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Studies on Physicochemical Parameters to Assess the Water Quality at Selected Sites of River Hooghly, a Tributary of the Ganges, West Bengal, India

Rajib Das, Paramita Karmakar and Susanta Nath*
Post Graduate Department of Zoology, Bidhannagar College, Salt Lake, Kolkata – 700 064, India
✉ susanta_nath@yahoo.com

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Abstract: The physico-chemical characteristics of Hooghly river water and drain water falling in the same river have been studied. Five sampling stations namely, Bataghat (BATA), Bagkhal (BAGK), Baromandir ghat (BARO), Ghoshpara (GHOS), and Sakherbazar ghat (SAKH) are situated in highly populated as well as industrial belt of West Bengal, India. Sampling was done between November 2009 and June 2010 to measure transparency, dissolved oxygen, free carbon dioxide, pH, alkalinity, hardness, calcium, magnesium and salinity. Alkalinity at Bataghat river water and Baghkhal sewage water almost maintained more than desirable limit (IS: 200 mg l^{-1}) and other places maintained high alkalinity during winter. pH was almost acidic which was not desirable (IS: 6.5 to 8.5). Though dissolved oxygen maintained a desirable limit in river water, but free carbon dioxide was very high almost throughout the study period. Hardness reached upto 360 mg l^{-1} in river water at Bataghat which was more than desirable (IS: 300 mg l^{-1}). The study indicated that the Hooghly river water is polluting regularly and becoming unsuitable for aquatic animals. People who used to bathe in the river were found affected by different skin diseases and had a serious gastric problem like dysentery due to intake of the water.

Key words: Hooghly river, physicochemical analysis, water quality.

Introduction

Hooghly river system is considered as life line for the people of West Bengal. The Hooghly river, also known as Bhagirathi-Hooghly, is approximately 260 km long distribution of the river Ganges. The river divides from the Ganges as a canal near Farakka of Murshidabad district and enters in South Bengal as Hooghly. Another part enters Bangladesh as river Padma. Hooghly, the lower-most stretch of the river Ganges, forms the principal drainage line of the Kolkata (Calcutta) Metropolitan Area. While flowing through West Bengal, the river is receiving both the industrial and domestic effluents because the biggest industrial as well as densely populated areas of India are located beside the river Hooghly (Chakraborty and Gupta, 2003). Mc Dowell and Prandle (1972) have given numerical models on salinity and circulation in the Hooghly estuary. Biswas (1985) has reported that, normally, the fresh water discharges are regulated from Farakka barrage to maintain water levels at Kolkata.

Gupta et al. (2009) indicated that maximum accumulation of zinc took place in the sediment as well as fish muscle in the river Ganges at Allahabad in comparison to other metals like lead, copper etc. Joshi et al. (2009) has studied the physicochemical parameters of river Ganges and reported some parameters like pH, total dissolved solid, turbidity, sodium etc. were found to be in excess than the prescribed limit in some water samples of the study area. Cieszynska et al. (2012) analyzed water quality for a period of eight years in the Gdansk Municipality region, southern coast of

*Corresponding Author

the Baltic Sea by both basic statistical parameters and chemometric method of cluster analysis. Mishra and Dutt Tripathi (2009) discussed the use of multivariate statistical approaches to interpret a large and complex data matrix obtained during monitoring of Ganges river water in India. But the information on physicochemical characteristics of the Hooghly river is very sparse. Here an attempt has been made to fill up these lacunas.

Methodology

The study site is situated at West bank of Hooghly river (a tributary of the Ganges) of West Bengal, India ranging around 6 kms (Figure 1). Sampling was done between November 2009 and June 2010. This is an important industrial area and extended from Rishra (Bagkhal) to Uttarpara (Sakherbazar). The study site was divided into six sampling stations namely Bataghat, Bagkhal (sewage water), Baromandir ghat, Ghoshpara I (contains sewage water before mixing with river water), Ghoshpara II (contains sewage water after mixing with river water) and Sakherbazar ghat (bathing place). The site was selected due to several high-drain and *nallahs* (canals) carrying huge amount of sewage and effluents including discharge from several factories which directly fall into the river. The discharge of urban liquid wastes (sewage, storm drainage with sewage, human, cattle and kitchen wastes) is carried by drains into the river. Sometimes dead bodies carcasses of human and cattle are thrown into the river.

Some ghats are used for bathing and ritual activities like burning dead bodies in an old traditional method, cattle wallowing and washing clothes especially with detergents. Defecation and brick-kilns along the bank of the river are major reasons to choose this particular area of river Hooghly. Samples of subsurface water were collected fortnightly in the early hours of the day i.e. between 7 am and 9 am. Care was taken to avoid spilling of water and air bubbling at the time of sample collection. Some of the physicochemical characteristics of water including transparency, pH, dissolved oxygen, free carbon dioxide, total alkalinity, total hardness, salinity, calcium and magnesium were determined at the sampling stations.

Water analyses were done according to the APHA (1995). The data on the environmental variables, observed from different sites of the river Ganges was used as explanatory variables to infer about the differences among the sampling sites using multivariate statistical analysis (Discriminant function analysis, DA) (Manly, 1994; Legendre and Legendre, 1998). The DA was applied to discriminate the sampling sites and infer about the water quality of the river. The DA allowed classification of the heterogeneity in the data based on the water quality features so as to segregate the sampling sites. This helps to determine if there is

Figure 1: Map of river Hooghly showing the sampling stations.

any significant difference among the sites with regard to the various physicochemical factors of the river at the sampling sites.

Overall, the inference about the water quality of the river could be made, since the sampling sites could be considered as a longitudinal transect. The Discriminant Analysis (DA) is a multivariate technique applicable for ordering a set of observations into previously defined categories. The category of an observation is determined on the basis of bunch of predictor or input variables (physicochemical parameters). The multivariate model is constructed on the foundation of a set of observations for which the categories are known. The DA is a reverse of multivariate analysis of variance (MANOVA) in the sense that dependent variables are the groups (sites) and the predictor or input variables (the water quality parameters) are the independent variables. In MANOVA, the independent variables are the groups and the dependent variables are the predictors.

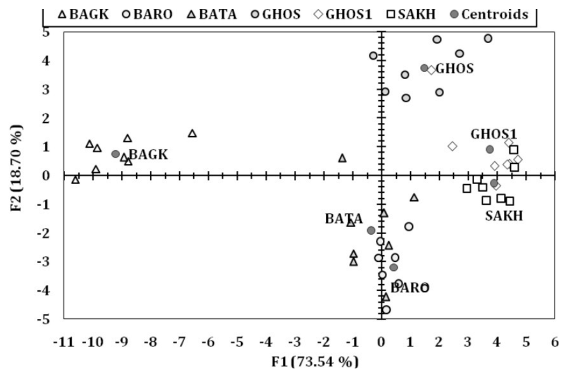
The DA is divided into two-phase study, beginning with, first, a test of significance for a determined number of discriminant functions, followed by categorization. The results of a DA can be represented through a series of tables consisting of Wilks' Lambda values, Eigen values and the corresponding percentage of variance explained by the factors and the Fishers distance among the variables. In the present context, the DA (Manly, 1994; Zar, 2009) was carried out using XLSTAT software release 10 (Addinsoft, 2010) and Origin 6.0 software.

Results

The results of the physicochemical characteristics of Hooghly river water and water falling in that river are summarized in Table 1. The boxplot representing the data on the environmental variables of the study site are shown in Figure 2.

Table 1: Results of the discriminant function analysis (DA) on the sampling sites of the water of river Ganges as dependent variables and the physicochemical factors of water as explanatory variables.

(A) The biplot showing ordination of the variables (Sampling sites) against the first two axes (F1 and F2 cumulatively accounting >92% variations of the data)



(B) Fisher distance among the variables (sampling sites)

SITES	*BAGK*	*BARO*	*BATA*	*GHOS*	*GHOS1*
BARO	**39.859**				
BATA	**33.193**	**3.018**			
GHOS	**45.947**	**18.455**	**13.522**		
GHOS1	**60.529**	**11.294**	**12.405**	**7.679**	
SAKH	**62.285**	**9.337**	**10.590**	**10.877**	1.644

(C) The Eigenvalue, % discrimination and canonical correlations against the three factors accounting for more than 97% variations in the data

	F1	*F2*	*F3*
Eigenvalue	22.104	5.621	1.565
Discrimination (%)	73.542	18.700	5.208
Cumulative %	73.542	92.243	97.451
Canonical correlation	0.978	0.921	0.781

(D) The standardized canonical discrimination function coefficients for the explanatory variables against the three factors. Highest coefficients against the factors are marked in bold.

	F1	*F2*	*F3*
Transparency	**0.742**	0.264	0.024
Salinity	**-0.963**	0.462	0.851
Alkalinity	-1.049	0.632	**0.814**
Free CO_2	**-0.401**	-0.041	-1.015
Dissolved O_2	-0.173	**-0.690**	0.188
Mg-ions	-0.008	**-0.220**	-0.049
Ca-ions	0.118	**0.341**	-0.169
Hardness	**-0.514**	-0.158	1.242
pH	**0.910**	0.812	-0.131

The values in bold indicate significance at $P < 0.05$ level. The Wilks' λ value was 0.001, $F = 11.664$; $df = 45, 155$, $P < 0.001$ suggesting significant discrimination among the sites could be achieved as shown in the biplot (A). The fishers distance (B) between the sites was significant, and the standardized discriminant functions are shown in the subsequent table (C and D). (The sites: BAGK – Bagkhal, BARO – Baromandir, BATA – Bataghat, GHOS – Ghoshpara, GHOS I – Ghoshpara I, and SAKH – Sakherbazar)

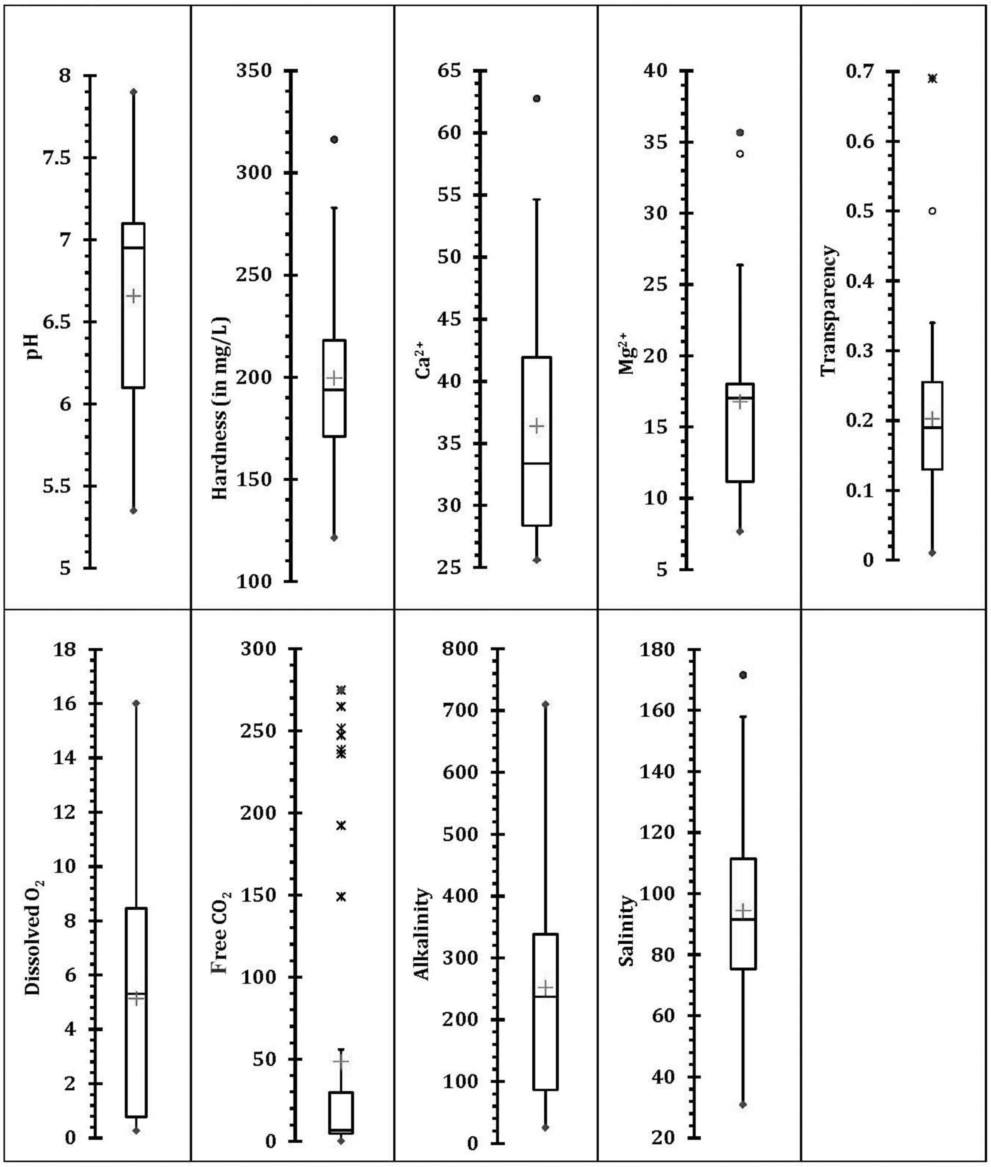


Figure 2: The boxplot representing the data on the environmental variables of River Ganges (*n* = 50).

Transparency

Transparency value varied from 18.9 cm to 68.5 cm at Bataghat with high transparency in June and low transparency in March (Figure 3). In Baromandir and Sakherbazar ghat transparency ranges between 18.90 cm and 38 cm and 12 cm to 29.10 cm respectively with high transparency in June and low transparency in March and April. In Ghoshpara, transparency ranges between 10.7 cm and 49.5 cm with high transparency in May and less transparency in June, whereas 1.60 cm to 6.7 cm transparency was observed in Bagkhal with highly transparent water in February and low transparency between November and January.

The intensity of sunlight, suspended soil particles, turbid water received from catchment area and density of plankton etc. are the causes of transparency or light penetration (Mishra and Saksena, 1991; Singh, 1999; Kulshreshtha and Sharma, 2006). Total solids partly and fully decomposed organic matters, silts and turbulence caused by the currents, waves, human and cattle activities also affect the transparency of river water (Singh and Rai, 1999). Water transparency indicates higher values during winter and summer seasons, whereas lower values are evident in monsoon season. The values were less in monsoon season due to high current which erodes the bank of the river and due to turbid flood water, suspended matter and dissolved particle. Present study revealed that the water was highly transparent at Bataghat, Baromandir and Sakherbazar from June when monsoon started in the area. This is in conformity with Singh and Rai (1999), who recorded high value of transparency in late post-monsoon and winter months as has also been observed by Nath and Srivastava (2001) and Shaikh and Yeragi (2004). Whereas Ghoshpara drain water showed high transparency value during monsoon rather than post-monsoon season probably due to huge amount of waste water carried by this drain.

Dissolved Oxygen

Dissolved oxygen (DO) at Bataghat ranged between 4.69 mg l^{-1} and 16.27 mg l^{-1} with minimum in December and maximum in April (Figure 4). Water of Baromandir ghat exhibit minimum (5.58 mg/l) during the month of November and maximum (13.20 mg/l) in April. The DO content at Sakherbazar ghat was minimum in May (4.01 mg/l) and 10.04 mg/l maximum in February. The high dissolved oxygen content in February is due to low water temperature and minimum DO in May is due to maximum water temperature and increased decomposition of dead aquatic vegetation. In all these three study sites DO reached maximum level during April-May when the water temperature is high. Sahu et al. (2000) reported that oxygen is generally reduced in the water due to rise in temperature, respiration of biota and decomposition of organic matter.

Ghoshpara and Bagkhal sewage water revealed 0.27 mg/l to 0.88 mg/l DO content almost throughout the year and that was probably due to brick-kiln and township (Hindmotor region) sewage and effluent water directly fall into the river without any treatment. Bagkhal is a large *nallah* (canal) and effluents of factories, *dhabas* (restaurant) and households are carried and enter into the river directly. Inorganic reducing agents such as hydrogen sulphide, ammonia, nitrites, ferrous iron and certain oxidizable substances also tend to decrease dissolved oxygen in water (Sahu et al., 2000). Water of river Hooghly in this region has DO content which is more than the value (3 mg l^{-1}) as suggested by Tarzwell (1957) which is necessary for healthy fish and other aquatic life. But the effluents water which is falling in this river is not suitable for healthy aquatic life.

Free Carbon Dioxide

Free CO_2 content of Hooghly River at Bataghat ranged from 0.16 to 149.03 mg l^{-1} with minimum in April to June and maximum in November-December (Figure 5). The free CO_2 at Baromandir ghat ranged from 2.11 to 6.13 mg l^{-1} with minimum in January and June and maximum in April. Free CO_2 at Sakherbazar ghat ranged from 1.67 to 5.39 mg l^{-1} with minimum in June and maximum in March. Free CO_2 at Ghoshpara I (before releasing in Hooghly river) ranged from 16.21 to 30.33 mg l^{-1} and Ghoshpara II (after releasing in Hooghly river) 4.94 mg l^{-1} to 16.15 mg l^{-1}. So the study revealed that the water in the Ghoshpara area have high content of free CO_2 almost throughout the year. Bagkhal water contained 45.93 to 274.75 mg l^{-1} of free carbon dioxide and maintained such high value throughout the year and also maintained low dissolved oxygen level. The present study also suggested an inverse relationship between dissolved oxygen and free carbon dioxide ($y = 6.354 - 0.02438x$; $r = 0.509$; $t = 5.705$; $p < 0.05$).

Alkalinity

The total alkalinity at Bataghat ranged from 216 to 329.25 mg l^{-1} with minimum in April and maximum in February (Figure 6). The total alkalinity at Baromandir ranged from 42.5 to 271.75 mg l^{-1} with minimum in March and maximum in January. The alkalinity at Sakherbazar ranged from 25.25 to 211.75 mg l^{-1} with minimum in June and maximum in January. The alkalinity at Ghoshpara I waste water ranged from 65.5 to 384.25 mg l^{-1} with minimum in April and maximum in March and at Ghoshpara II ranged from 26.5 to 365.75 mg l^{-1} with minimum in May and maximum in March. The study revealed that the value was high during winter and gradually decreased with onset of spring. The alkalinity is directly related to the abundance of phytoplankton which dissociate bicarbonate into carbonates and carbon dioxide which is used in photosynthesis (Shrivastava and Patil, 2002). The alkalinity at Bagkhal ranged from 406.5 to 709.75 mg l^{-1} with minimum in November and maximum in June. The alkalinity of water is caused mainly due to stagnancy of water and the settlement of waste material and soil particles in Bagkhal. With the onset of rainy seasons the alkalinity was low due to dilution effect through rain water. Singh and Rai (1999) had recorded similar seasonal variation in river Ganges at Varanasi. The natural water bodies in tropics exhibit wide range of fluctuation in total alkalinity values (Jhingran, 1991).

Hardness, Calcium and Magnesium

The hardness varied at Bataghat from 115.4 to 360 mg l^{-1} with calcium content from 28.15 to 35.5 mg l^{-1} (Figure 7) and magnesium content from 10.3 to 11.93

mg l^{-1} (Figure 8). It showed a gradual decrease from November to June. The hardness varied at Baromandir ghat from 102.6 to 200.3 mg l^{-1} and gradually decreased from November to June (Figure 9). Calcium varied from 25.11 to 29.2 mg l^{-1} and gradually decreased from March to June. Hardness ranged from 129.5 to 193.5 mg l^{-1} at Sakherbazar ghat. It was found to gradually decrease from November to June. Calcium ranged from 32.17 to 37.8 mg l^{-1}. There was gradual decrease in calcium content from March to June.

The present study revealed that hardness of water remains higher throughout the year but it was maximum in November to December and then gradually decreased. But the average hardness remains higher than normal condition probably due to the fact that in winter the water level remains very low in comparison to summer and monsoon. The uses of detergents for washing clothes might be the probable reason to keep high hardness along with calcium and magnesium throughout the year in this region. Similar observation was done by Sinha and Das (1997) who studied the physicochemical parameters of river Ganges near Patna. Hardness at Ghoshpara effluent and sewage water ranged from 245.3 to 250.3 mg l^{-1} from November to June. Calcium ranged from 50.3 (March) to 56.16 mg l^{-1} (June). Magnesium ranged from 27.83 to 33.88 mg l^{-1} and almost similar from March to June. Hardness at Ghoshpara Hooghly almost remains similar from November to April (198.9 to 200 mg l^{-1}). The decreasing patterns were observed from May to June. Calcium ranged from 32.15 to 42.15 mg l^{-1} and showed gradual decrease from March to April. Magnesium remains almost similar between 17 and 18.74 mg l^{-1} throughout the year. Hardness ranges between 169.5 and 251.3 mg l^{-1} in Bagkhal sewage water. Calcium ranged from 26.2 to 29.56 mg l^{-1} and magnesium varied from 17 to 18.51 mg l^{-1} and was found to slightly decrease between March and June. Decreasing pattern in hardness along with calcium and magnesium in May and June was probably due to rainfall during those time.

Gray (1994) revealed that hardness ranged between 150 and 250 mg l^{-1} which indicated a moderately hard water. The present study also showed a moderate hardness of Hooghly river water in this region. In monsoon there was a decreasing pattern of hardness observed. Maybeck and Helmer (1989) has reported that average calcium and magnesium content of river were 13.43 mg l^{-1} and 3.15 mg l^{-1} respectively. The present study revealed that calcium and magnesium content of river Hooghly ranged from 25.11 to 42.16 mg l^{-1} and magnesium ranged between 7.33 and 18.2 mg l^{-1} respectively and comparatively higher than the normal. Statistical analyses also revealed that there were significant relationship ($p < 0.05$) between hardness and calcium and magnesium (Table 1). The concentration of calcium and magnesium was higher than the normal level due to the presence of large amount of industrial effluents which directly enter into the river Hooghly by different sewage and drainage system of the study sites.

Salinity

In Bataghat salinity of river water varied from 47.7 to 116.23 mg l^{-1}. In Baromandir, salinity ranged from 68.23 to 113.12 mg l^{-1} (Figure 10). In Sakherbazar ghat salinity varied from 43.45 to 117.43 mg l^{-1} and was found to increase from November to June. The salinity at Ghoshpara I sewage water varied from 78.1 to 160.03 mg l^{-1} and Ghoshpara II Ganges ghat the salinity varied from 29.41 mg l^{-1} to 106.93 mg l^{-1} that is salinity decreased when mixed with the river water. During winter salinity in Baromandir, Ghoshpara ghat was low whereas, with the onset of spring and summer high salinity was recorded.. Joshi et al. (2009) revealed that physicochemical parameters were changed with the change of the season. In Bagkhal salinity ranged from 85.2 to 172.67 mg l^{-1}. This study area contained high amount of salinity throughout the year. This is probably due to sewage water, industrial effluents and other household wastes from most part of Konnagar town flowing through the drain and maintained a high salinity throughout the year. Livingstone (1963) has reported that the global mean salinity of river water was 120 mg l^{-1}. In the present study the maximum salinity was reported 172.67 mg l^{-1} in Bagkhal which is directly falling in river Hooghly. This high salinity in the effluents in this area reflects a very high amount of organic waste of animal origin along with municipal and industrial wastes as reported by Saksena et al. (2008) in case of river Chambal.

Conclusions

When the results of the present study was compared with that of Indian standards (IS:1991) for public water supply, fish culture and irrigation, it was revealed that all such parameters were not within the limits. Alkalinity at Bataghat river water and Baghkhal sewage water almost maintained more than desirable limit (200 mg l^{-1}). Moreover, other places maintained high alkalinity during

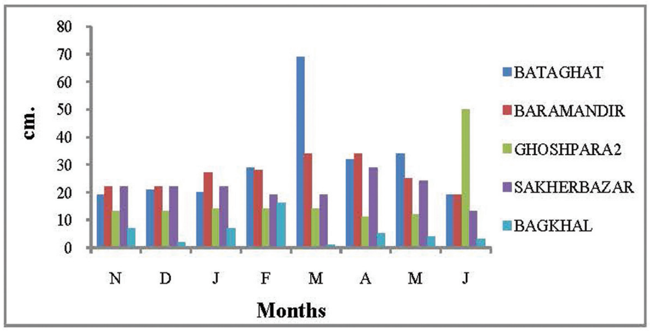


Figure 3: Transparency.

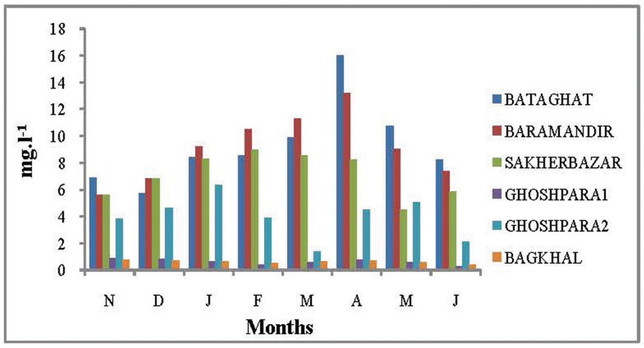


Figure 4: Dissolved oxygen.

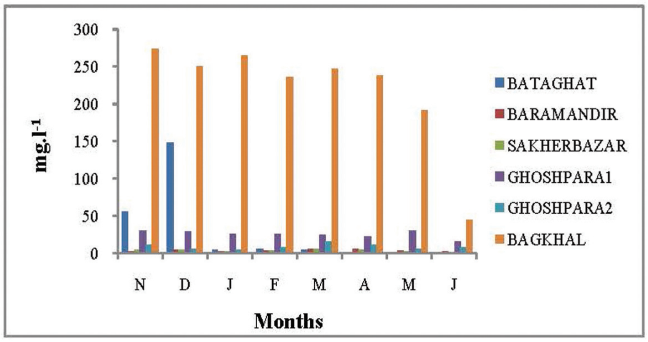


Figure 5: Free carbon dioxide.

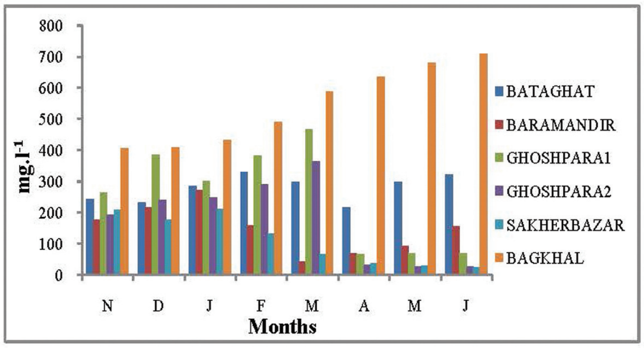


Figure 6: Total alkalinity.

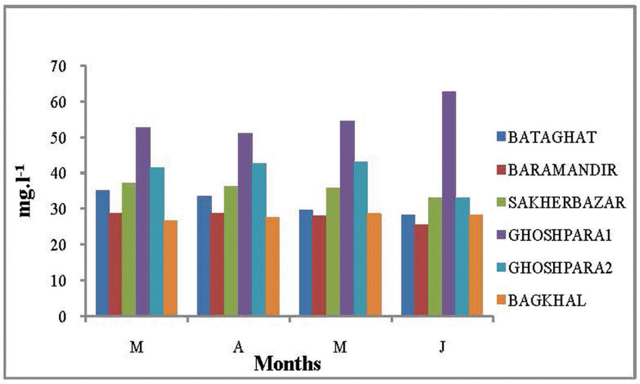


Figure 7: Calcium.

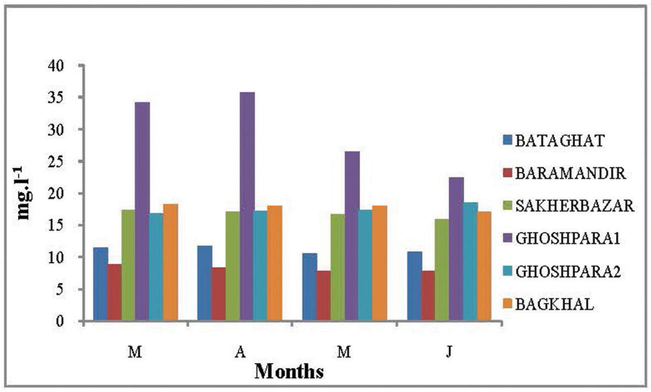


Figure 8: Magnesium.

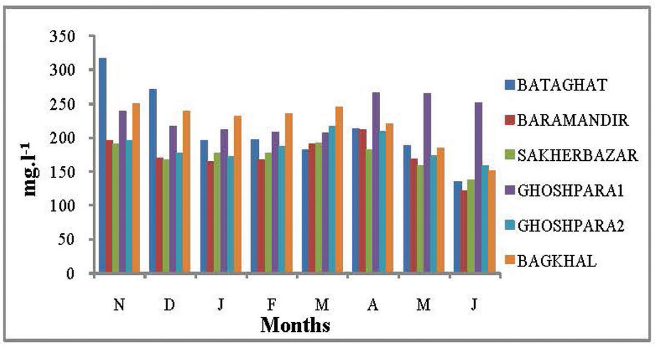


Figure 9: Total hardness.

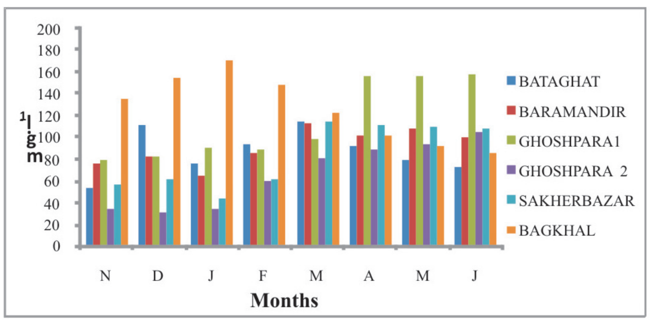


Figure 10: Salinity.

winter. pH was almost acidic which was not desirable (6.5 to 8.5). Though dissolved oxygen maintained a desirable limit in river water, but free carbon dioxide was very high almost throughout the study period. Hardness was sometime found to reach 360 mg l^{-1} which was more than desirable (300 mg l^{-1}). The water characteristics considered for the study indicated that the Hooghly river water is polluting regularly and becoming unsuitable for aquatic animals.

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References

Addinsoft (2010). software.informer.com.

APHA (1995). Standard methods for the examination of water and waste water. 19th Edn. American Public Water Health Association, Washington DC.

Biswas, A.N. (1985). Geohydro-morphometry of Hooghly estuary. *J. Inst. Eng. (India)*, **66:** 61-73.

Chakraborty, D. and T.K. Gupta (2003). Rapid estimation of major wastewater discharges to river Hooghly between the stretch of Palta to Dhankheti khal. West Bengal Pollution Control Board, 1-19.

Cieszynska, M., Wesolowski, M., Bartoszewicz, M., Michalska, M. and J. Nowacki (2012). Application of physicochemical data for water-quality assessment of watercourses in the Gdansk Municipality (South Baltic coast). *Environ. Monit. Assess*., **184:** 2017-2029.

Gray, N.F. (1994). Drinking Water Quality. John Willey & Sons Ltd., England.

Gupta, A., Rai, D.K., Pandey, R.S. and B. Sharma (2009). Analysis of some heavy metals in the riverine water, sediments and fish form river Ganges at Allahabad. *Environ. Monit. Assess.*, **157:** 449-458.

IS (1991). Tolerance Limits for Inland Surface Waters Subject to Pollution (IS-1055: 1991), New Delhi, India.

Jhingran, V.G. (1991). Fish and Fisheries of India. 3rd Edn. Hindustan Publishing Corporation (India), New Delhi.

Joshi, D.M., Kumar, A. and N. Agarwal (2009). Studies on physicochemical parameters to assess the water quality of river The Ganges for drinking purpose in Haridwar District. *Rasayan J. Chem*., **2(1):** 195-203.

Kulshrestha, H. and S. Sharma (2006). Impact of mass bathing during Ardhkumbh on water quality status of river The Ganges. *J. Environ. Biol*., **27:** 437-440.

Legendre, P. and L. Legendre (1998). Numerical ecology, 2nd English Edn. Elsevier Science BV, Amsterdam.

Livingston, D.A. (1963). Chemical composition of rivers and lakes. Data of Geochemistry U.S. Geol. Surv., **440-G:** 64.

Manly, B.F.J. (1994). Multivariate Statistical Methods:A Primer. 2nd Edn. Chapman & Hall, London.

McDowell, D.M. and D. Prandle (1972). Mathematical model for river Hooghly. *J. Waterways and Harbour Division ASCE*, **98:** 225-242.

Mishra, A. and B. Dutt Tripathi (2009). Ecological investigation of the Ganges river using Principal Component Analysis. *Evironmental Quality Management*. www.interscience.wiley.com.

Mishra, S.R. and D.N. Saksena (1991). Pollutional ecology with reference to physicochemical characteristics of Morar (Kalpi) river, Gwalior (M.P). *In:* Current trends in limnology (ed., N. K. Shastree). Narendra Publishing House, Delhi, India.

Maybeck, M. and R. Helmer (1989). The quality of rivers, from pristine stage to global pollution. *Palaeogerge. Palaeoclimatol. Palaeoecol*., **75:** 283-309.

Nath, D. and N.P. Srivastava (2001). Physico-chemical characteristics of Narmada for the stretch Sandia to Mola in MP state in the context of construction of reservoirs on the river or its tributaries. *J. Inland Fish. Soc. India*, **33:** 17-24.

Sahu, B.K., Rao, R.J., Behara, S.K. and R.K. Pandit (2000). Effect of pollutions on the dissolved oxygen concentration of river The Ganges at Kanpur. *In:* Pollution and Biomonitoring of Indian Rivers (ed., R.K.Trivedy). A B D Publication, Jaipur, India.

Saksena, D.N., Garg, R.K. and R.J. Rao (2008). Water quality and pollution status of Chambal river in National Chambal sanctuary, Madhya Pradesh. *J. Eviron. Biol*., **29(5):** 701-710.

Shaikh, N. and S.G. Yeragi (2004). Some physico-chemical aspects of Tansa river of Thane district, Maharastra. *J. Aqua. Biol*., **19:** 99-102.

Singh, H.P. (1999). Limnochemistry of river The Ganges and some of its major tributaries. *J. Inland Fish. Soc. India*, **31:** 31-35.

Singh, B.N. and S. Rai (1999). Physico-chemical studies of The Ganges river at Varanasi. *J. Environ. Pollut*., **6:** 43-46.

Sinha, R.K. and N.K. Das (1997). Ecological imbalances in river The Ganges. *In:* Recent Advances in Ecobiological Research. Vol. 1 (ed., M.P. Sinha), A.P.H. Publishing Corporation, New Delhi.

Shrivastava, V.S. and P.R. Patil (2002). Tapti river water pollution by industrial wastes: A statistical approach. *Nat. Environ. Pollut. Tech*., **1:** 279-283.

Tarzwell, C.M. (1957). Biological problems in water pollution. U.S. Department of Health Education and Welfare P.H.S.

Zar, J.H. (2009). Biostatistical Analysis. 4th edn. Pearson Education, New Delhi.