Cadmium Uptake and Relationship to Feeding Habits of Freshwater Fish from the Ayeyarwady River, Mandalay, Myanmar

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Introduction

Pollution of the aquatic ecosystem by heavy metals is increasing due to anthropogenic activities. Aquatic pollution is growing at an alarming rate and threatens conservation ecology and public health. This situation has further intensified due to increases in population, urbanization, industrialization, and agricultural practices. Long-term simultaneous application of fertilizer and manure in agricultural areas has been linked with higher metal accumulation in soil and plants. In some fertilizers, the presence of cadmium (Cd) at high concentrations is of most concern due to the toxicity of this metal and its ability to concentrate in soils and bioaccumulate in plants and animals. Most Cd is released from human activities such as mining and smelting of sulfide ores, fuel combustion, and application of phosphate fertilizers or sewage sludge.

Fish is consumed globally as a source of nutrients, particularly protein. Fish flesh contains high quality protein and high content of two types of omega-3 polyunsaturated fatty acids. Therefore, fish consumption is rising among an increasingly health-conscious population.

Cadmium acts as a fish stressor, leading to metabolic alterations and decreasing total protein concentrations. One route of exposure of Cd to humans is through the consumption of fish contaminated with Cd accumulating in the human body, especially in the kidneys, leading to kidney dysfunction with impaired reabsorption of proteins, glucose and amino acids, etc.

Myanmar is an agricultural country. According to informal interviews with local farmers and information available at agricultural centers, the application of phosphate fertilizers in this area is greater than land requirements, which may result in high concentrations of Cd in soil.

Background. Pollution of the aquatic ecosystem by heavy metals is increasing due to anthropogenic activities. Cadmium (Cd) can accumulate in soil, be taken up by plants, and passed on in the food chain to animals and humans. Objectives. The present study was conducted to analyze the uptake of Cd in muscles of sampled fish with different feeding habits and to compare levels of Cd in fish from the Ayeyarwady River, Myanmar with international standards. Methods. The acid digestion procedure was used for sample preparation. Cadmium concentrations in fish samples were determined by flame atomic absorption spectrophotometry (Perkin Elmer AAanalyst 800 and Winlab-32 software). Results. In herbivorous fish species, Cd content ranged from 0.07 (Catla catla) to 0.086 mg/kg (Osteobrama belangeri). In carnivorous fish species, Cd ranged from 0.060 (Mystus leucophasis) to 0.083 mg/kg (Wallago attu). In omnivorous fish species, Cd ranged from 0.07 (Botia histrionica) to 0.084 mg/kg (Gudusia variegata). Cadmium content did not differ significantly across the three types of feeding habits (p>0.05). Discussion. The accumulation of Cd in the muscle of studied fish was lower than the permissible limit set down by the European Union in 2001 (0.1 ppm), but above the limits set down by the Food and Agriculture Organization/World Health Organization, European Commission (0.05 ppm) and within the limit of United States Food and Drug Administration (0.01-0.21 ppm). The data obtained in the present study indicate that levels of Cd were not significantly different across fish species with different feeding habits. Conclusions. The examined fish samples were not fully safe for human consumption due to high levels of Cd.

Competing Interests. The authors declare no competing financial interests.

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Ayeyarwady River had been declining in water quality for many years. \cite{14}
Siltation occurs at a rate of 360 million tons annually, ranking the third highest in the world, due to mining operations, deforestation, lack of soil protection and land overexploitation. This poses a major threat to the river. Moreover, the agricultural sector also contributes to impacts on river water quality. \cite{14} Uncontrolled use of fertilizers and lack of runoff treatment mechanisms in agricultural areas may have contributed to this increase. Direct sewage disposal, landfills, organic wastes and manure are related to high ammonia nitrogen concentration in rivers. \cite{15} In light of these issues, the present study was conducted to analyze the uptake of Cd in muscles of fish species across different feeding habits and to assess the level of Cd in fish muscle compared to international standards.

In addition, the quality of fish for human consumption was assessed.

**Methods**

Gawwein fish landing is located in the western part of Mandalay City, on the east bank of the Ayeyarwady River (Figure 1). It is the only site that distributes fish caught from the river to markets in Mandalay City. The survey was conducted from July 2010.
Sample collection

Fish were purchased weekly, directly from local fishermen at Gawwein fish landing site, Ayeyarwady River, Mandalay segment. The collected fish species were identified following the method of Talwar and Jhingran.\(^7\) Total length and weight were measured and then categorized based on their feeding habits. Based on the stomach contents of fish collected, fish species were classified as herbivores, carnivores and omnivores.

Sample preparation

The collected fish were washed in tap water to eliminate contamination on the body surface. The fish were beheaded, scaled, gutted and then the muscles were dissected with a cleaned knife. After dissecting, the muscles were sun dried and powdered by blender and pestle and sieved. Finally, dried fish powder was stored in an airtight plastic container. One sample for each species was analyzed for Cd content. For sample preparation, two or three pieces of muscle tissue were used for large specimens and for small fish about 20 fish were pooled.

Acid digestion method

The acid digestion procedure was used following after Agemian \( et \ al.\)\(^{18}\). About 5 g of fish homogenate was first digested with 5 ml of concentrated nitric acid (65% analar grade) and 5 ml of concentrated sulphuric acid in borosilicate glass tubes and allowed to react overnight (about 15 hours) at room temperature. The following day, the tubes were placed in a sand bath and heated up to 60°C for about 30 minutes and allowed to cool. After cooling, 10 ml of nitric acid was added and the solution was heated again to about 300°C for 10 minutes. Then, 5 ml of hydrogen peroxide was added and heated until the sample was clear. All samples were totally dissolved. Finally, the samples were cooled again to room temperature and the volume was adjusted to 50 ml of deionized water.

Metal analysis

The prepared samples were sent to Universities’ Research Centre (URC), University of Yangon, to analyze the Cd content. The concentration of Cd was determined by flame atomic absorption spectrometry (Perkin Elmer AAAnalyst 800 and Winlab-32 software). The results were expressed as mg/kg or parts per millions (ppm) mg of Cd per kilogram of fish.

Data analysis

One-way analysis of variance was used to determine statistical differences in Cd content in fish species across different feeding habits (herbivorous, carnivorous and omnivorous fish species) using Statistical Package for the Social Sciences (SPSS) software (p>0.05).

Results

A total of 25 fish species from Gawwein fish landing in Mandalay were collected and their stomach contents were examined. A total of 1024 fish stomachs were observed, and fish were classified as herbivores, carnivores and omnivores based on their stomach contents (Table 1).

According to feeding habits, 5 herbivorous species, 12 carnivorous species and 8 omnivorous species (138 fish species) were analyzed for Cd content. Total length and Cd concentrations for herbivorous, carnivorous and omnivorous fish can be found in Tables 2, 3 and 4 respectively. Cadmium content did not differ significantly across the three fish groups representing different types of feeding habits (p>0.05).

Discussion

The results of the present study indicate that Cd was detected in all fish samples (total of 25 samples) examined. The lowest Cd level was found in Mystus leucophasis, while the highest was found in Osteobrama belangeri. In Myanmar, Mu reported that the accumulation of Cd in the muscle of Channa striata (Nga yant) in Hinthada township was 0.077 ± 0.025 mg/kg.\(^9\) Mar reported that the level of Cd in the muscle of Channa striata in the Ayeyarwady River segment, Mandalay Region, was 0.073 ± 0.007 mg/kg.\(^{16}\) The present findings agree with the results of these previous studies.

Paudel \( et \ al.\) found that the concentration of Cd in Clarias batrachus in fish markets of Kathmandu Valley, Nepal was 0.53±0.33 ppm, while Ahmed \( et \ al.\) reported accumulation of Cd in the tissues of Channa striata and Clarias batrachus from the Wang Mengkuang abandoned tin mine, Malaysia of 0.10 ± 0.00 ppm and 0.12 ± 0.01 ppm, respectively.\(^{10,12}\) The results of the present study were lower than the findings of these two previous studies.

In Myanmar, the source of Cd input to the Ayeyarwady River is not precisely known, but possible sources mentioned in the literature were electroplating and heavy industries. However, no industries of this nature are present in this area. The Bay of Bengal Marine Ecosystem Project, Country report on pollution—Myanmar\(^{3}\) states that industries, agriculture and municipalities commonly discharge waste into nearby creeks and rivers, eventually polluting larger water bodies. The growth of industries, increased use of
### Table 1 — Feeding Habits of Fish Species According to Stomach Contents

| Species                        | Stomach contents                                      | Feeding habit   |
|--------------------------------|--------------------------------------------------------|-----------------|
| *Notopterus notopterus*        | Fish, crustaceans and insects                          | Carnivore       |
| *Gudasia variegata*            | Algae and pieces of aquatic plants and small fish      | Omnivore        |
| *Labeo calbasu*                | Algae and aquatic plants                               | Herbivore       |
| *Catla catla*                  | Algae and aquatic plants                               | Herbivore       |
| *Cirrhinus mrigala*            | Pieces of aquatic plants                               | Herbivore       |
| *Osteobrama belangeri*         | Algae and aquatic plants                               | Herbivore       |
| *Pantus sophore*               | Algae and pieces of aquatic plants and small fish      | Omnivore        |
| *Salmo gairdneri*              | Algae and pieces of aquatic plants and small fish      | Omnivore        |
| *Lepidocephalichthys thermalis*| Pieces of aquatic plants and small fish                | Omnivore        |
| *Botia histrionica*            | Algae and pieces of aquatic plants and small fish      | Omnivore        |
| *Sperata aor*                  | Pieces of fish and beetles                             | Carnivore       |
| *Mystus cavasius*              | Fish, beetles and mud                                  | Carnivore       |
| *Mystus leucophysis*           | Pieces of fish, beetles and mud                        | Carnivore       |
| *Mystus menoda*                | Fish, beetles and mud                                  | Carnivore       |
| *Ompok bimaculatus*            | Algae and pieces of aquatic plants and small fish      | Omnivore        |
| *Wallago attu*                 | Fish and insect larvae                                 | Carnivore       |
| *Clupisoma prateri*            | Algae and pieces of small fish                         | Omnivore        |
| *Hemipimelodus jatus*          | Aquatic insects and fish                               | Carnivore       |
| *Bagarius yarrellii*           | Pieces of aquatic insects and fish                     | Carnivore       |
| *Xenentodon cancila*           | Aquatic insects and fish                               | Carnivore       |
| *Parambassis ranga*            | Aquatic insects and fish                               | Carnivore       |
| *Glassogobius giurus*          | Aquatic insects and fish                               | Carnivore       |
| *Oreochromis sp.*              | Algae and pieces of aquatic plants                     | Herbivore       |
| *Channa striata*               | Aquatic insects and fish                               | Carnivore       |
| *Mastacembelus armatus*        | Pieces of aquatic plants and insects                   | Omnivore        |

### Table 2 — Cadmium Content of Herbivorous Fish Species from the Gawwein Fish Landing Site

| Scientific Name | Local Name     | Number of specimens | Total length (cm) | Cd (ppm wt/wt ±SD) |
|-----------------|----------------|---------------------|-------------------|--------------------|
| *Catla catla*   | Nga-gaung-pwa  | 1                   | 21.7              | 0.070±0.001        |
| *Cirrhinus mrigala* | Nga-gyin-phyu | 1                   | 38.5              | 0.071±0.005        |
| *Labeo calbasu* | Nga-net-pya    | 1                   | 22.6              | 0.076±0.010        |
| *Osteobrama belangeri* | Nga-phant-ma   | 1                   | 15.1              | 0.086±0.008        |
| *Oreochromis sp.* | Tilapia        | 1                   | 20.3              | 0.083±0.009        |
fertilizers and pesticides, urbanization and discharge of municipal waste are increasingly polluting the river system. As a result, some rivers are polluted with residual fertilizers, pesticides and municipal waste. A total of 352,698 tons of chemical fertilizers and 4,940 metric tons of pesticides were used in 2009-10. In addition, agricultural chemicals, communities and cities along the river directly dispose of untreated raw sewage, municipal wastes, and medical wastes into rivers, polluting the river system. The Ayeyarwady River is the lifeline of Myanmar and the majority of the country's population is dependent on the river for their survival. The ecology of the river is under serious threat. Fish can accumulate Cd from the water, leading to possible human consumption of Cd-contaminated fish (contaminated food chain).
Information on heavy metal concentrations in fish is important for management of human health risks and pollution control strategies. Most fish species are at the top of the aquatic food chain and have the potential to accumulate high metal content even in mildly polluted conditions and metals accumulated in the muscle tissue of fish are of great importance due to human health concerns. An early example of environmental problems due to chronic Cd poisoning (itai-itai disease) occurred in Fugawa, Japan, in 1955. Moreover, the consumption of a Cd-contaminated rice and fish diet has been shown to cause chronic renal failure in northcentral Sri Lanka. Manures, fertilizers, and atmospheric precipitation are major sources of Cd leading to Cd accumulation in agricultural soils due to over use of manure and phosphate.

The maximum permitted level of Cd in fish muscle according to different organizations and guidelines is presented in Table 5. The European Union has set Cd tissue residues of 0.1 ppm fresh weight of marine fish as the criterion for human health protection, whereas the Food and Agriculture Organization/World Health Organization and European Commission limits Cd tissue residues to 0.5 ppm fresh weight of freshwater fish. The Cd content in the muscle of fish studied was above the permissible limit (0.05 mg/kg) set down by the European Commission and the Food and Agriculture Organization/World Health Organization but within the limits of (0.01-0.21 mg/kg) set by the United States Food and Drug Administration and (0.1 mg/Kg) of European Union limit (Table 5). It should be noted that no uniform source of guidance or standards for most metal residues in fish tissue is available. There is no single reference for acceptable levels of most metals in marine or freshwater fish, whether self-caught or commercially harvested.

Cadmium accumulates primarily in the liver and kidneys of vertebrates and not in the muscle tissue and as intestinal absorption is low, biomagnification through the food chain may not be significant. The present study presents information on Cd content in fish analyzed in the study area and indicates that Cd content did not differ significantly among fish with different feeding habits. The results of the present study suggest that Cd levels in fish are unrelated to the sources of food for fish in the study area.

From the results of this study, it can be assumed that Cd does not presently biomagnify through the food chain. Nevertheless, uptake of Cd by fish has important implications for human exposure to Cd, whether or not significant biomagnification occurs. The concentration of Cd in fish samples across different feeding habits indicate a human health risk for local consumers. The results of the present study suggest that measures should be taken to control the cumulative effects of Cd and to monitor the water quality of the Ayeyarwady River.

### Conclusions

The results of the present study indicate that the high level of Cd in muscle tissues of studied fish species may be due to anthropogenic activities such as municipal waste, and overuse of fertilizers, manures and pesticides on farms along the Ayeyarwady River, as well as domestic wastes. Although the number of samples was limited, the present findings highlight the presence of Cd contamination in fish from the Ayeyarwady River. In terms of public health, fish commonly consumed by the local people in the Mandalay Area may pose significant human health risks due to heavy consumption of Cd-contaminated fish.

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References

1. Malik N, Biswas AK, Qureshi TA, Borana K, Virha R. Bioaccumulation of heavy metals in fish tissues of a freshwater lake of Bhopal. Environ Monit Assess [Internet]. 2010 Jan [cited 2020 Mar 17];160(1-4):267-76. Available from: https://doi.org/10.1007/s10661-008-0569-8 Subscription required to view.

2. Giguerre A, Campbell PG, Hare I, McDonald DG, Rasmussen JB. Influence of lake chemistry and fish age on cadmium, copper, and zinc concentrations in various organs of indigenous yellow perch (Perca flavescens). Can J Fish Aquat Sci [Internet]. 2004 [cited 2020 Mar 17];61(9):1702-16. Available from: https://doi.org/10.1139/f04-100 Subscription required to view.

3. Gupta A, Rai DK, Pandey RS, Sharma B. Analysis of some heavy metals in the riverine water, sediments and fish from river Ganges at Allahabad. Environ Monit Assess [Internet]. 2009 Oct [cited 2020 Mar 17];157(1-4):449-58. Available from: https://doi.org/10.1007/s10661-008-0547-4 Subscription required to view.

4. Martin JA, Arias ML, Corbi JM. Heavy metals contents in agricultural topsoils in the Ebro basin (Spain). Application of the multivariate geostatistical methods to study spatial variations. Environ Pollut [Internet]. 2006 Dec [cited 2020 Mar 17];144(3):1001-12. Available from: https://doi.org/10.1016/j.envpol.2006.01.045 Subscription required to view.

5. Parkpian P, Leong ST, Laortanakul P, Thunhtaisong N. Regional monitoring of lead and cadmium contamination in a tropical grazing land site, Thailand. Environ Monit Assess [Internet]. 2003 Jun [cited 2020 Mar 17];85(2):157-73. Available from: https://doi.org/10.1023/A:102368012736 Subscription required to view.

6. Alloway BJ, editor. Heavy metals in soils. Glasgow: Blackie; 1990. 339 p.

7. Brigden K, Stringer R, Santillo D. Heavy metal and radionuclide contamination of fertilizer products and phosphogypsum waste produced by The Lebanese Chemical Company, Lebanon, 2002 [Internet]. Exeter, UK: Greenpeace; 2002 Nov [cited 2020 Mar 17]. 16 p. Available from: http://www.greenpeace.to/publications/LCC._2002.pdf

8. Levit, SM. A Literature Review of Effects of Cadmium on Fish November 2010 For the nature conservancy. CSP2, 2010. 16p.

9. Wangstrand H, Eriksson J, Oborn I. Cadmium concentration in winter wheat as affected by nitrogen fertilization. Eur J Agron [Internet]. 2007 Apr [cited 2020 Mar 17];26(3):209-14. Available from: https://doi.org/10.1016/j.ejagro.2006.09.010 Subscription required to view.

10. Clarkson WT. The three modern faces of mercury. Environ Health Perspect [Internet]. 2002 Feb [cited 2020 Mar 17];110(Suppl 1):11-23. Available from: https://doi.org/10.1289/ehp.02110s111

11. Domingo JH, Bocio A, Falco G, Llobet JM. Benefits and risks of fish consumption Part I. A quantitative analysis of the intake of omega-3 fatty acids and chemical contaminants. Toxicol [Internet]. 2007 Feb 12 [cited 2020 Mar 17];230(2-3):219-26. Available from: https://doi.org/10.1016/j.tox.2006.11.054 Subscription required to view.

12. Ahmed AM, Hussein MM. Residual levels of some heavy metals in fish flesh and water from El-Manzala lake, Egypt. J King Saud Univ. 2004;16(2):187-96.

13. Naing K. Country report on pollution: Myanmar [Internet]. Phuket, Thailand: The Bay of Bengal Large Marine Ecosystem (BOBLME) Project; 2011 [cited 2020 Mar 17]. 66 p. Available from: http://boblme.org/documentRepository/BOBLME-2011-Ecology-13.pdf

14. Robinson RA, Bird MJ, Ow NW, Hoey TB, Aye AH, Flavescens. The three modern faces of mercury. Environ Health Perspect [Internet]. 2002 Feb [cited 2020 Mar 17];110(Suppl 1):11-23. Available from: https://doi.org/10.1289/ehp.02110s111

15. Naing K. Country report on pollution: Myanmar [Internet]. Phuket, Thailand: The Bay of Bengal Large Marine Ecosystem (BOBLME) Project; 2011 [cited 2020 Mar 17]. 66 p. Available from: http://boblme.org/documentRepository/BOBLME-2011-Ecology-13.pdf

16. Robinson RA, Bird MJ, Ow NW, Hoey TB, Aye AH, Flavescens. The three modern faces of mercury. Environ Health Perspect [Internet]. 2002 Feb [cited 2020 Mar 17];110(Suppl 1):11-23. Available from: https://doi.org/10.1289/ehp.02110s111

17. Talwar PK, Jhingran AG, editors. Inland fishes of India and adjacent countries. Vol. 1. Calcutta: Oxford and IBH Publishing Co.; 1991. 1158 p.

18. Agemian H, Sturtevant DP, Austen KD. Simultaneous acid extraction of six trace metals from fish tissue by hot-block digestion and determination by atomic absorption spectrometry. Analyst [Internet]. 1980 Feb [cited 2020 Mar 15];105(1247):125-30. Available from: https://doi.org/10.1039/A0005000125 Subscription required to view.

19. Mu AA. Determination of toxic heavy metal contents in fresh water fish (Ka-kadit and Nga-yant) from Hinthada Township. Univ Res J. 2011;4(3):167-79.

20. Pandel PN, Pokhrel B, Kafle BK, Gyawali R. Analysis of heavy metals in some commercially important fishes of Kathmandu Valley, Nepal. Int Food Res J [Internet]. 2016 [cited 2020 Mar 17];23(3):1005-11. Available from: http://www.ifrj.upm.edu.my/23%20(03)%202016/(14).pdf

21. Bandara JM, Seneviratnha DM, Dasanayake DM, Herath V, Bandara JM, Abeyeskara T, Rajapaksha KHL. Chronic renal failure among farm families in cascade irrigation systems in Sri Lanka associated with elevated dietary cadmium levels in rice and freshwater fish (Tilapia). Environ Geochem Health [Internet]. 2008 Oct [cited 2020 Mar 17];30(5):465-78. Available from: https://doi.org/10.1007/s10653-007-9129-6 Subscription required to view.

22. Yousef TA, Gomma GM. Assessment of some heavy metal contents in fresh and salted (feseakh) mullet fish collected from EL- Burullus Lake, Egypt. J Am Sci. 2011;7(10):137-44.

23. European Union, EU Regulation on Chemicals in foods (2001).

24. Commission regulation (EC) No. 78/ 2005 of 19 January 2005. Off J Eur Union [Internet]. 2005 [cited 2020 Mar 17];20(1):43-5. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:016:0043:0045:EN:PDF

25. US FDA: Guidance document for arsenic in shellfish. Washington, DC: United States Food and Drug Administration; 1993.

26. Guidelines for drinking-water quality [Internet]. 2nd ed. Vol. 1. Geneva, Switzerland: World Health Organization; 1993 [cited 2020 Mar 17]. 202 p. Available from: https://www.who.int/water_sanitation_health/publications/gdwq2v1/en/

27. Sprague JB. Toxicity and tissue concentrations of lead, zinc, and cadmium for marine molluscs and crustaceans. Research Triangle Park, NC: International Lead Zinc Research Organization; 1986. 215 p.