STUDIES ON PHYSICOCHEMICAL PARAMETERS TO ASSESS THE WATER QUALITY OF RIVER GANGA FOR DRINKING PURPOSE IN HARIDWAR DISTRICT

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ABSTRACT
A systematic study has been carried out to assess the water quality index of River Ganga in Haridwar District. 90 water samples from five sampling stations were collected and analysed for physico-chemical parameters (Temp, velocity, pH, dissolved oxygen, free CO2, C.O.D., B.O.D., Carbonate, Bicarbonate, total alkalinity, hardness, turbidity, calcium, magnesium, sodium, potassium, nitrate, phosphate, chloride, sulphate, electrical conductivity, total dissolved solids and total suspended solids.)
The study area experiences a seasonal climate and broadly divided into three seasons as winter (November to February), Summer (March to June) and rainy (July to October). The samples were collected and analysed for two consecutive years 2007 and 2008. Each parameter was compared with the standard desirable limit of that parameter in river water as prescribed by different agencies.
The analytical data of various physicochemical parameters indicates that some parameters like pH, electrical conductivity, total dissolved solids , total suspended solids, turbidity and sodium are found to be in excess than the prescribed limit in some water samples of the study areas. The WQI value indicates that water samples of some sampling stations are quite unfit for drinking purpose because of high value of dissolved solids and sodium. It was also observed that the water in the year 2007 was of a better quality than in the year 2008. Suitable suggestions were made to improve the quality of river water.
Key words: Water pollution, Ganga river water, physicochemical analysis, Water quality index, potability.

1. INTRODUCTION

Pollution of a river first affects its chemical quality and then systematically destroys the community disrupting the delicate food web. Diverse uses of the rivers are seriously impaired due to pollution and even the polluters like industry suffer due to increased pollution of the rivers. River pollution has several dimensions and effective monitoring and control of river pollution requires the expertise from various disciplines[1].Pollution of river is a global problem. In India it is reported that about 70% of the available water is polluted. The chief source of pollution is identified as sewage constituting 84 to 92 percent of the waste water. Industrial waste water comprised 8 to 16 percent.
The indiscriminate and large scale deforestation and over grazing in the watershed areas of river basins have caused soil erosion resulting in considerable silting of dams and shrinkage of river flows. This leads to the flooding of the rivers at the time of excessive rains[2]. The disposal of waste leads to contamination of river and lakes chronically affecting the flora and fauna. According to surveys carried out on selected stretches of important rivers, it has been found that most of the rivers are grossly polluted. The domestic sewage discharged from a population of about 2 millions gives rise to numerous water -borne diseases like typhoid, cholera, dysentery, poliomyelitis and cysticercosis, thereby affecting the human health and deterioration of the water quality[3]. Ganga, the mighty Indian river originates from the snowed peaks of Himalayas, is the lifeline of millions of Indians. From its source to its entry in to the Bay of Bengal, it travels a distance of around 2525 Kms. The river with its well knit tributaries drains the Ganga Basin which encompasses an area of more than a million square kilometers. (1060,000 sq km)spread over four countries- India, Nepal, Bangladesh and China[4].
Hardwar is a city in Northern India on the bank of the Ganga River north east of Delhi. It is a Hindu pilgrimage centre. Hardwar lies along the Ganga River at the boundary between the Indo-gangetic plain (South) and the Himalayan foothills (North). The water supply of the Ganga system is partly dependent on the rains brought by the monsoon winds from July to October as well as on the flow from melting Himalayan glaciers in the hot season from April to June. The religious importance of Ganga may exceed than that of any other river in the world.
For this study, the water samples were collected from five spots. Sampling station A (Bhooma Niketan), sampling station B (Jai Ram Ashram), Samping station C (Har-Ki-Pauri), sampling station D (Prem Nagar Ashram) and sampling station E (Pul Jatwara) .
Sampling station A is situated in the north of Haridwar**.** The stream of the Ganga is separated from Malviya point and flows through Kharkhari via Jai Ram Ashram (sampling station B) and confluenced with second stream of Ganga river on the left side of Pant Dweep of Har-Ki-Pauri (sampling station C) . A number of pilgrims take their holy dip here, and their number is increased manifolds at the time of bathing festivals. The ashes and bones are also dumped here. Before this station, a cremation place is also situated and the effluents of Ashrams, hotels and other houses also enters the Ganga at Pant dweep. Nullah of Bheemgoda and Kangra Mandir also opens here. The sampling station D (Prem Nagar Ashram) is situated downwards to Kankhal bridge. The domestic sewage mixes upstream to the sampling point. The last sampling station -E (Pul Jatwara) is situated in Jwalapur, where two Nullahs are joining the main stream towards upstream of the water flow.
Accurate and timely information on the quality of water is necessary to shape a sound public policy and to implement the water quality improvement programmes efficiently. One of the most effective ways to communicate information on water quality

trends is with indices. Water quality index (WQI) is commonly used for the detection and evaluation of water pollution and may be defined as "a **rating reflecting the composite influence of different quality parameters on the overall quality of water."** [5] The indices are broadly characterized in to two parts: the physico-chemical indices and the biological indices. The physico-chemical indices are based on the values of various physico-chemical parameters in a water sample, while biological indices are derived from the biological information and are calculated using the species composition of the sample, the diversity of species, their distribution pattern, the presence or absence of the indicator species or groups etc.[6]. Here attempt has been made to calculate the water quality index of the Ganga river water in Haridwar on the basis of Harkins[7], Lohani[8] and subsequently modified by Tiwari et.al. [9] based on physico-chemical data.

2. EXPERIMENTAL

A total of 90 water samples were collected from five different spots during different seasons over a period of two years (November 2006 to October 2008). The samples were taken in BOD bottles and plastic jerry canes and brought to the laboratory with necessary precautions. All samples were labeled properly. Some parameters like temperature, velocity, pH and dissolved oxygen were measured on site. Grab sampling was generally applied during the sampling. Water samples were analysed by standard methods [10-17].The samples were analyzed for following physicochemical parameters:

Water Temperature (ºC), velocity(m/s), pH, hardness (mg/l), turbidity (JTU), total dissolved solids (mg/l), total suspended solids (mg/l), electrical conductivity (µmho/cm), free CO_2(mg/l), dissolved oxygen (mg/l), B.O.D. (mg/l), C.O.D. (mg/l), alkalinity (mg/l), chloride (mg/l), calcium (mg/l), magnesium (mg/l), sodium (mg/l), potassium (mg/l),carbonate (mg/l), bicarbonate (mg/l) and sulphate (mg/l).

Eleven parameters were taken for calculation[18] of water quality index : Ca, Mg, Na, K, NO_3^-, SO_4^{2-}, Cl^-, hardness, TDSD, B.O.D. and total alkalinity.

It is an established fact that the more harmful a given pollutant is, the smaller is its standard permissible value recommended for drinking water. Therefore, the "Weights" for various water quality characteristics

are assumed to be inversely proportional to the recommended standards for the corresponding parameters (Tiwari and Ali)[19]. that is,

$$W_i = K\backslash S_i$$

Where W_i is the unit weight and Si is the recommended standard for the ith parameter P_i. The constant of proportionality K in equation can be determined from the condition

$$\Sigma W_i = K\Sigma(1\backslash S_i)$$

The quality rating q_i for the ith parameter P_i is calculated from the following equation:

$$q_i = 100(V_i / S_i)$$

Where V_i is the observed value. The subindex S_i for the the parameter P_i is given by $(S_i)=(q_i w_i)$

The overall WQI can be calculated by aggregating the quality rating (q_i) or subindices, linearly, and taking their weighted mean, i.e.

$$WQI=[(\Sigma q_i w_i/\Sigma w_i)]$$

3. RESULTS AND DISCUSSION

The results obtained from analysis of water samples of river Ganga are shown in table 1 and table 2.

The reported values refer to the mean value of water samples collected in different seasons at different areas along the stretch of Ganga river. The results indicate that the quality of water varies considerably from location to location. A summary of the findings is given below:

The water temperature of the Ganga at Hardwar ranged between 10.18 ºC to 19.73 ºC. The maximum water temperature started decreasing due to the melting of snow at the peaks of the Himalaya. The water temperature showed an upward trend from winter season to summer season followed by a downward trend from rainy season onwards.

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. The maximum velocity 2.18 m/s of the Ganga at Haridwar was recorded in monsoon season and the minimum velocity 0.39m/s was observed in winter season.

The conductivity of water is affected by the suspended impurities and also depends upon the amount of ions in the water. The highest conductivity 415.66µmho/cm of the Ganga water was observed in monsoon season. From monsoon season onwards the conductivity decreased and minimum conductivity 95.89µmho/cm was observed in winter season.

The 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.

Total solids may affect water quality. Water with high total solids generally is of inferior potability. Total dissolved solids were observed maximum 540.68 mg/l in rainy season and minimum 42.58 mg/l in winter season. Total suspended solids were recorded maximum 3125.76mg/l in monsoon season and minimum 110.28 mg/l.

The pH of the Ganga river at Haridwar was slightly alkaline. It ranged from 7.06 to 8.35.

The Ganga water contained highest dissolved oxygen during winter season, followed by a gradual decrease to its lowest values during monsoon season. The higher concentrations of dissolved oxygen during winter season was probably due to low water temperature, no turbidity and increased photosynthetic activity of the green algae found on the submerged stones and pebbles. The maximum 11.71 mg/l oxygen content of water was recorded in winter season and minimum 7.08 mg/l in rainy season. From

monsoon season the water of Ganga starts becoming turbid which reduces the photosynthetic activity of the algae and thus decreases oxygen concentration.
Free carbon dioxide in the Ganga water was invariably present throughout the year. It fluctuated from 1.15mg/l in winter season to 5.39 mg/l in rainy season. The free carbon dioxide was found to be maximum in monsoon season and minimum in winter season. The following map is showing the river Ganga and sampling sites-

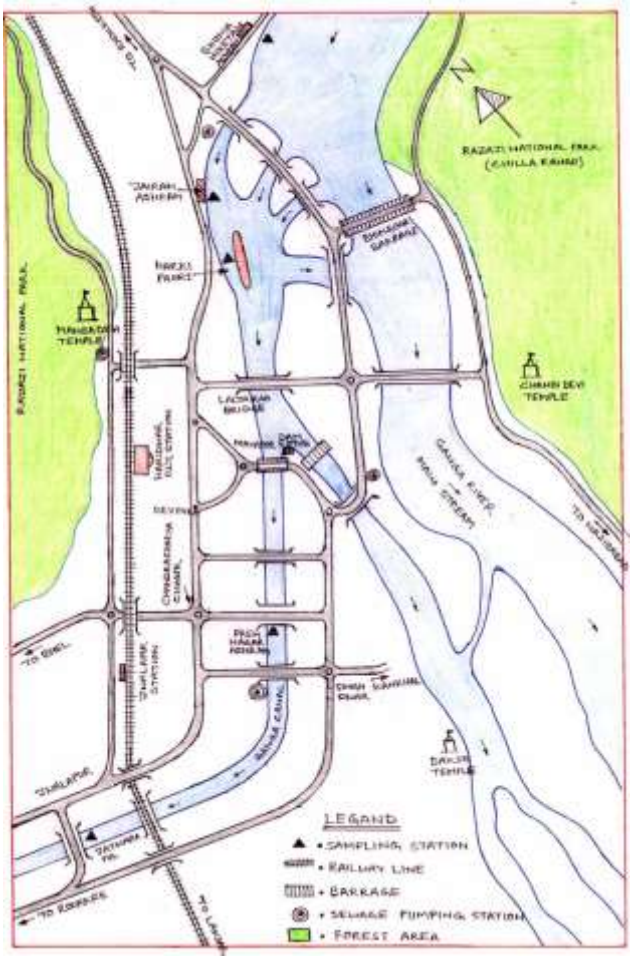

Fig 1 : Map of River Ganga showing sampling sites.

The C.O.D. ranged from 4.58mg/l to 13.72mg/l. The minimum C.O.D. was recorded in monsoon season and maximum in winter season.
The B.O.D. was maximum 3.90 mg/l in monsoon season and minimum1.35 mg/l in winter season.
Total alkalinity throughout the year ranges from 34.35 mg/l in winter season to 90.5 mg/l in summer season. The alkalinity due to carbonates was more or less nil.
Maximum calcium 27.4 mg/l was found in rainy season. Minimum calcium 10.9 mg/l was found in winter season . Similarly, maximum magnesium 7.4 mg/l was found in rainy season and minimum magnesium 2.3 mg/l was found in winter season. Concentration of Calcium was always greater than that of magnesium.
The hardness was higher in the monsoon season (120.62mg/l) and lower in the winter season (87.55mg/l).
Calcium ions make major contribution to the hardness of river water.
Maximum concentration of Sodium 28.320 mg/l was found in rainy season and minimum 6.720 mg/l in summer season. Similarly, maximum concentration of potassium 3.425 mg/lit was found in rainy season and minimum 1.216 mg/l in summer season. Sodium was found to have greater values than potassium throughout the study.
Maximum amount of nitrate (0.105mg/l) was found in rainy season and minimum amount (0.0115mg/l) was found in summer season. Nitrate concentration depends upon the activity of nitrifying bacteria.
The total phosphate was highest in monsoon season (0.23mg/l) and lowest in winter season. (0.037mg/l). Total sulphate was maximum in monsoon season (37.15mg/l) and minimum in winter season (16.45 mg/l).The chloride was observed maximum (13.48 mg/l) in rainy season and minimum (1.97 mg/l) in winter season.
Water quality index represents the integrated effects of the relevant water quality variables. Table 3 shows drinking water quality standards and unit weights for all the parameters used in calculating WQI. For Ganga river water, the rating of WQI of water samples was calculated and represented in table 4. Graphical representation of variation of WQI at all sampling stations in different seasons is shown in fig.-1.

It may be stated that the water quality requirements differ from one age to another and thus any polluted water may be considered suitable for some of the beneficial uses but may remain unsuitable for other purposes. Avash maruth[20] gave the rating of water quality as shown below:

WQI level	Water quality rating
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very poor
>100	Unfit for drinking purpose.

In the present study water of river Ganga was found to be in excellent quality in winter season at all the five sampling sites as the WQI ranged from 24.80 to 34.32 for both the years. Water of River Ganga was found to be of poor quality in rainy season as WQI at all sampling stations ranges from 47.30 to 59.81. The WQI starts increasing from winter to summer and it further increases from summer to rainy season. It was also observed that the water in the year 2007 was of better quality than in year 2008. It may be due to industrialization because of development of SIDCUL.

4. CONCLUSION

From present investigations we concluded that the quality of most of the water samples under study was suitable for drinking purpose except in rainy season. In rainy season WQI increases due to increased concentration of sodium and dissolved solids. Because of high concentration of sodium, there is potential

.**Table-1 :** Mean and Standard deviation of different parameters at different sampling stations

RASĀYAN J. Chem.
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Sampling station	Bhooma niketan		Jai Ram ashram		Har ki pauri		Prem nagar		Pul Jatwara	
Parameters	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean**	**S.D.**
Water Temp	16.70	4.2482	16.04	4.1811	16.45	4.1014	15.55	4.0425	15.82	4.0277
Velocity	1.18	0.7398	1.25	0.4964	1.52	0.5370	1.21	0.4834	1.32	0.5202
pH	8.16	0.1516	7.49	0.2675	7.47	0.3172	7.37	0.2777	7.42	0.3250
DO	9.28	1.4677	9.04	1.5955	9.53	1.8844	9.50	1.9003	9.38	1.7284
Free CO_2	3.00	1.5812	3.38	1.5684	3.05	1.5456	3.10	1.6316	3.13	1.6302
COD	3.89	1.3495	9.41	2.7837	8.77	3.0168	9.00	2.9982	9.38	2.9195
BOD	2.63	0.8041	2.95	0.7039	2.50	0.7390	2.60	0.7014	2.92	0.8602
CO_3^{2-}	2.46	1.2290	0.22	0.1241	0.20	0.0775	0.12	0.0628	0.15	0.0635
HCO_3^-	63.68	20.5654	52.46	13.7336	50.81	14.4990	50.26	14.0571	50.32	13.1820
Total Alkalinity	65.71	19.7929	52.69	13.6743	51.05	14.4619	50.51	14.2193	50.68	13.3678
Hardness	100.44	9.9355	109.97	7.5452	102.62	11.3952	117.09	26.6345	108.65	10.3600
Turbidity	235.63	281.4771	211.95	282.6695	208.57	278.0215	208.91	276.7748	203.11	267.0415
Ca	16.72	2.0371	19.18	2.4334	20.78	3.5819	15.57	2.3822	13.62	2.3524

Mg	4.18	0.5636	5.65	0.7868	6.78	0.5565	4.23	0.6947	3.48	0.7985
Na	12.1563	6.0644	14.5095	6.9261	15.8938	8.3367	15.5512	7.8066	15.4475	7.2250
K	2.21	0.5645	2.05	0.5812	2.07	0.8077	2.05	0.8115	2.07	0.8486
NO_3^-	0.0375	0.0354	0.0484	0.0372	0.0428	0.0315	0.0411	0.0233	0.0465	0.0335
PO_4^{3-}	0.0640	0.0565	0.1082	0.0749	0.0820	0.0508	0.1007	0.0676	0.0987	0.0662
Cl^-	6.11	5.1546	5.78	4.8231	5.71	4.8209	5.78	4.9050	5.84	4.9166
SO_4^{2-}	28.24	6.1971	24.52	6.3475	23.51	4.2921	22.76	3.4552	22.96	3.7560
Ec	223.56	147.5192	200.47	108.0951	197.93	119.8590	199.83	120.4835	197.77	117.9629
TDSD	275.87	229.9665	336.20	294.7332	397.26	396.4792	409.91	401.9551	407.83	397.6374
TSSD	1151.76	1348.9397	1123.55	1369.5643	1169.96	1452.3666	1143.09	1406.9099	1155.23	1401.192

risk of getting cardiovascular diseases and in women toxemia associated with pregnancy. From WQI values, it is suggested that further improvement is required to treat the Ganga water at Haridwar.

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