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Limnological characterisation of Hindon River at NCR (Uttar Pradesh), India

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Abstract

The Hindon River is an important River of western Uttar Pradesh. The river is highly polluted due to industrial, municipal and agricultural activities. Regular monitoring of the quality of water is essential because clean water is obligatory for human health and the integrity of aquatic ecosystems. Therefore an attempt has been made in this study to assess the Hindon river water quality by analysing various Physico- chemical parameters. The various Physico- chemical parameters analysed are temperature, pH, TDS, Turbidity, DO, BOD, COD, Free CO_2, Electrical Conductivity, Acidity, Total Hardness (TH), Chloride(Cl) and Alkalinity. During the study DO ranged from 0.5 mg/l to 1.8 mg/l, BOD ranged from 44.3 mg/l to 105.4 mg/l, TDS ranged from 320 mg/l to 690 mg/l, EC ranged from 788 µS/cm to 1625 µS/cm and the pH ranged from 6.4 to 8.2. Temperature was fund strongly negatively correlated (-0.906) with DO while a strong positive correlation was found between pH and DO (0.909) and between TDS and COD (0.914).

Keywords: Hindon River, Physico- Chemical Parameter, Pollution, Riparian zones

Introduction

Water is the most precise thing in this world, which we cannot live without. Water is super abundant on the planet as a whole, but fresh potable water is not always available at the right time or the right place for human or ecosystem use (Khanna *et al.,* 2012).Water is most abundant and familiar liquid, widely distributed in nature. About $4/5^{th}$ of the surface of the earth is covered with water (Kumar *et al.,* 2016). The quality of water is vital concern for mankind since it is directly linked with human welfare. It is unique liquid, without which life is impossible. It is naturally recycled through a process called hydrological cycle (Bhutiani *et al.,* 2016). From the ancient time Human beings and animals depend on Rivers, Lakes and springs to fulfill their need of water. So the rivers are significant resource for human civilizations as they meet water demand for various uses apart from supporting flora and fauna, improving aesthetic and landscape quality, moderating climate and providing resources for hydropower (Sharma *et al.,* 2008). Rivers also plays an important role in the assimilation and transportation of domestic and industrial waste waters, which form invariable pollution sources and agricultural runoff, which is temporal and commonly affected by climate (Zhou *et al.,* 2007).Water chemistry is responsible for many of the characteristics associated with the quality of rivers. An interdependent relationship exists between rivers and atmosphere. Variation of climate conditions can cause seasonal variation among all parameters of water systems; thereby inducing seasonal variation of water quality (Gentiana, 2016). Due to urbanization and industrial activities the water consumption rate and pollution has increased. Major cause of water pollution is mismanagement of sewage drains and industrial effluents. These all activities have not only affected the aquatic ecosystem but also the riparian zone (Riparian zones are transitional semi terrestrial/semiaquatic areas regularly influenced by fresh water, usually extending from the edges of water bodies to the edges of upland communities) and human being activities. Rivers are highly prone to pollution, therefore it becomes necessary to keep check on surface water quality and interpret the temporal and spatial variations (Yerel and Ankara, 2012). Regular monitoring of the quality of water is essential because clean water is obligatory for human health and the integrity of aquatic ecosystems (Babiker *et al.,* 2007). Monitoring water resources will quantify water quality and

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identify impairments, in order to not only preserve natural areas, but to improve the quality of life as well, (Bellingham, 2009). The river Hindon is among one of the important rivers in western Uttar Pradesh (India) having a basin area of about 7,083 km^2.The study area is a part of Indo-gangetic Plains, composed of Pleistocene and sub recent alluvium. The main sources of pollution in river Hindon include municipal wastes from Saharanpur, Muzaffarnagar, Baghpat, Meerut and Ghaziabad urban areas and industrial effluents of sugar, pulp and paper, distilleries and other miscellaneous industries through tributaries as well as direct outfalls. In summer months the river is completely dry from its origin upto Saharanpur town.

Materials and Method

Description of Study Area

Hindon River, a tributary of Yamuna River, is a river in India that originates in the Saharanpur District; Uttar Pradesh.The river is entirely rainfed and has a catchment area of 7,083 square kilometres (2,735 sq. mi). The catchment area is a part of the Indo Gangetic Plain, composed of Pleistocene and sub recent alluvium and lies between the latitude 28°30' to 30°15'N and longitude 77°20' to 77°50'E and flows 400 kilometres (250 mi) through six districts, including Muzaffarnagar, Meerut, Baghpat, Ghaziabad and Gautambudh Nagar until its confluence with the Yamuna. The Ganga River in the east and the Yamuna River in the west bounds the Hindon. It is a major source of water to the highly populated and predominantly rural population of western Uttar Pradesh (Suthar *et al.,* 2010). The climate of this region is tropical to temperate with extreme temperature conditions in summer (up to 43^0C) and winter (up to 3^0C). The mean annual rainfall in this region is 702 mm varying spatially in different subregions of the districts. The river is characterized by sluggish flow throughout the year, except during monsoon when rainfall causes a manifold increase in the runoff (Suthar *et al.,* 2010).Water quality of Hindon is deteriorating at an alarming rate attributable to rapid urbanization, untreated industrial effluents into the river stream. Some previous studies on River Hindon revealed that industrial and municipal effluents pose great stress on the health of river. The study area of the river under present study ranged from its entrance in the Ghaziabad to its confluence with the Yamuna River in Tilwada village, Noida. Total 4 sites were identified and selected for the collection of samples (Fig. 1, 2, 3 and 4).

To evaluate the water quality of Hindon River, sampling was done on the monthly basis from January 2013 to December 2013 from four different sampling locations**.** Inaccessibility, rough terrain and high water level in rainy season restricted us to choose only four sampling locations. Water samples were collected in pre-cleaned jerican (previously washed with 10% nitric acid and cleansed with distilled water) in the morning time and then transported to the laboratory for analysis of various physico-chemical parameters.

Analysis of various Physico-chemical parameter was performed with the help of APHA (2012), Khanna and Bhutiani (2008) and Trivedi and Goel 1986.

Sampling Stations:

a) Hindon Barrage, Ghaziabad (Site A)
b) IndraPuram, Ghaziabad (Site B)
c) Near Vishnu Nagar, Noida (Site C)
d) Dadri Road, Noida (Site D)

Results and Discussion

The Physico-chemical characteristic of the Hindon River water considered in the present study were water temperature, total dissolve solids (TDS), electrical conductivity(EC) total solids(TS), Total Suspended Solids(TSS),Turbidity, pH, dissolved oxygen (DO) , biochemical oxygen demand (BOD), chemical oxygen demand (COD), alkalinity ,acidity ,total hardness (TH) and chlorides is presented in the table from 1-5 and correlation is presented in table 6.

Temperature mainly depends on the atmosphere and weather condition. It is basically important for its effects on certain chemical and biological reactions taking place in water and aquatic organisms. During the study period the temperature ranges from 15.6^0C to 32^0C (Table 1, 2, 3 and 4). The average values of temperature at site 1, site 2, site 3 and site 4 were found as 24.2^0C ±5.4, 24.5^0C ±5.5, 25.2^0C ±5.3 and 25.2^0C ±5.4 respectively. The minimum monthly average value of temperature was observed in the month of January (16.3^0C ±0.6) while the maximum value was found in the month of August (31.5^{0}C ±0.4) and the overall average value was found 24.8^{0}C ±4.8 (Table-5). A strong negative correlation (-0.906) was found between temperature and DO while it was found positively correlated with BOD (0.763) (Table-6). The pattern of temperature fluctuation was more or less similar at all stations. The low water temperature in winter season can be explained on the basis of high water levels and lower solar radiations whereas higher temperature in summer was on account of low water level, low velocity, greater solar radiations and clear atmosphere. Kumar *et al.,* (2016) reported the same results while working on river Narmada (MP) India. Rizvi *et al.,* (2016) also observed the similar results of temperature in Hindon River. Total dissolved solid is a measure of the amount of particulate solids that are in solution.

Fig 1- Showing sampling site-1(Hindon Barrage, Ghaziabad).

Fig 2- Showing sampling site-2 (IndraPuram, Ghaziabad).

Fig 3- Showing sampling site-3 (Near Vishnu Nagar, Noida).

Fig 4- Showing sampling site-4 (Dadri Road, Noida).

This is an indicator of non-point source of pollution problems associated with various land use practices. During the study period the TDS ranges from 320 mg/l to 690 mg/l (Table 1, 2, 3 and 4). The average values of TDS at site 1, site 2, site 3 and site 4 were found as 353.9 mg/l ±22.4, 639.0 mg/l ±25.6, 550.5 mg/l ±16.4 and 608.1 mg/l ±13.5 respectively. The minimum monthly average value of TDS was observed in the month of January (515.8 mg/l ±134.4) while the maximum value was found in the month of August (568.5 mg/l ±131.3) and the overall average value was found 537.9 mg/l ±16.4 (Table-5). A strong positive correlation was observed between TDS and COD (0.914) while a strong negative correlation was found between

Month/Parameters	Temp	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO_2	Acidity	TH	Chloride	Alkalinity
January	15.6	321	144	788	7.1	1.8	51.6	165.8	78	86	198.5	35.6	198
February	18.4	335	166	845	7.2	1.8	44.3	160.5	71	72	208.6	42.6	210
March	20.1	320	179	815	7.9	1.6	49.8	162.3	62	71	178.6	40.2	205
April	27.1	346	200	856	7.6	1.5	52.6	171.5	44	70	210.3	41.6	215
May	28	352	211	890	8.2	1.3	69.7	190.7	41	75	205.4	46.8	195
June	29	360	152	1001	7.2	1.1	75.6	210.6	38	80	198.4	29.8	175
July	30	378	179	1050	6.9	0.8	98.4	280.6	35	86	170.8	36.8	167
August	31	380	189	1120	6.8	0.6	102.6	320.4	27	90	210.3	35.1	147
September	27	371	233	1023	7.1	0.9	85.6	280.5	38	78	206.1	42.6	185
October	26	345	199	998	7.5	1.1	79.5	261.3	42	72	211.4	81.3	200
November	21	388	212	1015	7.2	1.4	74.3	245.9	50.2	81	220.1	59.8	185
December	17	351	211	1002	7.7	1.5	60.2	260.8	52.4	78	219.7	58.6	190
Average	24.18	353.9	189.6	950.2	7.4	1.3	70.4	225.9	48.2	78.3	203.2	45.9	189.3
SD	5.4	22.4	26.6	106.2	0.4	0.4	19.2	55.7	15.3	6.6	14.9	14.3	19.3

Table 1- Showing variation in Physico-chemical parameters at site-1 in 2013

Month/Parameters	Temp	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO2	Acidity	TH	Chloride	Alkalinity
January	16	598	194	1510	7.9	1.5	68.7	189.9	43	42	347.3	128.2	210.3
February	18.1	620	201	1428	8.1	1.4	70.5	220.6	32.4	41	374.2	112.6	198.5
March	21.1	632	211	1528	7.6	1.2	75.9	225.4	29.9	34	413.9	110.8	185.6
April	28	634	231	1528	7.9	1	78.3	241.9	30.8	42	389.4	115.6	194.6
May	28.6	640	234	1411	7.2	0.9	83.6	255.8	26	28	371.3	112.6	201.6
June	29	645	189	1217	6.8	0.7	85.9	278.6	20.9	29	421.5	123.5	210.5
July	30.2	690	181	1623	6.4	0.7	88.4	290.7	22.1	22.1	431.5	105.6	185.9
August	31.2	678	190	1610	6.8	0.5	91.6	290.8	27.2	21	329.9	110.6	180.6
September	27	645	211	1216	7.2	0.7	85.6	265.4	34.8	34.8	389.7	142.3	195.4
October	26.4	647	223	1421	7.0	0.8	84.1	260.8	25.1	25.1	352.2	115.9	201.3
November	21.2	625	235	1331	7.3	0.9	81.3	251.8	36.9	36.9	381.1	126.7	198.2
December	17	614	234	1518	7.5	1.1	78.2	255.7	32.1	32.1	368.8	119.5	189.4
Average	24.5	639.0	211.2	1445.1	7.3	0.9	81.0	252.3	30.1	32.3	380.9	118.7	195.9
SD	5.5	25.6	19.9	135.4	0.5	0.3	6.9	29.6	6.4	7.4	30.6	10.1	9.4

Table 2- Showing variation in Physico-chemical parameters at site-2 in 2013

Month/Parameters	Temp.	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO2	Acidity	TH	Chloride	Alkalinity
January	16.6	532	256	1151	8	1.4	60.4	198.6	65	55	288.6	110.5	220.3
February	19	536	266	1180	7.9	1.2	64.2	222.3	56	53	305.2	121.3	190.6
March	22.3	541	281	1201	7.9	1.1	78.4	239.4	47	41	298.6	120.3	210.3
April	28	525	276	1136	7.7	0.9	79.5	210.6	39.6	67	300.1	101.7	201.6
May	29	550	276	1221	7.5	0.9	81.3	195.8	29.6	37	302.1	102.6	211.4
June	30	564	259	1238	7.3	0.7	85.4	188.5	25	42	310.5	99.7	208.5
July	30.5	562	221	1238	6.8	0.6	89.2	210.3	23.9	65	305.8	102.6	204.6
August	32	585	221	1219	6.9	0.4	93.1	235.8	26.1	33	312.3	98.4	220.1
September	28.1	548	256	1215	7.1	0.7	88.1	246.1	32.3	45	320.5	97.1	215.1
October	26.7	556	248	1230	7.3	0.7	80.3	245.2	26.9	60	309.7	101.3	216.3
November	22	560	281	1235	7.8	0.8	77.6	223.1	41.1	66	319.8	100.6	185.4
December	18	546	276	1210	7.9	1	65.3	204.4	38.9	61	285.4	109.8	198.7
Average	25.2	550.5	259.8	1206.2	7.5	0.9	78.6	218.3	37.6	52.1	304.9	105.5	206.9
SD	5.33	16.4	21.1	33.8	0.4	0.3	10.4	19.9	13.1	12.1	10.8	8.2	11.2

Table 3- Showing variation in Physico-chemical parameters at site-3 in 2013

Month/Parameters	Temp	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO2	Acidity	TH	Chloride	Alkalinity
January	17	612	247	1590	8.2	1.7	77.6	235	65.8	68	332.1	125.6	225.1
February	18.7	592	261	1556	7.9	1.7	82.1	245.1	49.4	62	310.4	121.4	230
March	22	605	309	1568	7.6	1.5	85.6	240.2	34.9	48	320.1	127.4	225
April	28.3	595	325	1550	7.5	1.1	90.4	284.1	35.2	72	305.4	120.3	222.4
May	29	589	311	1524	7.4	1	98.4	310.2	26.2	45	300.1	120.4	235.1
June	31	595	327	1560	7.2	0.8	100.5	315.4	19.7	49	304.5	102.6	240.3
July	30	625	287	1625	6.9	0.9	98.2	305.1	22	66	340.6	122.5	236
August	31.6	631	321	1640	6.9	0.7	105.4	320.4	25	37	338.9	112.9	234
September	29	621	309	1610	6.8	0.8	99.3	312.6	28.6	55	326.4	151.6	231.5
October	26.5	611	310	1600	7.3	1.1	92.4	312.5	26	61	308.4	154.2	230.5
November	22.4	611	327	1595	7.7	1.3	84.7	265.1	38.2	69	315.3	140.6	239.8
December	18	610	311	1560	7.7	1.5	81.3	250.1	37	64	310.9	141.5	235.4
Average	25.3	608.1	303.8	1581.3	7.5	1.2	91.3	282.9	34	58	317.8	128.4	232.1
SD	5.4	13.5	25.9	34.2	0.4	0.4	9.0	33.6	13.0	11.1	13.8	15.5	5.8

Table 4- Showing variation in Physico-chemical parameters at site-4 in 2013

TDS and pH (-0.944) (Table-6). A more or less same trend was observed by Gentiana (2016) while studying seasonal variation of the Osumi River. Seth *et al.,* (2016) also reported same trend of results in different rivers of Kumaun region. Rizvi *et al.,* (2015) also observed the more or less similar results of average TDS in Hindon River , Khanna *et al.,* (2014) in Malin River and Bhutiani *et al.,* (2014) in Song River.Turbidity is the term for the suspended dirt and other particles in water. Turbidity in natural water restricts the penetration of light thereby reducing the photosynthetic activity hence; act as limiting factor for productivity. During the study period minimum turbidity was found 144 NTU while the maximum turbidity was found 327 NTU (Table 1, 2, 3 and 4). The average values of turbidity at site 1, site 2, site 3 and site 4 are respectively 189.6 NTU ±26.6, 211.2 NTU ±19.9, 259.8 NTU ±21.1 and 303.8 NTU ±25.9 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of Turbidity was observed in the month of January (210.3 NTU ±51.9) while the maximum value was found in the month of November (263.8 NTU ±50.9) and the overall average value was found 241.1 NTU±18.0 (Table-5). More or less same trend of turbidity was observed by Khanna and Bhutiani,(2005).Electrical Conductivity (EC) is the capacity of water to conduct electricity. It is an indirect measure of the salt concentration. The conductivity of polluted water is higher. This measure therefore is often used as an index of pollution. During the study period the EC ranges from 788µS/cm to 1625µS/cm (Table 1, 2, 3 and 4). The average values of EC at site 1, site 2, site 3 and site 4 was found as 950.2 µS/cm ±106.2, 1445.1 µS/cm ±135.4, 1206.2 µS/cm ±33.8 and 1581.3 µS/cm ±34.2 respectively . The minimum monthly average value of Electrical Conductivity (EC) was observed in the month of February (1252.3 µS/cm ±313.2) while the maximum value was found in the month of August (1397.3 µS/cm ±266.4) and the overall average value was found 1295.7 µS/cm ±49.7 (Table-5). Electrical Conductivity was found strongly negatively correlated with alkalinity (-0.813) while it was found slightly negatively correlated with acidity (-0.110) (Table-6). More or less same results were observed by Mallika *et al.,* (2017) while studying Physico-Chemical and bacteriological parameters of vaigai River Water Tamilnadu. During the study period minimum pH was found 6.4 while the maximum pH was found 8.2 (Table 1, 2, 3 and 4). The average values of pH at site 1, site 2, site 3 and site 4 are respectively 7.4±0.4, 7.3±0.57.5±0.4 and 7.5±0.4 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of pH was observed in the month of July (6.8±0.2) while the maximum value was found in the month of January (7.8±0.5) and the overall average value was found 7.4±0.4 (Table-5). A strong positive correlation was observed between pH and DO (0.909) while a strong negative correlation was found between pH and COD (-0.868) (Table-6).The higher values of pH recorded during winter season could be attributed to decreased decomposition rate owing to reduced microbial activity and increased algal productivity (Ahipathy and Puttaiah, 2006). Chetana and Somashekar (1997) reported the summer minima are due to increased decomposition rate, leading to acidification and lowered pH. Similar findings of pH were observed by Rizvi *et al.,* (2016) while studying seasonal and spatial variation in the water quality of river Hindon at NCR India.Dissolved Oxygen 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 reluctant such as hydrogen sulphide, ammonia, nitrites, ferrous iron, etc. During the study period the DO ranges from 0.5 mg/l to 1.8 mg/l (Table 1, 2, 3 and 4). The average values of DO at site 1, site 2, site 3 and site 4 were found 1.3 mg/l ±0.4, 0.9 mg/l ±0.3, 0.9 mg/l ±0.3 and 1.2 mg/l ±0.4 respectively. The minimum monthly average value of DO was observed in the month of August (0.6 mg/l ±0.1) while the maximum value was found in the month of January (1.6 mg/l ±0.2) and the overall average value was found 1.1 mg/l ±0.3 (Table-5). A strong positive correlation was observed between DO and free CO_2 (0.920) while a strong negative correlation was found between DO and COD (-0.937) (Table-6). More or less same trend of DO were observed by Pratap and Kumar, (2016) in Hindon River.

Table 5- Showing average variation in Physico-chemical parameters in 2013

Month/ Parameters	Temp	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO2	Acidity	TH	Chloride	Alkalinity
January	16.3 ±0.6	515.8 ±134.4	210.3 ±51.9	1259.8 ±367.9	7.8 ±0.5	1.6 ±0.2	64.6 ±11.1	197.3 ±28.7	63.0 ±14.6	62.8 ±18.8	291.6 ±66.9	100.0 ±43.6	213.4 ±11.9
February	18.6 ±0.4	520.8 ±128.7	223.5 ±48.4	1252.3 ±313.2	7.8 ±0.4	1.5 ±0.3	65.3 ±15.8	212.1 ±36.2	52.2 ±15.9	57.0 ±13.2	299.6 ±68.3	99.5 ±38.1	207.3 ±17.1
March	21.4 ±0.9	524.5 ±141.6	245.0 ±60.3	1277.5 ±349.2	7.8 ±0.2	1.4 ±0.2	72.4 ±15.6	216.8 ±36.9	43.5 ±14.3	48.5 ±16.1	302.8 ±96.8	99.7 ±38.1	206.5 ±16.3
April	27.9 ±0.5	525.0 ±127.6	258.0 ±54.5	1267.5 ±333.8	7.7 ±0.2	1.1 ±0.3	75.2 ±16.0	227.0 ±47.7	37.4 ±5.7	62.8 ±13.9	301.3 ±73.2	94.8 ±36.3	208.4 ±12.6
May	28.7 ±0.4	532.8 ±126.0	258.0 ±44.4	1261.5 ±277.4	7.6 ±0.4	1.0 ±0.2	83.3 ±11.8	238.1 ±56.4	30.7 ±7.1	46.3 ±20.4	294.7 ±68.1	95.6 ±33.3	210.8 ±17.6
June	29.8 ±0.9	541.0 ±125.2	231.8 ±77.5	1254.0 ±230.4	7.1 ±0.2	0.8 ±0.2	86.9 ±10.3	248.3 ±58.9	25.9 ±8.4	50.0 ±21.6	308.7 ±91.1	88.9 ±40.8	208.6 ±26.7
July	30.2 ±0.2	563.8 ±134.4	217.0 ±50.6	1384.0 ±287.6	6.8 ±0.2	0.8 ±0.1	93.6 ±5.5	271.7 ±42.1	25.8 ±6.2	59.8 ±26.9	312.2 ±108.1	91.9 ±37.7	198.4 ±29.4
August	31.5 ±0.4	568.5 ±131.3	230.3 ±62.3	1397.3 ±266.4	6.8 ±0.1	0.6 ±0.1	98.2 ±6.9	291.9 ±39.9	26.3 ±1.0	45.3 ±30.6	297.9 ±59.4	89.3 ±36.7	195.4 ±39.4
September	27.8 ±1.0	546.3 ±123.9	252.3 ±42.1	1266.0 ±246.6	7.2 ±0.1	0.8 ±0.1	89.7 ±6.5	276.2 ±28.1	33.4 ±3.9	53.2 ±18.5	310.7 ±76.4	108.4 ±49.9	206.8 ±20.7
October	26.4 ±0.3	539.8 ±135.1	245.0 ±47.7	1312.3 ±258.3	7.4 ±0.3	0.9 ±0.2	84.1 ±5.9	270.0 ±29.3	30.0 ±8.0	54.5 ±20.4	295.4 ±59.6	113.2 ±30.8	212.0 ±14.4
November	21.7 ±0.7	546.0 ±108.9	263.8 ±50.9	1294.0 ±240.3	7.5 ±0.3	1.1 ±0.3	79.5 ±4.5	246.5 ±17.5	41.6 ±5.9	63.2 ±18.7	309.1 ±66.5	106.9 ±35.5	202.1 ±25.9
December	17.5 ±0.6	530.3 ±123.5	258.0 ±44.4	1322.5 ±264.6	7.7 ±0.2	1.3 ±0.3	71.3 ±10.1	242.8 ±25.9	40.1 ±8.7	58.8 ±19.3	296.2 ±61.8	107.4 ±35.1	203.4 ±21.8
Average ± SD	24.8 ±4.8	537.9 ±16.4	241.1 ±18.0	1295.7 ±49.7	7.4 ±0.4	1.1 ±0.3	75.6 ±23.2	244.9 ±28.7	37.5 ±11.4	55.2 ±6.5	301.7 ±7.0	99.6 ±8.0	206.1 ±5.4

Parameters	Temp	TDS	Turbidity	EC	pH	DO	BOD	COD	Free CO_2	Acidity	TH	Chloride	Alkalinity
Temp	1.000	0.717	0.068	0.378	-0.791	-0.906	0.763	0.731	-0.894	-0.489	0.402	0.483	-0.319
TDS		1.000	-0.062	0.796	-0.944	-0.901	0.729	0.914	-0.762	-0.289	0.497	-0.261	-0.773
Turbidity			1.000	-0.197	0.261	-0.112	0.387	0.137	-0.248	-0. 039	0.073	0.437	0.042
EC				1.000	-0.698	-0.581	0.447	0.689	-0.488	-0.110	0.103	-0.199	-0.813
pH					1.000	0.909	-0.664	-0.868	0.779	0.315	-0.525	0.383	0.626
DO						1.000	-0.820	-0.937	0.920	0.446	-0.459	0.275	0.526
BOD							1.000	0.795	-0.903	-0.475	0.531	-0.154	-0.555
COD								1.000	-0.833	-0.359	0.383	-0.009	-0.588
Free CO_2									1.000	0.500	-0.420	0.279	0.419
Acidity										1.000	0.095	0.323	0.106
TH											1.000	-0.139	-0.429
Chloride												1.000	0.322
Alkaklinity													1.000

Table 6- Showing average variation in Physico-chemical parameters in 2013

BOD is the measure of degradable organic matter present in a watersample and it can be defined as the amount of oxygen required by micro-organisms in stabilizing the biodegradable organic matter under aerobic condition. The aim of BOD test is to determine the amount of biochemically oxidisable carbonaceous matter. During the study period minimum BOD was found 44.3 mg/l while the maximum BOD was found 105.4 mg/l (Table 1, 2, 3 and 4). The average values of BOD at site 1, site 2, site 3 and site 4 are respectively 70.4 mg/l ±19.2, 81.0 mg/l ±6.9, 78.6 mg/l ±10.4 and 91.3 mg/l ±9.0 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of BOD was observed in the month of January (64.6 mg/l ±11.1) while the maximum value was found in the month of August (98.2 mg/l ±6.9) and the overall average value was found 75.6 mg/l ±23.2 (Table-5). A strong negative correlation was found between BOD and free CO_2 (-0.903) while moderate positive correlation was found between BOD and Total Hardness (0.531) (Table-6). Bhardwaj (2014) reported the high BOD value of the sewage along Hindon River Ghaziabad which falls in the Hindon River resulting in high BOD value of Hindon River water. COD is the amount of oxygen consumed during the chemical oxidation of organic matter. Chemical oxygen demand (COD) gives us a reliable parameter for judging the extent of pollution in water. During the study period minimum COD was found 160.5 mg/l while the maximum COD was found 320.4 mg/l (Table 1, 2, 3 and 4). The average values of COD at site 1, site 2, site 3 and site 4 are respectively 225.9 mg/l ±55.7, 252.3 mg/l ±29.6, 218.3 mg/l ±19.9 and 282.9 mg/l ±33.6 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of COD was observed in the month of January (197.3 mg/l ±28.7) while the maximum value was found in the month of August (291.9 mg/l ±39.9) and the overall average value was found 244.9 mg/l ±28.7 (Table-5). Bhardwaj (2014) reported the high COD value of the sewage along Hindon River Ghaziabad which falls in the Hindon River resulting in high COD value of Hindon River water. More or less similar range of COD was observed by Sharma *et al.,* (2014) in Hindon River. Free CO_2 is present in water in the form of a dissolved gas. Carbon dioxide is highly soluble in water. Corrosion is the principal effect of dissolved carbon dioxide. Carbon dioxide corrosion is frequently encountered in condensate systems and less commonly in water distribution systems. During the study period minimum free CO_2 was found 19.7 mg/l while the maximum free CO_2 was found 78 mg/l (Table 1, 2, 3 and 4). The average values of free CO_2 at site 1, site 2, site 3 and site 4 48.2 mg/l ±15.3, 30.1 mg/l ±6.4, 37.6 mg/l ±13.1 and 34.0 mg/l ±13.0 respectively. The minimum monthly average value of free CO_2 was observed in the month of July (25.8 mg/l ±6.2) while the maximum value was found in the month of January (63.0 mg/l ±14.6) and the overall average value was found 37.5 mg/l ±11.4 (Table-5). Free $CO_2$was found moderately positively correlated with acidity (0.500) and a moderate negative correlation was observed between free CO_2 and total hardness (-0.420) (Table-6). Acidity is produced by substances that yield hydrogen ions on hydrolysis. The definition for acidity is the reciprocal of that used for alkalinity with the substitution of the word hydrogen for hydroxyl. In other words, a substance is acidic if it will neutralize hydroxyl ions . During the study period minimum acidity was found 21 mg/l while the maximum acidity was found 90 mg/l (Table 1, 2, 3 and 4). The average values of acidity at site 1, site 2, site 3 and site 4 78.3 mg/l ±6.6, 32.3 mg/l ±7.4, 52.1 mg/l ±12.1 and 58.0 mg/l ±11.1 respectively. The minimum monthly average value of Acidity was observed in the month of August (45.3 mg/l ±30.6) while the maximum value was found in the month of November (63.2 mg/l ±18.7) and the overall average value was found 55.2 mg/l ±6.5 (Table-5). A slightly positive correlation was found between acidity and total hardness (0.095) (Table-6). Hardness value of water gives us a general idea of how easy water can form suds with soap, scale formation in water pipes or boilers. Cations of calcium, magnesium, iron and manganese contribute to the Total Hardness (TH) of water. During the study period the TH ranges from 170.8 mg/l to 431.5 mg/l (Table 1, 2, 3 and 4). The average values of TH at site 1, site 2, site 3 and site 4 are respectively 203.2 mg/l ±14.9, 380.9 mg/l ±30.6, 304.9 mg/l ±10.8 and 317.8 mg/l ±13.8 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of Total Hardness (TH) was observed in the month of January (291.6 mg/l ±66.9) while the maximum value was found in the month of July (312.2 mg/l ±108.1) and the overall average value was found 301.7 mg/l ±7.0 (Table-5).

A similar trend has been found by Khanna *et al.,* (2010) in the River Tons in Uttarakhand, Bhutiani *et al.,* (2016), Neelim and Jyoti (2013) in Hindon River and Bhutiani and Khanna,(2007). The origin of chloride is mostly from weathering of rocks but pollution can contribute locally. As chlorine is the main source of chloride, so by measuring the chloride one can easily identify he pollute water (Mishra *et al.,* 2009). During the study period the chloride ranged from 29.8 mg/l to 154.2 mg/l (Table 1, 2, 3 and 4). The average values of chloride at site 1, site 2, site 3 and site 4 were found 45.9 mg/l ±14.3, 118.7 mg/l ±10.1, 105.5 mg/l ±8.2 and 128.4 mg/l ±15.5 respectively. The minimum monthly average value of Chloride was observed in the month of June (88.9 mg/l ±40.8) while the maximum value was found in the month of October (113.2 mg/l ±30.8) and the overall average value was found 99.6 mg/l ±8.0 (Table-5). A more or less similar trend of chloride was observed by Rizvi *et.al.,* (2015) and by Pratap and Kumar, (2016) in Hindon River. Alkalinity of water is its capacity to neutralize a strong acid and is characterized by presence of all hydroxyl ions capable of combining with hydrogen ions (Koshy and Nayar, 2000). Determination of alkalinity is useful in understanding about parameter such as pH and hardness of water. It is useful in assessing the water used for irrigation and portability of drinking water. It can also be helping in understanding the water quality from pollution perspective. During the study period the alkalinity ranges from 147 mg/l to 239.8 mg/l (Table 1, 2, 3 and 4). The average values of alkalinity at site 1, site 2, site 3 and site 4 are respectively 189.3 mg/l ±19.3, 195.9 mg/l ±9.4, 206.9 mg/l ±11.2 and 232.1 mg/l ±5.8 (Respectively in Table 1, 2, 3 and 4). The minimum monthly average value of alkalininty was observed in the month of August (195.4 mg/l ±39.4) while the maximum value was found in the month of January (213.4 mg/l ±11.9) and the overall average value was found 206.1 mg/l ±5.4 (Table-5). Bhardwaj (2014) reported the high alkalinity value of the sewage along Hindon River Ghaziabad which falls in the Hindon River resulting in high alkalinity value of Hindon River water. More or less similar trend has been found by Khanna *et al.,* (2010) in the River Tons in Uttarakhand, Gangwar *et al.,* (2012) in River Ramganga Bareilly and Neelim and Jyoti (2013) in Hindon River.

Conclusion

The river water is sluggish during the study period except during the high flow period or in monsoon session. It is evident that during a high flow period, there is no significant effect of pollution owing to a very high dilution of the effluent, but once the flow decreases, there is visible sign of pollution, specifically during summer months although in the study stretch due to continuous merging of industrial effluent and sewage of the cities, the flow and volume of water, the river water parameter remains more or less same throughout the study period. Hence the pollution load generated from Ghaziabad city and Noida city and industrial effluents of this region is mainly responsible for the water quality degradation in the study stretch of the Hindon River that is Ghaziabad city and Noida city. Almost all of the constituents follow the same time patterns except DO, which shows a reverse pattern. This seasonal variation reflects that river water composition is influenced by annual cycles with biological and geological breakdown in the summer season which leads to the accumulation of chemicals during dry session, followed by dilution of those chemicals by monsoonal rainfall.

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