

Physicochemical Indicators Of Emerging Pollutants In Aligarh's Urban Water System

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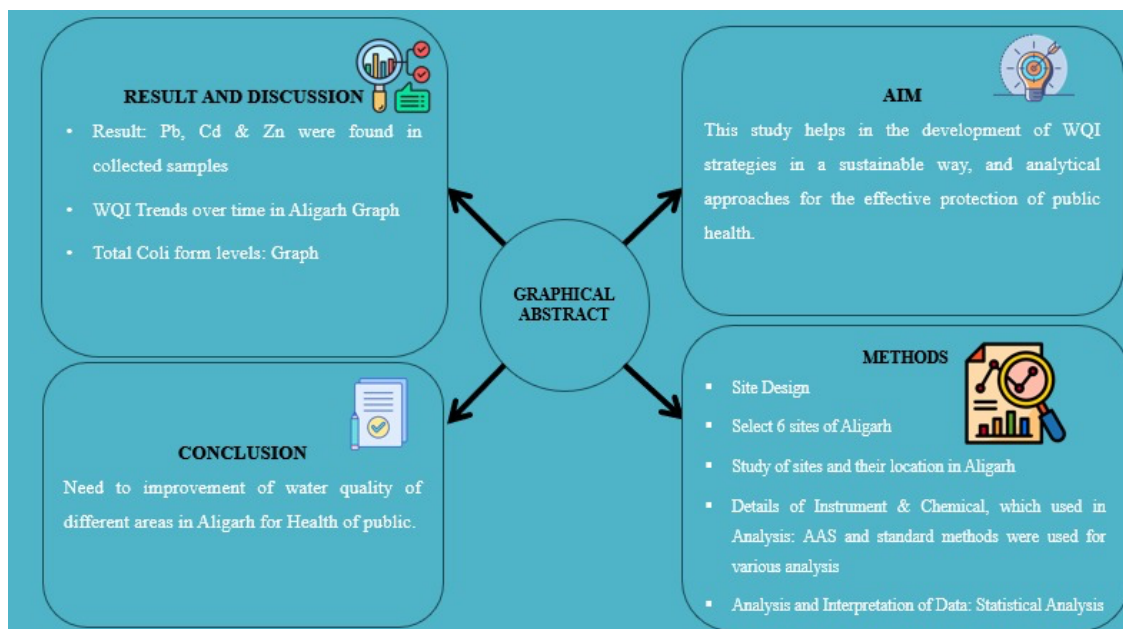
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Abstract-This study looked into emerging pollutants in the urban water system of Aligarh by way of key physico-chemical parameters in terms of pH, BOD, COD, Total Coliform, and trace metals through AAS analysis. With the help of WQI, seasonal and monthly alterations of water quality are presented which shows contamination risks during periods of time. A predictive model of Total Coliform levels and correlation analysis among parameters reflect complex dynamics in pollution. These will help in the development of water quality management strategies in a sustainable way, considering modern analytical approaches for the effective protection of public health.

Graphical Abstract



Keywords: Physicochemical parameters, Water Quality Index (WQI), Total Coliform, Atomic

Absorption Spectroscopy (AAS), Aligarh water system, Pollution dynamics, Predictive modeling.

Introduction

The urban water system provides clean water for drinking, sanitation, agriculture, and industry, hence it has a great bearing on public health, economic growth, and environmental sustainability. However, it is a very tall order to maintain those water systems' quality in rapidly growing cities like Aligarh. While economic progress was propelled by urbanization and industrialization, they also brought along huge environmental challenges. Agarwal, A. (2016), Ahmad, S. (2017) et. al. The major causes of deterioration in water quality in urban areas include the discharge of untreated industrial effluents, heavy agricultural runoff with pesticides and fertilizers, and the discharge of poorly treated domestic wastewater [1, 2]. Bhutiani, R. (2018), Kumar, A. (2021) et.al. Such pollutants, ranging from heavy metals and microbial contaminants to organic chemicals, pose serious risks to human health and aquatic ecosystems, which may threaten their long-term sustainability [3, 4].

Of particular concern are the heavy metals like lead, cadmium, and zinc. In general, these are introduced via industrial and agricultural activities. Krishan, A. (2023), Prasad, N.(2019) et.al These substances tend to persist in the environment, bio-accumulate in living organisms, and are toxic even at low concentrations. Microbial contaminants signal fecal pollution and are often related to outbreaks of waterborne diseases [5, 6]. Priyadarshi, H. (2020) et.al. Organic chemicals, pesticides, and industrial solvents in water further reduce the quality due to disruption in aquatic ecosystems by presenting a threat to human life in the longer run [7].

Water quality monitoring by regular physicochemical parameters can overcome these difficulties. Indicators such as pH, BOD, COD, and TDS can provide further insight into the biological and chemical state of water. You can learn more about the water's chemical and biological state by looking at indicators like pH, BOD, COD, and TDS. Additionally, they will detail the pollution's origins and extent, allowing policymakers to strategize responses among relevant parties. Precision in monitoring heavy metal pollutants has been further strengthened by advanced analytical techniques like Atomic Absorption Spectroscopy (AAS), which provide accurate data for appropriate control strategies.

The paper thus intends to discuss an integrated approach for the assessment of urban water quality, based on computation of the Water Quality Index and seasonal trend analysis. WQI is a composite score, computed from several physicochemical parameters showing the integral value of water quality and giving information on periods with an increased risk of pollution. Analysis of seasonal trends allows determination of conditions of temperature, rainfall, and anthropogenic activities that can affect water quality and deepen understanding of the dynamics of the pollution process.

This study will ensure valuable insights for policymakers and environmental managers in using advanced methods of analysis combined with the thoroughness of water quality assessments. These findings raise awareness of the importance of the sustainability of water management practices along with interventions that are efficient in reducing pollution, preserving citizens' health, and protecting urban water courses for future generations.

The sampling, analyses, and interpretation of results for the understanding of water pollution dynamics

need to be done in a systematic manner. In this paper, an attempt is made in the estimation of impacts of various pollution sources on water quality at the Yamuna River near Aligarh, Uttar Pradesh. Sampling sites were selected keeping in mind that a wide range of pollution profiles-from relatively unpolluted upstream to grossly contaminated downstream-must be covered. Besides, various advanced analytical techniques and instruments of physio-chemical properties of water were used and helped to find out the pollution dynamics.

Methodology

Site Design

This study was conducted along the Yamuna River, with the total number of sampling sites classified into upstream, midstream, and downstream locations. These were strategic selections in order to capture a wide range of pollutant sources and their impact on water quality. In the layout, both point and non-point pollution sources were represented to take up the challenge of holistic perspective water quality challenges:

- Site 1 (UPWS1): Located upstream, this site represents a relatively pristine area with minimal human interference.
- Site 2 (GS2): Situated near residential zones, it is primarily affected by domestic waste.
- Site 3 (IPS3): An industrial discharge point where untreated effluents are directly released into the river.
- Site 4 (IPS4): Adjacent to a treatment plant, highlighting both its efficiency and any potential leakage.
- Site 5 (WWJSS): A junction where industrial effluents mix with the river.
- Site 6 (DSS6): This site, which is both irrigated and located downstream, represents the cumulative effect of contamination from sources upstream.

By incorporating a wide variety of pollutants into the design, we can learn how each one affects water quality.

Study of Sites

At around 27.8974° N latitude and 78.0880° E longitude, you may find the Yamuna River of Aligarh on a geographical map. Industrial discharges, domestic trash, and agricultural runoff were considered while choosing sampling locations for this study. Table 1 provides the coordinates, elevation, and brief site description.

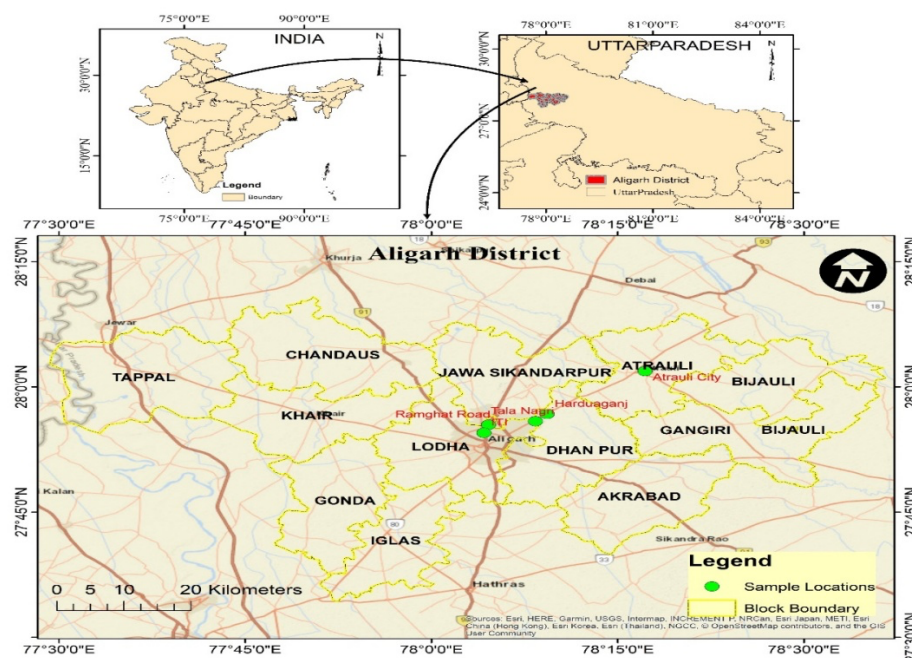


Fig.: 1 All sites shown on map of Aligarh, U.P., India

Table No. 1 Geographic and Descriptive Details of Sampling Sites Along the Yamuna River in Aligarh

Abbreviation	Test Sites	Brief Description
UPWS1	Site 1	Upper stream, relatively unpolluted area
GS2	Site 2	Near a residential area, subject to domestic waste
IPS3	Site 3	Effluent release point from a local industry
IPS4	Site 4	Outside the compound of the treatment plant
WWJSS	Site 5	Effluent joining point from the industry to the river
DSS6	Site 6	Downstream site where wastewater is used for irrigation

By classifying things in this way, we can show how toxins are distributed geographically and how the river is polluted.

Techniques Used to Analyze Physicochemical Properties of Water

Both in-situ and ex-situ investigations were used to examine the water quality for several physicochemical parameters. The comprehensive data on the biological and chemical state of the water was provided by these methods.

- In-Situ Analysis: At each sampling location, scientists conducted in-situ analysis using mobile equipment to monitor variables such as temperature, electrical conductivity, total suspended solids, and pH.
- Ex-Situ Analysis: a range of oxygen demand measurement, including COD, BOD, TN, TP, and TDS measurements were taken in controlled laboratory conditions. For key markers of water quality, these two approaches gave more accurate and reliable results.

Instruments and Chemicals

The following equipment and tools were used to record the measurements correctly:

- Thermometer: Measured water temperature, an essential parameter for assessing aquatic health.
- HACH-DR6000 UV-VIS Spectrophotometer: Used for COD and TN analysis, requiring specific reagents.
- EC Meter: Measured conductivity of electricity and total dissolved solids.
- pH Meter: Recorded acidity or alkalinity of water.
- Gravimetric Method: Used for determining the measurement of total suspended solids through filtering and weighing particles.
- Standard Method: For the purpose of determining BOD, oxygen consumption measures are utilized.

Analysis and Interpretation of Data

Physicochemical parameters examined in this study included:

- pH: These measurements measure the acidity or alkalinity of water.

- EC and TDS: High values indicated ionic pollutants from industrial effluents.
- BOD and COD: Oxygen demands of biological and chemical processes are significant markers of organic pollution.

We used statistical analysis to identify the patterns, seasonal shifts, and site-specific differences in the data collected. All these findings have provided a background for further studies on the sources and impacts of water contamination, as well as the formulation of more precise approaches toward long-term water sustainability.

Results and Discussion

The findings of this research throw light on the causes and mechanisms of water contamination in the urban water system of Aligarh. It has focused attention on the interdependencies among physicochemical parameters, heavy metal contamination, microbiological contamination, and water quality indices, thereby throwing light on the key variables influencing water quality and holding out promise for focused intervention to cut pollution.

Heavy Metal Analysis Using AAS

Heavy metal AAS testing showed significant contamination, especially at points further downstream. Use DSS6 as a case in point; the lead concentration at the latter site was 0.15 mg/L, which is way past the limit set by law. Both cadmium and zinc presented a steady increase as one moved downstream from the upstream sites. These data exemplify the impacts of anthropogenic activities-for example, untreated industrial wastes-on water quality.

Table No. 2AAS Analysis Results for Heavy Metals

Site	Lead (mg/L)	Cadmium (mg/L)	Zinc (mg/L)
UPWS1	0.01	0.002	0.05
GS2	0.03	0.005	0.10
IPS3	0.10	0.020	0.25
IPS4	0.08	0.015	0.20
WWJSS	0.12	0.025	0.30
DSS6	0.15	0.030	0.35

Water Quality Index (WQI) Trends over Time

Ahmad, I. K. (2012). Choi, Y. J. (2021),Panwar, A., Bartwal, S. (2015) et. al. WQI provided a detailed evaluation of water quality by computing it based on the major physicochemical parameters: Total Coliform, pH, BOD, and COD. Seasonal variations in weather, rainfall, and human actions all resulted in WQI values to fluctuate [8, 9, 10].

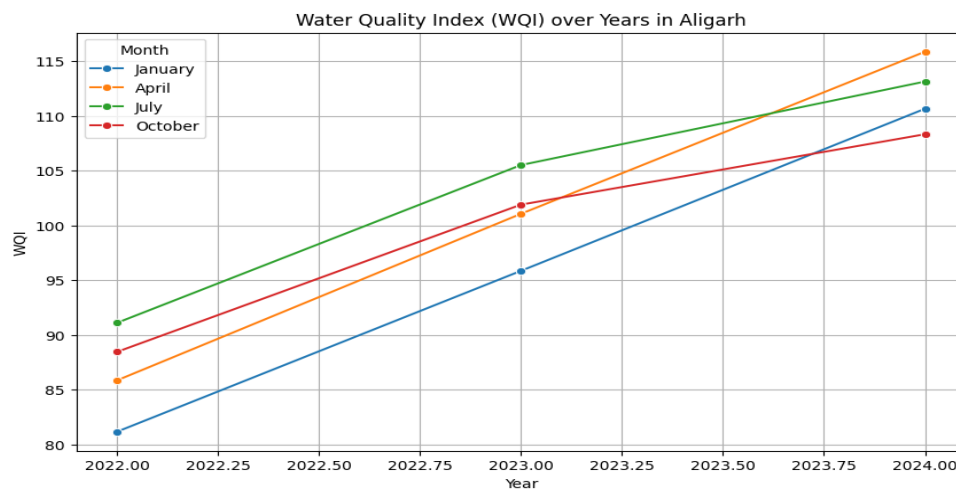


Figure No. 2:Trends in Water Quality Index (WQI) in Aligarh over the Years

The analysis revealed the following key inferences:

- Temperature, precipitation, and human-caused changes all played a role in the observed annual oscillations in WQI values.
- The discharge of wastewater from farms and industries, as well as agricultural runoff, were found to be associated with higher WQI values in certain months.
- It is probable that the water quality improved in other months with lower WQI values, as a result of the diffusion of pollutants during rainfall.

In order to address seasonal activities or point sources that contribute to pollution and to begin remedial steps during high-risk times, continual monitoring is crucial. These trends emphasize the relevance of this need.

Total Coliform Levels: Actual vs. Predicted

Gupta, N. (2019), Huang, J. (2020).Yadav, R. (2022) et. al. A linear regression model was used to evaluate total Coliform levels, which indicate the presence of microbiological contamination. The model's accuracy in predicting microbial contamination is supported by the fact that the predicted patterns closely match the observed data [11, 12, 13].

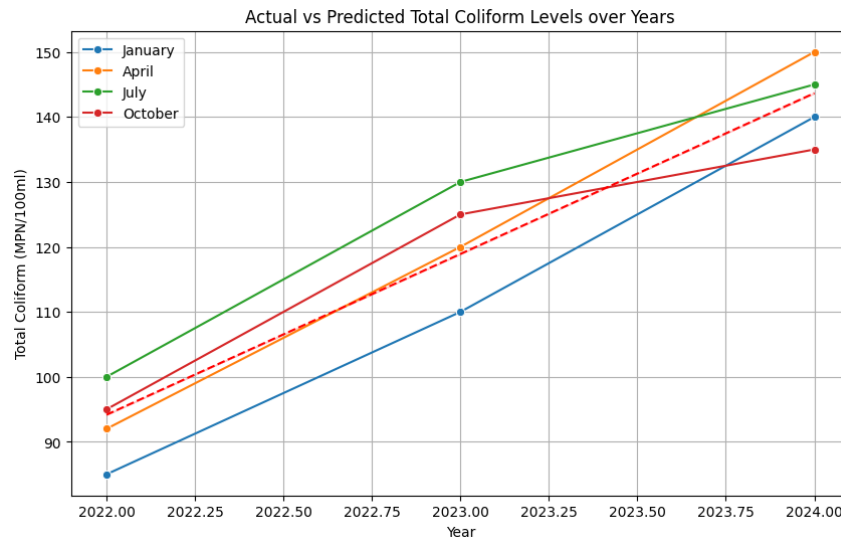


Figure No. 3:Actual vs. Predicted Total Coliform Levels Throughout the Years

Key observations include:

- Variability in Actual Total Coliform levels, with spikes during some months due to untreated wastewater overflows or seasonal factors.
- Results showed that the model was a good predictor of Total Coliform trend, which was in good agreement with the observed values.
- Increased microbiological monitoring and better waste management are necessary to safeguard public health in the face of high total coliform counts.

Predictive Modeling

The linear regression-based prediction models were quite good in predicting future Total Coliform levels. These models act as an early warning system to ensure that public health is protected and the hazard of microbiological contamination is prevented. They allow for immediate intervention.

These models act as an early warning system to protect public health and prevent microbiological contamination by alerting for timely intervention.

```
# Linear regression model to analyze trends in Total Coliform over the years
X = df[['Year']]
y = df['Total Coliform (MPN/100ml)']
linear_model = LinearRegression().fit(X, y)
df['Predicted Total Coliform'] = linear_model.predict(X)

# Visualization of actual vs predicted Total Coliform
plt.figure(figsize=(10, 6))
sns.lineplot(data=df, x='Year', y='Total Coliform (MPN/100ml)', hue='Month', marker="o")
sns.lineplot(data=df, x='Year', y='Predicted Total Coliform', color='red', linestyle="--")
plt.title("Actual vs Predicted Total Coliform Levels over Years")
plt.ylabel("Total Coliform (MPN/100ml)")
plt.xlabel("Year")
plt.grid(True)
plt.show()

# Correlation analysis heatmap of physicochemical parameters
plt.figure(figsize=(12, 8))
correlation_matrix = df.corr(numeric_only=True)
sns.heatmap(correlation_matrix, annot=True, cmap="coolwarm", fmt=".2f")
plt.title("Correlation Matrix of Physicochemical Parameters")
plt.show()
```

Correlation Analysis of Physicochemical Parameters

Bisht, A. K. (2017), Saleem, M. (2020), Lewis, S. (2020) et. al. In order to discuss the interrelationships of physicochemical factors, a correlation matrix was developed. From such analysis, it becomes clear how factor influences factor in relation to water quality and the interdependence between them [14,15,16].

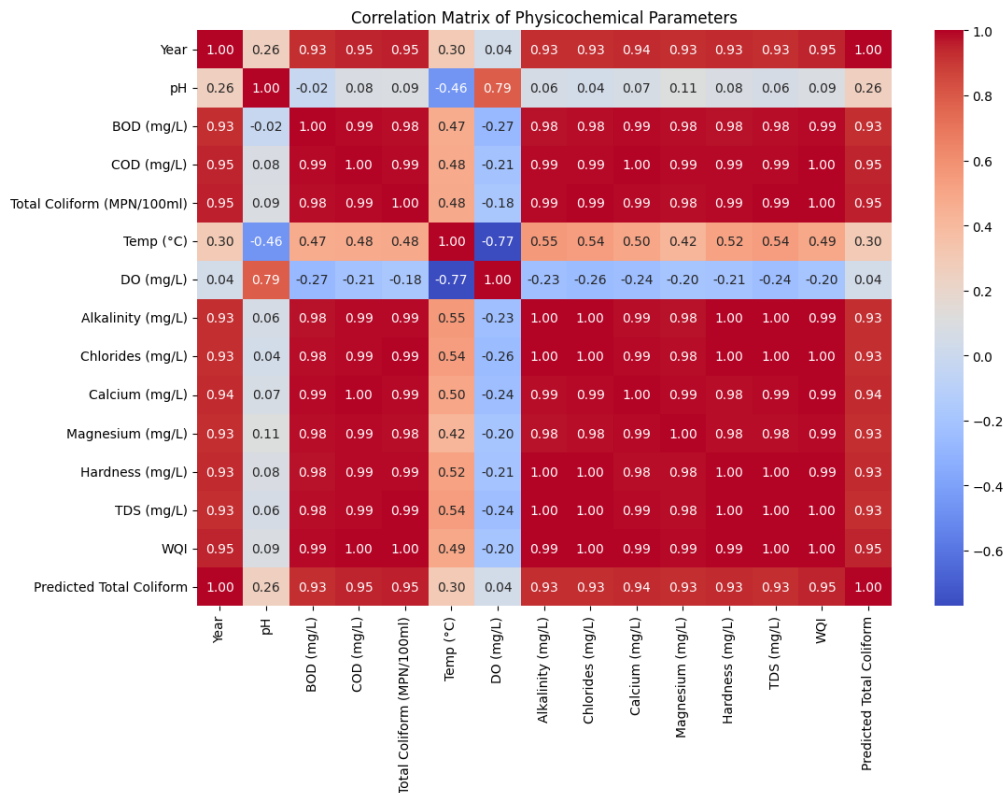


Figure No.4:Correlation Matrix of Physicochemical Parameters

Key findings include:

- **pH and Alkalinity:** Positive correlation, indicating buffering action but also potential chemical discharge.
- **BOD and COD:**Shows high correlation, which signifies common origins such as wastewater and organic pollution.
- **TDS and Hardness:**Show strong correlation, probably due to dissolved salts minerals coming from agricultural and industrial runoff.
- **Total Coliform and Temperature:** Moderate correlation, suggesting warmer months promote bacterial growth.

Asmael, N.(2021), Chabuk, A. (2017), Jackson, M. (2018), Silva, R. (2019) et. al. This analysis shows a dependency relationship among parameters. Hence, one parameter (e.g., BOD) could influence positively others, thus enhancing the general quality of water [17, 18, 19, 20].

Conclusion

The present study, therefore, highlights the importance of modern analytical techniques such as atomic absorption spectroscopy in the identification and quantification of heavy metal pollutants in urban water systems and in providing comprehensive insights into their dynamics by analyzing various physicochemical parameters like pH, BOD, COD, and Total Coliform. In addition, integration of the WQI trend, predictive modeling, and correlation analysis in this research provides ample knowledge

of the temporal and spatial variability in pollution related to Aligarh urban water, portraying the seasonal high state of pollution during summer on account of low dilution and agricultural runoff while it improves with the entry of the monsoon because of natural dilution. So, there exists an emergent requirement for meeting these site- and time-bound challenges of pollution. The findings bring out the need for regular and, wherever possible, advanced monitoring of water quality to correctly identify pollutants and their sources, besides developing strong infrastructure related to industrial and municipal wastewater treatment in order to reduce discharge of untreated effluents. Besides, this calls for strict enforcement of effluent discharge regulations along with sustainable industrial and agricultural practices to minimize the long-term impacts emanating from pollution. The present research makes some very actionable recommendations for policymakers in terms of instituting data-driven strategies that protect public health and make sure water resources and ecosystems are protected. The research contributes greatly to the sustainable management of urban water systems by bridging scientific analysis with practical interventions that help build environmental resilience and secure resources for future generations.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article. All the analyses and conclusions were based on research that was conducted in a neutral and objective manner, uninfluenced by commercial, financial, or personal relationships that could interfere with the outcome of the present research.

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