

Time Scale Changes in the Water Quality of the Ganga River, India and Estimation of Suitability for Exotic and Hardy Fishes

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Abstract

The water quality of rivers is an issue of serious concern today. Rivers are heavily impacted due to their use for carrying off the industrial, municipal, agricultural and domestic effluents. Water samples were collected for the present study from the Ganga River at Kanpur, Allahabad and Varanasi sites, during the period 2011-2012. The minimum temperature (17°C) was recorded in winter season. The pH, TDS, EC, sulphate, phosphate, nitrate, BOD and COD values exhibited their minimum at Allahabad site. The chloride and dissolved oxygen were recorded minimum at Kanpur site while alkalinity and total hardness had their lowest values at Varanasi site. The water quality of the Kanpur site was very poor compared to Varanasi and Allahabad sites. However, the Ganga river waters could host some tolerant fish species such as the exotic *Cyprinus carpio* and *Oreochromis niloticus* and also catfishes. All these species are very hardy, in respect of poor water quality, thus they (exotic species) have powerfully invaded in degraded systems worldwide.

Keywords: Ganga River; Water quality; Pollution; Environmental condition; Tolerant fish species

Introduction

The Ganga river quality is day by day deceased due to domestic and industrial influent. The Ganga River is a backbone of Indian biodiversity (aquatic flora and fauna). Pollution threatens not only humans, but also more than 130 fish species, 83 amphibian species and the endangered Ganga river dolphin. But, current time poor water quality of the Ganga River provides shelter to some exotic aquatic organisms.

The contamination of fresh waters through ample variety of pollutants has become a matter of great concern over the last two decades especially inland water [1-5]. The contamination level in the water bodies is changes according to season and. The concentrations of pollutants in water samples only indicate the condition at the time of sampling. Due to industrialization, the number of factories and population has increased rapidly. The riverine systems may be greatly infected with pollutants released from industrial, domestic, mining and agricultural effluents [6-8]. Discharge of pollutants into rivers or any aquatic environment can change aquatic species diversity, abundance and ecosystems, due to their toxicity and accumulative behavior [9-13]. Over the last two decades huge scale usage of chemicals in various human activities has grown very rapidly. In developing and underdeveloped countries, the industrial and domestic effluents are release directly or indirectly into the large water bodies [14,15].

Catfishes such as *Sperata aor*, *S. seenghala*, *Wallago attu*, *Rita rita*, *Clupisoma garua*, *Eutropiichthys vacha* and two exotics fish species Common carp (*Cyprinus carpio*) and Tilapia (*Oreochromis niloticus*) are commercially exploited with highly contribution in the landing of the Ganga river. Common carp (*Cyprinus carpio*) and Tilapia (*Oreochromis niloticus*) are exotic/alien fish species for India. Both species are of great economic importance in the country [16-18], and are commercially exploited in the Ganga River (at Kanpur to Varanasi section) and its tributaries [13,19-21]. Fishes are widely used to evaluate the health of aquatic ecosystems because pollutants are building up in the food chain and are responsible for adverse effects and death in the aquatic systems.

Water pollution of rivers in India has now been reaching to a point of predicament due to unplanned urbanization and rapid growth of industrialization. Various fragmented studies concerning the water quality of Ganga River are available, but complete middle stretch data are not available which is most important for fisheries and human life.

Record and assessment of the present research work is necessary to formulate up to date decisions about management of the river habitat and fishery to help of restoration and conservation of flora and fauna.

Materials and Methods

The River Ganga is the most important river system in India. It originates from the Gangotri glacier at Gomukh, at an altitude of about 6000 m in the Garhwal Himalaya. The Ganga river is about 2525 km long, covering a basin area of 861, 404 km². The Ganga river system drains about one fourth of the Indian subcontinent. The river supports abundant biological wealth, characterized by its rich fisheries and faunal diversity.

Collection of samples

Water samples were collected from all the selected sites (Kanpur, Allahabad and Varanasi) during January 2011 to December 2012 from the Ganga River, India (Figure 1). During the entire study period of one year, samples were collected three times in a year: during winter, summer and monsoon seasons. The sampling was done between 9.30 to 11.00 AM.

Water sampling procedures

For physico-chemical analysis, surface water samples were collected from each selected site in 500 ml polyethylene bottles fitted with polyethylene caps. For dissolved oxygen analysis, samples were fixed with manganese sulphate and alkaline iodide in 250 ml BOD bottles in the field. For the analysis of heavy metals, 500 ml of water sample was taken from each site and was immediately acidified with 10 ml of 6N HNO₃. All samples were brought to the laboratory. Acidified samples were stored at 4°C in the refrigerator for further analysis.

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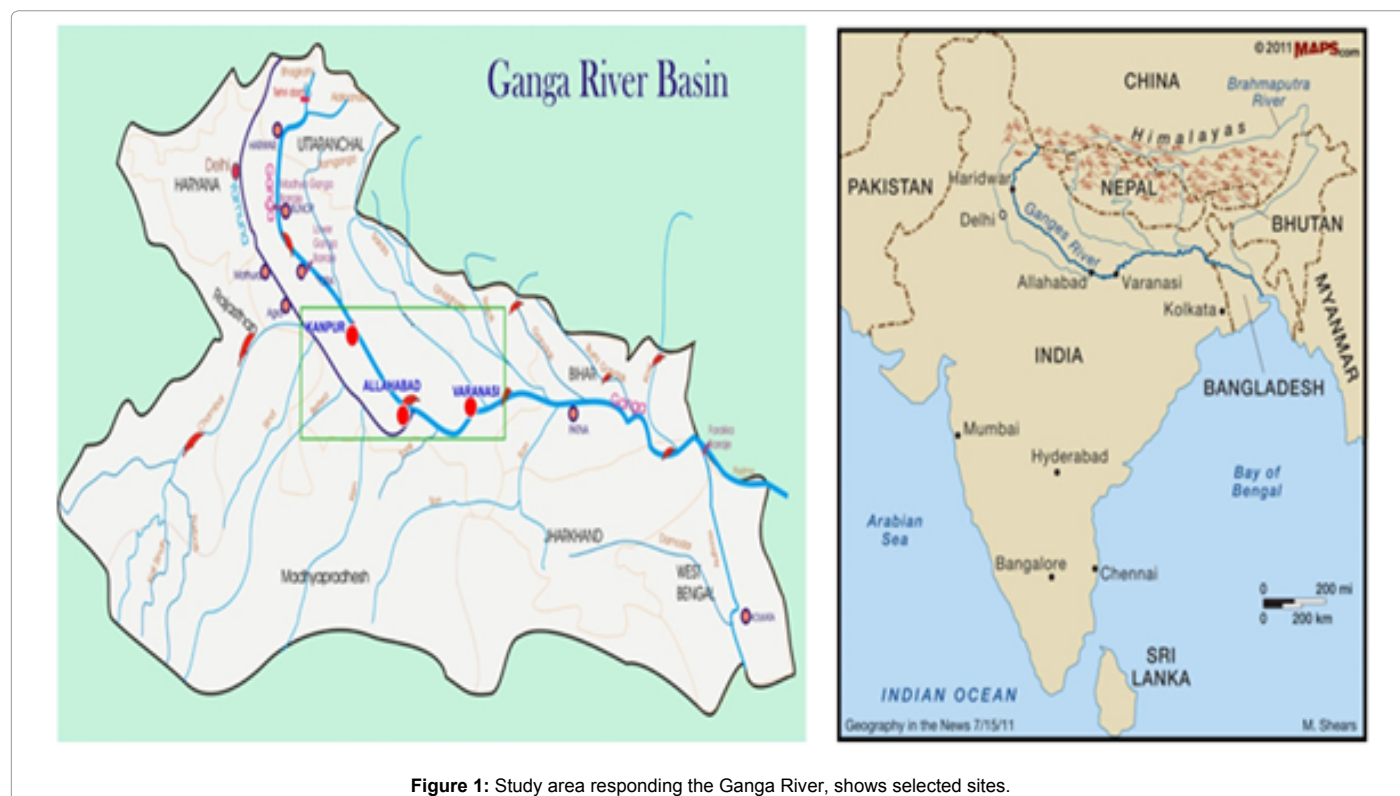


Figure 1: Study area responding the Ganga River, shows selected sites.

Analysis of physico-chemical parameters of water sample

For the analysis of physio-chemical properties of river water, specialised sampling and sample handling procedure are required. The water samples were analysed for various parameters in the laboratory of Botany Department, University of Allahabad, Allahabad, India. Various physio-chemical parameters like Temperature, pH, Total Dissolved Solid (TDS), Electrical Conductivity (EC), Total Hardness (TH), Sulphate, Phosphate, Alkalinity, Nitrate, Chloride, Dissolved oxygen, Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) have been analysed [22].

Temperature

Temperature was measured by Multi probe ITS-701.

pH

It was measured by Multi probes ITS -701 direct at the sampling site.

Total Dissolved Solid (TDS)

It was measured by Multi Parameter ITS-701 direct at the sampling site at the time of sample collection and expressed in mg/l.

Electrical Conductivity (EC)

The electricity conductivity is a measurement of capability of water to transmit electricity in a water bodies. It was measured by using Multi Parameter ITS-701 direct at the sampling site at the time of sample collection. It expressed in mhos/cm.

Sulphates

It was measured by nephelometric method in which the concentration of turbidity is measured against the known concentration of synthetically

prepared sulphate solution. Sulphate was measured by Perkin Elmer UV/ VIS spectrophotometer model Lambda 25. It expressed in mg/l.

Phosphates

Phosphates were measured by Perkin Elmer UV/VIS spectrophotometer model Lambda 25. Concentrations were expressed in mg/l.

Alkalinity

Alkalinity was measured by Multi parameter ITS-701 direct at the sampling site the time of sample collection and expressed in mg/l.

Chlorides

Chlorine was measured by chlorine meter model it's 1001 directly at the sampling site at the time of sample collection and expressed in mg/l.

Total Hardness

Total Hardness was measured by Multi Parameter ITS -701 direct at the sampling site at the time of sample collection and expressed in mg/l.

Nitrates

They were measured in a Perkin Elmer UV/VIS spectrophotometer model Lambda 25. Concentrations were expressed in mg/l.

Dissolved Oxygen (DO)

It was measured by using Multi Parameter ITS-701 direct at the sampling site at the time sample collection and expressed in mg/l.

Biochemical Oxygen Demand (BOD)

It was measured by automated oxygen analyser. It expressed inmg/l.

Chemical Oxygen Demand (COD)

An automatic analyser was used to measure the COD level

in all sample collected from different rivers at various sites. It is expressed in mg/l.

Results and Discussion

Temperature

At Kanpur site, the average temperature was $21.67 \pm 5.69^\circ\text{C}$. The minimum temperature has been recorded in winter (17°C) while the maximum in the summer season 28°C (Table 1). At Allahabad site, the lowest temperature was recorded in the winter (17°C), modest increase was noted in monsoon season (22°C) and the highest was noted in

Parameters	Summer	Monsoon	Winter	Mean \pm SD
Temperature ($^\circ\text{C}$)	28	20	17	21.67 ± 5.69
pH	8.8	8.2	8.5	8.50 ± 0.30
Total Dissolved Solid (mg/l)	412	540	258	403.33 ± 141.20
Electrical Conductivity (mhos/cm)	628	378	532	512.67 ± 126.12
Sulphate SO_4^{2-} (mg/l)	55	104	48	69.00 ± 30.51
Phosphate PO_4^{3-} (mg/l)	1.58	0.66	0.82	1.02 ± 0.49
Alkalinity (mg/l)	123	182	264	189.67 ± 70.81
Chloride Cl (mg/l)	32	15	27	24.67 ± 8.74
Total Hardness (mg/l)	174	110	240	174.67 ± 65
Nitrate (mg/l)	1.7	0.45	0.94	1.03 ± 0.63
Dissolved Oxygen (mg/l)	4	3	4.8	3.93 ± 0.90
Biological Oxygen Demand (mg/l)	36	48	32	38.67 ± 8.33
Chemical Oxygen Demand (mg/l)	22	38	29	29.67 ± 8.02

Table 1: Analysis of Physico-chemical properties from Ganga River water at Kanpur.

Parameters	Summer	Monsoon	Winter	Mean \pm SD
Temperature ($^\circ\text{C}$)	27	22	17	22.00 ± 5
pH	8.2	7.6	7.9	7.90 ± 0.30
Total Dissolved Solid (mg/l)	406	536	254	398.67 ± 141.14
Electrical Conductivity (mhos/cm)	612	375	528	505.00 ± 120.16
Sulphate SO_4^{2-} (mg/l)	46	68	38	50.67 ± 15.53
Phosphate PO_4^{3-} (mg/l)	1.5	0.63	0.78	0.97 ± 0.47
Alkalinity (mg/l)	120	178	261	186.3 ± 9.70
Chloride Cl (mg/l)	33	20	27	26.6 ± 8.51
Total Hardness (mg/l)	170	107	235	170.67 ± 7.56
Nitrate (mg/l)	1.5	1.4	0.23	1.04 ± 0.71
Dissolved Oxygen (mg/l)	5	4	6	5.00 ± 1
Biological Oxygen Demand (mg/l)	36	44	22	34.00 ± 11.14
Chemical Oxygen Demand (mg/l)	19	28	23	23.33 ± 4.51

Table 2: Analysis of Physico-chemical properties from Ganga River water at Allahabad.

Parameters	Summer	Monsoon	Winter	Mean \pm SD
Temperature ($^\circ\text{C}$)	27	25	20	24.00 ± 3.61
pH	8.2	7.7	8.0	7.97 ± 0.25
Total Dissolved Solid (mg/l)	406	425	385	405.33 ± 20.01
Electrical Conductivity (mhos/cm)	695	640	688	674.33 ± 29.94
Sulphate SO_4^{2-} (mg/l)	43	57	36	45.33 ± 10.69
Phosphate PO_4^{3-} (mg/l)	1.42	1.11	1.37	1.30 ± 0.17
Alkalinity (mg/l)	107	139	172	139.3 ± 32.50
Chloride Cl (mg/l)	49	45	43	45.67 ± 3.06
Total Hardness (mg/l)	134	95	211	146.67 ± 59.03
Nitrate (mg/l)	2.6	2.4	2.1	2.37 ± 0.25
Dissolved Oxygen (mg/l)	4	3.3	5	4.17 ± 0.76
Biological Oxygen Demand (mg/l)	30	38	25	31.00 ± 6.56
Chemical Oxygen Demand (mg/l)	21	36	26	27.67 ± 7.64

Table 3: Analysis of Physico-chemical properties from Ganga River water at Varanasi.

summer season (27°C). The average temperature was $22.0 \pm 5^\circ\text{C}$ (Table 2). At Varanasi site, the average temperature was $24.00 \pm 3.61^\circ\text{C}$. The minimum temperature of 20°C was recorded in winter; moderately increased was noted in monsoon season (25°C) and the maximum temperature in summer (27°C) (Table 3). The mean temperature of the Ganga River is most suitable for *C. carpio* and *O. niloticus* for breeding and growth [15,16,19]. The present environmental conditions of the Ganga river are most suitable for breeding of both fishes for two or three times in a year [15,19]. Praveen [23] reported that temperature at Kanpur ranged from 21°C to 30°C and 14°C to 32°C by Trivedi [24]. According to Raghuvanshi [25] temperature was varied from 24.2°C to 32.5°C from the Ganga River at Allahabad. Zafer [26] reported monsoon season temperature varied from 25.8°C to 26.1°C in 2002 and 2003 which was higher than present study. Singh [27] observed that temperature ranged from $22.1 \pm 1.3^\circ\text{C}$ to $33.8 \pm 1.4^\circ\text{C}$ at Rajghat (Varanasi) which was slightly higher than present finding. Thareja [28] recorded that the temperature ranged from 16°C to 30°C in Kanpur site from the Ganga river. Temperature is one of the important aspects in the aquatic ecosystem as it plays a key role in determination of other parameters such as conductivity, saturation stage of gases and different forms of alkalinity [29,30].

pH

The average pH values were 8.50 ± 0.30 , 7.90 ± 0.30 and 7.97 ± 0.25 at Kanpur, Allahabad and Varanasi sites, respectively (Tables 1-3). The lowest pH was recorded at Allahabad site (7.6, Table 2). It has been observed that pH is generally higher in summer than other season. Maximum values of pH during summer may be due to increased photosynthesis of the algal bloom resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates (Prakash et al.). The pH of different aquatic ecosystems determines the health and biological characteristics of those systems. The pH value of the Ganga river water falls between slightly acidic to moderately alkaline and has relationship with the solubility and accumulation of heavy metal in river water as well as sediment. The pH is not limiting factor for *C. carpio* and *O. niloticus* in the Ganga River and its tributaries, India. Tripathi [31] reported lower mean value of pH 7.60 ± 0.30 at Varanasi compared to present finding in all sampling sites while Rai [32] observed 7.2 ± 0.1 to 7.9 ± 0.1 at the same site in the year 2005. Rai [33] reported average value of pH 7.80 from lower stretch of the Ganga River at Kolkata. Gupta [34] observed pH values between 7.3-7.7 in Yamuna river water at Agra.

Total Dissolved Solid (TDS)

At Kanpur site, the average TDS recorded was 403.33 ± 141.20 mg/l. The minimum TDS 258 mg/l was recorded in the winter season, while as the maximum TDS in the monsoon 540 mg/l with moderately decreased 412 mg/l in summer season (Table 1). At Allahabad site, the minimum TDS was recorded 254 mg/l in the winter season, moderately increased in summer season which was 406 mg/l and the maximum 536 mg/l in monsoon season. The average TDS was noted 398.67 ± 141.14 . At Varanasi site, the average TDS was observed 405.33 ± 20.01 (Figure 2). The minimum TDS 385 mg/l was noted in the winter season, moderately increased 406 mg/l in summer season and the maximum 425 mg/l in monsoon season. A high content of dissolved solid element affect the density of water influence osmoregulation of fresh water in organism, reduce solubility of gases and utility, of water for drinking. The TDS is not limiting factor for *C. carpio* and *O. niloticus* in the Ganga River, India. After invasion of *C. carpio* in the Ganga River TDS was increased [15]. Its browsing nature increased suspended solids in the Ganga River [16]. According to Vilizzi [35] a considerably found in

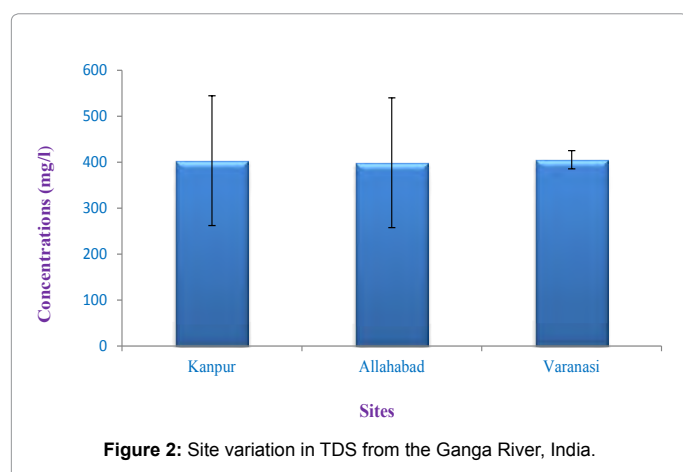


Figure 2: Site variation in TDS from the Ganga River, India.

various water bodies, to increase nitrogen, turbidity/suspended solids, phosphorus and phytoplankton or chlorophyll (about 66-87) in the water bodies due to *C. carpio*. Maheshwari [36] recorded that the TDS value varied from 178 to 200 mg/l in summer season from the Yamuna River at Agra, India. Khwaja [37] observed mean TDS values 152 ± 11 in summer and 725 ± 16 mg/l in winter at Kanpur from the Ganga River. Katiyar [38] reports TDS mean values 381.37 ± 70.39 mg/l in summer, 417.25 ± 4.33 mg/l in monsoon which are higher than present findings and 371.25 ± 14.22 mg/l in winter season at Jajmau, Kanpur which are lower than present finding.

Electrical Conductivity (EC)

Chemically pure water does not conduct electricity. Any rise in the electrical conductivity of water indicates pollution. The maximum EC was noted in summer season $628 \mu\text{mho/cm}$ while as the minimum $378 \mu\text{mho/cm}$ in the monsoon season with the moderately increased $532 \mu\text{mho/cm}$ in winter season at Kanpur site and average recorded was 512.67 ± 126.12 (Table 1). At Allahabad site, the minimum EC was recorded $375 \mu\text{mho/cm}$ in the monsoon season, moderately increased in winter season which was $528 \mu\text{mho/cm}$ and the maximum in summer season as $612 \mu\text{mho/cm}$. At Allahabad site, the average EC was recorded $505.00 \pm 120.16 \mu\text{mho/cm}$. At Varanasi site, the average EC was recorded $674.33 \pm 29.94 \mu\text{mho/cm}$ (Table 3). Gupta [34] reported EC values between 990 to 1285 mg/l in Yamuna river at Agra which are much higher than those of the present study. High EC values are indicating the presence of higher amount of dissolved inorganic substances in ionized form. Chandra [39] reported 222 mg/l from the Ganga river at Kasi and 215 mg/l in Gomti River at Lucknow which was lower as compared to present study.

Sulphates (SO_4^{--})

At Kanpur site, the average SO_4 recorded was 69.00 ± 30.51 mg/l, 50.67 ± 15.53 mg/l and 45.33 ± 10.69 mg/l at Kanpur, Allahabad and Varanasi sites, respectively. At Kanpur site, the minimum SO_4 was recorded 48 mg/l in the winter season, moderately increased 55 mg/l in summer season with the maximum in the monsoon season as 104 mg/l (Table 1). The slightly lower concentration of sulphate was recorded at Allahabad site compared to Kanpur site. At Allahabad site, the minimum SO_4 was recorded 38 mg/l in the winter season, moderately increased in summer season which was 46 mg/l and the maximum in monsoon season 68 mg/l (Table 2). The minimum SO_4 was recorded 36 mg/l in the winter season, moderately increased in summer season which was 43 mg/l and the maximum in monsoon season as 57 mg/l (Table 3).

Chavan [40] observed minimum sulphate 5.34 mg/l at winter, whereas maximum value 13.95 mg/l in monsoon season in which both season have lower value compared to present work. Discharge of industrial wastes and domestic sewage in water ends to increase its concentration. Sulphate present in fertilisers they contributes to water pollution and increase sulphate concentration in water bodies. They also come from the runoff water which contain relatively large quantitative of organic and minerals sulphate compound.

Phosphates (PO_4^{--})

Phosphates control the algal growth and primary productivity. In most natural water excess amount of phosphorus can cause eutrophication leading to excessive algal growth called algal blooms. At Kanpur site, the average PO_4 recorded was 1.02 ± 0.49 mg/l in the year 2011-2012. The maximum PO_4 was noted 1.58 mg/l in summer season while as the minimum in the monsoon season 0.66 mg/l with the moderately increased 0.82 mg/l in winter season. At Allahabad site, the minimum PO_4 was recorded 0.63 mg/l in the monsoon season, moderately increased in winter season which was 0.78 mg/l and the maximum in summer season as 1.5 mg/l. The average PO_4 was recorded 0.97 ± 0.47 and 0.98 ± 0.46 mg/l in the year 2011-2012 (Table 2). At Varanasi site, the average PO_4 was recorded 1.30 ± 0.17 mg/l. The minimum PO_4 was recorded 1.11 mg/l in monsoon season, moderately increased in winter season which was 1.37 mg/l and the maximum in summer season 1.42 mg/l. Singh [27] reported that the PO_4 was ranged from 1.01 ± 0.3 to 1.58 ± 0.7 mg/l at Rajghat (Varanasi).

Alkalinity

At Kanpur site, the average alkalinity recorded was 189.67 ± 70.81 mg/l. The minimum alkalinity was recorded 123 mg/l in the summer season while as maximum 264 mg/l in winter with the moderately increased 182 mg/l in monsoon season (Table 1). At Allahabad site, the minimum alkalinity was recorded 120 mg/l in the summer season, moderately increased in monsoon season which was 178 mg/l and maximum in winter season as 261 mg/l in year 2011-2012. At Allahabad site, the average alkalinity was recorded 186.3 ± 70.87 mg/l. At Varanasi site, the average alkalinity was recorded 139.33 ± 32.50 mg/l in the year 2011-2012. The minimum alkalinity was recorded 107 mg/l in summer season, moderately increased in monsoon season which was 139 mg/l and maximum in winter season as 172 mg/l. (Table 3). Praveen [23] reported that alkalinity value was ranged from 12.7 to 245 mg/l at Kanpur and Thareja [28] observed that the alkalinity was ranged from 108 to 260 mg/l at same site in 2008-2009. Maheshwari [36] recorded alkalinity values varied from 156 to 210 mg/l in summer season in the Yamuna River at Agra. The alkalinity of the river water was more in winter when the temperature was lower compared to monsoon and summer seasons.

Chloride (Cl)

The chloride concentration was varied from 15 to 32, 20 to 33 and 43 to 49 mg/l at Kanpur, Allahabad and Varanasi sites, respectively (Tables 1-3). The average Cl was recorded 24.6 ± 8.74 at Kanpur, 26.6 ± 6.51 at Allahabad and 45.67 ± 3.06 mg/l at Varanasi sites. Trivedi [24] recorded that Cl value was ranged from 8-30 mg/l in years 2009 at Kanpur. Gupta [34] reported Cl concentration varied from 180 to 218 mg/l in Yamuna River at Agra.

Total Hardness (TH)

At Kanpur site, the average TH was recorded 174.67 ± 65 in the year 2011-2012. The minimum TH was recorded in the monsoon

season 110 mg/l while as maximum in winter season 240 mg/l (Table 1). At Allahabad site, the minimum TH was recorded 107 mg/l in the monsoon season, moderately increased in summer season which was 170 mg/l and the maximum in winter season as 235 mg/l. At Allahabad site, the average TH was recorded 170.67 ± 64 (Table 2). At Varanasi site, the average TH was recorded 146.67 ± 59.03 in the year 2011-2012 (Table 3). The minimum TH 95 mg/l was recorded in the monsoon season and moderately increased in summer season which was 134 mg/l. The maximum TH was noted in winter season as 211 mg/l in year 2011-2012 (Table 3). Trivedi [24] observed that the TH was from 108 to 246 mg/l at Kanpur. Gupta [34] reported TH values ranged from 252 to 304 mg/l in the Yamuna River at Agra. Water hardness refers to the concentration of divalent calcium, Magnesium, Strontium, Ferrous, and Manganese ions. It is derived largely from soil and rock erosion.

Nitrates (NO_3^-)

At Kanpur site, the average Nitrate was recorded 1.03 ± 0 mg/l. The minimum Nitrate was recorded in monsoon season 0.45 mg/l, while as maximum in summer season 1.7 mg/l with the moderately increased 0.94 mg/l in winter season of year 2011-2012 (Table 1). At Allahabad site, the minimum Nitrate was recorded 0.23 mg/l in the winter season, moderately increased in monsoon season which was 1.4 mg/l and the maximum in summer season as 1.5 mg/l in year 2011-2012. At Allahabad site, the average Nitrate was recorded 1.04 ± 0.71 in the year 2011-2012 (Table 2). At Varanasi site, the average Nitrate was recorded 2.37 ± 0.25 in the year 2011-2012. The minimum Nitrate was recorded 2.1 mg/l in the winter season and moderately increased in

monsoon season which was 2.4 mg/l. The maximum Nitrate was noted in summer season as 2.6 mg/l in year 2011-2012 (Table 3). Tripathi [31] reported mean value of NO_3^- was 1.10 ± 0.40 mg/l at Varanasi, Rai [32] observed NO_3^- ranged 0.85 ± 0.31 mg/l to 1.30 ± 0.22 mg/l in the year (2005), at Rajghat (Varanasi) in the river Ganga. In surface waters nitrogen may exist as particulates or dissolved forms. Organic nitrogen decays to produce ammonia via anaerobic bacteria decayed process. Ammonia in turn converted to nitrites and ultimate to nitrates via the process of nitrification, an aerobic bacteria procedure. Algae readily take up dissolved inorganic nitrogen, which consist of ammonia and nitrate with a typical preference for ammonia. Nitrates added into the river water mainly by agricultural runoff.

Dissolved Oxygen (DO)

At Kanpur site, the average DO was recorded 3.93 ± 0.90 mg/l in the year 2011-2012. The minimum DO was recorded in the monsoon season 3.0 mg/l while as maximum in winter 4.8 mg/l with the moderately increased 4 mg/l in summer season of year 2011-2012 (Table 1). At Allahabad site, the minimum DO was recorded 4 mg/l in the monsoon season, moderately increased in summer season which was 5 mg/l and the maximum in winter season as 6 mg/l in year 2011-2012. At Allahabad site, the average DO was recorded 5.00 ± 1 in the year 2011-2012 (Table 2). At Varanasi site, the average DO was recorded 4.17 ± 0.76 in the year 2011-2012 (Figure 3). The minimum DO was recorded 3.3 mg/l in the monsoon season, moderately increased in summer season 4 mg/l and the maximum DO in winter season 5 mg/l in year 2011-2012 (Table 3). Tripathi [31] recorded mean value of DO was 0.90 ± 0.50 mg/l at Varanasi. Maheshwari [36] reported DO varied from 5.5 to 8.2 mg/l in summer from Yamuna river at Agra. According to USPH standard, DO values should range from 4.0 to 6.0 mg/l for fishes. Value of DO increased in winter due to circulation of cold water as well as high solubility of oxygen at low temperature. DO play an important role in water quality determination. The introduction of oxygen demanding materials, either organic or inorganic, in to water causes depletion of the dissolved oxygen in the water. This poses a threat to fish and other higher forms of aquatic life if the concentration of oxygen falls below critical point. But in case of *C. carpio*, *O. niloticus* and catfishes, even low concentration of oxygen are acceptable for growth and production in water [41]. Due to low concentration of oxygen in the river Ganga other fishes (especially carps) are suffer for survival and growth. DO levels in surface water body indicate the ability to support aquatic life. The high DO values means the rate of oxygen replenishment in water is greater than the oxygen utilization. Adequate DO is necessary for good water quality. DO levels between 5.0 and 8.0 mg/l are satisfactory for survival and growth of aquatic organisms. The concentrations of DO in surface waters are affected by water temperature. Colder water can hold more DO than warmer water and saturation occurs at higher concentrations in winter. DO may decrease in north temperature ecosystem.

Biochemical Oxygen Demand (BOD)

At Kanpur site, the average BOD was recorded 38.67 ± 8 (Figure 4). The minimum BOD was recorded in the winter season 32 mg/l while as maximum 48 mg/l in monsoon of year 2011-2012 (Table 1). At Allahabad site, the average BOD was recorded 34.00 ± 11.14 in the year 2011-2012. The minimum BOD 22 mg/l was recorded in the winter season, moderately increased in summer season which was 36 mg/l, and the maximum BOD was noted in monsoon season as 44 mg/l in year 2011-2012 (Table 2). At Varanasi site, the average BOD was recorded 31.00 ± 6.56 in the year 2011-2012. The minimum BOD was recorded 25 mg/l in the winter season, moderately increased in summer season

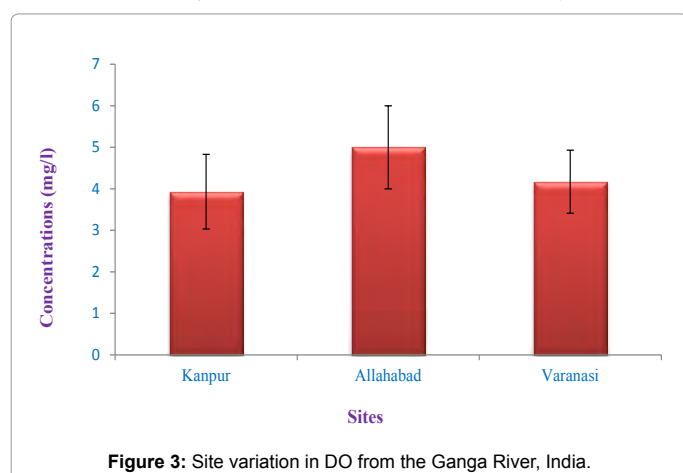


Figure 3: Site variation in DO from the Ganga River, India.

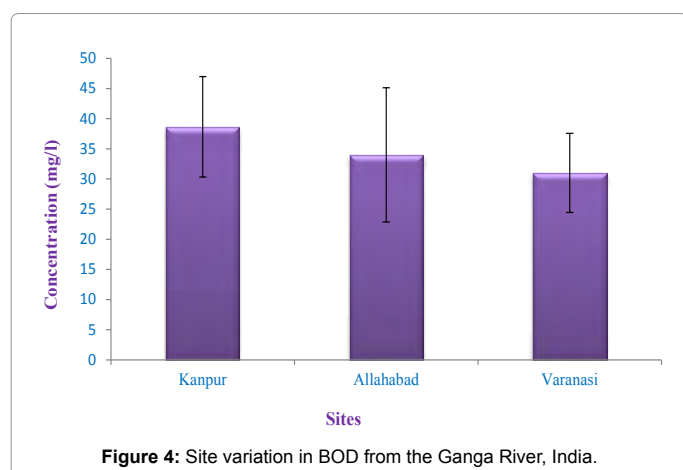
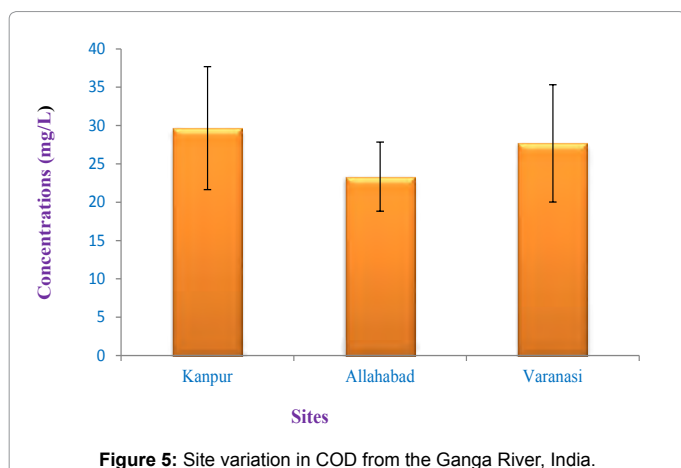


Figure 4: Site variation in BOD from the Ganga River, India.

which was 30 mg/l and maximum in monsoon season as 38 mg/l in year 2011-2012 (Table 3). Singh [27] observed that the BOD was ranged from 66.2 ± 3.4 to 87.5 ± 2.9 mg/l at Rajghat (Varanasi) while Rai [32] reported BOD range was from 97 ± 41 to 265 ± 78 mg/l in the year 2005 at the same site, Chandra [39], Chavan et al. reports minimum BOD 1.38 mg/l during winter and maximum value 6.51 mg/l in monsoon season. Chavan [40] records values of 3.9 mg/l BOD at Ganga Kasi, and 2.1 mg/l at Lucknow in Gomti River. Khwaja [37] provides mean BOD value 2.8 ± 0.4 in summer and 3.5 ± 0.4 mg/l in winter at Kanpur from the Ganga River. Katiyar [38] reports very higher BOD mean 41.7 ± 1.26 mg/l during summer, 34.12 ± 1.57 mg/l during monsoon, 36.69 ± 1.40 mg/l during winter at Jajmau, Kanpur compared to the present investigation. Due to higher values of BOD in the river Ganga are suitable for *C. carpio*, *O. niloticus* and catfishes (due to hardy nature) for growth and production while other fishes are suffer for survival and growth. BOD is the amount of oxygen required by the living organisms (microbes) in the utilization or stabilization of organic matter in water over a 5 day period. It is very important indicator of the organic pollution status of a water body. The unpolluted water has BOD values of 3 mg/l or less and industrial waste waters have BOD values 25000 mg/l. BOD values generally approximates the amount of oxidisable organic matter, and is therefore, used as a measure of degree of water pollution and waste level. BOD values are thus use full in evaluation of self-purification capacity of a water body and for possible control measure of pollution.

Chemical Oxygen Demand (COD)

COD is a method to determine the organic load of water body i.e., susceptible to oxidation. COD as a result of pollution is largely determined by the various organic and inorganic materials as like calcium, magnesium, potassium, sodium etc. The levels of COD seem to be the appropriate indices for assessing the pollution level of water bodies. The high COD values are found mainly in water, which may be due to the mixing of domestic and industrial wastes. At Kanpur site, the average COD was recorded 29.67 ± 8.02 mg/l. The minimum COD was recorded in the summer season 22 mg/l while as maximum in monsoon 38 mg/l with the moderately increased 29 mg/l in winter season of year 2011-2012 (Table 1). At Allahabad site, the minimum COD 19 mg/l was recorded in the summer season, moderately increased in winter season 23 mg/l and the maximum in monsoon season as 28 mg/l in year 2011-2012. At Allahabad site, the average COD was recorded 23.33 ± 4.51 mg/l in the year 2011-2012 (Table 2). At Varanasi site, the average COD was recorded 27.67 ± 7.64 in the year 2011-2012 (Figure 5). The minimum COD were recorded 21 mg/l in the summer season,



Fishes/groups	Water bodies	Relative abundance (according to number)			
		Kanpur	Allahabad	Varanasi	Source
Major carps	Ganga river	13.13	9.64	10.71	[13]
Catfishes (Hardy fishes)	Ganga river	63.44	72.04	70.47	[13]
<i>Cyprinus carpio</i>	Ganga river	10.25	8.75	9.64	[13]
<i>Oreochromis niloticus</i>	Ganga river	13.18	9.66	9.18	[13]
Landing scenario (according to weight)					
Major carps	Ganga river		8.74		[15]
Catfishes (Hardy fishes)	Ganga river		40.67		[15]
<i>Cyprinus carpio</i>	Ganga river		14.20		[15]
<i>Oreochromis niloticus</i>	Ganga river		12.54		[15]
Major carps	Yamuna river		12.97		[18]
Catfishes (Hardy fishes)	Yamuna river		25.32		[18]
<i>Cyprinus carpio</i>	Yamuna river		21.76		[18]
<i>Oreochromis niloticus</i>	Yamuna river		24.36		[18]
Major carps	Yamuna river		8.00		[15]
Catfishes (Hardy fishes)	Yamuna river		23.98		[15]
<i>Cyprinus carpio</i>	Yamuna river		25.18		[15]
<i>Oreochromis niloticus</i>	Yamuna river		19.07		[15]
<i>Cyprinus carpio</i>	Ken river		17.80		[17]
<i>Cyprinus carpio</i>	Paisuni river		6.43		[17]
<i>Cyprinus carpio</i>	Tons river		4.06		[17]

Table 4: Relative abundance and landing scenario of fishes and groups from the various rivers, India (%).

moderately increased in winter season 26 mg/l and the maximum in monsoon season as 36 mg/l in year 2011-2012 (Table 3). Tripathi [31] recorded higher mean values of COD 520 ± 180 mg/l at Varanasi compared to present findings. Chandra [39] reported 22 mg/l at Ganga Kasi and 14 mg/l at Lucknow from the Gomti River, lower compared to present observation.

The chemical oxygen demand is commonly used to determine the amount of organic pollutants found in surface waters. COD is a measure of the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate [42]. Oxygen demand value is useful in specifying toxic condition and presence of biological resistant substances. BOD and COD are usually at or near analytical limits of detection in relatively undisturbed systems. Khwaja [37] estimated lower mean values of COD compared to present findings 14 ± 0.8 in summer and 19.7 ± 0.9 mg/l in winter at Kanpur from the Ganga River. Heavy metals accumulation was reported higher in the gills from the Ganga river but gill rakers and gill lamellae found safe conditions in case of *C. carpio* and *O. niloticus* [43].

The poor water quality of the Ganga river was most suitable for catfishes (hardy fishes), *C. carpio* and *O. niloticus* at Kanpur, Allahabad and Varanasi sites. The Indian riverine sector (specially central India) presently dense by *C. carpio* and *O. niloticus* (Table 4) due to poor water quality. Table 4 is shows that the *C. carpio* and *O. niloticus* highly landed (shared in landing) in earlier in the Ganga, Yamuna, Ken, Paisuni and Tons rivers which is reported by Ref. [13,15,17,18]. Present dense condition of *C. carpio* and *O. niloticus* were also reported by Mayank [44], Dwivedi [45] from the Vindhyan region and Yamuna river.

It may be concluded that the water quality of the Ganga river contaminated by the ample pollutants at Kanpur, Allahabad and Varanasi sites. It may be also concluded that the water of the Ganga River most suitable for *C. carpio* and *O. niloticus* by earlier reports (landing and relative abundance). Due to higher values of BOD and

COD in the river Ganga are suitable for *C. carpio*, *O. niloticus* and catfishes for growth and production while other fishes are suffer for survival and growth.

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