Assessment of Heavy Metals in Water and the Fish Organs in River Ganga at Kanpur

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Abstract

Heavy metal accumulation in aquatic ecosystems signifies environmental pollution from industrial waste, agricultural runoff and sewage. In Kanpur, waste from the leather and textile industries contaminates the Ganga River, harming aquatic life, particularly fish. While some heavy metals are essential in small amounts, excessive levels pose health risks to fish and bioaccumulate in the food chain, impacting human health. This study investigated the heavy metals at the study site of the river Ganga and the accumulation of heavy metals like As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Tl and Zn in the body organs of fish (Labeo rohita), such as gills, intestine, liver and kidney. Samples were analysed for heavy metal accumulation across the summer, winter and monsoon seasons through ICP-OES (Inductively Coupled Plasma-Emission Spectroscopy). River water showed high amount of As, Cd, Co, Cr, Pb and Tl.

The study reveals that fish accumulates chromium, cadmium, cobalt, nickel and lead in higher concentrations than the other heavy metals. Higher accumulation is observed in fishes analysed in the summer season and the lowest accumulation is observed in the monsoon season. Heavy metals accumulate in higher concentrations in the kidneys and liver, possibly because these organs detoxify the metals from the body and storage. Elevated levels of Cr, Co, Cd, Ni and Pb in fish organs highlight significant heavy metal contamination in the Ganga River, despite water treatment efforts. This emphasizes the necessity for seasonal monitoring to mitigate harmful effects on aquatic life and human health.

Keywords: Heavy metals, pollutants, *Labeo rohita*, summer season, winter season, monsoon season.

Introduction

Rivers are India's lifeline[12] and the whole world is dependent on the river system for its water needs. Rivers are a source of water and food due to water requirements in agriculture[18]. The flora and fauna present in this water body are very useful for inhabitants living near the bank of a river and they are important for the economy as well. Heavy metals are generally defined as metals with relatively high densities, atomic weight, or atomic numbers[14]. These heavy metals are required in our bodies in very trace amounts[7]. However, if these heavy metals are present in our body in excess amounts, they will interfere with the daily functions of our body organs. In recent years, India has seen substantial growth across various sectors, particularly in urbanization, industrialization, and the development of infrastructure like road construction[10]. However, this rapid advancement comes with its share of challenges. While the benefits of progress are evident, there has also been a notable rise in pollution levels. This situation underscores the urgent need to find a balance between development and environmental sustainability, as every step forward carries both advantages and downsides.

In India, where the rivers, mountains, animals and trees are worshipped, the river Ganga holds a significant place, but nowadays, it is subjected to challenges like pollution from agricultural runoff, domestic sewage and industrial discharges[1]. Amidst the pollutants, heavy metals pose significant environmental challenges because of their non-biodegradable nature. Kanpur is well known for its textile, tannery and chemical industries. These heavy metals enter the aquatic environment through improper discharge from these anthropogenic activities[6,17,19].

Fish, as an integral part of the river ecosystem, is highly susceptible to the bioaccumulation of these heavy metals in their tissues. Heavy metals accumulate in the different body organs of fish at varying concentrations depending upon the water quality, bioavailability[16] of metals and the fish species. Furthermore, consuming these contaminated fish has serious health risks to humans. Fish is an essential part of people's diet worldwide, and most people who live along the banks of rivers rely on fish for their dietary needs. Annually, the rate of fish consumption is 5-6 kg in India for the general population and the consumption for regular ones is 8-9 kg. Around 50% of the global consumption is of fish in the world[13]. These heavy metals lead to neurological, reproductive and developmental diseases. Ganga river provides many fish for the residents relying on it. Rohu is abundantly present in the river.

Labeo rohita, commonly known as Rohu in the local or regional language, is a herbivore, column feeder and edible freshwater fish. It is rich in vitamins and omega-3 fatty acids[21]. It is among the three major Indian carp belonging to the Cyprinidae family. Despite the efforts of the Central and State Governments to remediate these water bodies, the Ganga river has a high concentration of heavy metals, particularly in the Kanpur region, where heavy metal pollution is higher than the standards.

This study evaluates the accumulation of heavy metals in different organs of fish collected from the Ganga river in the Kanpur industrial area at seasonal levels.

Material and Methods

Water: We collected three sets of water samples every two months in winter, summer and monsoon from specific location at Siddha Nath Ghat (Jajmau) along the Ganges river. The samples were taken from a depth of 1-2 feet and preserved in plastic bottles treated with HNO_3. We added 1 ml of concentrated HNO_3 solution to each litre of water sample. After collection, the samples were stored in an ice box and transported to the laboratory.

The water samples from each site were mixed during acid digestion, representing a pooled sample. The pooled samples of water were digested and analyzed for heavy metals. Heavy metals were analyzed in water according to the procedure described in APHA[2]. A 100 ml water sample was digested with 5 ml concentrated HNO_3. Digested samples were filtered by Whatmann no. 42 and diluted to 50 ml with 0.1 N HNO_3. Heavy metals were analyzed at specific wavelengths by inductively coupled plasma-optical emission spectroscopy (ICP-OES: Perkin Elmer 7300 DV).

Evaluation of Heavy Metal Accumulation in Fish Body Organ

Fish Collection: For this study, *Labeo rohita* fish were used. With the help of local fishermen, they were collected from the Ganga Ghat near the industrial area of Jajmau and brought to the laboratory at a controlled temperature. The fish were collected in three seasons, summer, winter and monsoon, to analyse heavy metal accumulation. The length and weight of the fish were recorded in the laboratory before the dissection. Six fish were taken and analysed for heavy metal accumulation each season.

1gm of each gill, intestine, heart, liver and kidney tissue sample was homogenized using a plastic pestle homogenizer and 2:1 V/V 10 ml mixture of nitric acid and perchloric acid was added to those tissue samples. Tissue samples were digested on the hot plate at 120° C until the solution became transparent and fumes arose. Digested samples were diluted to make up the final volume of 50 ml with HNO_3 (0.1N), filtered using Whatmann filter paper and analyzed through ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy).

Calculation

$$\text{Concentration of Heavy Metal in Fish } \left(\frac{\text{mg}}{\text{Kg}}\right) = \frac{(\text{ICP} - \text{OES Reading} \times \text{Digested Sample})}{\text{Sample Weight}}$$

Results and Discussion

Heavy metal accumulation in the aquatic ecosystem is a crucial measure of the impact of environmental pollutants. Heavy metals are introduced into the rivers through anthropogenic activities like industrial waste disposal, agricultural runoff and sewage disposal. Since Kanpur is a hub for the leather industry and textile manufacturing, improper waste disposal is concerning, because it goes into the waterbodies and, ultimately, into the River Ganga. This waste contains chemicals used in making textiles and leather, which are major contributors to the Ganga River's heavy metals. These heavy metals, through water, accumulate in the flora and fauna found in the water body. Since fish are a vital part of that ecosystem, they cannot escape its harmful effects.

Although some heavy metals are essential for the proper functioning of the body system, their presence above limits can cause serious health problems in fish and eventually bioaccumulate in the food chain, posing a risk to human health. River water showed a high amount of As, Cd, Co, Cr, Pb and Tl (Table 1). The pollution issues are alarming as the heavy metals from water move to other trophic levels through agriculture and fishery. The concentration of heavy metals is higher in the summer season and lower in the monsoon season. This study analysed six fish from each season for heavy metal accumulation in their organs: the gill, intestine, liver and kidney. Tables 2, 3, 4 and 5 give the average of the accumulated concentration in the organs.

Table 1
Heavy Metal Concentration in Ganga River at Jajmau

HM	Summer	Winter	Monsoon
As	0.071	0.043	0.031
Cd	0.102	0.078	0.048
Co	0.32	0.082	0.055
Cr	0.724	0.381	0.211
Cu	0.125	0.085	0.066
Mn	0.1	0.091	0.05
Ni	0.2	0.082	0.064
Pb	0.088	0.054	0.032
Tl	-0.008	0.014	0.005
Zn	0.25	0.13	0.093

Table 2
Heavy metal accumulation in gills

Gills			
HM	**Summer**	**Winter**	**Monsoon**
As	0.037	0.028	0.021
Cd	0.027	0.021	0.012
Co	0.016	0.011	0.009
Cr	0.042	0.032	0.024
Cu	0.039	0.043	0.028
Mn	0.081	0.077	0.051
Ni	0.028	0.01	-0.016
Pb	0.033	0.007	0.001
Tl	0.001	-0.003	-0.008
Zn	0.067	0.05	0.029

Table 3
Heavy metal accumulation in intestine

Intestine			
HM	**Summer**	**Winter**	**Monsoon**
As	0.021	0.018	0.013
Cd	0.014	0.009	0.01
Co	0.012	-0.008	-0.01
Cr	0.048	0.034	0.021
Cu	0.06	0.052	0.033
Mn	0.072	0.062	0.046
Ni	0.022	0.021	0.018
Pb	0.037	0.031	0.01
Tl	-0.007	-0.016	0
Zn	0.07	0.044	0.028

Table 4
Heavy Metal Accumulation in Liver

Liver			
HM	**Summer**	**Winter**	**Monsoon**
As	0.032	0.018	0.002
Cd	0.028	0.022	0.014
Co	0.014	-0.011	0
Cr	0.063	0.058	0.035
Cu	0.044	0.031	0.018
Mn	0.083	0.071	0.034
Ni	0.031	0.01	0.009
Pb	0.058	0.03	0.014
Tl	0.010	0.009	-0.009
Zn	0.088	0.078	0.038

The study on the seasonal variations in the accumulation of heavy metals in *Labeo rohita*'s gills, intestines, liver and kidneys reflects the complex relationship between fish physiology, metabolic activity and the environmental availability of heavy metals. According to the data, the concentration of heavy metals is higher in the summers than in winter and monsoons because in the summers, water evaporation is high and the flow is low. That is why all the elements become more concentrated. In this study, 10 heavy metal concentrations were analysed in *Labeo rohita* organs.

In gills, Mn concentration was at its peak in the summer at 0.081 mg/L, which decreased in the monsoon to 0.051 mg/L. Chromium also accumulated in significant concentrations, ranging from 0.042 to 0.024 mg/L from summer to monsoon. Results also show a significant concentration of Pb, which can lead to toxicity. The intestine had a high accumulation of Mn (0.072 mg/L in summers), Cr (0.048 mg/L) and significant levels of lead (0.037-0.01 mg/L), reflecting the level of heavy metal pollution in the river. The liver and kidneys were reported to have higher levels of heavy metal accumulation than the gills and intestines.

Table 5
Heavy metal accumulation in Kidney

Kidney			
HM	**Summer**	**Winter**	**Monsoon**
As	0.024	0.012	0.008
Cd	0.021	0.015	0.012
Co	0.018	0.008	0.005
Cr	0.063	0.031	0.025
Cu	0.055	0.036	0.031
Mn	0.078	0.075	0.055
Ni	0.021	0.011	0.009
Pb	0.053	0.038	0.018
Tl	-0.009	-0.01	-0.011
Zn	0.082	0.077	0.058

Generally, some heavy metals are essential for the body's functioning, but an excess amount of any of those is harmful and toxic to biological systems. These metals interfere with the other functions of the body. Accumulation of these in the edible fish body will lead to bioaccumulation and will impact the food chain.

The liver is well known for its storage function and detoxifying quality and has high Mn and Zn. These heavy metals have enzymatic roles in the body which may be responsible for their high affinity with the hepatic tissues, but high levels of Cr and lead were also observed in the liver. The kidney functions as an excretory organ that can contribute to the significant accumulation of Mn and Zn. Mn and Zn are not a matter of concern in this study because these are not present in significantly exceeding concentrations in any organs to cause toxic effects, but Cr and Pb are present in higher concentrations that can cause toxic effects and hinder the body's regular activity because Cr is also responsible to damage the respiratory epithelium of gill in fish and hinder growth[15,20], it can damage DNA and also can cause oxidative DNA damage[8].

Pb is genotoxic and cytotoxic and can damage gills and fins in fishes and can reduce red blood cell count in some fishes, it can delay embryonic development, affect reproduction, cause kidney dysfunction, can become the cause of gill hypertrophy[5,15]. A significant amount of Cd is also reported in the results. Cd can cause myocardial diseases[15]. It can also damage tissue integrity and structure, damage the antioxidant defence system and change gene expression in fish[11].

Thallium, a highly toxic heavy metal that is not needed in the body, can also be seen in the liver. It shows an immunosuppressive effect on fish fingerlings[3]. In our previous study we found thallium in human blood[4] and high concentration of other heavy metals such as Cr at this site[9,10]. However, cadmium and lead were below detection limit. High levels of heavy metal accumulation in summer could contribute to the increased temperature of water, which can elevate the solubility of heavy metals. A high accumulation of heavy metals in fish bodies can also affect the aquatic ecosystem and human health.

Conclusion

The study shed light on the significant organ-specific seasonal variations in the accumulation of heavy metals. The investigation reveals that different body organs have different affinities for heavy metals. In the study, Cr, Cd and Pb are the most prominent heavy metals accumulated by the fish across the seasons. The accumulation trend indicates that during summers, accumulation peaks, and until the onset of monsoon, dilution in concentration occurs.

The high accumulation of key heavy metals indicates the potential health and ecological risks. The study emphasizes the immediate need for advanced environmental monitoring and mitigation strategies to reduce heavy metal toxicity. This study provides valuable insight into the dynamics of environmental heavy metal pollution and its impact on biological systems, which can serve as the foundation for future environmental assessment and mitigation efforts.

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