Health Risk Assessment of Heavy Metals
in *Manila Catfish (Arius dispar)* from Laguna Lake

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ABSTRACT

Objective. The main objective of this study is to provide an assessment of the risks to human health associated with the exposure to heavy metal bioaccumulation in *Manila Catfish* (*Arius dispar*) from Laguna Lake.

Methods. *Manila Catfish* (common name *Kanduli*) samples were collected in eight sampling stations in three major areas of the lake during the dry and wet seasons. Dry season samples were collected from May to June 2010 and wet season samples from September to November 2010. Coordinates of sampling locations were recorded using Global Positioning System to facilitate re-sampling activities and ensured that subsequent samples for the wet season were collected in the area as that of the wet season samples. Heavy metals analyses for cadmium, lead, arsenic, and chromium were conducted using Atomic Absorption Spectrophotometer and Mercury Analyzer for mercury. Estimates of health risks associated with *Kanduli* consumption were estimated based on non-carcinogenic health effects of heavy metals.

Results. Non-carcinogenic Health Quotient (NHQ) values of the five heavy metals showed that lead is the most significant pollutant of concern in terms of adverse health effects from risks associated with *Kanduli* consumption from the lake.

Conclusion. From the point of view of disease prevention and control, long term consumption of *Kanduli* from Laguna Lake is expected to increase health risk due to lead contamination.

Key Words: bioaccumulation, Manila Catfish, lead, arsenic, cadmium, chromium, mercury, heavy metals, health risk assessment, Laguna Lake

Introduction

Heavy metals, nutrients, and other chemical contaminants are transported in water bodies, dissolved or associated to sediment particles. It is known that the dissolved divalent ionic form of trace metals is toxic to the biota, while the adsorbed or particulate fraction is considered biologically unavailable.[1] Heavy metals are among the more serious pollutants in our natural environment due to their toxicity, persistence and bioaccumulation problems.[2] Pollution of heavy metals in aquatic ecosystem is growing at an alarming rate and has become an important global problem.[3] With increased urbanization and industrialization, there has been a rapid increase in domestic and industrial wastewater which has intensified the environmental pollution in different environmental compartments. The major sources of contamination in surface waters can be traced to industrial discharges, domestic waste disposal and application of agrochemicals on farmlands. The pollutants like heavy metals after entering into aquatic environments accumulate in tissues and organs of aquatic organisms.[4] These contaminants may not directly damage the organisms but they can be deposited through the effects of bioaccumulation and food chain process that eventually threaten the health of humans through fish consumption.[5]

Biomagnifications of trace elements in living organisms describes the processes and pathways of these potential pollutants from one trophic level to another, exhibiting the higher bioaccumulation ability in the organisms concerned. Increasing concentration through the food chain caused higher retention time of toxic substances than that of the other normal food components.[6] Fish is considered as one of the most important indicators in freshwater ecosystems for the estimation of trace metals pollution. They are positioned at high trophic level of the food web and may accumulate large amounts of heavy metals from the water and often in concentrations several times higher than in the ambient water.[7] On the other hand, fish has been known for its reputation as the established health food for most of the world's population particularly developing countries in contrast to meat, poultry and eggs. The protein content in fish averages from 15 to 20 percent; hence fish provides comparatively cheap and readily available protein sources in complement with long chains of n-3 fatty acids, amino acids, vitamins and minerals that further contributes to healthy nutritional options for a balance dietary intake.[8] Health risk of heavy metals bioaccumulation in fish therefore is

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important to establish scientific basis for understanding risks versus benefits of fish consumption.

The Philippine Millennium Ecosystem Assessment Sub-global Assessment for Laguna Lake emphasized that the Laguna Lake Basin is a classic model of a multiple resource with multiple users. Its capacity to provide various ecosystem services to various users is continuously being challenged mainly by anthropogenic factors. Lake water quality has deteriorated through the years due to various point sources of pollution from industry, agriculture, and domestic sources. Detection of traces of heavy metals like copper, cadmium, chromium, and lead in the water and sediment is a major concern for human health.[9] The main objective of the study is to assess the risks to human health associated with the exposure to heavy metals bioaccumulation of *Manila Catfish (Kanduli)* from Laguna Lake. *Kanduli* is the species of choice in this study mainly because of its characteristics as a bottom dweller and as one of the most common edible fish harvested from the lake throughout the year.

Method

Sampling Zones and Sites

Laguna Lake, the largest inland body of water in the Philippines, was arbitrarily divided into five sampling zones: namely, Northern West Bay, Central West Bay, Central Bay, South Bay, and East Bay. These zones were selected to represent different areas of the lake with fishing operations. *Kanduli* samples were collected from each of the five designated sampling zones in the lake. There were two sampling sites each for Northern West Bay, Central West Bay, and Central Bay; and one sampling site each for South Bay, and East Bay; for a total of eight sampling sites. Allocation of number of sampling sites in the five sampling zones was based on the degree of fishing operations in the zone. Summary of sampling zones and sites is shown in Table 1. Fishing operations in the sampling sites are basically aquaculture and open water fisheries. Samples were collected in the open water because *Kanduli* is not normally propagated in fish pens or cages. About three to five fish samples of marketable size were collected per sampling station. Sizes of fish samples were comparable for both the wet and dry seasons.

Table 1. Sampling zones and sites

SAMPLING ZONES	NAME	NUMBER OF SAMPLING SITE/S
1	Northern West Bay	2
2	Central West Bay	2
3	Central Bay	2
4	South Bay	1
5	East Bay	1
	TOTAL	8

The coordinates of the sampling locations (latitude and longitude) of the eight stations in the different zones were recorded using a Global Positioning System (GPS) instrument and plotted in Geographic Information System (GIS) digital maps. The locations and coordinates of the sampling sites are shown in Table 2. This facilitated re-sampling activities and ensured that subsequent samples for the wet season were collected in the area as that of the wet season samples. A GIS map of Laguna de Bay showing the sampling zones is shown in Figure 1.
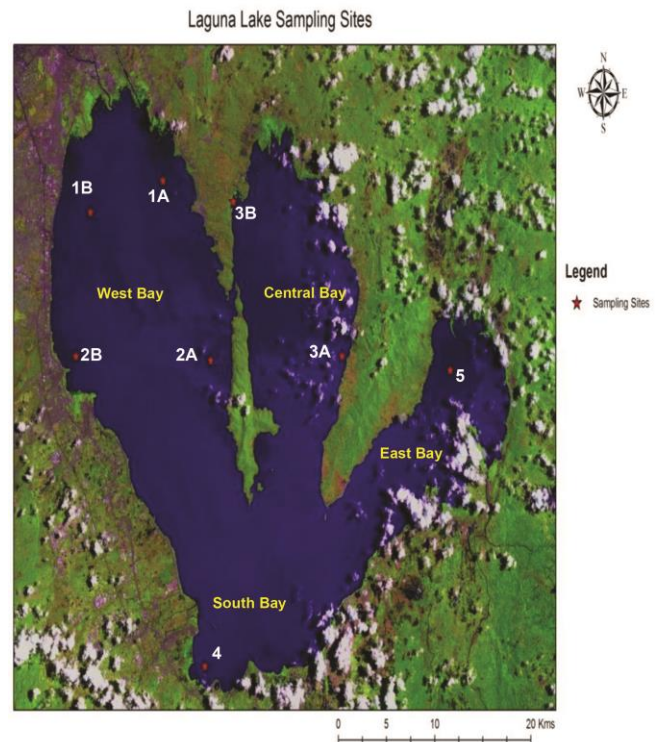

Figure 1. Location of sampling sites (GIS map).

Table 2. Sampling site locations and coordinates.

FISH SAMPLING SITE	LOCATION	COORDINATES
1A (Binangonan)	Northern West Bay	N 14°28′ 57.8″ E 121°09′ 22.6″
1B (Taguig)	Northern West Bay	N 14°27′ 50.6″ E 121° 05′ 19.3″
2A (Talim Island)	Central West Bay	N 14°22′ 34.1″ E 121° 12′ 03.6″
2B (Sta Rosa)	Central West Bay	N 14° 22′ 43.4″ E 121° 04′ 30.1″
3A (Jala-Jala)	Central Bay	N 14° 22′ 43.9″ E 121° 19′ 25.5″
3B (Cardona)	Central Bay	N 14° 28′ 13.5″ E 121° 13′ 19.4″
4 (Calamba)	South Bay	N 14° 11′ 41.4″ E 121° 11′ 43.5″
5 (Pakil)	East Bay	N 14° 22′ 12.9″ E 121° 25′ 28.8″

Sampling Frequency

There were two batches of fish samples collected from open water fishery. The first batch of fish samples was collected in May to June 2010 to represent the dry season conditions in the study area. The second batch of fish samples was collected during the months of September to November 2010 to represent wet season conditions.

Heavy Metals Included in the Study

The heavy metals included in the study were cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), and chromium (Cr). These non-essential metals from the point of view of human health are also known to have the ability to bioaccumulate and biomagnify through the food chain.

Sample Packaging and Preservation

Fish samples were individually wrapped in a waterproof plastic sampling bag. The edible portions of fish samples were processed on-site to avoid puncturing of the packaging material by the fish spines. Individual fish samples were sealed in the plastic bags and packed in a large plastic bag. Each sample was provided with an identification tag and sample code. After packaging, the samples were kept in an ice chest with ice and brought to the laboratory on the day of sampling.

Laboratory Procedures and Analysis

Samples submitted to the laboratory were stored in the freezer until all the samples had been collected to ensure uniform sample preparation. Prior to analyses, samples were thawed then osterized for homogeneity. Replicates were prepared and all quality control parameters were conducted to ensure integrity of the analyses. Cadmium, chromium and lead were analyzed using the AAS (Atomic Absorption Spectrometer). The sample solutions were aspirated into a flame and atomized.

Arsenic analysis involves the generation of arsine gas by reacting the arsenic in the sample with sodium borohydride. Reaction takes place in a hydride generation assembly that is attached to an AAS system.

Mercury in the fish samples was analyzed using the Mercur-Duo Mercury Analyzer, a single-beam instrument with a mercury low-pressure lamp as a light source for the excitation of mercury atoms and a photomultiplier to record the fluorescent or absorption radiation.

Estimate of Potential Human Exposure to Heavy Metal

The basic equation for calculating systemic toxicity (non-carcinogenic hazard) is:

$$NHQ = \frac{CDI}{RfD}$$

where:

NHQ = Non-carcinogenic Hazard Quotient
CDI = chronic daily intake for the toxicant expressed in mg/kg-day
RfD = chronic (oral) reference dose for the toxicant expressed in mg/kg-day.

Chronic oral reference dose (RfD) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily oral exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime. Chronic oral RfDs are specifically developed to be protective for long-term exposure to a compound. As a guideline, chronic oral RfDs generally should be used to evaluate the potential non-carcinogenic effects associated with exposure periods greater than 7 years (approximately 10 percent of a human lifetime). Chronic oral reference doses are expressed in units of mg/kg-day. The RfD values of heavy metal in this study were adopted from USEPA. For Arsenic, RfD=0.0003 mg/kg-day, Chromium, RfD=0.003 mg/kg-day, Mercury, 0.0001mg/kg-day, Cadmium, RfD=0.001 mg/kg-day, and Lead, Rfd=0.0000001 mg/kg-day.[10]

Non-Carcinogenic Fish Ingestion Equation: $CDI_{(nc)}$

$$CDI_{(nc)} = \frac{C \times EF \times ED \times IRF \times (kg/1000g)}{(365\ days/year) \times LT \times BW}$$

$$CDI_{res\text{-}fshw\text{-}nc\text{-}ing}\,(mg/kg\text{-}day) = \frac{C_{s\text{-}water}\left(\frac{mg}{L}\right) \times EF_r\left(\frac{350\ days}{year}\right) \times ED_r\,(30\ years) \times IRF_a\left(\frac{54\ g}{day}\right) \times BCF\left(\frac{L}{Kg}\right) \times \frac{10^{-3}\ Kg}{1\ g}}{AT_r\left(\frac{365\ days}{year} \times ED_r\,(30\ years)\right) \times BW_a\,(70\ Kg)}$$

Where:

CDI = chronic daily intake for the toxicant expressed in mg/kg-day
C = Concentration of heavy metal in fish (mg/kg)
BW = Body Weight (Average value for Filipino adult~ 65 kgs.)
ED = Exposure Duration (30 years)
EF = Exposure frequency (350 days/year)
IRF = Ingestion Rate Fish (fish consumption) = 102.74 g/day (FAO). This is the estimated average daily per capita consumption of fish in the Philippines from the FAO Fisheries and Aquatic Department.
LT = Lifetime (average), 30 years for non-carcinogenic health effects

The Non-carcinogenic Hazard Quotient (NHQ) is one of the measures of non-carcinogenic health effects of exposure to chemical contaminants. It is the ratio of an exposure level by a contaminant to a reference dose or value selected for the health risk assessment of a particular substance or chemical. If the exposure level is higher than the toxicity value, then there is the potential for risk to the receptor. Computed NHQ value of greater than 1.0 indicates that the exposure to a single chemical or substance will likely result to adverse health effects. The potential health effects are dependent on the type of chemical or substance of concern. NHQ values of 1.0 or below indicates that daily oral exposure level for the human population, including sensitive subpopulations, is likely to be without an appreciable risk of deleterious effects during a lifetime.[10-12]

Results

Results on the heavy metal concentrations in the edible portions of collected *Kanduli* samples are divided into two categories: (1) Heavy metal levels in *Kanduli* for dry season, and (2) Heavy metal levels in *Kanduli* for wet season.

(1) Heavy metal levels in *Kanduli* for dry season

Table 3 shows the concentrations of heavy metal (Cd, Cr, Pb, Hg and As) in *Kanduli* from eight sampling stations during the dry season. Cadmium (Cd) concentration ranged from 0.00731 mg/kg in sampling station 1A to 0.0809 mg/kg in station 3B. Chromium (Cr) ranged from 0.03304 mg/kg in station 1A to 0.12631 mg/kg in station 2B. Lead (Pb) ranged from 0.283114 mg/kg in station 2A to 6.8581 mg /kg in station 4. Mercury (Hg) ranged from 0.00347 mg/kg in station 4 to 0.15807 mg/kg in station 3B. Arsenic (As) ranged from 0.00003 mg/kg in station 3B to 0.73765 mg/kg in station 3A.

Table 3. Heavy metal concentration (mg/kg), dry season

Sampling Site	Cd	Cr	Pb	Hg	As
1A	0.00731	0.03304	1.31713	0.02733	0.36821
1B	0.03995	0.06510	0.58447	0.06064	0.01670
2A	0.03794	0.05595	0.28314	0.05797	0.14091
2B	0.05579	0.12631	1.57937	0.01078	0.20388
3A	0.07389	0.08206	0.77247	0.03893	0.73765
3B	0.08090	0.05461	0.97520	0.15807	0.00003
4	0.07570	0.06487	6.85810	0.00347	0.06151
5	0.04298	0.04018	0.38553	0.07166	0.20645

(2) Heavy metal levels in *Kanduli* for wet season

Table 4 shows the concentrations of heavy metal (Cd, Cr, Pb, Hg and As) in *Kanduli* from eight sampling stations during the wet season. Cadmium (Cd) concentration ranged from 0.0026 mg/kg in sampling station 2B to 0.31835 mg/kg in station 1A. Chromium (Cr) ranged from 0.00134 mg/kg in station 3B to 0.17079 mg/kg in station 1B. Lead (Pb) ranged from 0.00973 mg/kg in station 2B to 6.49705 mg /kg in station 1A. Mercury (Hg) ranged from 0.0127 mg/kg in station 2B to

0.03569 mg/kg in station 3B. Arsenic (As) ranged from 0.001 mg/kg in stations 2A, 2B, 3A, 3B and 5 to 0.09517 mg/kg in station 4.

Table 4. Heavy metal concentration (mg/kg), wet season.

Sampling Site	Cd	Cr	Pb	Hg	As
1A	0.31835	0.07272	6.49705	0.02167	0.08022
1B	0.27480	0.17079	1.93583	0.02402	0.09035
2A	0.00655	0.00275	1.85737	0.02338	0.00100
2B	0.00260	0.00696	0.00973	0.01270	0.00100
3A	0.00309	0.00168	0.01054	0.01332	0.00100
3B	0.01054	0.00134	0.11703	0.03569	0.00100
4	0.00273	0.00237	0.04439	0.01853	0.09517
5	0.00560	0.04147	0.01787	0.02560	0.00100

Discussion

During the dry season, lead appeared to have the highest concentration in *Kanduli* particularly in sampling station 4. The data showed that other heavy metals were fairly distributed in the different areas of the lake. In the wet season, concentrations of heavy metals in *Kanduli* were mostly detected in sampling stations 1A, 1B and 2A. Stations 1A and 1B are located in the Northern West Bay while 2A is located in the Central West Bay. Lead (Pb) concentrations were highest in sampling stations 1A, 1B and 2A. It is also apparent that lead (Pb) values were higher in the wet season than in the dry season in these three stations.

The results of laboratory analyses showed that the onset of the rainy season had both negative and positive effects on the heavy metal concentrations in *Kanduli* depending on its location in the lake. The positive outcome of rain could be due to the dilution effect of rainwater run-off which was apparent in the South bay, Central bay and East bay. On the other hand, the negative consequence of rain could be due to the "flushing-effect" from tributaries and run-off from adjoining areas with significant sources of heavy metals in the environmental compartments. This was observed in the West Bay where lead was highest during the wet season. In addition, during the dry season, decreasing level or depth of lake water allows the inflow of potentially contaminated water from the Pasig River.

Computed values of Non-carcinogenic Hazard Quotient (NHQ) of cadmium, chromium, lead, mercury and arsenic (in *Kanduli*) for all sampling stations during the dry season are summarized in Table 5. Results of the computations showed that NHQ values for cadmium, chromium, and arsenic are less than 1.0 (unit less value) in all sampling stations which indicate that the daily oral exposure level for the human population, including sensitive subpopulations, is likely to be without an appreciable risk of deleterious effects during a lifetime. However, NHQ value for mercury in sampling station 3B during the dry season was greater than 1.0 (NHQ=2.16) which shows potential deleterious effects due to long term fish consumption. NHQ values for lead in all sampling stations are way above 1.0, indicating

high risk for adverse human health effects associated with long-term *Kanduli* consumption.

Table 5. Summary of NHQ values for dry season.

Sampling Site	NHQ Values (DS)				
	Cd	Cr	Pb	Hg	As
1A	0.0111	0.0100	19963	0.3724	0.1860
1B	0.0606	0.0197	8859	0.8272	0.0084
2A	0.0575	0.0170	4291	0.7908	0.0712
2B	0.0846	0.0383	23938	0.1470	0.1030
3A	0.1120	0.0249	11708	0.5310	0.3727
3B	0.1226	0.0166	14781	2.1562	0.0000
4	0.1147	0.0197	103945	0.0473	0.0311
5	0.0651	0.0122	5843	0.9775	0.1043

For the wet season, computed values of Non-carcinogenic Hazard Quotient (NHQ) of cadmium, chromium, lead, mercury and arsenic in *Kanduli* for all sampling stations are summarized in Table 6. The NHQ values for cadmium, chromium, mercury and arsenic were less than 1.0 in all sampling stations. However, NHQ values for lead in all sampling stations were way above 1.0, indicating high risk for adverse human health effects associated with long-term *Kanduli* consumption.

Table 6. Summary of NHQ values for wet season.

Sampling Site	NHQ Values (WS)				
	Cd	Cr	Pb	Hg	As
1A	0.4825	0.0220	98473	0.2956	0.0405
1B	0.4165	0.0518	29341	0.3277	0.0456
2A	0.0099	0.0008	28151	0.3189	0.0005
2B	0.0039	0.0021	147	0.1732	0.0005
3A	0.0047	0.0005	160	0.1817	0.0005
3B	0.0160	0.0004	1774	0.4868	0.0005
4	0.0041	0.0007	673	0.2528	0.0481
5	0.0085	0.0126	271	0.3492	0.0005

Conclusion

Results of the study showed that arsenic, cadmium, and chromium do not pose significant non-carcinogenic health effects (NHQ < 1.0) associated with long term consumption of *Kanduli* from Laguna Lake. However, NHQ value for mercury in sampling station 3B during the dry season was greater than 1.0 (NHQ=2.16) which shows potential deleterious effects due to chronic fish consumption. Computed NHQ values for lead (Pb) in *Kanduli* showed highly elevated levels that are likely to cause adverse health effects on fish consumers overtime. This study therefore concludes that from the point of view of human health protection and disease prevention, long-term consumption of *Kanduli* from Laguna lake is not safe mainly because of the levels of lead that were found to be extremely above the acceptable NHQ values.

Recommendations

In the light of the above findings, the following recommendations for policy makers and other concerned stakeholders:

- Urgent mitigating measures should be done by concerned authorities to protect health of communities consuming *Kanduli* from the lake especially the children.
- Regular monitoring of heavy metals in fishes should be done at least twice a year.
- Issuance of regular health advisories regarding quantitative health risks associated with *Kanduli* consumption from the Laguna Lake Development Authority or the Regional Office of the Department of Health.
- Involvement of the Local Government Units in the lakeshore communities in terms of heavy metals monitoring in fish and in developing and disseminating advisories and other health-related information to the communities.
- Develop and implement an appropriate risk communication program for all stakeholders including but not limited to fishermen, fish pen owners, farmers, industries and the general public.
- Inventory and assessment of potential sources of heavy metals in the lake and more stringent regulation of effluents from industries around the lake.
- Regular monitoring of heavy metals in major rivers and tributaries draining into the lake.

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