# PHYSICOCHEMICAL AND MICROBIOLOGICAL ANALYSIS OF THE HINDON RIVER WATER IN WESTERN UTTAR PRADESH, INDIA

**K. Anita[1], Ram Naraian[2], Siya Ram[3]***

**Abstract**

The quality of Hindon river water has substantially declined because of unregulated discharge of waste materials without treatment, originating from industrial, domestic, and agricultural practices. Water quality monitoring is one of the most essential river protection and conservation activities. The present study was managed to access the physiochemical and microbiological parameter of Hindon river water that has been contaminated by the unwanted discharges. Between April to Dec., 2021, water samples from river Hindon were collected from the seven different sites from Saharanpur to its confluence in Yamuna River at Momnathal Village Greater Noida. The water samples were examined for multiple parameters, including Temp., pH, DO (Dissolved oxygen), Turbidity, TDS (Total Dissolved Solids), Salinity, TH (Total Hardness), COD (Chemical Oxygen Demand), BOD (Biochemical Oxygen Demand), as well as the occurrence of heavy metals such as Cd (cadmium), Ni (nickel), Mo (molybdenum), Cu (copper), As (arsenic), Cr (chromium), Pb (lead), Mn (manganese), Zn (zinc), Co (cobalt) and Fe (iron). Furthermore, the total and fecal coliform in all samples were quantified. After conducting a comprehensive study, it was found that all physicochemical and microbiological attributes have surpassed the permissible threshold compared to the BIS standard (IS-10500). Therefore, the river Hindon's water quality was found to be unfit for irrigation, fish farming, human consumption etc., based on the findings of current study, a complementary technique combining physicochemical and microbiological studies should be used to obtain a complete information of the river Hindon.

**Keywords:** Hindon river, Physicochemical properties, Heavy metal, Faecal coliforms, Total coliform

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## Introduction

Water is an essential substance found almost everywhere on the earth and recycled by the hydrological cycle, and provides a habitat for flora and fauna and the needs of humans. The river Hindon is a vital water source for the western part of Uttar Pradesh, India, predominantly to rural population. But three urban cities including Saharanpur, Muzaffarnagar and Ghaziabad significantly contributes to the pollution in the river Hindon (Bhutiani et al., 2017; Sharma et al., 2009). The wastewater from Saharanpur is released into the Kali and Krishni rivers before entering the Hindon river. The river Hindon is subjected to untreated wastewater discharge from the industrial corridor extending from Saharanpur to Noida. In addition, some of the significant problems with the water quality of the river includes microbial pathogens such as, bacteria, fungi, viruses, and protozoans along with organic/ inorganic pollutants, suspended particles, heavy metals like Cd, Pb, Ni and Fe, as well as elements like fluoride (Bhutiani et al., 2017; Mishra et al., 2016). The unplanned discharge of untreated sewage primarily introduces faecal materials into the surrounding ecosystem (Rehman et al., 2020; Abd-Elhamid et al., 2021), and contributes faecal contaminations. In several developed and developing nations, there are numerous incidences wherein semi-treated or untreated sewage is negligently discharged into surface water bodies. Contamination of groundwater can occur when contaminated water infiltrates the subsurface, diminishing its suitability for potable and agricultural use (Rehman et al., 2020; Abd-Elhamid et al., 2021). *Escherichia coli* is well recognized as the predominant bioindicator for detecting faecal contamination in river water. Water pollution is indicated by a concentration of 1-2 CFU)/100 ml, making it unfit for ingestion (Gwimbi et al., 2019). Such pollutants flow through water bodies from various sources, including home, industrial, and agricultural runoff. Therefore, the lack of a consistent policy to discharge effluent into rivers and a government strategy for river restoration is a prime drawback has made river water unfit particularly for human consumption (Rizvi et al., 2015).

Numerous river water quality investigations have found that physicochemical tests of river water exceed the standard set by the CPCB (Central Pollution Control Board) in 1995. Previously, Bhutiani et al. (2017) conducted a study on Hindon river water quality by analyzing various Physico-chemical parameters, including Temp., pH, TDS, EC, Turbidity, DO and BOD. According to an affidavit presented to the NGT (National Green Tribunal) by the CPCB, the water of the Hindon River does not meet the essential conditions for bathing in terms of primary water quality standards. In India, the CPCB and the SPCBs (State Pollution Control Boards) are regulatory entities responsible for ensuring compliance with environmental legislation to improve water quality (Greenstone & Hanna, 2014). The Water Prevention and Control of Pollution, Act, adopted in 1974, is a noteworthy example of domestic environmental regulation. The government needs to take the necessary steps to build a sewage treatment plant (STP) along the Hindon river while directing industries to make effluent treatment plants (ETPs) to cleanse their wastewater before it is discharged into the river. The Hindon river wastewater treatment facility is currently inoperable, forcing the bulk of sewage treatment plant (STP) facilities to close.

Therefore, many industrial sectors need adequate infrastructure to install efficient effluent treatment plants (ETPs) to treat wastewaters. According to the Water Quality and Waste Water Management Vision for 2012-2017, India is expected to generate 1,20,000 million liters of wastewater daily by 2051. According to the Central Water Commission (2014), (Ministry of Water Resources, India) demand of potable water is expected to rise from 813 billion cubic metres in 2010 - 1093 billion cubic metres in 2025. Moreover, based on the WaterAid India's Country Strategy (2016-2021), a large section of the Indian population, specifically over 76 million people, faces the challenge of insufficient access to safe drinking water. Accordingly, an annual mortality rate of more than 1,40,000 is seen among children under five due to diarrheal infections caused by contaminated water sources (WaterAid India Country Strategy for 2016-2021). Moreover, based on World Bank data research, it has been also established that contaminated water is responsible for around 21% of infectious disorders in India (Rajasulochana & Preethy, 2016). Therefore, the situation is likely to deteriorate in the absence of adequate intervention. Therefore, water contamination is a major environmental issue being tackled by several countries (Chabukdhara & Nema, 2012). In this regards, the monitoring and evaluating water quality are essential for preserving aquatic ecosystems and protecting human health. Based on the several issues of water contamination, the main objective of this study was planned to evaluate the effects of seasonal variations on the water quality of the river Hindon; which was accomplished by examining physicochemical and microbiological factors.

## Materials and methods

### *Study area*

The current study encompasses every phase of the river Hindon, that extend its entire trajectory of the river Hindon from (29º57'46" N77º38'20" E to 28º25'18" N77º30'14" E), commencing from the foothills of the Shivalik range and concluding at its confluence with the Yamuna River. The samples were obtained from seven distinct places during April, August, and Dec. 2021. For the Hindon river water quality assessment, water samples (1L) were collected 30 cm below the river water in clean sterile glass bottles from the river's left, mid and right banks at selected sites, as indicated in Figure 1. The samples from each sites (Left, Mid and Right) were mixed and subsequently kept in ice before being transported to the laboratory for further analysis (APHA 1998, Rice et al 2012). The enumeration of total and faecal coliforms at all sites was conducted using Multiple Tube Fermentation Technique as per (APHA 1998, Rice et al 2012).

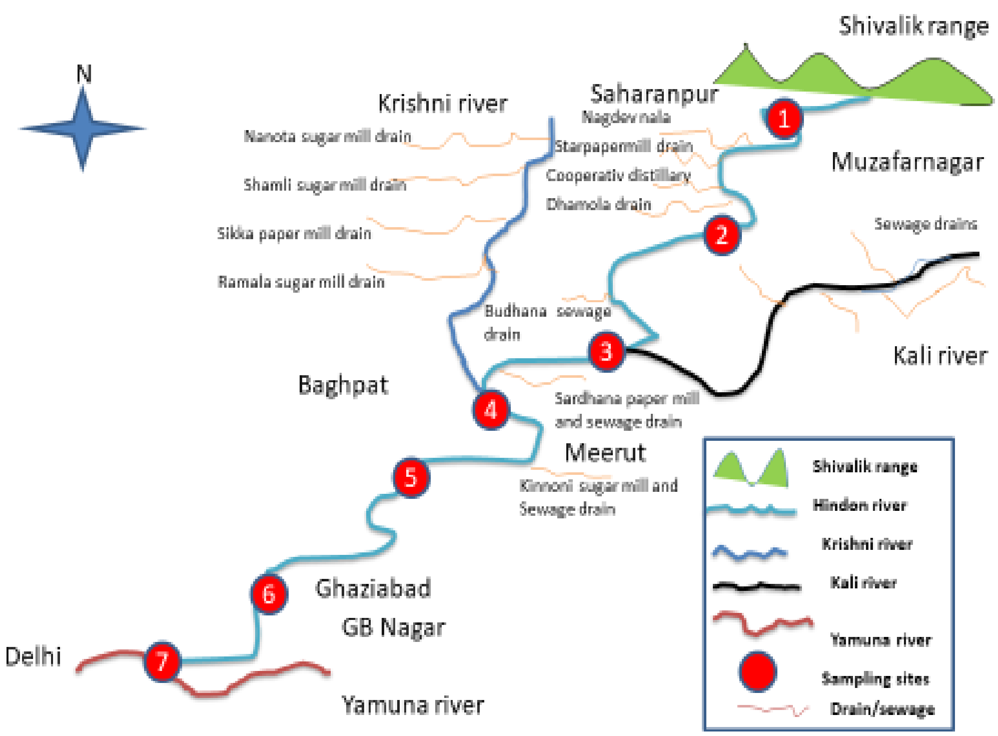


**Figure 1.** The study area and the sites (# Site 1 to # Site 7) where specimens of water were collected from the river Hindon in western Uttar Pradesh, India.

### *Physicochemical analysis*

Several physicochemical parameters, including Temp., pH, DO, EC, Turbidity, TDS, Salinity, TH, COD, BOD, heavy metals, and total and fecal coliforms were examined using the procedure described by the APHA (1998) and Sharma et al. (2021). The heavy metals including Cd, Ni, Mo, Cu, As, Cr, Pb, Mn, Zn, Co, and Fe were investigated using an Atomic Absorption Spectrometer (AAS) (ICP-OES, Agilent, Model no. 5110).

The Atomic Absorption Spectrophotometer (AAS) was calibrated using an E-Merck single-element standard. The concentration working standards were established using a method known as serial dilution. The experimental procedure encompassed diluting a stock solution with an initial concentration of 1000 ppm using Milli-Q water. The accuracy of the data was evaluated by regularly inspecting the standards during the entirety of the sample analysis procedure. The heavy metals were detected using an air/acetylene burner atomizer (Mukesh et al., 2017; Sharma et al., 2021).

### *Microbiological Analysis*

Quantitative enumeration of total and faecal coliform was performed by using the Multiple Tube Fermentation Technique as per standard (APHA 1998, Rice et al 2012) guidelines. The water sample collected from different sites were diluted serially (10, 01, and 0.1) with sterile distilled water. The water samples were further transferred to MacConkey broth (Himedia) with an inverted Durham tube for the detection of gas formation. The dilutions were incubated at 37℃ for 12-18 hours at 220rpm on an incubator shaker. In addition, positive tubes were inoculated into the BGLB (Brilliant Green Lactose Bile Broth) using a culture loop. The mixture was then incubated for 24 hours at 37°C. The presence of gas formation in the tubes was taken into consideration. The enumeration of coliforms was conducted using the most probable number (MPN) technique, expressed as MPN/100 milliliters of water. After the test was concluded, a loop containing a positive sample was used to streak on Eosin Methylene Blue (EMB) agar plates. These plates were then incubated at a temperature of 37°C for a duration of 18 to 24 hours. The positive test was confirmed with colonies showing metallic sheen green color. The MPN was calculated by referring to previously created tables that contain values corresponding to the number of positive tubes observed in various dilutions (APHA, 1998).

**Results and Discussion**

The physicochemical and microbiological properties are crucial for developing reliable water management and conservation strategies. In order to achieve the objective, water samples taken from multiple locations of the Hindon river during April, August, and December of 2021 were investigated. The multiple parameters of water including Temp., (°C), pH, DO, EC, Turbidity, TDS, salinity, total hardness, COD, and BOD were found to be variable on different sites.

The water temperature of the river Hindon exhibited variations within the range of 18°C to 34°C during the months of April, August, & December, 2021. Specifically, the temp. range observed in April was 29°C to 34°C. However, in August, it was 24°C to 30°C, while, during month of Dec., it was 18°C to 22.3°C (Tables 1, 2 & 3)

**Table1.** The physicochemical properties of surface water in the river Hindon basin during month of April, 2021.

| Parameters /Sites | RW-S1 | RW -Mu2 | RW -Me3 | RW -NGN4 | RW -GNS5 | RW -GNK6 | RW -GNM7 | SD ± |
|---|---|---|---|---|---|---|---|---|
| **Temperature ($^0$C)** | 29 | 29.5 | 30 | 30.4 | 31 | 31.6 | 34 | 1.09 |
| **pH** | 7.03 | 6.9 | 6.4 | 6.6 | 6.5 | 5.9 | 5.5 | 0.54 |
| **EC (µs/cm)** | 219 | 304 | 455 | 1071 | 1282 | 1345 | 1385 | 519.18 |
| **Turbidity (NTU)** | 144 | 180 | 188 | 200 | 222 | 250 | 350 | 66.58 |
| **TDS (mg/l)** | 293 | 325 | 354 | 429 | 532 | 612 | 653 | 143.63 |
| **Salinity(mg/l)** | 50.6 | 65.2 | 75.5 | 95 | 102 | 120 | 142 | 31.86 |
| **Total hardness(mg/l)** | 352 | 604 | 778.8 | 833.6 | 910.4 | 1104 | 1200 | 288.82 |

**Table 2.** The physicochemical properties of surface water in the river Hindon basin during month of August, 2021.

| Parameters /Sites | RW-S1 | RW -Mu2 | RW -Me3 | RW -NGN4 | RW -GNS5 | RW -GNK6 | RW -GNM7 | SD± |
|---|---|---|---|---|---|---|---|---|
| **Temperature ($^0$C)** | 24 | 25.2 | 25.8 | 26.2 | 27 | 28 | 30 | 1.96 |
| **pH** | 8.4 | 8.45 | 8.1 | 7.6 | 6.5 | 6 | 5.8 | 1.14 |
| **EC (µs/cm)** | 600 | 775 | 995 | 1200 | 1345 | 1450 | 1516 | 348.22 |
| **Turbidity (NTU)** | 193 | 225 | 320 | 411 | 450 | 500 | 550 | 136.46 |
| **TDS (mg/l)** | 220 | 298 | 468 | 564 | 698 | 735 | 800 | 222.60 |
| **Salinity(mg/l)** | 12.6 | 15.7 | 23.7 | 58 | 62.5 | 70.5 | 85 | 29.04 |
| **Total hardness(mg/l)** | 400 | 538 | 604 | 777.5 | 833.6 | 910.4 | 1104.5 | 240.46 |

**Table 3.** The physicochemical properties of surface water in the river Hindon basin during month of December, 2021.

| Parameters /Sites | RW-S1 | RW -Mu2 | RW -Me3 | RW -NGN4 | RW -GNS5 | RW -GNK6 | RW -GNM7 | SD± |
|---|---|---|---|---|---|---|---|---|
| **Temperature ($^0$C)** | 18 | 19 | 19.5 | 20.5 | 21.5 | 22 | 22.3 | 1.62 |
| **pH** | 7.6 | 7.6 | 7.8 | 8.4 | 8.32 | 8.19 | 8.41 | 0.36 |
| **EC (µs/cm)** | 1140 | 1204 | 1380 | 1450 | 1555 | 1585 | 1650 | 194.00 |
| **Turbidity (NTU)** | 220 | 295 | 345 | 440 | 535 | 550 | 600 | 143.69 |
| **TDS (mg/l)** | 345 | 485 | 575 | 696 | 770 | 835 | 873 | 194.17 |
| **Salinity(mg/l)** | 20.5 | 35.6 | 42.7 | 59.3 | 65.4 | 72.5 | 84.5 | 22.42 |
| **Total hardness(mg/l)** | 665 | 700 | 735 | 780 | 820 | 900 | 959 | 106.68 |

Temperature fluctuations in the atmosphere are influenced by a variety of factors, including latitude, height, and proximity to bodies of water. The reduced microbial metabolism caused by ambient cooling minimizes the breakdown of both organic and inorganic waste in water samples (Rizvi et al., 2017; Yadav et al., 2017).

Moreover, the pH levels of the river water varied between 5.5 -7.03 in April, 5.8 - 8.45 in August, and 7.6 - 8.41 in the month of Dec., 2021. Finally, the pH levels of the river Hindon water ranged between 7.6 to 8.41 in Dec., 2021 (Tables 1, 2 & 3). It is attributed that the parameters like seasonal fluctuations, industrial activity, and natural phenomena may influence the pH of water levels. Following a peak of pH in Dec., the pH level falls, correlating with the temperature increase recorded from April to August. The pH of river water is elevated due to the presence of $HCO_3$ (bicarbonate) and $CO_3$ (carbonates) of calcium and magnesium. According to Patil et al. (2012), the principal sources of these chemicals are often attributed to waste discharge and microbial decomposition of organic molecules within the aquatic environments of river.

Additionally, the electrical conductivity (EC) values of water ranged from 219 -1385 s/cm in April, 600 – 1516 s/cm in August, and 1140 - 1650 s/cm in Dec.2021 (Tables 1, 2 & 3). Das et al. (2006) argued that increased EC in aquatic environments indicates pollution load in water. Elevated electrical conductivity has been shown to influence crop germination and production negatively (Srinivas et al., 2000). As EC increases, it also rises to the level of ionizable solids. When sewage and river water are mixed, the conductivity of the water is observed to increase. The property of EC fluctuates due to dissolved salts, minerals, and other compounds in the water. Furthermore, discharging untreated sewage and industrial effluent can increase electrical conductivity in the upstream environment.

The TDS is a measurement of the amount of solid dissolved in water that include salts and organic materials such as nutrients and toxins. An aliquot of water with high TDS levels has low DO and an increased biological and COD. According to our study, the TDS concentrations ranged from 293 mg/l - 653 mg/l in April, in August 220-800mg/l and in Dec. 345-873mg/l (Tables 1, 2 & 3). High TDS levels are indicative of the presence of sewage, laundry effluent, and garbage disposal waste, in addition to the primary sources of TDS found in natural sources. These primary sources include sewage, urban runoff, wastewater from industries, and chemicals utilized in water treatment processes.

The most elevated degree of turbidity in water consists of solid components, encompassing substances such as sand, silt, clay, dissolved organic and inorganic compounds, plankton, and microorganisms. The standard filtration methods cannot successfully remove these materials. Bhutiani et al. (2017) and Rizvi et al. (2015) also observed the higher levels of TDS in the Hindon river water quality at Ghaziabad in their respective investigations. Similar to this observation, our study also recorded the TDS levels ranged between 293-653 mg/l to 345-873 mg/l throughout the periods before and after the monsoon seasons.

The current study reveals that the turbidity ranges from 144 - 350 NTU in April, 193 - 550 NTU in August, and 220 to 600 NTU in Dec., as shown in (Tables 1, 2 & 3). It is quite obvious that, TDS increases as particulate matter increases, whereas water purity increases as turbidity decreases. Various factors, including sedimentation, growth of algal blooms, and human activity, can cause turbidity changes. Several geographic and environmental factors, such as sites of sampling, study period, current climatic conditions and spatial variations, may lead to occurrence of turbidity in water. Bhutani et al. (2017) also reported higher levels of turbidity and EC in river water. The increased turbidity level and reduced sunlight penetration, significantly impacts the various metabolic processes of living organisms occurring in river water. As result, only fewer biological species can survive in to such river water.

The salinity of river water in the current study found to be ranged from 50.6 mg/l to 142 mg/l in April, while in August it was 12.6 mg/l to 85 mg/l, whereas in Dec., it was 20.5 mg/l to 84.5 mg/l (Tables 1, 2 & 3). It known that the river water's biological quality is directly influenced by the level of salinity. According to Khadse et al. (2008), the Nag River, which functions as a sewage water canal, has a substantial range in saline levels, notably from 374 to 486 mg/l. The ideal pH range for the survival of living organism and growth, particularly in aquatic conditions, is widely thought to be between 6.0 and 9.0. The elevated salt levels in river Hindon indicate that sewage in Ghaziabad has been diluted with river water. High salt levels may result from the accumulation of household wastewater and the use of fertilizers in agricultural practices. Salinity in aquatic habitats benefits fish and other aquatic creatures by protecting them against rapid variations.

Water hardness is defined as decrease in the boiling point of water and the suppression of soap lather formation (Patil & Patil, 2010). The concentration of dissolved calcium and magnesium in water is the most effective way to define its hardness. Soap scum results from the chemical reaction between soap molecules and calcium ions in water with a high mineral concentration. The calcium, magnesium, and other metallic compounds can affect the hardness of materials. It is considered soft when the calcium carbonate ($CaCO_3$) concentration in water is between 0 and 60 mg/l. The $CaCO_3$ concentrations ranging from 61 to 120 mg/l are deemed to be problematic. Hard water has a $CaCO_3$ content ranging from 121 to 180 mg/l, while very hard water has a $CaCO_3$ value >180 mg/l. According to present study, the TH level of the water samples obtained in April ranged from 352 mg/l to 1200 mg/l while, TH increased from 400 mg/l to 1104.5 mg/l in August. Tables 1, 2 & 3 depicts the total hardness range measured in Dec., ranged from 665 mg/l to 959 mg/l. In that order, the cations of calcium, magnesium, iron, and manganese determine the total hardness of water.

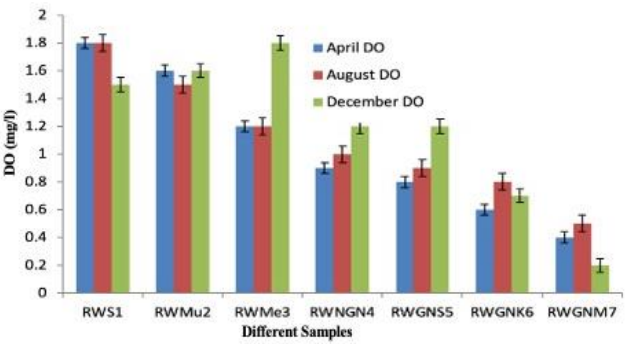


**Figure 2.** Levels of DO (dissolved oxygen) in the water of the river Hindon at various locations and months.

The DO is known as the available concentration of $O_2$ in the water and the $O_2$ balance of the system is the critical factor influencing the impacts of waste discharge in a water body. It is because of oxygen availability, which is required to survive a wide range of biological organisms in aquatic environments (Chang, 2005). The factor such as temperature, salinity, water turbulence, and air pressure all influence the oxygen level in natural water bodies (Gupta et al., 2017). Figure 2 depicts the range of DO concentrations recorded in our study. The depletion of DO in water bodies is caused by increased organic material contamination, as the breakdown of these materials needs a greater oxygen demand. According to CPCB guideline, the DO concentration should not exceed above 6 mg/l for better water quality. As a result, the DO levels in the entire sampling sites of the current study exceeded the permissible limit and created challenging situations of river water ecosystem.

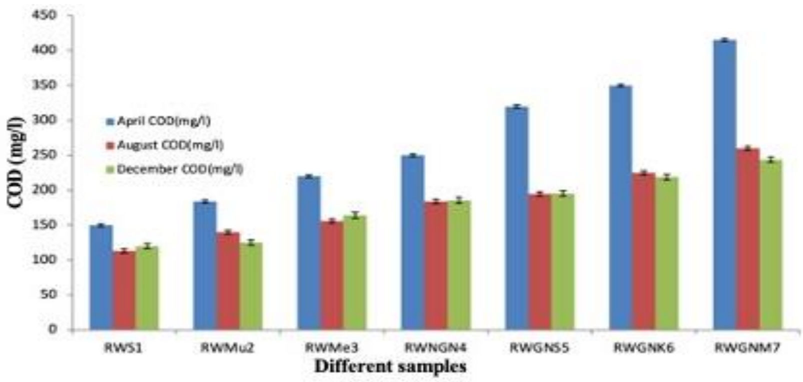


**Figure 3.** Level of chemical oxygen demand (COD) in water samples collected from multiple locations of the river Hindon during April, August and Dec., 2021.

In addition, the COD level of a river is the amount of oxygen required for the breakdown of chemical and inorganic pollutants. Figure 3 depicts the change in COD levels observed in the river Hindon during the month of April, August and Dec., 2021. According to our observations, the COD values in April ranged from 150 mg/l to 415 mg/l., 113 mg/l to 260 mg/l in August, whereas in Dec., it was between 120 mg/l to 243.82 mg/l. According to Yadav's (2019) findings, the Ganga River at Varanasi had a significant level of chemical oxygen demand (COD) ranging from 15.20 to 24.00 mg/l. Other factors that lead to elevated levels of COD include sewage discharge into waterways and industrial areas. According to the UPPCB (Uttar Pradesh Pollution Control Board), the Ghaziabad district is known as home to more than 300 industrial companies along the river. The COD concentrations beyond a certain threshold can reduce dissolved oxygen levels in aquatic environments due to microbial breakdown processes (Kumar et al., 1989). COD levels that exceed the set threshold of 250mg/l at some places may occur due to the amalgamation of wastewater from various sources, including industrial waste.

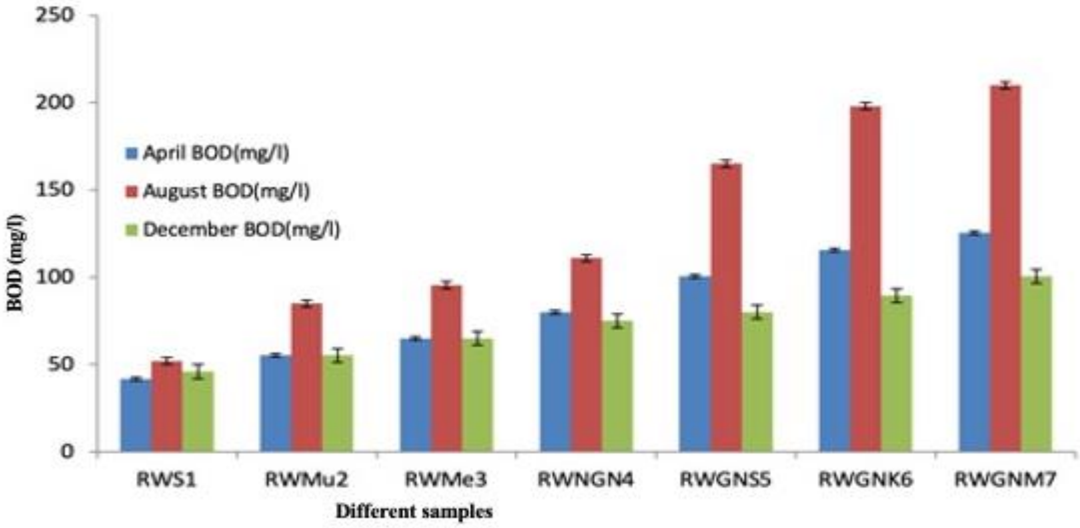


**Figure 4.** Levels of the biochemical oxygen demand (BOD) in all water samples collected over a year from multiple locations of river Hindon.

The BOD is a quantitative measure of the $O_2$ consumed by aerobic microorganisms when degrading organic contaminants in their environment. The urban wastewater that has not been treated or has only been partially treated contains a significant amount of nutrients and organic matter. When this organic matter decomposes, it releases additional nutrients into the water. Consequently, untreated or partially treated urban wastewater may be the main cause of the decrease in biochemical oxygen demand (BOD) in downstream of the river. The observation above is an essential indicator of the increasing load of organic pollution (Wen et al., 2017). The reduction in DO levels and the increase in BOD levels of water have an inverse connection. During April, the BOD ranged from 41.6 to 125.5 mg/l. Figure 8 of present study depicts the fluctuation in BOD concentrations between August to Dec., 2021. The observed BOD level was ranged from 52 to 210 mg/l in August and 46 to 100.5 mg/l in the month of December. The water availability, agricultural practices, and geological conditions can be attributed to the observed outcomes. Moreover, several studies show consistent trends in their findings (Bhutiani et al., 2017; Yadav et al., 2019).

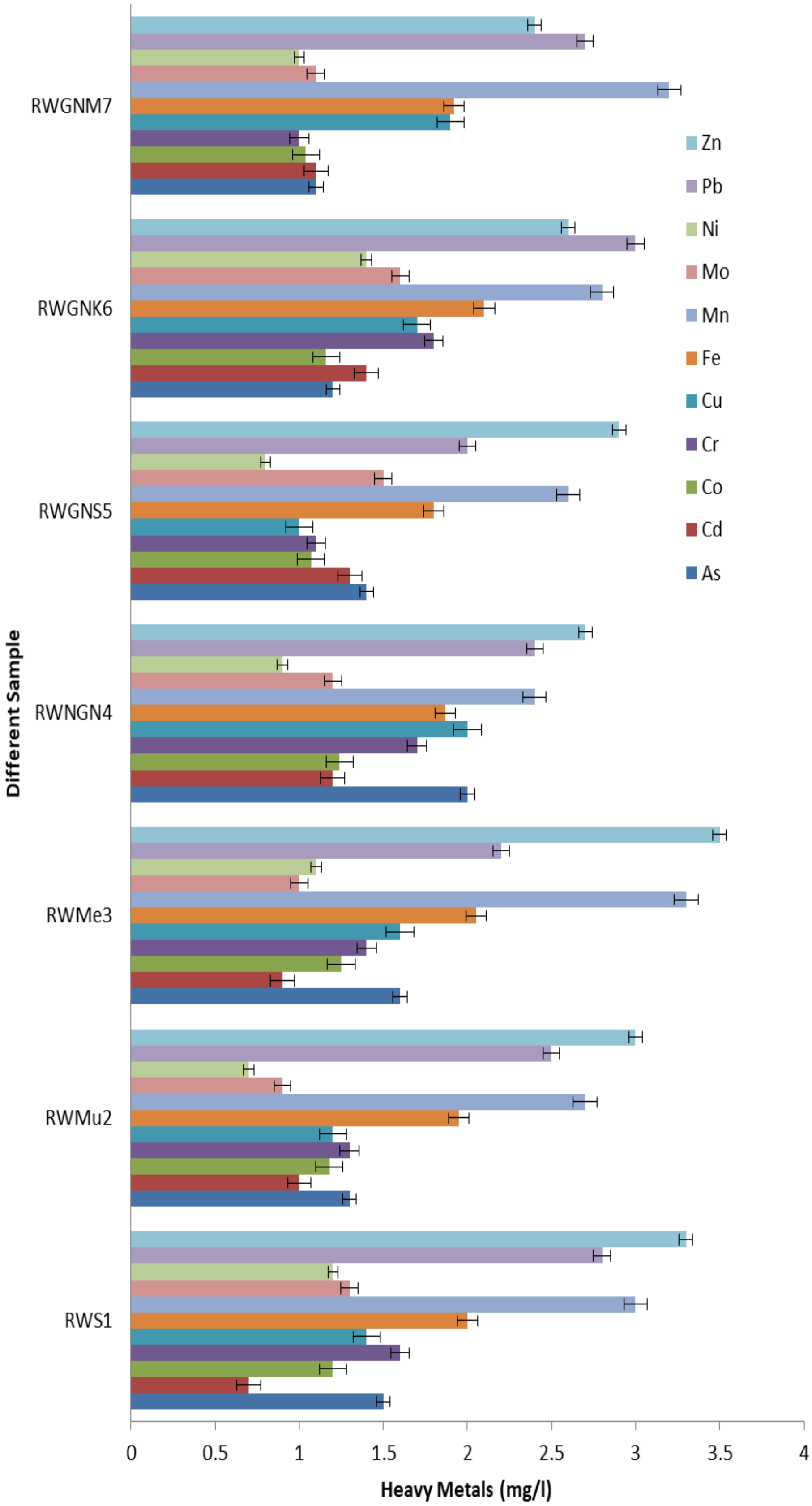


**Figure 5.** Level of heavy metals concentrations (mg/l) in water samples taken from multiple locations of the river Hindon in April, 2021.

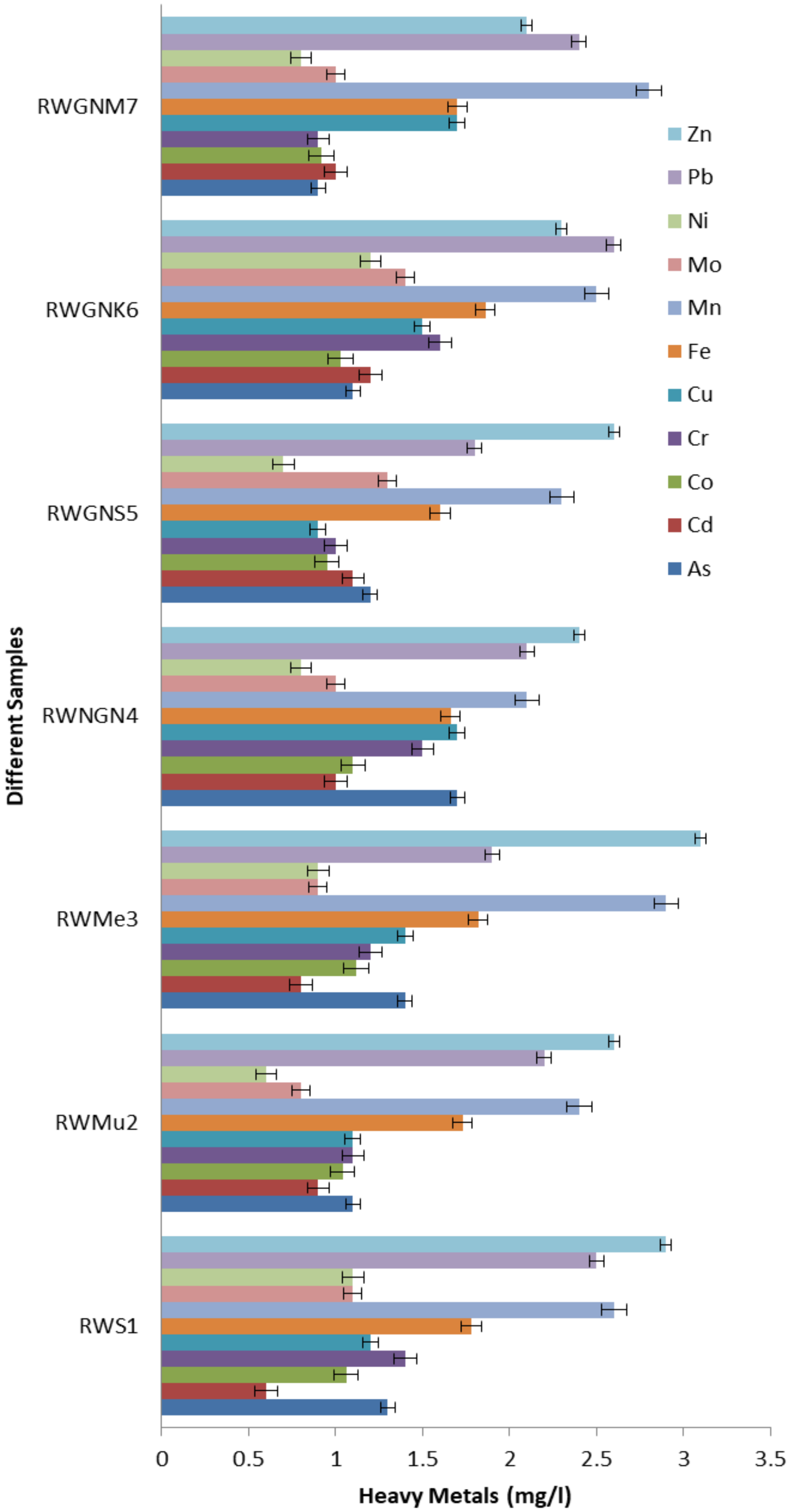


**Figure 6.** Level of heavy metals concentrations (mg/l) in water samples collected taken multiple locations of the river Hindon in August, 2021.

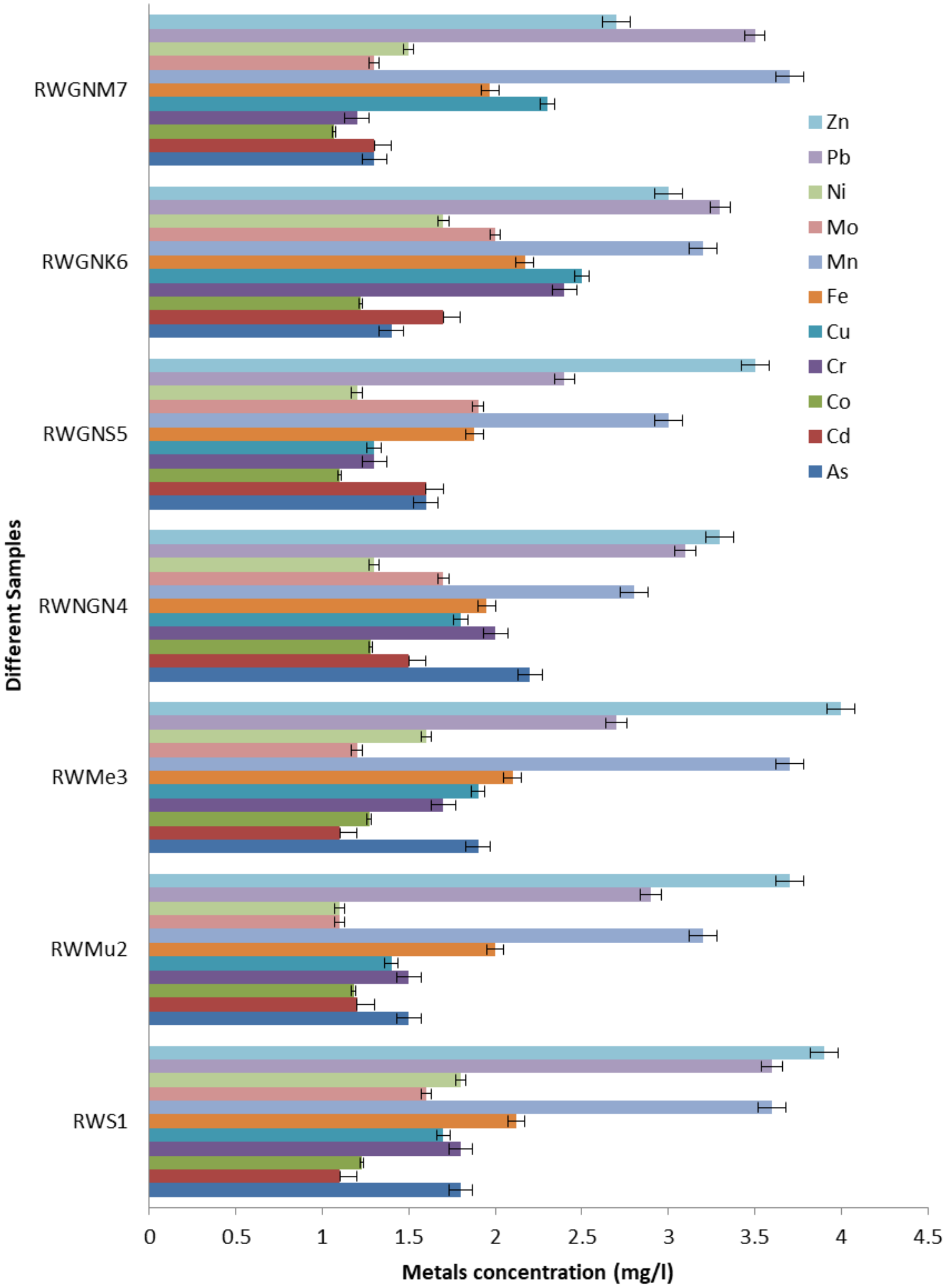


**Figure 7.** Levels of heavy metals (mg/l) in water samples collected from multiple locations of river Hindon in Dec., 2021.

The heavy metals were quantified using an Agilent 5110 Inductively Coupled Plasma - Optical Emission Spectrometer (ICP-OES) developed by Agilent, a US-based firm. The two sets of criteria were compared using recently generated metal standards in conjunction with pre-existing established norms. Calibration curves for testing heavy metals were created using standard metal solutions. The average values received from all three sets of identical data were used for each determination.

The levels of heavy metals in the water were lowest in August, compared to April and Dec., 2021. A comparison was carried out between the levels of different heavy metals, namely

cadmium, nickel, molybdenum, copper, arsenic, chromium, lead, manganese, zinc, cobalt, and iron, and the established standards set by the BIS (2012) and the WHO, UNICEF (2017). The examination of the levels of heavy metal concentration in the water of the river Hindon unveiled a progressive decline trend of Fe>Co>Zn>Mn>Pb>Cr>As>Cu>Mo>Ni>Cd.
The levels of heavy metal concentration in the month of April ranged from As 1.1-2.0 mg/l, Cd 0.7-1.4 mg/l, Co 1.04-1.25 mg/l, Cr 1.0-1.8mg/l, Cu 1.2-2.0 mg/l, Fe 1.87-2.10 mg/l, Mn 2.4-3.3 mg/l, Mo 0.9-1.6 mg/l, Ni 0.7-1.4 mg/l, Pb 2.0-3.0 mg/l and Zn 2.4-3.5 mg/l. In August, As 0.9-1.7 mg/l, Cd 0.6-1.2 mg/l, Co 9.2-1.12m g/l, Cr 9-1.5 mg/l, Cu 0.9-1.7 mg/l, Fe 1.60-1.86 mg/l, Mn 2.1-2.9 mg/l, Mo 0.8-1.4 mg/l, Ni 0.6-1.2 mg/l, Pb 1.9-2.6 mg/l, Zn 2.1-3.1mg/l. While, in Dec. the concentrations were As 1.3-2.2 mg/l, Cd 1.1-1.7 mg/l, Co 1.07-1.28 mg/l, Cr 1.2-2.4 mg/l, Cu 1.4-2.5 mg/l, Fe 1.88-2.17 mg/l, Mn 2.8-3.7 mg/l, Mo 1.1-2.0 mg/l, Ni 1.1-1.8 mg/l, Pb 2.4-3.6 mg/l, Zn 2.7-4.0 mg/l. In contrast, Sharma et al. (2021) found Fe concentrations ranging from 1.40 -1.90 to 1.21 - 1.59 mg/L, Cd concentrations ranging from 0.082 - 0.110 to 0.073 - 0.080 mg/L, and Pb concentrations ranging from 0.10- 0.13 to 0.08 - 0.10 mg/L in the river Hindon, Mohan Nagar barrage at Ghaziabad, Uttar Pradesh, India. The increased level of heavy metals possesses serious threat to the aquatic life forms. As result, extensive research has revealed that various human activities contribute to elevated levels of heavy metals in river water, potentially posing serious health risks to the aquatic ecosystem.

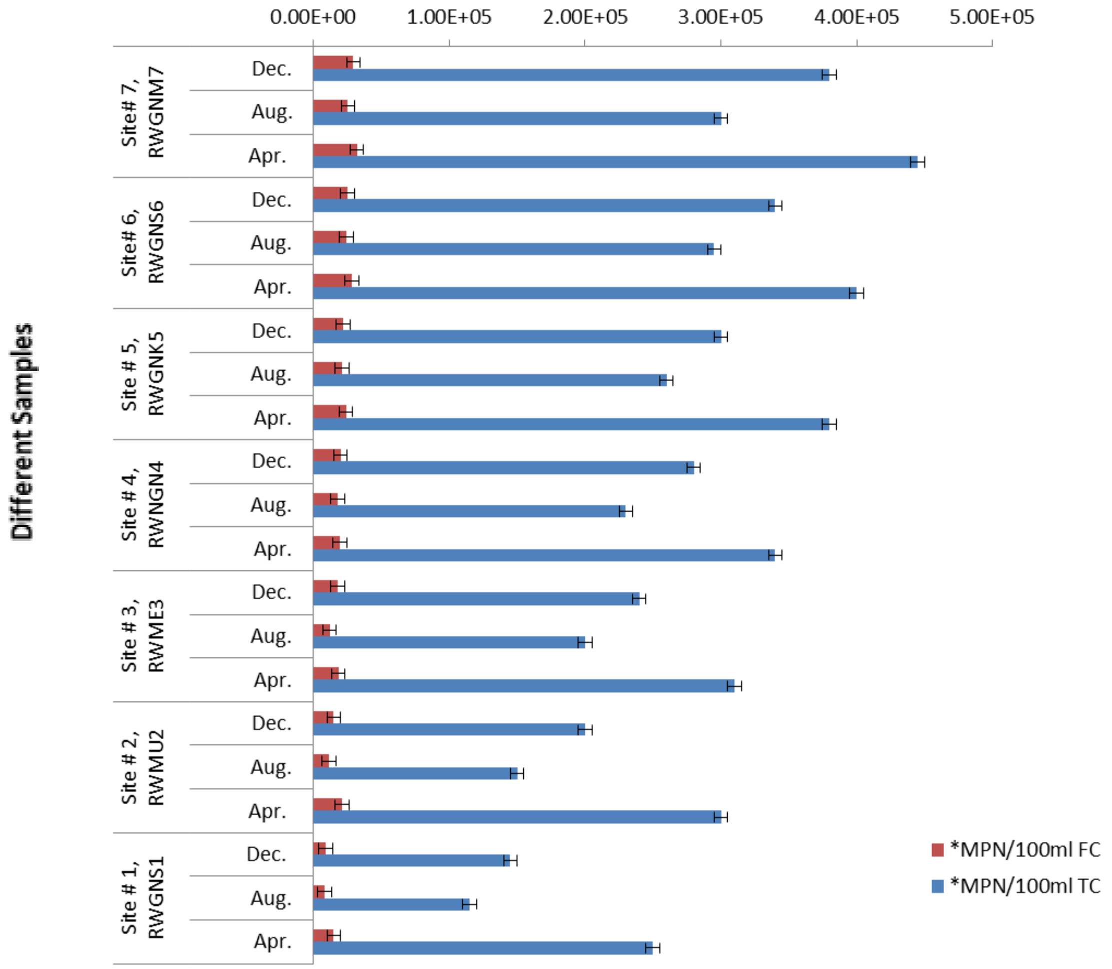


**Figure 9.** Levels of total coliform and faecal coliform in water samples collected throughout a year from various locations of the river Hindon.

Total coliforms (TC) and faecal coliform (FC) indicate the presence of pathogenic microorganisms commonly found in surface water, soil, and animal and human faeces. The

MPN/100 ml concentrations of TC and FC measured at all sampling locations exceeded the regulatory bodies' limit for river water bodies for drinking and recreational purposes (CPCB, 2013; WHO, 2017, Sharma et al., 2021). The selected sites of river Hindon have elevated total and faecal coliform density levels in the surface waters. The total coliform count was also significantly higher during April at Site #7 (445 × $10^3$ MPN/100 ml) and lower during monsoon at Site#1 (82 x $10^2$ MPN/100 ml). The highest total coliform and faecal coliform population were found at site #7, followed by sites #6 and #5. The increasing pattern of TC and FC can be attributed to urbanization, STPs, WWTPs, untreated disposal of sewage and open defecation along the river bank. Since, the monsoon dilutes the river water experienced the minimum TC value (115 x $10^3$ MPN/100ml) and FC value (90 x $10^2$ MPN/100ml) at site#1. On the other hand, the onset of cold of winter season did not support the optimum growth of bacteria (Tiefenthaler et al. 2008). Therefore, in Dec. the minimum TC value was (145 x $10^3$ MPN/100ml) and FC value (90 x $10^2$ MPN/100ml) at site#1. According to Schuettpelz (1969), researchers agree that faecal coliforms are more accurate indicators of sewage contamination than total coliforms. A sizable portion of the Indian population relies on treated river water as their main source of potable water. The analysis of faecal indicator bacteria provides a sensitive, albeit inefficient, method of assessing the contamination of surface waters and drinking water sources.

## Conclusion

Based on the observations of the present study, the river Hindon exhibits significant pollution levels resulting from the discharge of industrial effluents originating from different industries. These industries release partially treated or untreated pollutants into the Hindon river. The study observed a consistent pattern in the flow and volume of water, as well as the water quality parameters, which can be attributed to the ongoing mixing of sewage and industrial effluent in urban regions. Our observations on the physicochemical and microbiological parameters of the river Hindon, such as pH, DO, Turbidity, TDS, salinity, total hardness, calcium hardness, COD, BOD, heavy metals, total and faecal coliforms are very precious in term of water contamination. According to total coliform and faecal coliform, the water in the river Hindon found to be unfit for human consumption, and this waterway is assumed to be contaminated due to its proximity to the river Krishni and Kali. The pollution load from Ghaziabad and Noida, as well as industrial effluents, agriculture runoff and domestic waste from this area are responsible sources for the decline in water quality of the river Hindon. Therefore, based on the aforementioned data, it can be concluded that the river Hindon exhibits significant pollution levels and a deteriorating surface water quality.

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## Conflicts of Interest

The authors declare no conflict of interest in this work.

## References

1. Abd-Elhamid, H. F., Abd-Elmoneem, S. M., Abdelaal, G. M., Zeleňáková, M., Vranayova, Z., & Abd-Elaty, I. (2021). Investigating and managing the impact of using untreated wastewater for irrigation on the groundwater quality in arid and semi-arid regions. International Journal of Environmental Research and Public Health, 18(14), 7485.
2. APHA. 1998. Standard Methods for the Examination of Water and Waste Water, 20th Edition. American Public Health Association, Washington DC.
3. Bhutiani, R., Ruhela, M., & Ahamad, F. (2017). Limnological characterization of Hindon River at NCR (Uttar Pradesh), India. Environment Conservation Journal, 18 (1 & 2), 219-229.
4. BIS (2012). Bureau of Indian standards-Drinking water specifications IS 10500:2012.
5. Chabukdhara, M., & Nema, A. K. (2012). Assessment of heavy metal contamination in Hindon River sediments: a chemometric and geochemical approach. Chemosphere, 87(8), 945-953.
6. Chang, H. (2005). Spatial and temporal variations of water quality in the Han River and its tributaries, Seoul, Korea, 1993–2002. Water, Air, and Soil Pollution, 161,

267-284.
7. CPCB (Central Pollution Control Board) Central Pollution Control Board, Government of India; 2013. Pollution Assessment: RiverGanga. http://www.nationalwatermission.gov.in/sites/default/files/waterwiki/2.pdf.
8. Das, R., Samal, N.R., Roy, P. K, Mitra, D (2006). Role of electrical conductivity as an indicator of pollution in shallow lakes. Asian Journal of Water, Environment and Pollution 3(1), 143-146.
9. Gupta, N., Pandey, P., & Hussain, J. (2017). Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. Water Science, 31(1), 11-23.
10. Gwimbi, P., George, M., & Ramphalile, M. (2019). Bacterial contamination of drinking water sources in rural villages of Mohale Basin, Lesotho: exposures through neighbourhood sanitation and hygiene practices. Environmental Health and Preventive Medicine, 24, 1-7.
11. Khadse, G. K., Patni, P. M., Kelkar, P. S., & Devotta, S. (2008). Qualitative evaluation of Kanhan river and its tributaries flowing over central Indian plateau. Environmental Monitoring and Assessment, 147, 83 - 92.
12. Kumar, A.A., Logasamy, S., Thirumathal, K., Aruchami, M. (1989) Environmental investigation on the river Amaravathi. Environmental Conservation and Management. 22, 85 - 92
13. Ministry of Water Resources Central Water Commission (2014). Guidelines for improving water use efficiency in irrigation, domestic & industrial sectors. Performance overview & management improvement organization irrigation performance overview directorate. http://mowr.gov.in/sites/default/files/Guidelines_for_improving_water_use_efficiency_1.pdf
14. Mishra, S., Kumar, A., & Shukla, P. (2016). Study of water quality in Hindon River using pollution index and environmetrics, India. Desalination and Water Treatment, 57 (41), 19121-19130.
15. Mukesh, R., Rakesh, B., & Faheem, A. (2017). Pollution status of River Hindon from Ghaziabad to Noida with special reference to heavy metals. International Journal of Advance Engineering and Research Development, 4(8), 540-548.
16. Patil S., G., Chonde S., G., Jadhav A., S., & Raut, P., D. (2012). Impact of physico-chemical characteristics of Shivaji University lakes on phytoplankton communities, Kolhapur, India. Research Journal of Recent Sciences, 1(2), 56-60,
17. Patil, V. T., & Patil, P. R. (2010). Physicochemical analysis of selected groundwater samples of Amalner Town in Jalgaon District, Maharashtra, India. Journal of Chemistry, 7, 111-116.
18. Rajasulochana, P., & Preethy, V. (2016). Comparison on efficiency of various techniques in treatment of waste and sewage water–a comprehensive review. Resource-Efficient Technologies, 2 (4): 175–184.
19. Rehman, F., Subyani, A. M., Cheema, T., Harbi, H. M., Azeem, T., Naseem, A. A., Rehman, F., Ullah, M.F., Riaz, O. and Rehman, S. (2020). Contribution to the comparative study of treated and untreated wastewater: a case study (Wadi Fatima and Al Misk Lake) in Saudi Arabia. Arabian Journal of Geosciences, 13, 1-11.
20. Rice, E. W., Bridgewater, L., & American Public Health Association (Eds.). (2012). Standard methods for the examination of water and wastewater (Vol. 10). Washington, DC: American public health association.
21. Rizvi, N., Katyal, D., & Joshi, V. (2015) Assessment of water quality of Hindon River in Ghaziabad and Noida, India, by using multivariate statistical methods. Journal of Global Ecology and Environment, 3(2), 80-90.
22. Rizvi, S. W. A., Zaidi, A. A., & Singh, O. V. (2017). Microbial Pollution of River Ganga: A Review. Aquatic Ecosystem Health & Management, 20 (1), 1-14.
23. Schuettpelz, D. H. (1969). Fecal and total coliform tests in water quality evaluation (No. 42). Department of Natural Resources.
24. Sharma, M. K., Jain, C. K., Singhal, D. C., & Choubey, V. K. (2009). Kinetics of sorption of lead on bed sediments of River Hindon, India. Environmental Monitoring and Assessment, 157, 11-21.
25. Sharma, R., Kumar, A., Singh, N., & Sharma, K. (2021). Impact of seasonal variation on water quality of Hindon River: physicochemical and biological analysis. SN Applied Sciences, 3, 1-11.
26. Srinivas C. H., Piska R. S., Venkateshwar, C., Rao. M.S.S., Reddy, R.R. (2000) Studies on ground water quality of Hyderabad. Pollution Research. 19, 285–289

27. Suthar, S., Nema, A. K., Chabukdhara, M., & Gupta, S. K. (2009). Assessment of metals in water and sediments of Hindon River, India: impact of industrial and urban discharges. Journal of Hazardous materials, 171 (1-3), 1088-1095.
28. Tiefenthaler, L. L., Stein, E. D., & Lyon, G. S. (2009). Fecal indicator bacteria (FIB) levels during dry weather from Southern California reference streams. Environmental Monitoring & Assessment, 155, 477-492.
29. Water quality and Waste Water Management-Vision 2012–2017. http://mohua.gov.in/upload/uploadfiles/files/Water_Mgmt_CPCB_PPT_0.pdf
30. WaterAid India Country Strategy 2016 2021. https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/WaterAid_India_Country_Programme_Strategy_2016_2021.pdf
31. Wen, Y., Schoups, G., & Van De Giesen, N. (2017). Organic pollution of rivers: Combined threats of urbanization, livestock farming and global climate change. Scientific Reports, 7(1), 43289.
32. WHO, UNICEF (2017) Progress on drinking water, sanitation and hygiene: 2017 update and SDG baselines. World Health Organization (WHO) and the United Nations Children’s Fund (UNICEF), Geneva, ISBN: 978-92-4-154995-0, Licence: CC BY-NC-SA 3.0 IGO.
33. World Health Organization (WHO). Guidelines for Drinking—Water Quality, 2nd ed.; World Health Organization (WHO): Geneva, Switzerland, 1998; Volume 2, Available online: http://www.who.int/water_sanitation_health/dwq/2edaddvol2a.pdf (accessed on 1 June 2017).
34. Yadav, A. K., Gupta, N., & Singh, A. K. (2019) Pysicochemical and Bacteriological Analysis of River Ganga Water in Varanasi District, Uttar Pradesh, India. International Journal of Current Microbiology and Applied Sciences, 8 (1), 2839-2846.
35. Yadavel, P., Rubela, S., & Singh, A. K. (2017). Physico-Chemical and bacteriological analysis of River Ganga water in Allahabad District, Uttar Pradesh, India. International Journal of Current Microbiology and Applied Sciences, 6 (4), 2025-2033.