Assessment of Potential Dietary Toxicity of Heavy Metals in *Tilapia Mossambica* in the Industrially Polluted Area of M.I.D.C. Taloja, India

Jyotsna Thakur¹, Manda Mhatre²

¹Department of Chemistry, ²Department of Zoology

C. K. Thakur A. C. S. College, Sector 11, Khanda colony, New Panvel,
Dist. Raigad, State Maharashtra, India, PIN 410206

Corresponding Author: Jyotsna S. Thakur

Abstract:
This study aims to investigate the level of toxicity in terms of heavy metals accumulation in the fish samples found from the industrially polluted water system. Fish are considered as a source of various beneficial nutrients which makes them an important part of well balanced diet. However, they can also serve as a source of heavy metals if contaminated with heavy metals. In this study, high levels of heavy metals were found in various organs of fish. The order of accumulation were Fe > Zn > Pb > Ni > Cr > As > Hg > Co. In particular, Muscles, an edible part of fish found to contain Fe, Zn, Cr, Pb and Hg above the prescribed limit by WHO/FAO. These results highlight not only contamination of fish but also risk to human health. In addition, the measure of increasing levels of heavy metals in fish serves as bio-markers of water pollution due to industrial influence in the vicinity.

Keywords: Aquatic pollution, heavy metals, toxicity, fish, bioaccumulation.

Introduction:
Heavy metals in the food have become subject of concern in the recent years because of its potential association to cardiovascular diseases and other toxic health effects (Alisha et al. 2011). Human exposure to heavy metals is mainly due to high intake of these contaminants through food, water and air. Food from the plant and animal origin may extensively be contaminated with heavy metals released from anthropogenic activities.

Fish are most important part of the aquatic food chain and considered as rich source of protein, vitamins and omega 3 fatty acids. However, diet is the main route for human exposure to heavy metals which can be toxic in higher amounts. Fish have a tendency to accumulate large amount of metals from the water (Mansour and Sidky 2002) and thus, serves as a dangerous source of heavy metals. The levels of heavy metals in fish also evaluate the health of aquatic ecosystem.

Metal bioaccumulation is largely attributed to the differences in uptake and depuration period for various metals in different fish species (Tawari-Fufeyin and Ekaye 2007). The factors such as season, physical, chemical properties of water (Kargin 1996) and intrinsic factors such as feeding habits, age of fish can play a significant role in dynamics of metal accumulation in different tissues. For instance, the gills which are directly in contact with water show high level of metal accumulation and reflect metal concentration in water where the fish lives; skin also shows significant amount of heavy metals as it is in intimate contact with water. Muscles relatively show less accumulation. However, as muscles are eaten as food, study of the toxicity associated with it is crucial.

Heavy metal contamination is a major problem in developing countries primarily due to uncontrolled pollution levels driven by causative factors like industrial growth and heavy increase in traffic using petroleum fuels. Heavy metal contamination may occur due to factors such as irrigation with contaminated water, the addition of fertilizers and metal based pesticides, industrial emissions, transportation, harvesting process, storage and/or sale (Radwan and Salama 2006; Tuzen and Soyak 2007). Heavy metals are difficult to remove even after the treatment of wastewater at sewage treatment plants and thus, cause risk of heavy metal contamination of the soil and subsequently to the food chain (Fytianos et al. 2001). Heavy metal-contaminated food are responsible for decreasing immunological defences, intrauterine growth retardation, impaired...
psychosocial disabilities associated with malnutrition and high prevalence of upper gastrointestinal cancer rates (Iyengar and Nair 2000; Turkdogan et al 2003) and thus receiving attention from the public as well as governmental agencies.

Tilapia is a preferred freshwater fish for human consumption in Indian sub-continental region. It is found naturally in all freshwater bodies including rivers and lakes. In the present work, attempt has been made to study the accumulation of heavy metals in the fish *Tilapia mossambicus* which is mainly consumed by the local people staying around the MIDC industrial area of Taloja and the potential health risk of fish consumption.

1. **Materials and Methods:**

   **Sampling Area:** Sampling area of present investigation is the Kasardi River which flows along Maharashtra Industrial Development Center (MIDC) of Navi Mumbai situated in Taloja. It is the main source of industrial discharge into nearby water bodies and receives heavy loads through treated and untreated industrial discharge from various small and large scale industries.

   Maharashtra Industrial Development Center (MIDC) of Navi Mumbai is situated in Taloja, one of the largest projects initiated by the government of India. It lies between latitude 19°3'39"N longitudes 73°6'57"E. The Taloja Industrial Area consists of 277 Industrial Units all large, medium and small spread over 863.18 hectares of land. As a growing and constantly progressing suburban residential hub of Navi Mumbai, future developing node is Taloja. The main industries in this area are engineering, bulk drugs, paint, fertilizers, pesticides, chemical manufacturing, glass manufacturing, petrochemicals, food processing unit etc.

   **Sample Collection:** Fish samples and water samples were collected randomly from Kasardi River in the month of April, August and November. About 0.5 L of the water samples was collected in a pre-cleaned polyethylene bottle from sampling site. Samples were acidified with 10% HNO₃, placed in an ice bath and brought to the laboratory. The samples were filtered through filter and kept at 4°C until analysis. The samples were analyzed directly. The fish samples were carried in polythene bags to the laboratory where they stored into refrigerator at 4°C until prepared for analysis.

   **Sample Analysis:** Before refrigeration, the physical characteristics of all samples were assessed. A condition factor index (K) was calculated using the equation:

   \[ K = \frac{100W}{L^3} \]

   where, \( W = \) body weight in grams; \( L = \) body length in cm.

   According to the condition factor the fish samples were categorized as Medium sized fish (body weight: 65.0-85.0 g i.e. relatively mature fish) and small sized fish (body weight: 35.0-40.0 g, i.e. relatively young fish).

   The frozen samples were thawed at room temperature and then dissected for analysis using stainless steel scalpels. The gills, skins and muscles of the fish were dried in an oven at 40°C for two days until they reached a constant weight. Each dried sample was ground using a porcelain mortar and pestle. One gram dry weight of the powdered form of muscle, gill and skin were used for analysis. The samples were digested by adding mixture of conc. nitric acid and perchloric acid in 1:1 ratio. The solutions were heated to obtain a clear solution. After filtration the digest was diluted to 25 mL with double distilled water. The elements such as Fe, Zn, Cr, Pb, Co, Ni, Hg, Cd and As were assayed using inductively coupled atomic emission spectroscopy (ARCOS from M/s. Spectro, Germany). All the glassware were washed in nitric acid for 15 min and rinsed with double distilled water before being used.

   **Statistical Analysis:** Data obtained from the experiments were analyzed by using SPSS 11.5 software. The results were expressed as mean ± S.D. The results were evaluated using Student’s t test. Values of \( p < 0.05 \) were considered statistically significant.

2. **Results and Discussions:**

   The growing use of heavy metals in agricultural, chemical and industrial processes poses huge threats to lives of organisms. Heavy metals investigated in the present study are Iron (Fe), Zinc (Zn), Chromium (Cr), Cobalt
Physical characteristics and Condition Factor: The physical characteristics of fish samples were studied to determine the relation between their physical characteristics and bioaccumulation which are shown in table 1.

Table 1: Physical characteristics of fish samples
Condition factor is considered as index of growth and feeding intensity (Bang et al. 2008; Jones et al. 1999; Oni et al. 1983). Fish can accumulate high level of pollutants if it has a constant growth and live in polluted ecosystem. Thus, to study the effect of age on accumulation, young and mature fish were selected. It was observed that the accumulation level of heavy metal varies with the age.

Accumulation levels of heavy metals in fish samples: The concentration of heavy metals (mg/kg dry tissues) in the gills, skin and muscles of the medium and small fish samples are summarized in table 2 and 3 respectively.

Table 2: Bioaccumulation of heavy metals in various organs of Medium sized fish samples (mean ± S.D.)
(Note: The values were statistically significant at p < 0.05)

Table 3: Bioaccumulation of heavy metals in various organs of Small sized fish samples (mean ± S.D.)
(Note: The values were statistically significant at p < 0.05)
Metals like Fe, Zn, Cr, Pb, Co showed inverse relationships with fish age and size whereas concentration of Hg, Ni, As increased with age and size which is in agreement with previous reports (Canli & Atli 2003; De Wet et al. 1994). The tissues of the aquatic organisms serve as a site for uptake and absorption of heavy metals. These tissues have the ability to concentrate metals and therefore exhibit relatively high potentials for accumulation. Gills and skin are in direct contact with waterborne toxicants whereas muscles are exposed through media effect. (Heath 1995; Kotze 1997). In the present study the order of bioaccumulation in these three organs observed is Gills > Skin > Muscle. This difference in the accumulation may be attributed to the proximity of the tissue to the heavy metals in water. A probable reason for the high accumulation in gill is physiological state of the tissue and/or structural and functional organization of this organ. The highly branched structural organization of the gill and the resultant highly increased surface area, along with the large volume of water passing through the gill surface, highly vascular physiological state and the small biomass results in high accumulation in gill (Jayakumar & Paul 2006). Skin also has direct exposure to heavy metals in water. Muscles have no direct contact with water, thus show low accumulation of heavy metals. In contrast, mercury accumulates in high concentration in muscle as compare to gill and skin. Such contribution was also observed in previous studies (Goldstein et al. 1996; Voigt 2004).

It was observed that tissues of all samples contain Fe, Zn, Cr and Pb above the prescribed limit by WHO/FAO. Ni, As and Cd are below prescribed limit and Hg was found in muscle tissues only. The regular consumption of such fish may exert adverse effect on health.

**Toxicological effect:** The muscles, as compared to the other tissues, usually show low concentrations of metals but are often examined for metal content due to their use for human consumption. Table 2 and 3 elicit relatively low accumulation of metals in the muscles of fish than other tissues. However, levels of metals such as Fe (114.565± 8.426 and 276.750± 21.452 ), Zn (38.375± 1.232 and 73.750± 11.032 ), Cr (3.098± 0.111 and 16.550± 3.215), Pb (0.435± 0.041 and 9.500± 3. 233 ) and Hg (0.825± 0.094 and > 0.01) in medium sized and small sized fish respectively are beyond their respective WHO/FAO limits.

Although Fe and Zn are essential elements for metabolic activity and enzymatic processes respectively, consumption of Fe in high concentration may cause rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness (Davies et al. 2006). Zn is also potentially toxic when the internal available concentration exceeds the capacity of physiological detoxification processes. Cr and Pb are listed as toxic metals. Cr may lead to carcinogenic effects, ulceration, respiratory disorders, dermatitis, and allergic skin reactions. Pb is exhibitive of very dangerous health hazards such as brain damage, paralysis (lead palsy), anaemia and gastrointestinal symptoms. Long-term exposure can cause damage to the kidneys, reproductive and immune systems in addition to effects on the nervous system. The most critical effect of low-level lead exposure is on intellectual development in young children. Hg level above the WHO/FAO maximum permissible limit of 0.5mg/kg cannot be tolerated and the consumers might raise alarm if they were actually aware of its potential health risks. Arsenic (0.925± 0.046 and 0.600 ± 0.446) was found below prescribed limit, however potential risks for regular consumers cannot be ruled out.

**Heavy metal concentration in river water:** The results discussed in above section also indicate the pollution status of the study area. Thus the levels of metals in water of Kasardi River are also determined.

<table>
<thead>
<tr>
<th>S. N.</th>
<th>Metal</th>
<th>Water (mg/L)</th>
<th>Maximum Permissible Limit (mg/L) (WHO, 2008/US EPA, 1999)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Fe</td>
<td>4.268±0.112</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>Zn</td>
<td>0.089±0.01</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>Cr</td>
<td>0.011±0.001</td>
<td>0.05</td>
</tr>
<tr>
<td>4.</td>
<td>Pb</td>
<td>&lt; 0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>5.</td>
<td>Ni</td>
<td>0.021±0.001</td>
<td>0.07</td>
</tr>
<tr>
<td>6.</td>
<td>Co</td>
<td>0.010±0.001</td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>As</td>
<td>&lt; 0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>8.</td>
<td>Hg</td>
<td>&lt; 0.01</td>
<td>0.001</td>
</tr>
<tr>
<td>9.</td>
<td>Cd</td>
<td>&lt; 0.01</td>
<td>0.005</td>
</tr>
</tbody>
</table>

Table 4: Concentration of heavy metals present in water of Kasardi River
Table 4 shows that water of Kasardi River contains very low level of heavy metals except Fe (beyond the recommended level). According to Tabouret (2011) Fish have adaptive capacity under conditions of sub lethal chronic metal given by physiological changes that result ultimately in acclimation with increased biosynthetic processes (mitosis, enhanced metal binding proteins synthesis such as metallothionein) and up-regulation of other pathways to counteract or compete with the deleterious effects of the metal (ion regulation). As a consequence, the apparent independence of metal concentrations in the fish from the levels observed in the environment is not surprising, and it is in accordance with a previous study (Brusle, 1990).

Transfer Factor: The transfer factor expresses the ratio of contaminant concentration in fish to the concentration in water. It is used to characterize quantitatively the transfer of an element from the water to fish (Rodriguez et al. 2002, Vera Tome et al. 2003).

The transfer factors of all elements in fish from water are greater than 1 this mean that the fish undergo bioaccumulation of these elements from environment (e.g. water, sediment, feed) (Kalfakakour & Akrida-Demertzı 2000; Rased 2001). Small fish samples showed relatively high transfer factor which indicates that it is not affected only by the factors such as, the aquatic environments, the type and the level of water pollution, feeding habits whether omnivorous or carnivorous, and level of fish presence in water etc. but also the intrinsic factors of fish such as size, genetic composition and age of fish (Kamaruzzaman et al. 2010).

4. Conclusion:
High accumulation of toxic heavy metals such as Fe, Zn, Pb, Hg and As in the fish species examined could be related to the industrialization and anthropogenic activities in the M.I.D.C. Taloja area. From the results, it is quite evident that fish are highly contaminated by heavy metals and condition may get worse if the precautions are not taken. The metal contamination of edible part of the fish beyond the WHO permissible limit of human consumption evaluates the potential risk to human health. In fact, the present findings shows that the fish species examined are not safe for human consumption. It is very serious issue that aquatic life is being poisoned by toxic levels of heavy metals, which are then passed up the food chain posing threat to the life of human consumer. Thus, it is important to balance the beneficial effects of consumption of fish and detrimental effects of metals.

Acknowledgement:
Authors wish to thank University Grant Commission, India for providing research grant for this project under its minor research project scheme.

References:
[31] Voigt H-R 2004. Concentrations of mercury (Hg) and cadmium (Cd), and the condition of some coastal Baltic fishes, Environmentalalica Fennica 21:26.