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Bioaccumulation of heavy metals in commercially important marine fishes from Mumbai Harbor, India

A. Velusamy [a], P. Satheesh Kumar [b,*], Anirudh Ram [c], S. Chinnadurai [d]

[a] *Department of Marine Sciences, Bharathidasan University, Tiruchirappalli 691431, Tamil Nadu, India*
[b] *Department of Biological and Environmental Sciences, University of Messina, Messina 98166, Italy*
[c] *Reginal Centre National Institute of Oceanography, Mumbai, India*
[d] *Central Marine Fisheries Research Institute, Molluscan Fisheries Division, Kochi 682018, India*

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ABSTRACT

Seventeen commercially important marine fish species were caught in Mumbai Harbor using a trawl net and evaluated using Atomic Absorption Spectroscopy and ICP-OES. It was found that certain species of fish contained lower levels of all metals tested. *J. elongatus* and *C. dussumieri* had the highest levels of all 8 metals tested. The heavy metal concentrations were significantly varied within and between the studied fishes ($p < 0.05$). However, a significant correlation among heavy metals was observed. This investigation indicated that various levels of heavy metals exist in the fish species sampled, but those concentrations are within the maximum residual levels recommended by the European Union and FAO/WHO. Therefore, fish caught in Mumbai Harbor can be considered safe for human consumption.

Fish are considered an important protein source for human health. Marine pollution can increase aquatic concentrations of toxic metals and negatively affect fish health. Pollution can be caused by various sources, including agricultural drainage, industrial effluent discharge, sewage discharge, accidental chemical waste spills, and gasoline from fishing boats (Handy, 1994; Mishra et al., 2007; Satheeshkumar and Kumar, 2011). Higher concentrations of heavy metals are found in the sediment and enter the food chain via the feeding of benthic species. Macrobenthic invertebrates are an important nexus in the transfer of trace metals to higher trophic levels due to their dependent relationship on sediments and their ability to accumulate metals (Galay Burgos and Rainbow, 2001). The metal accumulation in fish depends on the location, distribution, habitat preferences, trophic level, feeding habits, age, size, duration of exposure to metals and homeostatic regulation activity (Sankar et al., 2006).

Fish are the main aquatic product of the west coast of India. The heavy metal pollution in Mumbai Harbor has an influence on the quality of the fishes. Several studies have focused on the bioaccumulation of heavy metal in fishes of India and international waters. These studies discovered that the impact of heavy metal bioaccumulation in fish focus a gradient of pollution in one moment in time (Topcuoglu et al., 2002; Kojadinovic et al., 2007; Deshpande et al., 2009; Kumar et al., 2012; Kalantzi et al., 2013). Heavy metals, such as iron (Fe), copper (Cu) and zinc (Zn), are important for fish metabolism, while cadmium (Cd), lead (Pb), mercury (Hg) and others have unknown functions in biological systems. Metabolic activity plays an important role in the bioaccumulation of trace metals in marine organisms (Langston, 1990; Roesijadi and Robinson, 1994).

Mumbai lies on the west coast of India, has a deep natural harbor and has a coastline of 140 km along its western edge. Mumbai is also the commercial capital city of the Maharashtra state and boasts the highest population and largest industrial center in the country,

* Corresponding author at: Department of Biological and Environmental Sciences, University of Messina, Messina 98166, Italy. Tel.: +39 3206253357; fax: +39 0906765526.
E-mail address: indianscientsathish@gmail.com (P. Satheesh Kumar).

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resulting in large amounts of waste water generation. This sewage water is treated and immediately discharged into the Arabian Sea. However, many industries also discharge their effluents directly into the ocean. These indirectly affect the health of the aquatic environment by transmitting toxicity through the food web (Deshpande et al., 2009). Recent water quality analyses of the Thane Creek and Ulhas River estuaries have shown increasing evidence of heavy metal contamination due to anthropogenic discharges from the surrounding areas (Thane Municipal Corporation, 2006). Heavy metal contents in the sediment exhibited spatial and temporal variability and recorded relatively high values of Pb, Cd, Hg, and Zn (NIO, 2010). Because seafood is the most preferred food among the local people and tourists, it is important to study the bioaccumulation of heavy metals in different commercial fishes in Mumbai Harbor. This study focused on determining heavy metal concentrations (Fe, Zn, Mn, Cu, Cr, Cd, Pb, Hg) in the muscle tissues of 17 marine fish species from Mumbai Harbor on the west coast of India. In addition, we investigated the relationships between heavy metal concentrations and fish size (length and weight) using statistical analyses. The results obtained from this study were compared with fish caught from international waters. Observed levels of heavy metals were compared with certified human consumption safety guidelines recommended by the Food and Agricultural Organization (FAO) and the World Health Organization (WHO).

Fishes used in this study have been sampled from different sites along Colaba, Vashi and Thane Creek. Thane Creek is part of the Ulhas River in Western India and flows into the Mumbai Harbor (see Table 1). This study region is within latitude 19°00–19°05′N and longitude 72°55–73°00′E (Fig. 1). Thane Creek flows through the most important industrial zones in Mumbai: bulb industries, chemical industries and other small scale industries. Many of these industries directly release their effluents, which contain metals and chemical compounds, into Thane Creek. The effluent water entering the creek causes nutrient pollution. However, the wastewater entering the estuarine environment has severely deteriorated the water quality in some areas. Dissolved oxygen (DO) and Biochemical Oxygen Demand (BOD) distribution patterns indicate that the daily organic load is being effectively dispersed (Deshpande et al., 2009).

The water quality parameters of pH, temperature, DO, BOD, total nitrogen, petroleum hydrocarbons, reactive silicates, ammonia, nitrite, nitrate and phosphate have been measured using standard procedure (APHA, 1995). Fishes were caught in January–February 2012 using a trawl net, which has a large opening measuring 20.7 m and 636 50-mm mesh openings throughout. The net was trawled for about 30–45 min in the direction opposite the current. Starting and finishing positions were taken using a handheld GPS. After trawling, the net was lifted into the boat and fish were collected and packed in polyethylene bags. Fish samples were stored in a deep freezer prior to analysis. The name of the fish species, feeding habits, length, weight, habitat, and fishery importance were documented. Approximately 5 g of muscle was removed, washed with deionized water to avoid contamination, and placed into glass beakers to dry at 60 °C. A wet sample was used to conduct the Hg analysis. Triplicate samples were collected, and the complete analytical study was conducted three times to compare to standards.

A microwave accelerated digestion system (CEM-MARS 5) is used to help digest a wide variety of materials in the laboratory, particularly during metal analysis. This system condenses materials of different matrices, allowing for the analysis of volatile metals, such as Hg. During the digestion portion of the Hg analysis, 1 ml of HNO_3 and 3 ml of HCL were added to 5 g of tissue sample, and the volume was increased to 10 ml using Milli-Q water. Teflon vessels containing the samples were kept in the double walled, outer liner of the digestion bomb, capped with a sensor head and pressure rupture disc. Sealed vessels were then placed in the microwave carousels in the same manner as for digestion. Each set of samples was accompanied with a blank, spike and certified reference material. Mercury was analyzed with a flow Injection Mercury System (FIMS-400, Perkin Elmer, Inc., Shelton, USA), whereas the other metals were analyzed using Graphite Furnace Atomic Absorption Spectrometry (GF-AAS, PerkinElmer, Analyst 600) and an Inductively Coupled Plasma Optical Emission Spectrophotometer (ICP-OES, Optima 7300 DV, Perkin Elmer, Inc., Shelton, USA).

The results obtained from this study were analyzed using Analysis of Variance (ANOVA), Duncan multiple range test (DMRT) for homogenous datasets of metal concentrations, and correlation coefficient (r) to study the significant variation between the fish length, weight and heavy metal concentrations observed in fish tissues. The physico-chemical parameters of water quality used in this study are given in Table 2. The Limit of Detection (LOD) and Limit of Quantification (LOQ) were obtained using the standard deviation of the blank signal multiplied by 3 and 10, respectively. The recovery percentages resulted in ranges from 96% to 101% using various spiked metal concentrations (Table 3).

Heavy metal pollution is a very serious issue in many countries and is caused by industrial waste disposal into the sea, where it becomes toxic for many marine organisms. Concentrations of heavy metals observed in the tissue samples of fishes from Thane Creek-Mumbai Harbor are presented in Table 4. The metal accumulation in the fish in this study was compared with samples

Table 1
Fishes sampled, length and weight, feeding habits and fishery importance.

Name of fish	Length (cm)	Weight (gm)	Habitat	Feeding	Fishery importance
Johnius elongatus	21.5	92	Demersal	Carnivorous	Commercial
Polynemus tetraductylus	28	240	Pelagic	Carnivorous	Commercial
Carangodiae sp.	27.5	310	Pelagic	Carnivorous	Commercial
Arius maculetus	36.2	411.6	Demersal	Carnivorous	Commercial
Dentrophysa russelli	19.2	72.4	Demersal	NA	Minor Commercial
Tetraden sp.	26.1	113	Demersal	Omnivores	Medicinal value
Coilia dussumieri	14.21	13	Neretic	Carnivorous	Commercial
Therapon jarbua	13.2	19.1	Demersal	Omnivores	Commercial
Lutjanus johni	37	374	Demersal	Carnivorous	Commercial
Thryssa mystax	14.2	113	Pelagic	Carnivorous	Commercial
Therapon jarbua	11	17.955	Demersal	Omnivores	Commercial
Plotosus limbatcus	28.5	220	Demersal	Carnivorous	Minor Commercial
Arius arius	13.5	128	Demersal	Carnivorous	Commercial
Thryssa hamiltonii	16.1	38.33	Pelagic	Carnivorous	Commercial
Scatophagus argus	9.6	7.1	Demersal	Omnivores	Aquarium
Trypauchen sp,	11.2	8.888	Demersal	Carnivorous	Minor Commercial
Trichiurus lepturus	37	22.6	Bentho Pelagic	Carnivorous	Commercial
Coilia dussumieri	14.8	14.5	Neretic	Carnivorous	Commercial
Johnius macropterus	13.5	24.64	Demersal	Carnivorous	Commercial
Liza macrojepis	17.9	37.714	Demersal	Omnivores	Commercial