Mercury accumulation in different tissues of fish from Ulhas River Estuary and Thane Creek and the pattern of fish consumption among fish-eaters

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Survey of fish-eating populations in five villages along Ulhas river estuary and Thane creek indicated inter-village differences in parts of fish consumed. Differential tissue analysis indicated higher Hg levels in gills, kidney and skin (0.895-1.118 µg/g), moderate levels in liver, bones and muscles (0.21-0.37 µg/g) and low levels in eyes and brain (0.04-0.093 µg/g). Skin and kidneys having elevated levels of Hg are commonly consumed by all. Pattern of fish consumption among villagers revealed that populations of Alimgarh and Diwe-Kewni villages consuming whole fish are exposed to high Hg concentration whereas populations of Vittawa and Airoli consuming only muscles are exposed to lower concentrations of Hg. In Wehele, a mixed population is observed as far as parts of fish consumed are concerned and therefore are exposed to Hg in moderate levels.

[Keywords: Mercury, Ulhas River Estuary, Thane Creek, Fish, Tissues, Populations]

Introduction

Ulhas river estuary (73°14′ E, 19°14′ N to 72°54′ E, 19°17′ N) and Thane creek (72°55′ E, 19° N to 73° E, 19°15′N) Mumbai, India are recipients of industrial and sewage discharges. Among the various pollutants, mercury is highly dangerous as it readily bioaccumulates in the aquatic organisms. Methyl-Hg, the most toxic form of mercury is a known neurotoxin. Consumption of Hg contaminated fish on a regular basis therefore has been recognised to cause severe health hazards\textsuperscript{1}. Presence of Hg in the waters, sediments and even in some fish of Ulhas river estuary and Thane creek has been reported by several workers in the past\textsuperscript{2,3}. During the survey of the populations along Ulhas River Estuary and Thane Creek, it was observed that the traditional fish eating communities of the villages consume large quantities of these contaminated fish. Study of their fish-consumption pattern revealed that some of these populations not only consumed muscles but also bones, skin, eyes, brain etc. Amount of Hg ingested by an individual depends upon the Hg levels in the parts of the fish consumed. This study therefore, aimed at tissue-wise analysis of Hg accumulation in fish, identifying inter-village differences in parts of fish consumed and in providing recommendations on the tissues to be avoided for consumption in order to reduce Hg exposure.

Materials and Methods

Study area

Present study involved examination of a relatively large group of people mainly households of substantial fish-eating communities along Ulhas river estuary and Thane creek. Five villages were selected for the present study as given in Fig. 1. Out of these, three are located along Ulhas river estuary and two are located along Thane creek both of which are polluted due to heavy industrialisation and sewage discharge. The study areas are described in brief here.

\textit{Wehele}, (73°03′ E, 19°14′ N) is situated on the northern bank of Ulhas river estuary opposite to Dombivli, a highly polluted area. It is a small village where the local people are subsistence fish-eaters. Though most of them have shifted to some other professions, a few families still are engaged in fishing.

\textit{Alimgarh}, (73°02′ E, 19°12′ N) is a village situated on the northern bank of the Ulhas estuary where the villagers catch and consume fish from the site. As one moves away from the estuarine coast, it is observed...
that the people are more inclined to consume sea fish than the estuarine ones.

Diwe-Kewni, (73°00′ E, 19°16′ N) are twin villages situated on the northern bank towards the seaward end of the estuary and therefore less polluted. Very few families now practice fishing however many of the villagers consume fish three times a day.

Vittawa, (72°59′ E, 19°11′ N) is a small village along the western bank of the Thane creek, easily accessible from the cities of Thane and Navi Mumbai. Very few families are engaged in fishing here but most of the villagers rely on fish as their staple food.

Airoli, (19°8′ N and 72°59′ E) is located on the east bank of Thane creek near Airoli village 4 kms downstream of Vittawa. This station receives effluents from the residential and industrial areas of Airoli region. There are many untreated sewage discharge in this region.

The questionnaire specially designed to study the fish consumption pattern in the study areas included parts of the fish consumed by the subjects. With the consent of the subjects, the process of cleaning, evisceration and slicing of the fish was also observed. Information regarding the removal of fins and scales was separately collected.

Method of fish collection for estimating tissue-wise Hg accumulation

*Mugil cephalus* were collected from the study areas during the post-monsoon season (September-November) in 2005 from the local fishermen. *Mugil cephalus* were preferred owing to their popularity among the villagers, availability throughout the year and wide distribution in all the study areas.

The fish were placed in ice-boxes and transported to the laboratory. They were washed with distilled water. Fish were identified with the help of Day (1878) and their standard lengths were measured in centimeters. In all, twenty one fish samples ranging between 14 and 18 cms were analysed for tissue-wise Hg accumulation. Skin, bone, muscle, kidney, brain, eyes and liver were carefully dissected out with sterilized instruments and placed in separate pre-cleaned sterilized petridishes. Small tissues were homogenized with mortar and pestle while larger tissues like muscles were ground and homogenized in stainless steel mixer-grinder and further, if needed, with mortar and pestle. Homogenized tissue was then carefully transferred to 50 mL pre-cleaned PPE vials. These vials were labelled properly and kept at a temperature of −4°C till further processing.

Sample analysis

At the time of digestion, the homogenized fish tissues were thawed and were then digested by APHA...
(1981) method, which involved addition of sulphuric acid, nitric acid, potassium permanganate and potassium persulphate and then heating the sample on a water-bath at 70°C to breakdown organic compounds and oxidise the released Hg to Hg\(^{2+}\). Prior to estimation, the excess of oxidants were reduced with NaCl-hydroxylamine and further the vapours of Hg were released from the solution by reducing it with SnCl\(_2\). Hg concentration was then estimated on Mercury analyzer (AAS) at Bhabha Atomic Research Centre (BARC), Mumbai and expressed in µg/g on a wet weight basis.

Accuracy and precision of the analyses were assured using NRC Canada Certified Standard Reference Material, DORM-3 which not only demonstrated the accuracy of the method but also assured the instrument remained calibrated during the course of the study. Reagent blanks were analysed periodically. In addition, sample duplicates and spiked samples were also included during the analysis. The values obtained for tissue-wise Hg levels were statistically analysed by ANOVA-single factor method. Further, groupings of the tissues were carried out by Tukey’s test.

**Results and discussion**

**Tissue-wise Hg accumulation in fish**

Figure 2 shows the average mercury levels in different tissues of *Mugil cephalus*. ANOVA revealed a significant difference in Hg accumulation among different tissues of the fish \((P = 7.37 \times 10^{-11})\). Tukey’s test segregated kidney, dorsal skin, ventral skin and gills in one group and liver, bone, muscles and eye in another group with reference to Hg accumulation.

Out of the different tissues, gills exhibited a higher concentration of mercury. Gills accumulated higher levels of metals because they were directly exposed to the surrounding medium\(^6\). Gills and skin of fish are the routes through which toxic elements from the surrounding water enter the body of fish, both of them posing as principle pathways before the metal is distributed to other parts of the body. Therefore they serve as the storage depots of Hg\(^7\). High accumulation of Hg in skin can also be accounted for the direct exposure of skin to the surrounding medium. Skin also acted as an excretory organ helping in the elimination of heavy metals to certain extent\(^8\). Therefore skin is considered to be a storage site for metabolic waste products. In the present study, dorsal skin had comparatively higher values of Hg than ventral skin which was because of the higher distribution of chromatophores on the dorsal side, resulting in more accumulation of Hg in it\(^7\). Another organ found to be a major site of Hg accumulation was kidney which is an excretory organ. As most of the toxic elements are eliminated out of the body through kidney, it becomes a target organ for final deposition of various heavy metals\(^9\).

Lower concentration of Hg in bones was observed in the present study. The same results were also reported by Tejam and Haldar (1975)\(^10\). Concentration of Hg in muscle tissue also showed low level of accumulation. There are several reports stating that Hg accumulation in muscle tissue was low\(^11-13\). Muscle is known to reflect a chronic exposure to pollutant inputs whereas liver is recognized as the tissue which reflects short term exposure\(^14\). In the liver, there are many enzymes such as succinic dehydrogenases, alkaline phosphatases and Glutathione which detoxify the heavy metals before it is distributed to other organs\(^15\). Hence, high values of Hg in liver show instant exposure to heavy metal and lower levels reveal the completion of the detoxification process and subsequent elimination through the bile. In the present study, comparatively low levels of Hg have been observed in the liver tissue indicating the completion of detoxification process. As in the present study, low range of Hg in the brain tissue was observed by many\(^10,16\). Brain showed less accumulation probably due to the blood brain barrier which prevents the passage of Hg to the brain to some extent. Membrane covering the eyes probably prevented the entry of Hg to a certain extent through them.
Parts of the fish consumed by the populations

The study on the pattern of fish consumption revealed that the entire population surveyed in the study areas removed the scales but kept the skin on before cooking. During the cleaning process, the alimentary canal and liver were discarded but kidneys which were attached to the mid-dorsal side of the coelom covered by peritoneum were seldom removed. As per the parts consumed, the surveyed population was categorized into three groups as detailed below-

1) Group I—The entire fish particularly small and medium sized ones were consumed on the whole by this group. Very small fish were consumed along with fins also. The fish were boiled or fried entirely without making slices. Skin was also kept intact. While consuming, maximum portion of the fish was ingested.

2) Group II—This group kept the head portion intact and the trunk portion was sliced before cooking. The skin on the sliced portions remained during cooking. While eating the head region, the gills and skull bones were chewed and then spit out.

3) Group III—This group was particular about consuming only the middle trunk portion mainly comprising of muscles. All other parts were discarded except the kidneys which remain attached to the peritoneum and skin covering the sliced portions of the muscle. However, compared to the large muscle portion, the part of the skin attached to it was negligible.

Hg levels in parts of the fish consumed by different groups suggested that there would be no much difference in the Hg intake by Groups I and II. Group I consumed the entire fish which were small in size with low Hg levels. Being small, the bones of these fish are soft and often consumed by the subjects. The other organs such as kidney and gills, which contain high levels of Hg, are also consumed in addition to eyes and brain. Group II consumed larger fish having higher Hg levels. The hard parts of the larger fish like gills and skull bones being difficult to swallow were chewed and discarded during meals. Therefore, Hg accumulated in gills and skull was ingested to some extent. Thus, the net effect may result in the ingestion of the same amount of Hg by both the groups. These two groups are vulnerable to the risk of Hg exposure. The third group that consumes only muscle fillet is at a lower risk of Hg exposure owing to the low levels of Hg in muscles.

Figure 3 shows the percentage of population consuming different parts of fish in the study areas. In Alimgarh and Diwe-Kewni, maximum people consume whole fish, which means majority of people ingests gills, bones and other tissues having greater amounts of Hg. Therefore, these are the populations at very high risk of exposure to Hg poisoning as far as parts of the fish consumed are concerned. In Vittawa and Airoli, majority of the population consume muscles only. Therefore, these populations are prone to lesser risk of Hg exposure. Wehele, on the other hand, had mixed population consuming whole fish as well as only muscles thus were moderately exposed to Hg.

Asians comprising of Japanese, Malaysians and Indians mainly consumed the whole fish compared to

![Figure 3](image_url)
American immigrants consumed only the fillets (muscle)\textsuperscript{17}. Asian immigrants consumed other parts of fish along with fillet which was the feasible reason why the hair Hg was prominent in Asians than in Americans\textsuperscript{18}. Thus tissue-wise Hg accumulation in fish and parts of the fish consumed are important factors that influenced Hg accumulation in fish-consumers and need to be studied in detail while framing advisories for a particular area.

**Conclusion**

The tissue-related study of Hg accumulation revealed higher Hg levels in tissues like gills, kidney and skin and lower levels of accumulation in liver, bones and muscles, eyes and brain. Skin and kidneys which had elevated levels of Hg exposure are consumed by all in the study areas. Populations like Alimgarh and Diwe-Kewni who consume parts of the fish with high Hg concentration are exposed to high levels of Hg. In Vittawa and Airoli, the majority of population consumes only muscle fillets and therefore exposed to lower risk of Hg levels. In Wehele, a mixed pattern of fish consumption, as far as parts of fish consumed, is observed and therefore, they are at a moderate risk of exposure.

From the results obtained, it is highly recommended to avoid the consumption of gills, kidneys and skin. The survey revealed that kidneys are usually not removed during the cleaning process. Kidney had the highest level of Hg and people are prone to the risk of Hg exposure through it. So the importance of removing it while cleaning the fish should be emphasized among the fish-consuming populations. Gills and bones should be preferably discarded in order to reduce the effects of Hg exposure. Considering the nutritive benefits, palatability and also mercury bioaccumulation, muscle (fillet) of fish is recommended as the best part for consumption.

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**References**