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BIOACCUMULATION OF HEAVY METALS IN THE MUSCLE OF SOME COMMERCIAL FISHES FROM HLAING RIVER SEGMENT OF SHWE PYI THAR TOWNSHIP, YANGON REGION*

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Abstract

Analysis of some heavy metals in the muscle of some commercial fishes collected from Hlaing River in Shwe Pyi Thar Township, Yangon Region were conducted during April 2015 to March 2017. Suspected toxic metals from industrial sewages such as Al, Cr, Cd, As, Ni, Hg and Pb were analysed in detail. The majority of tested heavy metals were found to be high concentration in the muscles of all studied commercial fish species. The concentration of Al, Cr, Cd, As, and Hg in the fish muscles were exceeding the permissible limits of FAO/WHO (1992) standard for human consumption. Condition factors of studied fishes were negatively correlated with the concentration of heavy metals in their muscles. High bioaccumulation factor value were observed in all studied fish species, so as tested heavy metals were accumulated by fish showing long term exposure of heavy metals to fish in its surrounding. The bioaccumulation factors of demersal fishes were higher in most of the tested metals than benthopelagic fishes. Bioaccumulation factors of all tested heavy metals were found to be higher in the dry season than other seasons. Daily consumption in large amount of studied fish species captured from the Hlaing River may cause health problems if bioaccumulation continues in the same rate without taking effective management for pollution in the Hlaing River.

Key words: Heavy metals, pollution, Hlaing River, commercial fishes, bio-indicator.

Introduction

Heavy metals are metallic elements which have a high atomic weight and a density much greater at least 5 times than water. Among more than 20 heavy metals, lead (Pb), cadmium (Cd), mercury (Hg), and inorganic arsenic

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(As) are particular concern to human health. They are highly toxic and can cause damaging effects even at very low concentrations (Chang *et al*., 1996).

One of the important environmental problem is the pollution of aquatic ecosystems due to heavy metals, as heavy metals constitute some of the most hazardous substances that can bioaccumulate in various biotic systems. Bioaccumulation is a process in which a chemical pollutant enters into the body of an organism and is not excreted, but accumulated in the organism's tissues. Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage, while also posing a threat to human health. Cancer and damage of the nervous system have been documented in humans as a result of metal consumption (Van den Broek *et al*., 2002).

Anthropogenic impacts including industrial discharge, domestic sewage, non-point source runoff and atmospheric precipitation are the main sources of the heavy metal pollution of aquatic ecosystems. It is often most obvious in sediments, macrophytes and aquatic animals, than in elevated concentrations in water (Linnik and Zubenko, 2000). Many aquatic organisms have been used as bioindicators, especially fish (Burger *et al*., 2002). Fishes, being major components of most aquatic habitats have also been recognized as good bio-accumulators of organic and inorganic pollutants (King and Jonathan, 2003). In addition, fish are located at the end of the aquatic food chain and may accumulate metals and pass them to human beings through food causing chronic or acute diseases (Al-Yousuf *et. al*., 2000).

Around the Yangon Region, water pollution is nearing hazardous levels as waste water and chemicals from factories and industrial zones are increasingly discharged into the rivers (Kyi Wai, 2009). **According to research from the Green Motherland Development Association (GMDA) (2015), the level of organic pollutants in waste water discharged from the Hlaing Tharyar and Shwe Pyi Thar industrial zones into Hlaing River was higher than standard specifications of WHO.**

A few research works on water pollution were carried out in Hlaing River based on the impact of industrial zones (DMR, 2013; Mya Thandar, 2014; GMDA, 2015). The academic studies on the contamination of heavy metals in fish have not been conducted yet so far in the Hlaing River.

In the study area, the small fisheries were carried out for selling in the markets of Insein, Shwe Pyi Thar, Hlaing and adjacent townships. Therefore, the present study aimed to access the pollution of Hlaing River with the following objectives:to detect the concentration of some heavy metals in the muscle of commercial fishes collected from Hlaing River Segment in Shwe Pyi Thar Township, Yangon Region, to access the possible potential human risk for consumption compared with FAO/WHO (1992) standard and, to seek the relationships of heavy metal bioaccumulation in fish muscle with size, age and feeding types, seasons and condition factor of fishes.

Materials and Methods

Study area

Study area was the Hlaing River segment situated in Shwe Pyi Thar Township, Yangon Region, and located between 16° 58' N, 96° 02' E, and 16° 55' N, 96° 04' E. Total distance of Hlaing River segment of the study area was approximately 8.19km in length (Figure 1).

Study periods

Study period lasted from April 2015 to March 2017.

Target fish species

The target fish species were the commercial fishes in the study area such as *Otolithoides pama* (Hamilton, 1822) (Pama croaker, Nga-poke-thin), *Polynemus paradiseus* Linnaeus, 1758 (Paradise threadfin, Nga-pon-nar), *Mystus spp.* (Hamilton, 1822) (Dwarf catfish, Nga-zin-yaine), *Cirrhinus cirrhosus* (**Bloch, 1795**) (Mrigal carp, Nga-gin-lone), *Illisha megaloptera* (**Swainson, 1839)** (Big eye illisha, Nga-zin-byarr), *Silonia silondia* (Hamilton, 1822) (Silond catfish, Nga-myin) and *Pangasius hypophthalmus* (Sauvage, 1878) (Striped catfish, Nga-dan). These fishes were available in all the year round in the study area and abundant enough for selling in the markets. They were found to be different habitats and food types according to Talwar and Jhingran (1991) (Table 1).

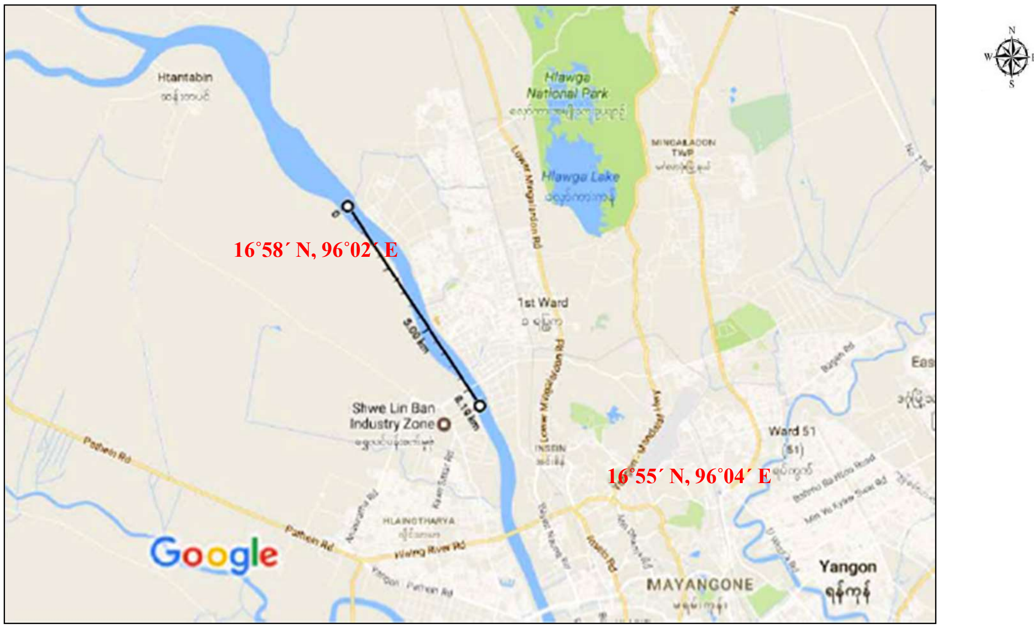


Figure 1. Location map of the study area (Source: Google Map, 2016)

Table 1. Habitats and feeding types of target commercial fishes

Scientific name	Common name	Myanmar name	Habitat	Feeding type
O. pama	Pamacroaker	Nga-poke-thin	Benthopelagic	Carnivore
P. paradiseus	Paradise threadfin	Nga-pon-nar	Demersal,	Carnivore
I. megaloptera	Bigeyeillisha	Nga-zin-byarr	Benthopelagic	Omnivore
C. cirrhosus	Mrigal carp	Nga-gin-lone	Benthopelagic	Herbivore
Mystus spp.	Dwarf catfish	Nga-zin-yaine	Demersal,	Carnivore
S. silondia	Silond catfish	Nga-myin	Demersal,	Omnivore
P. hypophthalmus	Striped catfish	Nga-dan	Benthopelagic	Omnivore

Specimen collection

Fish specimens were purchased from local fishermen in the study area. A total of 231 specimens as a ratio of three specimens for each commercial fish species per month were collected during the study period. Specimen collections were carried out from June 2015 to January 2017. Some months in the rainy season were excluded from specimen collection due to the increasing of water level in the study area when the fishing activities were ceased temporally. Collected specimens were kept in the ice box and bring to the laboratory of Zoology Department, West Yangon University for further study.

Examination of recorded specimen

In the laboratory, collected fish specimens were identified the species according to the statement of Talwar and Jhingran (1991). Standard length and body weight were measured to calculate the condition factor of the fish. Adult and young fish were also categorized according to the development of reproductive organs. Size of fish was categorized as small size (<10cm), medium size (>10cm-<20cm) and large size (>20cm).

Preparation for heavy metal test

Collected fish specimens were skinned and approximately 50g of the axial muscles were cut out from the fish and weighted. Then, flesh of fish was cut into slices for dry rapidly. Consequently, fish slices were dried in drying oven at 60˚C overnight. Each dry specimen was weighted again and kept in separate polyethylene bag and stored in the refrigerator at 20˚C before heavy metal test. Code number of each specimen, collection date, wet weight and dry weight were labelled on the respective bag. Each specimen was homogenized by using electric blander before conducting heavy metal test.

Method of heavy metal test

The heavy metal concentration of each sample was assessed by Energy Dispersive X Ray Fluorescence spectrometer (EDXR) analysis at Department of Physics, University of Mandalay.

Bioaccumulation factor

The bioaccumulation factor (BAF) is the ratio between the accumulation of a given pollutant in any organ and dissolved concentration in water according to Authman and Abbas (2007).

$$BAF = Con_{fish} / Con_{water}$$

Con_{fish} = pollutant concentration in fish tissue (mg/kg)

Con_{water} = pollutant in water (mg/l)

The parameter is zero if the element accumulates only from the water. If the BAF is greater than 1.0 then bioaccumulation for metals occurs by fish species (Aboul Ezz and Abdel-Razek, 1991).

Condition factor

Fulton's condition factor (K) was calculated according to Bagenal (1978) as follows: $K= 100\ W/L^3$

Where W is the total body weight in grams and L is standard length in centimeters.

Heavy metal level limit for human consumption

Standards of heavy metal safety guideline consumption for fish muscle and water were followed after FAO/WHO (1992) and WHO (1993) standards, respectively.

Statistical analysis

Recorded data were statistically analyzed using SPSS Version 16. Concentrations of heavy metals were presented as mean and standard deviation. Variation of heavy metal concentrations in fish muscle among different sizes of fish, sexes and different seasons were analyzed using ANOVA and presented with bar graph. Relation of heavy metal concentrations with size, age, condition factor, feeding habits, and also seasons were analyzed using Pearson's correlation coefficient test.

Results

Altogether 231 fish specimens were analysed by Energy Dispersive X Ray analysis (EDXR), and the results showed that 15 heavy metals including essential and toxic metals were detected in the muscles of tested fish samples.

Among detected heavy metals, Aluminium (Al), Chromium (Cr), Cadmium (Cd), Arsenic (As), Nickel (Ni), Mercury (Hg) and Lead (Pb) were analysed in detail since these metals were the suspected waste from industrial zones and highly hazardous to organisms.

Variation of heavy metal concentrations were observed among studied fish species. Some heavy metal concentrations in the studied fish muscles were exceeding the permissible limit of FAO/WHO (1992) standard as Al, Cr, As and Hg concentrations in *Polynemus paradiseus*; Al, Cr, As concentrations in *Otolithoides pama*; Al, Cr, and Hg concentrations in *Silonia silondia*; Al and Cr concentrations in *Illisha megaloptera*, *Cirrhinus cirrhosus*, *Mystus spp.* and *Pangasius hypophthalmus* (Table 2).

Table 2. Heavy metal concentrations in the muscle of some commercial fishes in the study area during the study period (ppm in wet weight)

Species name	**Heavy metal concentrations in wet weight (ppm)**						
	Al	**Cr**	**Cd**	**A**	**Ni**	**Hg**	**Pb**
Otolithoides pama	**354.09** ± 41.68	**1.43** ± 0.17	0.33 ± 0.04	**0.98** ± 0.12	0.04 ± 0.01	0.31 ± 0.04	0.20 ± 0.02
Polynemus paradiseus	**335.78** ± 40.14	**1.74** ± 0.20	0.21 ± 0.02	**0.91** ± 0.10	0.11 ± 0.01	**0.55** ± 0.06	1.14 ± 0.13
Illisha megaloptera	**522.15** ± 44.58	**1.18** ± 0.10	0.43 ± 0.04	0.47 ± 0.04	0.06 ± 0.01	0.37 ± 0.03	0.21 ± 0.02
Cirrhinus cirrhosus	**393.06** ± 92.95	**1.70** ± 0.04	0.21 ± 0.05	0.12 ± 0.03	0.12 ± 0.03	0.40 ± 0.09	0.24 ± 0.06
Mystus spp.	**421.61** ± 56.48	**1.71** ± 0.23	0.12 ± 0.02	0.34 ± 0.05	0.17 ± 0.02	0.48 ± 0.06	0.22 ± 0.03
Silonia silondia	**381.44** ± 56.35	**1.94** ± 0.27	0.49 ± 0.07	0.32 ± 0.29	0.10 ± 0.01	**0.53** ± 0.08	0.25 ± 0.03
Pangasius hypophthalmus	**306.12** ± 84.33	**1.62** ± 0.45	0.45 ± 0.12	0.38 ± 0.11	0.07 ± 0.02	0.41 ± 0.11	0.45 ± 0.12
FAO/WHO (1993)	100	0.5	0.5	0.5	0.8	0.5	2.0

Condition factor of studied fishes indicated that majority of studied fishes were in good condition (K> 1.00). Exception was observed in *I. megaloptera* in which under good condition criteria as 0.82 was observed (Figure 2).

Pearson's correlation coefficient analysis showed that all tested heavy metals were negatively correlated with condition factors of studied fishes. In *Illisha megaloptera* and *Cirrhinus cirrhosus*, concentrations of all tested heavy metals were significantly negative correlated with condition factors of those fishes. In *Otolithoides pama*, chromium and lead concentrations were significantly negative correlated with its condition factor (Table 3).

The water samples in the study area indicated that the tested heavy metals concentrations were found to be exceeding the drinking water standard of WHO (1993) (Table 4).

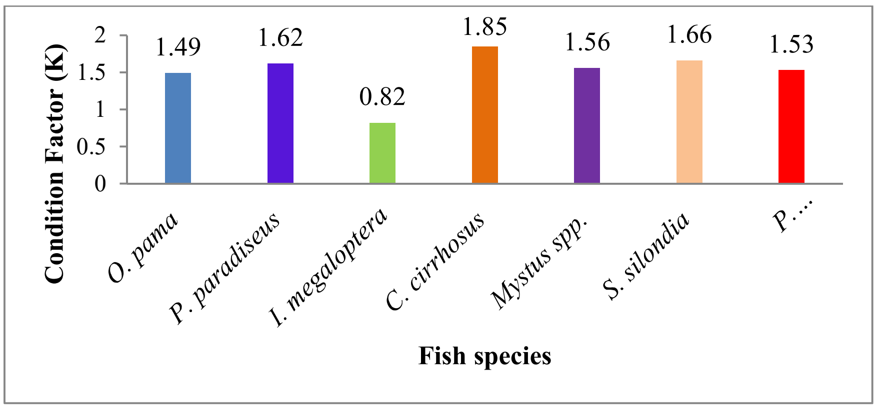


Figure 2. Condition factors of tested fish species

Table 3. Relationship between heavy metals concentrations of fish muscles and condition factors of studied fishes

Species	Coefficient of correlation (r)						
	Al	**Cr**	**Cd**	**As**	**Ni**	**Hg**	**Pb**
O. pama	- 0.740	- 0.758*	- 0.749	- 0.722	- 0.742	- 0.751	- 0.758*
P. paradiseus	- 0.380	- 0.319	- 0.283	- 0. 188	- 0.349	- 0.355	- 0.363
I. megaloptera	- 0.981*	- 0.982*	- 0.949*	- 0.977*	- 0.866*	- 0.976*	- 0.965*
C. cirrhosus	- 0.771*	- 0.767*	- 0.795*	- 0.795*	- 0.851*	- 0.790*	- 0.810*
Mystus spp.	- 0.144	- 0.256	- 0.235	- 0.095	- 0.182	- 0.091	- 0.389
S. silondia	- 0.202	- 0.385	- 0.345	- 0.321	- 0.183	- 0.404	- 0.329
P. hypothalmus	- 0.244	- 0.321	- 0.374	- 0.400	- 0.383	- 0.386	- 0.374

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

Table 4. Comparison of heavy metal concentration in the study site and drinking water standard of WHO (1993)

Description	Heavy metal concentrations (ppm)						
	Al	Cr	Cd	As	Ni	Hg	Pb
Drinking water standard WHO (1993)	20	0.05	0.003	0.01	0.03	0.001	0.01
Water sample in the study site	30	0.6	0.03	0.11	0.04	0.08	0.12

Among the tested heavy metals, the highest bioaccumulation factor of aluminium (17.41) was observed in the muscle of *I. megaloptera*, followed by those of *Mystus spp.*, *C. cirrhosus*, *S. silondia*, *P. paradiseus*, *O. pama*, and *P. hypophthalmus* (Table 5).

In chromium test, the highest bioaccumulation (3.23) was observed in *S. silondia*, followed by *P. paradiseus*, *Mystus spp.*, *C. cirrhosus*, *P. hypophthalmus*, *O. pama*, and *I. megaloptera* (Table 5).

Table 5. Bioaccumulation factors of studied fish species

Species	Bioaccumulation factors						
	Al	Cr	Cd	As	Ni	Hg	Pb
Otolithoides pama	11.80	2.38	11.00	**8.91**	1.33	3.88	1.67
Polynemus paradiseus	11.86	2.89	6.85	8.30	3.81	**6.85**	**9.51**
Illisha megaloptera	**17.41**	1.97	14.33	4.27	2.00	4.63	1.75
Cirrhinus cirrhosus	13.10	2.83	7.00	1.09	4.00	5.00	2.00
Mystus spp.	14.05	2.85	4.00	3.09	**5.67**	6.00	1.83
Silonia silondia	12.71	**3.23**	**16.33**	2.91	3.33	6.63	2.08
Pangasius hypophthalmus	10.20	2.70	15.00	3.45	2.33	5.13	3.75

In cadmium test, the highest bioaccumulation (16.33) was observed in *S. silondia*, followed by *P. hypophthalmus*, *I. megaloptera*, *O. pama*, *C. cirrhosus*, *P. paradiseus*, and *Mystus spp.* (Table 5).

In arsenic test, the highest bioaccumulation (8.91) was found in *O. pama*, followed by *P. paradiseus*, *I. megaloptera*, *P. hypophthalmus*, *Mystus spp.*, *S. silondia*, *C. cirrhosus* (Table 5).

In nickel test, the highest bioaccumulation (5.67) was found in *Mystus spp.*, followed by *C. cirrhosus*, *P. paradiseus*, *S. silondia*, *P. hypophthalmus*, *I. megaloptera*, and *O. pama* (Table 5).

In mercury test, the highest bioaccumulation (6.85) was found in *P. paradiseus*, followed by *S. silondia*, *Mystus spp.*, *P. hypophthalmus*, *C. cirrhosus*, *I. megaloptera*, and *O. pama* (Table 5).

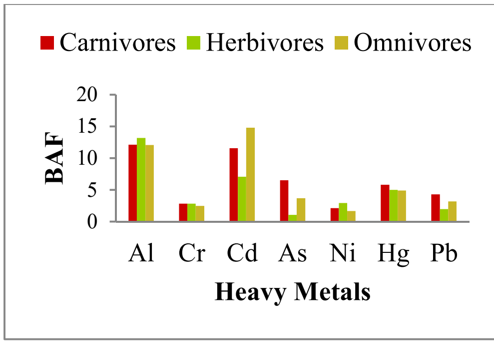
In lead test, the highest bioaccumulation (9.51) was found in *P. paradiseus*, followed by *P. hypophthalmus*, *S. silondia*, *C. cirrhosus*, *Mystus spp.*, *I. megaloptera*, and *O. pama* (Table 5).

In the carnivorous fishes, bioaccumulation factors of three metals as As, Hg and Pb were found to be higher than herbivorous and omnivorous fishes. In the herbivorous fishes, bioaccumulation factors of two metals as Al and Ni were found to be higher than carnivorous and omnivorous fishes. In the omnivorous fishes, only one metal, Cd was the higher than carnivorous and herbivorous fishes (Figure 3A).

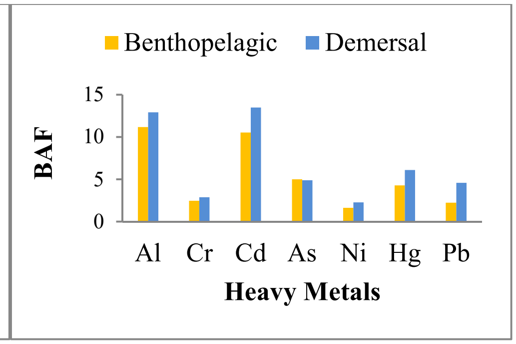
Bioaccumulation factors of demersal fishes were higher in most of the tested metals except in arsenic which showed nearly the same in both demersal and benthopelagic fishes (Figure 3B).

Among the studied fishes, higher bioaccumulation factor was observed in adult fish group than young fish group. Significant variation was found in majority of tested metals as Al, Cd, As, Hg and Pb (Figure 3C).

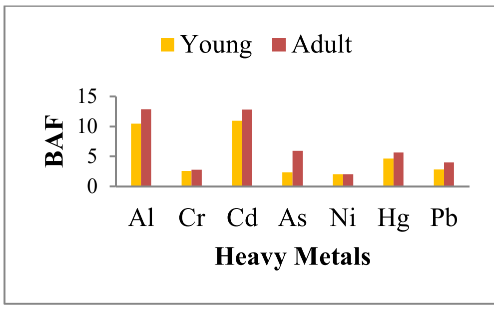
Variations of bioaccumulation factors of tested heavy metals among different size of fishes were observed. Bioaccumulation factors of Cd and As were found to be higher in large sized fishes, while BAF of Al and Pb were higher in medium sized fishes. Small sized fishes showed slightly higher BAF values in Cr, Ni and Hg than other sized groups (Figure 3D).



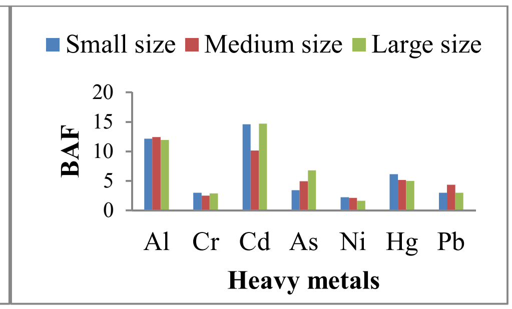
(A) Among feeding habits



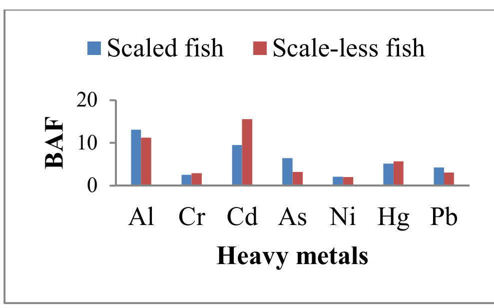
(B) Among different habitats



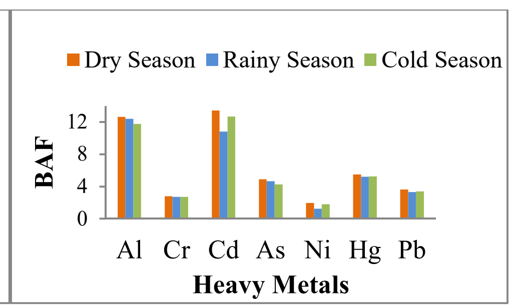
(C) Among young and adult fishes



(D) Among different size



(E) Among scaled and scale-less fishes



(F) Among season

Figure 3. Comparison of BAF with some descriptive account of studied fishes and seasons

Some tested heavy metals such as Cr, Cd and Hg were found to be higher bioaccumulation factors in scale-less fishes such as *Mystus spp.*, *S. silondia* and *P. hypophthalmus*. However, bioaccumulation factors of Al, As, Ni and Pb were higher in scaled fish such as *O. pama*, *P. paradiseus*, *I. megaloptera* and *C. cirrhosus* (Figure 3E).

Bioaccumulation factors of all tested heavy metals were found to be higher in the dry season than other seasons. Significant variation was observed in cadmium as the ranking order of dry>cold>rainy seasons (Figure 3F).

Mean bioaccumulation factor of tested heavy metals was significantly negative correlated with condition factor of studied fishes ($r= -0.641$, $p<0.05$), while those bioaccumulation factor was not significantly correlated with seasons, feeding type of fish (carnivores, herbivores or omnivores), present or absent of scales, habitat types (demersal or benthopelagics) and the size of fish.

Discussion

So far, fish consumption become popular as the first choice among the people all over the world due to their nutritive and economical values which are attributed to its good and cheap, source of protein and minerals, richness in non-saturated fatty acids and Omega-3 as stated by Erkkilä *et al*. (2004). Unfortunately, the habitats of fishes became polluted in worldwide due to the progress of industries which led to increased emission of pollutants as heavy metals into ecosystems. Environmental pollution can cause poisoning, diseases and even death for fish. As xenobiotics, some of these pollutants sometimes find their way into the human system through the food chain (Gabriel *et al*., 2006). In the present study, heavy metal analysis was conducted in edible muscle tissues of 231 specimens belonging to seven commercial fish species were analysed for accessing the safety consumption on fishes in the study area.

In the present study, heavy metal concentrations in studied fish muscles and those of the surface water in the study area were significantly correlated. It indicated that the pollutant heavy metals in the water enter the Hlaing River ecosystem and bioaccumulation took place in the studied fishes. The tested heavy metals assumed to enter the study area by anthropogenic activities such as industrial wastes, chemical fertilizers and pesticides used in agricultures, sand and gravel digging in the river and storage at the river bank, fuel discharged from large vessels, etc. This finding is in agreement with the statement of Zeitoun and Mehana (2014) that industrial wastes are potential source of heavy metal pollution in aquatic environments.

The majority of tested heavy metals were observed to be high concentration in the muscles of all studied commercial fish species, whereas aluminium, chromium, cadmium, arsenic, and mercury were exceeding the permissible limits of FAO/WHO (1992) standard for human consumption. Besides, surface water in the study area was polluted with tested heavy metals exceeding the permissible limit of the drinking water standard of WHO (1993). Therefore, people who consumed these highly contaminated fishes with heavy metals seemed to be also affected and can cause the respective health problems.

In the study area, nearly all studied fish species were in good condition showing condition factor values exceeding the critical value (K=1), although condition factors of those fishes were found to be negatively correlated with the concentration of heavy metals in their muscles. However, *Illisha megaloptera* was not in good condition in the study area due to the pollution of heavy metals as indicating significant negative correlation with the heavy metal concentrations in their muscles. This finding is in coincidence with the finding of Hashim *et al*. (2014) in the Kelantan River of Malaysia.

In all studied fish species, high bioaccumulation factor value were observed and greater than critical value (BAF=1), so as tested heavy metals were accumulated by fish showing long term exposure of heavy metals to fish in its surrounding. In addition, all tested heavy metals were significantly correlated with those in surface water of the study area. Besides, the bioaccumulation factors of demersal fishes were higher in most of the tested metals than benthopelagic fishes. This result indicated that most of the tested metals as Al, Cr, Cd, Ni, Hg and Pb were seem to be highly polluted with industrial and agricultural wastes since long been.

The seasonal variations of bioaccumulation factors were observed in studied fish species while bioaccumulation factors of all tested heavy metals were found to be higher in the dry season than other seasons. It is seemed to be fact that the heavy metal concentrations in river water were elevated by increasing temperatures and also some anthropogenic activities especially sand and gravel excavations in the river increased in the dry season. Besides, the low heavy metal bioaccumulation during the rainy season was due to the dilution of heavy metals by heavy rain resulting increased water levels in the study area. This finding is similar to the finding of previous studies (Idodo-Umeh, 2002, and Oguzie, 2003).

In the study area, feeding habits of studied fishes were not correlated with the bioaccumulation factors of all tested heavy metals. However, the previous studies stated that the feeding habits of herbivorous, carnivorous and omnivorous fish were significantly different in heavy mental concentrations (Voigt, 2004 and Weber *et al*., 2013). The finding of the present study was contrast with the finding of previous authors. The feeding habits of studied fishes could not be the main factor of bioaccumulation of tested heavy metals in the study area. It is possible that the heavy metals in studied fish muscle came directly from water current through the gill lamellae and reached into the circulatory system and bioaccumulated in the muscles. Since bioaccumulations of tested heavy metals were higher in both demersal and benthopelagic fishes, the whole ecosystem was seem to be polluted. The same trend were expected in their food sources both plants and animals.

Among the studied fishes, adult fishes were found to be higher bioaccumulation factor than young fishes. This finding is in coincidence with the finding of the previous authors (Ahmad and Suhaimi-Othman, 2010, Hashim *et al*., 2014). They found that mature fish accumulated higher metals compared to juvenile and premature fish. It is due to the fact that adult fishes were living in continuous polluted habitats and bioaccumulation was also greater than young fishes.

In the present study, bioaccumulation of Cr, Cd and Hg were higher in scale-less fishes than scaled fishes. According to Hashim *et al*. (2014), these heavy metals were the sources from pesticides and chemical fertilizers used in agriculture. Therefore, the studied scale-less fishes probably came from the upstream of Hlaing River nearby agriculture land. In addition, bioaccumulation of Al, Ni, As and Pb were higher in scaled fish than scale-less fishes. These heavy metals were the possible sources of industrial wastes, erosion, dissolution of minerals and salts, atmospheric dust pollution and rain according to Ismailand Saleh (2012) in Malaysia. Therefore, these scaled fish assumed to be came from the downstream of Hlaing River nearby many industries and sand and gravel excavation activities.

In Hlaing River, bioaccumulation of Cr, Ni and Hg were higher in small sized fishes, those of Al and Pb were higher in medium sized fishes and those of Cd and As were higher in large sized fishes. However, the size of the fishes was not correlated with bioaccumulation factors of tested heavy metals. Besides, bioaccumulation factors of tested heavy metals were not significantly different among the size of the fishes. Therefore, all sized of fishes were nearly the same potential of heavy metal contamination in the study area during the study period.

Conclusion

In conclusion, the high concentrations of heavy metals were observed in the muscle of all studied commercial fishes. It is noticeable that aluminium, chromium, cadmium, arsenic, and mercury were exceeding the permissible limits of FAO/WHO (1992) standard for human consumption. Like in other organisms, heavy metals are not destroyed by humans, so as they tend to accumulate within the body and threaten the health of fishes and consumers of them. Therefore, everyday consumption of studied fish species in the Hlaing River may cause health problems if bioaccumulation continues in the same rate without taking effective management for pollution in the Hlaing River. Regular monitoring of environmental parameters should be carried out as a key activity in not only managing the restoring polluted environments but also anticipating the effects of anthropogenic activities in the study area.

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