

Assessment of Water Quality Status of Chandrabhaga River at Rishikesh, Dehradun, Uttarakhand, India

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Abstract

In the background of the ambitious 'National Mission for Clean Ganga' to clean, conserve and protect the River Ganga in a comprehensive manner, this study was undertaken to evaluate the status of Water Quality of Chandrabhaga river at Rishikesh, district Dehradun, India, between the Dhalwala bridge area and Mayakund area where it merges with the river Ganga, affecting adversely its water quality. The characteristics of Chandrabhaga river water were assessed during July to September 2017 by monitoring the water quality at most garbaged and contaminated five locations by determining physicochemical and biological parameters and metal ions. The observed values of dissolved oxygen (DO) varied from 0.4 to 1.29 mg/L, such a low DO, high biological oxygen demand (BOD, 21 ± 2.64 to 56 ± 6.08 mg/L) and much high Coliform (1760 ± 13.23 to 3180 ± 27.61 MPN/ 100 ml) at all the locations reflects the poor water quality of Chandrabhaga River. Recorded values of total dissolved solid (TDS), electrical conductivity (EC), total hardness (TH), alkalinity, phosphate, sodium, potassium and calcium exceeded the WHO standards. Pearson's correlation analysis revealed the highly positive correlations all the time between EC and TDS, TH and TDS, TH and EC, while during high flow period good correlations were recorded between alkalinity and pH, TDS, EC and TH. Irrigation water quality parameters such as soluble sodium percentage (SSP), sodium adsorption ratio (SAR), magnesium adsorption ratio (MAR) and Kelly's Ratio was evaluated to test the suitability of river water for irrigation purpose.



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Introduction

River water is a dynamic system and dissolves variety of substances from industrial waste and domestic waste water- sewage and the access of so many

substances and microorganisms leads to severe contamination of river water.¹ Since long, rivers are used as valuable freshwater sources for drinking cum domestic purposes, irrigation, construction, hydro

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power generation, water transport, fishery, water sports and in amusement parks.² Huge quantity of water is required by chemical, pharmaceutical, dyeing- bleaching, textiles, paper-pulp industries, etc. which intern releases effluents containing wide variety of chemicals and toxic metals to nearby land fill that ultimately reaches to water bodies.³ Presently, most of the water resources are being polluted mainly by ever increasing population, urbanization, industrialization and other anthropogenic activities.⁴ Anthropogenic activities and inadequate wastewater treatment facilities affect greatly water quality in the downstream sections of the rivers that causes irreversible deterioration of the river water quality.⁵ Huge water flux during heavy rain from country sides carry with it agricultural run-off, debris, mud and humus that ultimately join water bodies. The input of wastewater from mining cum metallurgical operations containing toxic metals on reaching to water bodies and soil may also percolate to ground water sources.⁶

The quality of river water varies spatially and temporally due to the variation in its composition and concentrations of the components,¹ and by a wide range of natural and human influences.⁷ Exploitation of water resources to meet the demand with the exponential population growth and supported by industrialization and urbanization, put water resources under great threat both in terms of quality as well as quantity.⁸ The surface run-off during the rainy season also affects river water quality as it effects the concentration of river water pollutants.⁸ Presently, rivers have become dumping ground for industrial wastewater, municipal waste, agri-runoff and even for sewage. Municipal and industrial wastewater discharge constitutes a constant polluting source, whereas surface runoff is a seasonal phenomenon.⁹ The composition of surface and underground water depends on topographical, hydrological and biological factors and varies with seasonal differences in runoff volumes, weather conditions and water levels.¹ As water flows through the various geological environments, the site-wise and seasonal variation in water quality is governed by soil, geology, climate and anthropogenic activities that keep modifying the composition of dissolved materials and other parameters.¹⁰

The River Ganga, after originating at Gaumukh (30°362 N, 79°042 E) in the snout of the Gangotri

glacier as Bhagirathi river in the Himalayas at an elevation of 4356 m¹¹ and passing nearly 250 Km through narrow Himalayan valley, emerges at Rishikesh and then flows to the flat and fertile Gangetic plain, before merging in the Bay of Bengal at Ganga Sagar, covering the journey over 2500 km.¹² During this journey, Ganges gets polluted due to atmospheric deposition, erosion, and weathering of crustal materials and anthropogenic activities such as sewage, industrial effluents, and agricultural run-off.⁷ The River Ganga basin is one of the most densely populated river basins in the world¹⁰ and religious bathing, tourism, Kanvar and Kumbh mela, crematoria are major activities which are responsible for are causing higher pollution load to River Ganga.¹³

In view of the commitment of the Indian Government to protect the River Ganga, the objective of this study was to assess the status of the Chandrabhaga river water quality within the Rishikesh municipal area between Dhalwala Bridge and Mayakund area, where it merges with the river Ganga. The Chandrabhaga water quality was evaluated in terms of various physicochemical and biological parameters and SSP, SAR, MAR and Kelly's Ratio were also evaluated to test the suitability of river water for irrigation purpose. Seasonal and site wise variations in parameters were observed by weekly monitoring five sampling stations (S1 to S5) during July to September in the year 2017. The Pearson Correlation coefficients were evaluated to find the inter-relations among parameters. The obtained data may be used later to find out the influence of Chandrabhaga water on Ganges water quality at the confluence point.

Material and Method

Description of the Study Area

Rishikesh is gateway to pilgrimage to Badrinath, Kedarnath, Hemkund Sahib, Gangotri, and Yamunotri and trekking destinations to Pawali Kantha, Dodital, Harsil, Dayara Bugyal, Goumukh, Auli, Valley of Flowers and many more.¹⁴ The latitude of Rishikesh is 30.08690 N and the longitude is 78.26760 E and the elevation above sea level is 356 m. The Chandrabhaga River emerges out of *Banali-Kashmalidhar*, nearly 1800 m from sea level, in district Tehri, Uttarakhand, India. It first flows South West about 15 km then from *Gujrada* in south, then North East nearly 5 Km and finally South East when

it merges with river Ganges at *Mayakund*, Rishikesh. Once, a perennial stream it gradually faded away due to huge deposition of heavy boulders and deep sand bed brought during high flow months with fast flowing rain water from high hilly area to the plains of Rishikesh, making a deep sand bed throughout. Due to seepage in the deep sand bed, the river water loses its appearance in the dry season. The study area is consisting of Simla group, Karol Group and Garhwal group of rocks which are delineated by Krol Nappe.¹⁵ The Blaini formation of Krol group is exposed near Muni Ke Reti, Rishikesh. The rocks are folded and faulted due to which they show overlapping over many formations.^{15, 16} Friction clays and carbonaceous matter are observed near Ganges- Chandrabhaga Confluence on the left bank of river Ganges, Rishikesh where southwest-directed thrusting along a shear plane is observed in the river terraces.¹⁷ The substratum of the river at upstream and somewhat middle segment consists of bedrocks, boulders and gravels while it is composed of sand, silt and clay at downstream.

The mining activities are restricted in Chandrabhaga river bed, yet the river bed from Dhalwala bridge area (30.117367N, 78.286590E) to Maya Kund area (30.104462 N, 78.307146E) witnessed immense human activities. The hotels – restaurants, brick depots, dozens of unauthorized automobile vehicle washing Tillu pumps, small dairies and hundreds of unauthorized jhuggi-jhoperies (temporary settlements) made by slum dwellers, migrants and seasonal labours on both the banks of the river that directly discharge their refuse and other domestic waste in open, ultimately reaches to the Ganges. In rainy season, the open areas - street runoffs, vehicle washings, dung water, bricks and construction waste reaches to the river bed that deteriorates the hydro-biological quality of river water. In addition to the several households and commercial openings on the Rishikesh city side bank of Chandrabhaga river, fifteen Nalahs and drains in Dhalwala-Muni Ki Reti side river bank carry sewage and storm water that finally reaches to river Ganga.¹⁸ In Rishikesh town, in addition to existing STP at Swargashram, Lakkarghat¹⁰ and IDPL (with total 23 MLD capacity), two STPs of 5MLD at Chorpani, Muni Ki Reti and four-storied 7.5 MLD capacity at Chandrashwar Nagar were inaugurated by the Prime Minister in September, 2020 to treat sewer of respective areas, yet tapping of various Nalahs

releasing domestic waste water directly in the river bed, are to be undertaken to avoid their discharge in Chandrabhaga river bed that reaches finally to the River Ganges.¹⁰ The climate of Rishikesh is humid subtropical with heavy precipitation during July –August. Minimum, maximum and average temperatures during the study period were, 23°C, 31°C and 28°C, in July 2017, 23°C, 30°C, and 27°C, in August and 21°C, 29°C and 26°C in September, 2017. The reported average rain fall during this period was 161.02 in July 2017, 200.8 in August 2017 and 72.02 mm in September, 2017.¹⁹

Collection of Water Samples

In all 60 samples were collected on weekly basis, during July to September, 2017, from five sampling sites (S1 to S5) selected on Chandrabhaga River in Rishikesh municipal area between Dhalwala bridge and Mayakund area, before it merges with the River Ganga, as per standard methods of sampling techniques.^{20, 21} The identified sampling sites (S1 to S5) were among the heavy garbaged and most encroached segments of Chandrabhaga River (Fig. 1): S1 (Dhalwala bridge area), S2 (near Gopal Nagar), S3 (near Roadways bus stand), S4 (Chandrabhaga bridge area) and S5 (Mayakund area). To cover the seasonal variations, three sampling surveys were undertaken, one during July (low flow period), other during August (high flow period) and the third during September (least flow period). The brand new transparent polythene cans were used for collection of water samples. The cans were cleaned using non-ionic detergent, rinsed with tap water and finally washed with distilled water. Prior to use, cans were thoroughly rinsed with the water sample to be collected. For the estimation of dissolved oxygen and biochemical oxygen demand, dried, cooled, sterilized and labeled BOD bottles were used. All necessary precautions were taken during sampling and transportations of samples to the laboratory.

Analysis of Water Samples

The pH and dissolved oxygen (DO) of collected samples were analyzed on the spot by following standard procedures, using WTW OXI 3205 Portable DO Meter and EUTECH pH Meter. Determination of total dissolved solids (TDS), electric conductivity (EC), biological oxygen demand (BOD5), total hardness (TH), total alkalinity, chloride, nitrate, and phosphate were done in the laboratory as per

standard procedures.²⁰⁻²³ The BOD was estimated by the modified Winkler method, using WTW OXI Top IS 16 BOD Meter. Alkalinity was determined by titration method and TH by complexometric titration method. Conductivity was measured on Cyber Scan CON 700 Conductivity Meter. TDS was determined by evaporating the sample in a weighed dish to constant weight in an oven at 105°C. Chloride was determined by Argentometric titration method. Phosphate and nitrate were estimated spectrophotometrically using Carry 60 UV-Vis spectrometer (Agilent). Total

coliforms were determined following the standard methods^{21, 24} as MPN per 100 ml. Each analysis was done in triplicate and the mean value was taken. The sodium, potassium, calcium and magnesium were estimated by using Perkin Elmer Atomic Absorption Spectrometer, Analyst-200. The standard stock solutions of metal ions used were procured from Sigma-Aldrich. All the reagents, solvents and chemicals used were of analytical grade. Doubly-distilled water was used for all purposes.



Fig. 1: (a) Map of India, (b) Map of Uttarakhand and (c) Google Map showing locations of Sampling Sites (S1 to S5) in Chandrabhaga River, Rishikesh, Uttarakhand, India

**Table 1: Site wise values of various parameters of Chandrabhaga River at Rishikesh
(Values are as mean \pm standard deviation)**

Parameters		S1	S2	S3	S4	S5	Standards ^{23,34}
pH	July	7.53 \pm 0.04	7.68 \pm 0.04	7.82 \pm 0.04	7.95 \pm 0.03	7.56 \pm 0.03	7.0-8.5 (WHO)
	August	7.13 \pm 0.03	7.22 \pm 0.03	7.38 \pm 0.04	7.46 \pm 0.03	7.78 \pm 0.03	
	Sept.	7.65 \pm 0.04	7.91 \pm 0.06	7.88 \pm 0.06	7.92 \pm 0.04	8.16 \pm 0.03	
TDS , mg/L	July	790 \pm 4.64	814 \pm 7.24	784 \pm 7.21	916 \pm 5.52	680 \pm 5.52	500 (WHO)
	August	980 \pm 8.09	1186 \pm 9.08	1151 \pm 11.72	1214 \pm 9.30	1290 \pm 11.18	
	Sept.	876 \pm 8.34	824 \pm 7.81	736 \pm 6.44	916 \pm 8.19	791 \pm 8.12	
EC, μ S/cm	July	1214 \pm 7.81	1278 \pm 11.27	1317 \pm 13.38	1330 \pm 10.58	1362 \pm 11.29	500 (WHO)
	August	1320 \pm 9.16	1360 \pm 12.48	1345 \pm 9.84	1350 \pm 11.13	1380 \pm 13.22	
	Sept.	1506 \pm 12.29	1492 \pm 9.64	1416 \pm 8.89	1532 \pm 10.44	1488 \pm 10.58	
TH, mg/L	July	299 \pm 10.27	306 \pm 10.02	310 \pm 9.87	312 \pm 8.72	267 \pm 8.66	100 (WHO)
	August	242 \pm 8.72	248 \pm 9.54	264 \pm 10.79	276 \pm 8.89	290 \pm 6.10	
	Sept.	381 \pm 9.54	338 \pm 10.15	286 \pm 8.18	388 \pm 11.27	326 \pm 10.58	
Alkal- inity mg/L	July	131 \pm 8.12	142 \pm 8.16	155 \pm 8.76	164 \pm 8.54	148 \pm 7.81	100 (WHO)
	August	118 \pm 7.0	136 \pm 8.18	129 \pm 7.81	132 \pm 8.72	128 \pm 6.24	
	Sept.	165 \pm 9.11	158 \pm 9.15	154 \pm 8.72	162 \pm 9.64	157 \pm 9.34	
DO, mg /L	July	0.7 \pm 0.03	0.4 \pm 0.01	0.7 \pm 0.04	0.4 \pm 0.01	0.5 \pm 0.01	5.0 (WHO)
	August	0.7 \pm 0.02	0.7 \pm 0.01	0.9 \pm 0.02	0.7 \pm 0.01	0.8 \pm 0.01	
	Sept.	1.15 \pm 0.07	1.28 \pm 0.072	1.22 \pm 0.061	1.26 \pm 0.065	1.29 \pm 0.062	
BOD, mg/L	July	52 \pm 5.29	49 \pm 5.19	56 \pm 6.08	50 \pm 5.19	46 \pm 4.36	28-30 (WHO)
	August	21 \pm 2.64	26 \pm 3.0	23 \pm 2.64	21 \pm 3.0	24 \pm 2.64	
	Sept.	25 \pm 3.60	28 \pm 3.46	32 \pm 2.64	29 \pm 2.64	36 \pm 3.24	
Coli forms,	July	2870 \pm 26.46	2910 \pm 22.91	2960 \pm 27.61	3070 \pm 21.79	3180 \pm 27.61	Nil/ 100 ml (WHO)
	August	2310 \pm 17.32	2490 \pm 23.72	2465 \pm 21.79	2635 \pm 24.75	2860 \pm 22.91	
	Sept.	1870 \pm 13.23	1760 \pm 13.23	1830 \pm 14.80	1920 \pm 17.32	1800 \pm 13.23	
NO ₃ ⁻ mg/L	July	39.20 \pm 4.52	37.50 \pm 4.35	42.40 \pm 5.41	52.60 \pm 6.33	49.80 \pm 5.61	45 (BIS)
	August	19.26 \pm 4.65	24.60 \pm 4.33	23.82 \pm 3.97	20.46 \pm 2.84	21.20 \pm 2.74	
	Sept.	34.16 \pm 4.84	39.42 \pm 5.05	36.50 \pm 4.06	38.64 \pm 4.55	40.28 \pm 4.51	
Cl- mg/L	July	66.4 \pm 10.48	76.2 \pm 10.70	69.8 \pm 11.12	63.6 \pm 7.50	84.3 \pm 9.21	250 (WHO)
	August	28.1 \pm 6.24	36.7 \pm 4.96	34.5 \pm 4.56	26.8 \pm 3.57	38.4 \pm 4.70	
	Sept.	42.6 \pm 5.37	56.5 \pm 6.41	50.4 \pm 7.12	46.2 \pm 5.57	62.5 \pm 7.49	
PO ₄ ⁻³ , mg/L	July	0.16 \pm 0.02	0.16 \pm 0.01	0.18 \pm 0.02	0.17 \pm 0.01	0.21 \pm 0.02	0.10 (WHO)
	August	0.12 \pm 0.01	0.13 \pm 0.02	0.14 \pm 0.02	0.13 \pm 0.01	0.14 \pm 0.01	
	Sept.	0.13 \pm 0.01	0.15 \pm 0.02	0.14 \pm 0.01	0.15 \pm 0.02	0.16 \pm 0.017	
Na ⁺ , mg/L	July	46.6 \pm 5.96	50.8 \pm 6.49	54.4 \pm 4.59	60.5 \pm 5.54	57.4 \pm 5.50	20 mg/L (WHO)
	August	19.2 \pm 1.74	21.6 \pm 2.06	24.8 \pm 2.17	28.2 \pm 3.20	21.8 \pm 2.17	
	Sept.	24.8 \pm 2.27	29.2 \pm 2.68	31.4 \pm 1.50	34.6 \pm 1.78	26.2 \pm 1.30	
K ⁺ , mg/L	July	21.6 \pm 2.08	14.8 \pm 1.47	13.9 \pm 1.47	15.7 \pm 1.55	16.2 \pm 1.30	12 mg/L (BIS)
	August	11.3 \pm 1.31	10.6 \pm 1.21	12.8 \pm 1.30	10.4 \pm 1.21	11.5 \pm 0.95	
	Sept.	7.6 \pm 1.05	8.2 \pm 0.95	9.8 \pm 1.13	9.6 \pm 1.30	8.7 \pm 0.95	
Ca ⁺² , mg/L	July	156 \pm 9.53	142 \pm 9.64	151 \pm 9.60	162 \pm 10.44	149 \pm 9.56	75 mg/L (BIS)
	August	82.4 \pm 5.29	67.6 \pm 4.34	78.2 \pm 8.78	89.6 \pm 6.24	71.4 \pm 4.94	
	Sept.	59.6 \pm 3.65	46.4 \pm 3.50	42.8 \pm 4.32	51.3 \pm 3.72	39.8 \pm 3.36	
Mg ⁺² , mg/L	July	23.6 \pm 1.90	18.3 \pm 1.83	17.3 \pm 2.11	17.6 \pm 1.61	19.4 \pm 1.65	30 mg/L, (BIS)
	August	8.6 \pm 1.47	7.2 \pm 1.38	6.5 \pm 0.70	8.3 \pm 1.30	7.6 \pm 1.13	
	Sept.	14.7 \pm 1.47	15.2 \pm 1.38	16.8 \pm 1.47	17.2 \pm 1.38	15.9 \pm 1.38	

Result and Discussion

The results of various water quality parameters of the Chandrabhaga River water, between Dhalwala

Bridge and Maya kund area in Rishikesh are presented in Table.1 The river water quality is affected by a wide range of natural and human

influences.¹ As water flows through the various geological environments, the variation in water quality is governed by soil, geology, climate and

anthropogenic activities that modify the composition of dissolved materials.¹⁰

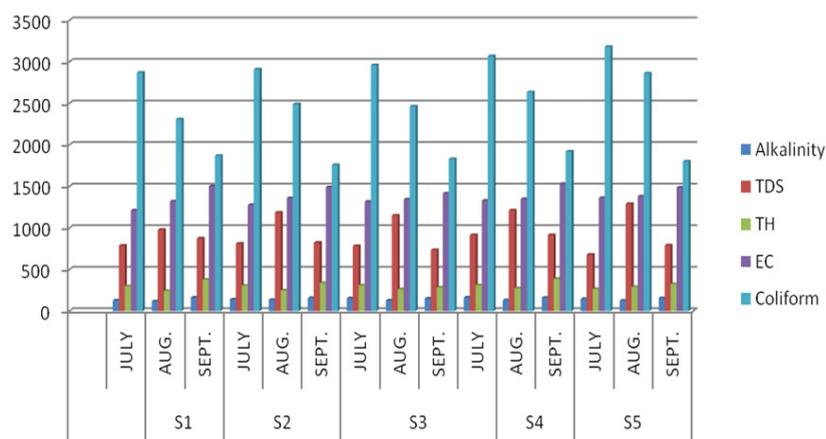


Fig. 2: Site and month wise Values of TH, TDS, Alkalinity, mg/L, EC, μ S/cm and Coliforms, MPN/100mL

Hydrogen Ion Concentration (pH)

As per Table 1, the observed pH values varied from 7.13 ± 0.03 to 8.16 ± 0.03 and all are within the WHO desirable range. The higher values of pH indicate slightly alkaline nature of water samples. The order of seasonal variation in pH was September > July > August. During heavy rain, water dissolves atmospheric carbon dioxide that forms a weak carbonic acid and lowers the pH,²⁵ thus during high flow month (August) at all the sampling locations pH were lower than other months.

Total Dissolved Solids (TDS)

The permissible limits of TDS in water for drinking purpose and for irrigation is up to 1,000 mg/L and 2,000 mg/L respectively, while water with TDS above 3,000 mg/L are not suitable even for irrigation.²⁶ The observed values of TDS, as shown in the Table 1 and Fig.2 varied from 680 ± 5.52 to 1290 ± 11.18 mg/L. The recorded TDS values during high flow month (August) were higher than during low flow months at all the locations.

Electrical Conductivity (EC)

All the observed values of conductivity, (Table 1, Fig.2) were above WHO standard that varied from 1214 ± 7.81 to 1362 ± 11.29 μ S/cm, from 1320 ± 9.16 to 1380 ± 13.22 μ S/cm and from 1416 ± 8.89 to 1532 ± 10.44 μ S/cm during July, August and September

respectively. Such higher values of EC may be attributed to the high degree of anthropogenic activities as wastewater from domestic sewage often contains high amounts of dissolved salts.^{10, 27}

Total Hardness (TH)

Total hardness of water is due to bicarbonate, sulphate, chloride, and nitrates of Ca and Mg and expressed as mg/L of calcium carbonate.^{26, 28} Desirable limit for total hardness as per Indian standards is 300 mg/L. As per Table 1 and Fig.2, total hardness observed during July varied from 267 ± 8.66 to 312 ± 8.72 mg/L and during September varied from 286 ± 8.18 to 388 ± 11.27 mg/L. While, during high flow month (August) TH varied from 242 ± 8.72 to 290 ± 6.10 mg/L.

Total Alkalinity

Total Alkalinity of water is its capacity to neutralize a strong acid and it is normally due to the presence of bicarbonate, carbonate, phosphate, borate, silicate and hydroxides of Ca, Na and K. Total alkalinity is due to salts of weak acids and bicarbonates.²⁸ The alkalinity is expressed in term of CaCO_3 equivalent. Alkalinity of all samples, were much higher than the WHO limit. The values (Table1, Fig.2) during July varied from 131 ± 8.12 to 164 ± 8.54 mg/L, while during September, varied from 154 ± 8.72 to 165 ± 9.11 mg/L, and during high flow month the alkalinity

values varied from 118 ± 7.0 to 136 ± 8.18 . The high values of alkalinity during September (least flow month) as compared to July may be due to higher input of contaminants.

Total Coliforms

The sources of Coliforms are live stocks, septic systems, manure, and household waste water.²⁵ Coliforms in a water sample are undesirable and its presence in water is indicator of the contamination of human or animal facial waste that causes water-borne diseases such as diarrhea, typhoid and hepatitis.³¹ As per Table 1 and Fig.2, the observed values of Coliforms are quite high in all the seasons that varied from 1760 ± 13.23 to 3180 ± 27.61 MPN/100 ml. The evidence of such a high value of Total Coliforms is that the river bed is subjected to encroachment by slum dwellers discharging their excreta in open.

Biochemical Oxygen Demand (BOD₅)

BOD is the oxygen required by aerobic organisms to decompose organic matter present in water samples. It reflects the contamination in water bodies due to inputs of the nutrients, food, plants and animals. Higher is the BOD, the more rapid is the depletion of the dissolved oxygen in the river water.²⁹ The BOD during July varied from 46 ± 4.36 to 52 ± 5.29 mg/L that falls considerably during high flow month (August) ranging from 21 ± 2.64 to 26 ± 3.0 mg/L. This may be due to dilution and decomposition of contaminants by fast flowing huge flux of water that may carry garbage with it. The BOD showed increasing trend during the least flow month of September and varied from 25 ± 3.60 to 36 ± 3.24 mg/L, which may be due to added organic matters and inorganic nitrogen from domestic waste waters and dairy effluents.²⁸



Fig. 3: Site and month wise Values of BOD, Nitrate and Chloride, mg/L

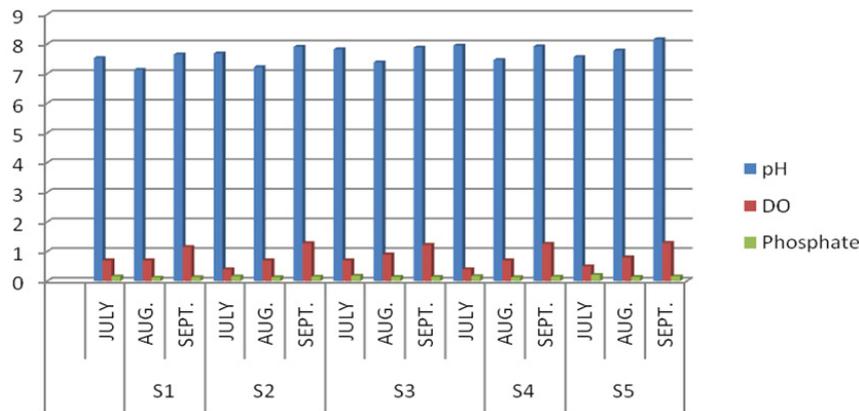


Fig. 4: Site and month wise Values of DO, Phosphate, mg/L and pH

Dissolved Oxygen (DO)

The DO value of a water body reflects its self-purification capacity and organic matter in it.²⁷ The flowing river water have approximately 8 mg/L DO, values lower than this indicate the presence of considerable organic contaminants in water samples.²⁸ The recorded values (Table 1, Fig.3) of DO varied from 0.4 ± 0.01 to 1.29 ± 0.062 mg/L, such a low DO is attributed to the heavy load of wastewater and sewage in the river-bed. The use of pesticides and chemical fertilizers in agricultural runoff increases the inputs of nitrate and phosphates that increases microbial activities to decompose organic matter.³⁰ A water body that is rich in such nutrients flourishes algal growth that consumes much of the DO from river water.²⁵

Chloride (Cl⁻)

Chloride enters in water due to dissolution of salt deposits, discharges of industrial and domestic effluents, sewage, fertilizers, agricultural and

irrigation runoff. High chloride content is harmful to soil bacteria already plants and galvanized iron pipes used in domestic water supply system.³² Chloride concentrations in all the samples collected were well below the WHO permissible limit and varied from 26.8 ± 3.57 to 84.3 ± 9.2 mg/L.

Nitrate (NO₃⁻)

The presence of nitrates in the water samples is suggestive of some bacterial action and bacterial growth.³³ The WHO guideline value for nitrate in drinking-water is 50 mg/L as nitrate ion.³⁴ Algae and bacteria undergo atmospheric nitrogen fixation in nitrates.³⁵ The concentration of nitrate in water samples varied from 19.26 ± 4.65 to 52.60 ± 6.33 mg/L. The observed values of nitrate were lowest (19.26 ± 4.65 to 24.60 ± 4.33 mg/L)³⁶ in August (high flow month) that varied from 37.50 ± 6.15 to 52.60 ± 8.95 and 34.16 ± 6.84 to 40.28 ± 6.38 mg/L, during July and September 2017, respectively.

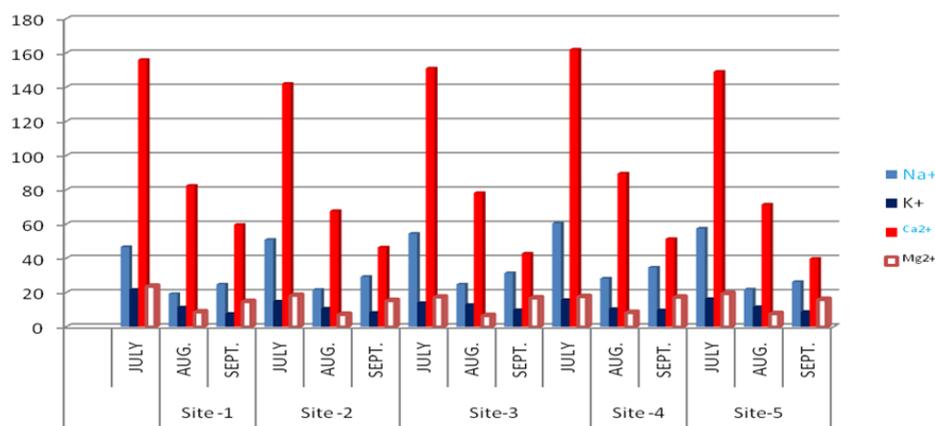


Fig. 5: Site and month wise Values of Na⁺, K⁺, Ca²⁺ and Mg²⁺, mg/L

Phosphate (PO₄³⁻)

Phosphate occurs in river water mainly due to detergents and fertilizers. Phosphorus in low concentration is essential for the growth of organisms;³⁷ however its high concentration favours high algal growth that during decay leads the depletion of dissolved oxygen.³⁵ Overall phosphate ranges from 0.12 ± 0.01 to 0.21 ± 0.02 mg/L (Table 1).

Metal Ions

The results of metal ion concentrations are presented in Table-1 and Fig. 5. Sodium is used to classify irrigation water, due to its reaction with soil, which

reduces its permeability.¹⁰ The observed values of sodium in water samples vary from 19.2 ± 2.43 to 60.5 ± 6.42 mg/L. Important sources of potassium are weathering of rocks, silicate minerals and domestic waste.⁶ The high concentration of potassium in natural water is an indication of pollution by domestic waste.¹⁰ The observed concentration of potassium varied from 7.6 ± 1.15 to 21.6 ± 2.36 mg/L. The concentration of calcium varied from 39.8 ± 3.39 to 162 ± 12.16 mg/L. The high level of calcium indicates the high value of hardness of water. The observed values of magnesium varied from 6.5 ± 0.79 to 23.6 ± 2.17 mg/L.

Table 2: Correlations Matrix of Chandrabhaga River

Para meters	pH	TDS	EC	DO	BOD	TH	Coli form	Alkalinity	NO ₃ ⁻	Cl ⁻	PO ₄ ⁻³
during July, 2017											
pH	1.0000										
TDS	0.7616	1.0000									
EC	-0.1921	0.9463	1.0000								
DO	0.4876	-0.1381	-0.4213	1.0000							
BOD	0.3688	0.1959	-0.2225	0.5512	1.0000						
TH	0.6445	0.9074	0.7670	-0.6869	0.8510	1.0000					
Coli-form	0.7705	0.0775	0.3919	0.6088	0.3206	-0.1939	1.0000				
Alkalinity	0.8829	0.8934	0.9790	-0.4126	0.3328	0.6835	0.4490	1.0000			
NO ₃ ⁻	0.4439	-0.7032	-0.5846	0.5263	-0.7108	-0.9139	0.1919	-0.528	1.0000		
Cl ⁻	-0.4256	0.4660	0.3802	-0.7597	0.0403	0.2379	-0.2398	0.4407	0.0438	1.0000	
PO ₄ ⁻³	-0.1865	0.2623	0.2192	-0.3589	0.0727	-0.0391	-0.0741	0.2003	0.4321	0.7671	1.0000
during August, 2017											
pH	1.0000										
TDS	0.8366	1.0000									
EC	0.8081	0.9511	1.0000								
DO	0.5999	0.7940	0.9368	1.000							
BOD	0.8089	0.8089	0.6879	0.564	1.000						
TH	0.9765	0.8336	0.7396	0.358	-0.512	1.0000					
Coli-form	0.8216	0.9146	0.8981	0.8025	0.5407	0.9346	1.0000				
Alkalinity	0.8216	0.9514	0.9994	0.7556	0.7284	0.7540	0.9114	1.0000			
NO ₃ ⁻	-0.0723	0.3457	0.3818	0.0437	0.7400	-0.862	0.4461	0.3487	1.0000		
Cl ⁻	0.1990	0.5595	0.6433	0.7595	0.1675	-0.0635	0.0093	0.6095	0.4975	1.0000	
PO ₄ ⁻³	0.7549	0.7713	0.2797	0.2489	0.7244	0.4854	-0.2874	0.2727	-0.0058	0.5298	1.000
during September, 2017											
pH	1.0000										
TDS	-0.3623	1.0000									
EC	-0.0677	0.9306	1.0000								
DO	0.8207	0.2143	0.4473	1.0000							
BOD	0.5980	0.1709	0.2144	0.8981	1.0000						
TH	-0.3938	0.9888	0.9330	-0.8132	0.0876	1.0000					
Coli-form	-0.3756	0.6430	0.4151	0.0610	0.4838	-0.8683	1.0000				
Alkalinity	-0.5988	0.8982	0.7998	-0.1413	-0.1573	-0.4521	0.4775	1.0000			
NO ₃ ⁻	0.9026	-0.124	0.1676	0.5914	0.5194	-0.2331	0.3151	-0.6834	1.0000		
Cl ⁻	0.8747	-0.548	-0.213	-0.2679	0.1374	0.5139	-0.5509	0.4140	0.8215	1.0000	
PO ₄ ⁻³	0.9550	-0.133	0.1707	-0.3807	0.5968	0.5938	-0.6463	0.3434	0.5205	0.8297	1.0000

Pearson Correlation Matrix

Karl Pearson Correlation analysis (r) was computed in order to find out the closeness of relationship between the water quality parameters and the results are presented in Table- 2. Some of the highly positive correlations observed were between EC and TDS ($r = 0.9463, 0.9511$ and 0.9356), between TH and TDS ($r = 0.9074, 0.8336$ and 0.9888) and, between TH and EC ($r = 0.7670, 0.7396$ and 0.9330) during July, August and September respectively. Alkalinity is positively correlated during August with pH ($r = 0.8216$), TDS ($r = 0.9514$), EC ($r = 0.9994$) and TH ($r = 0.7540$) and Coliforms ($r = +0.9114$) during high flow month, August. DO is positively correlated with pH ($r = 0.5999$ and 0.8207) during August and September. BOD is positively correlated with DO ($r = 0.5512, 0.564$ and 0.564) during July, August and September. Coliforms is positively correlated with DO (0.6088 and 0.8025) during July and August. Nitrate is negatively correlated with TDS ($r = -0.7032$), EC (-0.5846) and TH (-0.9139) during July. Chloride is positively correlated with TDS ($r = 0.5595$), EC ($r = 0.6433$) and Alkalinity ($r = 0.6095$) during August. The closeness of correlation coefficient value, r to 1 indicates perfect linear relationship between two selected water quality parameters.

Irrigation Water Quality

The suitability of water for irrigation is determined by the total concentration of salt present and the kind of salts.³⁸ By interrelating observed concentrations of some parameters, various important irrigation water quality indexes are evaluated.

Soluble Sodium Percentage (Ssp)

Soluble sodium percentage (SSP) as meq /L was calculated from the Todd equation.³⁹

$$SSP = (Na^+ + K^+) \times 100 / (Ca^{+2} + Mg^{+2} + Na^+ + K^+)$$

On the basis of SSP values, five irrigation water categories may be excellent, good, permissible, doubtful, and unsuitable. In the present study the SSP values (Table 3) varied from 20.97 to 25.10 %, indicate that the river water samples had good quality (20- 40 % Na) for irrigation purpose.

Sodium Adsorption Ratio (Sar)

Sodium adsorption ratio (SAR) is related to the amount of sodium in relation to the calcium and magnesium concentration in water. The SAR of water mainly depends on soil type, texture, drainage capacity. Mathematically, SAR is the ratio of the sodium concentration and the square root of half of the total concentration of calcium and magnesium in water. It was calculated using the Raghunath equation,⁴⁰ in which the concentration of the ions was expressed in meq /L.

$$SAR = Na^+ / \sqrt{(Ca^{+2} + Mg^{+2}) / 2}$$

Higher values of sodium in water sample may alter the permeability of soil and reduce or stop water from moving into soil. Water with SAR < 3 is best for plant growth. SAR values (Table 3) were varied from 1.28 to 1.75.

Magnesium Adsorption Ratio (Mar) or Magnesium Hazard (Mh)

Magnesium concentration is important for productivity of soil therefore it determines the suitability of water under study for irrigation. Magnesium adsorption ratio (MAR) was calculated by using following expression.³⁹

MAR = $Mg^{+2} / (Ca^{+2} + Mg^{+2}) \times 100$, where cation concentrations are expressed in meq /L.

Table 3: Irrigation water quality of Chandrabhaga River water

Collection Sites	SSP	SAR	MAR	KR
S1	20.97	1.28	20.79	0.209
S2	24.52	1.55	20.94	0.273
S3	25.06	1.61	19.91	0.282
S4	25.10	1.75	19.12	0.286
S5	24.99	1.59	21.58	0.276

The observed MAR results (Table 3) were between 19.12 and 21.58. Water with Magnesium hazard

less than 50 is considered safe and suitable for irrigation purpose,¹⁰ higher value than this has an

adverse effect on the crop yield as the soil becomes more alkaline.³⁸

Kelley's Ratio (KR)

The level of Na⁺ measured against Ca⁺² and Mg⁺² is known as Kelley's ratio (KR) that is used for rating irrigation water. KR is calculated using following expression.⁴¹

$$\text{Kelley Ratio} = \text{Na}^+ / (\text{Ca}^{+2} + \text{Mg}^{+2})$$

All the values of Kelley's ratio (Table 3) varied from 0.209 to 0.286 suggesting that river water is not unfit for irrigation purpose.¹⁰

Conclusion

Under National Mission for Clean Ganga Project, the focus is to clean and protect the River Ganga in a comprehensive manner, with the priority to build sewage pumping stations (SPS) and sewage treatment plants (STP) as long term requirement along the Ganga route to block the pollutants going into the river. Yet tapping of various Nallahs releasing domestic waste water directly in the river bed are to be undertaken to avoid their discharge in Chandrabhaga river bed that reaches finally to the River Ganges. The analytical results of water quality parameters studied revealed that in the Chandrabhaga River water, much low DO values that varied from 0.4 to 1.29 mg/L with high BOD and much high total Coliforms at all the sampling locations reflects the poor water quality of the River. However, recorded values of TDS, EC, TH, alkalinity and phosphate exceeded the WHO standards. TDS

values during high flow month of August at all the sampling sites recorded higher than in low flow months. Highly positive correlations were found all the time between EC and TDS, TH and TDS, TH and EC, while during high flow month good correlations were recorded between alkalinity and pH, TDS, EC, Coliforms and TH. Thus continuous charging of the urban and agricultural runoff and sewage directly in the river bed has lead to the irreversible degradation of the quality of Chandrabhaga water. Further, merging of such highly contaminated river water directly with the Ganges at Mayakund area is deteriorating the River Ganges water quality. To prevent the merging of waste water and domestic effluents in River Ganges, all the nallahs and outlets on both the banks of Chandrabhaga River should be connected with sewage pumping stations (SPS) or STP.

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Conflict of Interest

There is no conflict of interest.

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