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Full Length Research Paper

Limnochemical characteristics of river Yamuna in Yamunanagar, Haryana, India

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The present paper deals with the monthly variations of limnochemical characteristics of river Yamuna, Yamunanagar which is polluted with industrial effluents and domestic sewage via, maskara nala. Three sampling points that is, Station-Y1: Upstream of the river; Station-Y2: Point of influx of industrial effluents and domestic sewage; Station-Y3: About 5 km downstream from station Y2 were selected for the investigation. Studies revealed high values of conductivity, free CO_2, Biochemical oxygen demand (BOD), Chemical Oxygen Demand (COD), total alkalinity, calcium, hardness, chloride, nitrite and nitrate whereas, low values of Dissolved Oxygen (DO) at the point of getting effluent samples. The differences in various parameters were statistically significant ($P<0.05$) when compared from upstream and downstream stretches of the river. DO, BOD and COD were found to be important parameters which showed strong correlation with other parameters and hence can serve as good indices of river water quality. Water quality may be designated as 'medium' according to Brian Oram's water quality Index and 'severely polluted' according to Kaur's water quality index at station Y2.

Key words: Water quality index, Yamuna River, limnochemical characteristics, industrial effluent, sewage.

INTRODUCTION

Rivers have always been the most important fresh water resources, and most developmental activities are still dependent upon them. Rivers play a major role in assimilating or carrying industrial and municipal waste water, manure discharge and runoff water from agriculture fields, road ways and streets which are responsible for river pollution (Ward and Elliot, 1995). Host of workers have contributed to our knowledge of riverine pollution, notable studies are on Scotland's rivers (Benzie et al., 1999); St. Clair river, Canada (Griffiths et al., 1991); Chinese rivers (Zhang et al., 1995); Orogodo river, Agbor Nigeria (Rim-Rukeh et al., 2006); Huangpu river, China (Yang et al., 2007), Sava river, Slovenia (Toman, 2009), Indian rivers such as river Chambal (Kulshrestha et al., 1991), river Ghaggar (Bhatnagar and Garg, 1998), basins Kothaiyar and Pazhayar in Kanyakumari district (Raj and Jayasekher, 2007), river Kosi (Bhandari and Nayal, 2008), river Hindon (Dalal and Arora, 2008; Suthar et al., 2010), river Godawari (Deshmukh and Sonawane, 2008), river Damodar (Singh et al., 2009),river Yamuna (Kaushik et al., 2001; Khaiwal et al., 2003; Bhatnagar et al., 2009) and river Karmana (Sujitha et al., 2011).

According to Kaushik et al. (2009), in India, it is important to systematically study the status of pollution of the rivers in relation to various anthropogenic activities as river water has been used as drinking water, for agriculture and for fish culture throughout the history of mankind. The Yamuna is one of the most important rivers of the Indogangetic plains in India and outnumbers any other river in the number of industries on its bank. The industrial belt of Haryana state in India is mainly situated along the north-eastern part of the state along the river Yamuna. The waste from these industries, agricultural runoff and the drains carrying municipal sewage of the cities enter into the river and affect its water quality. Yamunanagar, one of the major industrial cities of Haryana, receives effluents from sugar mills from the district of Saharanpur through 'Maskara nala'. Therefore, this present study has been undertaken to evaluate the

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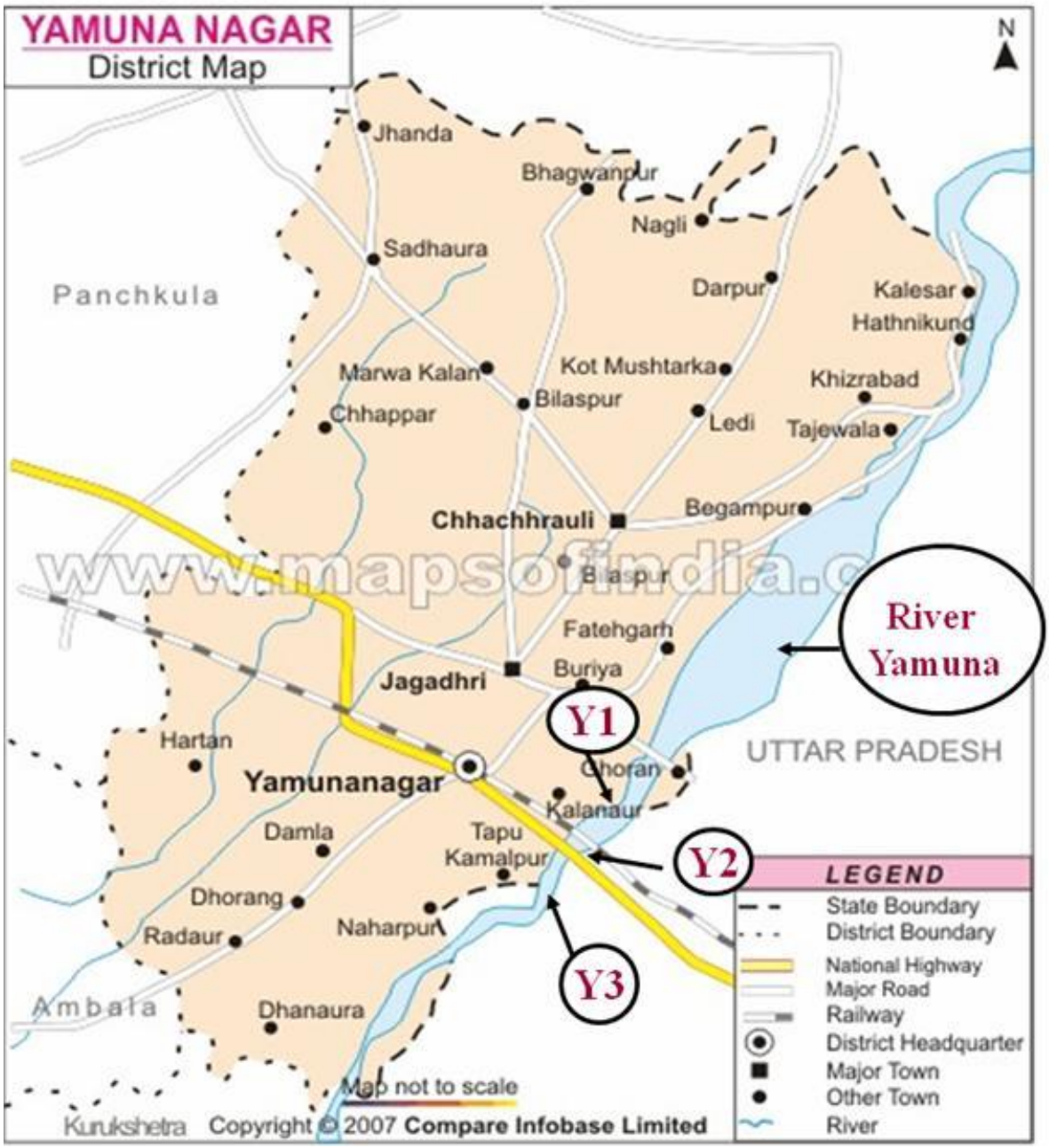

Figure 1. Map of Yamunanagar showing selected stations on river Yamuna.

water quality of river Yamuna in Yamunanagar in terms of limnochemical characteristics and water quality indices. The results obtained are useful to the authorities and the other stakeholders.

MATERIALS AND METHODS

As noticed in Figure 1, taking into cognizance the points of discharges into the river, three stations Y1, Y2 and Y3 were selected. Station-1 (Y1) lies in village Kalanaur, upstream of the river before the influx of discharges. Station-2 (Y2) lies 4 to 5 km downstream from station Y1 at middle reach of the river where the mill effluents joins the river. Station-3 (Y3) at 5 km downstream from station-2 after the influx of discharges (Figure 1). Water samples were collected monthly from August 2008- July 2009 in three replicates from all the sampling stations.

Limnochemical characteristics

Surface water samples were collected monthly from August, 2008 to July, 2009 from river Yamuna, from all the selected three stations, in triplicate, in polythene bottles. The limnochemical characteristics, viz., temperature, dissolved oxygen, free CO_2 and

and alkalinity were analyzed at the site itself as their values are liable to change soon, whereas, other parameters were analyzed in the laboratory according to standard procedures (Golterman et al., 1978; APHA, 1998) within the following 3 to 4 days, during which samples were kept in cold storage. Dissolved oxygen, pH, conductivity were analyzed using MultiSet F Line three Water analysis kit (E Merck). Free CO_2, alkalinity, chlorides, hardness, calcium, magnesium were anlysed by titrimitric method. BOD was determined following dilution and incubation method (APHA, 1998). COD was analyzed by reflux method and ammonia, nitrite, nitrate and orthophosphate were determined spectrophotometerically (APHA, 1998).

Water quality index calculation

Water quality index, a measure of overall water quality, was calculated by using Brian Oram's on line calculator (Oram, 2007) (WQI A) and Horton Water Quality Index (Horton, 1965) modified by (Kaur et al., 2001) (WQI B). Kaur's water quality index calculation was based on the weightage of the individual parameters and its rating scale.

Statistical analysis

The coefficient of correlation was calculated using SPSS packages.

RESULTS

Monthly and stational variations in different limnochemical characteristics are shown in Figures 2 and 3. Table 1 depicts the mean values of the water quality characteristics at different stations. The values of DO and pH decreased significantly from station Y1 to Y2. DO showed significant ($P<0.05$) negative correlation with free CO_2 ($r = -0.521$) and positive with alkalinity ($r = 0.529$). The values of BOD during present investigation ranged from 4.2 to 8.2 mg L^{-1}. BOD values showed a sharp and significant ($P<0.05$) increase at station Y2 and thereafter the values significantly decreased at Y3. BOD showed a statistically significant positive correlation (Table 2) with COD ($r = 0.499$).

The mean value of COD was recorded maximum at station Y2 (282 mg L^{-1}). Conductivity, free CO2, BOD, COD, total alkalinity, hardness, calcium, chloride, significantly ($P<0.05$) increased from station Y1 to Y2 and then decreased at Y3. Amongst nutrients the values of orthophosphate ranged between 0.1 mg L^{-1} to 0.2 mg L^{-1} at station Y1, 0.1 mg L^{-1} to 0.3 mg L^{-1} at station Y2 and 0.1 mg L^{-1} to 0.4 mg L^{-1} at station Y3. The mean values of orthophosphate showed an increasing trend from station Y1 (0.1±0 mg L^{-1}) to Y2 (0.2±0 mg L^{-1}) and Y3 (0.2±0 mg L^{-1}). The mean values of nitrite increased from station Y1 (0.2±0.1 mg L^{-1}) to Y2 (0.4±0.1 mg L^{-1}) and then further decrease from station Y2 to Y3 (0.3±0.1 mg L^{-1}). No significant variations were observed in the values of ammonia from station Y1 and Y2; however the values decreased at station Y3. The values of nitrate ranged between 0.1 mg L^{-1} to 0.7 mg L^{-1} at station Y1, 0.2 mg L^{-1} to 0.9 mg L^{-1} at station Y2 and 0.1 mg L^{-1} to 1.9 mg L^{-1} at station Y3. The mean values showed a gradual and significant ($P<0.05$) increase from station Y1 (0.3±0.1 mg L^{-1}) to Y3 (0.5±0.1 mg L^{-1}). No significant variations were observed in the values of ammonia from station Y1 and Y2, however, the values decreased at station Y3 Water quality may be designated as 'bad' according to Brian Oram's water quality Index and 'severely polluted' according to Kaur's water quality index at station Y2.

DISCUSSION

Conductivity, free CO2, BOD, COD, total alkalinity, hardness, calcium, chloride, nitrite and nitrate significantly ($P<0.05$) increased whereas the values of DO, pH and values of water quality index decreased significantly from station Y1 to Y2 (where the mill effluents joins the river) depicting that introduction of industrial waste and domestic sewage has changed the overall condition of the river's water.

DO in water is usually depleted, if high amount of organic matter undergoing biological degradation is present (Rim-Rukeh, 2006). The mean concentration of DO in the Yamuna river was below 5.0 mg L^{-1} at all the stations and, therefore, the river water appeared to be less conducive for aquatic organisms. ICMR guidelines also recommend DO >5.0 mg L^{-1}. Increase in BOD at Y2 may be attributed to influx of pollutants and decrease at Y3 may be the result of self purification process of the river. There occurs a natural process of self purification which extends over several kilometers of a river (Hawkes, 1978). This results in a regeneration of polluted river back into this normal original state. Maximum permissible limit for the discharge of effluent for BOD is 30 mg L^{-1} (Polestya et al., 2008). However, the BOD was higher at station Y2 and Y3 when compared with ICMR (1975) standards (<5 mg L^{-1}). BOD and COD are important index of organic pollution in the river. The values of these two parameters significantly ($P<0.05$) increased with influx of pollutants at station Y2. Statistically also COD showed a significant positive correlation with BOD ($r = 0.499$, $P<0.05$).

pH was alkaline through out the study period. The values were significantly ($P<0.05$) high at station Y1 and decreased at station Y2. The lowering of pH at station Y2 seems to be due to input of wastes (Bhatnagar and Sanghwan, 2009). At this station, pH was low but alkalinity was higher.

The high value of free carbon-dioxide at Y2 may be associated with low DO at this station. Statistically, free CO2 showed a significant negative correlation with DO ($r = -0.521$) $P<0.05$). In the present study, it has been observed that amount of total hardness was high during rainy season than during summer season, confirming that the rain water brings more amounts of Ca and Mg (Devis and DeDewiest, 1996; and Mathivanan et al., 2008). Nitrate, the most highly oxidized form of nitrogen compounds is commonly present in surface waters

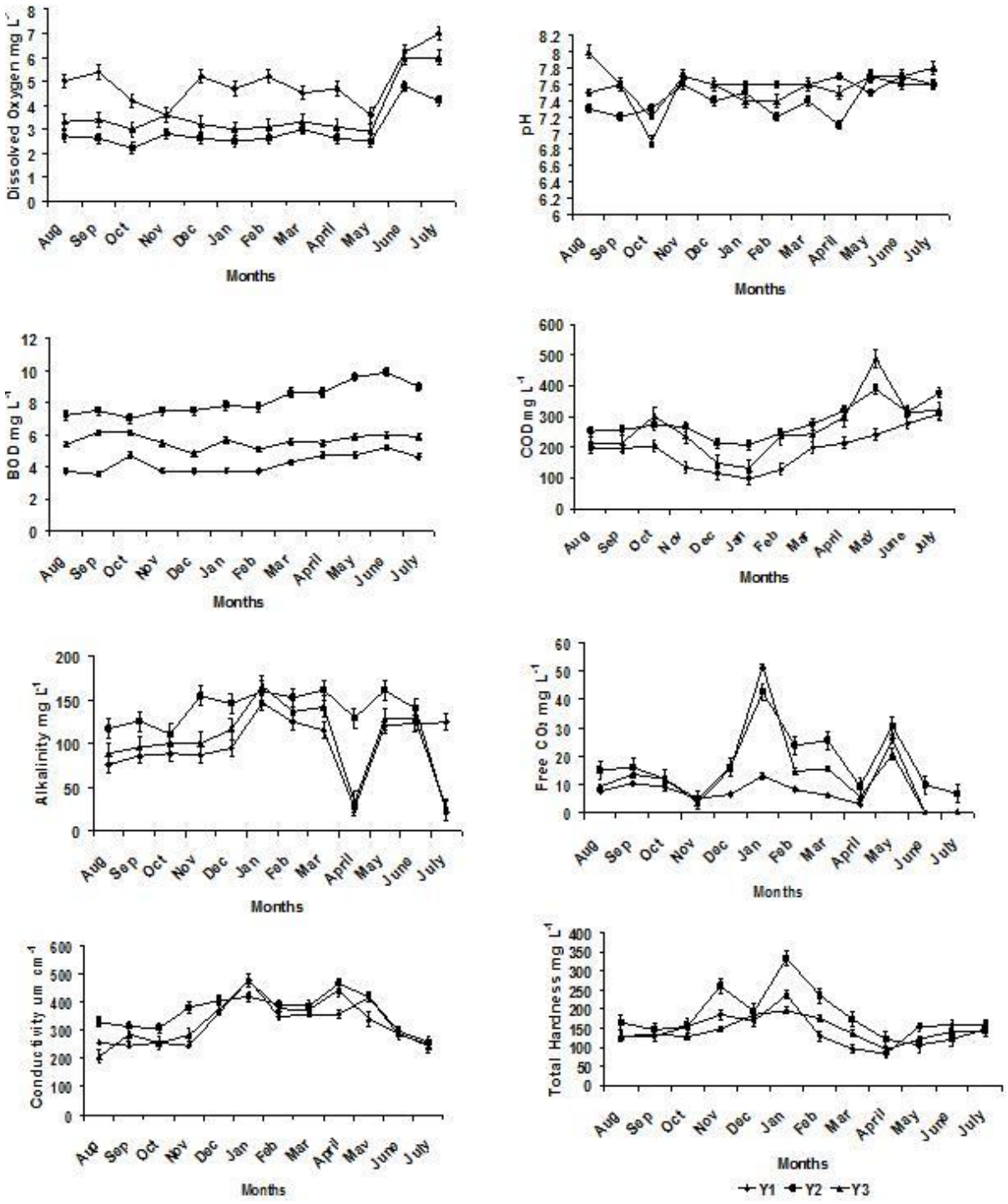

Figure 2. Monthly variations in DO, pH, BOD, COD, alkalinity, free CO_2, conductivity and total hardness on various stations.

because it is the end product of aerobic decomposition of organic nitrogenous matter (Polestya et al., 2008). The values of nitrate were in the range of 0.2 to 0.4 mg L^{-1}. Kaur et al. (1997) also measured nitrate in the same range, supporting the present results. Nitrite was observed in the range of 0.3 to 0.5 mg L^{-1}. A similar trend in nitrite-nitrogen was observed by Jaji et al. (2007) in Ogun River, Nigeria.

A comparison of the mean values of analyzed physico-chemical conditions with drinking water standards of

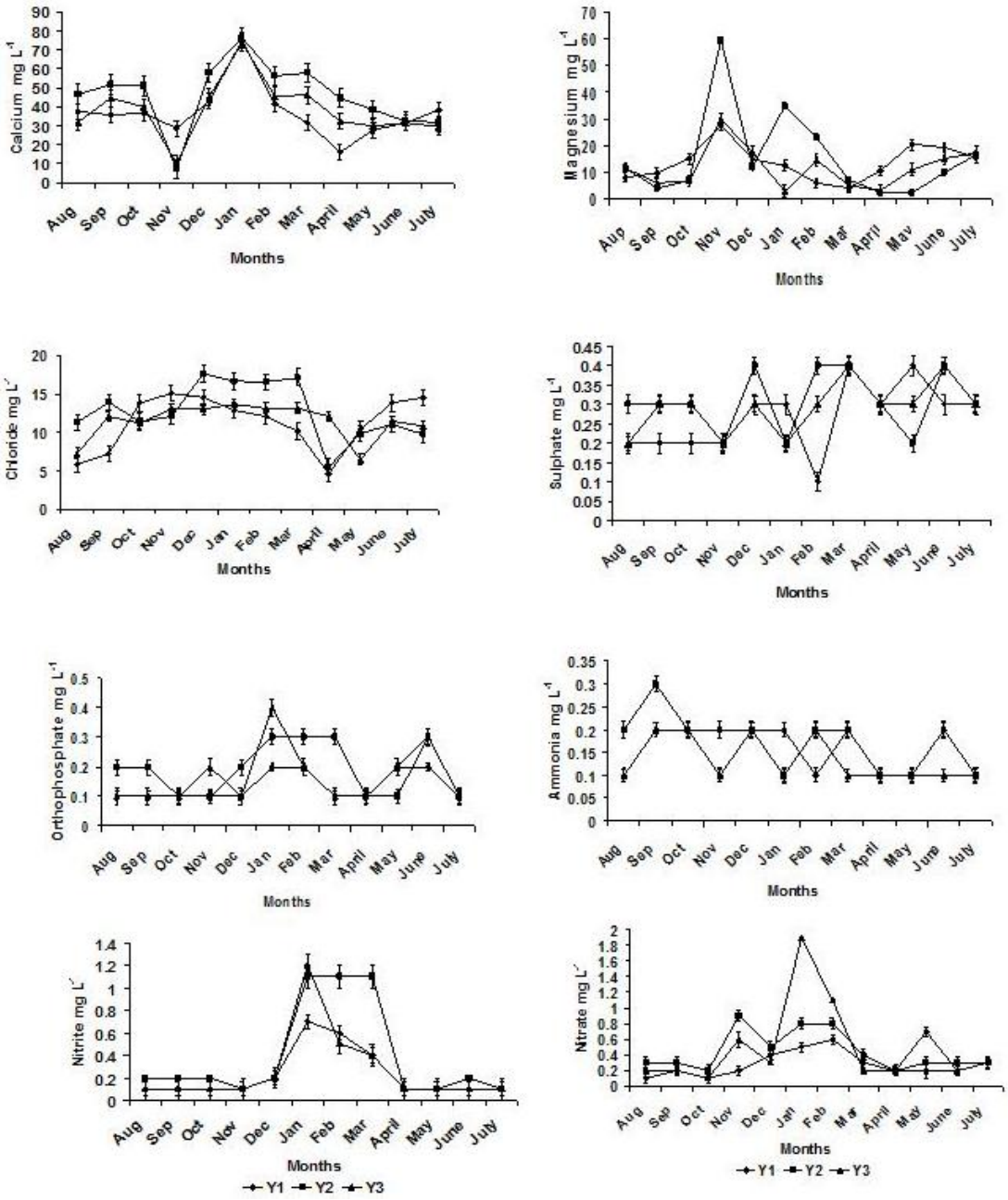

Figure 3. Monthly variations in Calcium, magnesium, chloride, sulphate orthophosphate, ammonia, nitrite and nitrate on various stations.

ICMR (1975), WHO (1984, 1993) reveal that DO is low in the present studies whereas BOD, COD, calcium and hardness are high. The values of other parameters are within permissible limits. It is necessary to treat the water of river Yamuna and to establish efficient treatment plants by the effluents generating industries for maintaining the important parameters within the permissible limit prescribed by world health organization/Indian council ofmedical Research.

To communicate the information on water quality depicting the overall quality of water at all the selected stations of river Yamuna, the mathematical values in terms of water quality index (WQI) according to Brian Oram's (on line calculator), Horton (1965) and Kaur et al. (2001) was calculated. According to Oram's water quality index (Oram, 2007) water quality legend (WQI A) in the range of 90-100 indicate excellent quality, 70-90 good, 50-70 medium, 25-50 bad and 0-25 very bad. It was found that the water was considered of 'medium quality' according to Brian Oram's water quality index at

Table 1. Mean values of water quality characteristics of river Yamuna on various stations

Water quality characteristics	Y1	Y2	Y3	ICMR, 1975 Standard	WHO(1984,1993) Standard for drinking Water
Temperature ºC	22.7±0.9^{A}	23.3±0.9^{A}	22.7±0.9^{A}	-	-
pH	7.6±0^{A}	7.4±0.1^{B}	7.6±0.1^{A}	<7.0-8.5	6.5-8.5
Conductivity µm cm $^{-1}$	320 ±21.1^{B}	363±17^{A}	328±22.5^{B}	-	0-300
Turbidity NTU	6±1.7^{A}	5.6±1.5^{A}	4.6±1.5^{A}	>5	5-10
Free CO_2 mg L^{-1}	9.6±1.9^{C}	17.8±3.0^{A}	16.3±4.0^{B}	-	
DO mg L^{-1}	4.9±0.3^{A}	2.9±0.2^{B}	3.7±0.3^{B}	>5	
BOD mg L^{-1}	4.2±0.2^{C}	8.2±0.3^{A}	5.6±0.1^{B}	<5	<6.0
COD mg L^{-1}	192±17.7^{B}	282±15.8^{A}	262±25.6^{A}	<120	<10.0
Total Alkalinity mg L^{-1}	100±8.6^{B}	131±10.5^{A}	104±11.4^{B}	600	13-246
Total Hardness mg L^{-1}	148±11.2^{B}	179±18.3^{A}	144±7.9^{B}	<75	300-600
Calcium mg L^{-1}	37.1±3.8^{B}	46.1±4.8^{A}	38.5±4.1^{B}	<50	28-48
Magnesium mg L^{-1}	13.6±1.8^{A}	15.8±4.5^{A}	11.7±2.1^{A}	<200	9.23-26.24
Sulphate mg L^{-1}	0.3±0^{AB}	0.3±0^{A}	0.3±0^{B}	<250	50-91
Chloride mg L^{-1}	11.3±1.0^{B}	12.8±1.0^{A}	11.5±0.6^{B}	-	7-26
Orthophosphate mg L^{-1}	0.1±0^{B}	0.2±0^{A}	0.2±0^{B}	-	
Ammonia mg L^{-1}	0.2±0^{B}	0.2±0^{A}	0.1±0^{B}	-	
Nitrite mg L^{-1}	0.2±0.1^{B}	0.4±0.1^{A}	0.3±0.1^{B}	-	
Nitrate mg L^{-1}	0.3±0.1^{B}	0.4±0.1^{A}	0.5±0.1^{A}	-	0-1.77
WQI A	60±0.50^{A}	56±0.50^{B}	58±0.52^{A}	-	
WQI B	67.4±2.8^{A}	39.9±4.3^{B}	47.5±3.0^{B}	-	

Means with different letters in the same row are significantly (P<0.05) different. (Data were analyzed by Duncan's multiple range tests).

Table 2. Coefficient of correlation between various limnochemical characteristics of river Yamuna.

	pH	Conductivity	DO	BOD	COD	Free CO_2	Alkalinity	Calcium	Hardness	Magnesium	Turbidity	Chloride	Ammonia	Sulphate	O-PO_4	Nitrite	Nitrate
Temp	0.105	-0.514	0.363	0.101	0.519	-0.247	-0.222	-0.406	-0.376	-0.069	0.385	-0.354	-0.182	-0.006	-0.080	-0.559	-0.428
pH	-	-0.194	0.394	-0.348	-0.09	-0.257	0.236	-0.381	-0.135	0.144	-0.085	-0.200	-0.307	-0.080	-0.118	-0.222	-0.092
Conductivity	-	-	-0.492	0.250	0.012	0.554	0.486	0.469	0.309	-0.043	-0.487	0.190	0.020	0.148	0.367	0.485	0.505
DO	-	-	-	-0.278	-0.065	-0.521	-0.529	-0.349	-0.228	0.026	0.048	-0.125	-0.305	0.131	0.273	-0.289	-0.243
BOD	-	-	-	-	0.499	0.362	0.463	0.270	0.280	0.038	-0.043	0.259	0.180	0.092	0.310	0.269	0.104

Table 2. cont.

COD	-	-	-	-	-	-0.011	0.166	-0.231	-0.292	-0.112	-0.018	-0.191	-0.141	0.140	0.052	-0.228	-0.230
Free CO_2	-	-	-	-	-	-	0.558	0.650	0.415	-0.071	-0.067	0.247	0.047	-0.115	0.648	0.666	0.615
Alkalinity	-	-	-	-	-	-	-	0.485	0.483	0.084	-0.186	0.428	0.264	0.103	0.593	0.528	0.469
Calcium	-	-	-	-	-	-	-	-	0.489	-0.269	0.001	0.446	0.278	0.076	0.512	0.704	0.363
Hardness	-	-	-	-	-	-	-	-	-	0.558	-0.138	0.593	0.201	-0.202	0.404	0.558	0.529
Magnesium	-	-	-	-	-	-	-	-	-	-	-0.159	0.218	0.006	-0.260	-0.024	-0.023	0.205
Turbidity	-	-	-	-	-	-	-	-	-	-	-	-0.191	0.198	-0.252	-0.111	-0.226	-0.290
Chloride	-	-	-	-	-	-	-	-	-	-	-	-	0.301	0.107	0.334	0.468	0.340
Ammonia	-	-	-	-	-	-	-	-	-	-	-	-	-	0.131	0.073	0.095	0.028
Sulphate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.113	0.133	-0.156
O-PO_4	-	-	-	-	-	-	-	-	-	-	-	-	-		-	0.642	0.618
Nitrite	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.627
Nitrate	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

the point of influx.

According to Kaur et al. (2001) (WQI B) based on extent of pollution, water has been designated as Absolutely clean when WQI is 100, Slightly to moderately polluted when WQI is between 60-80, Excessively polluted when WQI is between 40-60 and Severely polluted when WQI is between 0-40. Water quality was considered severely polluted according to Kaur's water quality index at station Y2. This may be due to influx of effluents through Maskara nala at this point. Moundiotiya et al. (2004) and Sisodia and Moundiotiya (2006) have also reported excessive pollution in Kalakho Lake and Jamwaramgarh wetland respectively in Rajasthan on the basis of WQI.

Thus, in the present study, the values of WQI indicated that water was being polluted at station Y2.

Conclusion

Study of different limnochemical parameters revealed that the intensity of pollution increased as the river was subjected to sewage and industrial wastes. In the growing awareness of relationships between human health and water pollution, it is essential to undertake regular monitoring and surveillance of such important aquatic ecosystems. In order to manage the pollution load of river Yamuna that pass nearby Yamunanagar, it is recommended that various methods of sewage/industrial wastes treatment should be used before the disposal of effluents.

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