Research Article

Impact of seasonal variation on water quality of Hindon River: physicochemical and biological analysis

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Abstract
Water is the basic necessity for a living being and detritions in the quality of water led to many harmful impacts. It is important to regulate the water quality to maintain the balance in all the variation of lives. In the present study, the water samples were collected during the pre-monsoon and post-monsoon periods of February 2015–January 2017 from Mohan Nagar barrage, Ghaziabad (Uttar Pradesh, India). The assessment of the seasonal variation of water quality and its impact on the Hindon River water was evaluated by physicochemical and biological analysis. Samples were analyzed for twelve physicochemical parameters such as Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Hardness (TH), Nitrate Nitrogen, Phosphates, Sulphates, and Heavy metals (Cadmium (Cd), Lead (Pb) Iron (Fe), Zinc (Zn) and biological parameters such as Total Coliform count (TCC), Fecal Coliform count (FCC) and Standard Plate count (SPC). Besides this, River Metal Pollution Index and Integrated River Metal Pollution Index were also calculated and found above permissible limits (RMPI > 1 and IMPI > 2). The trend of heavy metal load in the Hindon River water was observed to be Fe > Zn > Pb > Cd. Lower recorded values of DO and higher levels of EC, TDS, BOD, COD, TH, Nitrate Nitrogen, and Sulphates indicate high pollution levels in Hindon River water. TCC (MPN/100 ml) in water samples was found 7.4×10^4 in pre-monsoon season and 5.8×10^4 in a post-monsoon season, FCC (MPN/100 ml) were 4.5×10^4 in pre-monsoon and 3.6×10^4 in a post-monsoon season whereas SPC (CFU/ml) were 75×10^4 in pre-monsoon and 62×10^4 in post-monsoon. Analysis of water quality parameters was performed as per Standard Methods (APHA, 1998). The Correlation coefficient matrix has been obtained to validate the interrelationship between different physicochemical parameters. The results of our study show the necessity of regular monitoring of Hindon River water for the integrity of aquatic flora, fauna, and human health.

Keywords Water quality · Hindon River · Physicochemical analysis · Biological analysis · River metal pollution index

1 Introduction

Water is an important and widely distributed resource on earth. It fulfills the various necessities of human civilization, improves climate and landscape quality, supports flora and fauna [1],and is recycled through the hydrological cycle. The major rivers of India are River Ganges (its sub-basin Yamuna), Kaveri, Indus, Brahmaputra, Godavari, Narmadha, Mahanadhi, Krishna, Brahmini, Sabarmati, Pennar, Mahi, and Tapi [2].In the 1970s the wave of industrialization begun and most of the industries were established along the riverbanks and has changed the scenario of India's once placid landscape [3]. Some of the major water quality issues in water bodies include the presence of pathogens (like bacteria, fungi, virus, protozoan, etc.), Organic and Inorganic matter, Suspended solids, Heavy

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metals such as Cadmium, Lead, Mercury, Nickel, Iron, etc. and elements like Fluoride. The possible sources of such contaminants in water bodies are agriculture run-off, domestic and industrial wastewater. By the year 2051, the projected wastewater generation will be 120,000 million liter per day in India [4]. The Union Ministry of Water Resources has estimated an increase in water demand (Billion Cubic Meters- BCMs) from 813 BCMs in 2010–1093 BCMs in 2025 [5].According to the WaterAid India Country Strategy 2016–2021, there are around 76 million peoples in India who don't have access to safe water. The report also mentioned that over140,000 children under 5 years of age die due to diarrhea diseases caused by polluted water [6]. The World Bank estimates that polluted water is responsible for 21% of communicable diseases in India [7]. This situation is getting to be more serious if appropriate measures have not been taken. Therefore, deterioration of water has become a crucial and threatened environmental issue in most countries [8]. Regular monitoring and assessment of the water quality are obligatory for maintaining the integrity of aquatic ecosystems and also for human health [9]. For regular monitoring and assessment, India has a relatively extensive set of environmental policies implemented through the Water (Prevention and Control of Pollution) Act, 1974 and the Air (Prevention and Control of Pollution) Act, 1981.The Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs) ensures enforcement and implementation of these Environmental Laws to improve air and water quality in India [10].

Due to the rising pollution day by day, Hindon River is now gasping for breath. Low levels of Dissolved oxygen have been reported by several workers in different catchment zones of Hindon River. The lack of Dissolved Oxygen primarily affects aquatic andriparian biodiversity [11]. Municipal and industrial (sugar, distilleries, pulp, and paper, etc.) wastes from Saharanpur, Muzaffarnagar, and Ghaziabad urban areas are the main pollution sources of Hindon River. Heavy metals, pesticides, and other pollutants discharged from municipal and industrial effluents and surface runoff or other anthropogenic activities merged into the river system. These pollutants ultimately reach the groundwater and enter into the food chain, and have a negative impact on human health [12].Mohan Nagar area in Ghaziabad district (Uttar Pradesh) has major Industrial setups like Textiles, Distillery, Paper, Glass, Electroplating, Chemicals, Engineering works, etc. This area near Railway Bridge receives sewer drains and industrial effluents from nearby sites [13]. Such industrial units and untreated wastewater discharge progressively transform this site as one of the major hotspots of contaminated water. The Ghaziabad district area near the Hindon River basin experiences a wider range of seasonal temperature variation and receives an increase in runoff during monsoon season. Based on the above observations and available literature, the present study has been designed with the major objective of assessing the impact of seasonal variation on the quality of Hindon River water through Physicochemical, Biological, and RMPI analysis. The study is supported by statistical data analysis and efforts have been made to arrive at some rational interpretations that would be helpful to the concerned stakeholders to develop future follow-up actions to reduce the level of water pollution in the Hindon River basin.

2 Study site

Hindon River (a tributary of Yamuna River) flows through Ghaziabad district at latitude 28° 40′ north and 77° 25′ east [8].The Hindon River is around 350 km long with a catchment area of about 5975 sq. km [14]. The basin area originates from Saharanpur and falls in the districts of Muzaffarnagar, Meerut, Baghpat, Ghaziabad, and Gautambudh Nagar [13] in Western Uttar Pradesh.The Hindon River basin has two major urban settlements, one near the origin of Hindon (Saharanpur) and the other near its confluence with the Yamuna (Ghaziabad)(Fig. 1) [15].The climate ranges from tropical to temperate with temperature variation up to 3 °C in winter and up to 43 °C in summer and mean annual rainfall of 702 mm subjected to spatial variations [8].The minimum mean temperature ranges from 15.50 °C in winters (October 2016–January 2017) to 28.25 °C in summers (June 2016–September 2016) (Fig. 2) [16].The maximum mean temperature ranges from 27.25 °C during winters (October 2015–January 2016) to 37.00 °C in summers (June 2015-September 2015).The highest average rainfall occurs during the month of June–September (monsoon period) (Fig. 3) [16]. The water quality analysis has been performed in two different seasons i.e. during pre-monsoon (February to May) and post-monsoon (October to January) [17]. The rainfall usually starts at the end of June and normally it rains till October [15].

3 Materials and methods

3.1 Sampling and analytical methods

The water samples were collected during the pre-monsoon and post-monsoon periods of February 2015 to January 2017 from Mohan Nagar barrage, Ghaziabad (Fig. 1).The collection of water samples has been made four times during each study season (pre-monsoon and post-monsoon) continuously for two years.Samples were

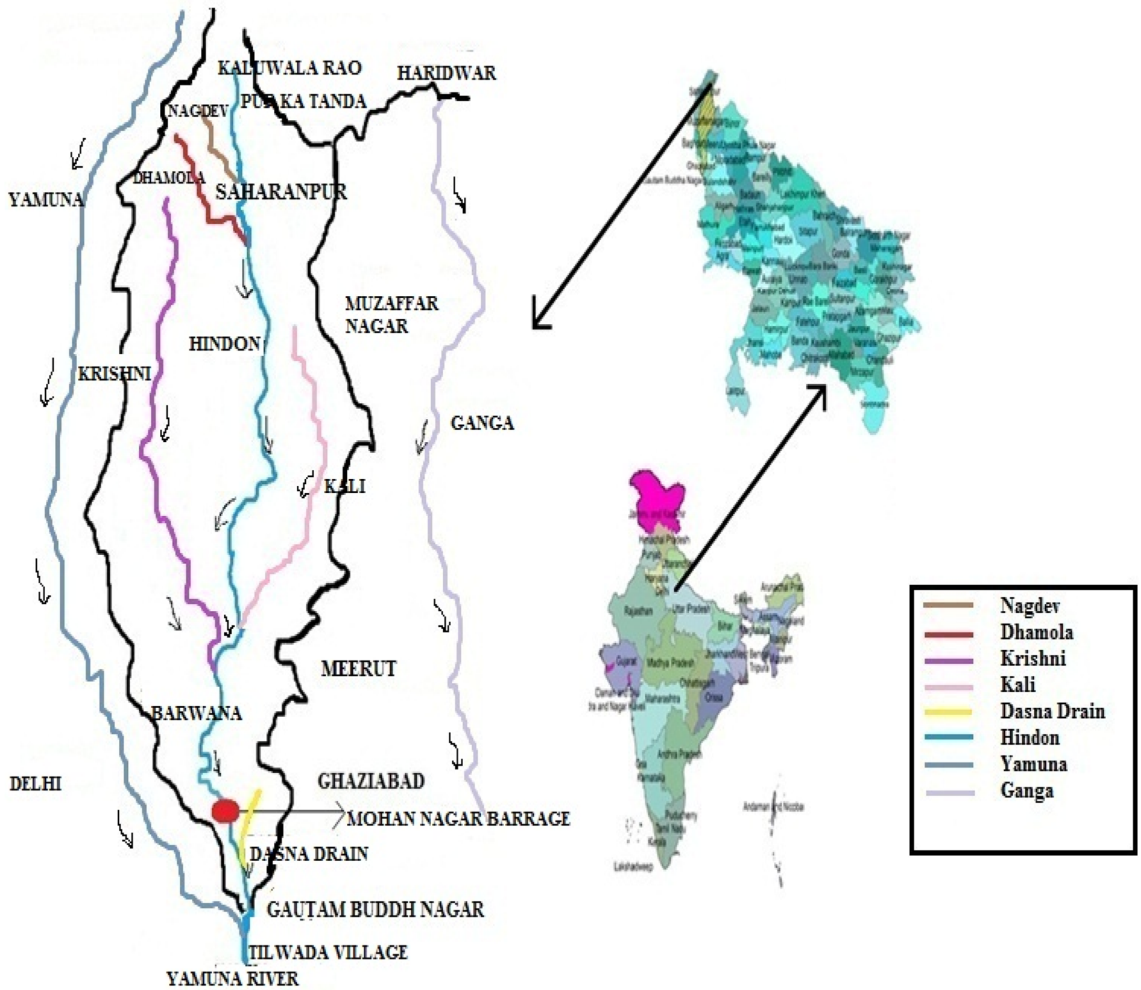

Fig. 1 Hindon River Map showing Study site [12, 18]

collected at 15 cm water depth to avoid impurities and stored in polyethylene bottles fitted with screw caps. Samples taken were preserved by adding an appropriate reagent and brought to the laboratory in sampling kits maintained at 4 °C for detailed physicochemicalanalysis. For microbiological analysis, samples were immediately placed in a lightproof insulated box containing ice-packs to ensure rapid cooling [19].On spot analyses of water samples have been performed for Temperature, EC, pH, and TDS. Temperature (°C) and EC (µS/cm) was measured using Conductivity meter, while pH and TDS (mg/liter) was measured using digital pH and TDS meter respectively. Other selected physicochemical parameters such as DO, BOD, COD, Turbidity, TH, Nitrate Nitrogen, Phosphates, and Sulphates were measured by following standards method of water and wastewater analysis [20]. Heavy metals analysis (Fe, Zn, Cd, and Pb) wasperformed using atomic absorption spectrophotometer (ECIL, India) following the acid digestion method as described by APHA [20]. The biological analysis includes Total coliform count, fecal coliform count, and Standard plate count [20].

3.2 Reagents and standards

All the reagents and standards used throughout the study were of analytical grades. Double distilled water has been used for the preparation of standards and stock solutions for analysis. All the glassware used was pretreated with dilute Nitric acid followed by multiple washing with distilled water to remove surface impurities. All the analysis was carried out in triplicates and the mean was calculated. The Correlation coefficient matrix was calculated for different physicochemical parameters using Microsoft Office Excel 2007.

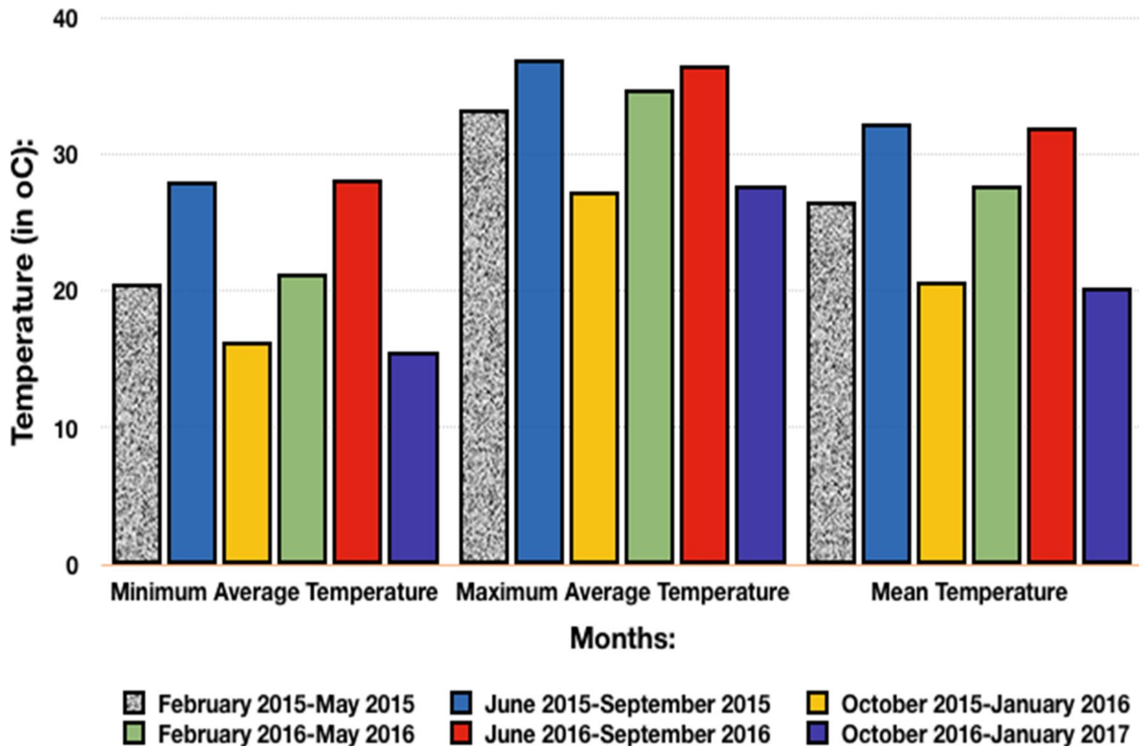

Fig. 2 Variation in air temperature in Ghaziabad district during the study period [16]

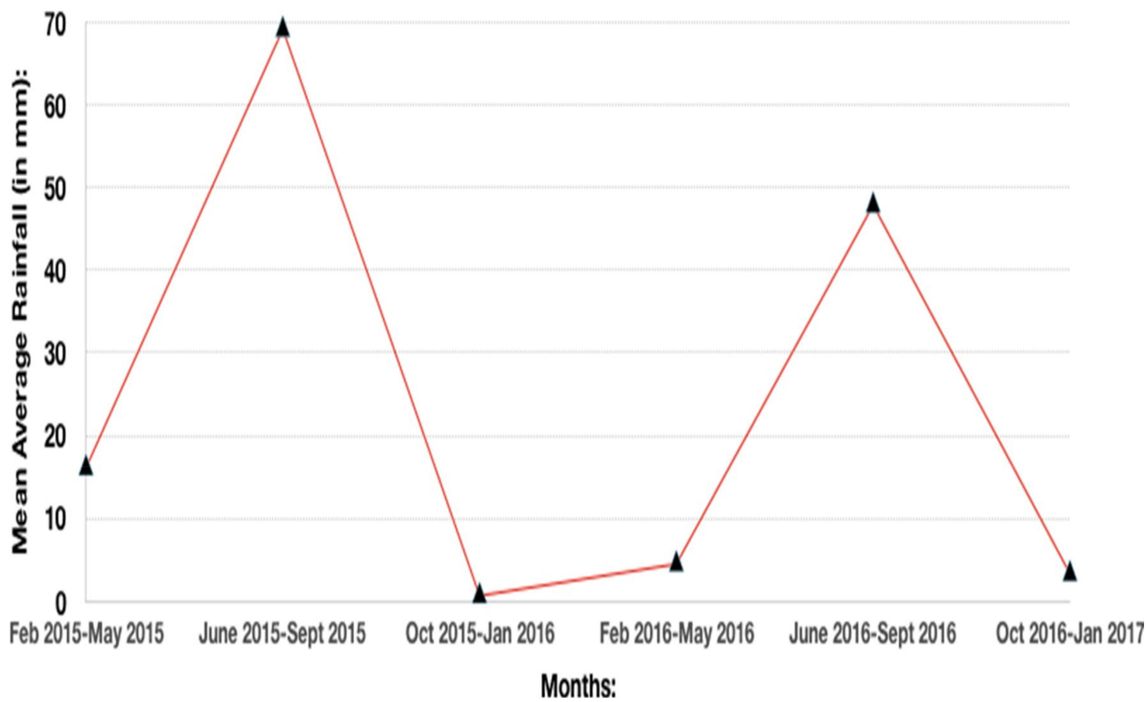

Fig. 3 Variation in Average Rainfall pattern in Ghaziabad district during the study period [15]

3.3 River metal pollution index (RMPI)

River Metal Pollution Index is applied to different metals present in water-bodies. RMPI facilitates the depiction of water quality [21] for metal concentrations. Metal Index or River Metal Pollution Index was calculated as per the following equation [21. 22].

$$\text{RMPI} = Crmc/Csmc$$

Here *Crmc* is the measured metal concentration (mg/L) in river water. *Csmc* is the standard metal concentration (mg/L) in surface water.

The standard permissible limits considered for calculating RMPI values will be taken from BIS (0.01 mg/L for Cd, 5.00 mg/L for Zn, 0.30 mg/L for Fe and 0.01 mg/L for Pb) [23].The River is considered as polluted if RMPI is greater than one.The mean values for all the RMPI of all considered metals isdefined as Integrated Metal Pollution Index (IMPI) [21] and calculated by the formula below:

$$\text{IMPI} = \Sigma\text{RMPI}/\text{n}$$

where 'n' is the number of metals considered.

The River water at the study site is classified as low contaminated if the $\text{IMPI} \le 1.0$, moderately contaminated if ranges between $1.0 < \text{IMPI} \le 2.0$, or highly contaminated when $\text{IMPI} > 2.0$ [24].

4 Results and discussion

4.1 Physicochemical characteristics of Hindon River

The quality of water is a reflection of physicochemical characteristics. It is necessary to study the physicochemical characteristics of water for the planning of water conservation and the management of basic human needs. The water temperature of the Hindon River varies between 15.5 °C and 39 °C in pre-monsoon and 7.5 °C to 19 °C during post-monsoon seasons. Temperature shows a strong positive correlation with pH, TDS, BOD, COD, TH, Nitrate Nitrogen, and Phosphates in the pre-monsoon season ($R^2 > 0.91$) (Table 1) and with EC, Turbidity, DO, and Phosphates in the post-monsoon season ($R^2 > 0.93$) (Table 2). The obtained value of pH ranges between 6.8 to 7.8 in the pre-monsoon and 7.2 to 8.2 in the post-monsoon season. Chabukdhara et al. [21] recorded pH values of Hindon River water (Ghaziabad) 6.80–7.85 and 7.25–8.55 during pre- and post-monsoon seasons respectively. Thus pH of Hindon River water (Ghaziabad) falls into an alkaline range during the post-monsoon season. pH in the present study shows a strong positive correlation with TDS, BOD, COD, TH, Nitrate Nitrogen, and Phosphates during pre-monsoon and with BOD, TH, Nitrate Nitrogen, TDS, and Sulphates in the post-monsoon season. EC is a determinant of ecosystem pollution in water bodies [25].It ranges between 836 - 845 µS/cm in pre-monsoon and 792–802 µS/cm in the post-monsoon season. EC has a strong positive correlation ($R^2 > 0.93$) with Turbidity, DO, and Phosphate in the post-monsoon season. Turbidity ranges from 141 to 148 NTU in pre-monsoon and 110–120 NTU in post-monsoon season (Fig. 4) and has a strong positive correlation with DO and Phosphates in the post-monsoon season. This could be due to various environmental and geographical conditions such as sampling sites, study period, prevailing climatic conditions, spatial variations, etc. Bhutiani et al. [26] recorded comparatively higher levels of EC (µS/cm) and Turbidity (NTU). The TDS values in the present study ranged from 235 to 677.80 mg/L in the pre-monsoon and 215–677.82 mg/L in the post-monsoon season. TDS has

Table 1 Correlation coefficient matrix of physicochemical parameters in Pre-monsoon season

Parameters	Temp	pH	EC	Turbidity	TDS	DO	BOD	COD	TH	Nitrate Nitrogen	Phosphates	Sulphates
Temp	1.00											
pH	**0.91**	1.00										
EC	−0.88	−1.00	1.00									
Turbidity	0.59	0.21	−0.13	1.00								
TDS	**0.98**	**0.98**	−0.95	0.42	1.00							
DO	−0.88	−0.62	0.55	−0.90	−0.77	1.00						
BOD	**0.99**	**0.95**	−0.92	0.50	**1.00**	−0.83	1.00					
COD	**0.94**	**1.00**	−0.99	0.29	**0.99**	−0.68	**0.97**	1.00				
TH	**0.93**	**1.00**	−0.99	0.26	**0.99**	−0.65	**0.97**	**1.00**	1.00			
Nitrate nitrogen	**0.99**	**0.95**	−0.92	0.51	**1.00**	−0.83	**1.00**	**0.97**	**0.96**	1.00		
Phosphates	**0.99**	**0.97**	−0.94	0.45	**1.00**	−0.80	**1.00**	**0.98**	**0.98**	**1.00**	1.00	
Sulphates	−0.54	−0.15	0.07	−1.00	−0.36	0.87	−0.45	−0.23	−0.20	−0.45	−0.40	1.00

*Highlighted values in bold shows strong positive correlation ($r > 0.9$) [29]

Table 2 Correlation coefficient matrix of physicochemical parameters in Post-monsoon season

Parameters	Temp	pH	EC	Turbidity	TDS	DO	BOD	COD	TH	Nitrate Nitrogen	Phosphates	Sulphates
Temp	1.00											
pH	−0.99	1.00										
EC	**0.99**	−0.97	1.00									
Turbidity	**0.93**	−0.90	**0.97**	1.00								
TDS	−0.99	**0.99**	−0.98	−0.91	1.00							
DO	**0.97**	−0.98	**0.93**	0.83	−0.98	1.00						
BOD	−0.99	**0.99**	−0.96	−0.88	**0.99**	−0.99	1.00					
COD	−0.76	0.70	−0.85	−0.94	0.73	−0.60	0.68	1.00				
TH	−0.99	**0.99**	−0.98	−0.92	**0.99**	−0.97	**0.99**	0.75	1.00			
Nitrate nitrogen	−0.96	**0.98**	−0.92	−0.81	**0.98**	−0.99	**0.99**	0.58	**0.97**	1.00		
Phosphates	**0.99**	−0.99	**0.99**	**0.94**	−0.99	**0.96**	−0.98	−0.78	−0.99	−0.96	1.00	
Sulphates	−0.99	**0.98**	−0.99	−0.96	**0.98**	−0.94	**0.97**	0.83	**0.99**	**0.93**	−0.99	1.00

*Highlighted values in bold shows strong positive correlation (r > 0.9) [29]

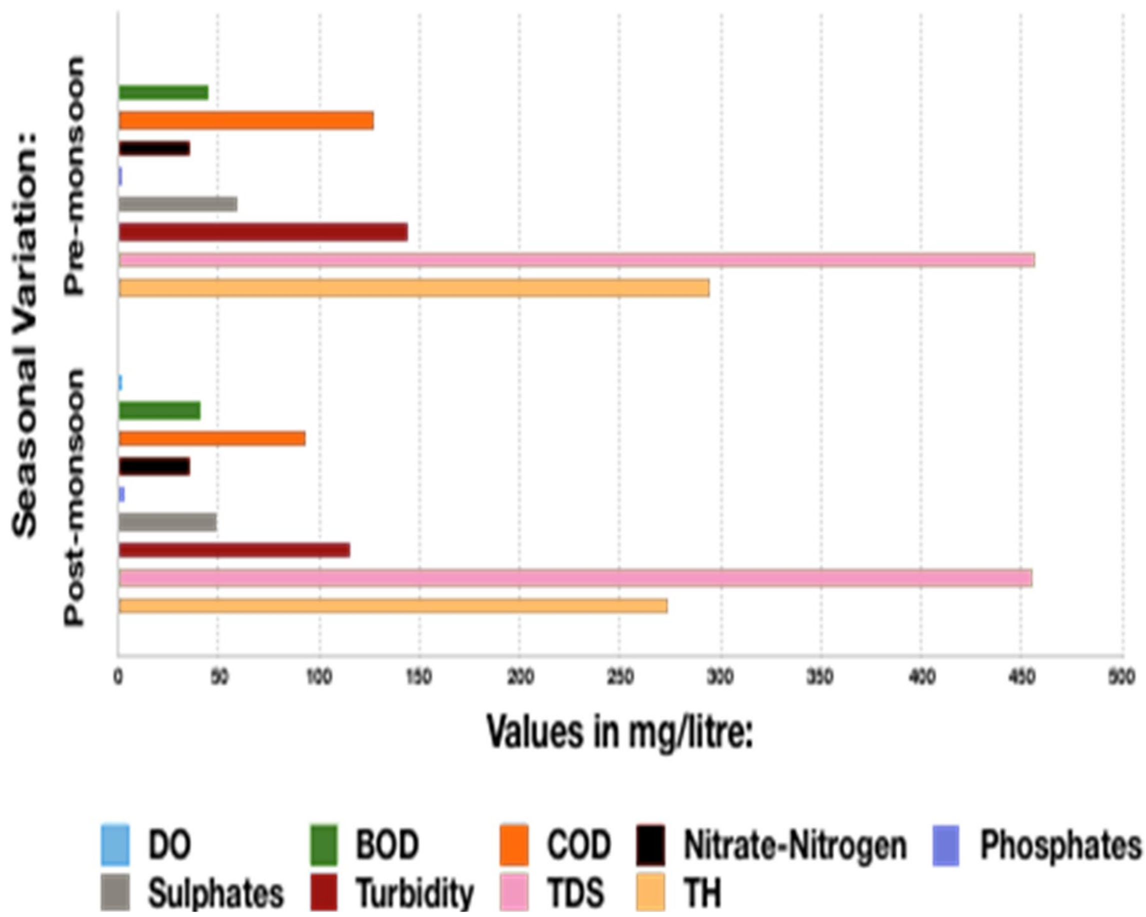

Fig. 4 Comparison of various physicochemical parameters in Pre-monsoon and Post-monsoon season

a strong positive correlation with BOD, COD, TH, Nitrate Nitrogen, and Phosphates in pre-monsoon and with BOD, TH, Nitrate Nitrogen, and Sulphates during post-monsoon season. Low DO values have been recorded throughout the study season (0.98–2.5 mg/L). Bhutiani et al. [26] also reported higher values of TDS (320–690 mg/L) and a lower DO range from 0.5 to 1.8 mg/L in Hindon River wastewater. The higher values of BOD and COD indicate large-scale disposal of untreated industrial effluent in river water.The recorded levels of COD are higher than BOD levels and findings are in agreement with available studies [27, 28]. TH values in previously conducted studies on Hindon River water (Ghaziabad district) ranges from 120 to 340 mg/L [27], 105.0–139.4 mg/L [28] and 170.8 mg/L-431.5 mg/L [26]. The mean TH value in the present study was recorded as 279.24 mg/L.TH shows a strong positive correlation with Nitrate Nitrogen and Phosphates in pre-monsoon and with Nitrate Nitrogen and Sulphates during the post-monsoon season. The observed values of Nitrate Nitrogen during pre- and post-monsoon season were 32–40 mg/L and 32.7–38.2 mg/L respectively (Fig. 4).The level of Phosphates and Sulphates recorded 1.2–3.1 mg/L and 2.9–3.5 mg/L during pre-monsoon, while 55–63 mg/L and 45–52 mg/L during pre-monsoon season respectively. Higher values of Nitrate-Nitrogen and Sulphate have confirmed the presence of inorganic impurities apart from other anthropogenic contaminants in River water [27].

4.2 Biological analysis of Hindon River water

According to the UPPCB [15], at Hindon River stretch (from Saharanpur to Ghaziabad) total of 90 villages are located having a population of 3,80,155 and generate 41.057 MLD of sewage. Ghaziabad district receives 381.203 MLD of total sewage discharge from which 195.203 MLD is untreated. Domestic effluent has been discharged into the Hindon River (Ghaziabad district) without any treatment [15]. It is hypothesized that one of the sources of fecal coliforms in the Hindon River could be due to the discharge of untreated domestic effluent and human settlements near the bank of River.The presence of Fecal Coliforms indicates human sewage or animal droppings contamination in water bodies [30], whereas organic load can significantly accelerate total coliforms count. The microbiological analysis showed a higher presence of total coliforms and fecal coliforms in the water samples.Total coliforms (MPN/100 ml) in water samples were found 7.40×10^4 in pre-monsoon and 5.80×10^4 in post-monsoon season, whereas fecal coliforms (MPN/100 ml) were 4.50×10^4 in pre-monsoon and 3.60×10^4 in the post-monsoon season. The standard count recorded were 75.00×10^4 CFU/ml in pre-monsoon and 62.00×10^4 CFU/ml in post-monsoon seasons, which were very high than the standard permissible limits (Fig. 5) [23].Ghildyal [30] calculated the fecal coliforms in Hindon River Ghaziabad (Down Stream Kulsera) and recorded a decrease in the count (Mean value 12.75×10^4 MPN/100 ml) during the Rainy season (July to September) as compared to count (Mean value 13.00×10^4 MPN/100 ml) in Summer season (April to July). Similar observations have been made in the present study and the observed trend could be due to the dilution of rainwater with the river water during monsoon season.

4.3 Analysis of heavy metals (Fe, Zn, Cd, Pb) in Hindon River water

A literature survey has been undertaken to understand the major sources of various pollutants including heavy metals in the Hindon River (Ghaziabad district) [15]. A total of 453 industries are located at the bank of Hindon River out

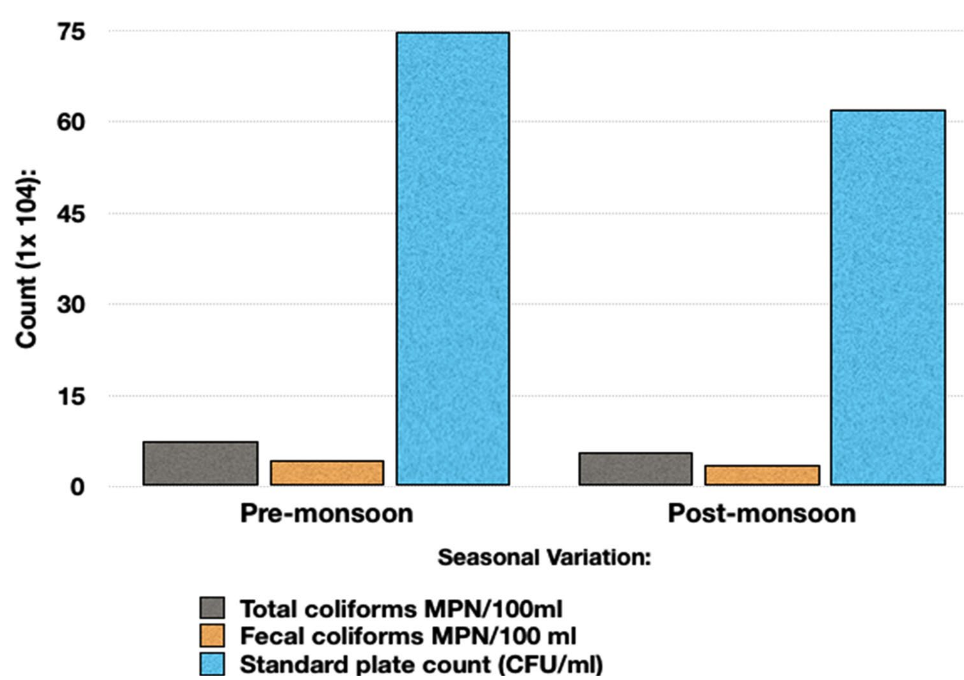

Fig. 5 Biological analysis of Hindon River in Pre-monsoon and Post-monsoon season

of which some grossly polluting includes Textile, Sugar, Distillery, Pulp & Paper, Slaughterhouse, Tannery, etc. The Hindon River catchments in Ghaziabad district also have such industrial units [13, 8]. Such Industrial effluents could be the potential source of contaminants if discharged untreated in water bodies.Available studies highlight the impact of industrial and urban settlements on the quality of Hindon River water (Ghaziabad district) [13].The district Ghaziabad is an industrial hub as the majority of industries (353 out of a total 453 at Saharanpur-Ghaziabad stretch) are located in this region. In Ghaziabad district total of nine drains are located from which Karedha, Sahibabad, Jawali mainly carries Textile effluents; Dasna and Meerut road Kaila Bhatta are known for effluents from metal surface treatment units; Indirapuram, Hindon Vihar and Pratap Vihar drains carries domestic effluents, while Arthla drain has mixed effluents. As per the report, Industrial effluents will be treated before discharge into the Hindon River while domestic effluents were discharged without any treatment. As a result of operating illegal units in non-conforming areas and over-discharge by consented industries, the actual levels of industrial effluent could be higher than reported [15].

In the present study, the concentration of Zn ranges from 1.06 to 1.38 mg/L and 1.02–1.24 mg/L in the pre-monsoon and post-monsoon seasons respectively and found within the permissible limits. The values for Fe and Cd were found above the permissible limits (BIS). Fe ranges from 1.40 to 1.90 mg/L in pre-monsoon and 1.21–1.59 mg/L in the post-monsoon season. The values for Cd varied from 0.082 to 0.110 mg/L in pre-monsoon and 0.073–0.080 mg/L in post-monsoon season. The levels of Pb were 0.10–0.13 mg/L in pre-monsoon and 0.08–0.10 mg/L in post-monsoon season (Fig. 6).The overall concentration of heavy metals recorded during pre-and post-monsoon seasons were in the order of Fe > Zn > Pb > Cd.The mean values recorded for all the studied heavy metals were comparatively lower during the post-monsoon season. This could be due to the mixing of rainwater with river water and described as a dilution effect [21].The mean Pb concentration during the post-monsoon season was found within the permissible limits [23]. Chabukdhara et al. [21] also observed lower mean values of Zn, Fe, Cd, Pb, Cu, Cr, Mn, and Ni in the Hindon River (Ghaziabad district) during post-monsoon as compared to pre-monsoon season.Therefore, the undertaken study demonstrates the effect of seasonal variation on heavy metal presence in river water. These observations were further supported by RMPI and IMPI analysis. The Metal Index helps to estimate the "Overall Quality of Drinking Waters" [22]. The higher RMPI and IMPI values indicate increased levels of heavy metal contaminants. The recorded RMPI values for Zn, Fe, Cd, and Pb during pre-monsoon were comparatively higher than post-monsoon season values (Fig. 7) and follows the overall trend Cd > Fe > Pb > Zn.The RMPI values were greater than one for all the studied heavy metals except Zinc during both the seasons. Chabukdhara et al. [21] studied the metal pollution index in the Hindon River at Ghaziabad district. They have also noticed a similar trend with comparatively higher contamination levels at all the sampling sites in pre-monsoon. The trend in overall RMPI values reported by them were in order of Pb > Cd > Zn > Cr > Cu > Fe > Ni. IMPI values calculated for heavy metals in the pre-monsoon were higher than the post-monsoon season in the present study and showed higher levels of pollution (IMPI > 2) during both the seasons (Fig. 8).

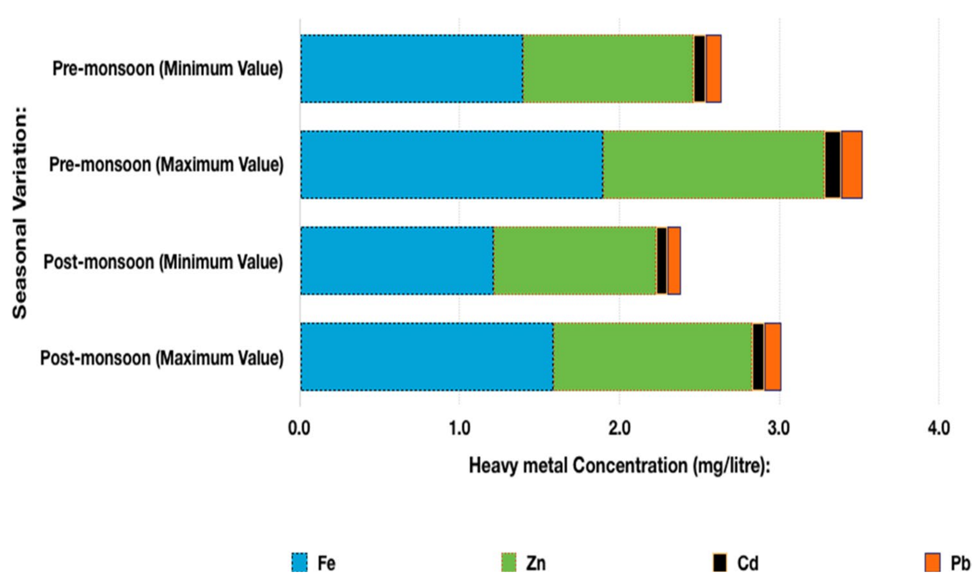

Fig. 6 Heavy metal concentration (mg/L) during Pre-monsoon and Post-monsoon season in Hindon River water

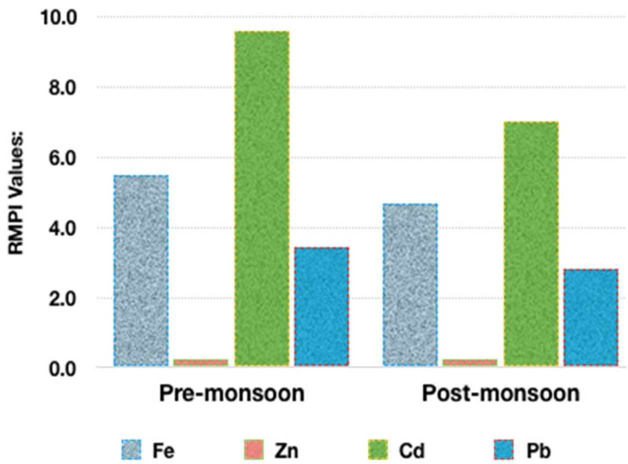

Fig. 7 Comparison of River Metal Pollution Index in Pre-monsoon and Post-monsoon seasons

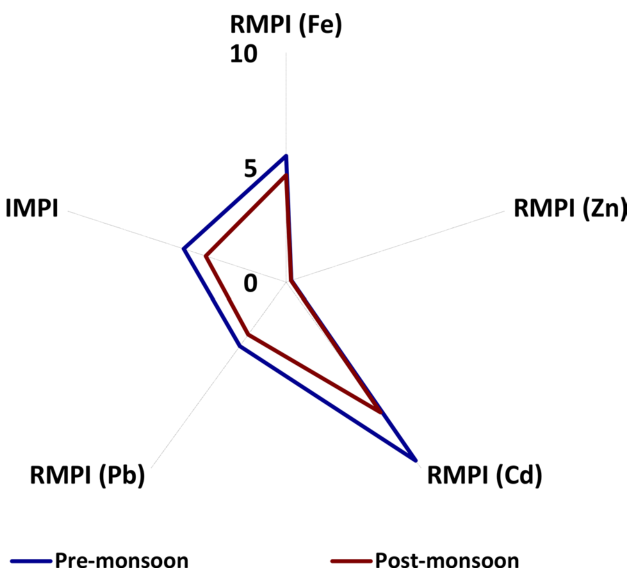

Fig. 8 Star plot indicating the effect of seasonal variation on RMPI and IMPI values of heavy metals

4.4 Water quality assessment of Hindon River based on Indian water quality standards

Central Pollution Control Board has defined "Water quality" as those Physical, Chemical, or Biological characteristics of water by which the user evaluates the acceptability of water" [31]. The Inland surface water into 5 classes (Class A–E). Here class-A is drinking water source without conventional treatment but after disinfection, class B is outdoor bathing water (organized), class C is drinking water source with conventional treatment followed by disinfection, class D is water for the propagation of wildlife, fisheries and class E is water for irrigation, industrial cooling and controlled waste disposal [32].Such water quality assessment studies explorethe possibility of utilizing River water for different purposes (Table 3). Based on average data for DO, BOD, and Total Coliform counts during water monitoring survey (Hindon River and its tributaries Kali-West and Krishni) by UPPCB [15], it was observed that the River water is not suitable for Classes A to D and can be restricted for use only under Class-E for irrigation purposes.In the present study, pH of the river water is suitable for all the classes (A-E) defined by CPCB. The mean value of Zinc (mg/L) belongs to all the designated classes (Class-A and C). The mean value of Lead (mg/L) was found suitable for Class-A and C during Post-monsoon season, while in pre-monsoon it was recorded above the classified limits. The mean values of Sulphate and TDS fall into all the designated classes (Class-A, C, and E). The mean values of DO (mg/L) were found below the classified limits in both the seasons. The mean values of BOD, TH, Total coliform (MPN/100 ml), and heavy metals tested (Fe and Cd) were found above the classified limits.

5 Conclusions

The Metal pollution Indices like RMPI and IMPI can be effectively employed for the assessment of heavy metal contamination in water bodies. The study site has significant levels of Fe, Cd, and Pb. This could be due to the population load and discharge of industrial effluents and agricultural runoff in this region. Chemometric investigations of Chabukdhara and Nema [8] revealed anthropogenic influence on the availability of Zn, Cd, Pb, Cu, and Ni in the Hindon River. Elevated levels of physicochemical parameters like BOD, TH, and Total Coliform counts are the indications of River water contamination with sewage effluents. Studies are available that highlight the impact of industrial and urban settlements on the quality of Hindon River water at Ghaziabad district [13].The studied water quality parameters were apparently lower during the post-monsoon season, which could be due to the dilution of river water with rainwater. The seasonal variation has detrimental effects on the quality of Hindon River water. The possibility of utilizing river water for different purposes has also been explored and the recorded parameters such as DO, TH, TCC, and Heavy metals like Cd and Fe were found above-classified limits [32] during both pre- and post-monsoon seasons. Hindon River (from Saharanpur to Ghaziabad) is a priority- 1 polluted stretch in Uttar Pradesh [15]. It receives massive quantities of wastewater on daily basis from catchment areas of Ghaziabad district. The higher levels of sewage and industrial effluents in water bodies could impose serious threats to aquatic and human life. Rising incidences of various water-borne diseases and chronic ailments like cancer

Table 3 Assessment of studied Water Quality Parameters based on Indian Water Quality Standards [32]

Water quality parameters analyzed in the present study	Classes of water (Source IS 2296:1992)					
	Class A	Class B	Class C	Class D	Class E	Above the classified limits
pH	✓	✓	✓	✓	✓	X
Electrical Conductivity (µS/cm) (Maximum limits)	NA	NA	NA	NA	✓	X
Total Dissolved Solids (mg/L) (maximum limits)	✓	NA	✓	NA	✓	X
Biochemical Oxygen Demand (mg/L) (Maximum limits)	X	X	X	NA	NA	✓
Total Hardness (mg/L) (Maximum limits)	X	NA	NA	NA	NA	✓
Nitrate Nitrogen (mg/L) (Maximum limits)	X	NA	✓	NA	NA	X
Sulphates (mg/L) (Maximum limits)	✓	NA	✓	NA	✓	X
Zinc (mg/L) (Maximum limits)	✓	NA	✓	NA	NA	X
Iron (mg/L) (Maximum limits)	X	NA	X	NA	NA	✓
Cadmium (mg/L) (Maximum limits)	X	NA	X	NA	NA	✓
Lead (mg/L) (Maximum limits)	X, *	NA	X, *	NA	NA	✓,#
Total Coliform MPN/100 ml (Maximum limits)	X	X	X	NA	NA	✓

✓ = Calculated values in present study belong to particular class maximum limits; X = Calculated values in present study not applicable to a particular class; NA = Recommended values of parameter not available for a particular class; * = Calculated values of Lead (mg/L) in Post-monsoon belongs to Class-A and C limits; # = Calculated values of Lead (mg/L) in Post-monsoon not belongs to Class-E limits. Calculated values considered were Mean values obtained for different water quality parameters during Pre-monsoon and Post-monsoon seasons

are reported in the polluted stretch of Hindon River [28]. At Ghaziabad district, the Hindon River is a major source of recharging groundwater. Thus, periodic monitoring of industrial and sewage effluent discharge is prerequisite to maintain the physicochemical and biological profile of Hindon River water as per prescribed water quality standards. The present study is supported by experimental data based on physicochemical, biochemical, and Metal Pollution Index analysis for assessing water quality status at the study site. It is expected that the presented findings will be helpful to derive some coherent elucidations that would be materialized in the coming future for developing various analytical and monitoring strategies to study pollution levels in different water-bodies.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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