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ORIGINAL ARTICLE

Physico-Chemical Properties and Correlation Co-Efficient of River Ganga at Allahabad

***Divya Raghuvanshi , Harendra Singh *, Rubi Pandey*, Beenu Tripathi and D.N. Shukla**
Bhargawa Agricultural Laboratory, Department of Botany, University of Allahabad,Allahabad, India-211002
E-mail:divyaraghuvanshi11@gmail.com

ABSTRACT
This paper is an attempt to analyse the water quality of river Ganga in Allahabad district. Water samples were collected from RasoolabadGhat to ChatnaagGhat from five sampling sites in the year 2012-2013. Ten water quality parameters for all the sites were estimated by adopting the standard methods and procedures.The results revealed that the average pH value was measured as 8.07±0.44 mg/L, Electrical Conductivity was 188.49±63.00 µmho-cm^{-1}, Dissolved Oxygen was 6.47±0.82 mg/L,Biochemical Oxygen Demand was 9.41±1.41 mg/L, Chemical Oxygen Demand was 15.28±3.07 mg/L,Total Hardness was 118.56 ±40.91 mg/L,Total Alkalinity was 168.46±12.50mg/L, Chloride was 27.49±16.97 mg/L and Total Dissolved Solids was 216.83±13.84mg/L. Comparison of estimated values with WHO and USPHS standards revealed that water of study area is polluted which may be harmful for aquatic bio-system and human beings.So water quality management is urgently required to achieve the water quality standards determined by WHO and USPHS. Correlation coefficient showed highly significant positive and negative relationship (p<0.05 level).
Keywords: *Ganga; Allahabad; Physico-chemical parameters; Water quality; Seasonal variations; Correlation coefficient*

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INTRODUCTION

All great civilizations in world have evolved around the rivers [1,2]. Rapidly increasing population, indiscriminate urbanization and rapid industrialization along the rivers have put tremendous pressure on water resources and their quality[3,4].Water quality monitoring has one of the highest priorities in environmental protection policy [5].The quality of water is identified in terms of its physico-chemical parameters[6,7,8,9,10]. The healthy aquatic ecosystem is depended on the physico-chemical and biological characteristics [11].

Allahabad (25.45°N 81.85°E) is also called as *Tirtha-Raja* which means 'king of all holy places', as it is the site of confluence of three rivers Ganga,Yamuna and invisible SaraswatiRiver.It has 58 large scaled and 3,000 small scaled industries [12]. The main sources of pollution in river Ganga at Allahabad are industrial effluents, domestic sewage, and disposal of dead bodies [13].

The present work intends to assess the pollution status of River Ganga at Allahabad by estimating and comparing the physico-chemical properties of water at different sites along the river.

STUDY AREA

The study covers stretch of Ganga from RasoolabadGhatto Chatnaagpassing through the Sangam area of the Allahabad district.

RasoolabadGhat

This sampling site is situated at upstream where the river enters into the domain of city of Allahabad. The sources of pollution at this site are cremation, disposal of untreated sewage, washing of clothes on *dhobhighat*, agricultural run-off, temple's solid waste disposal etc.

DaraganjGhat

It is situated at downstream of RasoolabadGhat, on the left bank of the river. This site is known for having big and glorious temples on its bank. Many drains like Saloridrain, Govindpurdrain, and Mori drain find

their way directly near to this site. Other sources of pollution at this site are cattle wallowing, agricultural run-off, mass bathing, *dhobighat*, flower offerings etc.

Ram Ghat

This site is situated at downstream of DaraganjGhat, on the left bank of the river. This site is also known for having many big temples. The main sources of pollutionat this site are open drains carrying untreated domestic sewage from Jhunsi area, religious fairs on its bank, garlands and flower offerings.

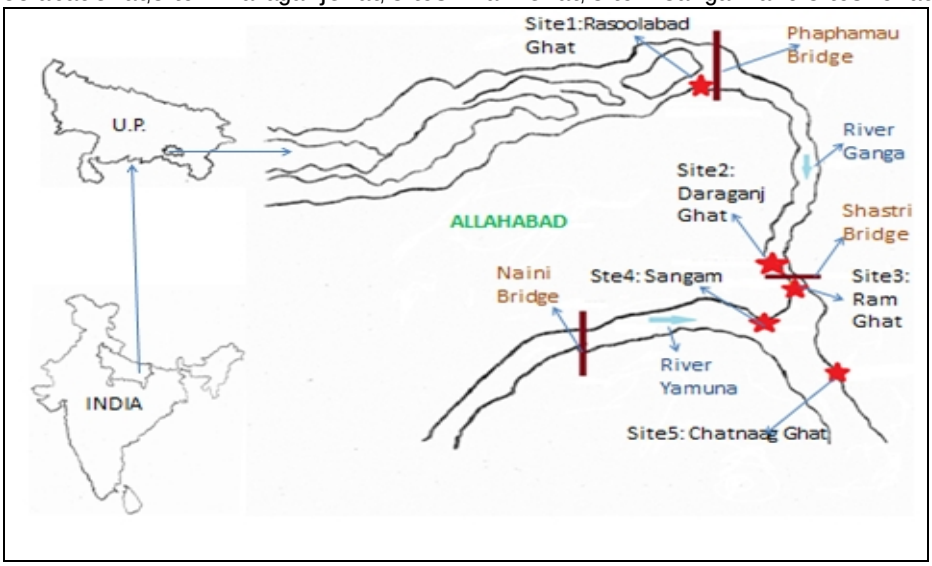
Sangam

This site is situated at the confluence point of River Yamuna, Ganga and invisible Saraswati. Because of this rare occurrence, this site is known for the huge fair *'KumbhMela'* organized every year due to it's great religious value. People from all over the world come here to have a holy dip. Main source of pollution at this site are mass bathing, flower offerings, cremation activities and religious fairs.

ChatnaagGhat

At this site river leaves the city and carries water of both the rivers Yamuna and Ganga. This site is situated at the downstream of river Ganga after the *Sangam.* This site is also used as the crematorial ground. Cattle wallowing are a common picture here. This site also receives untreated sewage and agricultural run-off.

Fig: 1. Study area showing five sampling sites along the River Ganga in Allahabad. Site1=RasoolabadGhat,Site2=DaraganjGhat, Site3= Ram Ghat, Site4=Sangam and Site5=ChatnaagGhat.



MATERIALS AND METHODS

Collection and Analysis of sample of River water

Depending on the locationand the level of pollution five sampling sites were selected along the River Ganga in Allahabad city*viz*: RasoolabadGhat, DaraganjGhat, Ram Ghat, Sangam and ChatnaagGhat. The Water samples were collected in triplicates in 5 litre plastic containers cleaned thoroughly and rinsed with distilled water. The seasonal sampling was conducted from December 2012 to July 2013. The water samples were collected during winter, summer and rainy seasons from 6 inches depth at 8:00am to 10:00am from five sampling sites. pH, temperature and conductivity were estimated on the spot by automated water analysis kit-ITS-701. For the analysis of Dissolved oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, total hardness, total alkalinity, chloride and total dissolved solids the samples were brought to the laboratory in ice-boxes. Standard methods [14] for the examination of water and waste-water was followed.The samples for the determination of DO were collected in BOD bottles and they were fixed at site and brought immediately to laboratory and analysed by modified Winkler'smethod.

Statistical analyses:

- Pearson's coefficient of correlation (r) between various parameters at each sampling site using the formula:
  The relationship between two parameters x and y is determined by the Karl Pearson's correlation coefficient, r and it is determined as follows:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[\, n\Sigma x^2 - (\Sigma x)^2 \,][\, n\Sigma y^2 - (\Sigma y)^2 \,]}}$$

here, n = number of data points ; x = values of x–variable ; y = values of y–variable

To study the correlation between various water quality parameters, computer software SPSS, version–16.0 was used.Pearson's correlation only provides information about the direction and strength of the ***linear relationship*** between the two variables.The correlation coefficient indicates positive and negative significant correlation of physico-chemicalparameters with each other. A Positive correlation is a relationship between two variables such that their values increase or decrease together. While, in a negative correlation as the value of one variable increases, the other decreases.

- Mean: or the average is the sum of observations divided by the number of observation using Microsoft Excel 2010.
- Standard Deviation: It shows how much variation or dispersion about the average exists. A low standard Deviation indicates that the data points tend to be very close to the mean, a high standard deviation indicates that the data points are spread out over a large range of values using Microsoft Excel 2010.

RESULTS AND DISCUSSION

Variations in physico-chemical properties of River Ganga in summer, winter and rainy seasons at all the considering sites are presented in Table1 whereas the correlation coefficients (r) among the average of each parameters are presented in Table2 .

Table 1: Site wise results of the physico-chemical parameters of river Ganga at Allahabad (During December' 2012-July' 2013)

Parameter	Site1: Rasoolabad Ghat			Site2: Daraganj Ghat			Site3: Ram Ghat			Site4: Sangam			Site5: Chatnaag Ghat			Avg.±SD	Permissible limit	Standards
	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W			
Temp.(°C)	31.3	28.6	26.2	32.5	28.5	25.7	30.8	27.6	24.6	30.9	25.2	24.2	31.2	27.5	25.7	28.03± 2.66	-	-
pH	8.8	7.6	8.2	8.2	7.5	8.0	8.5	7.4	8.1	8.7	7.5	8.4	8.2	7.6	8.3	8.07±0.44	6.5-8.5	USPHS[15]
EC(µmho-cm^{-1})	220.6	296.0	197	188.7	278	145.9	129.9	245.6	119.2	129.3	256.3	100.6	147.9	249.65	122.7	188.49±63.0	300	USPHS
DO(mg/L)	4.7	5.7	6.05	6.0	6.4	7.0	6.3	6.9	7.1	5.4	6.1	7.9	6.9	7.1	7.5	6.47±0.82	4.0-6.0	USPHS
BOD(mg/L)	12.6	11.9	9.2	10.4	8.7	7.8	10.1	9.2	8.7	10.2	8.9	8.6	9.4	8.4	7.0	9.41±1.41	5.0	USPHS

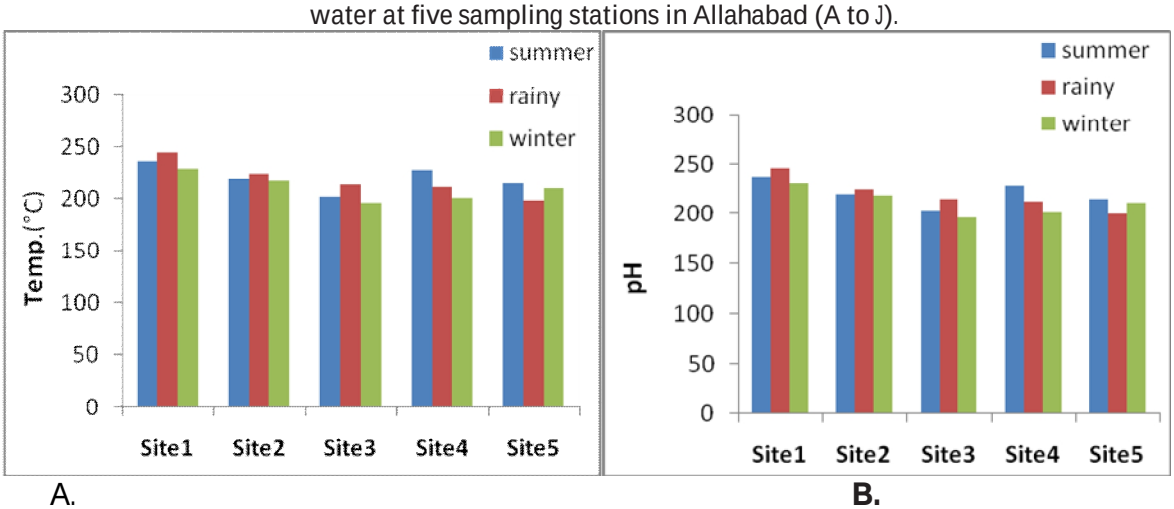
TDS(mg/L)	Cl^- (mg/L)	TA(mg/L)	TH(mg/L)	COD(mg/L)
USPHS	USPHS	-	WHO[16]	USPHS
500	250	-	500	4.0
216.83±13.84	27.49±16.97	168.46±12.50	118.55±40.91	15.28±3.07
210.5	17.9	179.4	70.2	10.9
199.0	10.9	157.8	83.2	11.1
215.0	33.7	167.5	99.6	11.9
201.0	21.1	182.7	67.9	12.7
212.0	11.5	154.7	92.7	14.3
228.0	51.13	185	101.3	15.6
196.0	19.0	164.7	89.6	14.8
214.0	10.9	152.9	96.5	15.4
202.0	47.2	180.3	114.6	16.9
218.0	22.2	161.2	127.4	13.5
225.0	11.6	150.7	163.7	15.7
220.0	54.2	169.6	199.4	16.2
230.0	27.6	176.2	112.0	18.2
245.0	12.6	154.9	177.2	19.5
237.0	60.8	189.3	183.0	22.5

Table 2: Two-tailed Pearson'sCorrelation coefficient values among the studied physico-chemical parameters of the river Ganga at Allahabad.

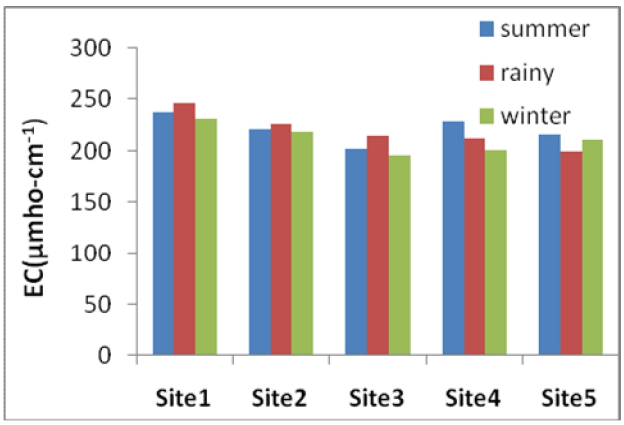
Parameters	Temp	pH	EC	DO	BOD	COD	TH	TA	Cl^-	TDS
Temp	1									
pH	.430	1								
EC	.038	-.886	1							
DO	-.980	-.244	-234	1						
BOD	.986	.274	.204	-1.000*	1					
COD	.995	.334	.141	-.996	.998*	1				
TH	.952	.134	.341	-.994	.990	.979	1			
TA	.367	.998*	-916	-.177	.207	.269	.066	1		
Cl	.811	.877	-554	-.679	.702	.746	.594	.842	1	
TDS	.858	-.096	.547	-.942	.931	.906	.974	-164	.394	1

*. Correlation is significant at the 0.05 level (2-tailed).

Fig: 2. Graphical representation of seasonal variations in physico-chemical properties of river Ganga water at five sampling stations in Allahabad (A to J).



A. B.



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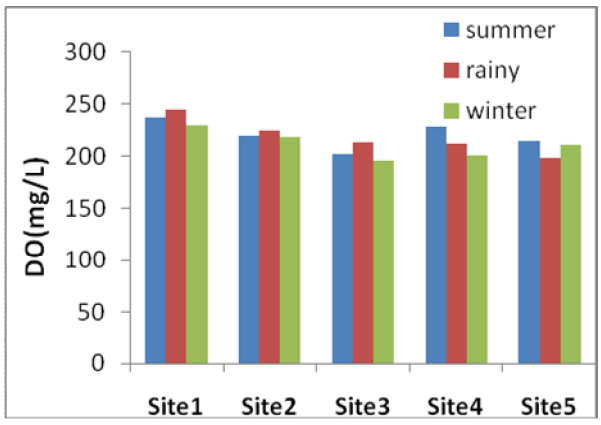

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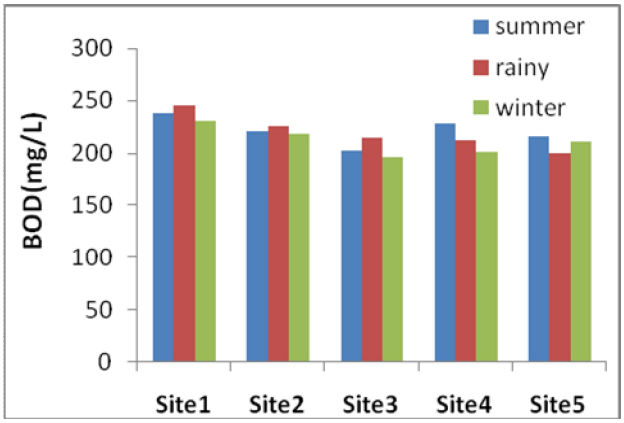

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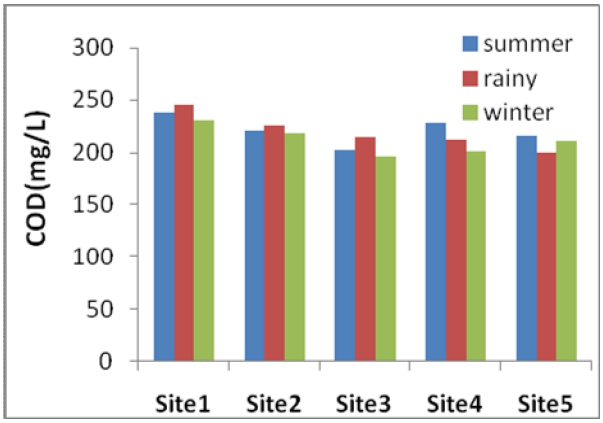
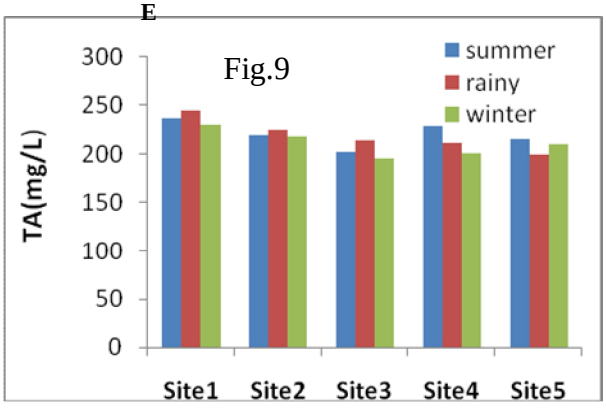


F

Fig.9



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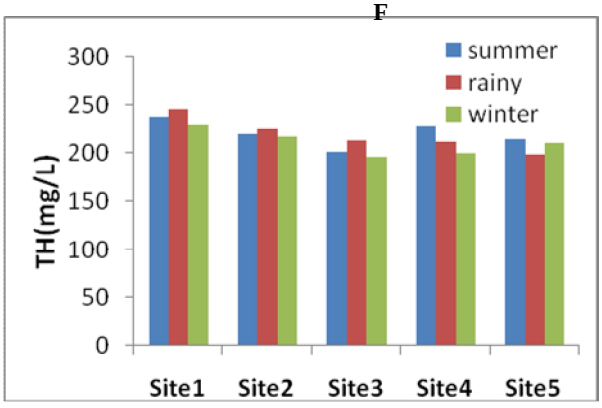

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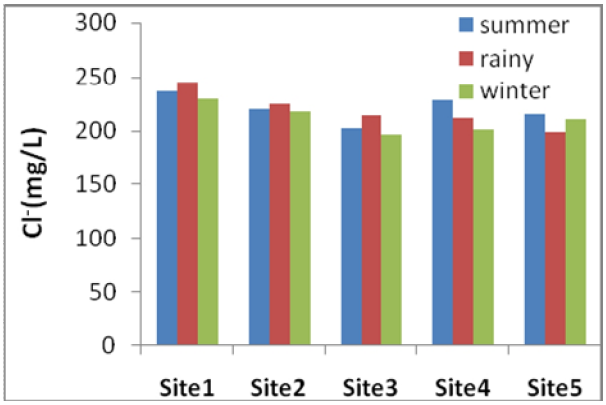

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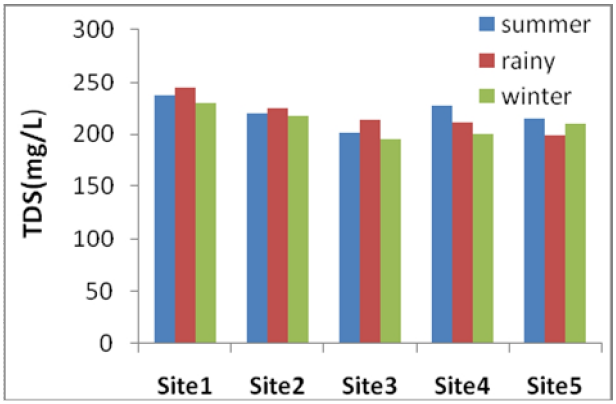

J

Temperature

Water temperature is very important parameter, because it influences the biota in a water body by affecting activities such as behaviour, respiration and metabolism. In the present investigation the recorded temperature was in the range from a minimum of24.2°Cat Site 4 during winter season to the maximum of 32.5 °Cat Site 2 during the summer season and its average was 28.03±2.66 mg/L (Table1 and Fig.2-A). It was observed that the temperature was highest during the summer followed by rainy and winter seasons.

Similar results were observed by 17. The high temperature during the summer season is due to the low water level, high air temperature and clean atmosphere.

pH

In natural waters, pH usually ranges from 6 to 9. In the present investigation, the value of pH was in the range from a maximum of 8.8 at Site 1 during the summer season to a minimum of 7.4 at Site 3 during the rainy season and its average was 8.07±0.44 mg/L(Table1 and Fig.2-B). Seasonally the pH was highest in summer followed by winter and rainy season. Similar results have been observed by 17 and 18.High pH of water in the summer may be attributed to the utilization of free carbon dioxide in algal photosynthesis resulting in high algal population[19].

EC (Electrical Conductance)

EC is reciprocal to electrical resistance and G values shows total ion per cm. It is numerical expression of the ability of a water sample to carry an electric current. EC was minimum of 100.6 µmho-cm^{-1} at site 4 during the winter season and maximum of 296.0 µmho-cm^{-1} at site 1 during the rainy season and the average was 188.49±63.00 µmho-cm^{-1}(Table1and Fig.2-C)**.** EC was found minimum in winter, maximum in rainy and intermediate in summer season. Similar results have been observed by [17].

DO (Dissolved Oxygen)

It is the amount of oxygen dissolved per litre volume of the water. The DO values may range from a minimum of 4.7 mg/L at site 1 during summer season to a maximum of 7.9 mg/L at site 4 during the winter season. The overall mean was 6.47±0.82 mg/L (Table1 and Fig.2-D).

Seasonally, the DO was highest in winter season, lowest in summer season and intermediate in monsoon season. Similar results were reported by [17and 18]. According to [17 and 20], the lower value of DO during summers is due to high temperature and high rate of microbial growth and activity.

BOD (Biochemical Oxygen Demand)

BOD has been used as a measure of the amount of organic materials in an aquatic solution which supports the growth of micro-organisms[21]. In the present investigation the value of BOD ranged from a minimum of 7.0mg/L at site 5 during the winter season to a maximum of 12.6mg/L at site 1 during the summer season and its average was 9.41±1.41 mg/L(Table1 and Fig.2-E). Seasonally, BOD was maximum during the summer season, minimum during the winter season while intermediate during the rainy season. Similar results have been observed by 20. Higher value of BOD indicates a higher level of organic pollution and thus higher consumption of dissolved oxygen.

COD (Chemical Oxygen Demand)

COD determines the amount of oxygen required for chemical oxidation of organic matter using potassium dichromate under reflux conditions. The value of COD ranged from a minimum of 10.9 mg/L at site 5 during the winter season to a maximum of 22.5mg/L at site 1 during the summer season and its average was 15.28±3.07 mg/L(Table1 and Fig.2-F)**.** Seasonally, COD value was highest in summer followed by rainy then winter. Similar results have been recorded by [17 and 22].

TH (Total Hardness)

Hardness is the capacity of water for reducing and destroying the lather of soap. It is total concentration of calcium and magnesium ions.Temporary hardness in water is attributed to bicarbonates of Calcium and Magnesium, while the permanent hardness is due to the sulphates, chlorides and nitrates of calcium and magnesium.In the present investigation, the value of total hardness at all the sites was in the range of 67.9mg/L at site 4 during the winter season to a maximum of 199.4mg/L at site 2 during the summer season and its average was 118.56 ±40.91 mg/L(Table1 and Fig.2-G).Seasonally the hardness was found highest during the summer season, lowest in winter and intermediate in rainy season. Similar results have been observed by [18].

TA (Total Alkalinity)

It is the capacity to neutralize acid. Alkalinity is due to the presence of carbonates, bi-carbonates and hydroxide compounds of Ca, Mg, Na and K. TA was in the range of 150.7mg/L at site 2during the rainy season to a maximum of 189.3mg/L at site 1 during summer season and its average was 168.46±12.50mg/L(Table1 and Fig.2-H).

Seasonally, TA was maximum during the summer, minimum in winter while intermediate during the rainy season. Similar seasonal variations have been observed by [17]. TA was lowest in the rainy season due to the dilution of water in comparison to summer and winter season.

Cl^- (Chloride)

Main sources of chloride in river waters are sediments, sewage and industrial effluents. The ecological significance of chloride lies in its potential to regulate salinity of water and exert consequent osmotic stress on biotic communities. The observed chloride level was in the range of 10.9 mg/L at site 5 during rainy season to a maximum of 60.8 mg/L at Site 1 during the summer season and its average was 27.49±16.97 mg/L(Table1 and Fig.2-I).Seasonally the values of chloride were maximum during summer season, minimum during rainy season and intermediate during winter season. Similar results have been observed by [17, 22, 23 and 24]showed that higher concentration of chloride is associated with increased level of pollution.

TDS (Total Dissolved Solids)

Solid refers to suspended and dissolved matter in water. They are very useful parameters describing the chemical constituents of the water and can be considered as general of edaphically relation that contributes to productivity within the water body.[25]

TDS was recorded minimum at Site 3 as 196.00mg/L during the winter season to a maximum of 245.00mg/L at site 1 during the rainy season and its average was 216.83±13.84mg/L(Table1 and Fig.2-J). Seasonally,TDS was highest in rainy and lower in winter and the intermediate values were recorded in summer season.Similar observations have been made by [17]. The high value of TDS during the rainy season is probably due to the agricultural run-off and water-erosion. Higher concentration of total solids in water is undesirable as it reduces euphotic zone, light penetration, transparency and thus interferes with plankton community and primary productivity of the river and creates imbalance for aquatic life[19].

Correlation (r) between different parameters

In the present study the correlation coefficient (r) between every parameter pairs is computed by taking the seasonal average values of each parameter at all the sites as shown in table-2. Correlation coefficient (r) between any two parameters, x & y is calculated for parameter such as water temperature, pH, electrical conductivity, dissolved oxygen and biochemical oxygen demand, chemical oxygen demand, total hardness, total alkalinity, chloride and total dissolved solids of the river Ganga. The degree of linear association between any two of the water quality parameters as measured by the simple correlation coefficient (r) is presented in table-2 as 10×10 correlation matrix. The temperature has been found to show excellent correlations with DO (r=-0.980), BOD(r = 0.986), COD (r=0.995) and TH (r=0.952). Total dissolved solids showed excellent correlations with DO (r=-0.942), BOD (r=0.931), COD (r=0.906) and TH (r=0.974). COD showed significant positive correlation with BOD (r=0.998).DO showed significant negative correlation with BOD (r=-1.000).TA showed significant positive correlation with pH (r=0.998).

CONCLUSION

The holy river Ganga of India is frequently used for different purposes. Present study indicates the pollution state of river Ganga. The summer, monsoon and winter seasons showed different level of seasonal fluctuations in various physicochemical parameters. All the physico-chemical parameters of Ganga river water at Allahabad for pre-monsoon, monsoon and post monsoon during 2012-2013 are within the maximum permissible limit prescribed by WHO and USPHS except BOD and COD which exceeded the limits in all the seasons. Hence, direct consumption of untreated Ganga water and bathing in the Allahabad region is at high risk for human health.

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