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Physico-Chemical Parameters of River Ganga, Prayagraj, Uttar Pradesh, India

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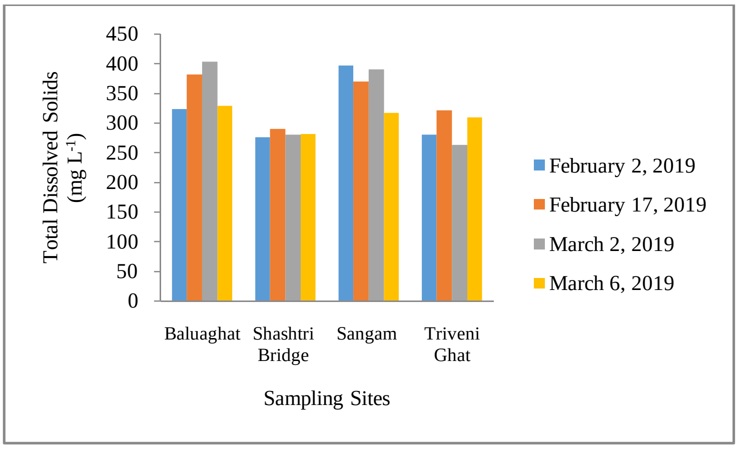
ABSTRACT

In this paper a systematic study has been carried out to analyze the Physico-Chemical properties of River Ganga in Prayagraj District. Total forty samples from four different sampling sites and on four different dates were collected and analyzed for physico-chemical parameters (water temperature, pH, total dissolved solids, electrical conductivity, dissolved oxygen, biochemical oxygen demand, chloride, and fluoride). It was observed that most of the parameters were within permissible limit according to WHO (2009) and BIS (2004) with some exceptions where the values were slightly raised in comparison to others.

Graphical Abstract



Total Dissolved Solids.

Keywords: River Ganga, Physico-chemical parameters, Water potability, Water quality.

INTRODUCTION

Water is an essential natural resource. Earth is recognized as blue planet as it is covered with water. All living things need water to survive. Water is necessary for life existence. Nearly three-fourth of the earth surface covered with water. Inspite of this water scarcity is a common phenomenon in many areas. Fresh water is limited source. Population growth and rapid industrialization are main causes for water pollution in urban areas [1]. River Ganga occupies a distinctive position in the cultural spirit of India. Millions of Hindus accept its water as sacred and count as river of devotion, faith and worship. River Ganga has originated from two headwaters at an altitude of about 6000 m in the Garhwal Himalaya, it flows through the Shivalik hills and entered the plains at Haridwar. Flowing towards south, crossing over several hundred kilometers in the Indo-Gangetic plains in Uttar Pradesh, Bihar and West Bengal, with surface water availability (446 million-acre feet) and the annual flow of freshwater in the river (142.6 million m^3), it nourishes the mostly densely populated regions of the world. Over 29 cities, 70 towns and thousands of villages extend along the Ganga banks depends on River Ganga basin from agriculture to domestic, commercial to industrial use. During its over 2,525 km journey from Gangotri to Ganga Sagar (Bay of Bengal), there are complex, nested sets of challenges that intimidate the very existence of this revered river by millions of Indians. Not only is the river a vital resource for agriculture and industry, it also holds an iconic status in India's cultural heritage [2, 3]. Ganga suffers from extreme pollution levels which is caused by the 400 million people who live close to the water body. The water quality of River Ganga is getting affected day by day due to tremendous urbanization and industrialization, and about 70% of the river water is polluted. Hence, in the last few decades, there has been a focus on the deterioration of water quality of River Ganga [4 -6].

Keeping in view of the above scenario the present study has been undertaken to analyze the impact of variation on concentration of physico-chemical parameters in River Ganga.

Study Area: Prayagraj is located at 25.45°N 81.84°E in the southern part of the Uttar Pradesh at an elevation of 98 meters (322 ft) and stands at the confluence of two, the Ganges and Yamuna. The Ganga and the Yamuna are the main rivers of the district. The plain area of the district is situated in between Ganga and Yamuna so these rivers play a very pivotal role in the agriculture of the district. The study covers stretch of Ganga from Baluaghat through the Sangam area of the Prayagraj district and some upstream-downstream areas

Samples from four different areas of the River Ganga were taken on different dates and at different time intervals. Samples were taken from the depth of 1.5 meter below the water surface. The sites were -

Baluaghat (9:10 a.m.) - 25º25″23.99′ N, 81º50″27.26′ E;

Shashtri Bridge (11:30 a.m.) - 25º26″8.31′ N, 81º53″25.25′ E;

Sangam (01:10 a.m.) - 25º25″13.00′ N, 81º53″22.83′ E;

Triveni (02:30 a.m.) - 25º24″31.84′ N, 81º53″34.73′ E;

The dates for the samples collection were 4th February, 17th February, 2nd March and 6th March 2019.

MATERIALS AND METHODS

Total 40 water samples were collected for physico-chemical analysis from the four different sampling sites at different interval, selected on the basis of the Kumbha 2019 [7, 8]. As per the norms of the APHA, Wide mouth plastic bottles of one liter size, B.O.D bottle and sterilized 250 mL glass bottle were used for collecting the samples [9-13].

These are analysed using standard methods for physiochemical examination of water (APHA) [14]. Samples were collected in a routine manner from the all sites of river Ganges at Prayagraj. Sample were analysed for Physiochemical analysis of River Ganges at Prayagraj in Uttar Pradesh. 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 analyzed by standard methods. The samples were analyzed for following physicochemical parameters: Water Temperature (ºC), pH, total dissolved solids (mg L^{-1}), electrical conductivity (µmhos cm^{-1}), free, dissolved oxygen (mg L^{-1}), B.O.D. (mg L^{-1}), chloride (mg L^{-1}), fluoride (mg L^{-1}). It is an established fact that the more harmful a given pollutant is, the smaller is its standard permissible value recommended for drinking water [15].

Temperature: Place the thermometer approximately where the sample is to be collected. Do not measure temperature right at the edge or too deep in the middle. The temperature profile of the stream changes depending on where it is measured, so be sure to get a measurement that is representative of the sample taken. Allow the thermometer to adjust to the water temperature for a few minutes. Record the readings in Centigrade (°C) for each sample [16].

pH: The basic principle of electrometric pH measurement is determination of the activity of the hydrogen ions by potentiometer measurement using a standard hydrogen electrode and a reference electrode. The Hydrogen electrode consists of a platinum electrode across which hydrogen gas is bubbles at a pressure of 101 kpa. Because of difficulty in its use and the potential for poisoning the hydrogen electrode, the glass electrode commonly is used. The electromotive force (E.M.F) produced in the glass electrode system varies linearly with pH. This linear relationship is described by plotting the measured E.M.F against the pH of different buffers. Sample pH is determined by extrapolation.

Instrument calibration in each case follows manufacturer's instructions for pH meter and for storage and preparation of electrodes for use. Establish equilibrium between electrodes and sample by stirring sample to ensure homogeneity; stir gently to minimize carbon dioxide entrainment. For buffered samples or those of hi ionic strength, condition electrodes after cleaning by dipping them into sample for 1 min. Blot dry, immerse in a fresh portion of the same sample and read pH. With dilute poorly buffered solutions equilibrate electrodes by immersing in three or four successive portions of sample. Take a fresh sample to measure pH.

Dissolved oxygen: Winkler method with Azide modification. Collect sample in BOD bottle, add 2 mL $MnSO_4$ and 2 mL alkali iodide-azide and close it with a stopper. Mix well and allow the precipitate to settle down then add 2 mL concentrated H_2SO_4, mix well till precipitate dissolves. Now take 203 mL (Correspond to 200 mL) sample in a conical flask and titrate against sodium thiosulphate (0.025 N) till pale yellow color is observed at that point add few drops of starch into it and titrate till the blue disappears and the solution becomes colorless.

Biological Oxygen Demand: To prepare dilution water aerates the required volume of D.W. by bubbling compressed air for 1-2 days to attain D.O. saturation. Then add 1 mL of phosphate buffer, magnesium sulphate, calcium chloride and ferric chloride each per liter of the dilution water and mix well. In case, waste not expected sufficient bacterial population, add seed (2 mL settle sewage per liter of dilution water) and determine DO using Winkler method with azide modification and perform the calculation by using the data obtained from DO determination.

Total dissolved solids: Filter your water sample through a rinsed and dried glass fiber filter. Collect the filtrate (liquid) and rinse water in a flask. The minimum sample volume should be 100 mL and you should use at least 3 rinses of 20 to 30 mL volumes. Transfer the filtrate to a ceramic or glass Pyrex container. The container should be weighed to the nearest 0.0000 g and place the dried container. Add the filtrate to the container and allow the sample to stay in the oven at 103°C for 24 h. If possible, increase the temperature of the drying oven to 180°C and allow the sample to dry for up to 8 h. Remove the container, place it in a desiccator to cool in a dry air environment for at least 3 to 4 h. Re-weigh the container after it cools down at least three times to the nearest 0.0000 g

(Recording your data) subtract the initial weight (in grams) of the empty container from the weight of the container with the dried residue to obtain the increase in weight.

$$\text{Concentration (mg L}^{-1}\text{)} = ((B - A)/ C)*(1000 \text{ mg g}^{-1}) * (1000 \text{ ml L}^{-1})$$

Where A-Weight of clean dried container, B-Weight of container + residue and C- Volume of Sample

Chloride: Chloride is determined in a natural or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as an indicator. Silver chloride is quantitatively precipitated before red silver chromate is formed.

Fluoride: Under acidic conditions fluorides (HF) react with zirconium SPADNS solution and the lake (colour of SPADNS reagent) gets bleached due to formation of ZrF_6. Since bleaching is a function of fluoride ions, it is directly proportional to the concentration of fluoride. It obeys Beers law in a reverse manner (Table 1).

Table 1. Water quality parameters and analytical methods used in analysis of water samples

S.No.	Parameter	Analytical method
1	Temp(°C)	Mercury Thermometer
2	pH	pH-Meter
3	EC(μSiemens cm^{-1})	Electrometric Method
4	Chloride ion (mg L^{-1})	Argentometric Method
5	DO- (mg L^{-1})	Winkler's Method
6	BOD- (mg L^{-1})	Winklers Method
7	TDS (mg L^{-1})	Gravimetric method
8	Fluoride (mg L^{-1})	Colorimetric method

RESULTS AND DISCUSSION

The results from the bar graphs indicate that the quality of water varies considerably from location to location as well as for different dates. A summary of the findings is given below: Whenever the values of any parameter go beyond the permissible limit it adversely affects the aquatic ecosystem and organism by making other corresponding parameters fluctuate up to a fatal level. Thus, increasing pollution causes ecological balance of the system to spoil [17].

Temperature: As water temperature increases, the rate of chemical reactions generally increases together. The minimum value of temperature during Kumbha Mela was noted to be 17.23°C at site 1st and the maximum value of temperature was noted to be 27.1°C at site 2nd. The water temperature started increasing due to the rise in atmospheric temperature and also due to the bathing of Kumbha Mela. The water temperature showed an upward trend from winter season to summer season. Effects- cold water holds more oxygen than warm water. As temperatures rise, the oxygen concentration of water declines [18]. Rising water temperatures are also a trigger for many other climate change impacts, such as warmer air temperatures, greater flood risk, rising sea levels, shifting seasons, altered precipitation, stronger storms, migrating species and declining water levels etc.

Temperature exerts a major influence on biological activity and growth. Temperature governs the kinds of organisms that can live in rivers and lakes. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. As temperatures get too far above or below this preferred range, the number of individuals of the species decreases until finally there are none [19].

pH: From the table 3, the pH of the Ganga river at Prayagraj was slightly alkaline. It ranged from 7.8 to 8.5. It is observed that the maximum pH was found to be at the Baluaghat site-8.50 and the Sangam site-8.47. Though, pH of all the sites varied from 7.8 to 8.5, it falls within WHO and BIS permissible limit of 6.5-8.5[20].

pH is one of the importance on determining the corrosively of water because generally the lower the pH, the higher the level of corrosion (WHO, 1996). Cautious attention to pH is necessary at all stages of water treatment before distribution to ensure satisfactory clarification and disinfection to minimize the corrosion of water. Exposure to extreme (pH >11) results in irritation in eyes, skin and mucous membrane and also cause hair fibers to swell in human. Similarly, low pH also results in same effects with the severity of which increases with decreasing pH [21].

The presence of hydrogen ion concentration is measured in terms of pH range. In our investigation the pH value of surface water ranged from 7.8 to 8.5, indicating that the nature of water is slightly basic to strong basic. The min pH recorded at Sample site 2 on 2nd March. Aquatic organisms are affected by pH, because most of their metabolic activities are pH dependent. Optimal pH range for sustainable aquatic life is pH 6.5-8.2. pH of an aquatic system is an important indicator of the water quality and the extent pollution in the watershed areas [22]. It has been mentioned that the increasing pH appear to be associated with increasing use of alkaline detergents in residential areas and alkaline material from industrial effluent.

Electrical Conductivity: EC is the measure of capacity of a substance or solution to conduct electrical current through the water. The range of EC varied from 331.22-483.40 µs cm^{-1} with an average of ±65.94 µs cm^{-1} in this study. The min and max value were reported at the site 4 and site1 respectively (Table 1and 2). High conductivity at the sites indicates the mixing of sewerage in river water as these sites are located near populated towns [23].

EC is significantly increasing at all sites to downstream, similar observation were also reported by Srivastava and Sinha at Allahabad [24]. The increased in EC values of water indicates that there is a source of dissolved ions in the vicinity. Higher the value of dissolve solids, greater the amount of ions in water. Increasing levels of conductivity and cations are the products of decomposition and mineralization of organic materials. While the electrical conductivity is a good indicator of the total salinity, it still does not provide any information about the ion composition in the water.

Dissolved Oxygen: DO is a factor which determines whether the biological changes are brought about by aerobic or anaerobic organisms. It reflects the physical and biological processes prevailing in the water. The oxygen present in water can be dissolved from air or produced by photosynthetic organisms. Oxygen is generally reduced in the water due to respiration of biota, decomposition of organic matter, rise in temperature, oxygen demanding wastes and inorganic reductant such as hydrogen sulphides, ammonia, nitrites, ferrous iron, etc. In the present study the overall lowest and highest mean value of dissolved oxygen was observed 3.06 mg L^{-1} at Site 2 and 4.90 mg L^{-1} at Site 1. The lowest value at Site 2 indicates load of pollution in comparison to Site 1.

If dissolved oxygen concentrations drop below a certain level, fish mortality rates will rise. Sensitive freshwater fish like salmon can't even reproduce at levels below 6 mg L^{-1}. Low DO levels may be found in areas where organic material (dead plant and animal matter) is decaying. Bacteria require oxygen to decompose organic waste, thus, deplete the water of oxygen. Areas near sewage discharges sometimes have low DO levels due to this effect. DO levels will also be low in warm, slow moving water.

Biological Oxygen Demand: The BOD is nothing but a measure of the amount of oxygen consumed by micro- organisms to decompose organic matter in water within five days period. In the present study, BOD is ranged from 27.01to 33.89 mg L^{-1} from upstream site Baluaghat to Downstream site

Triveni Ghat. The site 1 showed BOD as 27.3 mg L^{-1} which is not within the permissible limit of 6 mg L^{-1} as per CPCB. This indicated that the riverside stretch is contaminated by organic pollution. The BOD of the midstream site Sangam and downstream site Triveni were also found to be out of permissible limit of CPCB which might be due to an increasing organic matter load from upstream to downstream ultimately the decomposition process of organic matter by microbes consume large amount of oxygen. The decreasing trend in DO and an increasing trend in BOD towards downstream show an increase in the load of pollution from upstream to downstream.

The results obtained from analysis of water samples of river Ganga are shown in table 2-5 respectively. The reported values refer to the mean value of water samples collected on different dates and at different areas along the stretch of Ganga River.

Table 2. Physico-Chemical Parameters on 04 February 2019 for different sampling sites

S.No.	Parameter	Baluaghat	Shastri Bridge	Sangam	Triveni
1	Temperature (0°C)	17.23	19.10	19.85	19.01
2	pH	8.55	8.10	8.42	7.93
3	Electrical Conductivity (μ Siemens cm^{-1})	452.03	381.05	401.21	351.32
4	Dissolved Oxygen (mg L^{-1})	5.31	4.92	4.61	4.13
5	Biochemical Oxygen Demand (mg L^{-1})	31.23	27.91	24.52	29.17
6	Total Dissolved Solids (mg L^{-1})	324.2	275.87	397.26	281.22
7	Chloride (mg L^{-1})	28.21	24.41	29.12	27.17
8	Fluoride (mg L^{-1})	0.33	0.43	0.52	0.41

Table 3. Physico-Chemical Parameters on 17 February, 2019 for different sampling sites

S.No.	Parameter	Baluaghat	Shastri Bridge	Sangam	Triveni
1	Temperature (°C)	20.6	21.4	21.3	19.6
2	pH	8.33	8.09	8.31	7.89
3	Electrical Conductivity (μ Siemens cm^{-1})	448.01	388.11	398.03	381.5
4	Dissolved Oxygen (mg L^{-1})	5.28	4.82	3.15	3.09
5	Biochemical Oxygen Demand (mg L^{-1}	31.63	27.18	24.15	28.89
6	Total Dissolved Solids (mg L^{-1})	382.18	290.32	370.47	321.06
7	Chloride (mg L^{-1})	28.56	22.13	29.75	27.72
8	Fluoride (mg L^{-1})	0.31	0.39	0.49	0.42

Table 4. Physico-Chemical Parameters on 02-March, 2019 for different sampling sites

S.No.	Parameter	Baluaghat	Shastri Bridge	Sangam	Triveni
1	Temperature (°C)	24.8	24.7	26.1	24.5
2	pH	8.42	7.79	8.33	8.01
3	Electrical Conductivity (μ Siemens cm^{-1})	451.07	387.12	407.25	331.22
4	Dissolved Oxygen (mg L^{-1})	5.31	4.79	3.18	3.15
5	Biochemical Oxygen Demand (mg L^{-1})	28.19	27.01	23.43	29.15
6	Total Dissolved Solids (mg L^{-1})	403.76	280.52	390.22	263.21
7	Chloride (mg L^{-1})	27.16	21.03	29.89	26.01
8	Fluoride (mg L^{-1})	0.31	0.4	0.48	0.36

Table 5. Physico-Chemical Parameters on 06-March, 2019 for different sampling sites

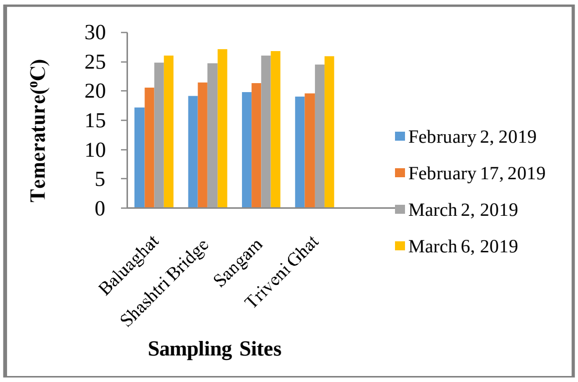
S.No.	Parameter	Baluaghat	Shastri Bridge	Sangam	Triveni
1	Temperature (^{0}C)	26.2	27.1	26.8	25.9
2	pH	8.47	8.11	8.29	8.65
3	Electrical Conductivity (μ Siemens/cm)	483.42	380.05	421.7	393.09
4	Dissolved Oxygen (mg/L)	5.12	4.88	3.16	3.11
5	Biochemical Oxygen Demand (mg/L)	33.13	27.12	24.15	29.07
6	Total Dissolved Solids (mg/L)	328.61	281.73	317.15	310.11
7	Chloride (mg/L)	29.22	23.16	29.94	28.12
8	Fluoride (mg/L)	0.34	0.48	0.51	0.39

High biological oxygen demand (BOD) means that a lot of oxygen is being used up, typically by bacteria breaking down organic material. As well as potentially high bacterial loads, a strong possibility that the BOD is associated with other pollutants as well, and a likely associated loss of water clarity that has its own negative effects, this can lead to a lack of oxygen in the water (hypoxia or anoxia). Hypoxia can result in- suffocation of fish and other animals that play important ecological roles, release of other pollutants (including nutrients and toxicants) that may be stored in the sediments due to changing chemical conditions associated with anoxia, when the high BOD is chronic, a loss of biodiversity.

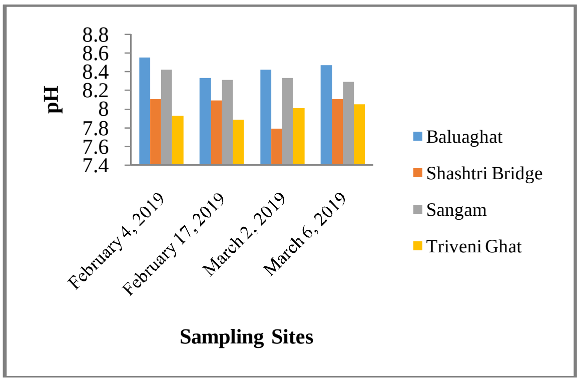
Total Dissolved Solids: Total solids may affect water quality. The total dissolved solids are expressed by the weight of residue left when a water sample has been evaporated to dryness. Water with high total dissolved solids generally is of inferior potability. Total dissolved solids were observed maximum 403.76 mg L^{-1} at sampling site 1and minimum 263.21 mg L^{-1}. The effect of presence of TS is due to silt and organic matter.

TDS from natural source have been found to vary from 30 to 6000 mg L^{-1} (WHO/UNEP, GEMS, 1989). WHO standard for drinking water is <1000 mg L^{-1}, the observed TDS in present study was varied from 250-420 mg L^{-1} with mean 335 mg L^{-1}. High TDS increase density of water, decrease solubility of gases like oxygen and ultimately make the water unsuitable for drinking (WHO, 1984). High TDS level (>500 mg L^{-1}) result in excessive scaling in water pipes, water heater, boilers, and household appliances.

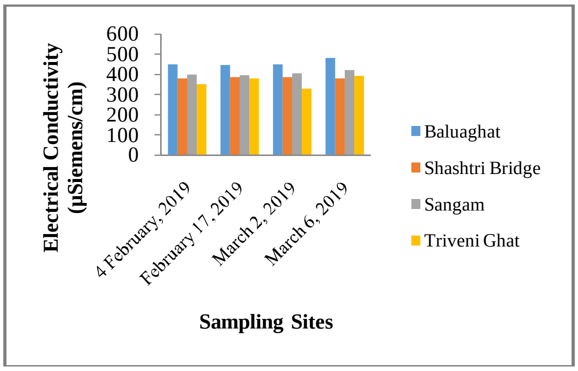
Dissolved solids are also important to aquatic life by keeping cell density balanced. In distilled or deionized water, water will flow into an organism's cells, causing them to swell. In water with a very high TDS concentration, cells will shrink. These changes can affect an organism's ability to move in a water column, causing it to float or sink beyond its normal range. TDS can also affect water taste, and often indicates a high alkalinity or hardness.



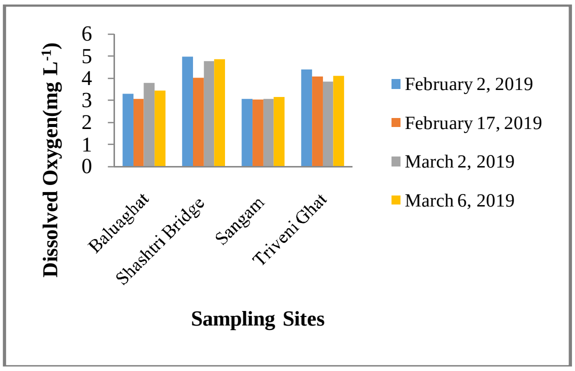
Graph 1: Temperature



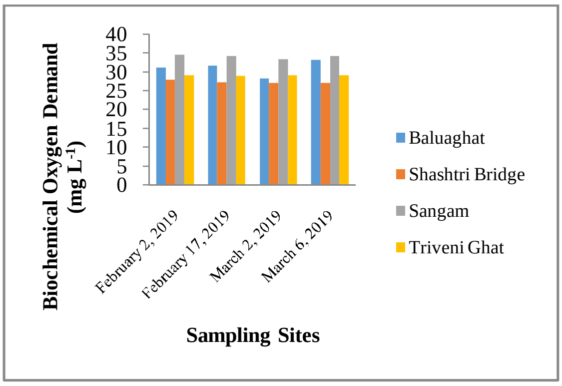
Graph 2: pH



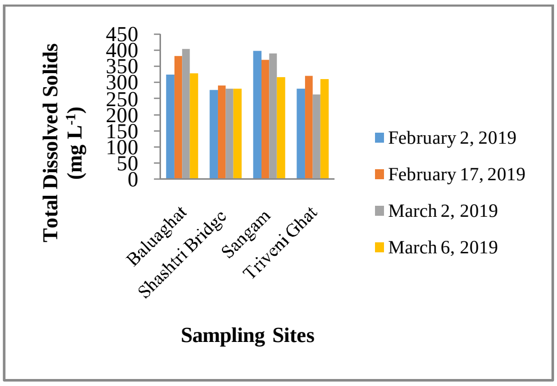
Graph 3. Electrical Conductivity



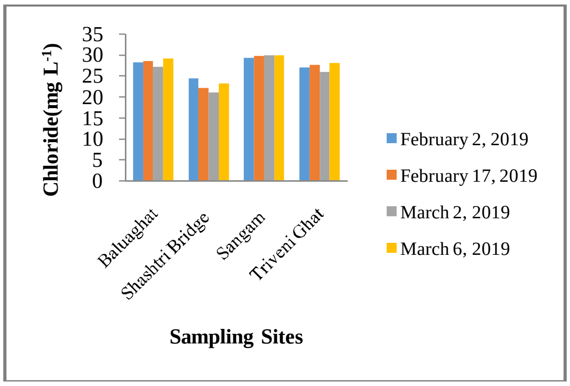
Graph 4. Dissolved Oxygen



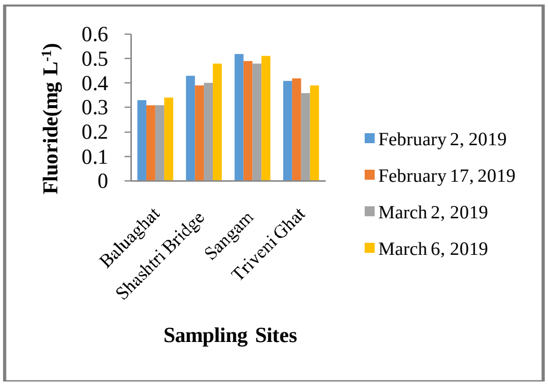
Graph 5. Biochemical Oxygen Demand



Graph 6. Total Dissolved Solids



Graph 7. Chloride



Graph 8. Fluoride

Figure 1. Bar Graph Representations of Various Physico-Chemical Parameters.

Chloride: During Kumbha Mela the minimum value of chloride was found to be 21.03 mg L^{-1} at site 2^{nd} and the maximum value was noted to be 29.94 mg L^{-1} at site 3rd. Average value of chloride was found to be 25.38 mg L^{-1} which was far lesser than the maximum permissible limit (250 mg L^{-1}) according to WHO (2009).

Average value of chloride was found to be 25.38 mg L^{-1} which was far lesser than the maximum permissible limit (250 mg L^{-1}) according to WHO (2009). According to different studies, drinking and long-term exposure to chlorinated water can potentially increase the risks asthmatic attacks particularly in children who do not have improved airway systems. Chlorine can be described as a pesticide whose sole purpose is to cause damage to living organisms. Drinking water contaminated with chlorine destroys cells and tissues inside our body. This explains the carcinogenic behavior of chlorine, bad taste and odor results in heart problems.

Fluoride: During Kumbha Mela the minimum value of fluoride was noted to be 0.31 mg L^{-1} at site 1^{st} and the maximum value was noted to 0.52 mg L^{-1} at site 3^{rd}. Average value of fluoride was found to be 0.40 mg L^{-1} which is far lesser than the maximum permissible limit for fluoride according to WHO (2009).

Fluoride (F-) is a chemically reactive electronegative univalent gaseous halogen found in small amount in the water, air, plants and animals. Fluoride is essential for the maintenance and solidification of our bones and to prevent dental decay. It has beneficial effects on teeth and bones when it is present at 0.5 -1.5 mg L^{-1} in drinking water, but excessive exposure to fluoride in drinking-water, or in combination with exposure to fluoride from other sources, can give rise to a number of adverse effects which include teeth decay, fluorosis and harm to bones, reproductive organs, nerves and muscles. Fluoride, when in excess, is known to interfere with thyroid gland function causing TSH elevation and lessen T3/T4 hormones in some populations which may be due to its antagonistic properties towards iodine. As an endocrine disruptor, F-induces more toxic outcome in diabetic patients.

APPLICATION

At present, Prayagraj city is depended on rivers *Ganga* and *Jamuna* for water source. Now a day's river water protection has become a major issue. Estimation of parameters is helpful to protect the river water quality. This study is applicable for all rivers. Protection and restoration of water bodies is essential thing to serve society and to ensure sustainable development. Present study helps the Government authorities and local people in analysis of river water quality and to take necessary actions in order to improve the same.

CONCLUSION

The holy river *Ganga* flowing through Prayagraj (Allahabad) is frequently used for different purposes, primarily for drinking and irrigation purposes. Present study indicates the pollution state of river *Ganga* with reference to physico-chemical properties of water. Most of the physico-chemical parameters of *Ganga* river water at Allahabad are within maximum permissible limit as prescribed by WHO and USPHS except DO, TDS, Fluoride which exceeded the limits at certain periods of time. Hence, the direct consumption of untreated *Ganga* water and bathing in the Allahabad region is at risk for human health [**25**].

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