J. Myanmar Acad. Arts Sci. 2025 Vol. XXII. No.3

SEASONAL VARIATIONS OF HEAVY METALS ANALYSIS IN SOME FISH SPECIES, CHINDWIN RIVER SEGMENT, HOMALIN TOWNSHIP

Kay Khaing Lwin[1]*, Kay Lwin Tun[2], Cho Cho Thin[3]

Abstract

Severe heavy metal contamination in freshwater ecosystems and significant health risks can result from mining activities. The current study aimed to assess the seasonal variations of heavy metal concentrations (lead, cadmium, arsenic and mercury) in fishes (*Wallago attu* and *Cirrhinus mrigala*) and their environs (water and sediment), Chindwin River segment, Homalin Township, Sagaing Region. The analysis was conducted using a Flame Atomic Absorption Spectrometer at the Universities' Research Centre of the University of Yangon and the Water Quality Laboratory in Yezin, Nay Pyi Taw. The study spanned from December 2022 to November 2023. Heavy metal concentrations were found to vary depending on the seasons (hot, rainy and cold) and species. The highest concentrations of Pb were recorded in both *Wallago attu* and *Cirrhinus mrigala* during the hot season. However, the concentrations of As, Hg, and Cd in the studied fish species were recorded within the maximum permissible limits set by the World Health Organization/Food and Agriculture Organization (WHO/FAO). These findings suggest that the fish, water and sediments in the study area may not be entirely safe from toxic metal contamination. The observed values for all tested metal concentrations of studied fish species and their environments, except for water, were below the maximum permissible limits, indicating a relatively lower risk of contamination.

Key words: Fish muscle, Water, Sediment, Metal Concentration

Introduction

Heavy metals represent a significant group of aquatic pollutants with persistent characteristics, leading to bioaccumulation within aquatic biota through the food chain. The entry of these pollutants into aqutic environments is primarily attributed to anthropogenic activities such as mining, industrial processes, and agricultural practices. Among the toxic heavy metals of concern, arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) pose severe threats to ecosystems.

Non-essential heavy metals As, Cd, Pb and Hg affect human health through food chain (Jarup, 2003). Toxic effects of Pb, Cd and Hg have been reported even at trace concentrations and they are not essential for human body (Goyer, 1995). During gold recovery Hg directly contaminates soil, water and air, finally reaching sediments where it is converted to methylmercury (MeHg), absorbed by plankton, whereby entering the food chain (Selin, 2009).Humans also get directly exposed from Hg vapor inhalation, in any case, both Hg species are highly to the nervous system (Aschner and Aschner, 1990), causing sensory and mental disturbances, motor and cognitive dysfunction, ataxia, constriction of the visual field, audition problems (Harada, 1995), as well as deleterious effects on the renal, pulmonary, cardiovascular, digestive and immune system (Bernhoft, 2012; Frodello *et al*., 2000; WHO, 2016), among others.

The Chindwin River, situated in the Sagaing Region of Myanmar, stands as one of the country's most significant rivers. The upstream areas of the Chindwin River Basin, encompassing Mahar Myaing, Htmanthi, and Hukaung valleys, boast diverse ecological conditions and habitats critical for the basin's healthy ecosystem functioning. However, these components of riverine biodiversity face threats from deforestation, mining, and illegal fishing activities. The use of chemicals in illegal mining poses additional risks to inland fishing activities.

Artisanal gold mining is said to be on the increase and it is said to be the major contributor of metals in surface and groundwater because of indiscriminate use of mercury (Hg)

[1]Department of Zoology (Fisheries and Aquaculture), University of Yangon
[2]Department of Zoology, University of Yangon
[3]Department of Zoology (Fisheries and Aquaculture), University of Yangon

and other chemicals, which are detrimental to human health during mining activities (Donkor *et al*., 2006). Small-scale gold mining all over the world is noted for its effects on water bodies through pollution of both ground and surface waters, because its activities by nature make use of a lot of water thereby seriously polluting water resources (Cunningham *et al*., 2005; Owens *et al*., 2005).

Fish is one of the indicators of heavy metals pollution in water. Due to fish consuming heavy metal toxicity affect in the human body. Fish populations are declining due to illegal fishing and gold mining. This mining activities can be caused the degradation of breeding grounds and habitat loss for aquatic animals in the Chidwin River. The fisheries and fish populations of the Chindwin River have been affected by water pollution caused or otherwise adversely affected by gold mining, logging and agricultural expansion (Win Maung, 2021).

Gold mining is one of the main occupations of the people living along the banks of Chindwin River. This mining activities contaminate the river water and cause harmful aquatic animals. As a result, the present study aims to assess and evaluate the presence and levels of specific heavy metals, specifically cadmium, lead, mercury and arsenic, in fish. *Wallago attu (*Bloch & Schneider , 1801) , (locally known as Nga-bat), *Cirrhinus mrigala* Hamiton 1822 locally known as Nga-Gyin *)* and their surrounding environments (water and sediment) within the Chindwin River segment of Homalin Township. This research is pivotal in understanding the extent of heavy metal contamination in the Chindwin River segment of Homalin Township, providing essential insights for effective environmental management and conservation strategies. To determine the heavy metals (Pb, Cd, As and Hg) concentrations in muscle of fishes and to assess the metal contents in water and sediments of the river.

Materials and Methods

Study Area

Chindwin river segment of Myin Thar Yae Lae village, Homalin township, Sagaing Region situated between 24º 50′ 19″ N and 94º 56′ 20″ E was selected as the study area to analyze element concentrations in some fish species and their environs (water and sediment) (Fig. 6 and 7). It is used for irrigation, mining, drinking and fisheries. The quality of this ecosystem has been degrading due to gold mining and human activities. Therefore, it has been selected as a study area to investigate the heavy concentrations.

Study Period

Study period lasted from December 2022 to November 2023.

Collection of Samples

Wallago attu (Nga-bat)

*Cirrhinus mrigala(*Nga-Gyin)

Plate 1. Collected species for the analysis of heavy metals

A total of 15 specimens of fish species (*Wallago attu, Cirrhinus mrigala*) were collected seasonally from local fishermen (Plate 1). Identification of studied fish was carried out follow after Talwar and Jhingran (1991) and Fish Base 2013.Collected specimens were washed by tap water until the contamination on the body surface was runoff. Total length (cm) and body weights (g) of specimens were measured. After that, they were dissected using stainless steel scalpels and forceps. A part of the tissue was removed and weighed. Samples were put into an oven to dry at 90°C and until reached constant weights. After that they were stored at low temperature until digestion. Digestion of the samples carried out according to dry method by using furnace (Model-L-3383). Water and sediment samples were also collected seasonally at study site during the study period.

Sample preparation

Preparation of water and sediment

Each water sample was filtered through a 0.45 µm Whatman filter. The sample was analyzed directly.

The sediment sample was sun dried, grounded and sieved with 200 mm sieve to obtain a find powder 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 and cool down, 2mL of nitric acid was added and evaporated to dryness on sand bath. Then, 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 0.45µm Millipore filter paper and then transferred to 25 mL volumetric flask by adding distilled water. The digested sediment sample was analyzed for heavy metals using the Flame Atomic absorption spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) Universities' Research Centre (URC) and Water Quality Laboratory, Yezin at Nay Pyi Taw.

Preparation of fish

Tissue samples were dried to constant weight in an oven and dried samples were weight and stored in airtight containers. Digestion was conducted according to dry method. Five grams of dry sample was placed into crucible. And then transfer to a furnace (Model-L3383) and slowly raise temperature to 500° C for 2 hours. Samples were allowed to ash overnight. Once remove, samples were allowed to cool in room temperature and 5 mL nitric acid were added and swirl. After that 10mL HCl were added. The digestion was transferred to furnace and slowly raised temperature to 500° C and hold at this temperature for 1 hour. The crucible was removed, cooled and added 50mL deionized water and transferred to volumetric flask.

Chemical Analysis

The concentration of elements (Mercury, Arsenic, lead and cadmium) in muscle of studied fish species and aquatic environs of study area were analyzed tri-replicates by Flame Atomic Absorption Spectrometer (FAAS) (Perkin Elmer AAanalyst 800 and Winlab-32 software) in Universities' Research Centre (URC) at University of Yangon and Water Quality Laboratory, Yezin at Nay Pyi Taw. The results were compared with WHO/FAO maximum permissible limits and U.S. Environmental Protection Agency (EPA) guidelines.

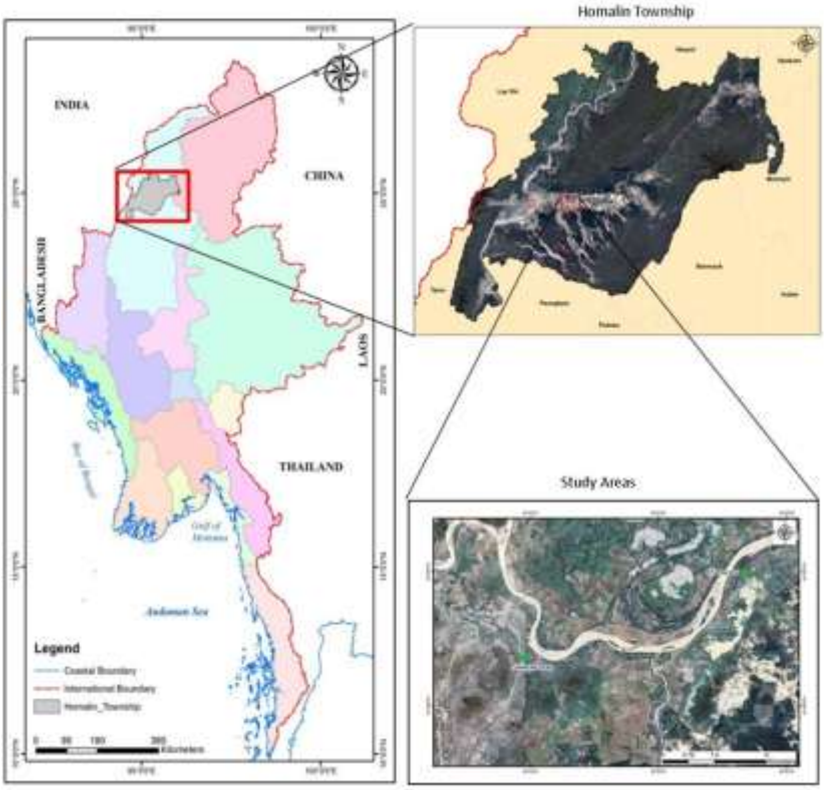

Figure. 1 Map of the study area and study site

Results

The concentrations of heavy metal (lead, cadmium, arsenic and mercury) in fish species (*Wallago attu* and *Cirrhinus mrigala*), water, and sediment in the Chindwin River segment, Homalin Township, were analyzed seasonally. Seasonal variations of test results were compared with (WHO/FAO) permissible limits for fish and water and the U.S. Environmental Protection Agency (EPA) guidelines for sediment.

The total length and weight of studied species were recorded in Table 1. The concentration of lead (Pb) was found to be highest in *Wallago attu* in three seasons. In hot season, this metal concentration of *Wallago attu* was found to be over the recommended maximum permissible limit WHO/FAO (Fig. 2).

The concentration of cadmium (Cd) in *Wallago attu* was also found to be highest in three seasons but it remained lower than the WHO/FAO permissible limits (Fig. 3).

The value of Arsenic in *Wallago attu* was not detected in three seasons throughout the study period (Fig. 4).

Lead (Pb) concentration in *Cirrhinus mrigala* was detected in three seasons but it was not over the WHO/FAO permissible limit except the hot season (Fig. 2).

The value of cadmium (Cd) in *Cirrhinus mrigala* was observed in three seasons and within the WHO/FAO permissible limits (Fig. 3).

Arsenic (As) content of *Cirrhinus mrigala* was found to be highest in rainy season but this value was not exceeded the WHO/FAO permissible limit (Fig. 4).

The concentration of mercury (Hg) in studied species (*Wallago attu* and *Cirrhinus mrigala)* was recorded in same value (0.003 mg/L) in hot season and below the WHO/ FAO permissible limits (Fig. 5). The concentrations of mercury in remaining seasons (cold and rainy) were not detected.

The value of lead contents in water was recorded to be higher than the WHO/FAO recommended limit in hot season. Cadmium, arsenic, and mercury contents in water were within the WHO/FAO maximum permissible limits (Fig. 6).

Test metal (Pb, Cd, As, and Hg) concentrations in sediment were found within the U.S. Environmental Protection Agency (EPA) guidelines during the study period (Fig. 7).

Table 1 Length and weight of studied fish species during study period

Sr. No.	Species	Season	Number	Mean Total Length (cm)			Mean Body Weight (g)		
1	*Cirrhinus mrigala*	Hot	5	21.6	±	6.10	108.88	±	115.87
		Rainy	5	18.4	±	3.86	54.18	±	28.12
		Cold	5	16.64	±	0.48	38.72	±	4.10
2	*Wallago attu*	Hot	5	37.94	±	6.02	243.32	±	123.26
		Rainy	5	17.78	±	4.06	20.32	±	8.69
		Cold	5	26.28	±	0.61	74.44	±	6.81

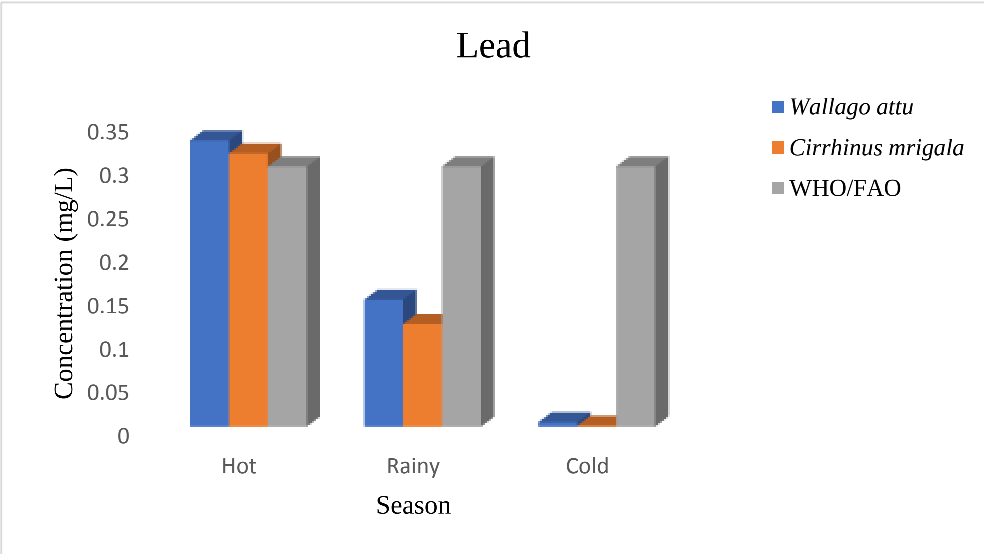

Figure. 2 Seasonal variation of lead concentration in studied fish species

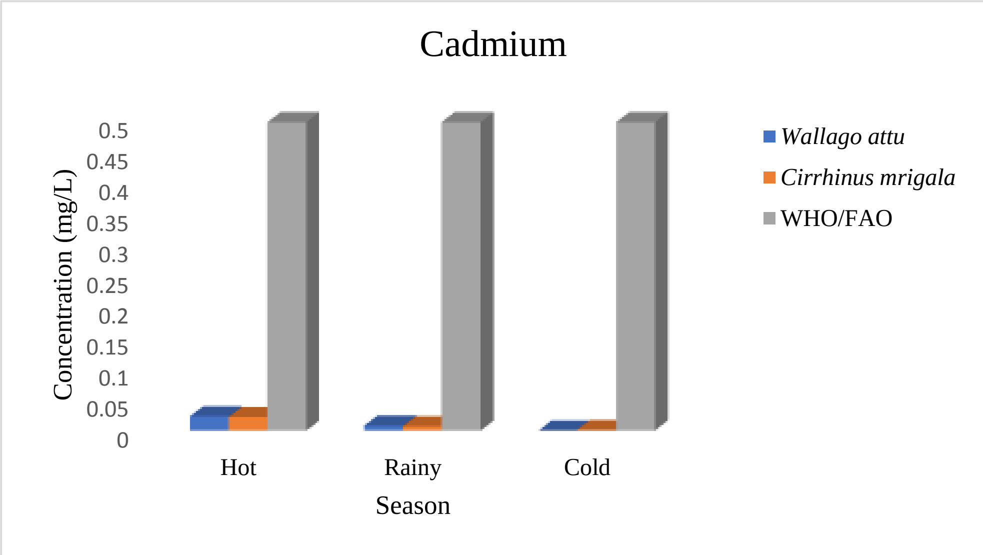

Figure.3 Seasonal variation of cadmium concentration in studied fish species

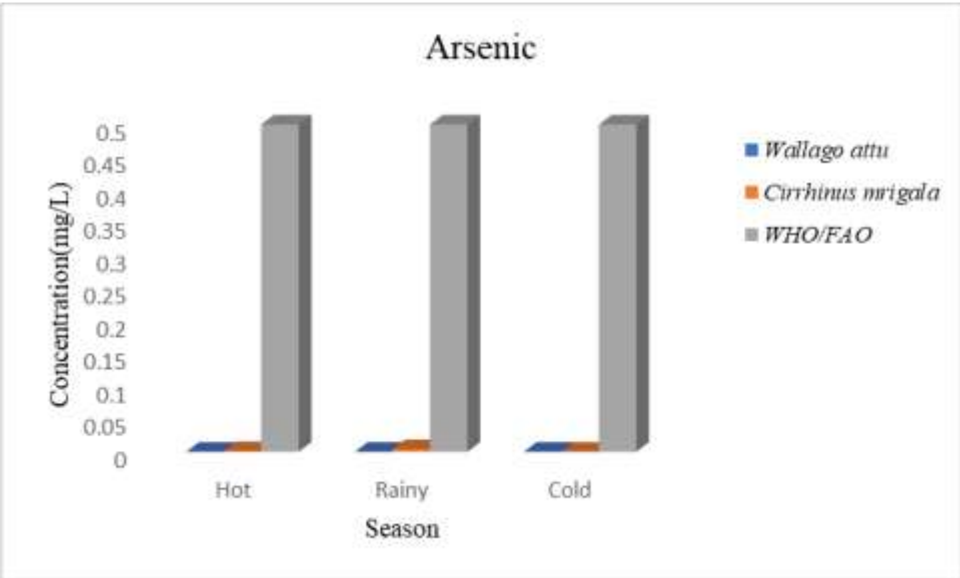

Figure. 4 Seasonal variation of arsenic concentration in studied fish species

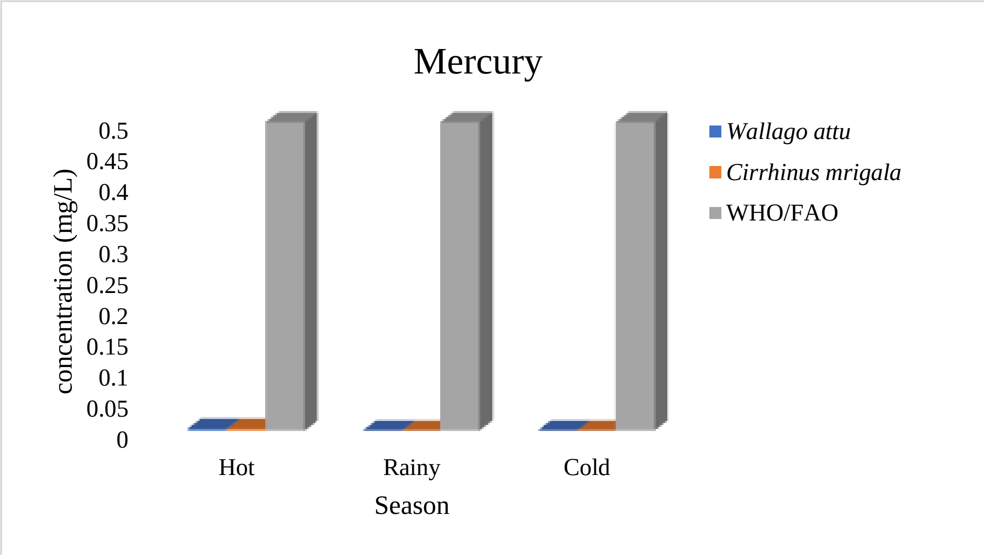

Figure. 5 Seasonal variation of mercury concentration in studied fish species

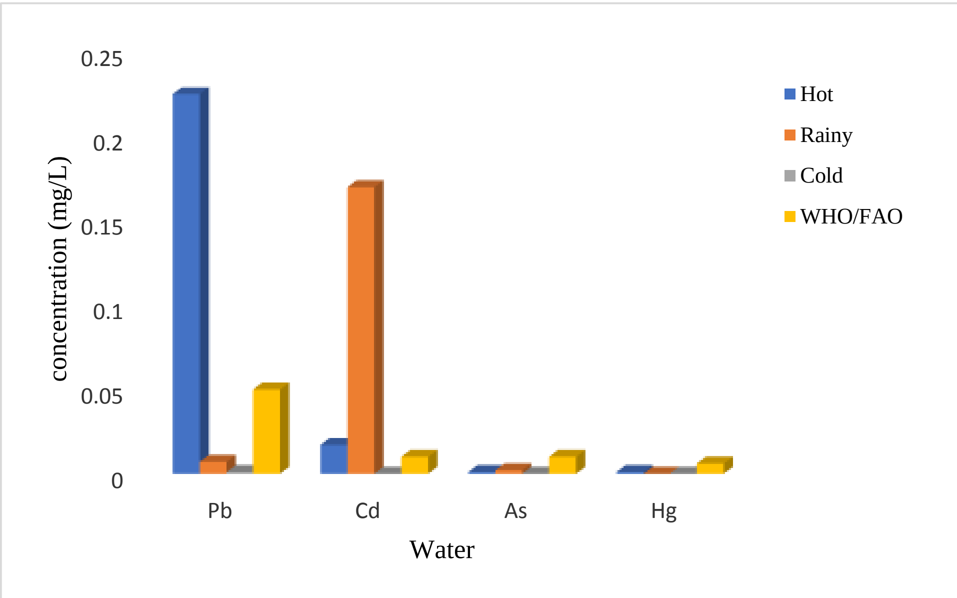

Figure. 6 Seasonal variation of metals concentration in water samples

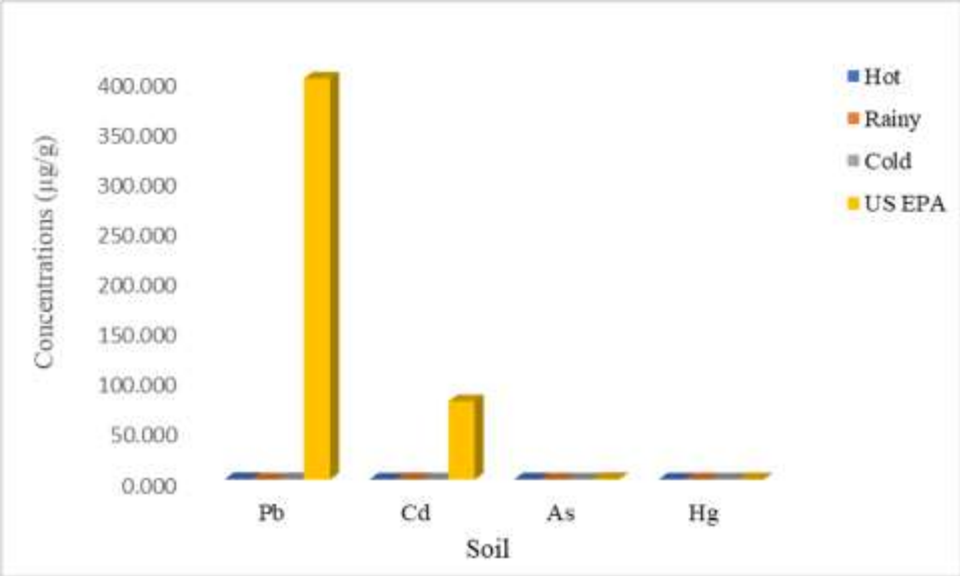

Figure. 7 Seasonal variation of metals concentration in soil samples

Table 2 Maximum permissible limit of metal concentrations (mg/L) stated in WHO and FAO guidelines and U.S. Environmental Protection Agency (EPA) (µg/g)

Sr. no.	Metal	WHO/FAO limit	WHO/FAO limit	US EPA
		Muscle	Water	Sediment
1	Pb	0.3	0.05	400
2	Cd	0.5	0.01	78
3	As	0.5	0.01	0.4
4	Hg	0.5	0.006	0.1

Discussion

The present study was aimed to investigate the concentrations of heavy metals (Pb, Cd, As, Hg) in fish species (*Wallgo attu* and *Cirrhinus mrigala*) and their surroundings (water and sediment) collected from the Chindwin River segment of Homalin Township. Moreover, the heavy metals contents found in tested samples (fish, water, and sediment) were compared WHO/FAO maximum permissible limits and U.S. Environmental Protection Agency (EPA). The levels of heavy metals were analyzed in this species due to its significance for human consumption. The gold mining activities reveals crucial insights into the differential responses of herbivorous and carnivorous fish species to heavy metal contamination.

Ahmed and Hossam (2013) reported high Cd and Pb concentrations in the muscle tissue of *Clarias gariepinus* during the summer and the lowest concentrations in winter of the study area and these concentrations in muscle were under the permitted in all area. So, the result was coincided with the current study. Moreover, Sein Moh Moh Paing (2019) found that Pb and Cd concentrations in study fish were exceeded than the maximum permissible limits in all seasons.

In the rainy season, Pb concentrtions in the muscle tissue of *Channa striata* (Nga Yant) were observed slightly than these of hot season and cold season in Hinthada Township (Aye Aye Mu, 2011). In the present results, the highest concentrations Lead and Cadmium in fish species (*Wallgo attu* and *Cirrhinus mrigala*) in hot season were found over the WHO/FAO maximum permissible limits. Cadmium concentration in *Wallago attu* was not detected in cold season during the study period.

Arsenic concentrations in *Wallago attu* were not found in all seasons although this metal concentration in *Cirrhinus mrigala* was observed in hot and rainy season. However, the concentrations of arsenic did not exceed the maximum permissible limits during study period. According to the Aye Aye Mu (2011), arsenic concentration in muscle tissue of *Lates calcarifer* were over in hot>rainy>cold season and *Channa striata* was high on rainy>hot>cold season. Chun *et al*. (2018) highlighted that arsenic concentration in the muscle tissue of their study fish were high in monsoon season. Sein Moh Moh Paing (2019) reported that arsenic concentration in all study fish species were exceeds the maximum permissible limits and guide line limit of WHO/FAO within the study period.

Regarding mercury concentrations, Khin Myint Mar (2011) reported levels exceeding the WHO(1990) maximum permissible limit in omnivorous and carnivorous fish species. In the present result, mercury contents in fish species carnivore (*Wallago attu*) and herbivore (*Cirrhinus mrigala*) were observed within the maximum permissible limits in hot season. Mercury concentration in studied fish species was not found in remaining seasons (cold and rainy).

Herbivorous fish species exhibit distinct patterns in heavy metal concentrations, with analyses revealing elevated levels of Pb and Cd Cho Cho Thin (2017) observed that lead concentration of *Labeo rohita* in rainy season in Ayeyarwady River segment of Salay environ was higher than the recommended maximum permissible limit of WHO/FAO, which is not coincided with the present findings as well. This suggested the potential contamination in their aquatic habitats, emphasizing their susceptibility to direct uptake of contaminants from polluted water and sediments due to their reliance on primary producers.

Karadede *et al.* (2004) reported that carnivorous fish, which mainly eat fingerlings, shrimp and zooplankton, are known to be active swimmers. These activities are known to accumulate high levels of heavy metals in the body. In contrast, carnivorous fish species, characterized by their dietary habits of preying on smaller organisms, display higher concentrations of Cd and Pb. This indicates the potential biomagnification of these heavy metals through the food chain, highlighting the role of predators in accumulating contaminants from lower trophic levels.

Herbivores may serve as indicators of direct contamination from mining effluents, while carnivores may reflect the biomagnification of contaminants through the food web. The presence of elevated concentrations of Pb and Cd in herbivores, along with increased levels of Cd and Pb in carnivores, emphasizes the importance of understanding the intricate pathways of heavy metal transfer in aquatic ecosystems affected by gold mining activities.

In the present results, lead concentrations of water were found to be higher than the maximum permissible limit (0.05 mg/L) in hot season. The remaining season (rainy and cold) within the WHO/FAO limit. The concentration of cadmium in water was exceeds the limits of (0.01mg/L) during rainy and hot season. Arsenic and mercury contents in water were observed to be lower than the maximum permissible limits recommended by WHO/FAO in hot and rainy seasons. Mercury concentrations in water was not detected in rainy and cold season. The obtained results of all metal concentrations (Pb, Cd, As and Hg) from sediment during the study period were observed to be lower than the U.S. Environmental Protection Agency (EPA). In the current study, the highest concentrations of heavy metals may originate from small scale gold mining and agricultural activities.

The seasonal variations of heavy metals in fish, water, and sediment further highlight the dynamic nature of contamination in response to gold mining impacts. This study indicates that the species is safe for human consumption. Although heavy metal concentrations of water over the WHO/FAO maximum permissible limits, heavy metals contents in sediment within the U.S. Environmental Protection Agency (EPA). Therefore, a regular monitoring of heavy metals level in fish, water and sediment in the study area is necessary.

Conclusion

In the current study, heavy metals concentrations in studied fish species were found to be lower than the maximum permissible limit. Base on the results, it can be concluded that the consuming the studied fish species is safe. However, heavy metals concentrations in water exceed the maximum permissible limits and heavy metals contents in sediment within the U.S. EPA guidelines. Therefore, regular monitoring of heavy metal levels in both fish and their surroundings, including water and sediment.

Acknowledgements

I would like to express my gratitude to Professor/Head Dr. Ye Chan, University Research Center (URC) and University of Yangon, for the permission to use FAAS. I would also like to thank Daw Lay Shee Phine, Homalin Township, Sagaing Region for her invaluable contribution in providing the fish samples.

References

Ahmed, T., A. and Hossam, M. O. 2013. Seasonal variation of heavy metals accumulation in muscles accumulation in muscles of the African Catfish *Clarias gariepinus* and in river Nile water and sediments at Assiut Governorate, Egypt. *Journal of Biology and Earth Sciences*, Vol.3, Issue 2, B236-B248.

Aschner, M. and Aschner, J.L. 1990. Mercury neurotoxicity: mechanisms of blood-brain barrier transport. *Neurosci Biobehay, Rev*. 14, *Rev, 14*, 169-176

Aye Aye Mu.2011. Determination of toxic heavy metal contents in freshwater fish (Ka-kadit and Nga Yant) from Hinthada Township. *University Research Journal* 2011, Vol.4, No.3.

Barletta, M., Lucena Lrr, Costa, M.F. and Cysneiros Fja. 2012. The interaction rainfall vs. weight as determinant of total mercury concentration in fish from a tropical estuary. *Environ Pollut.* 167: 1-6.

Bernhoft, R.A.2012.Mercury toxicity and treatment: a review of the literature. *J. Environ*. Public Health 2012, 460-568

Buchman, M.F *NOAA Screening Quick Reference Tables*; NOAA: Seattle, WA, USA, 2008; pp.1–34.

Burger, J., and Gochfeld, M. 2005. Heavy metals in commercial fish in New Jersey. *Environ Res* 99: 403-412.

Cho Cho Thin, 2017. Relation of some essential and toxic elements on different feeding types of some freshwater fishes along the Ayeyawady River Segment, Salay Environs. *PhD Thesis*. Department of Zoology, University of Yangon.

Cho Cho Thin, Nang Sandar Myint, May Thu Aung, May Thu Rein Oo, Khin Thu Zar Win, July Maung Maung, Kay Lwin Tun., 2022. Bioaccumulation of Heavy Metals in Tilapia Fish (Oreochromis niloticus Linnaeus, 1758) from Water and Sediment of Kyet Mauk Taung Dam, Mandalay Region. MAAS

Chuan, O. M., Aziz, N. A., Shazili, N. A. M. and Yunus, K. 2018. Selected heavy metals content in commercial fishes at different season landed at fisheries development authority of Malaysia complex, Kuala Terengganu, Malaysia. *Journal of Sustainability Science and Management*, Speciel Issue, No.5, 29-38

Cunningham WP, Cunningham MA, Saigo, B. 2005. *Environmental science: a global Concern*, 8th edn. McGraw-hill, Boston.

Donkor A. K., *et al*. 2006. Environmental impact of mercury from artisanal gold mining in west Africa. *Environmental Monitoring and Assessment*, 117(1-3), 207-218.

Donkor AK, Nartey VK Bonzongo JL, Adotey DK (2006) Artisanal mining of gold with mercury in Ghana. West Afr J Appl Ecol 9:2–18

Fish Base, 2011.Catalogue of life: (cited 2012 September 3). Available from http://www.fishbase.org/manual/key/20 facts. html.

Food and Agriculture Organization, United Nations (FAO). 2018. Report on the formulation of a National water Vision to Action in the Union of Myanmar. Yangon: Ministry of Agriculture and Irrigation, ESCAP, FAO. http://www.fao.org/3/ae546e/ae546e04.htm.

Frodello, J., Romeo, M. and Viale, D. 2000. Distribution of mercury in the organs and tissues of five toothed-whale species of the Mediterranean. *Environ. Pollut*. 108, 447-452.

Goyer, RA. 1995. Nutrition and metal toxicity. Am. J. Clin. Nutr. 1995; 61:646S-650S.

Harada, M., 1995. Minamata disease: methylmercury poisoning in Japan caused by environmental pollution. Crit. Tev. Toxicol. 25,1-24.

Jarup, L. 2003 Hazards of heavy metal contamination. Brit. Med. Bull. 2003; 68:167-182.

Karadede, H., Oymak, S.A., Ünlü, E., 2004. Heavy metals in mullet, *Liza abu*, and catfish, *Silurus triostegus*, from the Ataturk Dam Lake (Euphrates) *Turkey Environment International.* 2004;30:183–188.

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, University of Mandalay.

Nriagu, J. O. (1989). A global assessment of natural sources of atmospheric trace metals. Nature, 338(6210), 47-49.

Owens PN, Batalla RJ, Collins AJ, Gomez B, Hicks DM, HorowitzAJ, Kondolf GM, Marden M, Page MJ, Peacock DH, PetticrewEL, Salomons W, Trustrum NA (2005) Fine-grained sediment in river systems: environmental significance and management issues. River Res Appl 21:693–717

Owens, P. N., et al. 2005. Sediment sources in disturbed watersheds: the role of channel banks and hillslopes. Hydrological Processes, 19(8), 1733-1751

Publishing Co. PVT. Ltd., Calcutta.

Rainbow, P. S. (2002). Trace metal concentrations in aquatic invertebrates: why and so what? Environmental Pollution, 120(3), 497-507.

Sein Moh Moh Paing, 2019. Seasonal variation of heavy metals accumulation in muscle tissues of some freshwater fishes of Panhlaing river segment, Nyaung Done Township. *PhD Thesis*. Department of Zoology. University of Yangon.

Selin, N.E. 2009. Global biogeochemical cycling of mercury: a review. *Annu. Rev.Environ. Resour*. 34, 43-63.

Smith, B. D., McFall, A., & Sheaves, M. (2017). Ecology of fishes in tropical rivers and estuaries. Oxford University Press.

Storelli, M. M., Storelli, A., & Marcotrigiano, G. O. (2003). Total and subcellular distribution of heavy metals in the organs of the Antartic fish Trematomus bernacchii. Polar Biology, 26(2), 93-99.

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

U.S. Environmental Protection Agency (EPA). *Generic Soil Screening Levels 2011*; US EPA:Washington, DC, USA; pp. 1–11.

U.S. Environmental Protection Agency. (2006). Soil Screening Guidance: Technical Background Document.

WHO/FAO, 2011. ‘Joint FAO/WHO food standards programme codex committee on contaminations in food’. Food and Agricultural organization of the United Nations, Geneva, World Health Organization, 90pp.

Win Maung. (2021). Impacts of Gold Mining on Fish and Fishery Resources in the Chindwin River, Myanmar. Chindwin Futures.