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Heavy Metal Contamination in Biotic Component: A gradual case study in West Bengal

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Abstract

Fish is a popular human food. Over two-and-a-half billion people globally obtain their daily nutrient intake from fish. In India, it is a major dietary component for over 50 percent, and is a particularly important nutrition source for the poor. Mercury is a deadly environmental pollutant, both in its elemental form and in combination with other chemicals. When released into the environment mercury is transformed into methylmercury through microbial action. Methylmercury is the most pernicious form of mercury. It bioaccumulates in fish and enters human body with the consumption of contaminated fish. Fish in polluted water bodies accumulate methylmercury – a toxic pollutant of high potency that crosses the blood brain barrier and placental barrier, making it an intergenerational toxin. It enters the food chain both from point and non-point sources. Effluent pipes from industrial processes often contain mercury or mercury compounds. Emissions and ash from coal-fired power plants also contain mercury. It is well known that mercury circulates globally and deposits in water, bioaccumulating in the food chain through algae and fish. The higher the pecking order of a fish in the food chain, greater is the amount of mercury it is likely to contain. Advisories on fish consumption are quite common in developed countries, especially for pregnant women. Human exposure to such toxins therefore assumes significance. Contamination of this vital food is a key issue.In developing countries, issues like food contamination rarely draw attention. Mere availability of food is argued to be of foremost concern. In this scenario of poverty and hunger, system of industrial production has largely remained unaccountable to society and the environmental pollution it causes.

Keywords: Contamination, Methyl mercury, bioaccumulation, human exposure

Introduction

Mercury can exist in three oxidation states: Hg^0 (metallic), Hg^{1+} (mercurous) and Hg^{2+} (mercuric). The properties and behaviour of mercury depend on its oxidation state. Mercury in water, soil, sediments, or biota (i.e., all environmental media except the atmosphere) occurs either as inorganic mercury salts or organic forms.

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Mercury in environment

Natural sources of atmospheric mercury are rocks, including coal, from where it enters the atmosphere through weathering and volcanic emissions. Another source is volatilisation from the oceans. Anthropogenic sources of mercury in the environment include coal combustion, mercury uses in cathodes, metal processing, chloroalkali industries, pharmaceuticals and mining of gold and mercury disseminated and can circulate for years, accounting for its widespread distribution.[2] The distances it travels and eventual deposition depends on the chemical and physical form of mercury emissions.

The residence time of oxidised mercury compounds in the atmosphere is uncertain. Even after it is deposited, mercury is commonly emitted back to the atmosphere either as a gas or in association with particulates to be redeposited elsewhere. Mercury undergoes a series of complex chemical and physical transformations as it cycles in the biosphere.

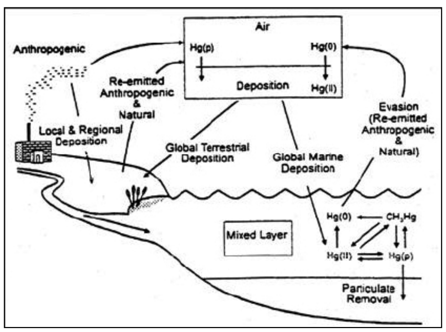

Fig1.A basic diagram of the global mercury cycle

As indicated, mercury is emitted in the atmosphere by a variety of sources, dispersed and transported by air, deposited to the earth, and stored in or transferred between the land, water and air.

Environmental Mercury: Transport and Destinations

Mercury cycle in figure 2 below illustrates the major physical and chemical transformation expected to occur in mercury in freshwater lakes. These processes include a number of infinite and/or indefinite loops

Health impacts of Mercury Humans

The three possible forms of mercury exposure are elemental mercury, inorganic mercury and organic mercury. Each of them has specific effects on human health. Of these, methylated mercury (organic mercury) is of the greatest concern. Methylated mercury is the most toxic of all organic mercury compounds. Of its two common forms – monomethyl mercury and dimethylmercury, the latter is extremely toxic. However, dimethylmercury is very unstable and its occurrence in non-laboratory environment is rare. In nature, it quickly degrades into monomethyl mercury. Monomethyl mercury constitutes the greatest hazard, as it is highly toxic and bioaccumulates in organisms and biomagnifies as it climbs the trophic ladder. It's a neurotoxin that causes a wide array of neurological disorders and can easily be fatal at higher concentrations.

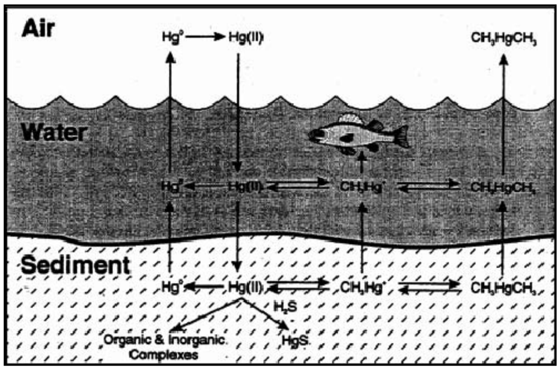

Fig.2

Mercury Cycle in Freshwater Lakes

Cited from EPA Mercury Study Report to Congress. Adapted from Winfrey, M.R. and Rudd, J.W.M. 1990. Review-- Environmental Factors Affecting the Formation of Methylmercury in Low pH Lakes. Environ. Toxicol. Chem. 9:853-869.

Other Organisms

Mercury has adverse effects on a wide range of organisms. Effects of mercury on birds and mammals include death, reduced reproductive success, impaired growth and development and behavioural abnormalities. Sublethal effects of mercury on birds and mammals include liver damage, kidney damage and neurobehavioral effects. Effects of mercury on plants include death, plant senescence, growth inhibition, decreased chlorophyll content, leaf injury, root damage and inhibited root growth and function.

Mercury concentrations in the tissues of wildlife have been reported at levels associated with adverse effects. Toxic effects in piscivorous avian and mammalian wildlife have been associated with point source release
s of mercury in the environment.

Mercury Methylation, Bioaccumulation and Exposure Pathways

Mercury methylation is a key step in mercury absorption in food chains. The biotransformation of inorganic mercury into methylated mercury occurs in the sediments of water bodies. Not all mercury compounds entering an aquatic ecosystem, however, are methylated; demethylation reactions as well as degradation of dimethylmercury occur, and these reactions decrease the amount of methylmercury available in the aquatic environment. There is scientific consensus, however, on the environmental factors that influence variability in mercury methylation in waterbodies.

Often, almost 100 percent of mercury that bioaccumulates in fish tissue is methylated. Numerous factors influence bioaccumulation of mercury in aquatic biota. These include the acidity of the water (pH), the length of the aquatic food chain, temperature and dissolved organic material.

Mercury accumulates in an organism when the rate of uptake exceeds the rate of elimination. Although all forms of mercury accumulate to some degree, methylmercury has a higher propensity for bio-accumulation. Its half-life ranges from months to years in different organisms. Elimination of methylmercury from fish is extremely slow.

Plants, animals and humans are exposed to methylmercury either by direct contact with contaminated environments or ingestion of mercury contaminated water and food. Generally, mercury builds up more in the higher trophic levels of aquatic food chains (biomagnification). At the top are piscivores, such as humans, eagles, hawks, cormorants and other fish-eating species. These species prey on fish, such as the bronze featherback (Notopterusnotopterus) or the long-whiskered catfish (Sperataaor), which in turn feed on smaller forage fish. Smaller piscivorous wildlife (e.g., kingfishers) feed on the smaller forage fish, which in turn feed on zooplankton or benthic invertebrates. Zooplanktons feed on phytoplankton and the smaller benthic invertebrates feed on algae and detritus. Thus, mercury is transmitted and accumulated through several trophic levels. [5] Accordingly, mercury exposure and accumulation is of particular concern for animals at the highest trophic levels in aquatic food webs and for animals and humans that feed on these organisms.[6]

Methylmercury – Human Exposure Pathways

Humans are most likely to be exposed to methylmercury through fish consumption. Exposure may occur through other pathways as well (e.g., the ingestion of methylmer- cury-contaminated drinking water and food sources other than fish, and uptake from soil and water through the skin). However, for humans and other animals that eat fish, methylmercury uptake through fish consumption dominates these other routes.

There is a great deal of variability in fish-eating populations with respect to fish sources and fish consumption rates. As a result, there is a great deal of variability in exposure to methylmercury in these populations. The presence of methylmercury in fish is, in part, the result of anthropogenic mercury releases from industrial sources. As a consequence of human consumption of the affected fish, there is a risk of human exposure to methylmercury.

Methylmercury is a known human toxicant. Clinical neurotoxicity has been observed following exposure to high amounts of mercury (for example, Mad Hatter's Disease). Consumption of mercury contaminated food has produced overt neurotoxicity. Generally, the most subtle indicators of methylmercury toxicity are neurological changes. The neurotoxic effects range from less immediately observable weakening of motor skills and sensory ability at comparatively low doses to tremors, inability to walk, convulsions and death at very high exposures.[7]

Methylmercury – Absorption and Excretion

Methylmercury is rapidly absorbed through the gastrointestinal tract and distributed throughout the body. It penetrates the blood-brain and placental barriers in humans and animals. It is relatively stable and only slowly demethylated to form mercuric mercury in rats. Methylmercury has a relatively long biological half-life in humans: estimates range from 44 to 80 days. Excretion occurs via the faeces, breast milk and urine. The knowledge

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of mercury absorption from inhalation is limited.[8]

Methylmercury – Health Effects

Methylmercury-induced neurotoxicity is of the greatest concern when exposure occurs to the developing foetus, as it easily penetrates the placental and blood-brain barrier. Post-natal brain development continues well into childhood. Methylmercury exposure at early developmental stages adversely affects a number of cellular events in the developing brain both in utero and post-natally. The post-natal age when the development of various regions of the brain is completed varies, and development of many functions continues through the first six years of life.[9]

Methylmercury Disasters

The most notorious methylmercury incident occurred among people and wildlife of Minamata, on the shores of Minamata Bay, Kyushu, Japan. The source of methyl- mercury was a chemical factory that used mercury as a catalyst in the production of acetyldehyde. A series of chemical analyses identified methylmercury in the factory's waste sludge, which drained into Minamata Bay, as a toxicant affecting the people and wildlife in the region. This methylmercury accumulated in the tissue of the Minamata Bay fish and shellfish that were routinely consumed by wildlife and human populations in the region. The symptoms characteristic of nervous system damage. The symptoms included:

Impairment of peripheral vision

Disturbing sensations (feeling of "pins and needles" pricks, numbness) usually in the hands and feet and sometimes around the mouth

Difficulty in movement coordination as in writing

Speech impairment

Hearing impairment

Difficulty in walking

Mental disturbances

It took several years before people realized that they were developing the signs andsymptoms of methylmercury poisoning. Over the next 20 years the number of people known to be affected with what came to be known as Minamata disease increased to thousands. In time, the disease was recognized to result from methylmercury occurring in fish in the Minamata Bay. Deaths occurred among both adults and children. It was also recognized as a potent toxin that could damage the nervous system of growing foetus, if the mother ate fish contaminated with high concentrations of methylmercury during pregnancy.

The nervous system damage from severe methylmercury poisoning among infants was very similar to congenital cerebral palsy. In the fishing villages of this region, the occurrence of congenital cerebral palsy due to methylmercury was very high compared to the incidence for Japan in general. After the source of toxic contamination was identified, mercury release into the bay was checked. Over time the symptoms were seen to reduce in the local population.

Another methylmercury poisoning outbreak occurred in Japan, in the area of Niigata, in 1965. Again, investigations identified the source to be an acetaldehyde producing chemical factory releasing methylmercury into the Agano river[10].

Effects of methylmercury on nervous system are well established. Consumption of methylmercury contaminated food products (including grains and pork products) has also resulted in severe poisoning with pathological changes in the nervous system and clinical symptoms identical to Minamata disease.

These developments brought to the fore two major points of concern:

Methylmercury in fish is the most prevalent source of mercury poisoning

Methylmercury in fish is the most important source of mercury poisoning among humans.

Methylmercury – safe levels

The concern of methylmercury contamination of food has gradually led to the emergence of permissible or tolerable methylmercury dose standards in different countries including India. Although India now has the Food Safety and Standards Act, specific food standards on the basis of the said Act are not yet in place, and moreover, its standards are not meant to apply to products of farming, fishing and aquaculture.

Food standards in terms of permissible levels of contamination are only available with the Prevention of Food Adulteration Act and Rules, 1954. This gives the limit of mercury in fish as 0.5 ppm by weight and that of methylmercury (calculated as an element) in the case of all foods (including fish) as 0.25 ppm by weight.[11] The fact that the aforesaid Act and Rules mention methylmercury, has tremendous import for this study: for it is the mercury in the methylated form that is of the greatest toxic significance and its presence in our food chain needs to be checked and contained. The study also compares its findings with the PFA standards.

However, it is not enough to determine methylmercury contents in fish, it is also important to know people's average dietary fish intake. It is only when one combines methylmercury contents in fish with the average fish intake that one can assess mercury exposure. This is because the body flushes out methylmercury at a very slow rate, and if the rate of methylmercury intake exceeds the rate of its excretion, it starts building up, causing poisoning. The degree of poisoning per unit intake of methylmercury depends on the body weight: for the same amount of intake, poisoning is less severe in people of higher weight. And finally, young people and pregnant women (the foetus) are most vulnerable, and therefore methylmercury stipulations are of the greatest importance in their case.

Nowadays, standards for the tolerable doses of methylmercury account for its total intake over a period (e.g. per week) or the average daily intake. Of these, the most stringent standard is that of the US EPA, which explicitly factors in the body weight of the recipient. The EPA reference dose for methylmercury is 0.1 μg/kg of body weight/day and this standard has been supported by the US National Research Council as well.[12] The US

Agency for Toxic Substances and Disease Registry (ATSDR) has a less stringent standard or MRL (minimal risk level) of 0.3 µg / kg of body weight / day.[13]
The US FDA has a different standard. It does not speak in terms of body weight of the recipient, but of total permissible dose per week. For one-ppm methylmercury in fish, it advises fish consumption below 198.4465 gm per week and for 0.5-ppm methyl- mercury in fish it advises consumption below 396.893 gm per week. The FDA has been criticised for its relatively lenient standards.[14]
In year 2004, the Joint FAO-WHO Expert Committee on Food Additives developed a norm for tolerable levels of methylmercury in fish. The said Expert Committee reconfirmed this standard in 2006.[15] Its Provisional Tolerable Weekly Intake (PTWI), the tolerable limit of exposure, is given as 1.6 µg/kg of body weight/per week or around 0.228571 µg/kg of body weight/day. Although it is less stringent than the EPA's, is more stringent than that of the ATSDR and far more stringent than that of the FDA.
It is important in this context that the European Food Safety Authority (EFSA) has issued a guideline based on both the Joint FAO-WHO Expert Committee On Food Additives recommendations of PTWI (1.6µg/kg body weight) and the US National Research Council's reference dose of 0.1 µg/kg body weight/day, which is the same as the US EPA's and leads to 0.7 µg/kg body weight PTWI. Essentially the EFSA's recommendations tend to ask vulnerable groups to cut down on their fish consumption.[16]

Objectives

- Quantify the level of mercury in fish and crustacean samples from prominent markets in Kolkata and select waterbodies.
- Study the nature and extent of mercury contamination, and reach a reasonable conclusion through laboratoryanalysis.
- Assesshealthriskfromintakeofcontaminatedfish(basedonlevelofcontamination).
- Provide recommendations on the basis of results andanalysis.

Sampling Locations

Samples for the study were collected from fish markets in Kolkata as well last from various water bodies spread across different area to get a broadview of mercury contamination of fish inKolkata.
After collecting total samples, they were submitted to the EFRAC (Edward Food Research & Analysis Centre Limited) laboratory for total mercury analysis of the fishes collected from Kolkata markets. The sampling strategy required to support thorough going analysis of mercury contamination of edible fish.The locations were selected to represent wide geographical spread, influences of industrial installations and land use practices. Lab results were determined in ppm (mg/kg).

Table 1: List of markets in Kolkata from where samples were collected

Sl. no.	Market	Waterbodies
1	Gariahat	Bantala
2	Sahababu Bazaar	Basirhat
3	Manicktala	Kharibari
4	Sealdah	Nalban
5	Dumdum	Rajarhat
6	Muchipara	Paradwip, Canning
7	Baguihati	Jainagar
8	Ashubabur bazar	Hasnabad, Ghushighata
9	Narayanpur Bazar	Haroa

Materials and Methods:

Mercury analysis is performed as per laboratory internal method, Quantification is performed by ICP-MS.

Microwave assisted wet digestion:

A suitable quantity of sample was weighed accurately and transferred into a clean Teflon digestion tube. Then 7 ml of conc. Nitric acid was added into it and the tube was closed with cap. The tube was kept in microwave tube stand and then kept in microwave digester (CEM

Corp., USA). The door was closed and the digester was switched on. After that the required method was selected and loaded then start button was on. The operating conditions are summarized in Table. After completion of digestion the digester was switched off and allowed to cool the system, then the tube was removed and opened; the content was filtered using Whatman No. 42 filter paper. The filtrate was collected in any graduated vessel and diluted suitably with Milli-Q water

Operating conditions of microwave digester (CEM Corp.)

Ramping stage	Hold time (minutes)	Temperature (^oC)	Power (W)
1	20	180	800
2	20	160	800
3	20	160	800
Cool down	10	140	-

INSTRUMENT SPECIFICATION

Inductively coupled plasma mass spectrometry (ICP-MS) 7700 X Make Agilent Technology

Instrumental operating parameters

Plasma condition		Plasma flow (15L /min) Nebulizer pump speed (0.1 rps) RF power 1550 watts
S/C Temperature		2^0C
Detectors parameters		5 mV
TMP Revolution		100 %
Auto sampler conditions	Working mode	Continuous
	wash	Between runs

Fish Intake Survey

The survey was conducted in Kolkata and nearby areas to get a general idea of fish consumption among families with different income levels. No similar survey was conducted in rural areas with ponds, rivers or the sea owing to difficulty in ascertaining actual consumption, as a significant portion of fish intake in such areas comes from non-market sources. However, the necessity of such a survey, conducted in a methodologically rigorous manner, is obvious if one has to get a clear picture of fish intake patterns in West Bengal.

Table 2: Fish intake survey in 200 families in and around Kolkata

Monthly Income (Rs.)	Monthly average fish consumption (kg)
0-10,000	8.5
10,001-20,000	12
20,001-30,000	15.5
30,001-40,000	17.5
40,001-50,000	23
50,001-60,000	25
60,001-70,000	25
70,001-80,000	32
80,001-90,000	32.5
90,001-1,00,000	22

Results and Discussion

Methods

Samples were collected at the point of time and the place where the fishers brought in their catch. This norm was followed in all locations A few other varieties that had been brought in earlier and stocked with the Aaratdar (fish wholesaler) in the market were thus also included. All the samples were taken only after a careful cross-questioning about their sources.

It is important to clarify that the term ‘location’ here specifies a certain geographical entity and not a particular pond or a river. For instance, the varieties caught from the kharibari have come from different ponds within a radius of about two kilometre. Each pond constitutes a different ecosystem and therefore it can be argued that the fish have come from different locations. But, in this study the term ‘location’ implies a particular area;

Fish samples were chosen on the basis of the following criteria:

Preference for commonly eaten varieties(mercury in these is the greatest hazard for fish eating people)

Matured specimens (mercury bio-accumulates with age)

To analyse mercury bio-accumulation in different specie

After collection, the samples were identified in the following manner:

By local name of the species /variety

By scientific name of the species (in so far as scientific species identification was possible)

By photographing each sample (for future identification, if necessary)

By weighing and measuring the length of each sample (for estimating age)

Results

The total mercury concentrations of samples collected from Kolkata markets and other locations in West Bengal,including the species average for each location/ market, are given in various tables .There liable detection limit of the instrument and methodology was 0.20mg/kg. That is, for the given methodology and instrumentation, mercury values arrived at below the aforesaid value may not be accepted with a high degree of confidence. Therefore, in this study any value indicated by<0.20mg/kgimpliesavaluex:0<x<0.20 mg/kg (here x is understood to be always, even if slightly, greater than 0, as mercury naturally occurs in the environment and faint traces are present in all organisms).This factor creates obvious problems in working with the data, for example, even at the simplest level of working out mean values.

Since people eat a variety of fish, methylmercury level in an individual fish variety does not give complete picture of their exposure. People’s intake of methylmercury depends on a variety of fish in their food and methylmercury contamination levels of these fish. The average methylmercury level of the study samples thus gains significance here. Furthermore, fish in the markets come from variegated sources. A consumer buying her fish from a local market is exposed to contaminated catch coming from different places. Therefore, the state average for mercury contamination of fish would be a good indicator of people’s risk of exposure.

It may be noted here that the two scenarios described above depict relatively low levels of fish consumption, and that fish consumption could easily be higher, particularly in families with higher incomes, costal populations or areas in the vicinity of large waterbodies. The risk of exposure increases with increase in fish-flesh consumption for a given body weight.

The research (Toxic Link and Disha) shows that methylmercury levels in 69 percent samples exceed PTWI for a child weighing 25 kg and consuming 250 gm fish flesh in an entire week. Likewise, 59 percent samples exceed PTWI for women/adolescents of 60 kg consuming 500 gm fish flesh in a week.

It is abundantly clear from the findings that a large number of samples have alarmingly high levels of methylmercury. Especially samples collected from some of the fishing locations across West Bengal show disturbingly high mercury and methylmercury averages. Table 3. Number and percentage of samples exceeding PTWI limits

Given body weight and consumption level	**Percentage of samples showing PTWi exceedance**
A child of 25 kg consuming just 250 gmof fish flesh in aweek	68.56
An adolescent or pregnantwomanof60kg consuming 500 gm offish flesh in aweek	58.71

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The coastal/estuarine areas of Jharkhali, Kakdwip and Digha show high mercury levels. So does Budge Budge, very close to and downstream of Kolkata in the Hooghly estuary. The Hooghly estuary and the coastal waters of West Bengal are the recipients of industrial effluents, untreated urban sewage and agricultural wash-offs, containing an extraordinarily large variety of toxins from a number of sites across densely populated SouthBengal. Mercury concentration in fish samples from Haldia (Haldi River), an industrial area abutting estuarine site, though high for safe consumption was relatively low in comparison to estuarine samples.The explanation for this anomaly may lie in the fact that Haldi river,which flows into the Hooghly at Haldia and from where many of the samples came, is not as polluted as Hooghly.

The results can be further analysed by comparing the species/variety averages displayed in tables with their feeding habits. It is observed that predatorial and carnivorous species tend to show significantly higher values former cury in comparison to mainly herbivores or omnivores varieties. A striking example is *Harpadonneherus,* described as an 'aggressive predator',which shows very high mercury and methyl- mercury values.Other examples are *Epinepheloussp.*and *Eleutheronematetradactylum,* which feed on small fish and crustaceans, show high mercury values. On the other hand *Catlacatla*, basically a phytoplankton, detritus and insect feeder, shows quite low mercury values, and so do *Oreochromis nilotica*, *Labeobata*and *Labeorohita*. This reaffirms that methyl mercury undergoes biomagnification at higher trophic levels, and therefore predator species show higher concentration of mercury. However,a few anomalies also exist. In our study a few herbivorous species like *Liza parsia*werealso found to show high mercury values.

It is interesting to look at the distribution of fish species. The Table 4 shows the situation for Digha, Kakdwip and Budge Budge.Once again there is a predominance of carnivorous types, though perhaps a little les spronouncedthan that ofJharkhali.

Table 4 . Mercury and methyl mercury in sample species from Digha, Kakdwip and Budge Budge (Data Source: Toxic Link and DISHA)

Digha			**Kakdwip**			**Budge Budge**		
s scientific name	**hg (mg/ kg)**	**Mehg(mg/ kg)**	**Species scientific name**	**hg (mg/kg)**	**Mehg(mg/kg)**	**s scientific name**	**hg (mg/kg)**	**Mehg(mg/ kg)**
Otolithoides sp.	0.63	0.504	*Otolithoides sp.*	0.45	0.36	*Ompokpabda*	0.20	0.160
Otolithoides sp.	0.39	0.312	*Otolithoides sp.*	0.50	0.4	*Ompokpabda*	0.20	0.160
Apolectusniger	0.40	0.32	*laginopsispanijus*	0.42	0.336	*Sillagosihama*	0.37	0.296
Apolectusniger	0.42	0.336	*laginopsispanijus*	0.36	0.288	*Sillagosihama*	0.56	0.448
Pellona sp.	<0.20	<0.20	*ephaloussp.*	0.48	0.384	*Tenualosailisha*	0.70	0.560
Pellona sp.	<0.20	<0.20	*ephaloussp.*	0.69	0.552	*Tenualosailisha*	0.58	0.464
Devariodevario	0.60	0.48	*Arius sp.*	0.60	0.48	*Eleutheronematetradactylum*	0.56	0.448
Devariodevario	0.72	0.576	*Arius sp.*	0.58	0.464	*Eleutheronematetradactylum*	0.82	0.656
Sillagosihama	0.26	0.208	*Racondarussiliana*	0.83	0.664	*lydactylussexfilis*	0.69	0.552
Sillagosihama	0.24	0.192	*Racondarussiliana*	0.71	0.568	*lydactylussexfilis*	0.59	0.472
Liza parsia	0.26	0.208	*Setipinnaphasa*	0.96	0.768	*Harpadonnehereus*	0.45	0.360
Liza parsia	0.29	0.232	*Setipinnaphasa*	1.09	0.872	*Harpadonnehereus*	0.42	0.336
Portumuspelagius	0.50	0.4	*Devariodevario*	0.84	0.672	*Panna microdon*	0.61	0.488
Portumuspelagius	0.48	0.384	*Devariodevario*	0.96	0.768	*Panna microdon*	0.44	0.352
Eleutheronematetradactylum	1.14	0.912	*Liza parsia*	0.96	0.768	*Otolithoides sp.*	1.03	0.824
Eleutheronematetradactylum	1.10	0.88	*Liza parsia*	0.94	0.752	*Otolithoides sp.*	0.46	0.368
Penaeus sp.	1.39	0.556				*Nibea soldado*	0.83	0.664

Penaeus sp.	1.99	0.796				*Nibea soldado*	0.63	0.504
Trichuruslepturus	0.43	0.344						
Trichuruslepturus	<0.20	<0.20						

Table 5. Mercury and methylmercury in sample species from Kolaghat and Durgapur(Toxic Link and DISHA)

Kolaghat			**Durgapur**		
Speciesscientificname	**hg (mg/kg)**	**Mehg(mg/kg)**	**Species scientific name**	**hg (mg/ kg)**	**Mehg(mg/kg)**
Pangasius pangasius	0.41	0.328	*Wallagoniaattu*	0.25	0.2
Pangasius pangasius	0.22	0.176	*Wallagoniaattu*	0.21	0.168
Catlacatla	0.60	0.48	*Sperataaor*	<0.20	<0.20
Catlacatla	<0.20	<0.20	*Sperataaor*	0.22	0.176
Hypophthalmichthysmolitrix	<0.20	<0.20	*Ophisternonbengalense*	0.20	0.16
Hypophthalmichthysmolitrix	0.20	0.16	*Ophisternonbengalense*	0.21	0.168
Cirrhinuscirrhosus	0.27	0.216	*Cyprinus carpio*	<0.20	<0.20
Cirrhinuscirrhosus	<0.20	<0.20	*Cyprinus carpio*	<0.20	<0.20
Labeobata	0.24	0.192	*Eutropichthysvacha*	<0.20	<0.20
Labeobata	<0.20	<0.20	*Eutropichthysvacha*	0.20	0.16
Macrobrachiumrosenbergii	<0.20	<0.20			
Macrobrachiumrosenbergii	<0.20	<0.20			
Oreochromis nilotica	<0.20	<0.20			
Oreochromis nilotica	0.29	0.232			

In the case of Kolaghat, except for two species, all others were herbivorous or mostly herbivorous. But in the case of Durgapur, all varieties except Cyprinus carpio were carnivorous. Yet, the average mercury value for Durgapur is lower than that of Kolaghat .

The other possible factor for variation in mercury concentration in fish across species and locations can be its size and weight. Fish of greater body weight are likely to show higher levels of mercury bioconcentration. It is evident that neither the feeding habits of the species nor the weight of the catch is sufficient to explain the wide range of variation in mercury values across different sampling locations in general.

The other possible explanation may be in the character of the locations. The fish samples from Durgapur, which is a major industrial site, do not show high levels of mercury, whereas coastal/estuarine sites, often far removed from industrial areas, show high levels. The point is that mercury emitted from thermal power plants may not necessarily end up in the local water bodies. On the contrary, once in the air, mercury is dispersed and transported thousands of kilometre from its likely emission sources.[17]

On the other hand, Mercury used in industrial processes can get into water bodies only if it is discharged as waste with effluents.[18] This is precisely what happened in Minamata and Niigata.

The mean MeHg value for Hugli is considerably high given the fact samples were collected from a purely agricultural zone. A possible source of mercury may be pesticides used in the agricultural fields. Mercury is a known constituent of a large number of fungicides and rodenticides. The known inorganic mercury fungicides are mercurous chloride, mercuric chloride and mercuric oxide, while there are a host of organomercury fungicides.[19]

In order to locate the possible sources of the contamination, a detailed study of the areas is needed – one that investigates mercury concentration not only in the aquatic fauna, but also in the local water bodies.In fact, there are other questions that remain to be explored. When mercury is tested in aquatic fauna, the testing is done on uncooked samples. Yet, there is every likelihood of various changes during the process of cooking. What happens when mercury/ methylmercury contaminated fish is fried, roasted, boiled or curried? These aspects need to be investigated for fuller assessment of possible mercury intake from contaminated fish.

Table 6: Mercury concentration in some fishes available in Kolkata markets

Sl. No	Name of fish	Scientific name	Result	Catch point	Sale point
1	PangashTangra	Pangasius pangasius	0.08	Bantala	Muchipara market
2	Rui	Labeorohita	0.11	Bantala	Maniktala market
3	BagdaChingri	penaeus monodon	0.06	Bashirhat	Dum Dum Bazar
4	BagdaChingri	Penaeus monodon	0.06	Bashirhat	Dum Dum Bazar
5	Magur	Clariasbatrachus	0.08	Bashirhat	Dum Dum Bazar
6	Magur	Clariasbatrachus	0.08	Bashirhat	Dum Dum Bazar
7	Tangra	Mystusgulio	0.06	Bashirhat	AE Market(Saltlake)
8	Tangra	Mystusgulio	0.05	Bashirhat	Dum Dum Bazar
9	Tangra	Arius sp.	0.03	Bashirhat	Ashubabur Bazar
10	Tangra	Mystusgulio	0.04	Bashirhat	Baguihati Market
11	Tangra	Mystusgulio	0.05	Bashirhat	Dum Dum Bazar

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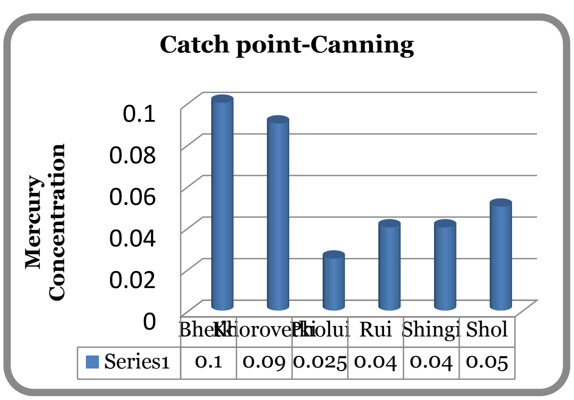
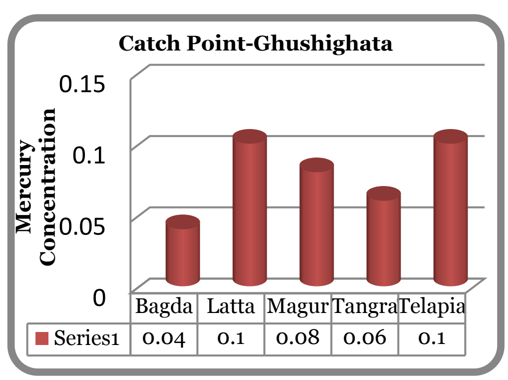
12	Telapia	Oreochromis nilotica	0.025	Bashirhat	Ashubabur Bazar
13	Telapia	Oreochromis nilotica	0.05	Bashirhat	Dum Dum Bazar
14	Telapia	Oreochromis nilotica	0.05	Bashirhat	Dum Dum Bazar
15	Vetki	Latescalcarifer	0.07	Bashirhat	Dum Dum Bazar
16	Vetki	Latescalcarifer	0.07	Bashirhat	Dum Dum Bazar
17	Latta	Harpadonnehereous	0.12	Birati	Ashubabur Bazar
18	Bhetki	Latescalcarifer	0.1	Canning	Ashubabur Bazar
19	Khorovetki	Latescalcarifer	0.09	Canning	Muchipara Bazar
20	Pholi	Notopterusnotopterus	0.025	Canning	Muchipara Bazar
21	Rui	Labeorohita	0.04	Canning	Muchipara Bazar
22	Shingi	Heteropneustesfossilis	0.04	Canning	AE Market(Saltlake)
23	Shol	Channasilondia	0.05	Canning	Muchipara Bazar
24	Bhola	Otolithoides sp.	0.05	Digha	AE Market(Saltlake)
25	Bagda	Penaeus monodon	0.04	Ghusighata	Ashubabur Bazar
26	Latta	Harpadonnehereous	0.1	Ghusighata	Ashubabur Bazar
27	Magur	Clariasbatrachus	0.08	Ghusighata	Ashubabur Bazar
Sl. No	**Name of fish**	**Scientific name**	**Result**	**Catch point**	**Sale point**
28	Tangra	Mystusgulio	0.06	Ghusighata	Ashubabur Bazar
29	Telapia	Oreochromis nilotica	0.1	Ghusighata	Ashubabur Bazar
30	Katla	Catlacatla	0.07	Haroa	Dum Dum Bazar
31	Koi	Anabustestudineus	0.05	Haroa	Narayanpur Bazar
32	Parshe	Liza parsia	0.06	Haroa	Dum-Dum bazar
33	Parshe	Liza parsia	0.06	Haroa	Dum-Dum bazar
34	Tangra	Mystusgulio	0.06	Haroa	Dum Dum Bazar
35	Telapia	Oreochromis nilotica	0.1	Haroa	Dum Dum Bazar
36	Koi	Anabustestudineus	0.08	Hasnabad	Dum Dum Bazar
37	Koi	Anabustestudineus	0.08	Hasnabad	Dum Dum Bazar
38	Parshe	Liza parsia	0.06	Hasnabad	Dum Dum Bazar
39	Parshe	Liza parsia	0.06	Hasnabad	Dum Dum Bazar
40	Shingi	Heteropneustesfossillis	0.04	Hasnabad	Dum Dum Bazar

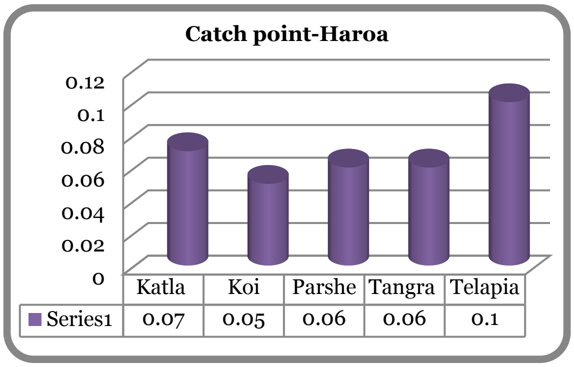
41	Shingi	Heteropneustesfossillis	0.04	Hasnabad	Dum Dum Bazar
42	Koi	Anabustestudineus	0.025	Jainagar	Baguihati Market
43	koi	Anabustestudineus	0.025	Jainagar	Maniktala Market
44	Magur	Clariasbatrachus	0.03	Jainagar	Maniktala Market
45	Shingi	Heteropneustesfossillis	0.09	Jainagar	Baguihati Market
46	Shol	Channasilondia	0.025	Jainagar	Maniktala Market
47	Bata	Labeobata	0.06	Kharibari	Baguihati Market
48	Bata	Labeobata	0.11	Kharibari	Baguihati Market
49	Bata	Labeobata	0.09	Kharibari	Dum Dum Bazar
50	Bata	Labeobata	0.09	Kharibari	Dum-Dum bazar
51	Bhetki	Latescalcarifer	0.04	Kharibari	Narayanpur Bazar
52	Katla	Catlacatla	0.06	Kharibari	Baguihati Market
53	Katla	Catlacatla	0.08	Kharibari	Dum Dum Bazar
54	katla	Catlacatla	0.08	Kharibari	Dum Dum Bazar
55	kholse	colisafasciata	0.025	Kharibari	Baguihati Market
56	Latta	Harpadonnehereous	0.025	Kharibari	Muchipara Bazar
57	Lilentika	Oreochromis nilotica	0.11	Kharibari	Baguihati Market
58	Lilentika	Oreoghromisnilotica	0.15	Kharibari	Baguihati Market
59	Mrigel	Chirrhinuscirrhosus	0.15	Kharibari	Baguihati Market
60	Parshe	Liza parsia	0.06	Kharibari	Dum-Dum
61	Parshe	Liza parsia	0.06	Kharibari	Dum-Dum bazar
62	Parshe	Liza parsia	0.025	Kharibari	Narayanpur Bazar
63	Rui	Labeorohita	0.05	Kharibari	Ashubadur Bazar
64	Rui	Labeorohita	0.03	Kharibari	Dum Dum Bazar
65	Rui	Labeorohita	0.03	Kharibari	Dum-Dum
66	Sarpnuti	Puntius sarana	0.09	Kharibari	Muchipara Bazar
67	Tangra	Mystusgulio	0.06	Kharibari	Baguihati Market
68	Tangra	Mystusgulio	0.48	Kharibari	Narayanpur Bazar
69	Telapia	Oreochromis nilotica	0.05	Kharibari	Dum Dum Bazar
70	Telapia	Oreochromis nilotica	0.05	Kharibari	Dum-Dum
71	Telapia	Oreochromis nilotica	0.12	Kharibari	Narayanpur Bazar

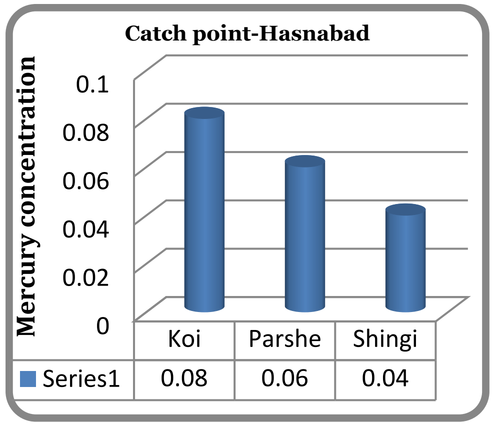
72	Vetki	Latescalcarifer	0.13	Kharibari	Baguihati Market
73	Lilentika	Oreochromis nilotica	0.18	Lowhati	Baguihati Market
74	Mrigel	Chirrhinuscirrhosus	0.18	Lowhati	Baguihati Market
75	Rui	Labeorohita	0.025	Lowhati	Baguihati Market
76	Telapia	Oreochromis nilotica	0.08	Malancha	Dum-Dum
77	Telapia	Oreochromis nilotica	0.08	Malancha	Dum-Dum
78	Vetki	Latescalcarifer	0.06	Malancha	Dum-Dum
79	Vetki	Latescalcarifer	0.06	Malancha	Dum-Dum
80	Magur	Clariasbatrachus	0.08	Mednipur	Ashubadur Bazar
81	sole	Channasilondia	0.05	Mednipur	Ashubadur Bazar
82	Katla	Catlacatla	0.06	Nalban	Maniktala Market
83	Telapia	Oreochromis nilotica	0.07	Nalban	Maniktala market
84	Bhola	Otolithoides sp.	0.06	paradip	Ashubadur Bazar
85	Parsha	Liza parsia	0.04	paradip	Ashubadur Bazar
86	Bele	Platycephalous sp.	0.11	Rajarhat	Rajarhat
87	Mrigel	Cirrhinuscirrhosus	0.11	Rajarhat	Baguihati Market
88	Pabda	Ompokpabda	0.025	Rajarhat	Baguihati Market
89	Sharputi	Puntius sarana	0.1	Rajarhat	Baguihati Market
90	Katla	Catlacatla	0.06	Rajarhat	Narayanpur Bazar
91	Rui	Labeorohita	0.08	Rajarhat	Narayanpur Bazar

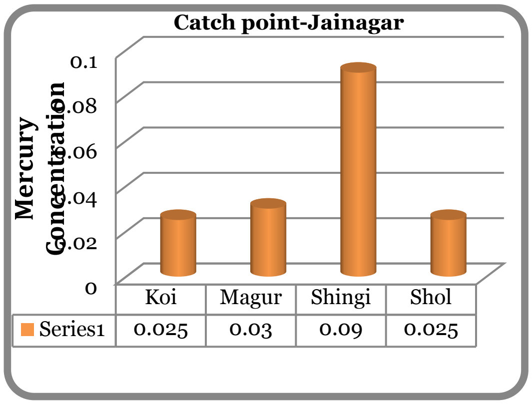
Graphs(Set1): Comparison drawn on different species from same geo- location water body

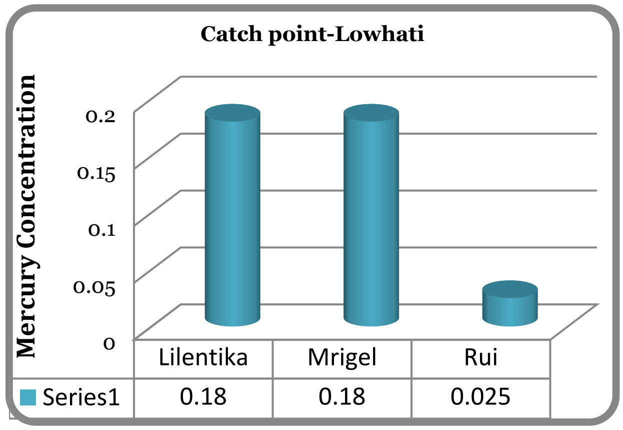












Brief Account of Industrial Belt Locations and Fishing Locations of West Bengal

Durgapur Asansol Region

This is the most important heavy industry region in the state. The western part of the districtis dry and has a large number of industries and mines;agriculture dominates in the eastern part.

Steel plants and coal miningare the most important features of this region. Apart from DPL thermal power plant of 395MW there are several captive powe rgenerating stations. Many heavy industries are situated near the river Damodor. There is also a barrage on Damodor connecting Bardhaman with Bankura district.

Hugli

Hugli districtis adjacent to Kolkata. Eastern part of the district, lying on the western side of the Hooghly river,is under Kolkata Metropolitan Area. A large number of industries are situated in the district, mostly by the side of the river.The eastern part of the district,which has wonderfully richalluvial deposits as well as excellent irrigation facilities, is famous for

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al fertilizers and pesticides are used.

Kolaghat

Kolaghat is in East Midnapore district ,adjacent to western border of Howrah dis trict. It is on the bank of Rupnarayan River, which is the border line of Howrah andEast Midnapore district. Kolaghat has 1260 MW thermal powerplant.

Kolkata

Kolkata is one of the most densely populated cities in the world. Once the capital of India, it is one of the earliest industrial hubs in Asia. A large number of heavy, medium and small industries are situated in and around the city.

EastKolkataWetland(EKW):

It is situated in the eastern side of the city ,where the city sewage flows into Bidyadhari river. The area has a large number of sewage fed ponds. These ponds also act as settling tanks.

BudgeBudge

It is an industrial hub adjacent to southern Kolkata by the side of the Hooghly river. The area has several oil depots of different companies and a thermal power plant of 500 MW are capacity.

Haldia

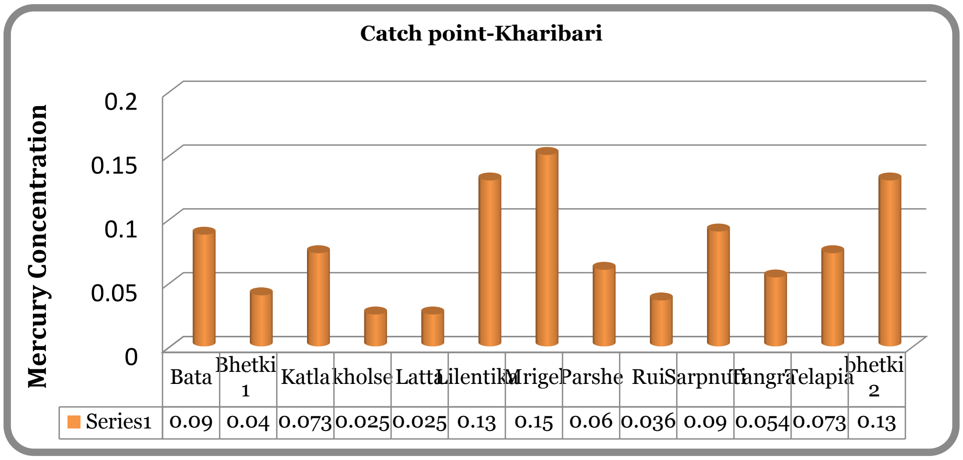
Haldia is an industrial port town in EastMidnapore district. It is situated on the western bank of Hooghly river,where the latter meets the Haldi river. The town has a number of petro-chemical, chemical, oil refinery units.

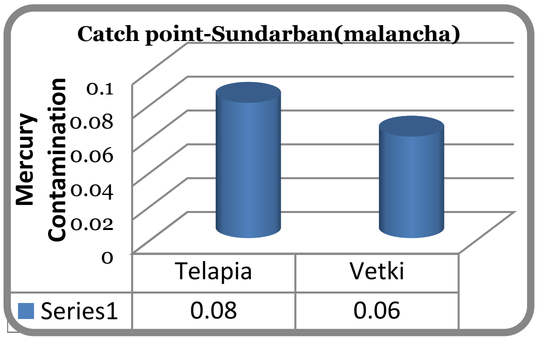
Kakdwip

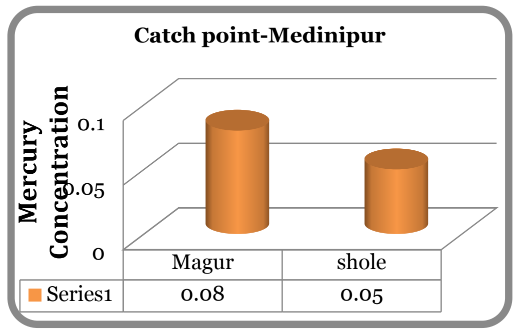
Kakdwip is situated on the eastern bank of the Hooghly estuary and is almost on the Bay of Bengal. The area is in South 24 Parganas district, one of the gateways to the Sundarban. There is no big industry. Agriculture and fishing are the main occupations.

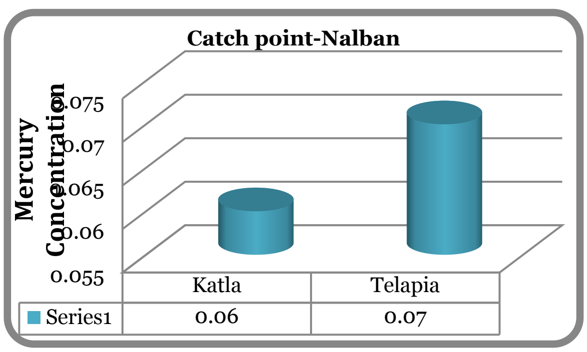
Digha

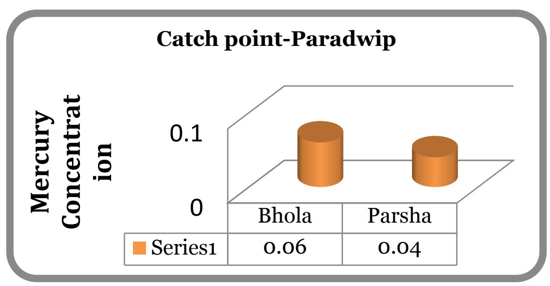
Digha is the most important sea resort of West Bengal,situated in East Midnapore district, adjacent to Orissa border. It has a fishing harbour.

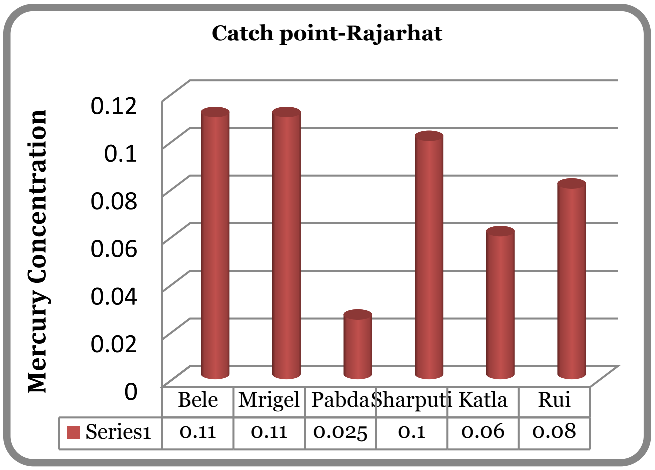

Catch point-Kharibari
Mercury Concentration
0.2
0.15
0.1
0.05
0
Bata
Bhetki 1
Katla
kholse
Latta
Lilentika
Mrige
Parshe
Rui
Sarpnuti
Tangra
Telapia
bhetki 2
Series1
0.09
0.04
0.073
0.025
0.025
0.13
0.15
0.06
0.036
0.09
0.054
0.073
0.13

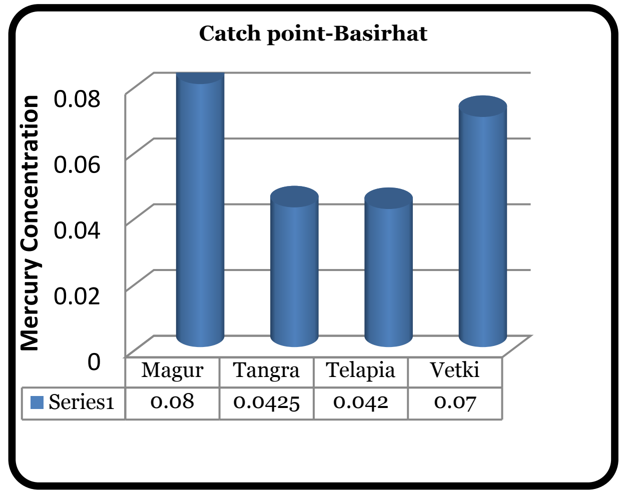

Catch point-Sundarban(malancha)
Mercury Contamination
0.1
0.08
0.06
0.04
0.02
0
Telapia
Vetki
Series1
0.08
0.06


Catch point-Medinipur
Mercury Concentration
0.1
0.05
0
Magur
shole
Series1
0.08
0.05


Catch point-Nalban
Mercury Concentration
0.075
0.07
0.065
0.06
0.055
Katla
Telapia
Series1
0.06
0.07


Catch point-Paradwip
Mercury Concentrat ion
0.1
0
Bhola
Parsha
Series1
0.06
0.04


Catch point-Rajarhat
Mercury Concentration
0.12
0.1
0.08
0.06
0.04
0.02
0
Bele
Mrigel
Pabda
Sharputi
Katla
Rui
Series1
0.11
0.11
0.025
0.1
0.06
0.08


Catch point-Basirhat
Mercury Concentration
0.08
0.06
0.04
0.02
0
Magur
Tangra
Telapia
Vetki
Series1
0.08
0.0425
0.042
0.07

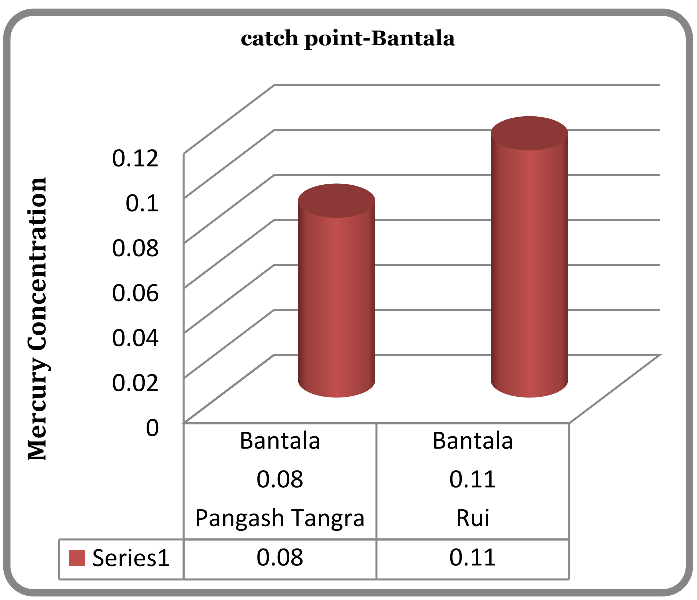

catch point-Bantala
Mercury Concentration
0.12
0.1
0.08
0.06
0.04
0.02
0
Bantala 0.08 Pangash Tangra
Bantala 0.11 Rui
Series1
0.08
0.11

Table7:ComparativeTable of mercury concentrationdepending on catchpoint				
Code No.	**Name of fish**	**Result**	**Catch point**	**Average**
24	BagdaChingri	0.04	Ghusighata	
5	BagdaChingri	0.06	Bashirhat	
10	BagdaChingri	0.06	Bashirhat	
				0.053
47	Bata	0.06	Kharibari	
48	Bata	0.11	Kharibari	
49	Bata	0.09	Kharibari	
50	Bata	0.09	Kharibari	
				0.0875
18	Bhetki	0.1	Canning	
51	Bhetki	0.04	Kharibari	
				0.07
23	Bhola	0.05	Digha	
85	Bhola	0.06	Paradip	
				0.055
52	Katla	0.06	Kharibari	
53	Katla	0.08	Kharibari	
54	katla	0.08	Kharibari	
82	Katla	0.06	Nalban	
90	Katla	0.06	Rajarhat	
29	Katla	0.07	Haroa	
				0.06833
34	Koi	0.05	Harowa	
35	Koi	0.08	Hasnabad	
36	Koi	0.08	Hasnabad	
41	Koi	0.025	Jainagar	
42	koi	0.025	Jainagar	
				0.052

17	Latta	0.12	Birati	
25	Latta	0.1	Ghusighata	
56	Latta	0.025	Kharibari	
				0.081
57	Nylontikka	0.11	Kharibari	
58	Nylontikka	0.15	Kharibari	
73	Nylontikka	0.18	Lowhati	
				0.147
6	Magur	0.08	Bashirhat	
26	Magur	0.08	Ghusighata	
43	Magur	0.03	Jainagar	
80	Magur	0.08	Mednipur	
11	Magur	0.08	Bashirhat	
				0.07
59	Mrigel	0.15	Kharibari	
74	Mrigel	0.18	Lowhati	
88	Mrigel	0.11	Rajarhat	
				0.147
86	Parshe	0.04	paradip	
30	Parshe	0.06	Haroa	
31	Parshe	0.06	Haroa	
37	Parshe	0.06	Hasnabad	
38	Parshe	0.06	Hasnabad	
60	Parshe	0.06	Kharibari	
61	Parshe	0.06	Kharibari	
62	Parshe	0.025	Kharibari	
				0.053
2	Rui	0.11	Bantala	
21	Rui	0.04	Canning	
63	Rui	0.05	Kharibari	
64	Rui	0.03	Kharibari	

65	Rui	0.03	Kharibari	
75	Rui	0.025	Lowhati	
91	Rui	0.08	Rajarhat	
				0.05214
66	Sarpunti	0.09	Kharibari	
83	Sarpunti	0.1	Newtown	
				0.095
39	Shingi	0.04	Hasnabad	
40	Shingi	0.04	Hasnabad	
44	Shingi	0.09	Jainagar	
46	Shingi	0.04	canning	
				0.0525
22	Shol	0.05	Canning	
45	Shol	0.025	Jainagar	
81	Shol	0.05	Mednipur	
				0.042
3	Tangra	0.06	Bashirhat	
7	Tangra	0.05	Bashirhat	
12	Tangra	0.03	Bashirhat	
13	Tangra	0.04	Bashirhat	
27	Tangra	0.06	Ghusighata	
67	Tangra	0.06	Kharibari	
68	Tangra	0.048	Kharibari	
14	Tangra	0.05	Bashirhat	
32	Tangra	0.06	Haroa	
				0.05
4	Telapia	0.025	Bashirhat	
8	Telapia	0.05	Bashirhat	
15	Telapia	0.05	Bashirhat	
28	Telapia	0.1	Ghusighata	
33	Telapia	0.1	Haroa	

69	Telapia	0.05	Kharibari	
70	Telapia	0.05	Kharibari	
71	Telapia	0.12	Kharibari	
76	Telapia	0.08	Malancha	
77	Telapia	0.08	Malancha	
84	Telapia	0.07	Nalban	
				0.07
9	Vetki	0.07	Bashirhat	
16	Vetki	0.07	Bashirhat	
72	Vetki	0.13	Kharibari	
78	Vetki	0.06	Malancha	
79	Vetki	0.06	Malancha	
18	Vetki	0.1	canning	
51	Vetki	0.04	Kharibari	
				0.075
87	Bele	0.11	Rajarhat	
55	kholse	0.025	Kharibari	
19	Khorovetki	0.09	Canning	
89	Pabda	0.025	Rajarhat	
1	PangashTangra	0.08	Bantala	
20	Pholoi	0.025	Canning	

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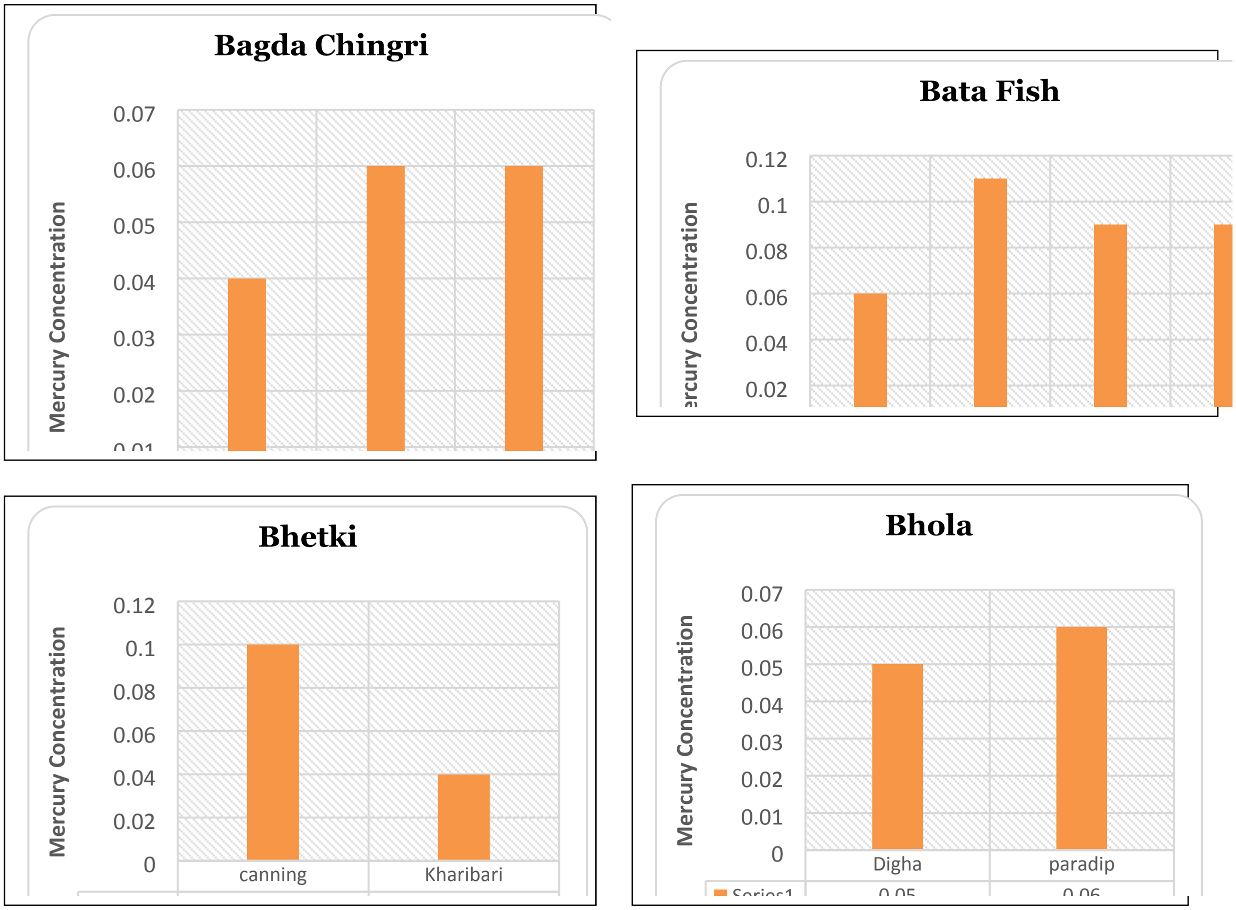
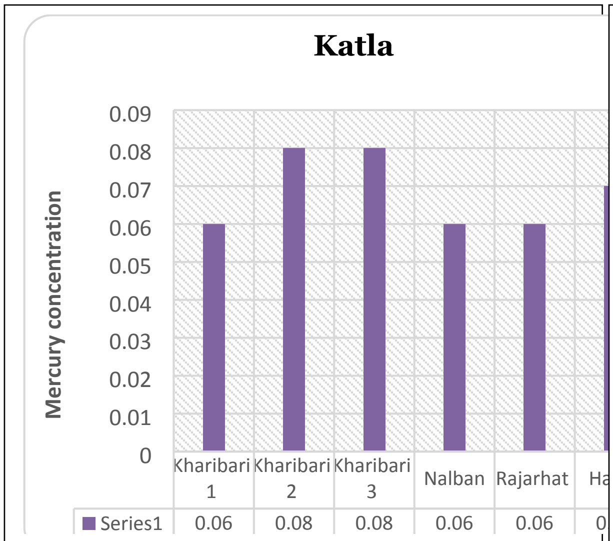
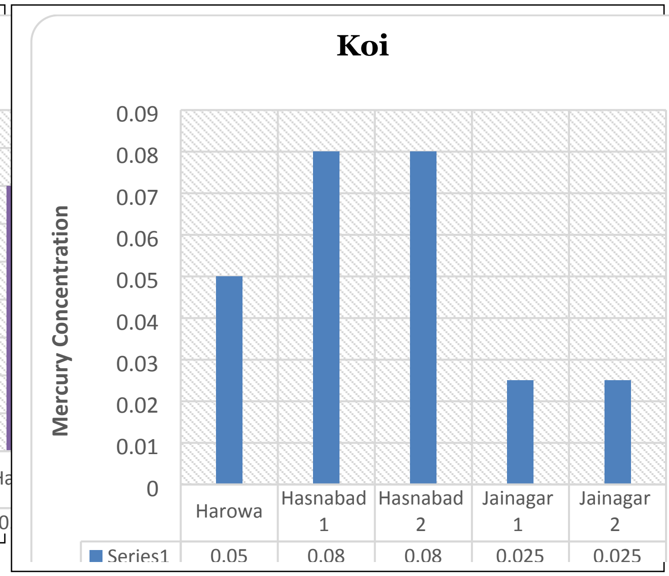
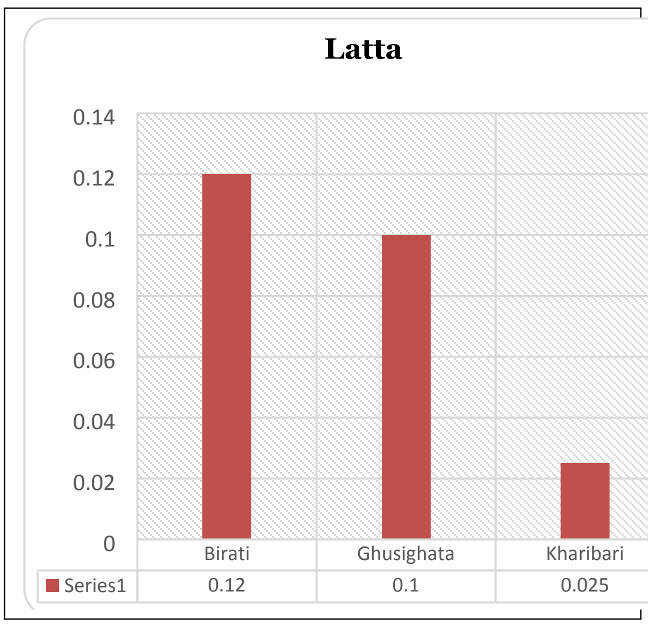
Graph (Set2): Comparison of same fish species from different waterbody




Katla
Mercury concentration
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Kharibari 1
Kharibari 2
Kharibari 3
Nalban
Rajarhat
Series1
0.06
0.08
0.08
0.06
0.06


Koi
Mercury Concentration
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Harowa
Hasnabad 1
Hasnabad 2
Jainagar 1
Jainagar 2
Series1
0.05
0.08
0.08
0.025
0.025


Latta
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Ghusighata
Kharibari
Series1
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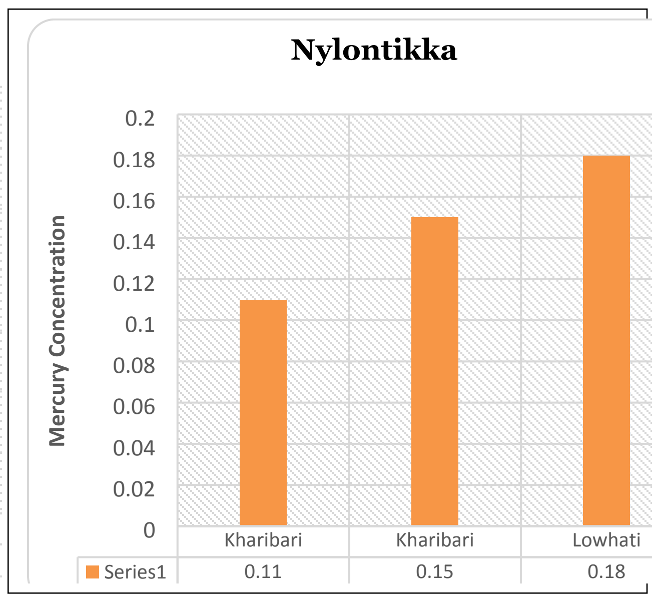
0.1
0.025


Nylontikka
Mercury Concentration
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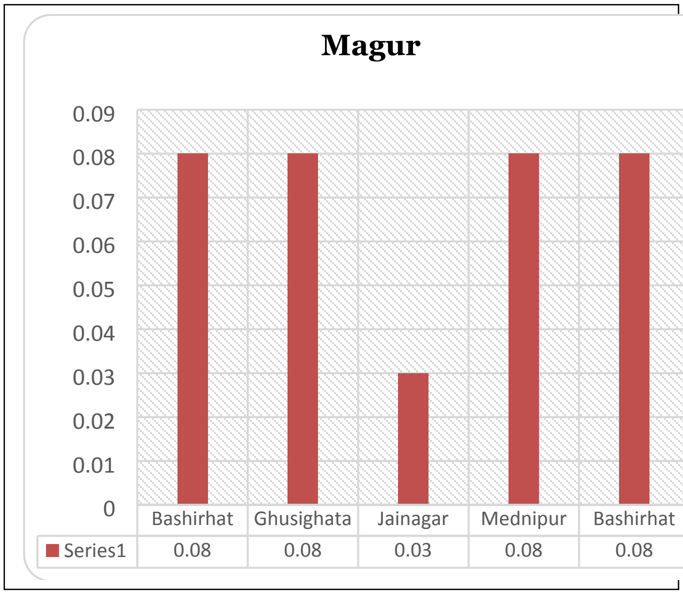
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Kharibari
Kharibari
Lowhati
Series1
0.11
0.15
0.18


Magur
0.09
0.08
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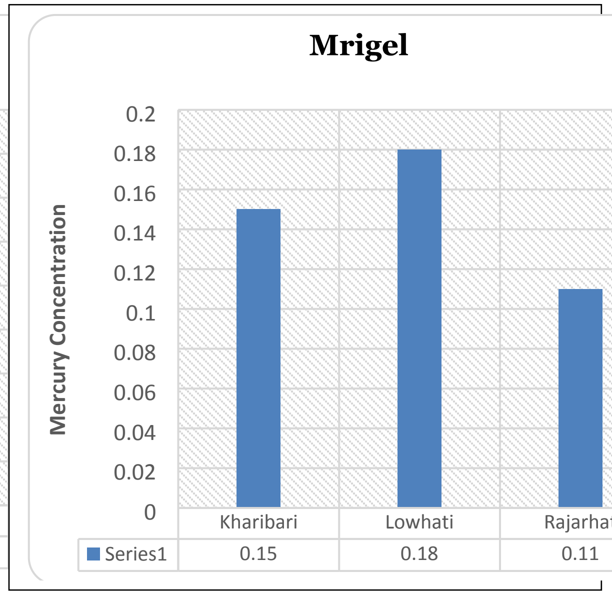
Ghusighata
Jainagar
Mednipur
Bashirhat
Series1
0.08
0.08
0.03
0.08
0.08


Mrigel
Mercury Concentration
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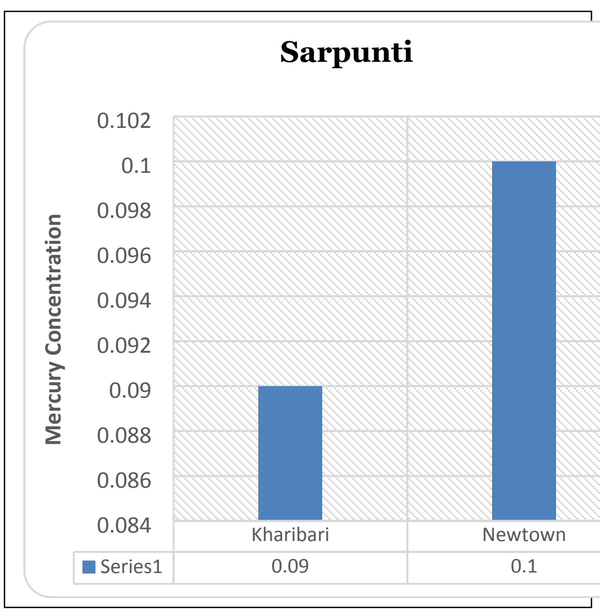
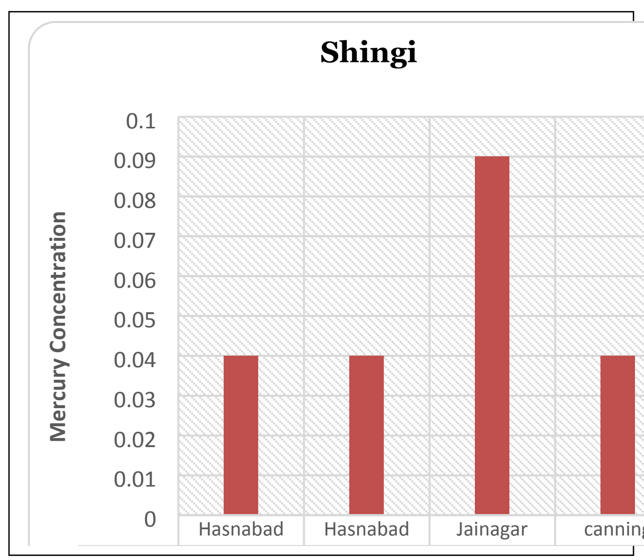
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Kharibari
Lowhati
Rajarhat
Series1
0.15
0.18
0.11


Sarpunti
Mercury Concentration
0.102
0.1
0.098
0.096
0.094
0.092
0.09
0.088
0.086
0.084
Kharibari
Newtown
Series1
0.09
0.1


Shingi
Mercury Concentration
0.1
0.09
0.08
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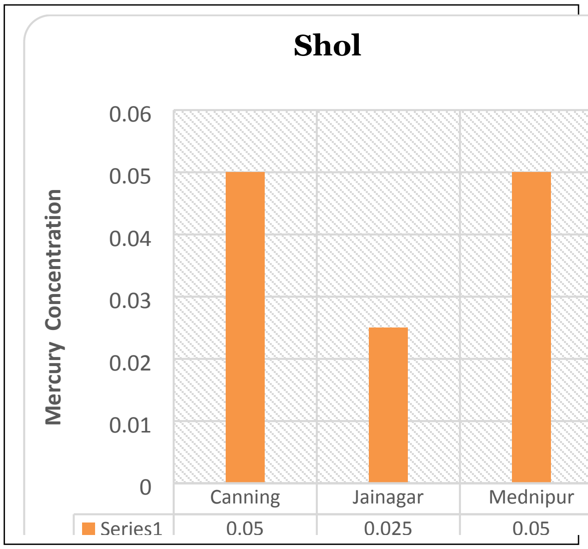
0.06
0.05
0.04
0.03
0.02
0.01
0
Hasnabad
Hasnabad
Jainagar


Shol
Mercury Concentration
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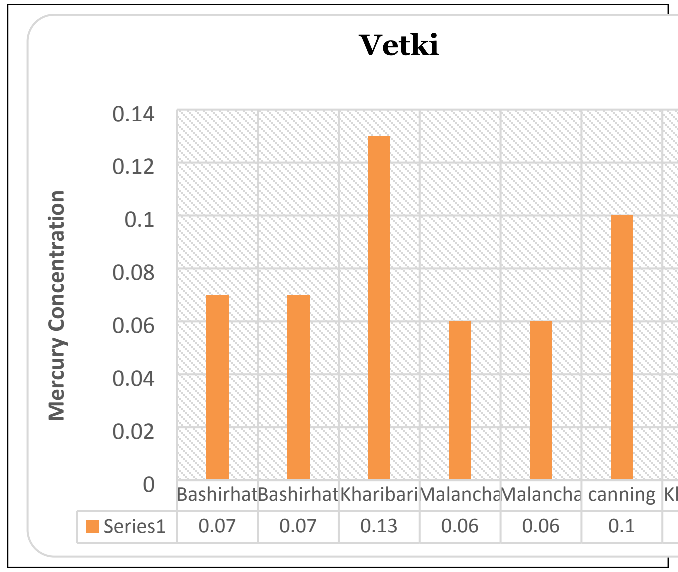
0.05
0.04
0.03
0.02
0.01
0
Canning
Jainagar
Mednipur
Series1
0.05
0.025
0.05


Vetki
Mercury Concentration
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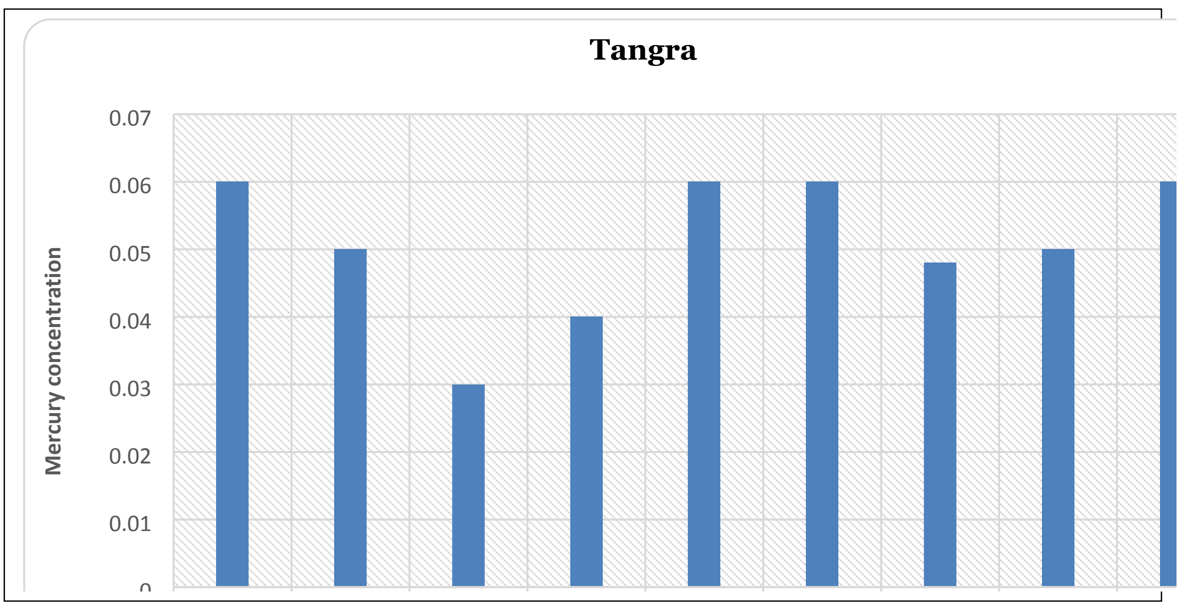
0.12
0.1
0.08
0.06
0.04
0.02
0
Bashirhat
Bashirhat
Kharibari
Malancha
Malancha
canning
Series1
0.07
0.07
0.13
0.06
0.06
0.1


Tangra
Mercury concentration
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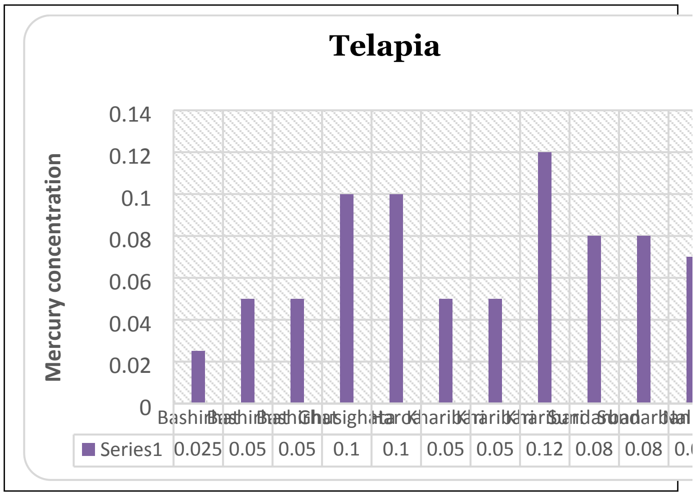
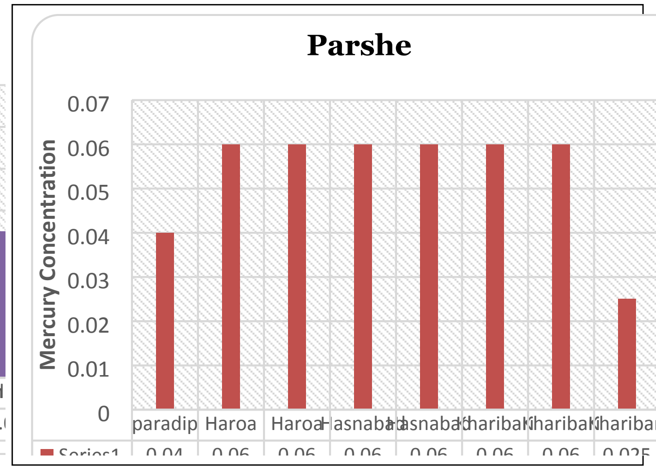
0.03
0.02
0.01


Telapia
Mercury concentration
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Series1 0.025 0.05 0.05 0.1 0.1 0.05 0.05 0.12 0.08 0.08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Mercury Concentration
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0.04
0.03
0.02
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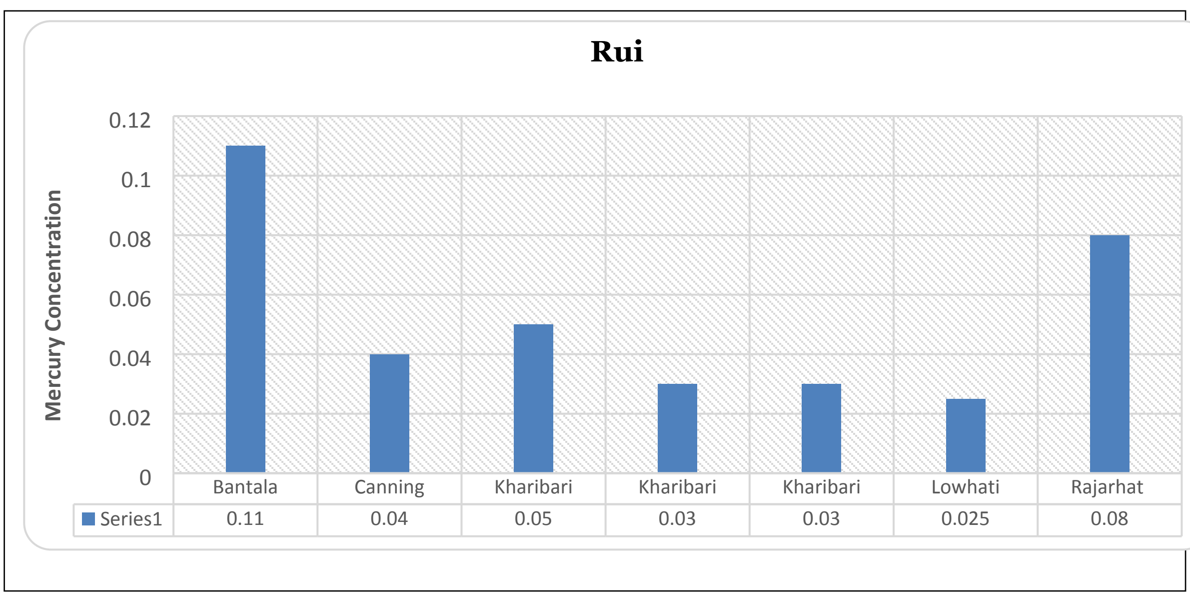
0
paradip
Haroa
Haroa


Rui
Mercury Concentration
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0.1
0.08
0.06
0.04
0.02
0
Bantala
Canning
Kharibari
Kharibari
Kharibari
Lowhati
Rajarhat
Series1
0.11
0.04
0.05
0.03
0.03
0.025
0.08

Table 8: Average Mercury Concentration		
Sr. No	**Type**	**Concentration of Mercury mg/kg**
1	Kholse	0.025
2	Pabda	0.025
3	Pholoi	0.025
4	Shol	0.04
5	Tangra	0.05
6	Koi	0.052
7	Rui	0.052
8	BagdaChingri	0.053
9	Parshe	0.053
10	Bhola	0.055
11	Katla	0.0683
12	Magur	0.07
13	Telapia	0.0704
14	Vetki	0.075
15	PangashTangra	0.08
16	Latta	0.081
17	Bata	0.0875
18	Khorovetki	0.09
19	Sarpunti	0.095
20	Nylontikka	0.147
21	Mrigel	0.147

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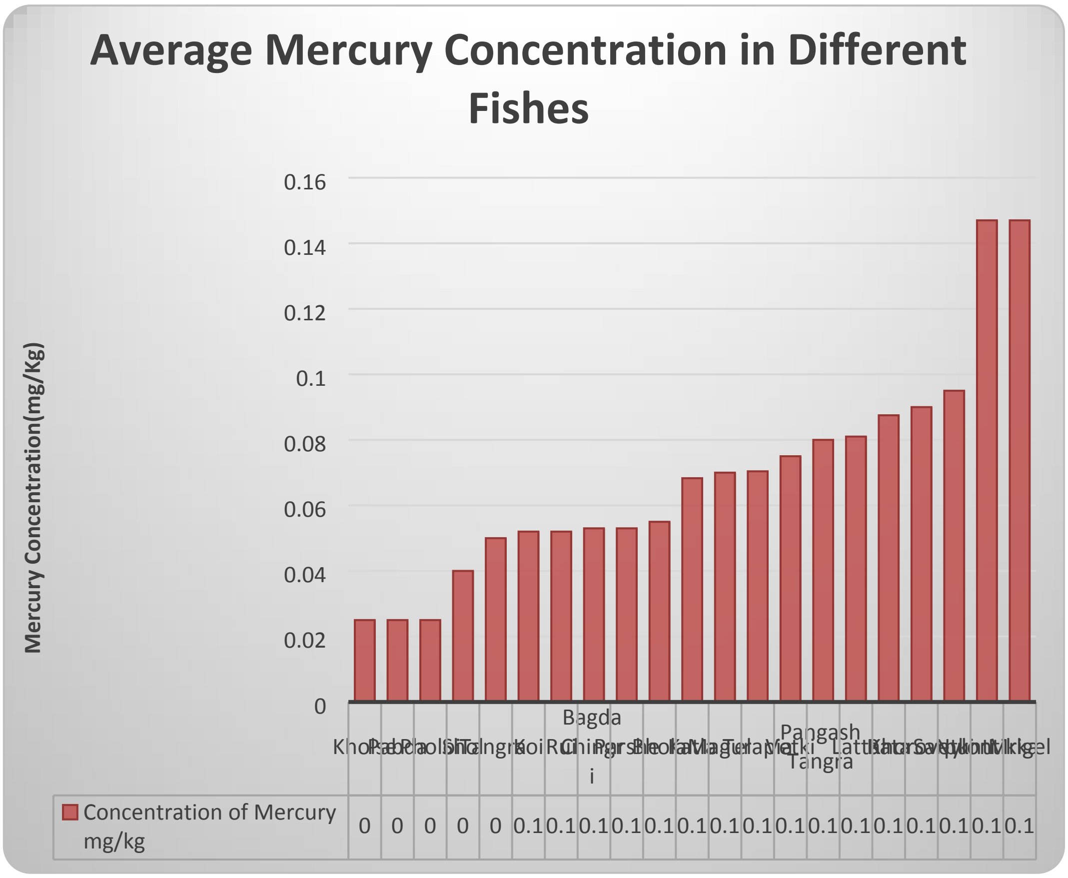

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Conclusion

That fish in kolkata have significant, and often alarming, levels of mercury contamination is evident from this study. Both the government and civil society should wake up to this problem. The Health and Environment Departments of the government should undertake a thorough investigation of the scale, intensity and sources of mercury pollution.

Not only fish, but water and soil samples as also blood and hair samples of the population need to be tested to judge the levels of contamination.

- Immediate release of advisories on fish consumption guiding citizens about relatively safe/unsafe fish species and sources.
- The scientific community should independently and in collaboration with the government, undertake such investigation.
- Once the sources of pollution are identified, efforts must be made to bring mercury pollution down to safe levels.
- Mercury and other pollutants of similar severity should be come an important item in civil society initiatives.
- Medical practitioners should include pollutant-induced pathology as a key item in their diagnostic and therapeutic procedures.

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