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SEASONAL VARIATION OF ESSENTIAL AND TOXIC METAL CONTENTS IN WATER, SEDIMENT AND SOME FISHES AT AYEYAWADY RIVER SEGMENT OF SALAY ENVIRONS

Cho Cho Thin[1], Myinzu Minn[2], Min Thu Aung[3]

Abstract

Seven metals concentrations in the muscular tissue of 15 fish species and water and sediments collected from Ayeyawady River segment of Salay environs were seasonally examined by Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) in Universities' Research Centre (URC) during the period from February 2015 to January 2016. The mean concentrations of toxic metals in all studied fishes with different feeding habits were lower than the WHO permissible limits except the arsenic in cold season. However essential metal concentrations were found within the permissible FAO range. The cadmium concentrations of water in rainy and cold seasons and arsenic in cold season were higher than WHO guideline values. Essential metal concentrations of water were within the WHO permissible limits. Toxic metals of sediments were within probable effect concentrations (PEC).

Keywords: muscle, water, sediment, element concentration, heavy metal, seasons

Introduction

Heavy metals are environmentally ubiquitous, readily dissolved and transported by water and readily taken up by aquatic organisms (Alam *et al*., 2002). Fishes are often at the top of aquatic food chain in aquatic ecosystems and fish living in the polluted waters may accumulate toxic trace metals. It is well known that fish, as a regular constituent of the human diet, can represent a dangerous source of certain heavy metals (Mansour and Sidky, 2002).

[1]. Dr., Lecturer, Department of Zoology, University of Yangon
[2]. Dr., Pro-rector, Mandalay University
[3]. Dr., Professor, Department of Zoology, Magway University

The discharge of wastewater and industrial effluents whether treated or not can be regarded as constant pollution source which is negatively have an impact on water quality. Knowledge of water quality parameters can produce a better understanding of the environmental situation and assist policy makers to design priorities for sustainable water management. Water quality includes all physical, chemical and biological variables influencing the suitability of water for any intended use (Hung *et al*., 2010). Relationships between two parameters may influence in the concentration of others.

In this study, concentrations of seven metals (calcium, magnesium, sodium, potassium, cadmium, lead and arsenic) were determined in 15 fish species as well as in water and sediment samples from the Salay segment of Ayeyawady River.

Humans primarily consume fish muscle tissue. It is important to verify whether the concentrations of contaminants like heavy metals in the muscle are within the recommended limits which are suitable for human consumption. Therefore, the metal contents in fish muscle tissue were analyzed in the present study and especially, the mean concentrations of the metals listed above were evaluated in terms of international guidelines.

Materials and Methods

Study Area

Salay Township, Magway Region of Ayeyawady River, situated at 20° 42′ N to 20° 51.30′ N and 94° 14′ E to 97° 47.51′ E, was chosen as the area of study. Fish, water and sediment samples were collected from this area and metal content of each sample was determined (Fig. 1).

Study Period

Study period lasted from January, 2015 to February, 2016.

Collection and Preparation of Fish Specimens

From the three study sites, a total of 111 specimens of 15 fish species were collected from local fishermen in hot, rainy and cold seasons. Feeding habits of recorded fish species were designated in accordance with Talwar and Jhingran (1991). From among the collected species, five species in each of herbivores, carnivores, and omnivores were selected for determination of metal concentrations. The specimens were washed by tap water until the body surface was clean. Total length (cm) and body weight (g) of the specimens were measured. Subsequently the specimens were decapitated, scaled and gutted with a clean stainless steel knife. The metal contents in the dorsal muscle (filet) of each species were analyzed to determine their suitability for human consumption.

Sample Preparations

Digestion of the muscle samples was conducted according to the dry method (Plate 1). Muscle samples were dried to a constant weight in an oven and dried samples were weighted and stored in airtight containers. Five grams of each of the dried muscle samples was placed into a crucible and transferred to a furnace (Model-L3383) in which temperature was slowly raised to 500°C over 2 hours. Samples were allowed to ash overnight. Once removed, samples were allowed to cool in room temperature and 5 mL of nitric acid were added and followed by addition of 10mL hydrochloric acid. The digestion was transferred to furnace and the temperature was raised slowly to 450° C and hold at this temperature for 1 hour. The crucible was removed, cooled and 50mL deionized water was added and transferred to volumetric flask.

The sediment samples were sun dried, grounded and sieved with 200 mm sieve to obtain a find powder. A quantity 1.0 g of dried sediment sample in a crucible was placed in a furnace at 200°-250° C for 30 min, and then ashed for 4 hours at 480° C. Then the sample was removed from the furnace, cooled and 2mL of nitric acid was added. The preparation was evaporated to dryness on a sand bath. Subsequently, 2 mL of concentrated HCl was added and transferred to furnace in which the temperature was raised slowly to 450°

C and hold at this temperature for 1 hour. The crucible was then removed, cooled and 50mL of deionized water was added. The solution was filtered through Whatman No-42 filter paper and 0.45µm Millipore filter paper (Issac and Kerber, 1971).

For water, each sample was filtered through a 0.45 micron Whatman filter.

Chemical Analysis

The concentration of seven elements (calcium, magnesium, sodium, potassium, cadmium, lead and arsenic) in muscle tissue samples of the fish specimens as well as in sediment and water samples were analyzed in tri-replicates by Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) in the Universities' Research Centre (URC) at University of Yangon. Seasonal variations of test results were compared with WHO/FAO maximum permissible limits. TEC (threshold effect concentration), MEC (midpoint effect concentration), and PEC (probable effect concentration) were also determined for toxic metal concentrations of sediment samples according to MacDonald *et al.*, (2000).

(A). Ashing samples in furnace

(B). Filteration of samples

(C). Samples ready for AAS

(D). Analysis by AAS

Plate 1. Apparatus used in sample analysis

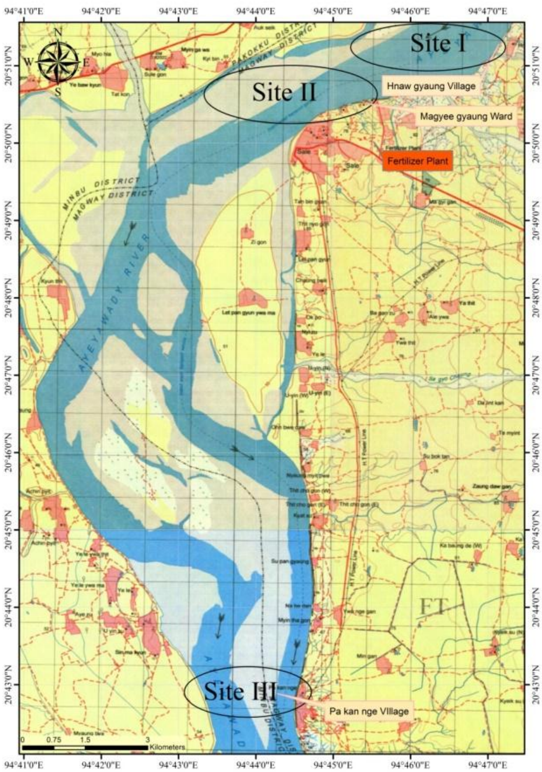


Figure.1 Map of the study area and study sites

Results

A total of 15 fish species which included five species of herbivores (*Cirrhinus mrigala*, *Labeo boga*, *Labeo calbasu*, *Labeo rohita*, *Oreochromis mossambicus)*, five species of carnivores *(Notopterus notopterus*, *Separata aor*, *Mystus cavasius*, *Eutropiichthys vacha*, *Channa punctatus)*, and five species of omnivores *(Tenualosa ilisha*, *Salmostoma sardinella*, *Rhinomugil corsula*, *Macrognathus zebrinus*, *Mastacembelus dayi*) were collected from the Ayeyawady River segment in Salay Environs.

Concentration of the essential metals (Ca, Mg, Na and K) in all studied fish species with different feeding habits were found within FAO standard ranges for all seasons (Table 1, 2, 3 and 4). The mean concentrations of the essential metals in the fishes were presented in Table 5 and Fig. 2, A, B, C, and D.

Cadmium concentrations of all studied fish species with different feeding habits for all seasons, were found to be lower than those of maximum permissible limits (MPL) recognized by WHO/ FAO, except in the carnivorous *Separata aor* in rainy season which have the cadmium concentrations of 0.48 mg/L was higher than the MPL of 0.2 mg/L (Table 6).

Lead concentrations of all studied fish species with different feeding habits in all seasons, were found to be lower than those of MPL recognized by WHO/ FAO except in *Labeo rohita,* a herbivorous fish in rainy season. The mean value of lead concentrations in latter species at 1.13 mg/L was found to be higher than the recommended highest standard of 1mg/L (Table 7).

Arsenic concentrations of *Labeo boga* (0.76 mg/L), *Oreochromis mossambicus* (0.57 mg/L) among the herbivorous fishes; *Salmostoma sardinella* (0.95 mg/L) *Macrognathus zebrinu* (0.98 mg/L) and *Mastacembelus dayi* (1.98 mg/L) among the omnivorous fishes in hot season; *Labeo boga* (1.08 mg/L) and *Labeo calbas* (1.2 mg/L) among the herbivorous fishes; and *Salmostoma sardinella* (2.59 mg/L) among omnivorous fishes were found to be lower than those of maximum permissible limits (0.26 mg/L) recognized by WHO/ FAO. In cold season, arsenic concentrations of all studied fish species in different feeding habits were found to be lower than those of maximum permissible limits except in carnivorous *Notopterus notopterus* (0.00 mg/L) (Table 8). The mean concentrations of the toxic metals were shown in Table 9 and Fig. 3, A, B and C.

Calcium, magnesium, sodium and potassium concentrations of water samples in all seasons were found to be lower than those of the maximum permissible limits recognized by WHO/ FAO. Cadmium concentrations (0.08 mg/L in rainy and 0.07 mg/L in cold seasons) and arsenic (1.40 mg/L) in cold season were higher than the MPL (Table 10 and 11. Fig. 4 and Fig. 5). Cadmium, lead, and arsenic concentrations of sediment in all seasons were observed to be lower than the TEC, MEC, and PEC (Table 12 and 13, Fig. 6 and 7).

Table 1. Seasonal variation of calcium concentration (mg/L) in fishes with different feeding habits

Types of Feeding habit	Species	Calcium			FAO Standard range
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	2.13	13.47	12.63	19 - 881
	Labeo boga	4.49	40.71	27.12	
	Labeo calbasu	1.50	47.99	20.75	
	Labeo rohita	1.11	13.89	28.97	
	Oreochromis mossambicus	1.51	14.18	36.35	
Carnivores	*Notopterus notopterus*	1.85	11.73	17.55	
	Separata aor	1.63	27.69	11.11	
	Mystus cavasius	57.45	39.91	19.29	
	Eutropiichthys vacha	1.50	19.44	20.77	
	Channa punctatus	22.06	17.17	17.87	
Omnivores	*Tenualosa ilisha*	4.87	51.47	17.55	
	Salmastoma sardinella	39.12	90.64	41.48	
	Rhinomugil corsula	5.97	48.55	18.66	
	Macrognathus zebrinus	6.43	33.38	30.09	
	Mastacembelus dayi	18.83	40.58	39.21	

Table 2. Seasonal variation of magnesium concentration (mg/L) in fishes with different feeding habits

Types of Feeding habit	Species	Magnesium			FAO Standard range
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	3.20	9.51	8.29	4.5-452
	Labeo boga	5.46	9.29	9.24	
	Labeo calbasu	3.59	9.05	9.09	
	Labeo rohita	4.53	9.29	8.99	
	Oreochromis mossambicus	2.49	9.26	9.19	
Carnivores	*Notopterus notopterus*	1.58	9.43	9.03	
	Separata aor	0.80	9.29	7.82	
	Mystus cavasius	9.80	9.57	8.81	
	Eutropiichthys vacha	1.41	9.40	8.94	
	Channa punctatus	9.38	9.31	9.14	
Omnivores	*Tenualosa ilisha*	3.05	9.33	9.18	
	Salmastoma sardinella	6.37	9.42	9.40	
	Rhinomugil corsula	7.35	9.42	9.21	
	Macrognathus zebrinus	9.41	9.25	9.11	
	Mastacembelus dayi	9.29	9.24	9.32	

Types of Feeding habit	Species	Magnesium FAO Standard range			FAO Standard range
		Hot	Rainy	Cold	
Omnivores	*Tenualosa ilisha*	3.05	9.33	9.18	
	Salmastoma sardinella	6.37	9.42	9.40	4.5-452
	Rhinomugil corsula	7.35	9.42	9.21	
	Macrognathus zebrinus	9.41	9.25	9.11	
	Mastacembelus dayi	9.29	9.24	9.32	

Table 3. Seasonal variation of sodium concentration (mg/L) in fishes with different feeding habits

Types of Feeding habit	Species	Sodium			FAO Standard range
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	13.51	27.8	10.41	
	Labeo boga	9.76	29.81	22.17	
	Labeo calbasu	9.09	25.34	14.60	
	Labeo rohita	6.96	35.78	16.26	
	Oreochromis mossambicus	10.99	29.11	21.06	
Carnivores	*Notopterus notopterus*	4.46	29.36	22.60	
	Separata aor	1.98	28.33	9.89	
	Mystus cavasius	24.13	36.13	13.87	30-134
	Eutropiichthys vacha	6.77	31.89	17.25	
	Channa punctatus	28.52	25.15	16.46	
Omnivores	*Tenualosa ilisha*	7.68	25.60	22.87	
	Salmastoma sardinella	14.10	33.65	25.56	
	Rhinomugil corsula	16.64	36.13	18.11	
	Macrognathus zebrinus	31.37	27.96	20.46	
	Mastacembelus dayi	29.36	32.92	28.10	

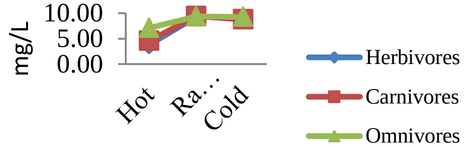
Table 4. Seasonal variation of potassium concentration (mg/L) in fishes with different feeding habits

Types of Feeding habit	Species	Potassium			FAO Range
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	142.20	12.63	12.54	
	Labeo boga	142.30	12.58	12.50	
	Labeo calbasu	143.20	12.51	12.50	
	Labeo rohita	141.10	12.58	12.52	
	Oreochromis mossambicus	141.50	12.58	12.52	
Carnivores	*Notopterus notopterus*	50.10	12.56	12.50	
	Separata aor	8.41	12.56	12.55	
	Mystus cavasius	143.00	12.66	12.52	19-502
	Eutropiichthys vacha	141.50	12.60	12.51	
	Channa punctatus	12.59	12.54	12.51	
Omnivores	*Tenualosa ilisha*	141.10	12.53	12.50	
	Salmastoma sardinella	143.70	12.64	12.52	
	Rhinomugil corsula	141.90	12.61	12.50	
	Macrognathus zebrinus	144.20	12.59	12.51	
	Mastacembelus dayi	145.50	12.58	12.52	

Table 5. Mean values of essential metals in fishes with different feeding habits

Feeding habit	Calcium			Magnesium			Sodium			Potassium		
	Hot	Rainy	Cold	Hot	Rainy	Cold	Hot	Rainy	Cold	Hot	Rainy	Cold
Herbivores	2.15	26.05	25.16	3.85	9.28	8.96	10.06	29.57	16.90	142.06	12.58	12.52
Carnivores	16.90	23.19	17.32	4.59	9.40	8.75	13.17	30.17	16.01	71.12	12.58	12.52
Omnivores	7.84	52.92	29.40	7.09	9.33	9.24	19.83	31.25	23.02	143.28	12.59	12.51

(A) Calcium



(B) Magnesium

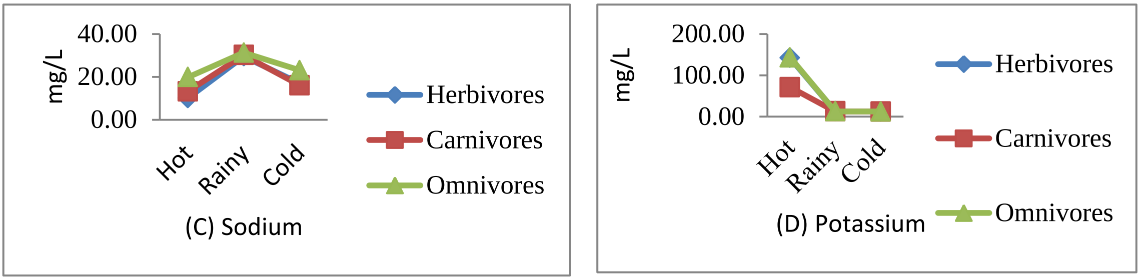


Figure 2. Seasonal variation of essential metal content in fishes with different feeding habits

Table 6. Seasonal variation of cadmium concentration (mg/L) in studied species with different feeding habits

Types of Feeding habit	Species	Cadmium			WHO/FAO MPL
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	-0.05	0.08	0.07	0.2
	Labeo boga	-0.06	0.01	0.07	0.2
	Labeo calbasu	-0.04	0.15	0.08	0.2
	Labeo rohita	-0.06	0.08	0.08	0.2
	Oreochromis mossambicus	-0.06	0.10	0.08	0.2
Carnivores	*Notopterus notopterus*	-0.04	0.07	0.07	0.2
	Separata aor	-0.06	0.48	0.07	0.2
	Mystus cavasius	-0.07	0.10	0.07	0.2
	Eutropiichthys vacha	-0.04	0.10	0.07	0.2
	Channa punctatus	0.10	0.07	0.08	0.2
Omnivores	*Tenualosa ilisha*	-0.04	0.14	0.09	0.2
	Salmastoma sardinella	-0.04	0.11	0.09	0.2
	Rhinomugil corsula	-0.04	0.33	0.08	0.2
	Macrognathus zebrinus	-0.04	0.09	0.08	0.2
	Mastacembelus dayi	-0.03	0.09	0.09	0.2

Table 7. Seasonal variation of lead concentration (mg/L) in fishes with different feeding habits

Types of Feeding habit	Species	Lead			WHO/FAO MPL
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	-1.31	0.07	-0.03	1
	Labeo boga	-3.38	0.10	0.00	1
	Labeo calbasu	-3.64	0.06	0.08	1
	Labeo rohita	-1.86	1.13	0.03	1
	Oreochromis mossambicus	-2.80	0.04	0.29	1
Carnivores	*Notopterus notopterus*	-0.87	0.14	0.25	1
	Separata aor	-2.03	0.41	-0.05	1
	Mystus cavasius	-2.34	0.15	-0.04	1
	Eutropiichthys vacha	-2.60	0.09	-0.03	1
	Channa punctatus	-0.11	0.06	-0.03	1
Omnivores	*Tenualosa ilisha*	-0.63	0.13	0.32	1
	Salmastoma sardinella	-3.58	0.21	0.05	1
	Rhinomugil corsula	-2.97	0.38	0.36	1
	Macrognathus zebrinus	-3.57	0.04	-0.04	1
	Mastacembelus dayi	-4.09	0.09	0.07	1

Table 8. Seasonal variation of arsenic concentration (mg/L) in fishes with different feeding habits

Types of Feeding habits	Species	Arsenic			WHO/FAO MPL
		Hot	Rainy	Cold	
Herbivores	*Cirrhinus mrigala*	-2.53	-0.91	0.83	0.26
	Labeo boga	0.75	1.08	2.16	0.26
	Labeo calbasu	1.37	1.20	1.61	0.26
	Labeo rohita	-2.20	-0.99	1.50	0.26
	Oreochromis mossambicus	0.57	-0.86	2.46	0.26
Carnivores	*Notopterus notopterus*	-3.07	-0.47	0.00	0.26
	Separata aor	-1.93	-0.80	0.80	0.26
	Mystus cavasius	-1.78	0.13	1.29	0.26
	Eutropiichthys vacha	-1.00	-0.52	2.11	0.26
	Channa punctatus	4.89	-1.10	1.69	0.26
Omnivores	*Tenualosa ilisha*	-2.75	-1.50	0.52	0.26
	Salmastoma sardinella	0.95	2.59	2.46	0.26
	Rhinomugil corsula	-0.06	-0.99	1.98	0.26
	Macrognathus zebrinus	0.98	-1.00	1.52	0.26
	Mastacembelus dayi	1.98	-0.66	2.84	0.26

Table 9. Mean values of toxic metals in fishes with different feeding habits

Feeding habits	Cadmium			Lead			Arsenic		
	Hot	Rainy	Cold	Hot	Rainy	Cold	Hot	Rainy	Cold
Herbivores	-0.05	0.08	0.08	-2.60	0.28	0.07	-0.41	-0.10	1.71
Carnivores	-0.02	0.16	0.07	-1.59	0.17	0.02	-0.58	-0.55	1.18
Omnivores	-0.04	0.15	0.09	-2.97	0.17	0.15	0.22	-0.31	1.86

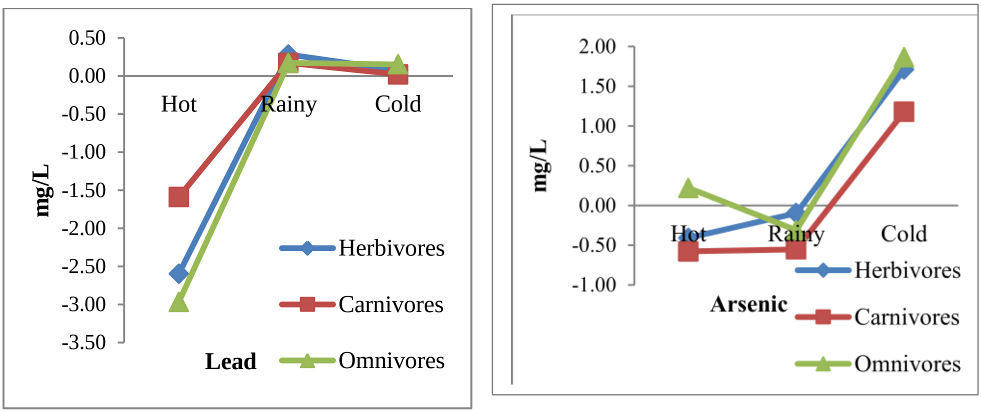


Figure 3. Seasonal variation of toxic metal content in fishes with different feeding habits

Table10. Seasonal variation of essential metal content in water samples of Ayeyawady River segment of Salay environs

Elements	Concentration (mg/L) Hot	Rainy	Cold	WHO/FAO MPL
Calcium	-0.01	7.22	9.61	100
Magnesium	0.33	8.45	8.60	150
Sodium	0.33	12.33	17.01	200
Potassium	-0.01	0.69	3.99	12

MPL = maximum permissible limit

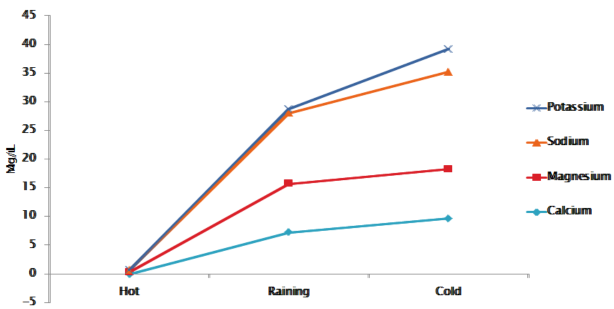


Figure 4. Seasonal variation of essential metal content in water samples of Ayeyawady River segment in Salay environs

Table 11. Seasonal variation of toxic metal content in water samples of Ayeyawady River segment of Salay environs

Elements	Concentration (mg/L)			WHO/FAO MPL
	Hot	Rainy	Cold	
Cadmium	-0.02	0.08	0.07	0.01
Lead	-0.86	−0.15	−0.17	0.05
Arsenic	-4.71	-1.26	1.40	0.01

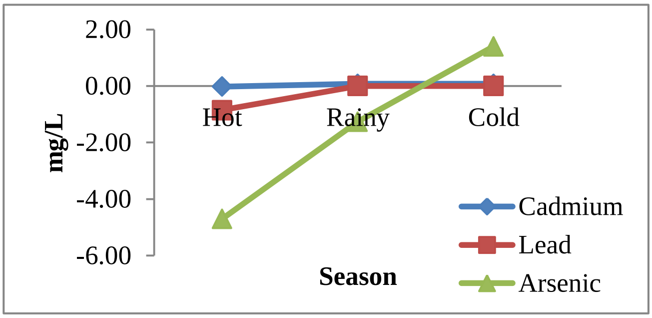


Figure 5. Seasonal variation of toxic metal content in water samples of Ayeyawady River segment, Salay environs

Table 12. Seasonal variation of essential metals content in sediment samples of Ayeyawady River segment of Salay environs

Elements	Concentration (mg/L)		
	Hot	Rainy	Cold
Calcium	4.93	5.72	1.32
Magnesium	9.09	9.04	8.93
Sodium	18.42	18.00	5.90
Potassium	8.47	7.79	5.73

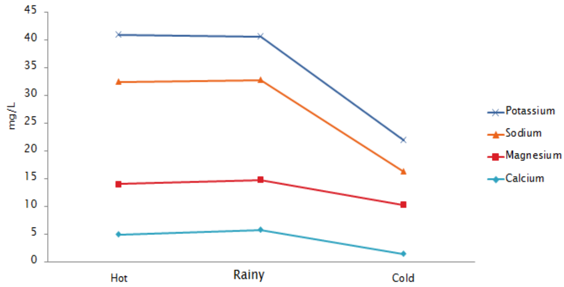


Figure 6. Seasonal variation of essential metal content in sediment samples of Ayeyawady River, Salay environs

Table 13. Seasonal variation of toxic metal content in sediment samples of Ayeyawady River segment of Salay environs

Element	Concentration (mg/L)			MPL		
	Hot	Rainy	Cold	TEC	MEC	PEC
Cadmium	0.12	0.12	0.08	0.99	3	5
Lead	0.13	0.11	−0.18	36	83	130
Arsenic	4.62	2.37	2.46	9.8	21.4	33

TEC = Threshold effect concentration, MEC = Midpoint effect concentration
PEC = Probable effect concentration, MPL = maximum permissible limit

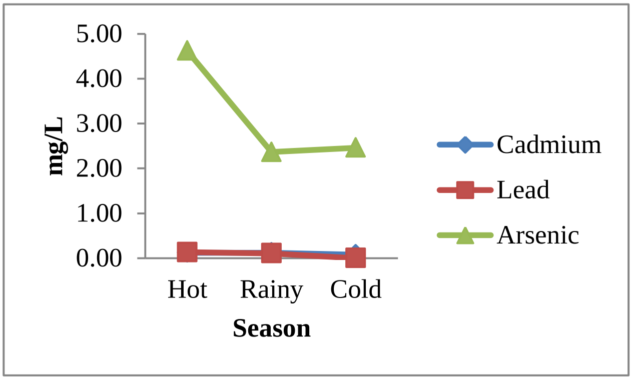


Figure 7. Seasonal variation of toxic metal content in sediments of Ayeyawady River, Salay environs

Discussion

Knowledge of element concentrations in fish is important for both human health and environmental management. Forstner and Wittmann (1981) reported that aquatic organisms fish are capable of accumulating metal concentrations much higher than those present in water, sediments and micro flora in their environment. Toxic metalsin the environment and food are very harmful because of their potential to bioaccumulate in different body parts of plants, animals and humans.

In this study, the effects of feeding habits and the seasons on element accumulation in muscle of fishes and their environs (water and sediments) were determined. The values observed for metal concentrations of all studied fish species of different feeding habits and their environs were lower than the maximum permissible limit in all seasons except for As in cold season.

Ca is needed for muscle development as well as heart and digestive system function. It is also essential for the normal development and maintenance of bones (Norman and Joseph, 1996). Mg plays important role in enzyme activities and maintaining electrical potential in nerves and membranes; it improves insulin sensitivity, protect against diabetes and also reduces blood pressure (Kiran *et al*., 2011). Na is one of the chief extracellular ions in the body: it involves in the production of energy and transport of amino acids and glucose into the body cells. Its deficiency results in hypothermia (Donatelle, 2005). K is the principle intracellular cation. It helps to regulate osmotic pressure and maintain pH. Its deficiency causes muscle weakness, respiratory paralysis and decreases reflex responses (Norman and Joseph, 1996).

Khin Myint Mar (2011) stated that Cd and Pb concentrations of all studied fish species were markedly lower than the permissible limit. WHO (2007) stated that Cd exposures are associated with kidney and bone damage. Cd has also been identified as a potential human carcinogen, causing lung cancer. Pb is toxic metal and non-essential element for the human body and it causes a rise in blood pressure, kidney damage and miscarriage (Kiran *et al*., 2011). Toxic effects appear when As is ingested in excess for long periods, resulting in cancer, cutaneous malignancies, etc.

The essential element concentrations recorded in the present study in all studied fishes with different feeding habits and their environs were within the maximum permissible limits of WHO/FAO. Toxic metal concentrations of all studied fishes were found to be lower than the maximum permissible limit except for As in the cold season. Toxic metal concentrations of water and sediment were found within the maximum permissible limit. Based on the present results, the fish species tested were found to be suitable for human consumption.

Conclusion

In the present study, essential and toxic metal concentrations of all studied fish species and in their environs (water and sediment), were found to be lower than the maximum permissible limits except the arsenic in cold season. Based on the results, it could be concluded that both the fishes and their environment were suitable for human health.

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References

Alam, M.G.M., Tanaka, A., Allinson, G., Laurenson, L.J.B., Stagnitu, F., and Snow, E.T., (2002). A comparison of trace element concentrations in cultured and wild carp **(***Cyprinus carpio*) of Lake Kasumigaura.Japn.Ecotox.Environ. Safe. 53:348-354.

Donatelle, R. J., (2005). Health: The Basics. Edn 7, Pearson Education Publishers. San Francisco, 20.

Forstner, U., Wittman, G. T. W., (1981). *Metal pollution in aquatic environment*. Spring Verlag Berlin, heides Berg, New York, 336 pp.

Hung, W. T, Manandhar, A. Ranasinghege, S A., (2010). A Walkability Survey in Hong Kong. TRANSED: 12th International Conference on Mobility and Transport for Elderly and Disabled Persons.

Issac R. A. and Kerber, J. D., (1971). Atomic Absorption and Flame Photometry Techniques and Uses in Soil, Plant and Water Analysis. In: Instrumental Methods for Analysis of Soil and Plant Tissue. Ed. L. M. Walsh, Soil Sci. Soc. Am. Inc., Madison, USA, pp. 17-37.

Khin Myint Mar, (2011). Uptake of heavy metals and its relationship to feeding habit of selected fish species in Ayeyawady River, Mandalay and Magway Segments. *PhD Thesis*. Department of Zoology, Mandalay University.

Kiran, Y. K., Mir, A. K., Rabia, N., Mamoona, M., Hina, F., Nighat, S., Tasmia, B., Ammarah, K., (2011). Element content analysis of plants of genus *Ficus* using atomic absorption spectrometer. African Journal of Pharmacy and Pharmacology 5 (3): 317-321.

Mance, G., (1987). Pollution threat of heavy metals in aquatic environment. Isevier Applied Science Publishers Ltd. London and New York. 372 pp.

Mansour. S. A., Sidky, M. M.. (2002). Eco toxicological Studies. 3. Heavy Metals contaminating water and fish from Fayoum Governorate, Egypt. *Food Chemistry*, 78(1):15-22

McDonald D.D., Ingersoil C.G., and Berger, A.T., (2000). Development and evaluation of consensus based sediment quality guidelines for freshwater ecosystems. Archieves of Environmental Contamination and Toxicology 39: 20-31.

Norman, N., and Joseph, H. H., (1996). Food Science, Chapman and Hall New York. Edn5, 55-62.

Refuel-Islam, M., Jahiruddin, M.d., Alim, M.d., and Akhtaruzzaman, M.d., (2013). Comsumption of unsafe foods: Evidence from heavy metal, mineral and trace element contamination. Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

Talwar, P. K., Jhingran, A. G., (1991). Inland fishes of India and adjacent countries. Oxford and IBH Publishing Co. PVT. Ltd., Calcutta.

WHO, (2007). Health risks of heavy metals from long-range trans boundary air pollution. WHO, Geneva