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A Study on Analysis of Water Quality of Two Rivers Ganges and Yamuna

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Abstract

Water is very essential for life existence. About 71% of earth's surface is occupied by water making it a blue planet. The 97% of the ocean water can't be used as it has high salt concentration, some is frozen in glaciers/ polar ice caps. Even the distribution of water on earth is uneven at some places there is flood and others drought. Human activities have interfered in the natural renewal of groundwater resulting in water shortage and availability for consumption. The degradable and non-biodegradable wastes which are discharged openly in water bodies pose severe threat to aquatic life. The article presents a study on on quarterly changes in water parameters including temperature, transparency, dissolved oxygen, pH, free carbon dioxide, alkalinity, conductance, total dissolved solids, hardness, chloride, nitrate, phosphate, dissolved organic matter, BOD in the water of river Ganges and Yamuna.

The results showed rising trend in the levels of these parameters over the years. The results show increase in levels of CO_2, hardness, total dissolved solid, pH and BOD during the months of April to September. The levels of nitrate and phosphate were detected in trace amounts. The chloride level of Yamuna was high as compared to that of Ganges. The drop in alkalinity during monsoon months may be due to increased dilution and disappearance of CO_2. The studies made in water of river Ganges and Yamuna has shown that the river is under severe threat of pollution due to the discharge of untreated or semi treated sewage and industrial effluents.

Keywords: Ganges Yamuna; Water Parameters; TDS; BOD; DO

Introduction

We need air and water to stay alive. Water is very much essential to all living beings. Without which, origin of life was impossible. Water is used in all our daily life activities and required by all metabolic processes going in the body. About 71% of earth surface is covered with water. Oceans and seas cover 97% of all earths' water and left 3% exists in rivers, lakes, ponds. The physico chemical properties of water like dissolve oxygen, pH, nitates, chlorides, total dissolved solids, biological oxygen demand etc all tell us about the ionic states as well as toxicity of water. Water being the universal solvent, as temperature increases the interaction of molecules increases, which may sometime lead to toxicity to aquatic organisms. The shift in Carbon dioxide which acts as a boon to aquatic life, maintain the pH of water otherwise it may be toxic. Dissolved oxygen and biological oxygen demand, both are inversely related tells us about the presence of oxygen in water. Less oxygen is toxic to aquatic biota.

Presence of solids, nitrates, chlorides all contribute to increase the toxicity of water if found in high concentrations. Persistence of all these contaminants may impose severe threat to aquatic organisms. A number of investigations carried out on the physico-chemical and biological characters of water from different riverine systems including river Ganges and Yamuna at different places in India have indicated significant seasonal variations in the values of the most of the aquatic parameters due to mixing of various contaminants. In the light of previous reports, the study aims to monitor the physico-chemical parameters of water of river Ganges and Yamuna at interval of three months consecutively up to two years

Materials and Methods

Water samples were collected in plastic reagent bottles and for estimation of dissolved oxygen the water samples were collected in 125ml reagent bottles, immediately fixed with alkaline potassium iodide and manganous sulphate. Parameters like carbon dioxide, bicarbonate, carbonate, dissolved oxygen, pH, conductance and dissolved solids were analysed on the spot. For other parameters samples were brought to laboratory for analysis. These physico-chemical parameters were analysed by methods given by Jhingran, et al. [1] and APHA, et al. [2].

a) Water Temperature: Temperature was measured with the help of ordinary thermometer (accuracy upto 0.10C) [3].
b) Transparency: It was recorded with a secchi disc. The depths d1 and d2 were noted at which the disc disappeared and reappeared in water and the transparency was taken as: (d1+d2)/2 [4].

Dissolved Oxygen

Dissolved oxygen was fixed immediately after collection and analyzed on the spot by Winklers, method. The method is based on the fact that manganous hydroxide (formed as a result of addition of two reagents manganous sulphate and alkaline potassium iodide) absorbs the oxygen present in the sample to form oxyhydroxide $Mn(OH)_2$. In this form oxygen is fixed which is released again by the addition of concentrated H_2SO_4. The nascent oxygen liberated causes liberation of an equivalent amount of Iodine from potassium iodide, which in turn is titrated against N/40 $Na_2S_2O_3$ solution using starch as an indicator.

The overall chemical reactions are illustrated below.

$MnSO_4 + 2KOH \longrightarrow Mn(OH)_2 + K_2SO_4$ (white precipitate)

$2Mn(OH)_2 + O_2 \longrightarrow 2MnO(OH)_2$

$Mn(OH)_2 + H_2SO_4 \longrightarrow MnSO_4 + 3H_2O$

$Mn(SO_4)_2 + 2KI \longrightarrow MnSO_4 + K_2SO_4 + I_2$

$Na_2S_2O_3.5H2O + I_2 \longrightarrow Na_2S_4O_6 + 2NaI + 10H_2O$

$2NaN_3 + H_2SO_4 \longrightarrow 2HN_3 + Na_2SO_4$

$HNO_2 + HN_3 \longrightarrow N_2 + N_2O + H_2O$

Calculation: Volume (ml) of 0.025 Na2S2O3.5H2O solution used x 4 = mg/l of dissolved oxygen.

Free Carbondioxide Measurement

N/44 NaOH solution: 4.0g of A.R. grade sodium hydroxide was dissolved in one litre of water to get 0.1 NaOH and the solution was standardized against 0.1N H_2SO_4 using phenolphthalein as indicator. 100ml of this solution was diluted to 440ml with distilled water to get N/44 NaOH solution. 50ml of the sample was taken in a conical flask and two drops of phenolphthalein were added to it. If the water remained colourless, N/44 NaOH was added to restore the pink colour.
Calculation: Volume (ml) of N/44 NaOH solution required x 20 = mg/l CO_2.

e) Alkalinity: Alkalinity or acid combining capacity was determined by titrating the water samples with sulphuric acid using methyl orange as an indicator.
Calculation: Volume (ml) of acid required x 20 = mg/l of alkalinity.
f) Conductance Measurement: The ability of water to conduct electricity is known as conductance and it depends on the concentration of ions in solution. Conductance is measured in µohms. The measurement was made in the field immediately after a water sample has been obtained, because conductance changes with storage time. Conductivity is measured with the help of conductometer.
g) Total Dissolved Solids Measurement: Total Dissolved Solids (TDS) refers to any minerals, salts, metals, cations or anions dissolved in water. This includes anything present in the water other than the pure water (H_2O) molecule and suspended solids. Suspended solids or any particles/substances that are neither dissolved nor settled in water. TDS is measured through the use of a meter. TDS in mg/l usually ranges from 0.5 to 1.0 times of the electrical conductivity.
h) Total Hardness Measurement: Divalent metals like calcium and magnesium form chelate complexes with disodium dihydrogen ethylene diamine tetra acetate (EDTA) or sodium versenate. When indicator like erichrome black T is added to water sample containing bivalent metal ions Ca^{++} and Mg^{++} the colour of dye changes. The overall chemical reactions are illustrated below.

Metal + Indicator $\longrightarrow$ Metal-Indicator complex
Metal-Indicator complex + EDTA $\longrightarrow$ Metal-EDTA complex + Indicator

If this solution is titrated against EDTA solution owing to

the formation of chelate complexes of the divalent ions, the original colour of dye is restored marking the end point.
Calculation: Total hardness = Volume (ml) of EDTA solution x 0.01 x 20 x 50.

Biological Oxygen Demand

The amount of oxygen needed to oxidize the organic matter by microorganism anaerobically gives a measure of Biological Oxygen Demand (BOD). For the estimation of BOD water samples were collected in BOD bottles and immediately brought to the laboratory for incubation. To avoid delay and decomposition the bottles were kept in ice box after collection. The oxygen was measured by Winklers' method. Then the bottles were incubated in for five days. One bottle was taken every day, oxygen was fixed and analysed. The total amount of oxygen consumed during incubation gives a measure of BOD in mg/l.

i) Dissolved Organic Matter: It was determined by dissolving the organic matter with acid permanganate.
Calculation: Volume (ml) of permanganate consumed for oxidation x 0.1 x 20 x 0.375 = mg /l Dissolved organic matter.
j) Chloride: Chloride was estimated by titrating the water sample with silver nitrate using potassium chromate as an indicator. 50ml of water sample was collected in conical flask, few drops of potassium chromate indicator was added and titrated with silver nitrate. The yellow colour slowly turns the brick red to give the end point. The overall chemical reactions are illustrated below.

$$Ag+ + Cl- \longrightarrow AgCl \text{ (White precipitate)}$$
$$2Ag+ + CrO_{4-} \longrightarrow AgCrO_4 \text{ (Red precipitate)}$$

Calculation: Volume (ml) of $AgNO_3$ required x 10 = mg/l of Cl.

k) Nitrate Estimation
Nessler's reagent, standard ammonium chloride solution, 3.819g of anhydrous ammonium chloride was dissolved in double distilled water. One ml of this solution contained 1ml of nitrogen. 10ml of this solution was diluted to 1 litre so that 1ml = 0.01mg of N.
Calculation: Volume (ml) stock solution for matched standard x 0.01 x 20 = mg/l of nitrate.

Acid Ammonium Molybdate Estimation

sulphuric acid 50%, ammonium molybdate10%, acid ammonium molybdate. 15ml of 50% sulphuric acid was mixed with 5ml of 10% ammonium molybdate, stannous chloride solution: 2.15g of A.R. quality of stannous chloride was dissolved in 20ml of concentrated HCl. When the solution was complete the mixture was diluted to 100ml and kept in bottle with small piece of metallic tin, standard phosphate solution: 4.338g of potassium dihydrogen phosphate was dissolved in 1 litre of water to give solution containing 1g of phosphate per ml. 1ml of this solution diluted to 1 litre to give 0.01mg/l.
Calculation: Volume (ml) of phosphate solution added to the standard x 0.01 x 20 = mg/l of phosphate.

Results and Discussion

Physico-Chemical Characteristics of River Ganges

The physico-chemical properties of water from the river Ganges at Allahabad during the 1st year and 2nd year is shown in Table 1 and Table 2, respectively. The average values of two years for all the physico-chemical properties of water from river Ganges tested were found in the following range.

- Water temperature 19.0–30.56°C
- Transparency 11.10–49.0cm
- Dissolved oxygen 6.10–9.10mg/l
- pH 7.8–16.5
- Free CO_2 3.3–6.0mg/l
- Total alkalinity 83.15–202mg/l
- Conductance 184.25–429µmhos
- Total Dissolved Solid 93.0–215.0mg/l
- Hardness 78.8–190mg/l (x) Chloride 163–31.0mg/l
- Nitrate 0.08–0.2mg/l
- Phosphate 0.05–0.13mg/l
- Dissolved organic matter 0.96–1.4mg/l
- Biological Oxygen Demand 5.6–7.1mg/l.

Physico-Chemical Parameters	January-March	April-June	July-September	October-December	Average
Water Temperature (^{0}C)	18.8±0.9	30.4±0.4	28.0±0.98	22.4±0.5	25.2
Transparency (cm)	48.0±1.2	40.0±2.5	11.4±1.97	44.2±1.76	35.9
Dissolved Oxygen (mg/l)	9.4±0.06	7.8±1.56	6.2±0.04	8.0±2.01	7.85
pH	8.5±0.03	8.3±0.87	7.8±0.5	8.1±0.5	8.2
Free CO_2 (mg/l)	0	0	5.8±1.3	3.8±1.2	2.4

Total Alkalinity (mg/l)	196.0±1.67	203.0±1.4	87.5±1.43	188.0±1.86	168.6
Conductance (µmhos)	396.0±2.32	430.0±2.01	187.5±1.98	343.0±1.42	339
Total Dissolved Solids (mg/l)	198.0±1.98	216.0±0.42	94.0±0.95	172.0±0.39	170
Hardness (mg/l)	168.0±0.4	192.0±1.86	80.6±1.38	158.0±1.42	149.6
Chloride (mg/l)	28.4±2.76	32.0±2.31	15.8±2.01	25.2±3.09	25.3
Nitrate (mg/l)	0.14±0.002	0.22±0.01	0.09±0.02	0.14±0.04	0.15
Phosphate (mg/l)	0.09±0.02	0.14±0.09	0.06±0.004	0.12±0.06	0.1
Dissolved Organic Matter (mg/l)	0.94±0021	1.18±0.2	1.48±0.96	1.12±0.11	1.18
BOD (mg/l)	5.8±1.56	6.4±0.96	7.2±1.8	6.4±0.99	6.45

Table 1: Physico-chemical parameters of river Ganges during different months in the 1st year.

Physico-Chemical Parameters	January-March	April-June	July-September	October-December	Average
Water Temperature (^{0}C)	19.2±0.34	30.8±0.37	27.8±0.56	21.8±0.06	24.9
Transparency (cm)	50.0±1.09	42.0±0.8	10.8±1.5	41.4±0.3	36
Dissolved Oxygen(mg/l)	8.8±1.74	7.6±1.23	6.0±0.99	8.2±1.02	7.65
pH	8.5±0.02	8.2±0.01	7.8±0.01	8.0±0.02	8.15
Free CO_2 (mg/l)	0	0	6.2±0.8	2.8±0.4	2.25
Total Alkalinity (mg/l)	194.0±1.27	201.0±0.96	78.8±1.1	182.0±1.01	163.9
Conductance (µmhos)	388.0±1.86	428.0±2.09	181.0±1.9	338.0±1.78	333.7
Total Dissolved Solids (mg/l)	195.0±0.089	214.0±0.09	92.0±0.05	169.0±0.05	167.5
Hardness (mg/l)	164.0±0.03	188.0±0.05	70.0±0.03	156.0±0.07	144.5
Chloride (mg/l)	24.8±0.02	30.0±0.01	16.8±0.08	24.0±0.01	23.9
Nitrate (mg/l)	0.14±0.001	0.20±0.003	0.08±0.002	0.12±0.001	0.13
Phosphate (mg/l)	0.10±0.05	0.12±0.02	0.04±0.01	0.10±0.02	0.09
Dissolved Organic Matter (mg/l)	1.12±0.9	1.20±0.89	1.32±0.9	0.98±0.45	1.15
BOD (mg/l)	5.4±1.2	6.8±0.99	7.0±1.4	6.2±1.34	6.351.5

Table 2: Physico-chemical parameters of river Ganges during different months in the 2nd year.

The average quarterly values for water temperature, free CO_2, dissolved organic matter and BOD were found to be minimum in the months of January to March of the 2 years, whereas the average maximum values during these two years were recorded for total alkalinity, conductance, total dissolved solids, hardness, chloride, nitrate and phosphate during the months of April to June. However, the average maximum values for dissolved organic matter and BOD were found during the months of July to September. The minimum and maximum transparency of water and the levels of dissolved oxygen and pH were observed during July-September and in January-March, respectively. The detailed procedure as how the parameters were determined is mentioned in materials and methods. Each value represents the mean±SEM of ten different observations.

The detailed procedure as how the parameters were determined is mentioned in materials and methods. Each value represents the mean± SEM of ten different observations. The average values of temperature for Ganges water varied within the range of 19.50–30.60°C being maximum during summer and minimum during winter. The transparency of water ranged between 11.10-49.0cm. Clarity of water was maximum during January to March and showed a sudden drop during monsoon months with the influx of silt laden flood water due to quick settling of silt particles. Transparency again increased in the fourth quarter. Free carbon dioxide was absent during summer and appeared only with the entrance of flood water, with the value going up to 6.0mg/l. Carbon dioxide again declined after disappearance of flood. Dissolved oxygen was high with values ranging between 9.1-6.1mg/l. It was maximum during winter and showed slight decline during flood season with the entrance of carbon dioxide.

Water was found to be always alkaline with pH ranging from 7.8-8.5. Similar to the level of oxygen, pH also showed some decline during monsoon. The chemical parameters such as alkalinity, conductance, dissolved solids and hardness all were maximum during summer; the values being 84.1-202.0mg/l; 184.2-429.0µmhos; 93.0-215.0mg/l; 75.3-190.0mg/l, respectively, during two years of observation. Their levels showed sudden drop during monsoon, with the entrance of flood water reaching minimum; the values being 87.5 and 78.8mg/l; 181 and 187.5µmhos; 92 and 94mg/l, and 70.0mg/l, respectively. After flood with the disappearance of carbon dioxide, the values of chemical parameters showed sharp increase. Chloride was lesser in Ganges water ranging from 15.8-32.0mg/l with an average of 25.3mg/l. Nutrient status of river in respect of nitrate and phosphate was also poor in the months of July to September (0.08-0.21mg/l and 0.05-0.13mg/l), and dissolved organic matter was considerably in the range (0.96-1.40mg/l). The BOD load was also low (3.95-5.1mg/l) during these two years.

Physico-Chemical Characteristics of River Yamuna

The physico-chemical properties of water from the river Yamuna at Allahabad during 2 years are shown in (Tables 3,4), respectively. The average values of two year for all the physico- chemical properties of water from river Yamuna tested were found in the following range.

- Water temperature 20.8-30.75°C
- Transparency 14.6-55.4cm
- Dissolved oxygen 6.5-9.2mg/l
- pH 7.8-16.5
- Free CO_2 2.5-7.7mg/l
- Total alkalinity 103-259mg/l
- Conductance 239.5-666.0µmhos
- Total Dissolved Solid 120.0-334.0mg/l
- Hardness 93.0-222mg/l
- Chloride 29.0-71.0mg/l
- Nitrate 0.11-0.22mg/l
- Phosphate 0.07-0.17mg/l
- Dissolved organic matter 2.33-2.59mg/l
- Biological Oxygen Demand 7.9-13.7mg/l.

Physico-Chemical Parameters	January March	April-June	July-September	October-December	Average
Water Temperature(°C)	20.2±1.2	31.0±0.9	29.0±1.5	22.0±1.5	25.6
Transparency (cm)	54.8±2.3	46.4±1.86	14.2±1.66	51.8±2.1	42.8
Dissolved Oxygen (mg/l)	9.2±0.6	7.8±0.47	6.4±0.93	8.9±0.62	8.1
pH	8.5±1.9	8.3±0.52	7.8±0.39	8.1±1.09	8.15
Free CO_2 (mg/l)	0	0	7.2±2.65	2.6±2.12	2.45
Total Alkalinity (mg/l)	228.0±0.93	260.0±1.0	102.0±0.69	242.0±0.65	208
Conductance (µmhos)	552.0±0.04	664.0±0.03	242.0±0.05	572.0±0.04	506.7
Total Dissolved Solids (mg/l)	276.0±1.32	333.0±1.84	120.0±1.97	286.0±1.75	253.7
Hardness (mg/l)	186.0±2.1	238.0±1.99	94.0±2.65	198.0±2.53	179
Chloride (mg/l)	54.0±1.6	70.0±1.2	30.0±1.7	54.0±1.6	52
Nitrate (mg/l)	0.15±0.064	0.20 ±0.05	0.11±0.04	0.17±0.032	0.16
Phosphate (mg/l)	0.12±0.096	0.16±0.032	0.08±0.005	0.11±0.002	0.12
Dissolved Organic Matter (mg/l)	1.86±0.62	2.58±0.96	1.28±0.99	1.52±0.43	1.81
BOD (mg/l)	7.8±0.32	13.4±1.1	9.2±0.2	9.8±0.54	10

Table 3: Physico-chemical parameters of river Yamuna during different months in the 1^{st} year.

Physico-Chemical Parameters	January-March	April-June	July-September	October-December	Average
Water Temperature (^{0}C)	21.4±1.5	30.5±1.58	28.9±1.6	22.5±0.9	26
Transparency (cm)	56.0±0.76	44.8±0.99	15.0±0.6	52.0±0.74	42
Dissolved Oxygen(mg/l)	9.0±2.4	7.6±2.46	6.6±2.34	9.2±1.99	8.1
pH	8.5±1.9	8.2±1.5	7.9±1.6	8.2±1.8	8.2
Free CO_2 (mg/l)	0	0	8.2±0.7	2.4±0.4	2.65
Total Alkalinity (mg/l)	230.0±0.96	258.0±0.94	104.0±0.4	240.0±0.3	208
Conductance (µmhos)	562.0±1.87	668.0±1.54	240.0±1.82	580.0±1.53	512.5
Total Dissolved Solids (mg/l)	281.0±2.6	335.0±2.90	120.0±2.3	290.0±1.97	256.5
Hardness (mg/l)	188.0±1.6	240.0±1.4	92.0±1.6	206.0±1.4	181.5
Chloride (mg/l)	55.0±2.01	72.0±2.40	28.0±1.99	53.0±1.42	52
Nitrate (mg/l)	0.16±0.03	0.24±0.02	0.12±0.07	0.16±0.09	0.17
Phosphate (mg/l)	0.10±0.05	0.18±0.05	0.06±0.03	0.11±0.013	0.12
Dissolved Organic Matter (mg/l)	1.78±0.07	2.60±0.08	1.38±0.85	1.50±0.94	1.82
BOD (mg/l)	8.0±0.9	14.0±1.2	8.8±0.7	9.6±0.4	10.1

Table 4: Physico-chemical parameters of river Yamuna during different months in the 2nd year.

The average quarterly values for water temperature, free CO_2, dissolved organic matter and BOD were found to be minimum in the months of January to March whereas the average maximum values during these two years were recorded for total alkalinity, conductance, total dissolved solids, hardness, chloride, nitrate, phosphate, dissolved organic matter and BOD during the months of April to June. However, the average free CO_2 value was found to be maximum in July-September. The minimum and maximum average values of physico-chemical parameters of Yamuna water for transparency, dissolved oxygen and pH were observed during July-September and in January-March, respectively.

The average values of temperature for Yamuna water varied within the range of 20.20–30.75°C being maximum during summer and minimum during winter. The transparency of water ranged between 14.6–55.4cm. Clarity of water was maximum during January to March and showed a sudden drop during monsoon months with the influx of silt laden flood water due to quick settling of silt particles. Transparency again increased in the fourth quarter. Free carbon dioxide was absent during summer and appeared only with the entrance of flood water, with the value going up to 7.9mg/l. Carbon dioxide again declined after disappearance of flood. Dissolved oxygen was high with values ranging between 6.5-9.2mg/l. It was maximum during winter and showed slight decline during flood season with the entrance of carbon dioxide. Water was found to be always alkaline with pH ranging from 7.8-8.5. Similar to the level of oxygen, pH also showed some decline during monsoon.

The chemical parameters such as alkalinity, conductance, dissolved solids and hardness all were maximum during summer; the values being 103-259mg/l; 239.5-660µmhos; 120.0–334.0 mg/l; 93.0-222mg/l, respectively, during two years of observation. Their levels showed sudden drop during monsoon, with the entrance of flood water reaching minimum; the values being 102 and 104mg/l; 240 and 242µmhos; 120mg/l, 94 and 92mg/l, respectively. After flood with the disappearance of carbon dioxide, the values of chemical parameters showed sharp increase. Chloride was higher in Yamuna water ranging from 54.0–72.0mg/l with an average of 52mg/l. Similarly, a seasonal trend was observed in respect of chloride to that of other parameters. Nutrient status of river in respect of nitrate and phosphate was also poor in the months of July to September (0.11–0.22mg/l and 0.07–0.17mg/l), but dissolved organic matter was considerably high (2.33–2.59mg/l) during 1st year (Table 3) and 2nd year (Table 4). The BOD load was also low (7.9–13.7mg/l) during these two years [4].

The detailed procedure as how the parameters were determined is mentioned in materials and methods. Each value represents the mean± SEM of ten different observations. The biological productivity of any ecosystem depends on the chemical characteristics of water. The process of energy fixation and utilization by the aquatic organisms and their whole life cycle depends on the chemical characteristics of water in which they live [5]. Among the changes in various environmental parameters in aquatic system, the dynamics and physico–chemical properties of water play vital role on productivity of the ecosystem.

The extensive works carried out all over the world have given valuable information about the indices of productivity. Many workers have established the role of chemical parameters for maintaining the health of the aquatic environment. Moyle and Nothcote and Larkin based on the observation in a number of lakes and reservoirs derived several indices for explaining the productivity of such waters [6-9]. Ryder, et al. [12] derived morphoedaphic index for the production of fish [10]. The indices although based on observation in lakes have been widely used for evaluating the productivity of aquatic systems in general including rivers.

Water temperature generally depends on climate, sunlight and depth. Every water body possesses certain heat content, and thus it has storage of heat which it can impart to surrounding on cooling. The seasonal fluctuation in water temperature is not so high to have any serious impact on the system in the tropical countries [11]. Another important factor is sunlight on which the photochemical synthesis of carbohydrate depends. Penetration of solar radiation determined by its transparency depends on many factors like inorganic suspension, plankton abundance and pigment from decomposed organic matter [12-15]. Plankton turbidity is indicator of productivity but this has been rarely observed in river Ganges. Turbidity can be due to many factors like suspended particles in the river, aquatic organisms and remnants of organisms produced through decomposition of organic matter.

Generally, the visibility is between 40-60 cm. Algal blooms increases the turbidity due to less penetration of light and reducing the aquatic productivity. The sudden drop in transparency is due to the influx of flood water. The settling of silt particles increases the clarity of water considerably which was either high in post monsoon or in winter. Another factor responsible for decreasing transparency is organic and suspended waste material. The clarity of water was comparatively higher in the winter months and showed sharp decline during monsoon due to influx of flood water. The national river water quality standard range is 6.5 to 8.5. Stream water usually ranges from pH 6.5 (slightly acidic) to a pH of 8.5, an optimum range for most organisms. pH values varied from 7.2 to 8.7mg/l are suitable for aquatic organisms [16-18]. Observations made by German scientists have shown that a slight alkaline pH (7.5–8.5) indicates productive water and accordingly the Ganges waters where the pH fluctuated between (7.8-8.5) during the present study period can be put under productive class. The seasonal variation in pH showed that during the flood season with the entrance of carbon dioxide and increase in hydrogen ion, pH showed a declining trend. Again, with the disappearance of carbon dioxide after monsoon pH showed an increase. The high level of CO_2 and associated decline in pH may cause adverse impact on aquatic life.

Alkainity is a measure of the buffering capacity of water or it is a measure of capacity of water to neutralize acids [19]. Rise in the alkalinity results into increase in the pH. Water was found to be alkaline in relation to pH varying from 7.8–8.5. This is caused by the carbonates and bicarbonates of calcium and magnesium. These along with dissolved carbon dioxide in water form equilibrium, which play important role in the ecology of environment [20,21].

$$CO_2 + CO_3^{-2} + H_2O \longleftrightarrow 2HCO_3\text{-}1$$

The above reaction acts as buffers which do not allow pH to fluctuate more. The reason for pH not fluctuating much due to sudden increase of carbon dioxide or hydrogen ion is because of the buffer action of above reaction. In fact, this buffer reaction not allowing pH to fluctuate more is a boon for the aquatic environment as the organisms inhabiting the system cannot withstand sudden rise and fall in pH. Moyle observed in a number of lakes and other systems have shown that alkalinity ranging from 40-90 mg/l reflect medium production and above 90mg/l indicate good production. Based on Moyle observation Ganges which has shown alkalinity ranging between 163.9-193.5mg/l can be very well put under productive class. Seasonal variation of alkalinity showed a sudden drop during monsoon due to increased dilution and appearance of carbon dioxide. This carbon dioxide dissolves carbonates deposits to bicarbonate and hence after flood with the disappearance of CO_2 bicarbonate or alkalinity registers sharp increase. Free carbon dioxide was either absent or present in small amount (2.4–6.2mg/l).

Among the two dissolved gases oxygen is most important as it reflects the health of the ecosystem. Dissolved oxygen (D.O) is a measure of the amount of oxygen freely available in water. Oxygen being the regulator of all the metabolic processes of plant and animal is an indicator of condition of water and provide more information about water quality than any other chemical parameter. Observations in many ecosystems have shown that a dissolved oxygen concentration more than 5.0mg/l is essential for good growth of aquatic biota and a decline below this limit will not only hamper the growth but also act adversely on many biochemical processes. Severe decline in oxygen may be fatal for aquatic life. The results show that Ganges has high dissolved oxygen and so has high production potential.

Hancock, et al. [3] and Mitra, et al. [4] have discussed several seasonal average fluctuations in DO, they reported maximum in winter and minimum in summer [22,23], DO values ranged from 6.1-7.2mg/l. DO levels below 1ppm will not support fish; levels of 5-6ppm are usually required for most of the fish population. Dissolved oxygen was in the range of 5.8–9.4mg/l in the water of river Ganges, in the present study. The compounds of calcium and magnesium cause hardness in water. Calcium being an important part of plant tissue increases the availability of other ions and reduces the toxic effects of environment, while magnesium is a component of chlorophyll and sometime acts as carrier of phosphorous or stimulates the bacterial reduction of organic matter [24].

Thus hardness can be linked with productivity [25]. The seasonal variation in hardness can be linked with alkalinity as both are interrelated parameters. It has been observed that hardness beyond certain limit acts as a negative role in productivity. Chloride is used to kill or inactivate microorganisms present in drinking water, swimming pools etc. in the form of bleach. Toxicity of chloride to aquatic organisms increases when it is combined with other toxic substances such as cyanides, phenols and ammonia. Being highly soluble and acidic in nature, it easily enters the fish body via gills during breathing and cause fish burn and rupturing of the membranes. It also removes the slimy layer of fish which is supposed to protect it externally. The chloride content in Ganges is well within the permissible limit. The high chloride content is a negative factor from productivity point of view. It can give a different taste in drinking water when it is above 250mg/l. Maximum chloride content has been associated with high degree of organic pollution and eutrophication [26].

The primary sources of nitrate are soil erosion, leaching, fertilizers, humic substances. Fish are aminotelic, the released ammonia is oxidized to nitrate by aerobic chemotropic bacteria resulting in decreased oxygen carrying capacity [27,28]. The optimum range is 0.02-0.05mg/l in the pond. The toxicity of nitrate to aquatic organisms is proportional to the exposure time [29]. High levels of nitrate can also lead to algae blooms, or in scarcity of nutrients can lead to eutrophication leading to water anoxia.

Phosphorus is one of the minerals which are required in trace amounts by plants and animals for growth. These phosphates come in the rivers as run off from agricultural fields were used as fertilizers in form of phosphoric acid. The salts of nitrates and phosphates leads to eutrophication resulting in decreased oxygen concentration for the aquatic organisms. They also increase the turbidity which restricts the penetration of sun rays. This makes the water fairly unliveable for aquatic organisms. The nutrient status of river in water phase was poor in respect of nitrate and phosphate [30,31]. The productive water should have nitrate more than 0.5mg/l and phosphate more than 0.2mg/l. The values of these parameters in the present study were comparatively very low in the river, Ganges.

Total Dissolved Solid (TDS) is a measure of salts/solids present in dissolved, ionized or suspended/ precipitated forms in water [32]. TDS concentrations in natural waters result from industrial effluent, by increased water use or increased precipitation or by salt-water intrusion. TDS can be toxic to aquatic organisms when there is increase in salinity it causes shift in biotic communities, toxicity of individual ions or ionic composition of water [33]. It has been proved that water bodies with higher dissolved solids (conductivity) are more productive than those with less value. A healthy aquatic environment should have conductance more than 200μmhos or total dissolved solids more than 100 mg/l. But again, the values of these parameters should not be very high. The chemical characteristics of Ganges have shown that the conductance was always more than 100 mg/l in present investigation.

Dissolved organic matter which is correlated to chemical oxygen demand, is also an important chemical factor to be related with productivity. It has been found that dissolved organic matter at a level of 1mg/l indicates good production, but above the certain level it is harmful to the aquatic system. The dissolved organic matter in Ganges on average is 1.0 to 2.29 mg/l (present investigation), which is good for production. The increase in organic matter is always associated with reduction in dissolved oxygen which hampers aquatic life. The observations made by other workers have shown that dissolved organic matter upto nearly 1mg/l or slightly more reflect good productive quality but its higher values reflect organic pollution. A very important factor which reflects the health of the aquatic environment is Biological oxygen demand (BOD) which is an indicator of many important events. BOD is a measure of the quantity of oxygen used by microorganisms (aerobic bacteria) in the oxidation of organic matter. The variation in BOD load is always related with variation in dissolved oxygen which hampers aquatic life. High BOD load reflects high organic load in the system.

This may cause severe reduction in dissolved oxygen. If dissolved oxygen concentrations drop below 5ppm, fish will be unable to live for very long (www.freedrinkingwater.com). A BOD around 15.0mg/l or less reflects quite satisfactory condition. The BOD load of Ganges was low within permissible limits in all the seasons (in present investigation). Both BOD and DO (dissolved oxygen) may be taken as indicator of deterioration of water quality. Seasonal variations in the Yamuna water near Allahabad: It has been observed that clean water should have a pH in alkaline range (7.5-8.5). In Yamuna pH fluctuates between 7.4 and 8.5. The sudden change in hydrogen ion concentration has direct bearing on the production of aquatic system. Among the two dissolved gases carbon dioxide is important. Carbon dioxide in water forms weak carbonic acid which dissociates ultimately to hydrogen ion and carbonate.

$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO^{-3} \longleftrightarrow CO_3^{-2} + H^+$$

Carbon dioxide in high concentration decreases the pH of water. Reduction in the pH of water may lead to several other consequences. As productive water should have pH in alkaline range, prolonged accumulation of this gas will lead to decline in productivity. On the contrary oxygen being the regulator of many metabolic processes is most important parameter which reflects the health of environment. Observations made in a number of aquatic systems have indicated that good and healthy water should have dissolved oxygen more than 5.0mg/l. In the present investigation in Yamuna dissolved oxygen, was in the range of 6.0 to 9.8. On this basis Yamuna may be considered to have healthy water. Alkalinity is another important parameter which has attracted the Limnologist everywhere. The buffer reaction keeping all the three parameters carbon dioxide, bicarbonate and carbonate in equilibrium has to play two important roles.

$$CO_2 + CO_3 + H_2O \longleftrightarrow 2HCO_3^- \longleftrightarrow O_2 + CO_3 + H_2O$$

To keep pH more or less stable in the respect that if hydrogen ion increases some amount of carbonate is converted to bicarbonate to maintain the equilibrium and of hydrogen ion is taken away, the bicarbonate is converted to carbonate and equilibrium is maintained again. In both the cases pH is not altered. Secondly, the carbon dioxide required by photosynthetic organisms in aquatic system is supplied from bicarbonate reserve. Thus, at the demand of system some bicarbonate breaks into carbon dioxide, carbonate and water to maintain the supply of carbon dioxide for photosynthesis. As stated, earlier alkalinity above 90mg/l indicates good productivity. In river Yamuna alkalinity has always found to be in the range of 194.5 to 210.0mg/l. Number of ions present in water is reflected by its productivity. It has been found that conductance more than 200μmhos or total dissolved solids more than 100mg/l indicates productive water. But water with higher values of these is less productive. The conductance and total dissolved solids in Yamuna were in the range of 461.0 to 516μmhos and 230.5 to 259.5mg/l, respectively.

The high values of conductance, dissolved solids and hardness give added support about the productive nature of the river. The observations made by workers have shown that dissolved organic matter nearly 1mg/l or slightly more reflect good productive quality but its higher values reflect organic pollution. In Yamuna, dissolved organic matter is always more than 1suggesting organic pollution in the river. The nutrient status of river in water phase was poor in respect of nitrate and phosphate. The productive water should have nitrate more than 0.5mg/l and phosphate more than 0.2mg/l. In Yamuna, chloride content was also very high. The high chloride content is a negative factor from productivity point of view. Similarly, high BOD load reflects high organic load in the system.

This may cause severe reduction in dissolved oxygen. The BOD load of Yamuna was low within permissible limits. The variation in BOD load is always related with variation in dissolved oxygen which was always high. The impact of man induced environmental degradations on the water quality and fishery of rivers have been studied by various workers. The physico-chemical characteristics of Yamuna analysed by Saini et al., showed water to be of alkaline pH, light green in colour and reported higher values of total dissolved solids (TDS), BOD indicating the presence of high content of organic matter. As observed from the present study, the river Yamuna has not shown any significant deterioration in water quality.

Conclusion

The studies made in water of river have shown that the river is under severe threat of pollution as the discharge of sewage and industrial effluents have badly damaged the ecosystem as reflected from water quality. Several cases of fish mortality have been observed due to acute reduction of oxygen and abrupt increase in BOD level. Strict timely monitoring of river to be done before these parameters crosses the optimum values. Laws to be made if any factory or industry is caught discharging wastes directly in open water bodies. Each individual need to take its own responsibility for no pollution and to save our ecosystem.

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Conflicts of Interest

There is no conflict of interest to be disclosed.

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