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Assessment of heavy metals status in a selected span of a lowermost stretch of river Ganga and their accumulation towards biotic and abiotic components

Lokenath Chakraborty[a], Sandip Mondal[b], Subir Kumar Nag[c] and Basanta Kumar Das[d]

[a] PhD student, NIT Durgapur
[b] Assistant Professor, NIT Durgapur
[c] Principal Scientist, ICAR-CIFRI, Barrackpore
[d] Director, ICAR-CIFRI, Barrackpore, West Bengal
E-mail: lokenath_chakroborty@yahoo.co.in

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Abstract: The objective of the present studies is to assess the heavy metal contamination level in the ecosystem of the lower part of the Ganga river. To meet the desired goal, accumulation level of heavy metals i.e. Cd, Cr, Ni, Pb, Fe, and Zn have been determined in the different parts like flesh, liver, kidney, gill tissues of the selected fishes (*Glossogobius* sp., *Mystus* sp., *Hilsha ilisha*, and *Jhonius gangeticus*) which are generally available in the study area. The contamination level indicates the potential health risk for the consumers. According to the mean value of the metals presented into the river water in this region are found Fe>Zn>Cr>Ni>Cd>Pd in this order. According to the mean value of the concentration of the metals into the tissues of the fishes the trend shows, Fe>Zn>Cr>Ni>Pb>Cd. Out of 90 tissue samples, 38 samples were above the safe limit which was almost 42% of the total samples. According to the Bioaccumulation Factor (BAF), the BAF of 24 samples is more than 1.0 and that indicates the accumulation pattern from water to 27% of fish tissues are in several folds. According to the estimation of the Estimated Daily Intake (EDI), 25% of fish fleshes are not suitable for human consumption although the estimated Target hazard quotient (THQ) values of all samples are below the threshold limit.

Keywords: Heavy metals, water, fishes, BAF, EDI, THQ.

1. Introduction

Ganga is the holy river of India originated from the Gangotri glacier and after traveling of 2,601 km, it is finally emptying into the Bay of Bengal. In between this journey,the river is bifurcated from Farakka of West Bengal and its eastern part enters into Bangladesh. This river accommodates huge biodiversity like Phytoplankton and Periphyton (1099 taxa), Zooplanktons (299 taxa), zoobenthos (478 taxa), fishes (295 taxa), higher vertebrates (1595 taxa) [1]. But after civilization, this river also carries partially treated and untreated wastewater from the 36 Class-I towns and 14 Class-II towns. 2723.3 MLD (Millions of litter per day) of wastewater is generated from these

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towns; out of which 1208.8 MLD is mostly treated which represents 40% of the total discharges [2]. The presence of emergent heavy metals (like Cd, Cr, Ni, Pb, Fe and, Zn) in the river water has been alreadyreported [3–7]. The main sources of contamination of the above metals in this river water are Industrial wastes, sewage effluent, agricultural runoff, and domestic wastes.

The Ganga River contributes a huge fish production to the nation and that is the main source of protein for the people lives in the adjoining area. Bioaccumulation of these contaminants increases the health hazardous level and that leads to the kidney and skeletal damages, neurological disorders, an endocrine disorder, cardiovascular disorder, and carcinogenic effects [8].

To determine the bioaccumulation index, fish, river water and drainage effluentshave been collected from the study area. To meet the objective of this work, all the samples have analyzed and the impact of the contaminants on the biodiversity has been delineated.

2. Materials and methods

2.1. Study area

Water and fish samples were collected from five numbers of sites of Ganga River (1) Titagarh, (2) Adyapith, (3) Ghusuri, (4) Botanical Garden, and (5) Godakhali during pre-monsoon period i.e. April to May 2019. Details of the sampling sites are given in Fig. 1.We also collected wastewater from 14 numbers of drains, 7 from the east bank, and 7 from west bank, detail locations of the drains are given in Table 2.

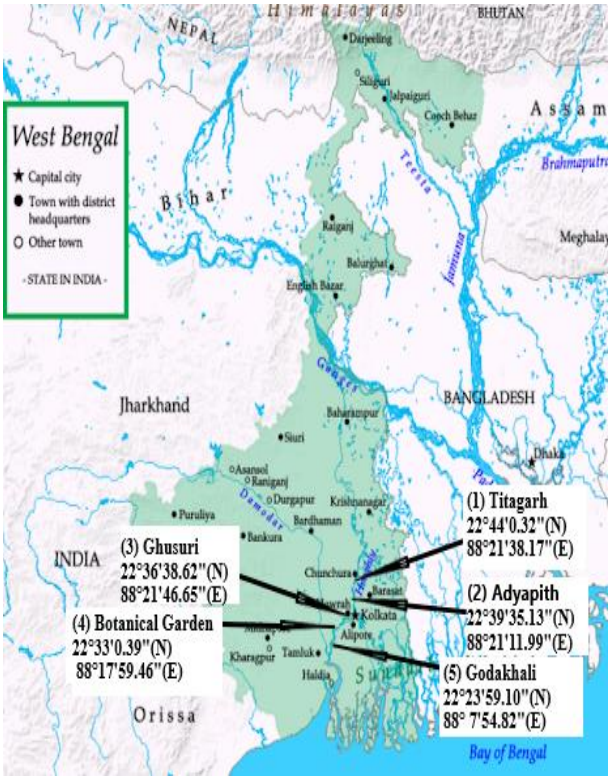

Fig. 1. Sampling site of the study

2.2. Methodology

All the containers and tools used in the experiment for the purpose of sample collection, processing and storage were cleaned with liquid detergent and rinsed with 2% HNO_3. The chemicals used in the analysis were of analytical grade and Milli Q water was used whenever required for analysis. Water samples were collected from each sampling site in triplicate into 500ml plastic containers. After collection, water was filtered with Whatman 42 filter paper to remove any suspended particle, dirt etc. and then 10ml concentrated HNO_3 was

added in each sample. Among the fishes, the four mostly common available species *Glossogobius* sp., *Mystus* sp., *Hilsha ilisha* and *Jhonius gangeticus* collected in triplicate from each spot. Fishes were kept in the icebox filled with ice at 4°C and brought to the laboratory for analysis.

At the laboratory, water samples were transferred into glass beakers and placed on a hot plate at 150°C for digestion which continued till the volume was reduced to 50 ml. The digested samples were cooled at room temperature and filtered with Whatman#42 filter paper and finally stored into plastic containers. The fish samples were first thawed by distilled water to bring at room temperature and scales were removed by scalpel. An amount of 5 g flesh and gill were sampled from each fish and kept in separate 50 ml glass beakers. Tri acid (HNO_3:$HClO_4$:H_2SO_4::10:4:1) mixture (20 ml) was added to the beakers and kept overnight for slow digestion. On the next day all the samples were placed on the hot plate at 200°C for 5 hours. Digested samples were cooled at room temperature and filtered with Whatman 42 filter paper and finally the volume was made up to 50 ml with 2% HNO_3. The filtrates were stored in plastic containers. Finally, the qualitative and quantitative analysis of digested samples of water and fish tissues was done in a flame mode Atomic Absorption Spectrophotometer (AAS) of Perkin Elmer make. The AAS was calibrated with certified reference standards of the elements analyzed (Cd, Cr, Ni, Pb, Fe, and Zn). A calibration standard curve was prepared for each element and the R^2 value was as 0.99. The results obtained from the samples were expressed in mg/l for water and mg/kg for fish.

3. Results and discussion

3.1. Metals in river water

The concentrations of the heavy metals recorded in the selected stretch of Ganga River water samples are shown in Table 1. The ranges at which of the heavy metals were detected were as follow: Cd varied from BDL to 0.0006mg/l, maximum was found at site no. 4. Cr concentration was observed in the range of 0.0254 to 0.0306mg/l; Ni concentration varied from 0.0006 to 0.0096mg/l, and; Pb concentration was found in the range of 0.0002 to 0.0006mg/l. As per BIS (Bureau of Indian Standard), the heavy metal concentrations were observed within the permissible limit.The river water samples contained iron, ranging from 4.938 to 7.218 mg/l, above permissible limit, and the highest concentration was observed at site no.3. Zn concentration in the samples was found in the range of 0.299 to 3.654mg/l. The maximum Zn concentration was found at the site no. 4 and the observed value within the permissible limit as per BIS standard.

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According to mean value, the metal concentrations in the river water samples was in the order: Fe>Zn>Cr>Ni>Cd>Pd. The heavy metals concentrations of the drainage wastewater are summarized in Table 2.

3.2. Metals in fish tissues

Discharges contributed by the anthropogenic activities into the river cause contamination of heavy metals in the river ecosystem. As a result, the heavy metals started accumulating in different parts of fishes through the intake of sediments and planktons. The accumulation status of the heavy metals in different fishes has been shown in Table 3.The level of Cd in the different fish tissues was found BDL only. The gill of *Glossogobius* contained 4.49 µg/g of Cd which was above the safe limit. In the case of Cr the lowest concentration was found in *Jhonius* flesh i.e. 3.04 µg/g and highest found in *Jhonius* liver i.e. 70.23 µg/g. Most of the fishe tissues excided within the safe limit. In the case of Ni, the lowest concentration was found in *Jhonius* flesh i.e. 0.13 µg/g and the highest concentration was found in *Jhonius* liver i.e. 19.64 µg/g. The lowest Pb concentration was found in the *Hilsha* kidney i.e. 1.54 µg/g and *Jhonius* liver contained 24.4 µg/g of Pb which is reported as a highest concentration. In the case of Fe, the flesh of *Jonious* was found to contain the lowest concentration of 8.76 µg/g and the highest (1261.78 µg/g) was found in *Mystus* kidney. In the case of Zn, the lowest concentration found in the flesh of *Jonious* at 4.47 µg/g and the highest was found in the liver of *Jhonius* at 52.38 µg/g. According to the mean value of concentrations of the metals in tissues of the fishes, the trend shows Fe>Zn>Cr>Ni>Pb>Cd. In fish tissue samples, 38 samples out of 90 samples 38 samples were above the safe limit which was almost 42% of the total samples.

Table 1. Heavy metals concentration (mg/l) in River Ganga water at selected sites.

Sites Code	Cd	Cr	Ni	Pb	Fe	Zn
1.	BDL	0.0254	0.005	0.0004	7.074	0.299
2.	BDL	0.027	0.0012	0.0002	6.618	0.374
3.	0.0006	0.0306	0.0006	0.0003	7.218	0.5564
4.	0.0012	0.0282	0.0032	0.0003	7.066	3.654
5.	BDL	0.0294	0.0096	0.0006	4.938	1.2466
Mean	0.0009	0.02812	0.00392	0.00036	6.5828	1.226
Max	0.0012	0.0306	0.0096	0.0006	7.218	3.654
Min	0.0006	0.0254	0.0006	0.0002	4.938	0.299
SD	0.000424	0.0254	0.0006	0.0002	4.938	0.299
Permissible limit as per BIS (IS 10500-2012)	0.003	0.05	-	0.01	0.3	15

BDL: Below Detection Limit

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Table 2. Heavy metals concentration (mg/l) in some selected adjacent drains.

Drains effluent (East bank)	GPS locations	Cd	Cr	Ni	Pb	Fe	Zn
Khardha Khal	22°43'34.88"N 88°21'44.53"E	0.006	0.0036	BDL	0.0716	3.75	0.352
Daksineswar drain	22°39'13.08"N 88°21'26.68"E	BDL	0.0672	0.0004	0.0003	4.33	0.2552
Alambazar(Baranagar) drain	22°39'8.96"N 88°21'28.21"E	0.0006	0.041	BDL	0.0008	5.58	0.516
Ratanbabu(Cossipore) drain	22°37'26.17"N 88°22'1.87"E	0.0036	0.0094	BDL	0.0004	2.574	0.6202
Circular canal(Bagbazar)	22°36'28.76"N 88°22'2.92"E	0.014	0.0052	BDL	0.0532	4.16	0.198
Adi ganga (Tolly canal)	22°33'0.15"N 88°19'29.99"E	0.0066	0.0344	0.0004	0.0004	3.612	0.7544
Jana para (Santoshpore) Khal	22°31'43.37"N 88°14'48.49"E	0.0052	0.0448	0.001	0.0008	6.248	1.098
Drains effluent (West side)							
Bally Khal(Uttarpara)	22°39'17.92"N 88°20'53.14"E	BDL	0.0072	0.0012	0.0002	1.66	0.2074
Bally drain(Nibedita bridge)	22°39'8.74"N 88°21'1.48"E	BDL	0.041	0.002	0.0004	0.746	0.248
Belur drain(Belur jetty)	22°37'49.58"N 88°21'29.42"E	0.0036	0.008	BDL	0.0005	1.417	0.4976
Botanical garden khal	22°33'14.36"N 88°18'0.64"E	0.004	BDL	BDL	0.0676	2.8412	0.0828
Gugaberiakhal (Mourigram)	22°33'26.33"N 88°16'36.36"E	0.0182	0.0324	0.001	0.0009	5.472	5.226
Banipurkhal (Sankrail)	22°33'31.00"N 88°13'59.93"E	0.0066	0.0284	0.0012	0.0013	3.658	1.0274
Sarengakhal (Nalpur)	22°31'10.34"N 88°12'26.75"E	0.007	0.036	0.0032	0.0016	9.056	0.006

BDL: Below Detection Limit

Table 3. Heavy metals concentration (µg/g wet weight) in tissues of selected fishes.

Fishes	Body tissues	Cd	Cr	Ni	Pb	Fe	Zn
*Glossogobius*sp.	Flesh	0.3	BDL	2.3	BDL	12.3	6.5
	Liver	BDL	BDL	BDL	BDL	127.6	25.2
	Gill	4.49	BDL	11.49	BDL	979.12	30.16
*Mystus*sp.	Flesh	BDL	6.63	BDL	7.98	24.45	42.81
	Liver	BDL	3.62	6.64	7.25	1261.78	49.1

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	Kidney	BDL	11.53	19.38	8.3	329.53	52.3
	Gill	BDL	6.17	0.37	1.74	358.63	50
	Flesh	BDL	5.21	1.93	1.83	13.17	5.16
	Liver	BDL	13.1	10.2	2.83	213.82	22.58
	Kidney	BDL	0.95	BDL	1.54	80.3	22.22
Hilshailisha	Gill	0.04	15.2	6.64	2.58	140.87	36.32
	Flesh	BDL	3.04	0.13	1.66	8.76	4.47
	Liver	BDL	70.23	19.64	24.4	130.35	52.38
	Kidney	BDL	BDL	BDL	7.18	192.26	25.69
Jhoniusgangeticus	Gill	BDL	4.87	4.35	3.14	94.87	22.37
Mean		1.61	12.777	7.551	5.869	264.520	29.817
Max		4.49	70.23	19.64	24.4	1261.78	52.38
Min		0.04	3.04	0.13	1.54	8.76	4.47
SD		2.497	19.565	6.973	6.429	367.486	16.909
Safe limit [Ref. 9]	Tissues	0.5	-	-	0.5	-	30
Safe limit [Ref. 10]	Tissues	-	0.15	-	2.0	-	-

BDL: Below Detection Limit

3.3. Bioaccumulation factor

The bioaccumulation factors (BAF) are the ratio of heavy metals concentration in fish organs to that in water. BAF was determined using the formula suggested by Lau et al., (1998) [11]. 24/90

$$BAF = \frac{\text{Concentration of heavy metals in fish}}{\text{Concentration of heavy metals in water}}$$

The BAF of fish tissues is shown in Table 4. Out of 90 samples, in 24 samples (27%) BAF was more than 1.0 which indicated the accumulation pattern from water to fish tissues was in several folds.

3.4. Quantitative health risk assessment

The fish fleshes are the main edible portion consumed by human. So, fish fleshes are used for the evaluating of human health risk assessment through an Estimated Daily Intake (EDI) of metals and Target Hazard Quotients (THQ).

Table 4. Bioaccumulation factor (BAF) of the selected fishes in different heavy metals.

Fishes	Body tissues	Cd	Cr	Ni	Pb	Fe	Zn
*Glossogobius*sp.	Flesh	0.186	-	0.304	-	0.046	0.217

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	Liver	-	-	-	-	0.482	0.845
	Gill	2.788	-	1.521	-	3.701	1.011
*Mystus*sp.	Flesh	-	0.518	-	1.359	0.092	1.435
	Liver	-	0.283	0.879	1.235	4.770	1.646
	Kidney	-	0.902	2.566	1.414	1.245	1.754
	Gill	-	0.482	0.048	0.296	1.355	1.676
Hilshailisha	Flesh	-	0.407	0.255	0.311	0.049	0.173
	Liver	-	1.025	1.350	0.482	0.808	0.757
	Kidney	-	0.074	-	0.262	0.303	0.745
	Gill	0.024	1.189	0.879	0.439	0.532	1.218
Jhoniusgangeticus	Flesh	-	0.237	0.017	0.282	0.033	0.149
	Liver	-	5.496	2.600	4.157	0.492	1.756
	Kidney	-	-	-	1.223	0.726	0.861
	Gill	-	0.381	0.576	0.534	0.358	0.750

3.4.1. Estimated daily intake of metals

To Estimated Daily Intake (EDI) of heavy metals was calculated using the following equation.

$$EDI = \frac{(C \times FIR)}{BW}$$

Where, C is the mean heavy metals concentration in fish flesh (µg/g) on a dry weight basis. For the conversion from dry weight to wet weight, 4.8 value istaken as the conversion factor [12]. Food Ingestion Rate (FIR) is the daily consumption of freshwater fish (gram per day per capita). The average FIR was 0.019g per person per day[13]. BW is the average body weight, which is 70kg for adults [14].

3.4.2. Target hazard quotient

The Target Hazard Quotient (THQ) is the estimate of non-carcinogenic risk level due to heavy metals exposure [15]. It is calculated by using of the following equation [14].

$$THQ = \frac{Efr \times ED \times FIR \times C}{Rfd \times BW \times ATn} \times 10^{-3}$$

Where, Efr (Exposure frequency) is 365 days per year, and ED (Exposure Duration) is 70 years (as set for this study). RfD (Reference Dose) assesses the health risk of

consuming fish, and ATn is the time of average exposure for non-carcinogenic (365day×no. of exposure year) [14, 16, 17].

The quantitative health risk assessment by the calculation of EDI and THQ has given in Table 5. For the *Glossogobius* sp. flesh EDI excided only in case of Ni and other metals are below the recommended daily allowance. For the *Mystus* sp. EDI excided in the case of Cr and Pb and other metals are below the recommended daily allowance. For the *Hilsha ilisha* EDI excided in the case of Cr and Ni and other metals are the below the recommended daily allowance. For *Jhonius gangeticus,* concentration exceeded in case of only Cr and other metals were below the recommended daily allowance. The Target hazard quotient for all fish fleshes was under the Reference Dose. So, in the flesh of selected four fishes of the lower most part of the river Ganga is safe for consumption.

Table 5. Quantitative health risk assessment

Fish species	Heavy metals	Average concentration	Recommended daily allowance mg day^{-1} 70kg^{-1} body weight	EDI 70 kg^{-1} body weight	Rfd µg kg^{-1} day^{-1}	THQ
*Glossogobius*sp.	Cd	0.3	0.07	0.027	0.001	0.000391
	Cr	BDL	0.23	-	0.003	-
	Ni	2.3	0.07	0.209	0.02	0.000149
	Pb	BDL	0.25	-	0.0035	-
	Fe	12.3	15	1.121	0.7	0.000022
	Zn	6.5	70	0.592	0.3	0.000028
*Mystus*sp.	Cd	BDL	0.07	-	0.001	-
	Cr	6.63	0.23	0.604	0.003	0.002879
	Ni	BDL	0.07	-	0.02	-
	Pb	7.98	0.25	0.727	0.0035	0.002971
	Fe	24.45	15	2.229	0.7	0.000045
	Zn	42.81	70	3.904	0.3	0.000186
Hilshailisha	Cd	BDL	0.07	-	0.001	-
	Cr	5.21	0.23	0.475	0.003	0.002263
	Ni	1.93	0.07	0.176	0.02	0.000126
	Pb	1.83	0.25	0.166	0.0035	0.000681
	Fe	13.17	15	1.201	0.7	0.000024
	Zn	5.16	70	0.470	0.3	0.000022
Jhoniusgangeticus	Cd	BDL	0.07	-	0.001	-
	Cr	3.04	0.23	0.277	0.003	0.00132
	Ni	0.13	0.07	0.011	0.02	0.000008
	Pb	1.66	0.25	0.151	0.0035	0.000618
	Fe	8.76	15	0.798	0.7	0.000016
	Zn	4.47	70	0.407	0.3	0.000019

4. Conclusion

The present studies show that the lowermost stretch of the river is contaminated with toxic metals and 42% of the fish's tissue samples were found above permissible limits as per BIS standard. According to the estimated value of EDI, 25% of fish fleshes are not suitable for human consumption though as per THQ findings, the samples are found within the safe limit.

Therefore, it is recommended that an in-depth analysis needs to be carried out in different stretches of the river to determine the bioaccumulation pattern of the heavy metals and its impact on the ecology and human food safety. A general awareness about river pollution through anthropogenic activity and its impact on the environment is also required to be generated among the public.

5. Conflict of interest

The authors declare that they have no conflict of interest.

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