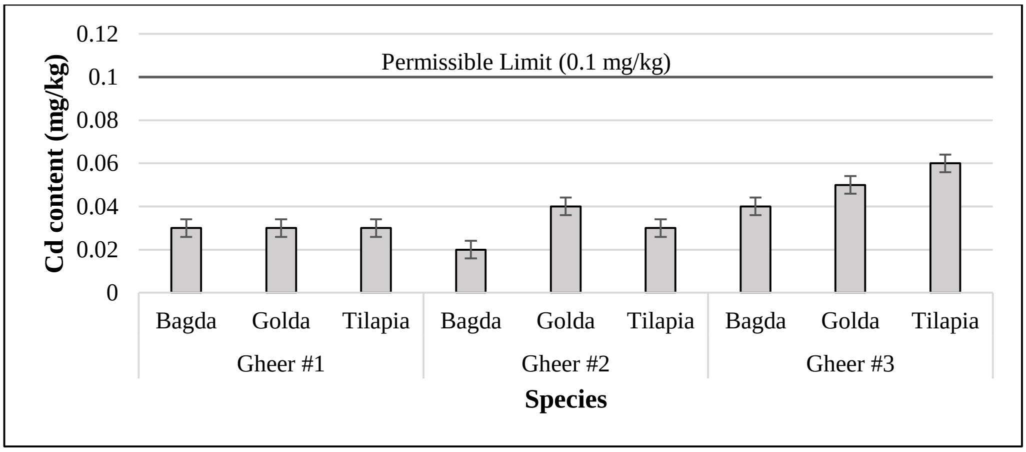

Figure 7. Cd bioaccumulation (mg/kg) in species

Additionally, the mean value of Cd in shrimp and tilapia was lower than the permissible levels conferred by CEPA (1995-97) and TFC (2002), while the induced level is 0.10 mg/kg, and 1 mg/kg, respectively, as mentioned in Raknuzzaman et al. (2016), and Ahmed et al. (2019). In a research by Kundu et al. (2017), Cd was detected in species and fluctuated between 9.083 and 10.453 mg/kg, exceeding our findings. But compared to other coastal locations, Raknuzzaman et al. (2016) demonstrated that the degree of metal content in the fish species was greater. Sarkar et al. (2016) identified an average Cd content of 0.13 mg/kg in the shell as well as 0.09 mg/kg in the muscle of *M. rosenbergii* at fish farm at Paikgacha, Khulna. The *M. rosenbergii* species near the Rupsha River in Khulna had the lowest concentration (0.05 mg/kg) in tissue, which also surpassed our findings. However, the Cd concentration in the studied species is still lower than the permissible levels conferred by FAO (1983). Despite being present in nature at relatively low concentrations instinctively, factory operations (such as casting or electroplating) and the application of agrochemicals may contribute to raising levels (Ahmed et al. 2016 and Kundu et al. 2016). The releasing points of Cd may not have considerably contributed to heavy metal accumulation in the surrounding environment, which decreases the level of contamination in species in this study.

Lead (Pb)

FSANZ (2008) and the European Community (EC 2001) stated that the maximum allowable Lead (Pb) values in fish are 0.5 mg/kg and 0.2 mg/kg, correspondingly. On a dry weight basis, Pb concentration was obtained in a range of 0.11 ± 0.020 to 0.26 ± 0.031 mg/kg (Fig. 8). The maximum Pb content (0.26 ± 0.031) mg/kg in golda shrimp (*M. rosenbergii*) collected from the *gheer* #2, exceeded not only the previous two international standards, but also the national standard (0.30 mg/kg) provided by MOFL (2014). Nevertheless, no discernible variation between the 3 species sampled from 3 different *gheer* was observed. According to this investigation, the highest Pb concentration (0.18 mg/kg) was detected in golda shrimp (*M. rosenbergii*), while the minimum level of Pb content (0.15 mg/kg) was detected in bagda shrimp *(P. monodon)*.

On aggregate, the Pb content of several species was less than the standards of FAO (1983) and MOFL (2014), as well as the permissible levels of CEPA (1995–1997) and TFC (2002). In comparison to prior research, the mean Pb content in all species was lower. The range of Pb concentrations (2.91 mg/kg to 4.63 mg/kg) was found in the fish taken from the Meghna river (Ahmed et al. 2019). The Pb content (mg/kg) fluctuated between 6.787 to 16.386 in fish collected from fish farms in Mymensingh (Kundu et al. 2017). Despite the fact that aquatic species may acquire significant levels of Pb without clear differences to their form or productivity, lead is a poisonous element that can be damaging to them. Results suggest that all species from the *gheer* had Pb concentrations below the allowable limit, making them safe for ingestion. The potential sources of Pb pollution in aquatic systems are the waste discharge from a variety of factories, including printing, dyeing, oil refineries, batteries, and textiles, in the surrounding area, which may not significantly contribute in this area.

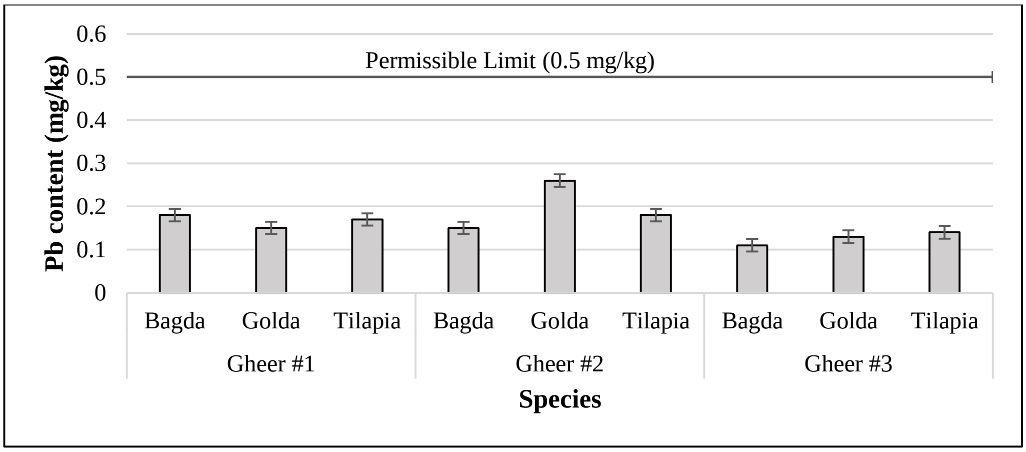

Figure 8. Pb bioaccumulation (mg/kg) in species

Arsenic (As)

The initial signs of acute arsenic poisoning are vomiting, stomach discomfort, and diarrhoea; in severe instances, these are followed by numbness and tingling in the extremities, cramping muscles, and death. Being exposed to As for prolonged term of time can culminate cancer of the skin, lungs, bladder, and kidney; and developmental effects, neurotoxicity, diabetes, and cardiovascular disease are all possible side effects of long-term ingestion of inorganic arsenic (Baki et al. 2018 and IARC 2009). According to this investigation, the level of As content was varied from 0.46 ± 0.035 to 1.96 ± 0.085 mg/kg in the tested species which is shown in Figure 9. The maximum As level was found in tilapia (*O. mossambicus*) (1.96 ± 0.085) mg/kg in *gheer* #3. Meanwhile, the lowest As concentration (0.46 ± 0.035 mg/kg) was present in bagda shrimp (*P. monodon*) from *gheer* #1. The tilapia (O. mossambicus) was discovered to have levels of As well above the allowable level of 1 mg/kg set by CEPA (1995–97) and FAO (1983). All the species were still beyond the maximum allowable limit (5 mg/kg) provided by MOFL (2014). The concentration ranges of As (0.75 mg/kg - 1.48 mg/kg) was observed by Ahmed et al. (2019), which is nearly identical to the outcomes of present research. As, the most hazardous element that is frequently in existence in the ecosystem, can enter a water body through both natural and manmade means (Arisekar et al. 2020). Since shallow groundwater has frequently been fed into aquaculture ponds for cultivation purposes, it is plausible to presume that the elevated level of as in species in the present study might have been caused by the introduction of shallow groundwater. Perhaps the farming water body might be contaminated by tube well discharge wastewater.

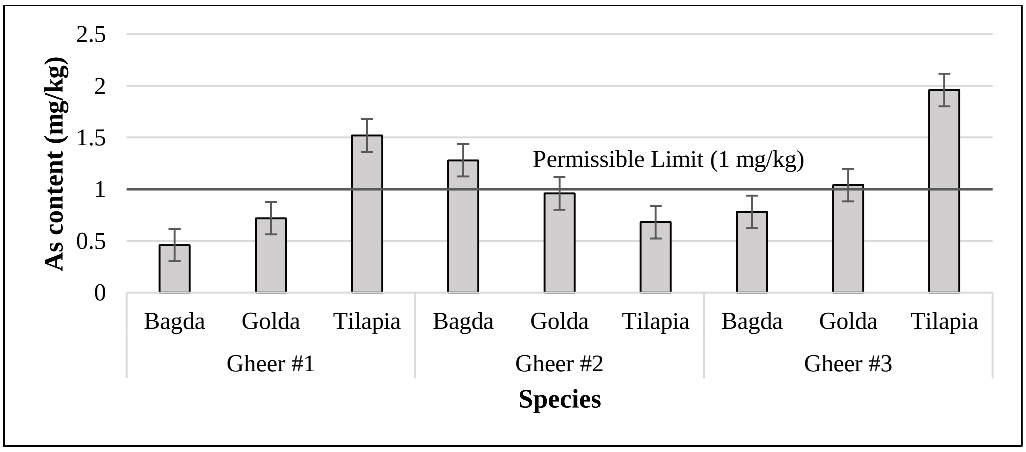

Figure 9. As bioaccumulation (mg/kg) in species

Heavy metal bioaccumulation in tilapia and shrimp

The concentration of all metals in bagda (*P. monodon)* and golda (*M. rosenbergii)* was demonstrated to be still below the standard acceptable level (FAO 1983, WHO 1989), except Mn and Cr. Nevertheless, the level of As, Mn, and Cr in tilapia *(O. mossambicus)* was found to be exceeding the permitted range suggested by FAO (1983) and WHO (1989). In the present study, there were considerable variations in the degree of metal bioaccumulation in different species and different fish farms. This may be because of variations in aquatic ecosystems, feeding sources, and the degree of metal contamination in bottom sediment and water. Alam and Haque (2021) mentioned the capability of fish to bio-accumulate toxic elements from bottom sediments (large metal storage, capturing and depositing >99% of the aggregate amount of deposited elements in the waterbody) and the water of their habitat. Biological requirements, metabolic processes, and the physico-chemical state of water are the crucial factors influencing the metal accumulation capacity of species (Kundu et al. 2017).

In the previous studies, the mean Cr concentration was documented at 0.186 ± 0.010 mg/kg in bagda collected from the river of Kobadak and <0.1 mg/kg in bagda shrimp from the different farms of the Satkhira area, conducted by Fatema et al. (2017), which were lower than our findings. The concentrations of Pb, Cd, and As were documented as lower than 0.1 mg/kg in the farmed bagda shrimp by Fatema et al. (2017), were much lower than our findings. Prior research done by Islam et al. (2016), found the average concentration of Pb, Cd, As, and Cr in golda shrimp sampled from the fish farms of the Satkhira, and Bagherhat regions. The detected concentrations of Pb, Cd in both studied areas were higher than our findings. But the detected concentration of As in the current research is much higher than the findings of the study conducted by Islam et al. (2016). Moreover, Sarkar et al. (2016) found Pb, Cr, and As concentrations of less than 0.1 mg/kg in farmed golda shrimp (*M. rosenbergii*), which is substantially lower than our findings. On the contrary, the concentration of Cd (0.96 ± 0.38) mg/kg in *M. rosenbergii* under the study done by Sarkar et al. (2016), is higher than the detected concentration of Cd in our study.

The concentration of Mn in tilapia *(O. mossambicus)* was found to be two times higher than the permissible limit, and the concentration of Cr was detected to be almost 10 times higher than the permissible limit recommended by FAO (1983) and WHO (1989). In the previous study conducted by Das et al. (2017) in the district of Noakhali, the average concentration of Cr varied from a range of (0.28 ± 0.16 to 0.42 ± 0.22) mg/kg in tilapia, which was 20 times lower than our findings. On the contrary, Cr was not recognized within the detectable limit (0.0001 mg/kg) in a study in the fish farms of Mymensingh, conducted by Kundu et al. (2017). However, it was discovered that the levels of Cd, Cu, and Fe varied to range from (9.083 to 10.453) mg/kg, (19.073 to 25.343) mg/kg, and (136.241 to 200.26) mg/kg respectively, (Kundu et al. 2017), which are higher than our findings. However, the differences in metal contamination between the current and earlier studies might be related to regional differences in the level of pollution in waterbodies, physicochemical condition of fish habitat (salinity, temperature, total dissolved solids etc.) and feeding practice of different region.

Among the three investigated species, golda (*M. rosenbergii*) accumulated the highest concentrations of almost all metals (Table 1). Fish length and weight were indicated by Kamaruzzaman et al. (2010), Ahmed et al. (2016) and Ghosh et al. (2021) as influencing variables of toxic effect in cultured fish. In addition, Kundu et al. (2016) mentioned a number of inherent characteristics of aquatic species, such as genetical buildup and age, that contribute to the degree of metal accumulation. Moreover, bio-chemical and physical properties of elements may affect the variations in levels of intake of different metals in similar species or even different species in similar habitats. Alam and Haque (2021) reported excess fish feed, human waste, agrochemicals, insecticides, livestock excreta, underground aquifers, wastewater irrigation, and farmland outflows as the potential causes of heavy metal abundance in the bottom sediment of aquatic ecosystems. Since there have been no additional man-made causes of metal pollution in aquaculture practices in this area, it may be presumed that the primary source of metal bioaccumulation in fish is fish feed.

Correlation matrix of heavy metals in species

The Pearson correlation analysis was conducted with the metal concentrations in the studied tilapia and shrimp samples, which are presented in Table 2. The findings from the Pearson correlation test demonstrate that the detected metals showed strong positive relationships. Such correlations reflect that the origins and properties of the metals in the corresponding specimens could be comparable in the aggregate. In the correlations, all metals but Fe-Cr (r=0.780), Mn-Cr (r=0.728), and Zn-Cu (r=0.690) suggested a significant relation ($p < 0.05$). Cd-Cr (r=0.923) and Pb-Cu (r=0.934) strong significant relations were found in previous research, carried by Ahmed et al. (2019) in the estimation of heavy metal content in fishes collected from the Meghna river estuary in Bangladesh.

Even, significant positive correlations were evident, such as As-Pb (r= 0.828), Cu-As (r= 0.833), Cr-Pb (r= 0.839) which indicates that the sources of the corresponded might be similar Ahmed *et al.* (2019). A substantial positive correlation among the heavy metal concentrations was demonstrated, such as follows: Cd-Co (r = 0.733), Fe-Al (r= 0.568), Ni=Co (r= 0.482), Mn-Co (r= 0.395), Cr-Co (r= 0.351), and Pb-Cr (r= 0.283) and concluded that the strong and moderate relationships imply that their origins are similar, such as factory effluents, domestic sewage, agricultural implements and wastewater supply.

Table 2. Pearson correlation matrix of heavy metals in species

	Fe	Mn	Zn	Cu	Cr	Cd	Pb	As
Fe	1							
Mn	0.468	1						
	0.204							
Zn	-0.172	-0.605	1					
	0.657	0.084						
Cu	0.033	-0.309	.690*	1				
	0.933	0.419	0.040					
Cr	.780*	.728*	-0.123	-0.001	1			
	0.013	0.026	0.752	0.999				
Cd	0.628	0.554	-0.250	0.319	0.434	1		
	0.070	0.122	0.516	0.403	0.244			
Pb	-0.167	-0.363	0.081	0.055	-0.402	-0.190	1	
	0.667	0.337	0.836	0.888	0.283	0.625		
As	-0.020	0.192	-0.547	-0.302	-0.313	0.466	-0.165	1
	0.959	0.620	0.128	0.430	0.411	0.206	0.672	

*. Correlation is significant at the 0.05 level (2-tailed).

Conclusion

The recorded data of the present study indicates that among the analysed 8 metals, Fe, Mn, Cr, and As were detected at a higher concentration than the maximum permissible limit recommended by FAO (1983) and WHO (1989). The use of commercial fish feed in fish farms raises the likelihood of aquatic animals accumulating certain heavy metal. To combat heavy metal accumulation in farmed tilapia and shrimp, it is imperative to closely monitor farming practices and develop different preventive actions. The findings could be anticipated to raise public awareness regarding the safety of ingesting shrimp and tilapia produced in aquaculture farm.

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Conflict of Interests

The authors declare no conflict of interest.

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