Assessing the Impact of Industrial Pollution on Water Quality in India: A Case Study of the Ganga River

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Abstract

The study examines how industrial pollution affects the water quality of the Ganga River in India which is a source of water to millions of people. The primary objective is to assess contamination levels caused by industrial effluents and their effects on aquatic ecosystems and human health. Water quality data were collected from selected monitoring stations at Chausa near Buxar in Bihar, Ghazipur at Abdul Hameed Setu in Uttar Pradesh, and Bhagalpur at the Road Bridge in Bihar. Key parameters analyzed included biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, pH, nitrates, chlorides, total organic carbon, conductivity, water temperature, depth, and turbidity. The findings indicate that industrial discharge, particularly from textile and chemical industries, has significantly degraded river water quality. Areas with intense industrial activity show higher pollution levels, adversely affecting aquatic life and increasing risks to public health. The study emphasizes the urgent need for improved wastewater treatment technologies, stricter enforcement of pollution control regulations, and increased public awareness initiatives nationwide. It highlights the importance of collaboration among government agencies, industries, and local communities to reduce pollution and restore the river's ecological health. This ensures long term protection of the river.

Keywords: Industrial pollution, Ganga River, water quality, wastewater treatment, environmental impact

Aims And Background

Ganga River is one of the most significant sources of water in India, thus it faces the growing environmental issues mainly due to industrial pollution. This research will help evaluate the impact of industrial effluents on the water quality of the river with special attention to the influence of the pollutants discharged by industries located on the river banks. In particular, the research will be aimed at discovering the leading pollutants of industrial discharge, identifying the intensity of their pollution, and commenting on the effects of each of them on the ecological situation in the Ganga and on the health of the population. The study will also be based on the effectiveness of the existing pollution control and policy recommendations to improve water quality management, wastewater treatment facilities, and implementation of environmental policies.

Besides being a potential source of water to millions of individuals, the Ganga River has a massive cultural and religious value. The river passes through the heart of India and it provides agriculture water, drinking water, sanitation, and other industrial needs. The Ganga has suffered so much pollution despite the fact that it is a major river particularly concerning the effluents it receives due to industries that are built along its banks. The key industries including the textile industry and the leather industries, the chemical industries and the food industries generate different types of pollutants that

constitute heavy metals, toxic chemicals, dyes and untreated sewage. Such pollutants released into the river without their appropriate treatment cause a drastic impact on the quality of the water, rendering it inapplicable as a source of water and recreation along with agriculture (Aggarwal et al. 2025). The ecosystem and communities that rely on the Ganga are greatly affected by the industrial pollution of the Ganga. Examples of such chemical contaminants include threats to aquatic organisms, interference with biodiversity in the area, and undermining of ecological balance in the river. Further, the pollution of industrial effluents causes health hazards to the people since people usually consume untreated water either as drinking water or in the course of irrigation, causing waterborne diseases such as cholera, dysentery, and typhoid (Dwivedi et al., 2018). The poor quality of water also affects agriculture, whereby toxic elements in the irrigation waters lead to lower yields and poor quality of soil, thereby worsening the nature of challenges the locals have to contend with.

The cause of industrial pollution of the Ganga may be explained by the fact that the high levels of industrialization and urbanisation within the last decades. The poor state of the river has been caused by ineffective wastewater treatment processes, unethical waste disposal processes, and inefficiency of the environmental laws. Even though the government has introduced numerous programs, which refer to cleaning and restoration of the river as to Namami Gange Programme, there are serious challenges. The role of the research is to measure the level of industrial pollution in the Ganga. The Ganga is polluted by the industry to a large extent because of the high rates of Industrialization and urbanization that India has undergone in the last few decades (Jhariya et al., 2020). It has also led to the state of poor river due to incompetence in waste water treatment, unethical waste disposal and ineffectiveness in environmental regulations (Kumar & Anshumali, 2025). Even though the river has a number of governmental programs to clean it and rehabilitate it, such as the Namami Gange Programme, it continues to have significant issues (NMCG, 2024). These issues are further complicated by the problem of ineffective wastewater treatment, industrial pollution, and insufficient enforcement of environmental concerns because they continue to pose a threat to the health of the Ganga River (Chaurasia et al., 2024; Gupta and Ahmad, 2025). The research will primarily seek to examine the impacts of industrial pollution of the river Ganga in India on its water quality.

The study will focus on the detection of the polluted by industries, observation of the influences of this to the ecology of the river and to the health of the human beings, and quantification of the effectiveness of the current pollution control strategies.

The major aims of the study are:

1. To establish the impact of industrial activity on the quality of water in the Ganga River, in particular, the level of various pollutants.
2. To determine the causes or nature of pollutants released by the industries, such as heavy metals, toxic substances, and is the untreated sewage, and how it affects the water quality.
3. To study the impacts of industrial pollution to aquatic life, biodiversity, and health of the population surrounding.
4. To assess the existing government programs, such as the Namami Gange Programme, and determine their success in preventing pollution.

EXPERIMENTAL

STUDY DESIGN

In the research, a cross-sectional study design , and quantitative research techniques will be used to examine the effects of industrial contamination on the quality of Ganga River water in India. The study focuses on the regions which are highly industrial like Chausa (Buxar, Bihar), Ghazipur (Uttar Pradesh) and Bhagalpur (Bihar). The data on the current research is directly obtained through the government sources, such as official records on the Central Pollution Control Board (CPCB) 2023 and Namami Gange Programme that provide detailed data sets of all the key parameters of water quality, such as pH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), heavy metals (e.g., lead, mercury), poisonous chemicals, and microbial contamination. The information that will be gained during this secondary analysis will be utilized to establish the level of influence of industrial pollution to the ecosystem of the river and health hazard which is due to usage of polluted water. The Study will create awareness of the existing pollution issues, examine the effectiveness of the existing pollution management tools, and specify the potential on how the water pollution management can be enhanced.

STUDY LOCATION AND POPULATION

The sampling is based on four sites on the River Ganga: Ghazipur, Abdul Hameed Setu, Uttar Pradesh, Bhagalpur, Bihar, Road Bridge (Bihar) Buxar (Bihar), and Chausa. The choice of these places was done by the availability of the available government data that will give a clear view of the industrial pollution in the river. Industrial discharges, especially the textile mills, chemical plants, and tanneries have a great influence on the sites thus it is important to determine their pollution levels and environmental effects.

INCLUSION CRITERIA

The inclusion criteria include data from places along the Ganga River that are highly affected by industrial discharges, especially those in textile mills, chemical plants, and tanners. The points of selection were determined by the locations of the available data that is present in the government database. The research involves areas where local people rely on the Ganga river for their daily requirements, like irrigation.

EXCLUSION CRITERIA

The study omits the data of the areas near the Ganga River that cannot be accessed easily through government sources. This restriction will make sure that only information on reliable and easily available reports is used to analyse the data. Regions remote to industrial processes or locations where data of water quality is sparse are not included. Moreover, the data that is above 5 km away of the river or is not actively used by its local populace will be removed. It lays emphasis on industrial release and water quality in the accessible, industrially affected areas of the river.

DATA COLLECTION

The study data is based on the official government reports such as the CPCB and the Namami Gange Programme. These reports are rich sources of secondary information on water quality parameters, such as the presence of heavy metals (ex: mercury, lead), toxic chemicals (ex: dyes and solvents), and microbial contamination. The study is also carried out through the administration of questionnaires to the local communities and the industrial workers to learn their perception towards pollution, health impacts of pollution, and the success of the current regulations. The questionnaires measure health effects that might be associated with pollution such as respiratory complications, gastrointestinal complications, and skin diseases. Such combination of water quality information and surveys is critical to ensure that the environmental and social elements of pollution are examined in details.

STATISTICAL ANALYSIS

Descriptive statistics are used to interpret the results obtained through the use of data obtained. The descriptive statistics involves the use of mean, median and standard deviation in summary of the concentration of the pollutants in the water samples.. Such statistics will give the idea of the overall patterns in the water quality in various places along the Ganga river. Correlation analysis will be formulated further to examine how some parameters of water quality, such biochemical oxygen demand (BOD), dissolved oxygen (DO), and water turbidity (NTU) are correlated. It will allow one to know the relationship between the parameters and the way they can affect the quality of water.

Results And Discussion

WATER QUALITY PARAMETERS

The study measured different parameters of water quality in an attempt to determine the effects of industrial pollution on the Ganga River. The results of the Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), pH, and Water Turbidity (NTU) showed considerable differences in the locations, particularly in the industrial regions. The BOD was between 2.23 mg/l and 3.23 mg/l with an average of 2.85 mg/l which demonstrates the existence of organic pollutants, which use oxygen, and hence has impact on aquatic life. DO was in the 7.05mg/l to 9.42mg/l range suggesting that the oxygen levels were not high and as such, even though pH levels were low, there was no significant stress indicating the infiltration of the stated material into the river. In industrial areas such as Bhagalpur and Buxar, the level of Turbidity was more as compared to other areas, since the turbidity levels could be seen to be between 31.15 to 49.25 NTU, which was an indication of the existence of suspended solids, which were not conducive to aquatic life. The table 1 shows the descriptive statistics of each of the water quality parameters of five locations along the river. The table contains the mean, standard deviation, minimum, and maximum values of each of the parameters, which gives a good understanding of the water quality situation in these areas.

Table 1. Descriptive Statistics of Water Quality Parameters

Parameter	Mean	Standard Deviation	Min	Max	25th Percentile	50th Percentile (Median)	75th Percentile
Biochemical Oxygen Demand (mg/l)	2.85	0.38	2.23	3.23	2.79	2.99	2.99
Dissolved Oxygen (mg/l)	8.29	1.14	7.05	9.42	7.24	8.34	9.42
pH	8.39	0.21	8.08	8.67	8.38	8.38	8.46
Water Temperature (°C)	19.73	1.77	17.58	21.56	18.79	19.14	21.56
Nitrate (mg/l)	0.74	0.99	0.30	2.52	0.30	0.30	0.30
Chloride (mg/l)	60.86	18.07	46.71	89.41	46.71	53.98	67.48
Chemical Oxygen Demand (mg/l)	12.80	2.08	9.81	15.68	12.55	12.99	12.99
Total Organic Carbon (mg/l)	6.28	1.11	4.68	7.34	5.58	6.89	6.89
Depth (m)	0.99	0.09	0.90	1.08	0.91	1.00	1.08
Conductivity (mS/cm)	587.47	47.95	535.50	630.54	535.50	611.30	624.50
Water Level (m above MSL)	50.88	12.27	37.74	62.11	37.74	55.43	61.36
Water Turbidity (NTU)	39.64	8.87	31.15	49.25	34.14	34.39	49.25

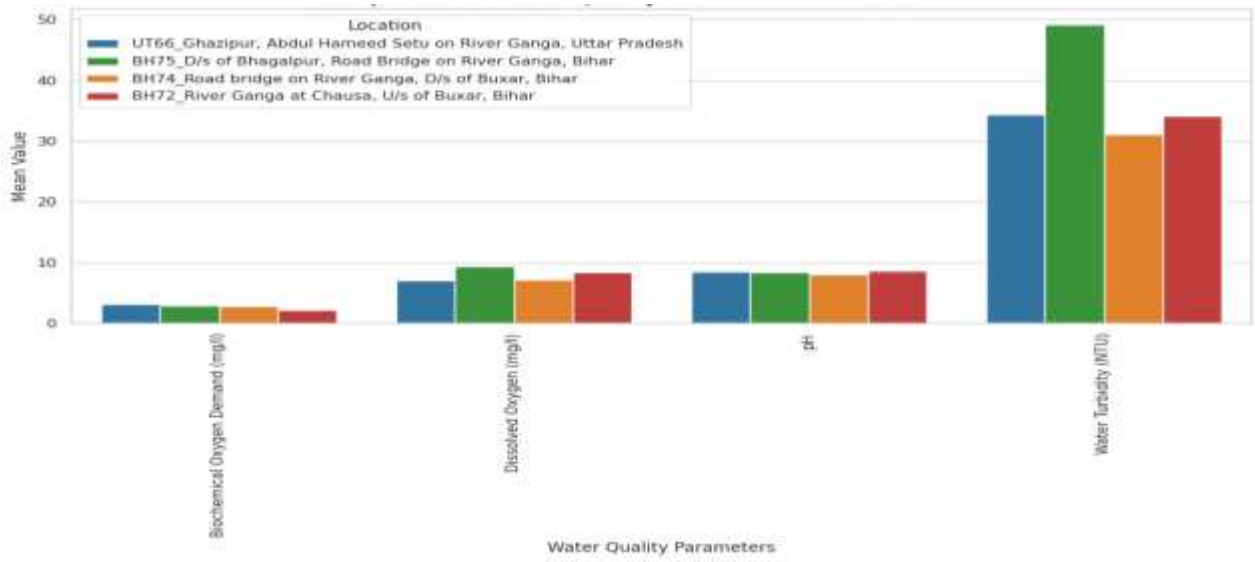

Fig 1. Comparison of Water Quality Parameters Across Locations on the River Ganga

Fig 1. compares the average Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), pH and Water Turbidity (NTU) in the various locations of the Ganga River. Water Turbidity being the highest at Chausa and Bhagalpur, depicting more contamination by the suspended particles.

SOURCES OF POLLUTION

The study found out that the major sources of industrial pollution were the textile mills, tanneries and chemical plants. These plants in the river release various types of destructive runoffs which contain dyes, heavy metals, and poisonous chemicals. The textile mills cause pollution by discharging toxic dyes and chemicals that contaminate the water and damage aquatic organisms. Tanneries play a vital role, especially since they emit chromium, a chronic toxic material that is a potential threat to the environment both in the short-term and in the long-term. The chemical industries also contribute to the magnitude of the problem through the discharge of solvents, heavy metals and other toxic materials, adding to the chemical burden in the river. In spite of different initiatives to reduce pollution including Namami Gange Programme, unregulated release of untreated industrial effluents still pollutes the water of Ganga to significant amounts of pollution. These results indicate that the stricter regulation and the creation of efficient wastewater treatment facilities are required.

CORRELATION BETWEEN WATER QUALITY PARAMETERS

The correlation matrix identifies the associations between the parameters of water quality in terms of their chemical associations. The correlation between Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) is negative as the chemical laws indicate: the higher the organic pollutants (e.g., decomposing organic matter) the greater the BOD, the more oxygen is used up in the process, and, therefore, the lower is the level of DO. The relationship between Water Turbidity (NTU) and DO is positive, which implies that the transfer of oxygen may also be influenced by suspended particles that may occur due to industrial wastes. The moderate relationship between Turbidity and BOD is in line with the notion that the level of organic load increases the level of particulate matter in the water, which in turn causes turbidity. Such results indicate chemical interactions in water bodies, where the pollutants affect the oxygen content and water turbidity.

Table 2: Correlation Matrix of Water Quality Parameters

Parameter	BOD	DO	pH	Turbidity
Biochemical Oxygen Demand (BOD)	1.000	-0.071	-0.409	0.344
Dissolved Oxygen (DO)	-0.071	1.000	0.238	0.912
pH	-0.409	0.238	1.000	0.071
Water Turbidity (NTU)	0.344	0.912	0.071	1.000

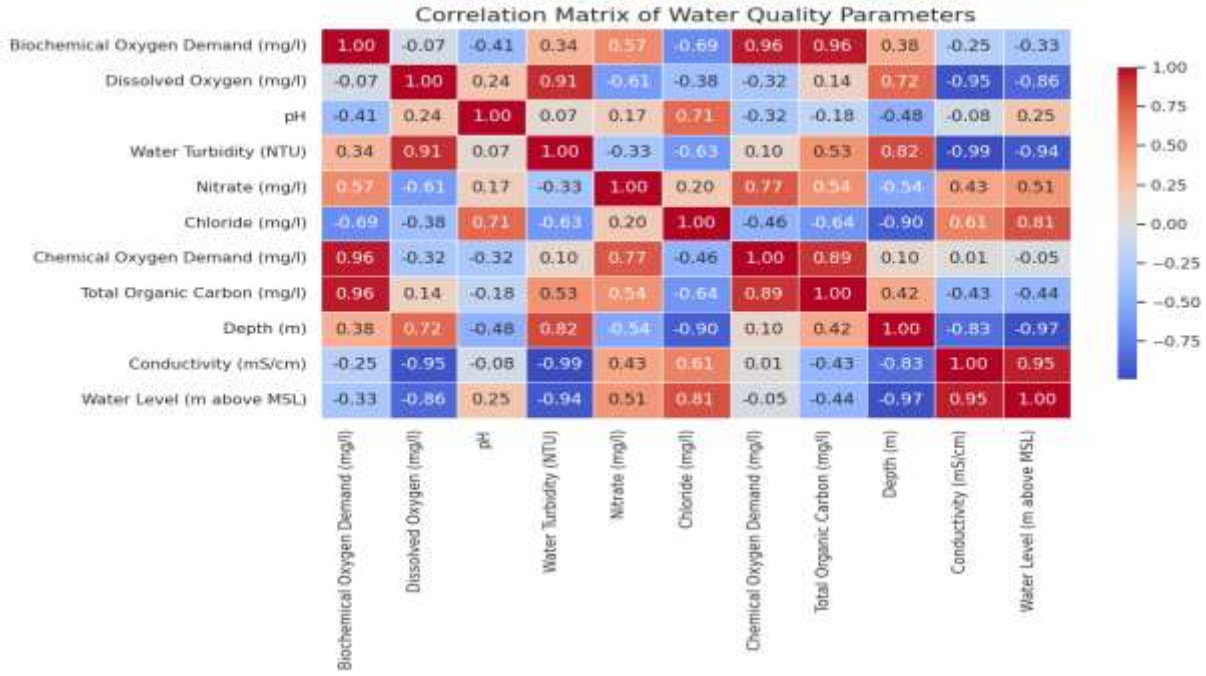

Fig 2. Correlation Matrix of Water Quality Parameters

Fig 2. presents the correlation table of different water quality parameters in the Ganga River. The relationships among the parameters such as Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), pH, Turbidity, and other chemical and physical parameters are highlighted in the matrix. Positive significant correlations are found between BOD and Chemical Oxygen Demand (COD), and Total Organic Carbon (TOC) and COD, which supports the idea that the regions with high organic pollution have the highest levels of chemical oxygen demand.

IMPACT ON HEALTH

It was found in the research that industrial pollution in the Ganga River is strongly linked with the health risks to the residents of the region, as indicated in secondary data. The people living in the neighborhood of industrial zones and practicing their day-to-day activities have been documented to exhibit a higher incidence of water borne illnesses. The secondary data reports have specifically revealed that cholera, dysentery, and typhoid have reached epidemic levels during the monsoon season, when the degree of pollution is also high due to the runoff of untreated industrial effluents (Upadhyay et al., 2023). Moreover, treatment of sewage has not been done, thus causing the water to be contaminated by the release of microbes in the water, which has increased the prevalence of these diseases. According to health statistics of different researches, there is a direct correlation between the declining quality of water and the increased cases of gastrointestinal disorders and diarrheal diseases in the regions where industrial effluents are mostly prevalent. These results highlight how badly the wastewater treatment systems and authorities should enforce the environmental laws to reduce the health hazards that the contaminated river water presents particularly in societies that use the Ganga on a day-to-day basis.

EFFECTIVENESS OF POLLUTION CONTROL MEASURES

The research observed that there is a strong association between industrial pollution on the Ganga River and the health hazards for people living in the area, as identified in secondary data. Individuals residing around industrial areas who practice their daily activities, such as bathing, washing, and drinking along the river, have been reported to show an increased rate of waterborne diseases. The secondary data, according to the health reports, have particularly shown that cholera, dysentery, and typhoid have attained epidemic levels in the monsoon season when the level of pollution is high due to the runoff of untreated industrial effluents. In addition, sewage treatment has not been done and the resulting water is contaminated through release of microbes which has added fuel to the spread of these diseases. According to health statistics of various research studies, the declining quality of water is directly related to the increasing rate of the gastrointestinal disorders and diarrheal diseases in the regions where the prevalence of industrial effluents is largely seen. The waste water treatment systems should be upgraded urgently to minimize the health risks that are posed by the river water that has been contaminated. Strong environmental measures are also recommended to be followed by the government (Roy and Shamim, 2020). Besides, proper pollution control should be considered to preserve the well-being of individuals (Patil and Arya, 2024).

Conclusions

The study points to the extensive effects of industrial pollution of the water body of Ganga River and that the river is significantly polluted by industrial effluents such as heavy metals, toxic chemicals and untreated sewage. These pollutants are dangerous to the ecosystem of the river and also threaten the local communities. There are also high levels of microbial contamination and chemicals, which have consequently increased waterborne diseases; gastrointestinal diseases, skin

diseases and respiratory diseases, especially in high industrial areas. The biodiversity of the river is highly stressed, and there are increased mortality rates of fish and the decrease in aquatic species in industrial areas. Although programs have been introduced to clean up the river such as the Namami Gange Programme, the study indicates that the application of the pollution control policies is not sufficient. The river is still receiving untreated effluents discharged by many industries as a result of laxity in enforcement of regulations and insufficient wastewater treatment plants. There is also a lack of mitigation due to financial constraints and the lack of awareness among people. To mitigate these, stricter implementation of environmental laws, use of cleaner technologies and increased investment on the treatment of wastewater is necessary. Sustainable water management practices can be achieved by involving the people through public awareness campaigns and participation. To sum up the Ganga healing process should be a holistic endeavor that involves the government, industry, and the local people in ensuring that this important resource is sustainable in the long run.

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