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Comparative study on seasonal variation in hydro-chemical parameters of Ganga River water using comprehensive pollution index (CPI) at Rishikesh (Uttarakhand) India

Gagan Matta[a,*], Pradeep K. Naik[b], John Machell[c], Amit Kumar[d], Laura Gjyli[e], Ashwani Kumar Tiwari[f], Avinash Kumar[a]

[a]Department of Zoology and Environmental Science, Gurukula Kangri University, Haridwar, India, email: drgaganmatta@gkv.ac.in

[b]Ministry of Water Resources, River Development and Ganga Rejuvenation, Govt. of India – Central Ground Water Board, Chandigarh, India

[c]Pennine Water Group, Department of Civil and Structural Engineering, The University of Sheffield, Sheffield, UK

[d]Centre for Glaciology, Wadia Institute of Himalayan Geology, Dehradun, India

[e]Deparment of Medicine, Universiteti Aleksander Moisiu Durres, Durres, Albania

[f]Department of Environment, Land and Infrastructure Engineering, Politecnico di Torino, Torino, Italy

* Corresponding author.

Abstract

The assessment of the Ganga River System at Rishikesh was investigated at five different sites for three different seasons (summer, winter and monsoon) using comprehensive pollution index (CPI), considering 10 physicochemical parameters such as conductivity, turbidity, total dissolved solids, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand, total hardness, Cl, phosphate and sulphate. The CPI was found to be 0.54–2.47, which indicates the variation in pollution level of the River Ganga. The variation in pollution index value clearly shows that water quality was slightly polluted in winter (0.54–0.72) and summer (0.64–0.88) whereas high contamination (1.68–2.47) was observed during monsoon season. Among various sampling stations, Pashulok Barrage (Site 5) was more contaminated than other sites. All the studied parameters were under the permissible limit of W.H.O. (2011) except turbidity, total solids and suspended solids which were higher than the permissible limit. This study also illustrates the correlation between parameters by developing correlation matrix. The result of this study clearly elucidates that the water quality is getting contaminated as we moved from upstream to downstream of river and helps to understand the potential effects of water quality on drinking, irrigation and other purposes.

Keywords: River Ganga; CPI; Water quality; Rishikesh; Physicochemical parameters

1. Introduction

Water security is rising as an inexorably critical and fundamental issue for India. Numerous Indian urban areas are starting to encounter direct to serious water deficiencies. A huge population is dependent on the Ganga River water for their daily need such as drinking, agricultural and industrial purposes. Unregulated development of urban zones, especially in the recent two decades, without infrastructural administrations for appropriate gathering, transportation, treatment and transfer of residential wastes prompted expanded pollution and health risks [1]. Today the Ganga canal is the source of agricultural prosperity in much of these states, and the irrigation departments of these states actively maintain the canal against a fee system charged from users [2].

With the length covering of more than 2,525 km long the Ganga (Ganges) River originates from Gaumukh (30°36′N; 79°04′E) in the proboscis of the Gangotri Glacier, one of the two headstreams is known as 'River Bhagirathi' in the Himalayas at an elevation of 3,800 m above mean sea level. The Bhagirathi River and the Alaknanda River (another headstream) combined together and that stream is

known as the River Ganga [3,4]. The physicochemical concentration of the Ganga River shows a maximum peak during rainy season, and low during winter and summer seasons. Annual discharge of the river is about 459,000 million m^3 at Farakka (West Bengal). Nearly all the wastewater of the population directly or indirectly goes into the river, totalling over 1.3 billion L d^{-1}. Further, approximately 260 million L of wastes from industries, fertilizers runoff and plenty of pesticides used in agriculture enters into the river basin [5–8]. The increasing population stress along with inadequate urban waste management, unplanned urban growth, rigorous use of fertilizers, poor waste management by industries, mass bathing activities on different festivals, etc. raise environmental pressure on the river ecosystem [7,9].

Rishikesh is a small serene town famous for meditation and yoga. The sacred River Ganges flows through Rishikesh. It is here at Shivpuri, that the river leaves the Shivalik Hills in the Himalayas and flows out into the plains of northern India. It is gateway to the Himalayas and being on the bank of River Ganges it is an ideal destination for adventure. Rishikesh is situated 25 km ahead of Haridwar at an elevation of 356 m above sea level [10]. But in today's scenario the river has now become one of the most polluted rivers of the country. The river is being polluted due to mass bathing, washing, disposal of sewage, industrial waste and these human activities are deteriorating its water quality. Appropriate biological and chemical treatment of domestic sewage and industrial effluents before discharge to river system is suggested [11]. Keeping above in view the present investigation was undertaken to study the seasonal hydrological assessment of the Ganga River water quality at Rishikesh (Uttarakhand).

2. Materials and methods

2.1. Study area

The present study has been carried out in Rishikesh to examine pollution status of the River Ganga, located in newly carved state, Uttarakhand. Rishikesh is extended from latitude 30°07′ in the north to longitude 78°19′ in the east. It has an elevation of 372 m. Rishikesh had a population of 102,138 as per 2011 census of India [12]. The average temperature of this area lies within the range around 5°C–39°C and average rainfall is 9–495 mm [13]. In monsoon season heavy rainfall and cloudburst actions are common, which is main cause for triggering the landslides in the area. During this study period physicochemical parameters of River Ganges were studied. Water samples were taken from two locations at Rishikesh in foot hills of Garhwal region of Uttarakhand. The sampling locations are depicted in Fig. 1. Site 1(Shivpuri), is control site for the study 18 km away from Rishikesh, a natural ecosystem, no domestic or commercial setups. Just next to sampling location, tourist spots are with hundreds of tourist everyday available for river rafting [8–10]. Site 1 (Shivpuri) control site, Site 2 (Chilla), Site 3 (Ram Jhula), Site 4 (Triveni Ghat) and Site 5 (Pashulok Barrage) 22 km from Shivpuri located in outer part of Rishikesh. After crossing all over from Rishikesh, the River Ganga flows from this sampling site. Fig. 1 shows highly commercial areas with loads of pollution and wastewater discharge.

Fig. 1. Sampling sites in the stretch of Ganga River.

2. Samples collection and analysis

Sampling was done in three different seasons' viz. winter, summer and monsoon for the period of 1 year from 2013 to Oct 2014. Water samples were collected using a clean plastic bucket, transferred to clean plastic bottles and transported to the laboratory on ice and stored in a deep freezer (–20°C) till analysis. Samples were collected in triplicate from each site and average value for each parameter was reported. The physical parameters such as temperature, conductivity, total dissolved solids (TDS), dissolved oxygen (DO) and velocity were recorded on the spot and other chemical parameters such as turbidity, total solids (TS) and total hardness (TH) were recorded in the laboratory which were determined using standard methods [14]. The colorimetric analyses were done with UV Spectrophotometer Cary 60.

2.3. Statistical analysis

All the data obtained subjected to statistical analysis. In statistical analysis, a correlation developed between parameters by using Karl Pearson's coefficient of correlation for data analysis of the Ganga River water to measure the variations between Site 1 and Site 2 parameters. MS Excel 2000 was used to measure the mean and standard deviation of the data.

Comprehensive pollution index (CPI): The CPI has been applied to classify the water quality status by many of the research findings [15]. It is evaluated by the following equations:

PI = Measured concentration of individual parameter

(1) Standard permissible concentration of parameter (CPI) = $\underline{1}\sum n$ PI

(2) n i=0

where PI is the pollution index of individual water quality parameter considered, as shown in Figs. 2(a–c), n is the number of parameters and CPI is a comprehensive pollution index.

a.

b.

c.

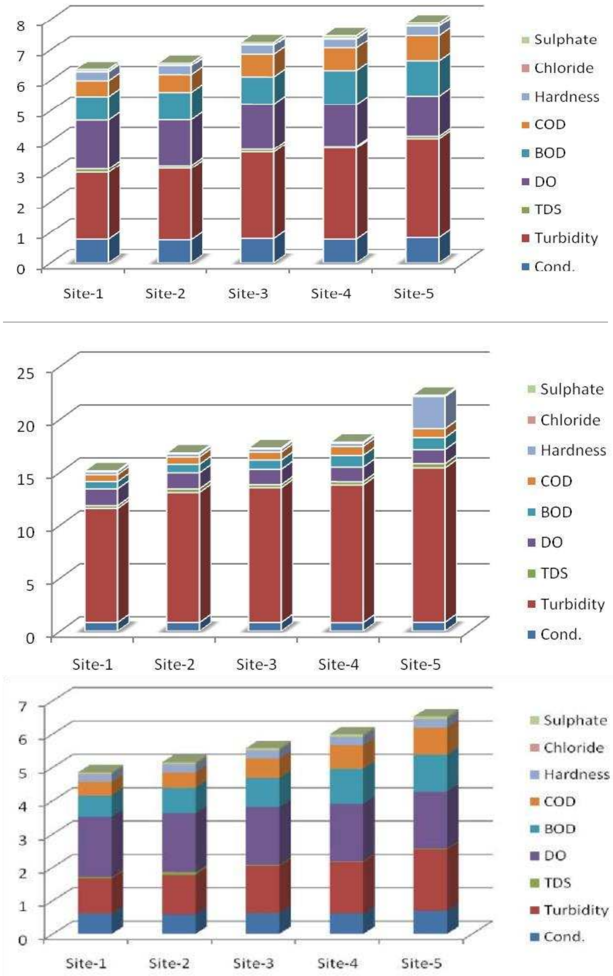

Fig. 2. PI of water quality parameters during summer (a), monsoon (b) and winters (c).

The standard permissible concentrations of each parameter considered in the study were obtained from the Central Pollution Control Board (CPCB) norms of the Indian government for a general discharge of environmental pollutant [16–19]. CPI ranges from 0 to 2 which classify water quality as: ≤0.20 is clean; 0.21–0.40 is subclean; 0.41–1.00 is slightly polluted; 1.01–2.0 is moderately polluted and ≥2.01 is severely polluted.

3. Results and discussion

The foremost purpose of the seasonal variation in physicochemical analysis of water is to determine its nutrient status. Since the water hold dissolved and suspended constituents in altering proportions, it has different chemical and physical properties. The value of water quality parameters may be affected in a variety of ways by pollution. Variations in physicochemical properties of the River Ganga in summer, winter and monsoon seasons at Site 1 (Shivpuri) control site, Site 2 (Chilla), Site 3 (Ram Jhula), Site 4 (Triveni Ghat) and Site 5 (Pashulok Barrage) sampling sites are appended in Tables 1(a) and (b).

Table 1(a)
Physicochemical characteristics of the Ganga River water with different sites at Rishikesh, Uttarakhand

Parameters	Seasons	Site 1	Site 2	Site 3	Site 4	Site 5	W.H.O. (2011) Standards	BIS (2012) Standards
Light intensity (μmol m^{-2} s^{-1})	Summer	1,905 ± 54.628	1,903.56 ± 56.95	1,917.30 ± 50.41	1,914.25 ± 0.034	1,888.35 ± 8.024	–	–
	Monsoon	1,288.7 ± 319.39	1,347.07 ± 400.44	1,139.54 ± 332.499	1,169.21 ± 302.716	1,144.54 ± 311.35		
	Winter	2,140.70 ± 447.15	2,136.21 ± 437.624	2,093.63 ± 379.27	2,035.39 ± 359.08	1,989.71 ± 547.73		
Temperature (°C)	Summer	17.80 ± 1.04	17.50 ± 0.50	18.80 ± 0.29	18.00 ± 0.50	18.50 ± 1.00	25–30	–
	Monsoon	19.10 ± 0.85	18.10 ± 0.63	19.10 ± 1.38	18.50 ± 0.71	19.90 ± 0.95		
	Winter	12.20 ± 2.59	12.30 ± 2.71	12.40 ± 2.92	12.60 ± 2.68	13.70 ± 2.89		
Conductivity (μmhos cm^{-2})	Summer	140.4 ± 2.147	136.50 ± 1.47	144.00 ± 1.22	140.20 ± 4.881	149.80 ± 11.01	180–1,000	–
	Monsoon	146 ± 2.49	145.22 ± 35.34	146.50 ± 4.56	143.00 ± 0.98	151.00 ± 1.25		
	Winter	109.30 ± 18.84	104.50 ± 21.35	112.00 ± 17.91	110.90 ± 18.4	124.50 ± 15.65		
Turbidity (NTU)	Summer	55.01 ± 43.45	58.65 ± 39.91	71.09 ± 60.09	75.01 ± 43.45	81.09 ± 60.09	5–25	1
	Monsoon	269.00 ± 34.00	307.00 ± 7.52	318 ± 73.5	325.00 ± 7.52	364.00 ± 122.00		
	Winter	26.5 ± 33	29.61 ± 35.31	35.43 ± 37.15	38.50 ± 33	46.19 ± 37.5		
Velocity (m s^{-1})	Summer	0.815 ± 0.178	0.91 ± 0.15	1.20 ± 0.45	0.93 ± 0.36	0.89 ± 0.34	–	–
	Monsoon	1.81 ± 0.09	1.29 ± 0.41	2.10 ± 0.24	1.87 ± 0.07	2.04 ± 0.20		
	Winter	0.722 ± 0.419	0.73 ± 0.07	0.60 ± 0.19	0.61 ± 0.17	0.79 ± 0.38		
TS (mg L^{-1})	Summer	278.20 ± 52.33	280.00 ± 163.3	295.30 ± 106.00	300.40 ± 70.36	321 ± 166.6	500–1,500	–
	Monsoon	240.50	599.82	828.00 ± 54.00	981.00 ± 109	1,016.00 ± 90.8		
	Winter	69.67 ± 37.79	69.53 ± 36.91	86.95 ± 71.85	94.62 ± 76.13	72.16 ± 31.14		
TSS (mg L^{-1})	Summer	265.4 ± 161.1	250.4 ± 120.2	235.8 ± 157.1	275.8 ± 69.63	268 ± 52.07	500	–
	Monsoon	890.6 ± 243.6	842.9 ± 111.2	831.5 ± 59.66	671.9 ± 58.71	591.7 ± 107.2		
	Winter	49.62 ± 32.3	28.85 ± 14.58	80.37 ± 61.28	75.64 ± 59.51	57.9 ± 29.2		
TDS (mg L^{-1})	Summer	55.68 ± 23.5	44.85 ± 16.65	44.15 ± 12.81	24.6 ± 3.617	40.23 ± 13.19	500	500
	Monsoon	138 ± 44.3	172.7 ± 27.7	150 ± 62.1	156 ± 28.6	205 ± 90.3		
	Winter	20.05 ± 15.03	43.31 ± 37.8	14.26 ± 14.94	11.31 ± 12.54	11.63 ± 8.081		
DO (mg L^{-1})	Summer	9.67 ± 0.62	9.11 ± 0.61	8.91 ± 0.35	8.23 ± 0.14	7.91 ± 0.24	2–6	>6 mg L^{-1}
	Monsoon	9.49 ± 0.75	9.02 ± 0.27	8.63 ± 0.37	8.21 ± 0.13	7.97 ± 0.15		
	Winter	10.80 ± 1.42	10.60 ± 1.37	10.40 ± 1.19	10.30 ± 1.66	10.20 ± 1.15		
BOD (mg L^{-1})	Summer	2.25 ± 0.42	2.63 ± 0.36	2.67 ± 0.28	3.33 ± 0.32	3.51 ± 0.25	2.5–6.5	2–3
	Monsoon	2.06 ± 0.24	2.42 ± 0.76	2.63 ± 0.53	3.32 ± 0.39	3.37 ± 0.52		
	Winter	1.93 ± 0.41	2.29 ± 0.24	2.62 ± 0.36	3.18 ± 1.03	3.34 ± 0.05		

Table 1(b)
Physicochemical characteristics of the Ganga River water with different sites at Rishikesh, Uttarakhand

Parameters	Seasons	Site 1	Site 2	Site 3	Site 4	Site 5	W.H.O. Standards	BIS (2012) Standards
COD (mg L^{-1})	Summer	5.32 ± 0.92	5.92 ± 1.83	7.50 ± 2.00	7.55 ± 0.77	8.30 ± 0.20	200–1,000	–
	Monsoon	6.49 ± 0.74	6.99 ± 0.69	7.57 ± 0.48	8.50 ± 0.60	8.50 ± 0.80		
	Winter	4.13 ± 1.71	4.60 ± 0.96	5.86 ± 1.08	7.06 ± 1.03	8.10 ± 0.32		
Free CO_2 (mg L^{-1})	Summer	1.1 ± 0.12	1.09 ± 0.07	1.09 ± 0.06	1.47 ± 0.10	1.50 ± 0.10	10	10
	Monsoon	1.2 ± 0.1	1.30 ± 0.20	1.30 ± 0.10	2.21 ± 0.08	2.27 ± 0.08		
	Winter	0.75 ± 0.35	0.76 ± 0.22	0.93 ± 0.19	0.93 ± 0.77	0.98 ± 0.77		
Alkalinity (mg L^{-1})	Summer	40.00 ± 8.97	47.00 ± 8.90	50.00 ± 10.20	51.00 ± 8.97	59.20 ± 3.18	–	200
	Monsoon	39.20 ± 6.26	42.20 ± 6.16	44.00 ± 7.31	44.60 ± 5.97	56.40 ± 10.20		
	Winter	28.90 ± 0.96	31.00 ± 9.00	33.00 ± 5.20	31.00 ± 3.50	47.00 ± 4.50		
Hardness (mg L^{-1})	Summer	57.3 ± 8.43	58.20 ± 9.73	59.20 ± 3.18	60.10 ± 10.80	61.10 ± 7.33	200	200
	Monsoon	55.5 ± 5.96	57.10 ± 7.08	56.40 ± 10.20	59.60 ± 6.06	60.80 ± 8.04		
	Winter	42.00 ± 9.60	45.00 ± 5.60	45.50 ± 7.62	47.00 ± 2.50	47.00 ± 4.50		
Acidity (mg L^{-1})	Summer	54.2 ± 10.3	55.50 ± 13.70	59.50 ± 12.40	61.40 ± 18.5	65.50 ± 20.9	–	–
	Monsoon	54 ± 10.9	54.50 ± 9.64	48.00 ± 10.60	55.00 ± 5.84	50.50 ± 9.66		
	Winter	48.2 ± 18.7	43.90 ± 11.70	59.90 ± 4.80	57.80 ± 2.76	60.90 ± 8.26		
Cl (mg L^{-1})	Summer	5.11 ± 0.24	5.47 ± 0.55	5.78 ± 0.33	5.51 ± 0.582	5.78 ± 0.28	250	250
	Monsoon	4.60 ± 0.34	4.51 ± 0.18	5.23 ± 0.35	4.65 ± 0.32	5.02 ± 0.18		
	Winter	4.09 ± 1.45	4.38 ± 0.72	4.45 ± 1.02	4.07 ± 1.40	4.31 ± 1.01		
P (mg L^{-1})	Summer	0.05 ± 0.02	0.06 ± 0.01	0.06 ± 0.03	0.08 ± 0.03	0.14 ± 0.05	–	–
	Monsoon	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.03	0.08 ± 0.01		
	Winter	0.03 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.05 ± 0.01		
TKN (mg L^{-1})	Summer	0.04 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.06 ± 0.02	0.08 ± 0.02	–	–
	Monsoon	0.04 ± 0.01	0.04 ± 0.02	0.04 ± 0.03	0.04 ± 0.02	0.06 ± 0.01		
	Winter	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.03 ± 0.01	0.05 ± 0.01		
Sulphate (mg L^{-1})	Summer	16.30 ± 0.25	19.00 ± 2.20	19.00 ± 4.40	20.60 ± 2.25	21.40 ± 2.04	250	200
	Monsoon	15.00 ± 0.06	18.00 ± 2.10	18.90 ± 2.56	20.00 ± 4.00	20.60 ± 1.36		
	Winter	14.60 ± 0.38	15.40 ± 0.38	15.80 ± 0.43	19.00 ± 2.97	19.90 ± 2.83		

The physicochemical analysis of the Ganga River showed that Site 5 was highly polluted because of the influx of sewage and domestic wastes in comparison with other sites. During the study period average range in light intensity (LI) was recorded maximum (1,989.71–2,140.70 µmol m^{-2} s^{-1}) in winter than summer and monsoon season with the Ganga River water at Sites 1–5. The maximum value of LI (2,140.70 µmol m^{-2} s^{-1}) was recorded at Site 1 (control site) as compared with other sites (Table 1(a)). This might be due to higher turbidity of river water at Sites 2, 3, 4 and 5, which obstructed the light available to phytoplankton at these sites [20]. The maximum LI (337.40–6,022.75 µmol m^{-2} s^{-1}) at control site in winter months and lower with summer and monsoon in the Ganga River water samples at Haridwar [7].

Temperature is one of the most significant characteristic that influence nearly all the physical, chemical and biological characteristics of water and thus the water chemistry. It never remains steady in rivers due to varying environmental conditions [21]. During the study the maximum temperature range (18.10°C–19.90°C) was recorded in summer in comparison with monsoon and winter season with the Ganga River water at Sites 1–5. The maximum value of temperature (19.90°C) was recorded at Site 5 in summer season, as compared with other sites (Table 1(a)). This might be due increasing rates of pollution, low water level, high air temperature and wastewater discharged at Site 5. Maximum temperature value (24.2°C–32.4°C) was reported in summer season for the Ganga River water at Allahabad [22].

Turbidity of water is an important parameter, which influences the light penetration inside water and thus affects the aquatic life [23,24]. During the study maximum value of turbidity (269.00–364.00 JTU) was observed in monsoon in comparison with summer and winter season with the Ganga River water at Sites 1–5. Higher value of turbidity (364.00 JTU) was noted in monsoon season at Site 5 (Table 1(a)). This is due to increasing quantity of waste, eroded material submerged in water, influx of rain water from catchment area and sand in monsoon season. This correlates with the findings of maximum turbidity in monsoon and minimum in winter season [25]. Similarly, turbidity in the River Ganga at Haridwar was lowest during winter season. From summer season onwards the water became turbid due to melting of snow and rains [26]. The maximum turbidity 608.15 JTU was observed in monsoon season and minimum 19.15 JTU was observed in winter season from water samples collected from five spots at Haridwar.

Velocity also has an effect on the water column. Fast flowing streams will hold suspended sediments in the water column longer, while quiet, slow-moving rivers will allow suspended sediments to settle out to the bottom quickly. Finally, velocity has an impact on the DO levels in a river or stream. Fast-moving sections of a river tend to have higher levels of DO than comparatively slower parts of a river because they are better aerated. The water level and its velocity started increasing from winter season onwards due to melting of snow at the place of origin of the river. Flow can affect the river's capability to incorporate pollutants; larger, swiftly moving streams and rivers can receive pollutants with a diminished negative effect. Smaller rivers with low flow have less of a capacity to dilute and degrade potentially harmful pollutants [27].

During the study the maximum range of velocity (1.81– 2.04 m s^{-1}) was recorded in monsoon season as compared with summer and winter season with the Ganga water at Sites 1–5. Maximum velocity of the River Ganga (2.04 m s^{-1}) was observed in monsoon season at Site 5 as compared with other sites (Table 1(a)). This was due to climatic conditions in which water level and its velocity started increasing from winter season onwards due to melting of snow at the place of origin of the river. The maximum velocity 2.18 m s^{-1} of the Ganga at Haridwar was recorded in monsoon season and the minimum velocity 0.39 m s^{-1} was observed in winter season [26].

The existence of TS is due to silt and organic matter. TS refer to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. In the study maximum range of TS (240.50–1,016 mg L^{-1}) was recorded in monsoon as compared with summer and winter seasons (Table 1(a)). Higher values of TS (1,016 mg L^{-1}) were observed in monsoon season at Site 5 as compared with other sites. This reflects heavy influx of pollution due to discharge of whole city sewage at this site. The maximum range of TS was reported (351.00–1,039.00 mg L^{-1}) in the Ganga River water at Haridwar [5].

In the aquatic ecosystem, where the rates of respiration and organic decomposition are high, the DO values usually remain lower than those of the system, where the rate of photosynthesis is high. When the water is polluted with large amount of organic matter, a lot of DO would be rapidly consumed in the biological aerobic decay, which would affect the water quality [28].

In the study maximum range of DO 10.20–10.80 mg L^{-1} was recorded during the winter season as compared with monsoon and summer months. During the study the overall highest mean value of DO was observed (10.80 mg L^{-1}) at Site 1 in comparison with other sites (Table 1(a)). It may be due to higher temperature, oxygen demanding wastes, inorganic reluctant and seasonal variation. Maximum DO (9.53–9.60 mg L^{-1}) concentration was determined for the Ganga River water at two distinct sites of Haridwar district (Uttarakhand) [29].

The degree of organic pollution which occurs due to an excessive amount of organic matter has typically been monitored by measuring biochemical oxygen demand (BOD) and chemical oxygen demand (COD) values in rivers. A high level of BOD deteriorates river water quality by rapid decomposition of biodegradable organic matter and the subsequent depletion of DO, while COD traditionally represents the total organic matter [30]. During the study the maximum range of BOD/COD (2.25–3.51 mg L^{-1})/(6.49–8.50 mg L^{-1}) was recorded in summer season as compared with monsoon and winter season with the Ganga water at Sites 1–5. Maximum BOD/COD of the River Ganga (3.51/8.50 mg L^{-1}) was observed in summer season at Site 5 as compared with other sites (Tables 1(a) and (b)). This was due to increased chemical and biological activities in summer and monsoon season. Higher BOD/COD value (5.53/36.40 mg L^{-1}) was observed in summer season as compared with monsoon and winter season in the Ganga River water at holy place Shringverpur (Allahabad), India [25]. Similarly, higher BOD/COD value (1.87–3.37/5.10–8.10 mg L^{-1}) was examined in summer season as compared with monsoon and winter season in the Ganga River water at Haridwar, India [5,31].

Carbon dioxide is fundamental in the existence of plants and microorganisms. It is produced due to respiration of aquatic organisms. During the study maximum range of free CO_2 (1.20–2.27 mg L^{-1}) was recorded in monsoon season as compared with summer and winter season. In the study maximum concentration of free CO_2 (2.27 mg L^{-1}) was recorded at Site 5 in comparison with other sites (Table 1(b)). The lower values of free CO_2 were observed in winter season and higher values were recorded in monsoon season (Table 1(a)). The increase in carbon dioxide level during these months may be due to decay and decomposition of organic matter due to the addition of large amount of sewage, which was the main causal factor for increase in carbon dioxide in the water bodies. High concentration of free CO_2 (1.58–4.29 mg L^{-1}) was reported in Kali River, Pithoragarh district of Uttarakhand, India. Lower concentration of free CO_2 was recorded in winter and higher in monsoon seasons [32].

The hardness of water is not a pollution indicator parameter but indicates water quality mainly in terms of Ca^{2+} and Mg^{2+}, bicarbonate, sulphates, chloride and nitrates.

In the study maximum value of TH (57.30–61.60 mg L^{-1}) was recorded in summer months than in monsoon and winter (Table 1). Higher concentration of TH (61.60 mg L^{-1}) was observed at Site 5 (Table 1(b)). This was due to result from poor dilution owing to low precipitation rate. The seasonal behaviours of TH were more or less similar at all the sites. It was lowest (90 ppm) in summer season and highest (200 ppm) in monsoon during the study of the Ganga River water at Bhagalpur (Bihar), India [33].

Acids contribute to corrosiveness and influence chemical reaction rates, chemical speciation and biological processes. During the study maximum range of acidity (54.20–65.50 mg L^{-1}) was recorded in summer, moderate in monsoon and lower in winter season (Table 1). Higher concentration of acidity (65.50 mg L^{-1}) was observed at Site 5 in summer season (Table 1(b)). This might be due to nitrate and sulphate emissions from natural and anthropogenic sources. Maximum acidity (68.92 mg L^{-1}) in the Ganga River water was reported at different sites of Ghazipur (Uttar Pradesh), India. They reported values of acidity were seasonally high in summer followed by rainy and winter season [34].

Cl^- affects freshwater organisms and plants by varying reproduction rates, increasing species mortality and changing the characteristics of the entire local ecosystem. SO_4^{2-} can be more troublesome, because it generally occurs in greater concentrations. Low to moderate concentrations of both chloride and sulphate ions add palatability to water [7].

During the study maximum range of Cl^-, SO_4^{2-}, total Kjeldahl nitrogen (TKN) and P were recorded to be 5.11–5.78, 16.30–21.40, 0.04–0.08 and 0.05–0.14 mg L^{-1} in summer as compared with monsoon and winter season (Table 1(b)). Higher concentration of Cl^- (5.78 mg L^{-1}), SO_4^{2-} (21.40 mg L^{-1}), TKN (0.08 mg L^{-1}) and P (0.14 mg L^{-1}) were recorded at Site 5 in summer month. This is due to increased human, animal, agricultural and industrial activities that released large volume of wastewater which is main sources of pollution. This finding is in agreement with other works of many researchers [7,25].

For the evaluation of seasonal variation in hydro-chemical parameters of the Ganga River water, CPI was used and given in Table 2.

Table 2

Sampling sites	CPI (summer)	CPI (monsoon)	CPI (winters)	Polluted
Site 1	0.706 (slightly)	1.680 (moderately)	0.539 (slightly)	Slightly (in sumn winters), moder monsoon)
Site 2	0.730 (slightly)	1.869 (moderately)	0.572 (slightly)	Slightly (in sum winters), moder monsoon)
Site 3	0.641 (slightly)	1.920 (moderately)	0.619 (slightly)	Slightly (in sum winters), moder monsoon)
Site 4	0.830 (slightly)	1.981 (moderately)	0.665 (slightly)	Slightly (in sum winters), moder monsoon)
Site 5	0.877 (slightly)	2.473 (severely)	0.724 (slightly)	Slightly (in sum winters), seve monsoon)

The graphical presentation of pollution level is presented in Fig. 3.

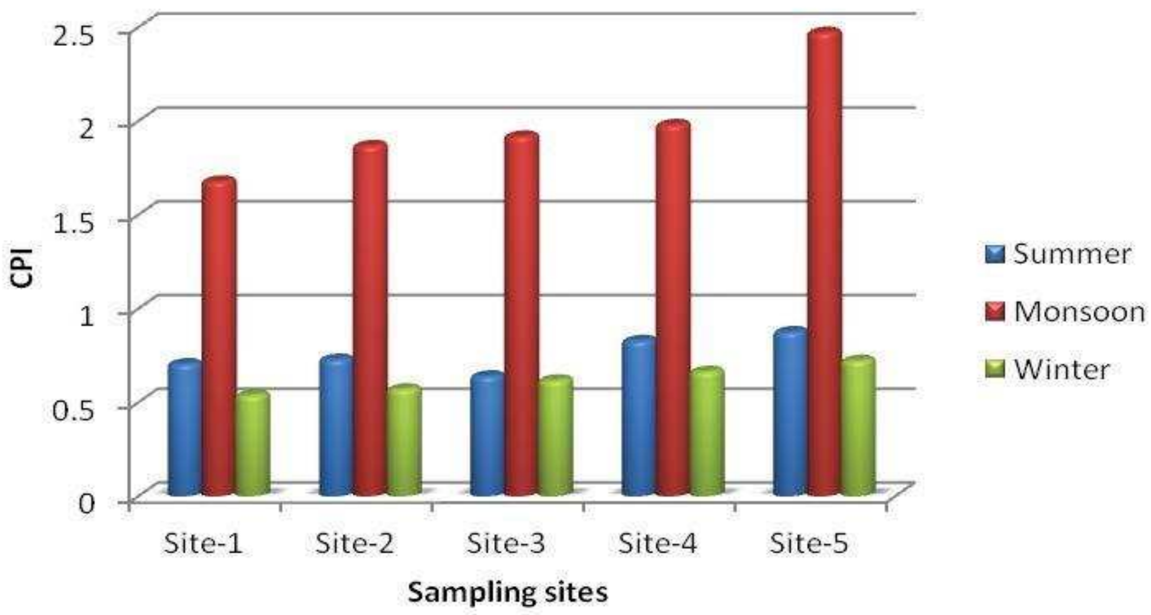

Fig. 3. Variation of CPI during summer, monsoon and winter.

The seasonal CPI values of Sites 1–5 varies within the range of 0.64–0.88 (in summer), 1.68–2.47 (in monsoon) and 0.54–0.72 (in winter). According to the rating sale of CPI, the observed pollution index values for all sites were reported lower than 2 except at Site 5 (2.47) during monsoon season which indicated that river water quality is slightly polluted in summer and monsoon season. However, in monsoon the water quality was moderately to severely contaminated. In graphical representation it is clearly illustrated that if the pollution level was low at upstream sites and high at downstream site in monsoon season in comparison with previous season, that is, summer and winter, it could be the reason of addition of runoff materials like soil, clay and sandy particulates. Similarly, high index value (CPI 10.31) was reported in monsoon season for one of the tributary of the River Ganga in Himalayan region [35]. The Karl Pearson's correlation matrix developed for each parameter is presented in Table 3. During the study, correlation between different physicochemical parameters revealed that LI, total suspended solids (TSS) and DO showed negative correlation with almost all other parameters. Rests of the parameters are positively correlated with each other.

4. Conclusion

On the basis of various parameters studied the present study concluded that physicochemical characteristics of the Ganga River water at Rishikesh were moderately satisfactory. The seasonal distribution pattern of different parameters was found to be influenced by different environmental factors. However, the slight erosion was observed in river Water pollution at each sampling location during different season

water in the summer season and monsoon season due to variation in rainfall, quickly developing improvement and poor land management strategies. Higher turbidity greater than permissible limit in the study can significantly reduce the aesthetic value of the Ganga River water, due to the presence of suspended solids, clay and other particulate materials. It can augment the cost of water treatment for drinking and food processing and harms aquatic life by reducing oxygen level, food, degrading spawning beds and affecting gill function. The correlation values in the study showed significant increase/decrease of one parameter over the other. There is also need of growing consciousness among the public to preserve the river water from contamination and its quality and purity level. Hence regular monitoring and stringent law enforcement is required to develop a strategy to manage the environmental hazards due to pollution and to improve environmental protection of the River Ganga.

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