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RESEARCH ARTICLE

Bioaccumulation of Heavy Metals in Tilapia Mossambicus Fish from Industrially Polluted Patalganga River, India

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Abstract

This study aims to investigate heavy metal concentration in the commercial fish found in industrially polluted Patalganga River, India. Heavy metal accumulation in the food chain results into various deleterious effects such as harm to living resources, hazards to human health, hindrance to aquatic activities etc. In present study, metal abundance in different tissues of fish was found in the order gill > skin > muscle. The muscles of the fish are the rich source of proteins and other nutrients; however, concentration of heavy metals such as Fe, Zn, Cr, Pb and As was very high and above the respective WHO/FAO limits. Such fishes are becoming rich source of toxic heavy metals too and posing threat to human health. In addition, contamination levels of fish serves as one of the most significant indicators in aquatic systems for the estimation of metal pollution level.

INTRODUCTION

Environmental deterioration of the aquatic world due to heavy metals contamination embarked with modernization, but it is only recently that people became aware of how trace metals in the aquatic environment could create deleterious effects on the aquatic flora and fauna and ultimately on their life.

Industrial discharge, anthropogenic activities, agricultural runoff, supply of inorganic ions and heavy metals in huge quantity in nearby water bodies such as rivers, lakes etc. are then accumulated in aquatic organisms including fish. Fish are an essential source of nutrition; they are high in protein and a great source of omega-3 fatty acids, vitamins and can reduce the risk of various diseases. However, it can raise some health concerns if contaminated with toxicants.

Toxicants such as heavy metals may occur in low concentration in water bodies; however, when accumulated by marine organism, concentration in their body tissues can be hundred times greater than the water where they live in (Riley and Chester, 1971). Different fish organs accumulate heavy metals at different levels depending upon contamination in aquatic environment, up-take, regulation and elimination inside the fish body (Nussey, 2000). Gills, liver and kidneys accumulate heavy metals in higher concentration in comparison to muscles, which exhibit lowest levels of metals accumulation (Wepener et al., 2001). The accumulation depends upon various factors such as exposure concentration, time, physico-chemical parameters of aquatic body, season and metabolic activity of tissue in concern. Various studies were reported worldwide to investigate the contamination of fish species by heavy metals.

Coastal region of the Mumbai Metropolitan Region (MMR) is considered as the industrial capital of India with various large scale and small scale industries ranging from chemicals, fertilizers, pharmaceuticals, steel, oil refineries, thermal power and so on (Murthy et al. 2001). Industrial pollution originated hand in hand with this development due to gaseous emissions, solid and liquid wastes, toxic and hazardous wastes. Patalganga River is located in the southern region of MMR. A huge industrial zone comprising of number of large scale and small industries situated on the bank of Patalganga River which is well known as Patalganga Industrial Region (PIR). The river receives large amount of industrial effluent load from chemical industries alongside.

The present investigation indicates the accumulation of heavy metals in the different organs of *Tilapia mossambicus* fish species found in Patalganga River and their hazards to the human health.

Study Area

Study area of the present study is the saline zone of Patalganga River catchment which receives treated as well as untreated effluent load from its industrial belt. The Latitude and Longitude of Patalganga River is 18.86^{o} N and 73.14^{o} E respectively. Patalganga industrial region (PIR) is an important industrial hub of Maharashtra state of India. The main industries in this area are chemicals, Insecticides, textiles, Pharmaceuticals, Hydro Power Station, Steel, paper, fertilizer, dye, engineering etc. resulting potentially high level discharge of heavy metals.

Materials and Methods

Sample collection

For the present study twelve fish samples of *Tilapia mossambicus* were collected randomly from the selected zone of Patalganga River in the month of April, August and November. The samples were carried into polythene bags to the laboratory where they stored into refrigerator at 4^{o} C until prepared for analysis.

Sample analysis

The physical characteristics of the sampled fish were assessed before refrigeration. The total length (cm) of each individual samples were measured. An electronic weight scale is used to weigh the individual mass (g) of the fish. A condition factor index (K) was calculated using the equation:

$$K = 100W/L^3$$

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

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 to a constant weight. Each dried sample was ground using a porcelain mortar and pestle. A one gram dry weight of the powdered form of muscle and 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 solution was diluted to 25 mL with double distilled water. Concentrations of Fe, Zn, Cr, Pb, Co, Ni, As, Hg and Cd were assayed by using an inductively coupled atomic emission spectroscopy (ARCOS from M/s. Spectro, Germany). All the glassware were washed in nitric acid for 15 minutes 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.

Results

In the present study, concentrations of iron (Fe), zinc (Zn), chromium (Cr), cobalt (Co), nickel (Ni), cadmium (Cd), lead (Pb) and arsenic (As) in different organs like gills, skin and muscles of the samples of Tilapia fish were determined.

Physical characteristics and condition factor

The physical characteristics and condition factor of fish samples were studied to determine the relation between their physical characteristics and bioaccumulation which are shown in table 1.

Accumulation of heavy metals in fish samples

The observed accumulation levels of heavy metals in different tissues of fish samples were summarised in table 2.

The results showed that the considerable amounts of metals were deposited in tissues of fish. Metal concentrations in the fish followed an order: Fe > Zn > Cr > Pb > Co > Ni > As. This order is in agreement with previous studies (Bhupander kumar et al., 2011; Damodaran and Reddy, 2013; Krishnmurti and Nair, 1999). Fe, Zn, Pb and Cr were found in very high concentration in all tissues and beyond the prescribed limit by WHO/FAO. Co, Ni and As were found below prescribed limit and Cd and Hg were found below detection limit. In the present study the order of bioaccumulation in these three organs observed is Gills > Skin > Muscle.

Table 1. Physical characteristics of samples of Tilapia fish

Species	N	Total length(cm)	Body weight (gm)	Fulton's Condition factor (K)	Feeding behaviour

Tilapia mossambicus	12	14 ± 0.711	45.068 ± 6.44	1.635 (1.529-1.725)	Omnivores

Table 2. Bioaccumulation of heavy metals in various organs of Tilapia mossambicus fish samples

S.N.	Heavy Metal	Concentration in mg/Kg (Dry weight)			Maximum Prescribed Limit (mg/Kg) (FAO/WHO 1984, 1989)
		Gill	Skin	Muscle	
1.	Fe	605.00±58.33	446.50±72.1	231.00±31.12	100
2.	Zn	62.55±20.94	86.05±28.01	55.54±34.5	50
3.	Cr	10.98±3.41	15.40±9.19	9.95±1.43	1
4.	Pb	8.66±1.38	6.01±3.45	9.31±1.66	1.5
5.	Ni	1.0±0.18	1.1±1.32	1.67±0.21	80
6.	Co	5.65±1.78	11.467±11.63	7.66±4.82	-
7.	As	< 0.01	1.25±0.69	0.67±0.23	1.4
8.	Hg	< 0.01	< 0.01	< 0.01	0.5
9.	Cd	< 0.01	< 0.01	< 0.01	0.3

(Note: The values were statistically significant at $p < 0.05$)

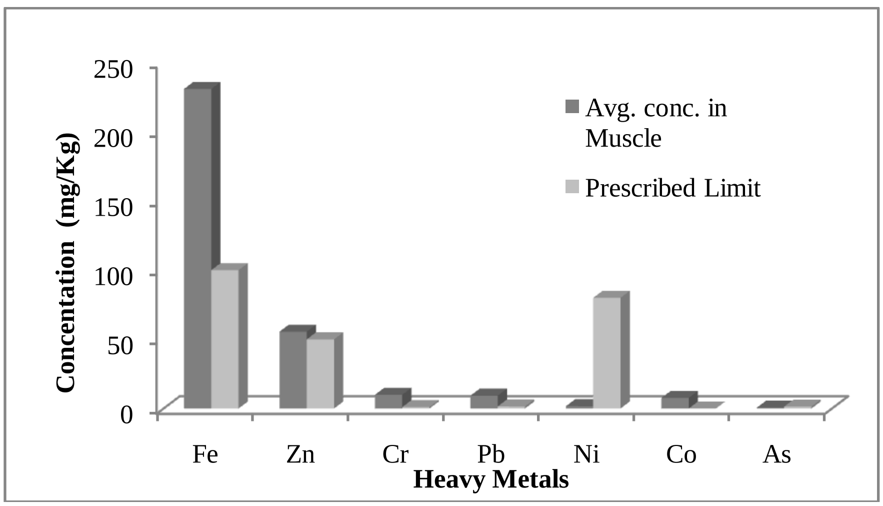

Figure 1: Comparative Chart of average distribution of heavy metals in muscles of Tilapia Fish Samples and their prescribed limit (WHO/FAO)

Discussion

Contamination of marine organisms with heavy metals is of ecological and health concern worldwide. Toxicity of metals not only causes histomorphological changes, deformities and biochemical alterations and sometimes death in the organism but also serious illnesses in humans due to consumption of heavy metal contaminated food (More et al., 2003).

Condition factor is considered as index of growth and feeding intensity (Jones et al., 1999; Oni et al., 1983). The accumulation is time dependant thus age factor or maturity of fish may influence the accumulation of heavy metals (Bang et al., 2008). More matured fish samples are found to contain high concentration of metals that is metals get accumulated in fish if it has a constant growth and live in polluted ecosystem. In the present work, the Tilapia fish studied were young with high accumulation of toxic heavy metals. It gives an idea about levels of accumulation of metals in the grown fish.

Accumulation of heavy metals such as Fe, Zn, Cr, Pb and As indicates not only contamination of fish but also the contamination level of aquatic body where they live in. The different tissues of the fish 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, which are in direct contact with waterborne toxicants showed high accumulation than muscles which are exposed to toxicants through media effect. (Heath, 1995; Kotze, 1997). This difference in the accumulation may be attributed to the proximity of the tissue to the heavy metals in water. Despite the fact that muscles show relatively low concentration of metals are often examined due to their use for human consumption.

Toxicological effects:

Accumulation of heavy metals may cause structural lesions and functional disturbances in fish itself (Jezierska and Wieteska, 2001). High level of accumulation may exert cumulative toxic effect and results in lethal disturbances. In Patalanganga area, large-scale mortality of fish is reported in 1988 (Ingale et al. 1993).

Also, fish being top in the food chain, may pose potential health risk for predatory fish, birds, and mammals, feeding on the contaminated fish. Muscles are the main edible part of fish and can directly influence the human health. Therefore, different regulatory bodies have established toxicological limits for heavy metals in seafood (Agah et al., 2009). Regular consumption of fishes containing heavy metals beyond prescribed limit by human may impair body metabolism (Ceirwyn, 1995; Pourang et al., 2005; WHO, 1980). Fig. 1 shows the levels of heavy metals in the muscles of fish samples and their prescribed limits by WHO/FAO.

Though Fe and Zn are considered as essential elements, ingestion in high concentration may lead serious health risk such as increase in pulse rate, coagulation of blood in blood vessels, hypertension and drowsiness (Davies et al., 2006; McCluggage, 1991). Fe and Zn are found above the maximum prescribed level in muscles of the fish samples examined in this study.

Chromium is listed as a toxic heavy metal. Adverse effects of the hexavalent form on the skin may include ulcerations, dermatitis, and allergic skin reactions. Inhalation of hexavalent chromium compounds can result in ulceration and perforation of the mucous membranes of the nasal septum, irritation of the pharynx and larynx, asthmatic bronchitis, bronchospasms and edema. Respiratory symptoms may include coughing and wheezing, shortness of breath, and nasal itch (Eisler 1986; Galvin 1996). This study indicated that the concentration of Cr (9.95 ± 1.43 mg/Kg) in the muscles is very high and beyond the prescribed limit (1 mg/Kg).

Lead is considered as a protoplasmic poison, which is a cumulative, slow - acting and subtle. Short-term exposure to high levels of Pb can cause 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 (Ogwuebgu and Muhanga, 2005). Most critical effect of low-level lead exposure is on intellectual development in young children (Udedi, 2003). Pb concentration (9.31 ± 1.66 mg/Kg) in the fish muscles examined is very high and beyond the prescribed limit (1.5 mg/Kg).

Arsenic has been classified by the International Agency for Research into Cancer (IARC) as a human carcinogen. Arsenic is also more acutely toxic than other metallic compounds and continual low level exposure to arsenic is associated with skin, vascular and nervous system disorders (Holum, 1983). Average concentration of As (0.67 ± 0.23 mg/Kg) found below prescribed limit (1.4 mg/Kg), however potential risks for regular consumers cannot be ruled out.

Conclusion

The fish samples exhibit high accumulation of heavy metals such as Fe, Zn Cr, Pb and As in different tissues which can be related to the industrial activities and anthropogenic activities in this area. The heavy metals are persistent and biomagnifies in the food chain. It is quite evident from the results that consumption of such highly contaminatedfish can represent potential health risk to the human consumers and not safe to consume. Also, further investigations with continuous monitoring and awareness programmes are recommended.

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