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Impact assessment on water quality of Ganga Canal System in Himalayan Region

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Abstract — Monthly variation of physico-chemical parameters of river Ganga at Haridwar, India was studied. Water samples for one year study (2013-14) were collected from 3 sites of the river Ganga located in Haridwar city and nearby places. Total 19 physico-chemical parameters were investigated. Correlation coefficient among various parameters was determined to bear positive or negative correlation. In the present analysis maximum concentration of LI (337.40-6022.75 μ mol. m^{-2} s^{-1}), temperature (11.52-18.52 ^{0}C), conductance (74.57-145.4 μmhos/Cm^{2+}), turbidity (4.83-252.20 JTU), velocity (0.97-1.64 m/s), TS (117.11-922.08 mg/l), TSS (25.48-729.60 mg/l), TDS (87.52-203.05mg/l), DO (7.57-0.56 mg/l), BOD (0.65-10.56 mg/l), COD (2.02-7.65 mg/l), Free CO_2 (0.47-1.81 mg/l), Alkalinity (18.99-54.8 mg/l), Hardness (28.11-66.77 mg/l), Acidity (29.94-72.56 mg/l), Cl (2.47-5.81 mg/l), P (0.03-0.13 mg/l), TKN (0.02-0.08 mg/l) and Sulphate (8.64-22.94 mg/l) respectively. The results were compared with the WHO water quality standards. The observed values of major parameters were slightly under the permissible limits of WHO, except the DO, turbidity and TSS. Therefore the observed water quality suggests that the water could not be used for drinking and bathing purposes. It could only be used for irrigation after suitable treatment.

Keywords— Water quality, physico-chemical Characteristics, Ganga Canal System, pollution, Haridwar

1 Introduction

River Ganga is a perennial river connected to several glaciers in the Himalayan mountain. In its initial course the river Alakhnanda and Bhagirathi meet at Dev Prayag and after their confluence, the resulting river is known as Ganga (1). The Dev Prayag is approximately 70.0 Km along from Haridwar - the off taking point of the Ganga canal. The contribution of Alaknanda is approximately 66% and river Bharigathi is 34% in the River Ganges. The total catchment area of the river Ganga above Haridwar is approximate 20,000.00 Sq Km in Himalayan Mountains. This river is the life line of large fertile agricultural track of the adjoining districts on its both banks. The economy of the inhabiting farmers mainly depends on the irrigation water which is supplied from the river Ganga. Originally the Ganga Canal irrigates the Doab region between the Ganges River and the Yamuna River in India (2,3). The canal is primarily an irrigation canal, although parts of it were also used for navigation, primarily for its construction materials. Separate navigation channels with lock gates were provided on this system for boats to negotiate falls. Originally constructed from 1842 to 1854, for an original head discharge of 6000 ft^3/s. The Upper Ganges Canal has since been enlarged gradually for the present head discharge of 10,500 ft^3/s (295 m^3/s). The canal system irrigates nearly 9,000 km^2 of fertile agricultural land in ten districts of Uttar Pradesh and Uttarakhand.

Today the 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 (4). The canal is administritatively divided into the Upper Ganges Canal the Lower Ganges Canal which constitutes several branches. The Upper Ganges canal is the original *Ganges Canal*, which starts at the Bhimgoda Barrage near Har ki Pauri at Haridwar, traverses Bahadrabad, Roorkee and flows to Uttar Pradesh. With increase in population and gap between demand and supply, the canal system has also increase throughout the world for maximum approach to freshwater. The Ganga basin accounts for a little more than one-fourth (26.3%) of the country's total geographical area and is the biggest river basin in India, covering the entire states of Uttarakhand. The Ganga Canal emerging out from Ganga basin has great ritual importance among pilgrims and tourists at Haridwar, Uttarakhand, India (4). The Canal is being polluted due to mass bathing, washing, disposal of sewage, industrial waste and these human activities are deteriorating its water quality. To determine the impact of these activities, Ganga Canal water quality at three major sites at Bhimgoda Barrage and Roorkee, Haridwar has been analyzed for various physico-chemical pollutants and compared with water quality standards for improved understanding.

2 Materials and Method

2.1 Studied area of Ganga Canal System

The study was carried out in Haridwar District to examine pollution status of Ganga Canal System, located in Uttarakhand State. Water samples were taken from three locations *i.e.* Bhimgoda Barrage (control site), Bahadrabad and Roorkee. The sampling locations are illustrated in Fig. 1 and there geospatial description is given in Table 1.

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2.2 Haridwar (Bhimgoda barrage – Control Site)

Bhimgoda Barrage is situated at Har Ki Pauri, Haridwar where the Ganga Canal System originates. The primary purpose for the barrage is irrigation but it also serves to control floods. The area behind the barrage is known as the Neel Dhara Bird Sanctuary and is a popular destination for various water birds and tourists.

2.3 Bahadrabad

A place few meters before the barrage (this barrage feed water to a Pathri power plant situated in Bahadrabad) and because of this water flow at this sampling site is slow relative to other sampling sites here. The water crossing all the point and non-point sources of Haridwar pass through this sampling location. Further major human activity like bathing and cleaning is very common phenomenon at this site also. This site is at a distance of 17.5 KM approximately from Bhimgoda Barrage, Haridwar (Control Site). Here, the floor of the canal is sandy and depth is not so high.

2.4 Roorkee

Roorkee is a city in Haridwar district, Uttarakhand, spread over a flat terrain with the grand spectacle of Himalaya's ranges flanking it in the East and the North-east. It is on the banks of the Ganges canal on the national highway 58 (Delhi - Sri Badnrinath - Mana) between Delhi and Dehradun. Also the National Highway 73, connecting Roorkee (Uttarakhand) and Panchkula (Haryana) originates from here. The dominant feature of the city is the Upper Ganges Canal which flows north-south and bisects the city. Also known for Roorkee Cantonment, one of the country's oldest headquarters of Bengal Engineer Group (Bengal Sappers) since 1853.The renowned IIT Roorkee is located in this city. This site is at a distance of 35.5 KM approximately from Bhimgoda Barrage and 17 Km from Bahadrabad. Here, the floor of the canal is sandy and depth is not so high.

Table 1: Location of Sampling Site in GPS

Site No.	Sampling Site	Type of system	Longitude	Latitude
1.	Bhimgoda Barrage (Haridwar)	Canal System (Origin Point)	29^0 57′ 26.66″ N	78^0 10′ 33.84″ E
2.	Bahadrabad	Canal System	29^0 54′ 36.30″ N	78^0 01′ 58.48″ E
3.	Roorkee	Canal System		

2.5 Sample collection procedure

Water samples were collected monthly from Ganga Canal at Haridwar for the period of one year from 2013 to 2014. Water samples were collected from 0.5 m depth from the surface of river using a clean plastic bucket, transferred to clean plastic bottles and transported to the laboratory on ice and stored in a deep freezer (-20^{o}C) till analysis. Samples were collected in triplicate from each Site and average value for each parameter was reported.

2.6 Analytical Methods

The physico-chemical parameters like Light intensity (LI), Temperature (Temp), Dissolved Oxygen (DO), Conductivity (Cond), Velocity (Vel) and Free CO_2 (F. CO_2) were fixed/recorded onsite. The other parameters such as BOD, COD, Alkalinity, Acidity, Hardness, Chlorine (Cl), Phosphorus (P), Total Kjheldal Nitrogen (TKN), Turbidity, Total Solids (TS), Total Dissolved Solids (TDS), Total Suspended Solids (TSS) and Sulphate (SO_4^{2-}) were analyzed in laboratory after samples preservation as per Bureau of Indian Standards (5) and American Public Health Association (6) guidelines. The colorimetric analyses were done with UV Spectrophotometer Cary 60.

3 Results and Discussion

The results were analyzed monthly from October 2013 to September 2014 of three sampling sites of Ganga Canal System in Uttarakhand Himalayas and presented in Table 2 – 4 and Fig 1 – 8.

In the present study maximum increase in LI was recorded at site-I in comparison to site-II and site-III. This was in accordance with Lionard et al. (7) who reported that increase in turbidity of river water imply large reduction on light available to phytoplankton. The maximum increase in LI (6022.75 μ mol. m^{-2} s^{-1}) was recorded in September and minimum (411.55 μ mol. m^{-2} s^{-1}) in July at site-I. Matta and Kumar (8) reported maximum LI (1989.71 μ mol. m^{-2} s^{-1}) in winter months and (1347.07 μ mol. m^{-2} s^{-1}) in River Ganga System at Himalayan Region. The water temperature plays an important role in the solubility of salts and gases. It is one of the most significant parameters which control in born physical qualities of water. During the present study maximum increase in temp was observed at site-II followed by site-III as compared with site-I. The maximum temperature (18.52^{0}C) was recorded in July and minimum (11.82^{0}C) was recorded in December at site-II. Khanna et al. (9) reported highest value of temperature 18.84 °C at site Ist and the least value (14.00 °C) was observed to be at site 2nd among four sites (Site 1st Harkipauri, Site 2nd Birla ghat, Site 3rd s Mayapur and Site 4th Singhdwar) at Haridwar. The velocity was found to be directly proportional to the flood level and also with gradient of the river stretch. 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 ability to assimilate 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 (10). During the present study the maximum mean velocity of River Ganga at Site-II was (1.64 m/s) in monsoon season and minimum mean velocity (0.97 m/s) in winter season as compared with Site-1 and site-III. Maximum velocity of River Ganga observed at site-II might be 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. Joshi et al. (11) also reported the maximum velocity 2.18 m/s of the Ganga at Haridwar was recorded in monsoon season and the minimum velocity 0.39m/s were observed in winter season.

Electrical conductance of water is a measure of its ability to carry electric current as a result of dissolved salts in the water. The conductivity measurements provide an indication of ionic concentrations. In the present study maximum increase in cond. was observed at site-II followed by site-III as compared with site-I. The maximum cond. (145.4 μmhos/Cm^2) was recorded in October and minimum (74.57 μmhos/Cm^2) was recorded in April. Higher conductivity values are expected because of the sewage and industrial waste disposal activities taking place at site-II. Haritash et al. (12) reported that EC of Ganga river water at Rishikesh varied from 38.0 to 170 μS/cm with the mean value of 85.2 μS/cm. Comparatively higher values were observed at location and downstream owing to the external input of wastewater and addition of sewage. Similar trends were also observed by Matta (1) in Ganga Canal System during 2011-12.

The magnificent parameter of river pollution is turbidity, as is well established by many studies already. Turbidity in water that affect the transparency or light scattering of the water. During the present study maximum increase in turbidity (252.20 JTU) was observed at site-II and minimum turbidity (224.95 JTU). The maximum turbidity was recorded in June and minimum was recorded in December. Recent study done by Joshi et al. (2009) reported that 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. 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 sampling Site A (Bhooma Niketan), sampling Site B (Jai Ram Ashram), Samping Site C (Har-Ki-Pauri), sampling Site D (Prem Nagar Ashram) and sampling Site E (Pul Jatwara). Total solids refer to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. The total solids content (TS, mg/l) of a water sample may be divided into dissolved (e.g. salts) and suspended (e.g. particulates) fractions. In the present study maximum and minimum range of T.S. (922.08-124.53mg/l), T.S.S (729.60-26.88 mg/l) and T.D.S (203.05-92.52 mg/l) was recorded at site-III in monsoon season and winter season respectively. Shirin et al. (13) reported maximum T.S. (336.86 mg/l), T.S.S (311.65 mg/l) and T.D.S (426.63 mg/l) water quality of Ganga River in Haridwar city, Uttarakhand.

Dissolved Oxygen content, has a vital role for maintaining aquatic life and are susceptible to slight environment changes. COD is similar in function to BOD, in that both measure the amount of organic compounds in water. COD is a measure of pollution in aquatic ecosystems. During the present study maximum DO (10.56 mg/l) and minimum (7.57 mg/l) were recorded in summer and winter season respectively. DO values ranged in all the three sites were depleted in summer and maximum in winter. Seasonal discrepancy in DO concentration was related to temperature and biological activities. A high pollution load has decreased the DO values at significant level. This was in accordance with Sarwade and Kamble (14) who reported maximum DO content in summer and minimum in winter season. In the present study maximum BOD (3.00 mg/l) at site-II followed by site-III in comparison to site-I. Higher concentration of BOD was observed in monsoon and lowers in winter season at all the three sites. This was in consideration with Naseema et al. (15) who reported maximum concentration of BOD (29.12±4.58 mg/l) were recorded in monsoon and minimum (2.9±0.40 mg/l) in winter season at River Ganga at Kanpur. Pandey et al. (16) reported maximum concentration of BOD (9.18/9.70 mg/l) and COD (129.2/170.5 mg/l) at Phaphamau/Shringverpur sites of Sangam River at Allahabad due to the huge amount of discharges industrial wastes, cremations wastes and domestic wastes etc. Carbon dioxide is vital in the life of plants and microorganisms. It is produced due to respiration of aquatic organisms. 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. Water with less than 75 mgl-1 of CaCO3 is considered soft and above 75 mgl^{-1}of $CaCO_3$ as hard (17,18)). In the present study maximum concentration of Free CO_2 (1.81 mg/l) was recorded at site-II followed by site-III and minimum (1.19 mg/l) at site-I. The hardness in the present study was recorded maximum (68.76) at site-II and minimum at site-I. Both Free CO_2 and hardness were recorded higher in summer months and lower in winter. The increase in carbon dioxide level during these months may be due to decay and decomposition of organic matter due the addition of large amount of sewage, which was the main causal factor for increase in carbon dioxide in the water bodies. This was in accordance with Matta et al., 2014 who reported that CO_2 is vital in the life of plants and microorganisms. It is produced due to respiration of aquatic organisms. They recorded maximum Free CO_2 (1.33 mg/l ± 0.61) in Ganga river water at Haridwar from June to September, while

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lower values of Free CO_2 were observed in the month of Nov to February.

Table 2: Monthly Fluctuation of water quality parameters at Bhimgoda Barrage (Haridwar) (Control Site) in 2013 - 2014

Parameters → / Months ↓	LI (µ mol. m^{-2} s^{-1})	Temp. (^{0}C)	Cond. (µmhos/C m^2)	Turbidity (JTU)	Vel. (m/s)	T.S. (mg/l)	T.S.S (mg/l)	T.D.S (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
October	3675.00	14.72	142.8	27.54	1.59	180.15	86.25	93.90	8.97	1.49	4.06
November	2021.74	13.10	98.86	8.02	1.32	117.11	32.01	87.52	9.81	1.15	3.00
December	3726.52	11.52	97.51	4.83	1.01	128.28	25.48	101.40	10.18	0.90	2.57
January	3594.50	12.37	96.91	7.64	1.27	147.06	39.16	107.90	10.56	0.65	2.08
February	3815.00	12.55	98.34	11.95	1.47	156.97	49.37	107.60	9.73	1.16	3.19
March	2290.20	14.26	122.7	28.01	1.43	202.15	86.25	115.90	8.47	1.80	4.88
April	2897.62	15.47	74.57	38.79	1.51	249.86	126.66	123.20	8.11	2.20	5.56
May	1049.72	17.04	138.2	127.22	1.23	584.04	427.10	156.94	7.77	2.39	6.13
June	411.55	17.87	139.1	224.95	1.46	892.71	689.66	186.92	7.78	2.66	7.31
July	427.00	18.22	106.6	90.61	1.63	497.93	324.55	173.37	7.68	2.94	7.38
August	3082.24	16.86	104.2	84.68±	1.28	425.56	264.14	161.42	7.79	2.47	6.78
September	6022.75	15.70	97.73	94.88	1.25	355.10	241.40	113.70	8.43	1.81	4.90
WHO Standards	-	25–30	180–1000	5 - 25	-	500 - 1500	20-150	500-2000	2-6	2.0-6.5	200-1000

Table 3: Monthly Fluctuation of water quality parameters at Bahadrabad in 2013 - 2014

Parameters → / Months ↓	LI (µ mol. m^{-2} s^{-1})	Temp. (^{0}C)	Cond. (µmhos/C m^2)	Turbidity (JTU)	Vel. (m/s)	T.S. (mg/l)	T.S.S (mg/l)	T.D.S (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
October	2781.75	14.65	145.4	18.35	1.61	156.12	61.22	94.90	9.32	1.41	3.77
November	1894.25	13.50	97.38	7.47	1.40	121.75	29.59	90.60	9.87	1.22	3.08
December	3556.77	11.82	99.12	5.31	0.97	126.95	26.59	101.47	10.13	0.89	2.63
January	4171.50	12.36	101.2	6.60	1.29	150.76	40.74	110.02	10.48	0.71	2.19
February	3784.50	12.77	101.4	9.15	1.51	161.11	54.49	106.62	9.48	1.17	3.14
March	2215.50	14.47	124.8	26.53	1.27	196.77	78.92	117.85	8.39	1.75	4.77
April	1382.65	15.50	77	34.81	1.56	235.90	118.23	117.67	8.15	2.19	5.54
May	1268.16	17.12	138.5	244.86	1.23	767.18	600.78	166.40	7.73	2.37	6.06
June	321.67	18.02	140.7	252.20	1.36	858.95	693.35	165.60	7.79	2.54	6.78
July	337.40	18.52	140.5	230.01	1.64	898.90	711.97	192.47	7.66	2.80	7.65
August	1892.44	16.74	141.4	249.84	1.34	842.26	668.70	173.56	7.72	3.00	7.52
September	5652.85	15.75	141.9	73.75	1.04	260.70	141.60	119.10	8.58	1.93	5.38
WHO Standards	-	25–30	180–1000	5 - 25	-	500 - 1500	20-150	500-2000	2-6	2.0-6.5	200-1000

Table 4: Monthly Fluctuation of water quality parameters at Roorkee in 2013 – 2014

Parameters → / Months ↓	LI (µ mol. m^{-2} s^{-1})	Temp. (^{0}C)	Cond. (µmhos/C m^2)	Turbidity (JTU)	Vel. (m/s)	T.S. (mg/l)	T.S.S (mg/l)	T.D.S (mg/l)	DO (mg/l)	BOD (mg/l)	COD (mg/l)
October	3860.50	13.90	152.3	25.92	1.62	136.46	45.16	91.30	8.72	1.50	4.08
November	2706.20	12.22	136.6	8.02	1.30	124.53	31.15	92.52	9.60	1.15	2.98
December	3756.76	11.80	140.7	5.28	0.99	126.97	26.88	100.38	9.93	0.86	2.43
January	3755.50	12.25	135	7.59	1.17	143.59	38.24	105.35	10.32	0.68	2.02
February	2131.50	12.77	139.9	11.36	1.42	150.56	47.11	103.45	9.93	1.17	3.21
March	1538.40	14.40	137.8	27.38	1.36	197.71	84.35	113.36	8.42	1.80	4.47
April	2716.00	15.45	76.93	38.29	1.52	244.48	123.93	120.55	8.09	2.21	5.57
May	1074.92	17.00	133.6	126.09	1.16	561.87	393.68	168.18	7.61	2.37	6.10
June	402.15	17.77	135.6	223.80	1.47	522.80	369.88	152.92	7.60	2.59	7.13
July	1861.30	18.12	132.4	89.74	1.58	922.08	729.60	203.05	7.57	2.99	7.35
August	2833.96	16.08	134.3	83.67	1.25	388.55	255.63	132.92	7.65	2.45	6.72
September	5761.00	15.12	143.2	75.37	1.25	226.44	115.12	111.32	8.24	1.79	4.87
WHO Standards	-	25–30	180–1000	5 - 25	-	500 - 1500	20-150	500-2000	2-6	2.0-6.5	200-1000

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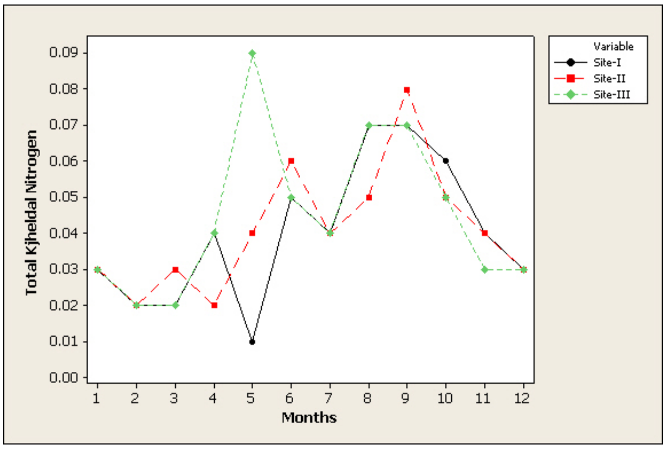

Fig. 1: Monthly fluctuation in TKN (mg/l)

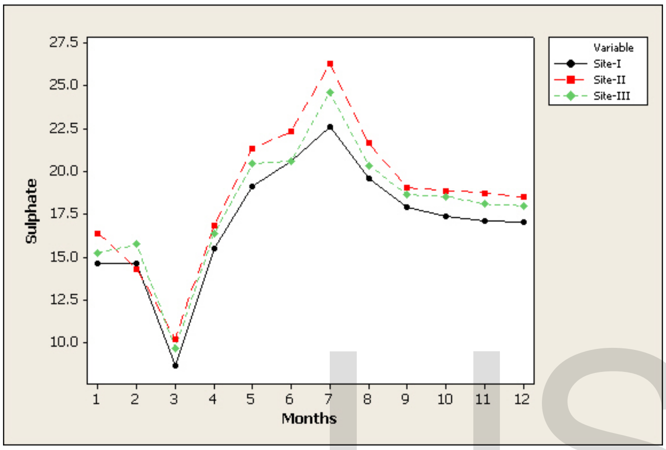

Fig. 2: Monthly fluctuation in Sulphate (mg/l)

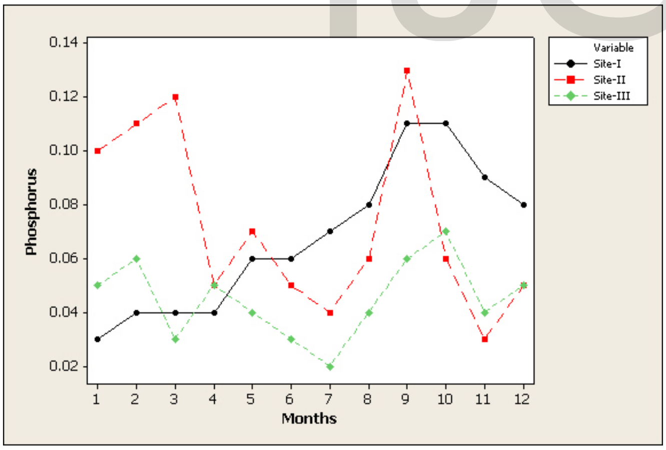

Fig. 3: Monthly fluctuation in Phosphate (mg/l)

Alkalinity is significant in many uses and treatments of natural waters and wastewaters. As alkalinity of many surface waters constitute of carbonates, bicarbonate and hydroxide contents, it is assumed to be an indicator of these constituents as well. Alkalinity in excess of alkaline earth metal concentrations is significant in determining the suitability of water for irrigation. Acids contribute to corrosiveness and influence chemical reaction rates, chemical speciation and biological processes. Acidity of water is its quantitative capacity to react with a strong base to a designated pH. In the present study maximum alkalinity was

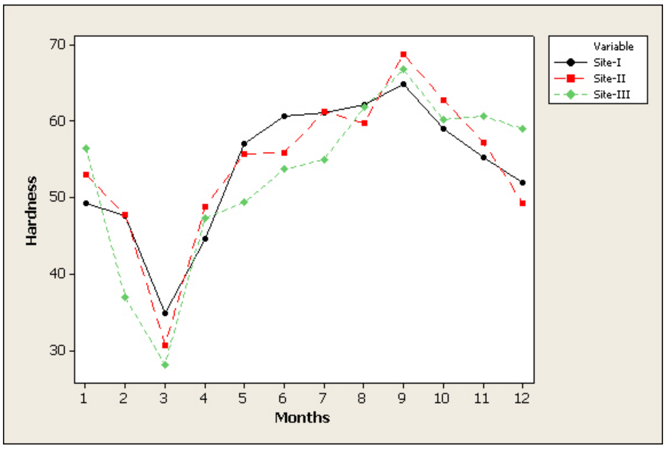

Fig. 4: Monthly fluctuation in Hardness (mg/l)

recorded at site-II (51.44 mg/l) followed by site-III in comparison to site-I**.** The maximum acidity in the present study was recorded to be (72.56 mg/l) at site-II followed by site-III in comparison to site-I. The acidity was found higher in January, while lower in April. The alkalinity was found higher in May and lower in April month.

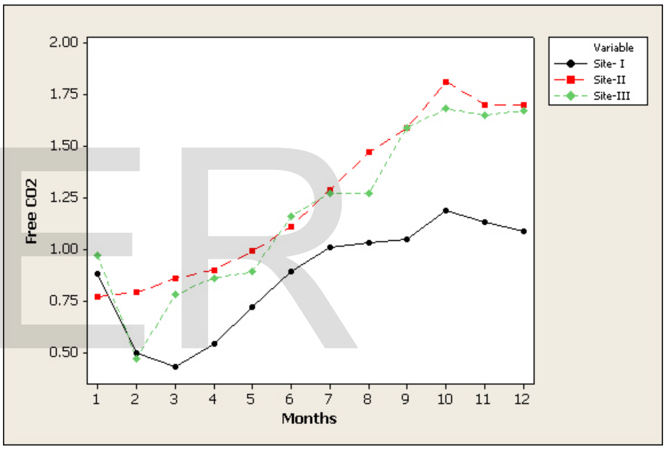

Fig. 5: Monthly fluctuation in Free CO_2 (mg/l)

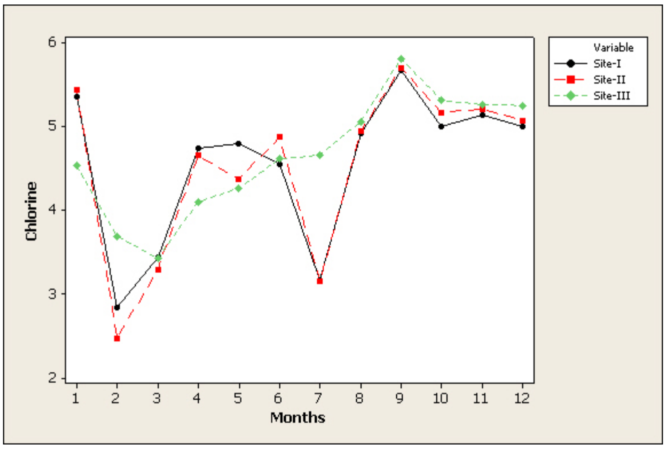

Fig. 6: Monthly fluctuation in Chlorine (mg/l)

Almost all natural waters contain chloride and sulfate ions. Low to moderate concentrations of both chloride and sulfate ions add palatability to water. In fact, they are desirable for this reason. Excessive concentrations of either, of course, can make water unpleasant to drink. TKN and phosphorus are nutrients that are natural parts of aquatic ecosystems. TKN is also the most abundant element in the air we breathe. TKN and phosphorus support the growth of algae and aquatic plants, which provide food and habitat for fish, shellfish and smaller organisms that live in water (10). During the present study maximum concentration of Cl (5.70 mg/l), P (0.13 mg/l), TKN (0.08 mg/l) and SO_4^{2-} (26.31 mg/l) was observed at site-II followed by site-III in comparison to site-I. The higher values of these parameters were observed in summer season and lower values were observed in winter season. Aggarwal and Arora (19) reported the maximum concentrations of Cl (15.88 mg/l), TKN (5.32 mg/l) and SO_4^{2-} (14.60 mg/l) Kaushalya River water at S4 site (Intake Channel of WSS Kalka) in Parwanoo. They observed that most of the parameters analysed for Kaushalya River were in acceptable range except COD, Alkalinity and Hardness, which showed human, animal and agricultural activities as the main sources of pollution.

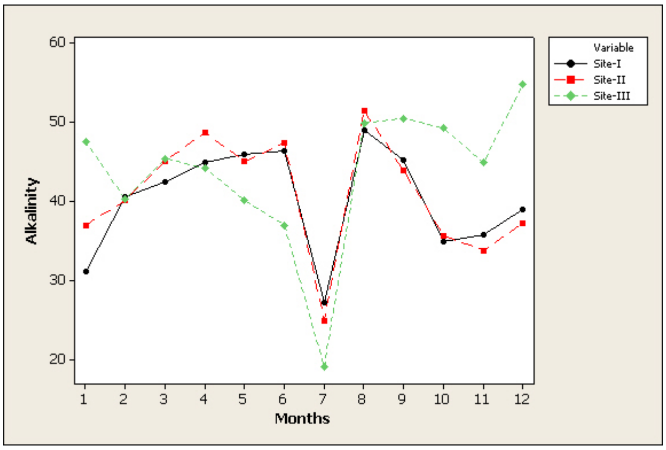

Fig. 7: Monthly fluctuation in Alkalinity (mg/l)

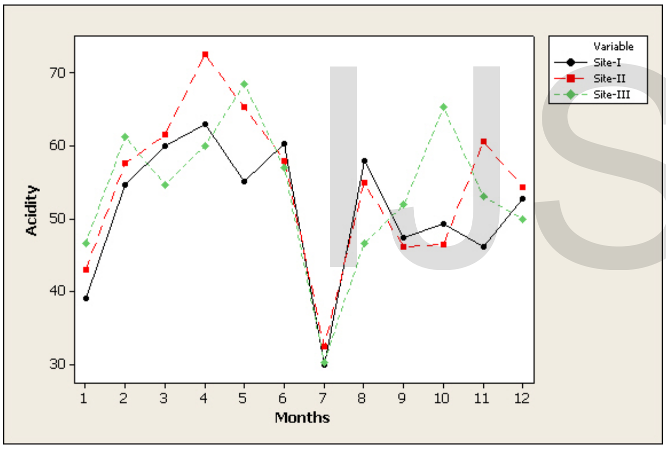

Fig. 8: Monthly fluctuation in Acidity (mg/l)

4 Correlation coefficient of physico-chemical parameters in Ganga Canal System

The strong correlations between the elements generally indicate that these elements had the same input sources and similar geochemical behaviour (20). Pearson correlation analysis was used to describe the data to assess the suitability of the water for human consumption and domestication purposes. Correlation coefficients were one of the indices to assess the strength of the relationship between different variables (21). The correlations among different parameters in Ganga Canal System at different sites were presented in Table. 3. From the results, it was observed that the LI was moderately positively correlated with DO (r=0.590) at site-I and with Free CO2 (r=0.568) at site-III and moderate negative correlation was observed with other different parameters at all the sites. Temperature showed significant positive correlation with T.S, T.S.S, T.D.S, BOD, COD and Turbidity at all the three sites, while it showed significant positive correlation with Free CO_2 at site-I and II. Temperature also showed significant positive correlation with P/acidity at site-I and with conductivity at site-II. Conductivity was observed to be positively correlated with T.S.S and Free CO_2 at all the sites. At site-I and II T.S, T.D.S, BOD, COD and turbidity was found positively correlated with conductivity. Acidity was recorded to be positively correlated with conductivity at site-I and III, while Cl at site-II and III. P showed

Table 5: Correlation matrix among the various physico-chemical parameters at Site-I during 2013 – 2014

	LI	Temp.	Cond.	Turbidity	Vel.	T.S.	T.S.S	T.D.S	DO	BOD	COD	Free CO_2	Alkalinity	Hardness	Acidity	Cl	P	TKN	Sulphate
LI	1.00																		
Temp.	-0.554	1.00																	
Cond.	-0.433	0.395	1.00																
Turbidity	-0.592	0.827	0.552	1.00															
Vel.	-0.306	0.398	0.243	0.160	1.00														
T.S.	-0.620	0.848	0.509	0.994	0.146	1.00													
T.S.S	-0.599	0.837	0.529	0.998	0.138	0.998	1.00												
T.D.S	-0.696	0.849	0.361	0.921	0.180	0.942	0.921	1.00											
DO	0.474	-0.945	-0.346	-0.734	-0.376	-0.749	-0.738	-0.759	1.00										
BOD	-0.604	0.967	0.298	0.767	0.399	0.799	0.780	0.853	-0.968	1.00									
COD	-0.581	0.969	0.337	0.819	0.372	0.833	0.815	0.879	-0.970	0.993	1.00								
Free CO_2	-0.233	0.731	0.663	0.445	0.489	0.440	0.441	0.417	-0.715	0.660	0.680	1.00							
Alkalinity	-0.107	-0.303	0.245	0.125	-0.398	0.091	0.099	0.045	0.326	-0.311	-0.274	-0.360	1.00						
Hardness	-0.091	-0.444	0.137	-0.166	-0.323	-0.158	-0.165	-0.111	0.502	-0.441	-0.428	-0.417	0.904	1.00					
Acidity	0.040	0.535	0.071	-0.166	-0.599	-0.168	-0.166	-0.170	0.482	-0.451	-0.438	-0.464	0.846	0.884	1.00				
Cl	-0.107	-0.445	0.653	0.581	0.316	0.587	0.589	0.537	-0.425	0.412	0.469	0.649	0.198	0.127	0.018	1.00			
P	-0.159	0.785	0.146	-0.161	-0.183	-0.207	-0.191	-0.286	0.601	-0.486	-0.505	-0.401	0.146	0.249	0.255	-0.331	1.00		
TKN	-0.735	-0.478	0.536	0.790	0.193	0.813	0.803	0.816	-0.717	0.752	0.758	0.416	0.043	-0.090	-0.055	0.471	-0.255	1.00	
Sulphate	0.350	-0.478	0.265	-0.405	-0.200	-0.429	-0.410	-0.508	0.576	-0.587	-0.561	0.065	0.213	0.368	0.435	0.108	0.550	-0.472	1.00

Table 6: Correlation matrix among the various physico-chemical parameters at Site – II during 2013 – 2014

	LI	Temp.	Cond.	Turbidity	Vel.	T.S.	T.S.S	T.D.S	DO	BOD	COD	Free CO_2	Alkalinity	Hardness	Acidity	Cl	P	TKN	Sulphate
LI	1.00																		
Temp.	-0.615	1.00																	
Cond.	-0.130	0.665	1.00																
Turbidity	-0.560	0.891	0.683	1.00															
Vel.	-0.524	0.298	-0.028	0.061	1.00														
T.S.	-0.643	0.885	0.631	0.985	0.167	1.00													
T.S.S	-0.648	0.884	0.634	0.986	0.170	0.999	1.00												
T.D.S	-0.582	0.865	0.593	0.956	0.137	0.977	0.972	1.00											
DO	0.590	-0.927	-0.557	-0.822	-0.228	-0.811	-0.807	-0.829	1.00										
BOD	-0.607	0.945	0.568	0.880	0.253	0.877	0.875	0.877	-0.967	1.00									
COD	-0.577	0.954	0.605	0.886	0.227	0.886	0.883	0.895	-0.962	0.995	1.00								
Free CO_2	-0.240	0.798	0.834	0.646	0.213	0.592	0.594	0.557	-0.738	0.757	0.762	1.00							
Alkalinity	0.168	-0.317	0.119	-0.056	-0.451	-0.079	-0.079	-0.078	0.336	-0.426	-0.401	-0.377	1.00						
Hardness	0.113	-0.263	0.159	-0.016	-0.170	0.009	0.008	0.021	0.309	-0.344	-0.311	-0.325	0.874	1.00					
Acidity	0.491	-0.549	-0.068	-0.197	-0.502	-0.216	-0.219	-0.182	0.520	-0.485	-0.469	-0.468	0.695	0.768	1.00				
Cl	-0.068	0.568	0.854	0.584	0.097	0.565	0.562	0.578	-0.497	0.471	0.517	0.629	0.176	0.207	-0.043	1.00			
P	-0.162	-0.175	-0.016	-0.124	-0.093	-0.116	-0.098	-0.273	0.337	-0.322	-0.315	-0.224	0.280	0.190	-0.054	-0.168	1.00		
TKN	-0.149	0.085	-0.069	0.059	0.254	0.089	0.081	0.164	-0.352	0.197	0.179	-0.045	0.087	0.202	-0.003	0.141	-0.285	1.00	
Sulphate	0.484	-0.565	0.156	-0.434	-0.248	-0.451	-0.443	-0.513	0.682	-0.628	-0.605	-0.154	0.441	0.504	0.582	0.010	0.387	-0.402	1.00

Table 7: Correlation matrix among the various physico-chemical parameters at Site – III during 2013 – 2014

	LI	Temp.	Cond.	Turbidity	Vel.	T.S.	T.S.S	T.D.S	DO	BOD	COD	Free CO_2	Alkalinity	Hardness	Acidity	Cl	P	TKN	Sulphate
LI	1.00																		
Temp.	-0.497	1.00																	
Cond.	0.173	-0.204	1.00																
Turbidity	-0.540	0.838	0.004	1.00															
Vel.	-0.260	0.417	-0.219	0.187	1.00														
T.S.	-0.666	0.849	-0.056	0.975	0.215	1.00													
T.S.S	-0.666	0.843	0.849	- 0.056	0.975	0.999	1.00												
T.D.S	-0.688	0.870	-0.135	0.870	-0.135	0.978	0.972	1.00											
DO	0.391	-0.944	0.224	-0.748	-0.386	-0.720	-0.715	-0.736	1.00										
BOD	-0.502	0.973	-0.276	0.745	0.464	0.768	0.763	0.786	-0.961	1.00									
COD	-0.484	0.977	-0.237	0.799	0.436	0.808	0.804	0.814	-0.963	0.992	1.00								
Free CO_2	0.568	-0.680	0.592	-0.571	-0.219	-0.652	-0.647	-0.669	0.645	-0.748	-0.724	1.00							
Alkalinity	0.112	0.235	0.817	0.424	-0.237	0.355	0.361	0.304	-0.151	0.105	0.158	0.240	1.00						
Hardness	0.025	0.135	0.756	0.346	-0.411	0.326	0.328	0.299	0.002	0.015	0.065	0.152	0.917	1.00					
Acidity	-0.123	-0.270	0.601	-0.198	-0.096	-0.116	-0.111	-0.146	0.439	-0.278	-0.286	0.261	0.361	0.568	1.00				
Cl	0.455	-0.021	0.665	0.031	-0.131	-0.086	-0.070	-0.191	0.018	-0.031	0.016	0.439	0.589	0.442	0.312	1.00			
P	-0.079	0.286	0.481	0.359	0.294	0.378	0.393	0.267	-0.120	0.215	0.229	-0.119	0.628	0.641	0.483	0.411	1.00		
TKN	-0.662	0.357	-0.018	0.417	0.259	0.472	0.463	0.524	-0.169	0.278	0.282	-0.122	0.052	0.095	0.287	-0.289	0.029	1.00	
Sulphate	-0.255	-0.277	0.639	-0.213	0.053	-0.182	-0.176	-0.214	0.255	-0.275	-0.301	0.471	0.214	0.174	0.519	0.207	0.109	0.164	1.00

significant positive correlation with P at site-I and with SO_4^{2-}, alkalinity/hardness at site-III. In the present study T.D.S, BOD, COD and T.S were found to be significantly positively correlated with turbidity at all the three sites, while with Cl and T.S.S at site-I and II. Turbidity was found to be positively correlated with TKN at site-I. T.S showed moderate positive correlation with T.D.S, BOD, COD and T.S.S at all the three sites, while with TKN and Cl at site-I. T.S was found to be significantly positively correlated with Free CO_2. During the present study BOD and COD was recorded to positively correlated with T.S.S. At site-II and III it was found to be positively correlated with T.D.S, while at site-I and II with Cl. T.S.S was also found to be positively correlated with TKN at site-I and Free CO_2 at site-II. T.D.S was found to be significantly positively correlated with COD and BOD at all the three sites of Ganga river water, while it was found to be positively correlated with Free CO_2 at site-II and TKN at site-III. DO was significantly correlated with SO_4^{2-} at site-I and III, while P, acidity and Free CO_2 was found to be significantly correlated with DO at site-I, II and III respectively. BOD was found to be significantly correlated with COD at all the three sites, while Free CO_2 was positively correlated with BOD at site-I and II and TKN at site-I only. Alkalinity was found to be significantly positive correlated with hardness and acidity at site-II. The significant values of correlation study revealed that the canal water was not much contaminated by anthropogenic activities and percolation of domestic sewage into the canal water of the study area. But its regular monitoring should be necessary to minimize the load of pollution in river Ganga.

5 Conclusion

The present study concluded that the physico-chemical conditions of Ganga canal system were fairly good in all the seasons, however the slight variations were observed in river water in the summer season due to anthropogenic activities, industrial activities and percolation of domestic sewage into canal. The concentrations of various nutrients and other water quality parameters undergo seasonal changes and the values showed a slight variation in all the seasons. The problem of pollution was not serious in the water but the management efforts should be made for the conservation of Ganga canal system at Haridwar for its purity and holiness otherwise it will turn into the state that would affect its physico-chemical status that may not be fit for human consumption as well as the growth and survival of aquatic life present in it. So its regular monitoring is should be done to preserve it from pollution point. Thus this work will serve as baseline information for future work.

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