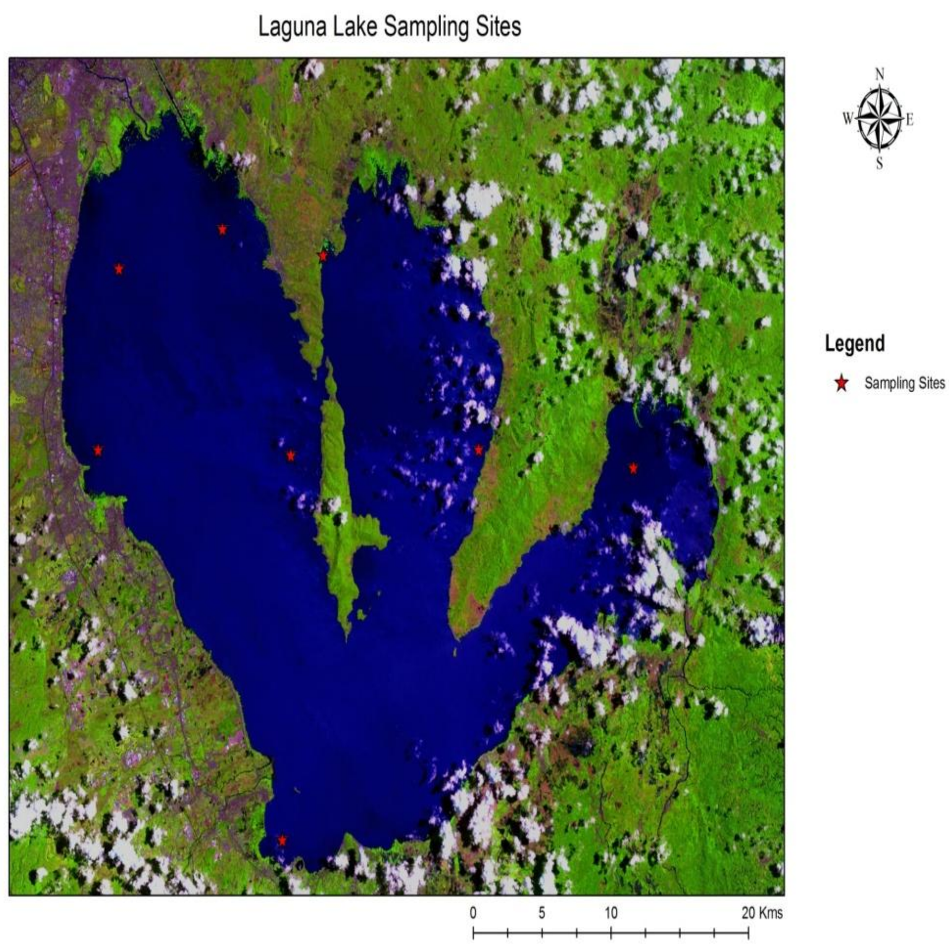
# HEALTH RISK ASSESSMENT OF HEAVY METALS BIOACCUMULATION IN LAGUNA de BAY FISH PRODUCTS






Victorio B. Molina, MPH, PhD
Department of Environmental and Occupational Health
College of Public Health, University of the Philippines Manila

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## ABSTRACT

This study provides an assessment of the risks to human health associated with the exposure to heavy metals bioaccumulation in fish products from Laguna de Bay. Samples of five edible fish species, namely; *Bangus, Bighead Carp, Dalag, Kanduli, and Tilapia* 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 site locations were recorded using Global Positioning System (GPS) and plotted in Geographic Information System (GIS) digital maps. Heavy metals analyses for Cadmium (Cd), Lead (Pb), Mercury (Hg), Arsenic (As), and Chromium (Cr) were conducted using Atomic Absorption Spectrophotometer (AAS) and Mercury Analyzer (Mercur-Duo).

Estimates of health risks associated with fish consumption were summarized according to non-carcinogenic and carcinogenic health effects. Non-carcinogenic Hazard Quotient (NHQ) values of five heavy metals showed that lead is the most urgent pollutant of concern in terms of adverse health effects from risks associated with fish consumption from all sampling locations in the lake. Elevated health risk for Mercury exposure was also evident in the west bay and central bay particularly for *dalag* and *kanduli* species. Among the five heavy metals only Arsenic is a confirmed human carcinogen (Class A) through the oral route of exposure. The highest life time cancer risk for arsenic was computed for *tilapia* from sampling station 2B (west bay) during the dry season with risk value of $8.5x10^{-4}$ or an excess of 85 cancer cases per 100,000 populations. The lowest life time cancer risk for arsenic is computed for *dalag, tilapia* and *kanduli* from all sampling stations except 1B and 4 (northern west bay and south bay) during the wet season with risk value of $9.7 \times 10^{-7}$ or 1 cancer case per 10,000,000 populations. From the point of view of human health protection and disease prevention, fish products from the lake particularly *bangus, bighead carp, dalag, kanduli and tilapia* are not fit for human consumption primarily due to lead contamination.



**Keywords**
Health Risk Assessment, heavy metals, Laguna Lake, bioaccumulation

# HEALTH RISK ASSESSMENT OF HEAVY METALS BIOACCUMULATION IN LAGUNA de BAY FISH PRODUCTS

Victorio B. Molina, MPH, PhD*

## Introduction

Laguna de Bay is the largest inland body of water in the Philippines and second largest lake in Southeast Asia. It is strategically situated in the midst of the country's center of urban and industrial development. This configuration makes the region a critical resource in terms of its importance as the main source of agricultural food commodities and industrial raw materials and manufactured goods.

The lake is inundated daily with anthropogenic pollutants from industrial, domestic and agricultural waste which are ultimately absorbed by aquatic plants and animals. The vulnerability of aquatic ecosystems to heavy metal contamination has been recognized as a serious pollution problem. Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage posing threat to human health and sustainable food supply due to biomagnifications over time. Potential harm to humans and environmental targets may arise from exposure to metal contaminants due to extent and location as well as current ecological services of the lake. When fish are exposed to elevated levels of heavy metals in polluted aquatic ecosystem, it tends to take these metals up from its direct environment. These contaminants come from human activities that bring economic growth and contribute benefits to society. The ultimate challenge of our generation is to find ways to sustain economic development activities that are managed at levels that promote human health and environmental protection.

*Faculty, Department of Environmental and Occupational Health
College of Public Health, University of the Philippines Manila
625 Pedro Gil Street, Ermita Manila, Philippines
Tel. (632) 524-7102
Fax (632) 523-7745
Email: vicmolina@yahoo.com

Health risk assessment is an important tool that evaluates the consequences of human activities and weighs the adverse effects to public health against the contributions to economic development. This study aims to evaluate existing levels of heavy metals such as arsenic, cadmium, chromium, lead and mercury in five edible fish species (i.e., *bangus, bighead carp, dalag, kanduli and tilapia*) in Laguna Lake and predict potential health consequences that can serve as scientific basis for decision-making and policy development.

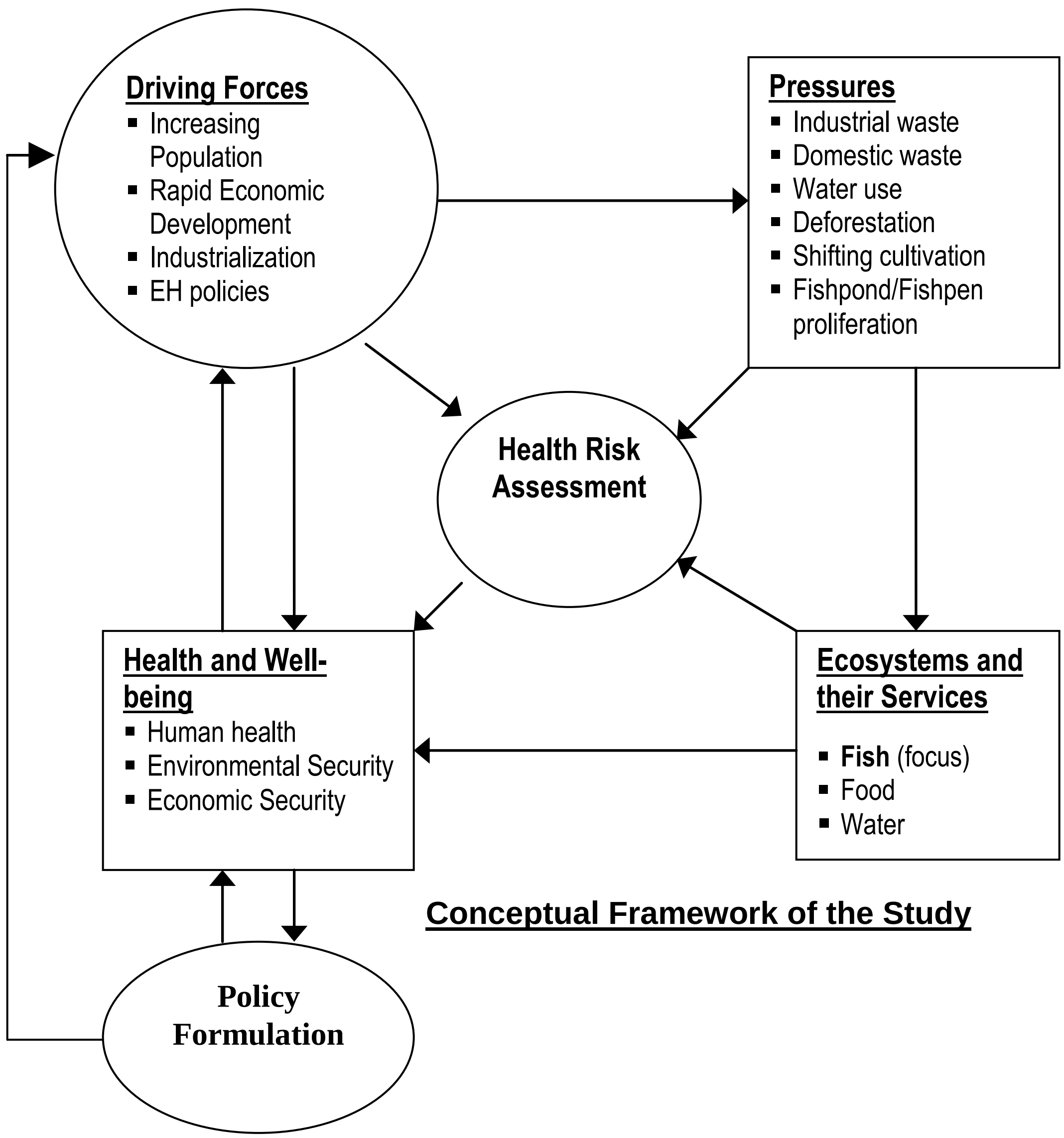
Common Name and Scientific Names of Fish Included in the Study

| Common Name | English Name | Scientific Name |
|---|---|---|
| 1. Mamaling | Bighead carp | *Aristichthys nobilis* |
| 2. Kanduli | Manila Catfish | *Arius dispar* |
| 3. Tilapia | Tilapia | *Oreochromis niloticus* |
| 4. Dalag | Snakehead/Murrel/Mudfish | *Ophicephalus striatus* |
| 5. Bangus | Milk Fish | *Chanos chanos* |

**Materials and Methods**

Conceptual Framework

The link between health and environment explicitly recognizes that although exposure to a pollutant or other environmentally mediated health hazard may be the immediate cause of ill health; the "driving force" and "pressures" leading to environmental degradation may be the most effective points of control of the hazard. The conceptual framework of the study shows that the relationship between human health and environment is complex. Environmental health hazards are associated with a variety of aspects of economic and social development. In response to environmental pressures, the state of the environment is often modified. The changes involved may be complex and far-reaching, affecting almost all aspects of the environment and all environmental media. Many changes are intense and localized, and often concentrated close to the source of pressure. Due to the complex interactions which characterize the environment, almost all these changes have extensive secondary effects.




**Conceptual Framework of the Study**

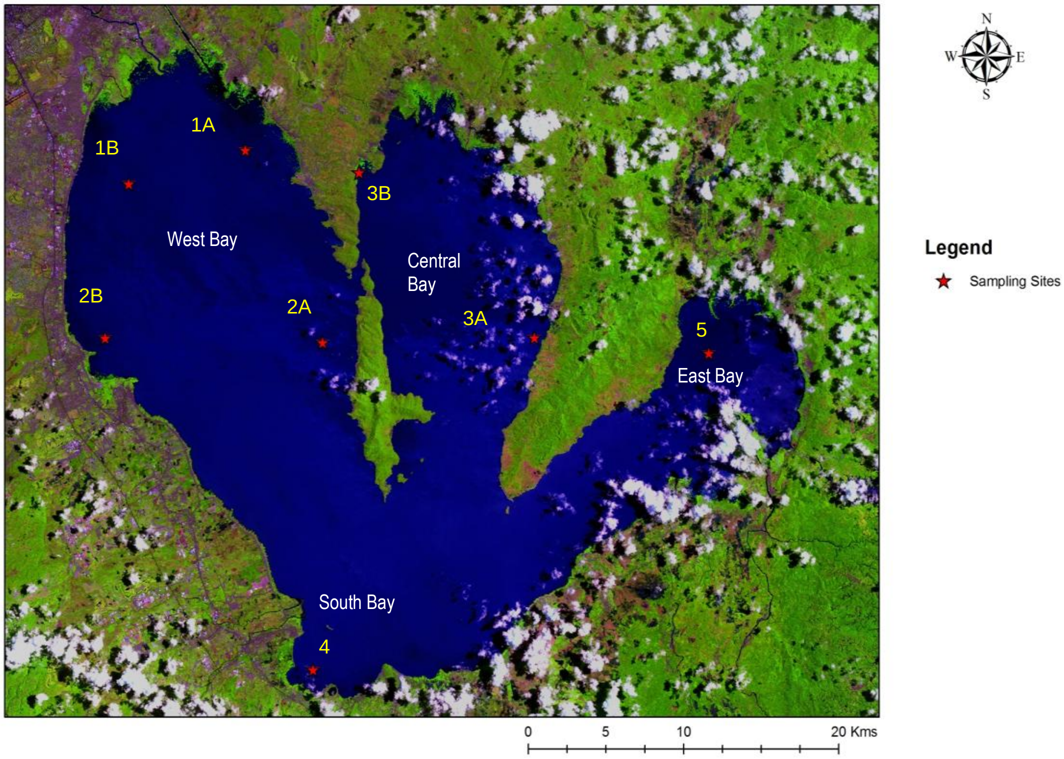
Driving forces include policies that determine trends in economic development, technology development, consumption patterns, and population growth. The driving forces in turn generate different kinds of pressures on the environment, in such forms as waste from human settlements and depletion of natural resources or emission of pollutants from human activities. These pressures can lead to changes in the state of the environment, as seen when land use is changed or when discharges of toxic chemicals or other forms of waste increase concentrations of pollutants in the environmental compartments.

Sampling Zones and Sites

The lake was 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.  Samples of five fish species were collected from 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 station. Coordinates of sampling location of eight stations in the different zones were recorded using Global Positioning System (GPS) and plotted in Geographic Information System (GIS) digital maps.

## Location of Sampling Sites

Laguna Lake Sampling Sites




| Fish Sampling Site | Location | Coordinates |
|---|---|---|
| **1A** (Binangonan) | Northern West Bay | N 14$^{o}$ 28’ 57.8” E 121$^{o}$ 09’ 22.6” |
| **1B** (Taguig) | Northern West Bay | N 14$^{o}$ 27’ 50.6” E 121$^{o}$ 05’ 19.3” |
| **2A** (Talim Island) | Central West Bay | N 14$^{o}$ 22’ 34.1” E 121$^{o}$ 12’ 03.6” |
| **2B** (Sta Rosa) | Central West Bay | N 14$^{o}$ 22’ 43.4” E 121$^{o}$ 04’ 30.1” |
| **3A** (Jala-Jala) | Central Bay | N 14$^{o}$ 22’ 43.9” E 121$^{o}$ 19’ 25.5” |
| **3B** (Cardona) | Central Bay | N 14$^{o}$ 28’ 13.5” E 121$^{o}$ 13’ 19.4” |
| **4** (Calamba) | South Bay | N 14$^{o}$ 11’ 41.4” E 121$^{o}$ 11’ 43.5” |
| **5** (Pakil) | East Bay | N 14$^{o}$ 22’ 12.9” E 121$^{o}$ 25’ 28.8” |

There were two major waves of sampling. The first batch of fish samples was collected May to June 2010 to represent the dry season conditions. The second batch of fish samples was collected during the months of September to November 2010 to represent wet season conditions. Fish samples were individually wrapped in a waterproof plastic sampling bag. Edible portion of the fish samples were processed on-site and sealed in a waterproof plastic bag. Each sample was provided with identification tag and sample code. After packaging, the samples were cooled immediately in an ice chest and submitted to the Industrial Technology Development Institute, Department of Science and Technology Laboratory on the same day.

**Estimate of Potential Human Exposure to Heavy Metals in Fish**

(1) Non-carcinogenic Health Effects

The basic equation for calculating systemic toxicity (i.e., noncarcinogenic hazard) is:

$$\text{Noncancer Hazard Quotient (NHQ)} = \frac{CDI}{RfD}$$

where:

CDI = chronic daily intake for the toxicant expressed in mg/kg-day
RfD = chronic reference dose for the toxicant expressed in mg/kg-day.

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

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

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
ED = Exposure Duration
EF = Exposure frequency
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)

(2) Carcinogenic Health Effects

Cancer Toxicity Values

Slope factors and unit risk values are used to assess cancer risk. A slope factor and the accompanying weight-of-evidence determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks. Generally, the slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical over a lifetime. The slope factor is used in risk assessments to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a potential carcinogen.

Oral Slope Factors

The oral slope factor evaluates the probability of an individual developing cancer from oral exposure to contaminant levels over a lifetime. Oral slope factors are expressed in units of $(mg/kg\text{-}day)^{-1}$

The basic equation for calculating excess lifetime cancer risk is:

$$Risk = CDI \times SF$$

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

Where:

Risk = a unit less probability of an individual developing cancer over a lifetime;

CDI = chronic daily intake or dose [mg/kg-day]

SF = slope factor, expressed in $[(mg/kg\text{-}day)^{-1}]$

Carcinogenic Fish Ingestion Equation: $CDI_{(c)}$

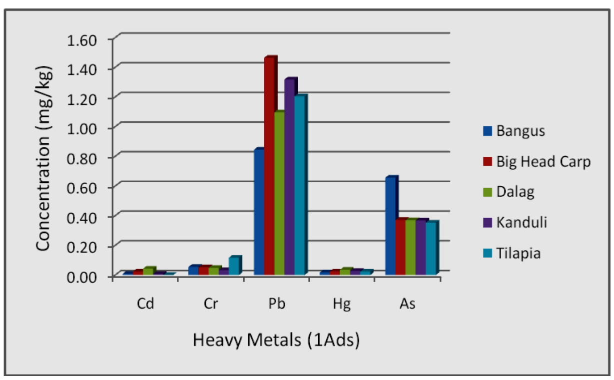
$$CDI_{(c)} = \frac{C \times EF \times ED \times IRF \times (kg/1000g)}{(365\ days/year) \times LT \times BW}$$

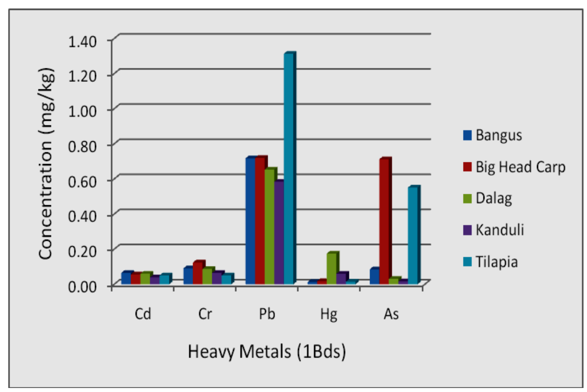
Where:

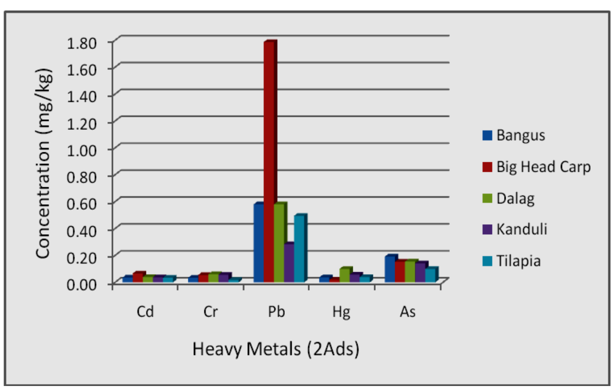
CDI = chronic daily intake for the toxicant expressed in mg/kg-day
C = Concentration of heavy metal in fish (mg/kg)
BW = Body Weight
ED = Exposure Duration
EF = Exposure frequency IRF
LT = Lifetime (average)

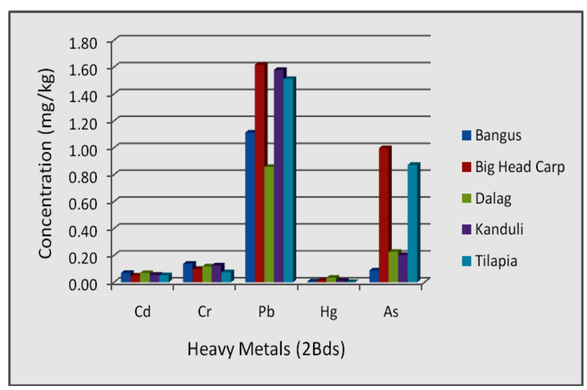
## Results and Discussion

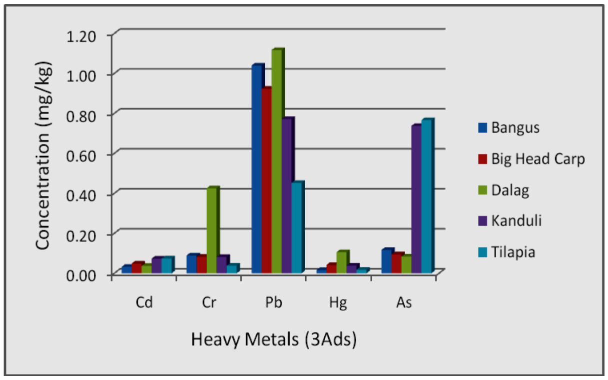
Concentrations of heavy metals in fish samples (dry season) for each of the eight sampling stations are shown in the figures below.

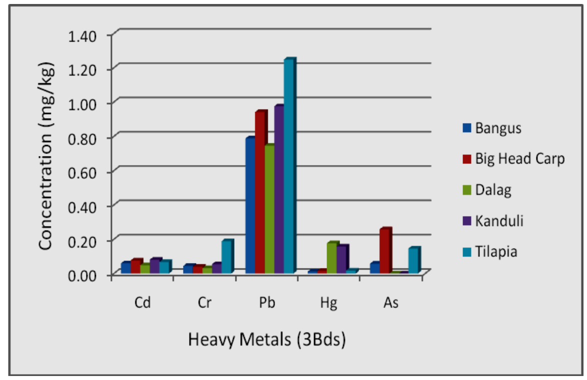


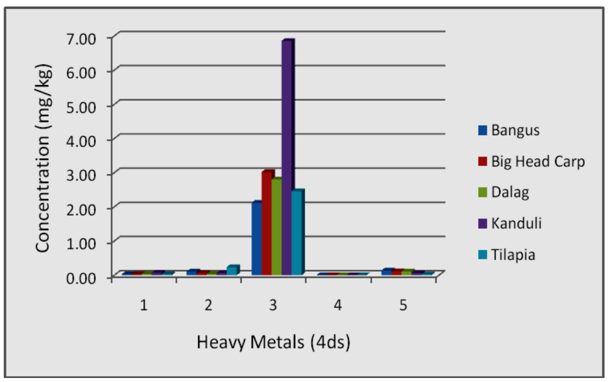



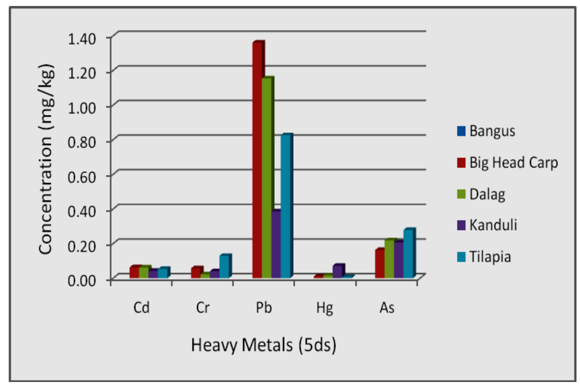



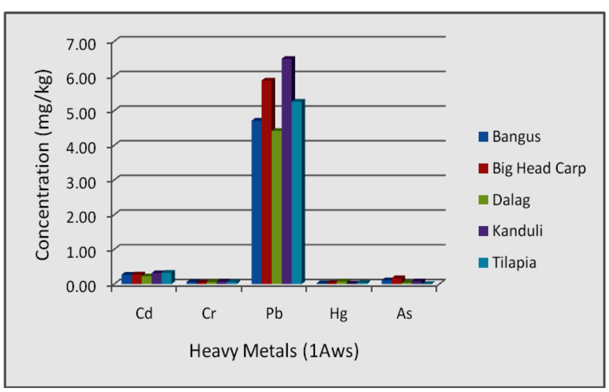


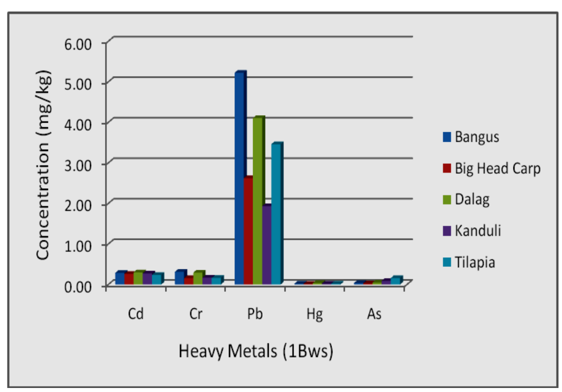



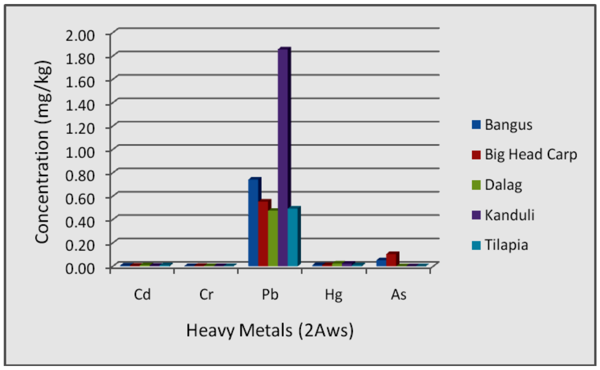



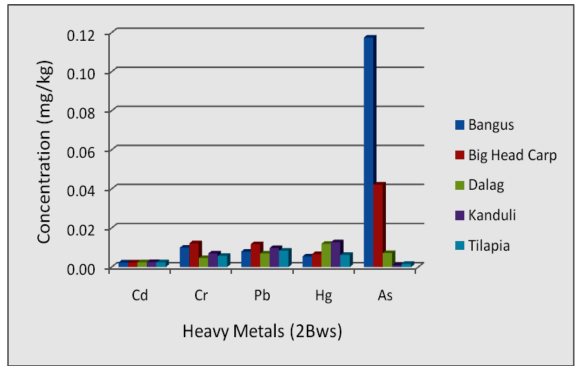



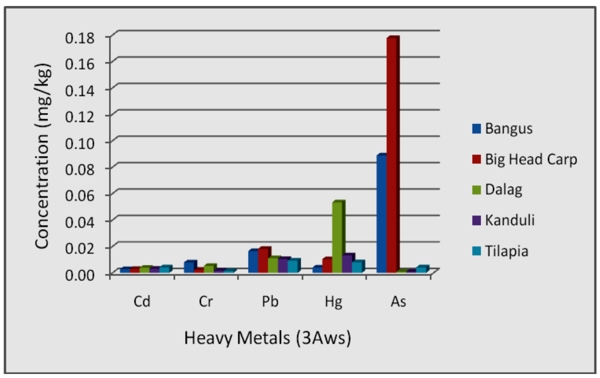

Concentrations of heavy metals in fish samples (wet season) for each of the eight sampling stations are shown in the figures below.

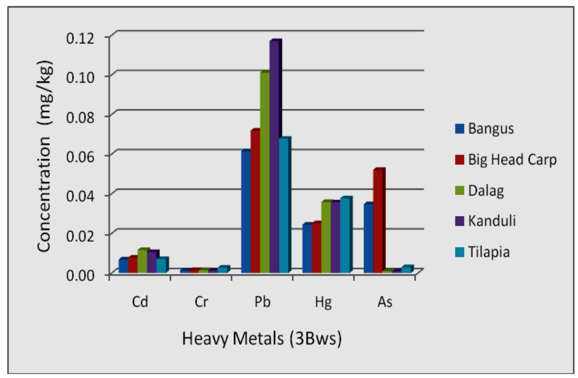


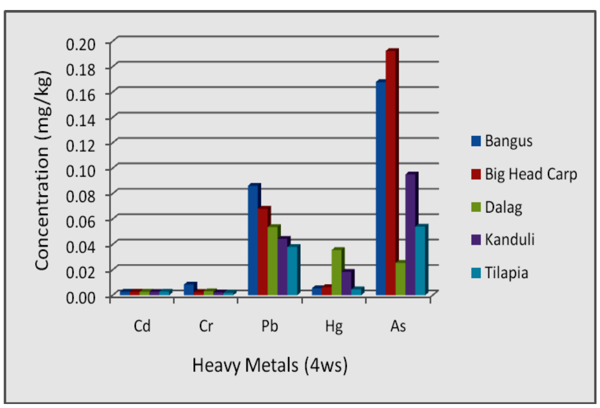



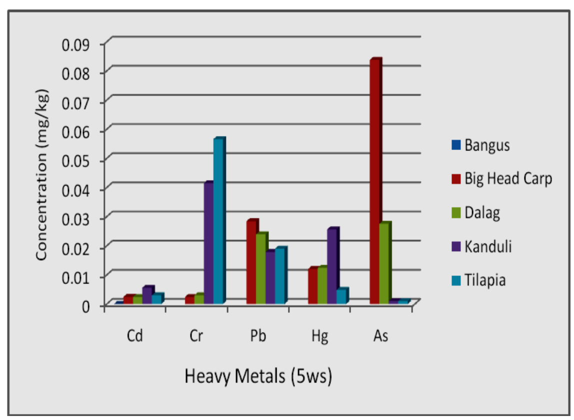

Concentration (mg/kg)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Cd
Cr
Pb
Hg
As
Heavy Metals (2Aws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia


Concentration (mg/kg)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Cd
Cr
Pb
Hg
As
Heavy Metals (2Bws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia


Concentration (mg/kg)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Cd
Cr
Pb
Hg
As
Heavy Metals (3Aws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia


Concentration (mg/kg)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Cd
Cr
Pb
Hg
As
Heavy Metals (3Bws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia


Concentration (mg/kg)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Cd
Cr
Pb
Hg
As
Heavy Metals (4ws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia


Concentration (mg/kg)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Cd
Cr
Pb
Hg
As
Heavy Metals (5ws)
Bangus
Big Head Carp
Dalag
Kanduli
Tilapia

The estimated health risks associated with consumption of fish products from Laguna Lake were summarized according to non-carcinogenic health effects and carcinogenic health effects for both dry and wet seasons.

Non-carcinogenic Health Effects

Summary of Non-carcinogenic Health Quotient (NHQ) values of five heavy metals in five fish species for dry season showed that Mercury and Lead are the two heavy metals of concern in terms of adverse health effects associated with heavy metals bioaccumulation. Mercury has NHQ values of greater than 1.0 in four sampling stations; namely, 1B, 2A, 3A and 3B, which corresponds to samples collected from west bay (1B and 2A) and central bay (3A and 3B), respectively. The fish species of important concern to mercury contamination is *dalag* in four sampling stations (1B, 2A, 3A and 3B) and *kanduli* in sampling station 3B. For Lead (Pb), NHQ values for all sampling stations in all fish species were way above 1.0 indicating high risk of adverse health effects from consumption of fish products from the Lake.

For the wet season, Non-carcinogenic Health Quotient (NHQ) values showed that among the five heavy metals investigated, lead is the most urgent pollutant of concern in terms of adverse health effects from risks associated with fish consumption from the lake. In one sampling station (Station 1A-northern west bay) Mercury has NHQ value of greater than 1.0 (NHQ = 1.1). The fish species of important concern to mercury contamination is *dalag* which confirms the findings in the dry season. Similarly, in case of Lead, NHQ values for all sampling stations in all fish species were way above 1.0 indicating high risk of adverse health effects from consumption of fish products from the Lake.

Carcinogenic Health Effects

Of the five heavy metals included in the study only Arsenic is confirmed human carcinogen (class A) through the oral route of exposure. Chromium is also carcinogenic through inhalation route but not carcinogenic through the oral route of exposure. The highest life time cancer risk for arsenic during the dry season is computed for *tilapia* from sampling station 2B (west bay) with risk value of 0.00085 or $8.5 \times 10^{-4}$. This shows that the lifetime probability of an individual developing cancer as a result of consumption of tilapia from sampling station 2B is $8.5 \times 10^{-4}$. This risk value also indicates that fish consumption of *tilapia* (from sampling station 2B) would result to an excess of 85 cancer cases per 100,000 populations. The lowest life time cancer risk for arsenic is computed for *dalag* and *kanduli* from sampling station 3B (central bay) with risk value of $2.92 \times 10^{-8}$. This means that fish consumption would result to an excess of 3 cancer cases per 10,000,000 populations.

Average life time cancer risks associated with fish consumption during the dry season for each of the five species included in the study considering the mean arsenic levels in all sampling stations are summarized below.

(1) *Bangus* - The average life time cancer risk associated with *bangus* consumption would result to an excess of 19 cancer cases per 100,000 populations.

(2) *Bighead Carp* - Average life time cancer risk associated with *bighead carp* consumption would result to an excess of 35 cancer cases per 100,000 populations.

(3) *Dalag* - Average life time cancer risk associated with *dalag* consumption would result to an excess of 15 cancer cases per 100,000 populations.

(4) *Kanduli* - Average life time cancer risk associated with *kanduli* consumption would result to an excess of 21 cancer cases per 100,000 populations.

(5) *Tilapia* - Average life time cancer risk associated with *tilapia* consumption would result to an excess of 38 cancer cases per 100,000 populations.

The average life time cancer risks associated with the consumption of fish from Laguna Lake during the dry season show the following order of magnitude: *Tilapia > Bighead carp > Kanduli >Bangus > Dalag*.

The highest life time cancer risk for arsenic during the wet season is computed for *bighead carp* from sampling station 3A (west bay) with risk value of 0.00017 or $1.7x10^{-4}$. This implies that lifetime probability of an individual developing cancer as a result of consumption of *bighead carp* from sampling station 3A is $1.7 \times 10^{-4}$. This also means that fish consumption would result to an excess of 17 cancer cases per 100,000 populations. The lowest life time cancer risk for arsenic is computed for *dalag, tilapia* and *kanduli* from all sampling stations except 1B and 4 (northern west bay and south bay) with risk value of $9.7 \times 10^{-7}$. This indicates an excess of 1 cancer case per 10,000,000 populations.

Average life time cancer risks associated with fish consumption (wet season) for each of the five species included in the study considering the mean arsenic levels in all sampling stations are summarized below:

(1) *Bangus* - Average life time cancer risk associated with *bangus* consumption would result to an excess of 8.5 or 9 cancer cases per 100,000 populations.

(2) *Bighead Carp* - Average life time cancer risk associated with *bighead carp* consumption would result to an excess of 10.4 or 11 cancer cases per 100,000 populations.

(3) *Dalag* - Average life time cancer risk associated with *dalag* consumption would result to an excess of 1.8 or 2 cancer cases per 100,000 populations.

(4) *Kanduli* - Average life time cancer risk associated with *kanduli* consumption would result to an excess of 3.3 or 4 cancer cases per 100,000 populations.

(5) *Tilapia* - Average life time cancer risk associated with *tilapia* consumption would result to an excess of 2.8 or 3 cancer cases per 100,000 populations.

The average life time cancer risks associated with the consumption of fish from Laguna Lake during the wet season show the following order of magnitude: *Bighead carp* > *Bangus* > *Kanduli* >*Tilapia* > *Dalag*.

**Conclusion**

Seasonal variation of potential health risks of fish consumption was observed from the results of the study showing that heavy metals are well-distributed in different areas of the lake during the dry season. Among the five heavy metals analyzed, lead is the most critical and of utmost non-carcinogenic health risk during the dry season for all sampling stations. During the wet season, concentrations of heavy metals in fish were generally lower than the dry season values except to sampling stations 1A, 1B and 2A. Stations 1A and 1B are located in northern west bay while 2A is located in central west bay. Consistent with the dry season findings, lead was highest among the five heavy metals in all sampling stations.

The onset of rainy season had both negative and positive effects on the heavy metals concentration in fish depending on its location in the lake. The positive effects of the rains could (possibly) be due to the dilution effect of rain water run-off. This phenomenon is apparent in south bay, central bay and east bay. On the other hand, the negative impact of the rainy season could be due to the “flushing-effect” from tributaries and run-off from adjoining areas with significant sources of heavy metals in the environment. This observable fact is apparent in the west bay where levels of lead were highest during the wet season.

Correlation analysis of fish (sample) standard size for each of the five fish species vis a vis the five heavy metals concentration showed that heavy metals levels in fish is not influenced by the size of the fish samples.

This study concludes that there is significant health risks associated with consumption of fish products from Laguna Lake. From the point of view of human health protection and disease prevention, fish products from the lake particularly *bangus, bighead carp, dalag, kanduli and tilapia* are not fit for human consumption primarily due to lead contamination.

**Recommendations**

In the light of the above findings, the following recommendations are made to help policy makers and other concerned stakeholders in decision-making as well as in crafting policies and mitigating measures.

1. On the basis of the health risk assessments results, major fish products from the lake (e.g., *bangus, bighead carp, dalag, kanduli and tilapia*) are not fit for human consumption due to lead contamination (and to a lesser degree mercury contamination). Urgent measures should be done by concerned authorities to protect health of communities consuming fish products from the lake especially the children. The most radical measure is to ban consumption of fish until such time that the levels of lead and mercury in fish are within the "acceptable" levels as supported by updated health risk assessment study. However, if this preventive measure is not feasible at the moment due to socio-economic reasons, urgent measures should be done to minimize exposure by equipping the community with the right information without necessarily creating fear or panic. The goal should be to minimize exposure by minimizing the amount of fish intake and the frequency of consumption.

2. Regular monitoring of heavy metals in fish at least twice a year (wet and dry seasons) by Laguna Lake Development Authority (LLDA) in collaboration with the Department of Health (DOH) and concerned Local Government Units (LGUs).

3. Issuance of regular health advisories regarding quantitative health risks associated with fish consumption from the Laguna Lake Development Authority or the Regional Office of the Department of Health.

4. Involvement of the Local Government Units, especially the lakeshore communities around the lake in terms of heavy metals monitoring in fish and in developing and disseminating advisories and other health-related information to the communities.

5. Inventory and assessment of potential sources of heavy metals in the lake (eg., industrial sources) most especially for lead and mercury.

6. More stringent regulation of effluents from industries around the lake.

7. Regular monitoring of heavy metals in major rivers and tributaries draining into the lake.

8. In terms of further research, more refine health risk assessment can be conducted to include potential bioaccumulation of heavy metals in other food sources from the lake such as vegetables (kankong), shellfish, ducks, eggs, among others. Stable isotope analysis of fish samples for lead and mercury should be done to trace natural and anthropogenic sources of these metals.

Socio-economic and cultural implications of above recommendations should be carefully considered without compromising the need to protect human health and disease prevention.

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