Bioaccumulation of Heavy Metals in the Selected Commercially Important Edible Fish Species Gray mullet (*Mugil cephalus*) From Negombo Estuary

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Abstract

Consumption of fish contaminated with non essential heavy metals such as Pb, Hg and Cd metals which exceed the required limits pose a risk to human health. Bioaccumulation of heavy metals in fish depend on several factors such as increased levels of industrial pollution and domestic solid waste dumping in the estuary.The present study was carried out to assess the levels of accumulated of heavy metal contents as Pb, Cd and Hg in edible tissue of commercially important *Mugil cephalus* fish species from Negombo estuary. The objectives of this study were to determine the non essential heavy metals concentration in fish tissues and assess the seasonal variations (rainy and non rainy periods) in the ecosystem. Based on the pollution inputs into the estuary, it is considered that different localities within the estuary are polluted at different rates. Fish samples were collected from selected nine sampling locations during January to December, 2014.

Results revealed that, the concentrations (mg/kg) of three non essential metals in the fish tissues were determined using Atomic Absorption Spectrophotometer. The mean concentrations varied from Pb 0 to 0.15±0.06, Cd 0.35±0.16 to 1.04±0.28 and Hg 0.0005±0.0004 to 0.05±0.046 mg/kg respectively. Significant differences ($P<0.05$) were observed for Pb and Hg depending on fish tissues. The detected lead, mercury and cadmium contents in fish tissue were below the standard limits defined for each element <0.5 mg/kg < 0.05 mg/kg and < 0.05 mg/kg respectively.

The heavy metal studies revealed that there is a public health hazard associated with industrial drainage, sewage wastewater and agriculture drainage as the quality of fish standard levels recommended by FAO. The value obtained on Cd (1.04±0.28) mg/kg concentration was much higher than the permissible threshold limit (0.05 mg/kg) observed in the north, south, east and west regions. The levels of Pb and Hg metals in muscle tissue were lower than the standard limit for FAO. The results obtained for Cd revealed that high metal pollution takes place in selected sampling locations. The distribution of heavy metals accumulated in all the muscle tissues of selected fish species followed the order Cd >Pb >Hg that indicated the adverse impact of industrialization and urbanization on the edible fish. It can be recommended that standard limit for discharge of effluents into surface waters should be followed when discharging effluent into water body and should be properly monitoring whether the regulations are followed. Negombo estuary has been contaminated with heavy metals which vary with seasons and often exhibit pronounced monsoonal effect. The most prominent increases in Pb and Cd metal concentrations in fish tissue were found during the October, November and December study of 2014, which corresponded to peak periods from October, November and December which apparently coincided with the second inter monsoon of the island respectively.

Keywords: Bioaccumulation, Heavy metals, Fish tissues, Seasonal variation

Introduction

Fish accumulate toxic chemicals such as heavy metals directly from water and diet, and contaminant residues may ultimately reach concentrations hundreds or thousands of times above those measured in the water, sediment and food (Goodwin et al., 2003). Heavy metals are normal constituents of aquatic environment that occur as a result of pollution, principally due to the discharge of untreated wastes into rivers by many industries. Bioaccumulation of heavy metals in tissues of aquatic organisms has been identified as an indirect measure of the abundance and availability of metals in the aquatic environment (Kucuksegin et al., 2006). Fish have been the most popular choice as test organisms because they are presumably the best understood organisms in the aquatic environment and also due to their importance to man as a protein source (Buikema et al., 1982).

Multiple factors including season, physical and chemical properties of water can play a significant role in metal accumulation in different fish tissues (Hayat et al., 2007).With increased urbanization and industrialization, there has been a rapid increase in the discharge of municipal wastewater (sewage and industrial effluents),which in turn has intensified the environmental pollution. The disposal of industrial effluents and municipal wastes is therefore a major problem for urban cities. The major sources of contamination in surface water can be traced to industrial discharges, domestic waste disposal and application of agrochemicals on farm lands (Vutukuru, 2005).

Aquatic ecosystems are very much vulnerable to water pollution. Notably aquatic ecosystems are often polluted with anomalously high levels of toxicants (organic and inorganic substances), which find their way into the aquatic systems with wastewater and effluents generated from industrial enterprises. Heavy metal accumulation in aquatic ecosystem shows that they are accumulated either in aquatic organisms or in the sediments. In estuarine ecosystem, sediments are not only functioning as heavy metal scavenger, but also as one of potential sources for heavy metals to the ecosystem. Due to the capability of aquatic organisms to accumulate heavy metals, there is a possibility of heavy metals to exert their toxic effect towards the organisms. In recent years, there has been an increasing interest in the utilization of fishes as bioindicators of the integrity of aquatic environmental system. Several studies have indicated enhanced levels of both non-essential and essential heavy metal load in muscle tissues of fishes (Nayar, 2006). Thus, the contamination of fish and the aquatic environment by heavy metals is viewed with serious concern (Malik et al., 2010).

These metals after accumulation by the body of aquatic organisms enter into food chain and extremely consumed by human. Reactions of these elements depend on the concentration, physico-chemical properties, chemical bonds and their solution on the absorption, accumulation, distribution in body and physiological effects on metals. Human mediation activities have locally and episodically introduced numerous potentially hazardous metals to the environment since the onset of industrial revolution. These chemicals accumulate in the tissues of aquatic organisms at concentrations many times higher than concentrations in water and may be biomagnified in the food chain to levels that cause physiological impairments at higher trophic levels and in human consumers (Raposo et al., 2009). Urban and industrial activities in estuary areas introduce significant amounts of heavy metals into the environment, causing permanent disturbances in estuarine ecosystems, leading to environmental and ecological degradation and constitute a potential risk to a number of flora and fauna species, including humans, through food chains (Boran and Altınok, 2010).

Water pollution from many sources, as a accidental spillage of chemical wastes, discharge of industrial or sewerage effluents, agricultural drainage, domestic wastewater and gasoline from fishery boots (Handy, 1994). Water pollution is one of the principal environmental and public health problems in Negombo estuary in Sri Lanka (Silva, 1996). Based on the levels of Hg, Pb and Cd in the fish, edible muscle of Etroplus suratensis and Ambassis commersoni fish species collected from the estuary was found to be safe for human consumptions (Indrajith et al; 2008).

However, today Negombo estuary is becoming polluted due to rapid industrialization and urbanization in the area. Industries, houses, boat repair stations, fuel supply stations, and fish marketing station are located along the estuary.With changing environmental conditions under increasing anthropogenic influences, especially from municipal and industrial sources (pollutants including heavy metals may enter the food chain, accumulate in organisms and affect their survival. Metals are natural component of the aquatic ecosystems. Heavy metals such as copper and zinc are essential for life whereas some metal including mercury, lead and cadmium are biologically non essential which can be toxic to biota at very low levels. High concentration of some essential trace metals may become toxic at concentration which exceeds the required limits (Wright and Welbourn 2002). The metal levels in many aquatic ecosystems have been increased due to anthropogenic activities in recent for today, which raises the concerns of metal bioaccumulation and related human health hazards.

Objectives

The objectives of this study were to determine concentration of non essential heavy metals in fish tissues and assess the seasonal variations of these heavy metals (rainy and non rainy periods) in the ecosystem.

Methodology

Study Site

Negombo estuary is a shallow basin estuary of approximately 3,164 ha in extent, located between latitude 7’- 7°12’ N and longitude 79°-79°53’ E in the West coast of Sri Lanka. The exchange of water in the estuary is influenced by the tides from the ocean and freshwater supply from the island. The estuary has been indiscriminately exploited for commercial, residential and industrial development and as a sink for industrial and domestic waste.

Sampling sites were selected for covering the entire estuary based on the channels and pollutant inputs from industrial, (Ja-ela and Katunayake free trade zones) tourism, domestic and municipal sources. The nine sampling locations were selected the sites at which the channels are entering into the estuary (Figure 1).

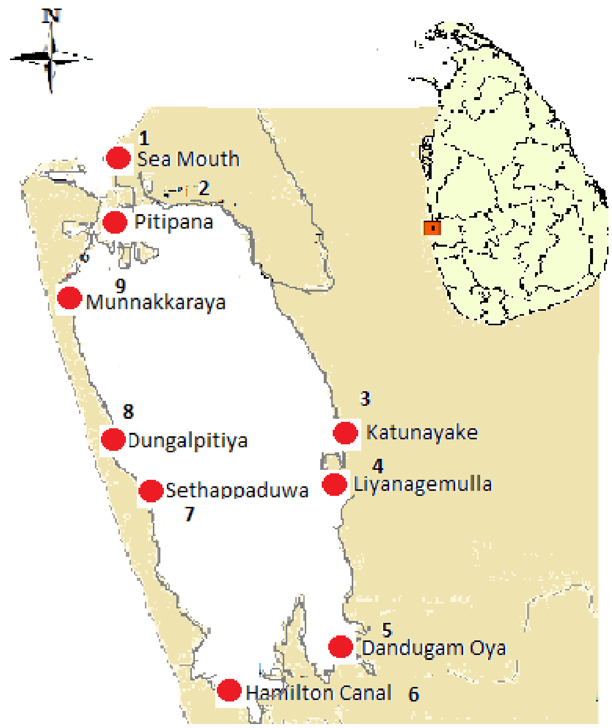

Figure 1: Sampling sites in Negombo Estuary

Three sampling locations were selected in the North region (site 1) (Figure 1). These region is being polluted due to various anthropogenic activities such as solid waste dumping, waste from industries, slaughter houses, domestic sewage outlets, shrimp farms, hatcheries and boat yards (Table 1).South region (site 2) receives from Hamilton canal and Dundugam oya and carry various effluents from Ekala industial zone (CEA, 1994). West region (site 3) receives waste from hotels, shrimp farms and fish processing industries. Eastern region(site4) receives effluent from mainly Katunayake industrial zone, hotels, and a housing scheme (Table 1).

Table 1: Description of Study Sites at Negombo Estuary

Sampling Locations	Section of the Estuary	Input sources (if any)
Location 1,2,9	Northern Estuary Site 1	Municipal solid waste, industrial effluents, urbanization, hotels outlet, fishing harbor and boat repair stations and domestic sewage outlets.
Location 5,6	Southern Estuary Site 2	Two fresh water canals, Ekala industrial zone, seaplane landing site, various effluents in Hamilton canal outlet.
Location 7,8	Western Estuary Site 3	Hotels, shrimp farm and fish processing industries.
Location 3,4	Eastern Estuary Site 4	Katunayake industrial processing zone, hotels and housing scheme.

Sample collection

Fresh fish samples (Mugil cephalus) were collected by using cast net from the sampling sites (Table 1) during the one year study period from January 2014 to December 2014.

Analysis of fish tissues

All fish samples were collected, labeled and placed in clean polyethylene bags with ice to maintain the freshness and immediately, taken to laboratory. In the laboratory, the total length and weight of the fish were recorded. The fish samples were dissected to removed muscle and place in a glass petri dishes. The muscles were oven dried to constant weight at 105˚C.

The dried fish tissues were crushed and powdered in an agate mortar and then the samples were kept in polyethylene bottles for analysis. One gram (01g) portions of fish tissues were digested by means of a microwave digestion after addition of nitric acid (65% v/v) and hydrogen peroxide (30% v/v). These were transferred into sterile sample bottles, labeled and kept for digestion and analysis of heavy metals. After complete digestion samples were stored in pre-cleaned polyethylene bottles until analysis using atomic absorption spectrophotometer AOAC (2002).

Statistical analysis

One-way ANOVA was done using a computer program minitab version 14.0. Where differences were significant, mean values were compared by Turkey's test. The significance level was tested at the $p < 0.05$. Microsoft Excel 2010 edition was used to calculate mean and standard deviation. Tables were used to represent results.

Results and Discussions

Heavy metals in fish

The mean concentrations and standard deviation of heavy metals in the muscles of mugil cephalus are presented in Table 2.

Table 2: Mean concentrations ± SD of heavy metal in muscle tissue (mg/kg) of fish species

	Pb	Cd	Hg
Site 1	0.15±0.06	1.04±0.28	0.03±0.018
Site 2	0.30±0.19	0.45±0.28	0.0005±0.0004
Site 3	0.25±0.04	0.55±0.48	0.001±0.0005
Site 4	0.0±	0.35±0.16	0.05±0.046

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In the present study result of measured metals in the edible muscle tissue were collected form Negombo estuary range from Pb,0 to 0.3, Cd, 0.35 to 1.04, and Hg, 0.0005 to 0.05 mg/kg respectively. The highest level of Cd were in the fish tissue were found at the sampling site 1. Whereas levels of Hg was high in the site 4 located in the east region (Table 2).

The detected lead, cadmium and mercury contents in fish tissue were below the standard limits defined for each element < 0.5 mg/kg, < 0.05 mg/kg, and < 0.05 mg/kg, respectively (FAO, 1983). The maximum levels of Pb, Cd and Hg in food fish specified by FAO international standard for food.

According to the mean concentration of metal levels in selected fish from Negombo estuary were much below these international standard for Pb and Hg. whiles the mean concentration of Cd were above the standard limits for site 1 to site 4.

Table 3: Mean concentrations ± SD of monthly variation of heavy metal concentration in Muscles (mg/kg) of fish species

	Pb	Cd	Hg
January	0.157±0.631	0.06±0.006	0.03±0.002
February	0.3±1.94	0.45±0.04	0.0005±0
March	0.25±0.044	0.55±0.05	0.001±0.0005
April	0.1±0.01	0.35±0.01	0.05±0.004
May	0.5±0.05	1.1±0.11	0.01± 0.005
June	0.5±0.05	0.43±0.04	0.09±0.008
July	0.1±0.01	1±0.19	0.04±0.003
August	0.003±0.002	0.008±0.065	0.01±0.002
September	0.03±0.002	0.09±0.008	0.04±0.002
October	0.4±0.03	1.6±0.19	0.08±0.007
November	0.6±0.06	1.4±0.15	0.09±0.01
December	0.03±0.003	1.2±0.35	0.05±0.045

The most prominent increases in Pb and Cd metal concentrations in fish tissue were found during October, November and December, which correspond to second inter monsoon. In the rainy season the pollution was lower, because of heavy metal concentration in fish tissue were high at the study sites. The increase in mean concentration of heavy metals in the samples could be attributed to more bioaccumulation due to metal concentration arising from reduced water volume during the dry season.

This high level of Pb and Cd accumulated by the fish species may be attributed to the fact that Pb and Cd occur at high levels in organic matter at the bottom of the estuary. So being typical bottom dwellers, the fish species were more exposed to the metal. Heavy metals were higher during the dry season than the rainy season. Seasonal variation influences the accumulation of metals by the fish species. The levels of heavy metals examined in the present study were above maximum permissible limits set by FAO, indicating that the Negombo estuary is polluted by heavy metals. The results for indicate that, large amounts of industrial and domestic wastewater containing organic pollutants & various processes of chemicals release to the estuary. The chemical factories discharge their effluents to estuary in the rainy season.

Conclusion

The finding of this study is consistent with the results obtained for accumulation of metals in the selected species from Negombo estuary followed the increasing order Cd>Pb>Hg. Based on the levels of toxic non essential heavy metals viz. Pb, Cd and Hg are biologically non essential metals which are accumulated in human tissue and harmful to human health. Hence the necessity of the regular monitoring of heavy metal pollution in Negombo estuary is emphasized as there are multiple sources of heavy metal contamination in the vicinity of the estuary. The implication of this finding is that the consumption of fish from the Negombo estuary could Cadmium to various health hazards induced by heavy metals. The present study, it can be concluded that the concentration of heavy metals in the Negombo estuary was very high particularly in intermonsoonal period. The high concentrations of heavy metals are mainly due to the discharge of untreated effluents from different industries. Based on the levels of this study Hg and Pb in the edible muscle of fish collected from the estuary was found to be safe for human consumption.

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