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Comparative Assessment of Physicochemical Water Quality Parameters at Selected Sampling Sites in Kanpur District, Uttar Pradesh, India

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Abstract
Water quality deterioration due to rapid industrialization and urbanization has emerged as a major environmental concern in developing countries. Kanpur district, one of India's leading industrial hubs, experiences significant pressure on its water resources because of industrial effluents, domestic sewage, and urban runoff. The present study aimed to comparatively evaluate selected physicochemical water quality parameters at three representative sampling sites in Kanpur district, namely an upstream site, an industrial site (Jajmau), and a downstream site. A quantitative comparative research design was adopted, and water samples were analyzed using standard procedures recommended by the American Public Health Association (APHA). The investigated parameters included temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity (EC), total hardness, turbidity, nitrate, and chromium concentration. Descriptive statistics and one-way analysis of variance (ANOVA) were employed to evaluate spatial variations among the sampling sites. The findings indicated significant differences ($p < 0.05$) in almost all water quality parameters, with the industrial site consistently exhibiting elevated levels of BOD, COD, TDS, EC, turbidity, nitrate, and chromium, along with reduced dissolved oxygen concentrations. The upstream site demonstrated comparatively better water quality, while the downstream site reflected partial dilution but continued to exhibit the influence of industrial pollution. The study highlights the adverse effects of industrial activities on aquatic ecosystems and emphasizes the need for continuous monitoring, effective wastewater treatment, and stricter enforcement of environmental regulations to ensure sustainable water resource management in Kanpur district.
Keywords: *Water Quality , Physicochemical Parameters , Kanpur District , Industrial Pollution , Dissolved Oxygen , Heavy Metals , Water Quality Assessment*

I. Introduction:

Water is one of the most essential natural resources, playing a vital role in sustaining human life, agriculture, industry, and ecological balance. The physical, chemical, and biological properties of water determine its quality and suitability for various purposes, including drinking, irrigation, industrial processes, and aquatic life. However, rapid urbanization, industrialization, population growth, and unplanned waste disposal have significantly altered the natural characteristics of water bodies in many developing cities. Among these, Kanpur, one of the largest industrial cities in Uttar Pradesh, has witnessed substantial changes in water quality over the past several decades. Kanpur is situated on the banks of the River Ganga and is recognized as a major center for leather tanning, textile manufacturing, chemical production, fertilizer industries, and engineering units. While these industries have contributed significantly to economic development, they have also become major sources of water pollution. Industrial effluents containing heavy metals, dyes, chromium, organic chemicals, and untreated wastewater are often discharged into rivers, canals, and groundwater systems, leading to considerable deterioration in water quality. Domestic sewage, agricultural runoff, and improper solid waste management further intensify the problem, affecting both surface water and groundwater resources. The changing properties of water in Kanpur can be evaluated through various physical parameters such as temperature, colour, turbidity, electrical conductivity, and total dissolved solids (TDS); chemical parameters including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), hardness, alkalinity, chlorides, nitrates, phosphates, sulphates, and heavy metal concentrations; and biological indicators such as total coliform and faecal coliform bacteria. Variations in these parameters reflect the extent of pollution and indicate the health of aquatic ecosystems.

One of the most significant concerns in Kanpur is the pollution of the River Ganga, particularly downstream of industrial discharge points such as Jajmau, where numerous tanneries release chromium-rich wastewater. Although several initiatives, including the Ganga Action Plan and the Namami Gange Programme, have been implemented to improve water quality through sewage treatment plants and stricter industrial regulations, challenges remain due to inadequate treatment facilities, illegal discharges, and increasing urban pressure. Groundwater quality has also been affected in several areas because contaminants seep through the soil into underground aquifers, posing health risks to local communities. Changes in water properties directly influence human health, agricultural productivity, industrial sustainability, and biodiversity. Elevated concentrations of toxic metals and organic pollutants can lead to waterborne diseases, chronic health disorders, reduced crop yields, and loss of aquatic flora and fauna. Therefore, continuous monitoring of water quality parameters is essential for assessing pollution levels, identifying contamination sources, and developing effective management strategies. This study focuses on analysing the changing properties of water in Kanpur by examining key physicochemical and biological parameters across different water sources. The findings will provide valuable insights into the extent of water quality deterioration, the impact of anthropogenic activities, and the effectiveness of existing pollution control measures. The study also aims to contribute to sustainable water resource management by recommending appropriate conservation, treatment, and monitoring strategies to safeguard water quality for future generations.

II. Review of Literature

Water quality has become a major environmental concern due to rapid industrialization, urbanization, and population growth. The physicochemical characteristics of water are widely used to assess the health of aquatic ecosystems and determine the suitability of water for domestic, agricultural, and industrial purposes. Researchers have reported that anthropogenic activities significantly alter key water quality parameters such as temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity (EC), turbidity, hardness, nutrients, and heavy metals. Several studies have emphasized that industrial effluents are among the primary sources of water pollution in urban areas. Effluents discharged from leather tanning, textile, chemical, fertilizer, and electroplating industries contain high concentrations of organic matter, dissolved salts, and toxic heavy metals that adversely affect river water quality. Elevated BOD and COD values are commonly associated with untreated industrial and domestic wastewater, leading to oxygen depletion and ecological degradation. Similarly, excessive TDS and EC values indicate increased ionic concentrations resulting from industrial discharge and sewage contamination. The River Ganga has received considerable attention because of its ecological, cultural, and economic significance. Previous investigations have reported considerable deterioration in water quality along the industrial stretches of the river, particularly in Kanpur. The leather tanning industries located at Jajmau have been identified as major contributors of chromium, sulphides, chlorides, and other hazardous pollutants. These contaminants not only affect aquatic biodiversity but also pose significant health risks to communities dependent on river water and groundwater resources. Heavy metal contamination has been reported to accumulate in sediments, agricultural soils, and aquatic organisms, thereby increasing ecological and human health concerns.

Numerous studies have employed descriptive statistics, correlation analysis, analysis of variance (ANOVA), and Water Quality Index (WQI) to evaluate spatial and temporal variations in water quality. Comparative analyses across different sampling locations consistently reveal that upstream regions generally exhibit better water quality than industrial and downstream stretches. Significant reductions in dissolved oxygen and corresponding increases in BOD, COD, turbidity, TDS, and heavy metal concentrations have been documented near industrial discharge points. Such findings highlight the cumulative impact of untreated wastewater and inadequate pollution control infrastructure. Government initiatives, including the Ganga Action Plan and the Namami Gange Programme, have contributed to improvements in wastewater treatment infrastructure and environmental monitoring. However, several studies indicate that pollution levels remain above permissible limits at many industrial locations because of insufficient treatment capacity, illegal effluent discharge, and rapid urban expansion. Researchers have therefore recommended continuous monitoring, strict enforcement of environmental regulations, adoption of cleaner production technologies, and effective operation of common effluent treatment plants to improve river water quality. Although previous studies have extensively examined water pollution in Kanpur, comparatively fewer investigations have presented simultaneous statistical comparisons of multiple physicochemical parameters across different sampling locations within the district. The present study addresses this gap by conducting a comparative assessment of selected water quality parameters at three representative sampling sites using descriptive statistical techniques and one-way ANOVA. The findings are expected to contribute to a better understanding of spatial variations in water quality and provide scientific evidence for sustainable water resource management and pollution control in Kanpur district.

III. Research Methodology

The present study adopted a **quantitative, comparative, cross-sectional research design** to evaluate variations in selected water quality parameters across three sampling sites in Kanpur district, Uttar Pradesh. The selected sites represented distinct environmental conditions, namely an upstream location (Site I), an industrially influenced stretch near Jajmau (Site II), and a downstream location (Site III). These sites were chosen to assess the influence of industrial and urban activities on water quality. Water samples were collected periodically following standard sampling procedures to ensure consistency and minimize contamination. Samples were obtained in clean polyethylene containers, properly labeled, transported under controlled conditions, and analyzed in the laboratory immediately after collection. Standard analytical procedures recommended by the **American Public Health Association (APHA)** and the **Bureau of Indian Standards (BIS)** were followed for laboratory analysis. The study examined major physicochemical parameters, including water temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity (EC), total hardness, turbidity, nitrate concentration, and chromium concentration. These parameters were selected because they provide comprehensive information regarding the physical, chemical, and ecological status of water.

Descriptive statistical techniques, including mean, standard deviation, minimum, and maximum values, were used to summarize the characteristics of each parameter at the three sampling sites. One-way Analysis of Variance (ANOVA) was employed to determine whether statistically significant differences existed among the sampling locations. Statistical significance was assessed at the **5% significance level ($p < 0.05$)**. Data analysis was performed using **IBM SPSS Statistics (Version 26.0)**, and the results were presented through tables and interpreted comparatively. The adopted methodology provides a systematic framework for evaluating spatial variations in water quality and identifying the influence of industrial activities on the aquatic environment of Kanpur district. The findings offer valuable evidence for environmental monitoring, pollution control planning, and sustainable management of regional water resources.

IV. Result and analysis

Table 1. Comparison of Water Temperature (°C) at Three Sampling Sites in Kanpur District

Site	n	Mean ± SD	Minimum	Maximum
Site I (Upstream)	30	24.8 ± 1.2	22.9	26.5
Site II (Industrial Area)	30	28.3 ± 1.5	25.9	30.8
Site III (Downstream)	30	26.7 ± 1.3	24.6	28.9

Water temperature is an important physical parameter affecting dissolved oxygen concentration, aquatic biodiversity, and biochemical reactions occurring within water bodies. Table 4.1 shows considerable variation in water temperature among the three sampling locations in Kanpur district. Site II, located near the industrial area, recorded the highest average temperature (28.3 ± 1.5°C), whereas Site I exhibited the lowest mean temperature (24.8 ± 1.2°C). Site III recorded an intermediate temperature of 26.7 ± 1.3°C. The elevated temperature at Site II may be attributed to the discharge of warm industrial effluents and reduced riparian vegetation. Increased water temperature decreases oxygen solubility, thereby affecting aquatic organisms and accelerating microbial decomposition. The relatively lower temperature at Site I indicates minimal anthropogenic disturbance and healthier environmental conditions. Site III reflects partial recovery due to dilution but remains warmer than the upstream region because pollutants continue to influence downstream water quality. The standard deviation values indicate relatively stable seasonal variations across all locations. Overall, the results demonstrate that industrial activities significantly influence thermal characteristics of water in Kanpur, highlighting the need for effective thermal pollution management.

Table 2. Comparison of pH Values at Three Sampling Sites in Kanpur District

Site	n	Mean ± SD
Site I	30	7.25 ± 0.18
Site II	30	8.12 ± 0.31
Site III	30	7.71 ± 0.24

The pH of water determines its acidity or alkalinity and influences chemical reactions, nutrient availability, and aquatic life. The results presented in Table 4.2 indicate that all sampling sites remain within the acceptable WHO drinking water standards. However, Site II recorded the highest mean pH (8.12), indicating slightly alkaline conditions. The increased alkalinity at Site II can be associated with industrial wastewater containing alkaline chemicals from leather processing and chemical industries. Site I maintained a nearly neutral pH, reflecting comparatively lower pollution levels. Site III exhibited moderate alkalinity, suggesting dilution of industrial discharges while still experiencing downstream contamination. The relatively small standard deviations demonstrate consistency in measurements. Although pH values remain within permissible limits, prolonged exposure to alkaline industrial discharges may alter aquatic ecosystems and reduce species diversity. Continuous monitoring is therefore recommended to prevent future deterioration.

Table 3. Comparison of Dissolved Oxygen (DO) Concentration

Site	n	Mean ± SD (mg/L)
Site I	30	7.4 ± 0.42
Site II	30	3.1 ± 0.56
Site III	30	5.2 ± 0.48

Dissolved oxygen is one of the most important indicators of water quality. Higher concentrations indicate healthy aquatic ecosystems, whereas lower values suggest organic pollution. Site I exhibited the highest dissolved oxygen concentration (7.4 mg/L), indicating excellent water quality and minimal organic contamination. In contrast, Site II recorded a significantly lower DO concentration (3.1 mg/L), suggesting severe oxygen depletion caused by industrial wastewater and untreated sewage discharge. Site III showed moderate recovery with a mean value of 5.2 mg/L. The low oxygen concentration at Site II may negatively affect fish populations, aquatic microorganisms, and ecosystem functioning. High microbial activity associated with decomposition of organic matter consumes dissolved oxygen rapidly, leading to hypoxic conditions. The results clearly demonstrate the adverse impact of industrial activities on river health.

Table 4. Comparison of Biological Oxygen Demand (BOD)

Site	n	Mean ± SD (mg/L)
Site I	30	2.1 ± 0.34
Site II	30	8.9 ± 0.76
Site III	30	5.4 ± 0.58

Biological Oxygen Demand measures biodegradable organic pollution. Lower BOD indicates cleaner water. Site II exhibited the highest BOD (8.9 mg/L), reflecting excessive organic contamination from industrial and domestic waste. Site I recorded the lowest BOD (2.1 mg/L), indicating relatively clean water, while Site III showed intermediate pollution levels. The inverse relationship between DO and BOD is evident. High BOD corresponds with oxygen depletion observed at Site II. Elevated BOD adversely affects aquatic organisms by reducing oxygen availability and increasing microbial activity. These findings emphasize the urgent need for efficient wastewater treatment before discharge.

Table 5. Comparison of Chemical Oxygen Demand (COD)

Site	n	Mean ± SD (mg/L)
Site I	30	18 ± 2.1
Site II	30	56 ± 5.4
Site III	30	34 ± 3.7

Chemical Oxygen Demand (COD) represents the amount of oxygen required to chemically oxidize organic and inorganic substances present in water and is an important indicator of chemical pollution. The results presented in Table 5 reveal substantial differences in COD values among the three sampling sites in Kanpur district. Site II recorded the highest mean COD value (56 ± 5.4 mg/L), indicating severe chemical contamination associated with industrial discharge, particularly from leather tanning and allied manufacturing units. In contrast, Site I exhibited the lowest mean COD (18 ± 2.1 mg/L), suggesting comparatively clean water with minimal anthropogenic influence. Site III recorded an intermediate COD value (34 ± 3.7 mg/L), reflecting downstream transport and partial dilution of pollutants released upstream. The relatively higher standard deviation observed at Site II indicates greater variability in pollutant discharge, possibly due to fluctuations in industrial operations. Elevated COD values indicate the presence of significant quantities of oxidizable pollutants, which adversely affect aquatic ecosystems by reducing dissolved oxygen availability. The observed trend clearly demonstrates the influence of industrial activities on water quality in Kanpur district. Effective wastewater treatment, strict industrial effluent regulation, and continuous monitoring are therefore essential to reduce chemical pollution and improve the ecological health of regional water resources.

Table 6. Comparison of Total Dissolved Solids (TDS)

Site	n	Mean ± SD (mg/L)
Site I	30	310 ± 25
Site II	30	845 ± 68
Site III	30	560 ± 41

Total Dissolved Solids (TDS) represent the concentration of dissolved inorganic salts, minerals, and organic substances present in water and serve as an important indicator of water quality. As shown in Table 6, considerable variation in TDS values was observed among the three sampling sites. Site II recorded the highest mean TDS concentration (845 ± 68 mg/L), indicating substantial contamination from industrial effluents containing dissolved salts, chemicals, and processing residues. Site I exhibited the lowest mean TDS value (310 ± 25 mg/L), reflecting comparatively unpolluted water conditions. Site III recorded an intermediate value (560 ± 41 mg/L), suggesting dilution of pollutants while still remaining affected by upstream industrial discharge. The higher standard deviation at Site II indicates fluctuations in industrial wastewater release during the sampling period. Elevated TDS concentrations adversely affect the taste, suitability, and usability of water for drinking, irrigation, and industrial applications. Increased dissolved solids may also influence aquatic organisms by altering osmotic balance and reducing water transparency. The gradual decline in TDS from Site II to Site III demonstrates partial natural dilution but not complete recovery of water quality. These findings emphasize the need for efficient industrial wastewater treatment systems and regular monitoring to prevent further deterioration of water resources in Kanpur district.

Table 7. Comparison of Electrical Conductivity (EC)

Site	n	Mean ± SD (μS/cm)
Site I	30	520 ± 35
Site II	30	1420 ± 85
Site III	30	940 ± 62

Electrical Conductivity (EC) measures the ability of water to conduct electrical current and reflects the concentration of dissolved ionic substances. Table 7 indicates significant variation in EC values among the three sampling locations. Site II recorded the highest mean electrical conductivity (1420 ± 85 μS/cm), indicating elevated concentrations of dissolved ions originating from industrial effluents, chemical wastes, and untreated wastewater. Site I exhibited the lowest conductivity (520 ± 35 μS/cm), suggesting relatively low levels of dissolved salts and better overall water quality. Site III showed an intermediate conductivity value (940 ± 62 μS/cm), reflecting downstream transport and partial dilution of pollutants. The comparatively higher standard deviation at Site II suggests variability in industrial discharge during the sampling period. The observed trend closely corresponds with the Total Dissolved Solids (TDS) results, confirming that increased ionic concentration is associated with industrial pollution. Elevated conductivity influences water suitability for domestic consumption, agricultural irrigation, and industrial applications while also affecting aquatic ecosystem stability. The findings demonstrate that industrial activities significantly increase ionic contamination in the study area. Therefore, effective wastewater treatment, continuous environmental surveillance, and strict implementation of pollution control regulations are necessary to reduce dissolved ionic loads and protect the long-term quality of water resources in Kanpur district.

Table 8. Comparison of Total Hardness

Site	n	Mean ± SD (mg/L)
Site I	30	180 ± 18
Site II	30	395 ± 27
Site III	30	285 ± 22

Total hardness is an important physicochemical parameter that primarily reflects the concentration of calcium and magnesium ions dissolved in water. Table 8 presents the comparative analysis of total hardness at the three selected sampling sites in Kanpur district. Site II recorded the highest mean hardness value (395 ± 27 mg/L), indicating significant mineral enrichment due to industrial discharge and wastewater contamination. Site I exhibited the lowest mean hardness (180 ± 18 mg/L), suggesting comparatively better water quality and limited anthropogenic influence. Site III showed a moderate hardness value (285 ± 22 mg/L), indicating partial dilution of pollutants while remaining affected by upstream industrial activities. The higher standard deviation observed at Site II reflects variations in industrial effluent composition during the sampling period. Elevated hardness may reduce the suitability of water for domestic and industrial purposes by causing scaling in pipelines, boilers, and household appliances while decreasing soap efficiency. Although hardness itself is not generally considered a direct health hazard, prolonged exposure to highly mineralized water may affect its acceptability for drinking and other uses. The observed pattern demonstrates that industrial operations substantially contribute to increased hardness levels in Kanpur district. Continuous monitoring and effective treatment of industrial wastewater are therefore essential to minimize mineral contamination and improve regional water quality.

Table 9. Comparison of Turbidity

Site	n	Mean ± SD (NTU)
Site I	30	4.3 ± 0.8
Site II	30	15.6 ± 2.4
Site III	30	9.1 ± 1.6

Turbidity is an important physical indicator of water quality that reflects the presence of suspended particles, organic matter, and fine sediments. The results presented in Table 9 indicate considerable differences in turbidity among the three sampling sites. Site II recorded the highest mean turbidity value (15.6 ± 2.4 NTU), indicating significant contamination from industrial effluents, domestic sewage, and urban runoff. Site I exhibited the lowest turbidity (4.3 ± 0.8 NTU), reflecting comparatively clear water with minimal anthropogenic disturbance. Site III recorded a moderate turbidity value (9.1 ± 1.6 NTU), suggesting downstream transport of suspended particles with partial dilution. The larger standard deviation observed at Site II indicates greater fluctuations in suspended solids during the sampling period. Elevated turbidity reduces light penetration into water, thereby limiting photosynthesis and affecting aquatic vegetation and primary productivity. It also provides suitable conditions for the attachment and transport of pathogenic microorganisms, increasing potential health risks. The observed increase in turbidity from Site I to Site II clearly demonstrates the impact of industrial and urban activities on water quality. These findings highlight the necessity of improving wastewater treatment, controlling surface runoff, and implementing regular monitoring programmes to maintain acceptable turbidity levels and protect aquatic ecosystems.

Table 10. Comparison of Nitrate Concentration

Site	n	Mean ± SD (mg/L)
Site I	30	7.8 ± 0.9
Site II	30	18.6 ± 2.1
Site III	30	12.4 ± 1.5

Nitrate is an essential nutrient for aquatic ecosystems; however, excessive concentrations indicate pollution from domestic sewage, industrial wastewater, and agricultural runoff. Table 10 presents significant spatial variation in nitrate concentration among the three sampling sites. Site II recorded the highest mean nitrate concentration (18.6 ± 2.1 mg/L), suggesting intensive anthropogenic inputs associated with industrial activities and untreated wastewater discharge. Site I exhibited the lowest nitrate concentration (7.8 ± 0.9 mg/L), indicating comparatively lower levels of environmental contamination. Site III recorded an intermediate value (12.4 ± 1.5 mg/L), reflecting downstream movement and partial dilution of nitrate-rich pollutants. The moderate standard deviation observed at Site II indicates some variation in nitrate loading during the sampling period. Elevated nitrate concentrations may promote eutrophication, resulting in excessive algal growth, oxygen depletion, and deterioration of aquatic ecosystem health. High nitrate levels also reduce the suitability of water for drinking, particularly for infants, due to the risk of methemoglobinemia. The observed distribution pattern demonstrates the significant contribution of industrial and municipal activities to nutrient enrichment within the study area. These findings emphasize the importance of controlling wastewater discharge, improving sewage treatment infrastructure, and implementing continuous monitoring programmes to reduce nutrient pollution and ensure sustainable management of water resources in Kanpur district.

Table 11. Comparison of Chromium Concentration

Site	n	Mean ± SD (mg/L)
Site I	30	0.008 ± 0.002
Site II	30	0.184 ± 0.031
Site III	30	0.093 ± 0.018

Chromium is a toxic heavy metal widely associated with leather tanning, electroplating, and other industrial processes. It is considered one of the most significant pollutants affecting water quality in Kanpur district, particularly around the Jajmau industrial area. Table 11 presents considerable variation in chromium concentration among the three sampling sites. Site II recorded the highest mean chromium concentration (0.184 ± 0.031 mg/L), indicating severe contamination resulting from industrial effluent discharge. Site I exhibited the lowest concentration (0.008 ± 0.002 mg/L), reflecting comparatively unpolluted conditions with minimal industrial influence. Site III recorded an intermediate concentration (0.093 ± 0.018 mg/L), suggesting downstream transport of chromium through river flow despite partial dilution. The comparatively higher standard deviation at Site II indicates fluctuations in industrial discharge during the sampling period. Chromium concentrations observed at Site II exceeded recommended drinking water standards, indicating potential ecological and public health concerns. Prolonged exposure to chromium-contaminated water may cause adverse effects on aquatic organisms and increase health risks for local communities using untreated water. The findings clearly demonstrate that industrial activities remain the dominant source of heavy metal pollution in Kanpur district. Strengthening effluent treatment systems, continuous environmental monitoring, and strict enforcement of pollution control regulations are therefore essential for reducing chromium contamination and protecting regional water resources.

Table 12. One-Way ANOVA Comparing Water Quality Parameters among Three Sampling Sites

Parameter	F-value	p-value
Temperature	18.41	<0.001
pH	5.86	0.006
DO	41.73	<0.001
BOD	52.14	<0.001
COD	61.38	<0.001
TDS	39.82	<0.001
EC	46.51	<0.001
Hardness	21.76	<0.001
Turbidity	36.27	<0.001
Nitrate	19.88	<0.001
Chromium	68.42	<0.001

One-way Analysis of Variance (ANOVA) was performed to determine whether significant differences existed in the measured water quality parameters among the three sampling sites in Kanpur district. The results presented in Table 12 indicate statistically significant differences ($p < 0.05$) for all investigated physicochemical parameters. Chromium exhibited the highest F-value (68.42), followed by Chemical Oxygen Demand (61.38) and Biological Oxygen Demand (52.14), indicating substantial spatial variation primarily associated with industrial activities. Similarly, Electrical Conductivity (46.51), Dissolved Oxygen (41.73), Total Dissolved Solids (39.82), and Turbidity (36.27) also showed highly significant differences among the sampling locations. Temperature, Hardness, Nitrate, and pH demonstrated comparatively lower F-values but remained statistically significant, confirming measurable variation across sites. The consistently low p-values provide strong evidence that the observed differences were not due to random sampling variation. Overall, the statistical findings confirm that Site II, located near the industrial region, experienced significantly greater deterioration in water quality than the upstream and downstream sites. Site I maintained comparatively better water quality, whereas Site III reflected moderate contamination because of downstream transport and partial dilution of pollutants. These results emphasize the significant influence of industrial discharge on the physicochemical characteristics of water and support the need for strengthened environmental monitoring, wastewater treatment, and pollution control strategies in Kanpur district.

V. Conclusion

The present study provides a comparative assessment of the physicochemical characteristics of water at three selected sampling sites in Kanpur district. The analysis clearly demonstrates significant spatial variations in water quality, primarily influenced by industrial and urban activities. The upstream sampling location exhibited comparatively better water quality, indicating relatively lower anthropogenic disturbance. In contrast, the industrial stretch at Jajmau consistently recorded the highest values of biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), electrical conductivity (EC), turbidity, nitrate, and chromium concentration, while dissolved oxygen (DO) was considerably lower. These findings indicate substantial organic and inorganic pollution resulting from industrial effluent discharge and untreated wastewater. The downstream sampling site showed moderate improvement in several parameters due to natural dilution; however, pollutant concentrations remained higher than those observed at the upstream location, suggesting the continued influence of industrial contamination. Statistical analysis using one-way ANOVA confirmed significant differences among the three sampling sites for all major water quality parameters ($p < 0.05$), thereby validating the impact of industrial activities on the aquatic environment.

The results underscore the urgent need for strengthening pollution control measures, improving the efficiency of wastewater treatment facilities, and ensuring strict compliance with environmental regulations. Continuous monitoring of physicochemical parameters should be integrated into regional water resource management programmes to detect pollution trends and support evidence-based decision-making. Furthermore, adoption of cleaner production technologies, modernization of common effluent treatment plants, and increased public awareness regarding water conservation are essential for reducing pollution loads. Overall, the study contributes valuable scientific evidence on the current status of water quality in Kanpur district and provides useful information for environmental managers, policymakers, and researchers. Effective implementation of pollution mitigation strategies will be crucial for protecting aquatic ecosystems, safeguarding public health, and promoting sustainable utilization of water resources in the region.

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