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Evaluation of the Anthropogenic Enrichment of Pollutant Loads amidst the COVID Restrictions: A Case Study in the Babughat, W.B, India

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ABSTRACT
Water pollution, mainly due to industrial and urban activities, is well known worldwide. The present study was conducted in Babughat, Kolkata, on the river Hooghly, where both the idol immersion and ferry services run parallel, accumulating all-way pollution loads. Various physicochemical parameters were estimated to understand the coupled effects of ferry services and idol immersion. The DO values are found to be very low (9.1 to 5.5 mg/l). The microbial analysis revealed the presence of microbial contamination in the river water (coliform: 540,000 MPN and E. coli: 15000 MPN). The WQI (415.82) and CPI (1.3 mg/l) show that the water is polluted and unfit for drinking consumption. The Heavy Metal Index (HPI) and Eutrophication Index (EI) revealed the heavy metal pollution and eutrophic nature of the water. The results indicated that most of the physicochemical parameters from the Babughat were within or at the periphery in comparison with the permissible limit. However, the microbial load was found to be very high. The results did not show any significant heavy metal or trace metal pollution. The improved results could be attributed to the passive restoration of restricted anthropogenic influence since the study was conducted in 2021, after the 1st wave of COVID lockdown in the country.
Key words: *Pollution, physicochemical parameters, heavy metals, the Eutrophication Index (EI), the Water Quality Index (WQI), and the Heavy Metal Index (HPI).*

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INTRODUCTION

Water is the most essential commodity; every livelihood needs water to survive. Potable drinking water plays an important role in the creation of good health conditions for a nation [1]. It is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance that is the main constituent of Earth's hydrosphere and the fluids of all known living organisms. The rapid increase in urbanization, agriculture, and other activities has increased the amount of pollution in both surface and groundwater sources [2–5]. The water quality and the aquatic environment of the Ganga have deteriorated over the past few decades. Due to an increase in various anthropogenic activities like urbanization, industrialization, and the direct discharge of waste into the river, the pollution load of the river has increased tremendously. The Ganga River's flow is also interrupted by the construction of many dams, which also affect the biodiversity of the river. Huge sediment deposition and all the physiochemical and microbial parameters are found far above the acceptable limits, which in turn affects the aquatic life therein [6].

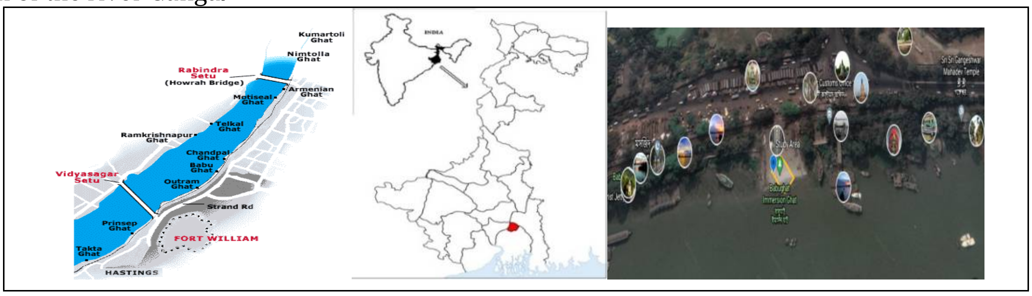
Today, freshwater resources are becoming scarcer and more polluted due to stresses on water quality and quantity. The hydro chemical quality of river water is affected by both anthropogenic activities and natural processes [7-9]. River pollution is an enormous problem in developing countries like India. The main causes attributed to them could be a lack of proper planning and ignorance of local and common people. The river Ganga today suffers from extreme pollution, which is affecting the people who live alongside the river and are dependent on it for their survival. There are several mixed factors applicable to such a worst-case scenario for the river Ganga. Kolkata is one of the largest metropolitan cities in India. The city has a significant impact on the river Ghats in all aspects, such as discharge flow and industrial and domestic sewage.

The present study was conducted to evaluate the present status of the water quality of one such important ghat in Kolkata, which accumulates pollutants from many dimensions, such as transportation, idol immersion, anthropogenic invasions, and industrial dumping.

Study Area:

The present study has been carried out in Babughat (22.566310 N to 88.3398230 E), West Bengal, India to evaluate the anthropogenic enrichment of pollutant loads amidst COVID 19 restrictions (Figure 1). Babu Ghat immersion ghat is popular for idol immersion. Religious festivals such as Durga Puja and Ganesh festival are traditionally celebrated as social and community activities in Kolkata.After the period of the festivals is over, the idols are immersed in the Ganga (Babughat Immersion ghat) or any nearby water body. This causes pollution of the water, making it unfit for consumption. It has been roughly estimated that around the festival period, almost 1600 idols are immersed in the Ganga from Babughat alone, in Kolkata. A huge crowd can be seen on Babughat for their different activities like baths, dumping the garbage, and different rituals. It is always bustling with passengers, who use it to cross the river to reach Howrah station. Babughat is a unique junction point in Kolkata where one can find various modes of transport like buses, ferries, and trains.

The water quality here supports loads of all three crucial aspects, *i.e.*, religious activities, domestic waste discharge, and industrial discharge, as well as transportation discharge, so the proper analysis of the selected water quality parameters will help us to understand the profundity of the water pollution problem of the river Ganga.



A B C

Figure 1. A – India Map shows the West Bengal, B- The Entire Stretch of Hooghly River, C- The Sampling Location

MATERIAL AND METHODS

The study was conducted in the year 2021. The sample water was collected at a depth of 5 m below the surface of the river water and stored in prewashed plastic bottles of 2 liter capacity. An extra additional water sample was collected in the two 500ml plastic bottles for on-site analysis. Preparation of the sampling bottles included washing with detergent and rinsing with river water. After collection, the samples were covered in aluminium foil and colored paper. On the spot, the water temperature was measured by a thermometer, and dissolved oxygen was measured by a DO meter for other parameters. The sample water was carried into the laboratory and analyzed. This sample was transferred to the laboratory under preserved conditions according to standard protocols used for both physicochemical and microbiological analyses. Sampling was done carefully to avoid the spilling of water and air bubbles. Various physicochemical parameters and heavy metals, *viz.* pH, Temperature, Dissolved Oxygen, Biological Oxygen Demand, Total Dissolved Solids, Turbidity, Arsenic, Chromium, Zinc, Iron, etc., were analyzed following the standard methods [10] (Table 1). The results were then subjected to statistical analysis. The Water Quality Index (WQI), Heavy Metal Index (HMI), and Eutrophication Index (EI) are calculated to evaluate the water quality.

Table 1. Water quality parameter Analytical methods and Instrumentation

Parameters	Abbreviations	Units	Analytical Methods	Instrument
Turbidity	T	Unit	Instrumental	Titration
pH	pH		Instrumental	pH meter
Electrical Conductivity	EC	NTU	Instrumental	Conductivity meter
Total Suspended Solids	TSS	mg./l		TSS meter
Total Dissolved Solids	TDS	mg./l	Instrumental	TDS meter
Alkalinity	Alky	mg./l	Tritrimetric	Titration
Chloride	Cl	mg./l	Tritrimetric	Titration

Total Hardness	TA	mg./l	Tritrimetric	Titration
Dissolved NO_3^-	NO_3^-	mg./l	Tritrimetric	Titration
Calcium	Ca	mg./l	Tritrimetric	Titration
Magnesium	Mg	mg./l	Tritrimetric	Titration
NO_{2-}	N	mg./l	Tritrimetric	Titration
Sulphate	SO^2	mg./l	Tritrimetric	Titration
Chlorine	Chl	mg./l	Tritrimetric	Titration
Fluoride	F	mg./l	Tritrimetric	Titration
Phosphate	P	mg./l	Tritrimetric	Titration
Chemical Oxygen Demand	COD	mg./l	Tritrimetric	Titration
BOD 3 days at 27 ◦ c	BOD	mg./l	Winkler Azide Method	Titration
Lead	Pb	mg./l	Tritrimetric	Titration
Cadmium	Cd	mg./l	Tritrimetric	Titration
Chromium	Cr	mg./l	Tritrimetric	Titration
Zinc	Zn	Mg./l	Tritrimetric	Titration
Nickel	Ni	mg./l	Tritrimetric	Titration
Iron	Fe	mg./l	Tritrimetric	Titration
Potassium	K	mg./l	Tritrimetric	Titration
Arsenic	As	mg./l	Tritrimetric	Titration
Free CO_2	FCO_2	mg./l	Tritrimetric	Titration
Dissolve Oxtgen	DO	mg./l	Tritrimetric	Titration
Temperature		ppm	Instrumental	Thermometer
Total Coliform	TC	mg./l	-	
E. Coli	E.Coli	◦ C	-	

The World Quality Index (WQI):

To get a comprehensive picture of the overall quality of water in the Babu Ghat, Hooghly River, a Water Quality Index is performed. A WQI is defined as a rating reflecting the composite influence of different water quality parameters on the overall quality of water. A Water Quality Index (WQI) is calculated for a comprehensive interpretation of the quality of water used for different purposes. Eleven water parameters are used in the study for checking the calculation of the water quality index. The calculation of the water quality index was done using the weighted arithmetic index method (11). The calculation of WQI is based on several physicochemical parameters, which are then multiplied by a weighting factor, and the final aggregate is obtained using the arithmetic mean. The calculation of the WQI is explained, and the same formula was applied to calculate the WQI in the present study (12).

Calculation of Water Quality Index:

Step: 1 – Calculate the Unit weight (Wn) factors for each parameter by using formula

Wn = K/Sn

Where,

wn = unit weight for n^{th} parameter

sn = standard permissible value for n^{th} parameter

k = proportionality constant.

Step: 2 – Calculate the Sub-index (Qn) value using formula

$$Qn = [(Vn - Vi)/(Vs - Vi) \times 100$$

Where,

Vn – Observed value

Vi – Ideal value (Generally Vo = 0 for most parameters except pH and DO is 7 and 14)

Vs – Standard value

Step: 3 – Combining Step 1 and Step 2, WQI is calculate as follows.

$$\text{WQI}=\sum_{n=1}^{n} q_n w_n / \sum_{n=1}^{n} w_n$$

Table 2. Water quality index grading (9)

WQI level	**Status**	**Grading**
0-25	Excellent	A
26-50	Good	B
51-75	Poor	C
76-100	Very poor	D
Above 100	Unsuitable for drinking, fish culture	E

Comprehensive Pollution Index (CPI):
CPI is used to access the overall pollution load of water bodies. It is calculated according to the following equation [13-14]:

$$CPI=\frac{1}{N}\sum_{i=1}^{n} PIi$$

$PIi=\frac{Ci}{Si}$

Where, PIi = pollution index of the i^{th} parameter,
Ci= measured concentration of the i^{th} parameter
Si= standard concentration of the i^{th} parameter

Table 3. Comprehensive pollution index (CPI) status [13,14]

CPI	**Status**
0.0–0.20	Clean
0.21–0.4	Sub clean
0.41–0.8	Qualified
0.81–1.0	Basically Qualified
1.01–2.0	Polluted
≥2.01	Seriously Polluted

***The Organic* Pollution Index (OPI):**
It is an important tool to classify the water quality of a water body based on only four physiochemical parameters, i.e., COD, DO, dissolve inorganic nitrogen (DIN), and dissolve inorganic phosphate (DIP) [11], and is mathematically expressed as:

$$OPI=\frac{COD}{COD_s}+\frac{DIN}{DIN_s}+\frac{DIP}{DIP_s}+\frac{DO}{DO_s}$$

Table 4. Grading of Organic Pollution Index

OPI	**Range**
<0	Excellent
0-1	Good
1-4	Polluted
4-5	Heavy Polluted

The Eutrophication Index (EI):
The Eutrophication index is used to classify the integration in the water portal based on only three physico-chemical parameters: COD, DIP, and DIN. Zhou et al. (1983) developed a
Eutrophication Index method for preliminary assessment of water quality in Bohai Bay, which accounts for the effects of chemical oxygen demand (COD), dissolved inorganic nitrogen (DIN), and dissolved inorganic phosphorus (DIP) [15].
Calculation:

$$EI=\frac{(COD\times DIP\times DIP}{4500})\times 10^6.$$

Where,
COD, DIN, DIP are measured concentration obtained during laboratory testing of collected water sample.
COD- concentration of chemical oxygen demand
DIN - concentration of dissolved inorganic nitrogen
DIP- concentration of dissolved inorganic phosphate

Table. 5 Grading of Eutrophication Index

Range	Category
<1	*No Eutrophication*
>1	*Eutrophication*

Heavy Metal Pollution Index:

Heavy metal pollution index is rating method and an effective tool to assess the water quality with respect heavy metals the value of heavy metal. Heavy metal index value will be less than hundred or be greater than hundred.

Wi $= \frac{K}{Si}$

Heavy metal index formula Institute of two different parts

1. Sub index value
2. Unit Weight (Wi)

Where

K= K is constant

Si = Standard permissible limit value of it parameter

Sub index of the value of the parameter is calculated by following

Where

Mi= Monitored value of heavy metal of ith parameter

Ii = Ideal value of the ith parameters

Si= Standard value of the ith parameter

$$\mathbf{Qi} = \sum_{i=1}^{n} \frac{(Mi(-)Ii)}{(Si-Ii)\times 100}$$

$$\mathbf{HPI} = \sum_{i}^{n} = \frac{WiQi}{\sum_{i}^{n}=Wi}$$

Table 5. Grading of Heavy Metal Index

HMI	Range
<100	Safe
>100	Contaminated

Correlation Study:

Interrelationship between different water quality parameters is useful in understanding the overall impact of different biochemical parameters on each other. The correlation co-efficient 'r' is calculated using the equation as follows (7).

$$r = \frac{n\sum(xy)-\sum(x)\sum(y)}{\sqrt{(n\sum x^2-(\sum x)^2}\sqrt{(n\sum y^2-(\sum y)^2)}};$$

Where n= number of data

RESULTS AND DISCUSSIONS

The physicochemical analysis carried out at the one site during the monsoon seasons has been summarized in table 6. Temperature is the most important factor that influences the chemical, physical, and biological characteristics of water bodies. The present study revealed that the temperature varied from 27–29 °C. The pH of a body of water is very important in the determination of water quality since it affects their chemical reactions such as solubility and metal toxicity. The pH is a measured intensity of acidity or alkalinity and measures the concentration of hydrogen ions in the water. During the present study, the value of pH was found to vary between 6 and 8. All the other parameters, except turbidity and conductivity, are reported to be higher than the standards. Chemical oxygen demand refers to the oxygen required to chemically oxidise all the organic and inorganic matter in the river. It is also an indicator of pollution, and especially reflects the industrial pollution load on the river. The value of COD is 39.52 mg/l in a collected water sample from the Hooghly River (Babu Ghat). This study area is famous for immersion of the idol, and for this reason, the lead level is found to be high (0.05 mg/l). The total coliform of the sample water is 540,000 MPN/100 ml. E. coli (Escherichia coli) is a type of bacteria that normally lives in human and animal intestines. It is also found in the guts of some animals. Most E. coli are harmless and even help to keep the digestive tract healthy. The microbial load of the river water is found to be very high.

Table 6. Summary of the physiochemical parameters of Babughat, Hooghly, W.B.

Sl. No.	Parameters	Unit	Result	WHO	BIS	
					Permissible	Maximum
1	Turbidity	NTU	4.2	0.0	1	5
2	pH	mg./l	7.58	6.5 – 9.2	6.5 – 8.5	6.5 – 8.5
3	Electrical Conductivity	s/cm	640.0	400	300	0.0
4	Total Suspended Solids	mg./l	23.0	200	0.0	0.0
5	Total Dissolved Solids	mg./l	392.0	500	500	2000
6	Alkalinity	mg./l	200.0	0.0	200	600
7	Chloride	mg./l	19.99	250	250	1000
8	Total Hardness	mg./l	190.0	500	200	600
9	Dissolved NO_3^-	mg./l	3.50	18	45	100
10	Calcium	mg./l	44.09	100	75	200
11	Magnesium	mg./l	19.2	50	30	100
12	Nitrite	mg./l	1.20	1	0.1	10
13	Sulphate	mg./l	27.4	200	200	400
14	Chlorine	mg./l	<0.01	0.02	0.2	1
15	Fluoride	mg./l	<0.1	1.5	1.0	1.5
16	Phosphate	mg./l	1.12	0.025	25	0.0
17	COD	mg./l	39.52	250	120	250
18	BOD 3 days at 27 ◦ c	mg./l	6.0	30	30	100
19	Lead	mg./l	<0.05	0.05	0.01	0.05
20	Cadmium	Mg./l	<0.01	0.003	0.003	0.01
21	Chromium	mg./l	<0.02	0.05	0.05	0.05
22	Zinc	mg./l	0.12	3	5	15
23	Nickel	mg./l	<0.02	0.02	0.0	3.0
24	Iron	mg./l	1.86	0.3	0.3	2.0
25	Potassium	mg./l	12.3	20	20	1
26	Arsenic	mg./l	<0.01	0.01	0.01	0.05
27	Free CO_2	ppm	320.0	250	350	450
28	DO	mg./l	09.1 -05.5	5	6	15
29	Temperature	◦ C	27 - 29	20- 30	15	40
30	Total Coliform	MPN/100 ml.	5.4×10^5	0.0	<400	0.0
31	E. coli	MPN/100 ml.	1.5×10^4	0.0	<200	<1000

(light green)	Under prescribed as WHO & BIS
(red)	Above WHO standard
(dark yellow)	Above WHO but under BIS prescribed level
(blue)	Above BIS Maximum

The water quality index and pollution index reveal that the water is polluted and unfit for drinking consumption. The higher values of WQI result from the high values of alkalinity. turbidity, EC, pH, free CO2, and microbial load. The Heavy Metal Index (HPI) value shows that heavy metal pollution in the water is still within safe limits. The Eutrophication Index reveals that the river water is eutrophic, not suitable for use. The organic pollution index (OPI) values reveal (1.3) that the water is polluted. The eutrophic nature of the water body and the high OPI index could be attributed to the high nitrite values. (Table 4).

Table 7 Summary of different Indices

Indices	Values	Remarks
Water Quality Index	415.82	Not Suitable for drinking
Comprehensive Pollution Index	1.3	Moderately Polluted
Eutrophication Index	4.63	Eutrophic
Heavy Metals Index	81.25	Safe

Organic Pollution Index	1.3	Polluted

Table .8 Study of the Correlation Coefficient among the physic chemical parameters

	Ca	Mg	NO2-	S	Cl	F	P	COD	BOD	Pb	Cd	Cr
Ca	1											
Mg	0.89**	1										
NO2-	0.1	0.26	1									
S	0.41*/**/**	0.33***	0.58**/***	1								
Cl	0.52**/***	.64*/**/***	0.87**/***	0.51	1							
F	-0.29	0.11	0-21	-0.08	-0.17	1						
P	-0.99	.94*/**/***	-0.13	-0.35***	-0.5**/***7	0.21	1					
COD	0.52*/**/**	.84*/**/***	0.44**/***	0.04	0.7	0.35***	-0.65**/***	1				
BOD	0.02	-0.1	-2.49	0.72**/***	-0.22	0.22	0.08	-0.41***	1			
Pb	0.39***	0.39**/***	-0.26	0.47**/**	-0.21	0.45***	-0.36***	0.05	0.76**/**	1		
Cd	-0.29	0.11	-2.19	-0.08	-0.17	1***	0.2	0.35***	0.22	0.45	1	
Cr	0.77*/**/**	.97*/**/***	0.29	0.13	0.67***	0.17	-0.86**/***	.94*/**/***	-0.33***	0.21	0.17	1
Zn	0.32***	0.28	0.38***	-0.19	0.63***	-0.61**/***	-0.36***	0.41***	-0.79**/***	-0.74**/***	-0.61	0.41
Ni	0.85**/***	0.89**/***	-0.09	0.44***	0.32***	0.22	-0.86**/***	0.58**/**	0.29***	0.76**/***	0.22	0.76**/***
Fe	0.25	0.57**/***	0.52**/***	0.54**/***	0.47**/***	0.71**/***	-0.31***	0.64**/***	0.38***	0.55	0.7**/***1	0.54
K	0.72**/***	0.77*/***	-0.09	0.47**/***	0.15	0.36***	-0.72*/***	0.44***	0.47***	0.89***	0.36***	0.62***
As	0.55**/***	0.31***	0.58**/***	0.76**/***	0.6**/***7	-0.67**/***	-0.47***	0.03	0.22	-0.05	-0.67	0.17
FCO2	0.18	.61*/**/***	0.25	-0.03	0.33***	.81*/**/***	-0.31***	.84*/**/***	-0.13	0.32	0.81**/***	0.71**/***
DO	0.15	0.12	-0.34***	0.42***	-0.41***	0.46**/***	-0.08	-0.21	0.89**/***	0.96	0.46***	-0.08
T	.63*/**/***	-0.36**/***	0.69**/***	0.19	0.27	0.39***	0.58**/***	0.04	0.09	-0.32	0.39	-0.26
TC	0.3	0.4	-0.7	-0.44***	-0.41***	0.42***	-0.35***	0.23	-0.13	0.5	0.42	0.41***
E. coli	.72*/**/***	0.56**/***	0.61**/***	0.58**/***	.84*/**/***	-0.62**/***	-0.68**/***	0.35***	-0.09	-0.15	-0.62	0.48

*P < 0.05 – Correlation is significant at the 0.05 level
**P <0.01 - Correlation is significant at the 0.01 level
***P <0.10 - Correlation is significant at the 0.10 level

The correlation coefficient is calculated to observe the interrelationship between the different parameters. A significant negative correlation is observed between phosphate and magnesium (-0.94). All other parameters were mostly positively correlated. Sulfate has a strong relationship with TDS and NO3-.Nickel is also highly positively correlated with TDS and with potassium. Chromium is positively correlated with magnesium and COD. Free CO2 was found to be correlated with total hardness and with EC (0.86); EC is highly positive correlated with fluoride and iron. $NO3^-$is observed to be highly correlated with TDS, which explains the eutropic nature of the body of water (Table-8).

CONCLUSIONS

The present study is conducted at the most polluted Ghat of the river Hooghly famous as Babughat. The study was conducted to evaluate the status of water quality amidst the COVID-19 restrictions. The improved effects of the restrictions were observed as revealed through the physicochemical parameters. However, some parameters like TDS and EC were reported to be high, which could be attributed due to anthropogenic invasions. Since the Ghat is a famous idol immersion site hence the lead contamination is observed to be high. The correlation coefficient reveals that most of the parameters are positively correlated.

Heavy metal in water causes many serious biochemical problems in human and aquatic life health. The COVID-19 lockdown may have forced us to stay home, but it's been a boon for the environment. With the industries shut, all transportations closed and people staying indoors, nature appears to be in rejuvenation mode water quality of the river has improved. The cause of water quality variations is mainly related to contamination load from nonpoint and point sources of temporal variations that are controlled by the precipitation and water runoff. From the results of the present study, it is found that the study site harbors both the total coliform and E. coli contamination, which indicates both municipal and anthropogenic invasions.

In order to prevent the further deterioration of the river water and to maintain the passive restoration as achieved through the COVID-19 restrictions, we need to be careful and aware of the problems associated with water pollution. The following recommendations are suggested;

- Regular monitoring and analysis of the water quality especially among the popular Ghats
- Social awareness and education regarding conservation of water;
- Improved legal and technological infrastructure for management of the wastewater.

The above-mentioned steps are mandatory to conserve and safeguard the water quality in the River Ganga basin and its tributaries. There is an urgent need for complete scenario building and understanding the need for passive restoration as visually depicted through the COVID -19 restrictions.

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