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Study the ecological challenges of Ganga River in the major sites of Uttar Pradesh, India

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Abstract-

Ecology of the Ganga river has become vulnerable after exploitation for years.The Ganga river holds a vital status within India as a cornerstone of the nation's ecological and socio-economic fabric. Flowing through diverse terrains like the Himalayas, Gangetic plains, and coastal regions, it fosters an incredibly rich biodiversity, supporting a myriad of life forms ranging from microorganisms to mammals. Beyond its ecological significance, the river sustains the livelihoods of millions, contributing significantly to the economy of northern India. The rampant human development over recent decades have posed grave threats to its well-being. Pollution from sewage and industrial waste has tainted its waters with heavy metals, posing risks of bioaccumulation and magnification within aquatic life. Infrastructure projects like dams and bridges disrupt natural habitats and impede the migration of aquatic species, further jeopardising the river's ecological balance. River is a highly dynamic ecosystem which is affected by activities that happen at the river bank including industrial and direct human activities. In this paper, Ganga river water quality isreviewed at five different sites of Uttar Pradesh including Kannauj, Kanpur, Prayagraj, Mirzapur and Varanasi.The river water quality monitoring data of the UPPCB was used for the analysis. Four water quality parameters, namely Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Coliform (TC) and Fecal Coliform (FC) were used for the analysis.

Keywords-

Ecological activities, Ganga river, Uttar Pradesh, Water quality, Water pollution

Introduction

Water sources are integral part of the ecosystem. Water sources are present in the form of rivers, glaciers, lakes, rain water, ground water etc. They not only ensure sustenance for animals but also facilitate for economic growth, agricultural development, power generation and industrial development. Human population living on the banks of rivers depend hugely on it for livelihood through fishing and livestock production. But this dependence also plays vital role in the deterioration of water quality of the water sources. Increasing population, industrialization and urbanization are some of the prominent factors responsible for the degradation of water quality [1]. In general trend, the water quality of the rivers is better in the upstream side as compared to the downstream side because of accumulation of waste and toxicants in the stream while flowing from the upstream side to the downstream side [2-3]. River water pollution is one of the major global environmental concerns today. Diminished river water quality upsets the balance of aquatic ecosystem and lead to fatal consequences both for humans and animals. It is not only and environmental concern but also a socio-economic issue that need to be acted upon immediately [4-5]. Anthropogenic activities like direct sewage discharge, washing and bathing, waste disposal and direct industrial discharge have deteriorated the river water quality globally. Ganga river is one of the most sacred rivers of India. But unfortunately it has been taking the jolt of pollution from decades and that has led to serious degradation in its water quality.

The Ganga is a major river in the Indian subcontinent, providing livelihoods to millions of people. It originates in the Himalayas and flows eastward across a vast plain to the Bay of Bengal (Figure 1). The Bhagirathi River, which begins at Gaumukh near the Gangotri and Khatilang glaciers in Uttarakhand, is considered the source of the Ganga. The Ganga forms at the con f luence of the Bhagirathi and Alaknanda rivers at Devprayag. Spanning about 2,510 km (1,560 miles), it passes through the Indian states of Uttarakhand, Uttar Pradesh, Bihar, and West Bengal. The Ganga's drainage basin covers approximately 861,404 km², accounting for a quarter of India's geographical area [6]. Ganga's major tributaries from the Hima layas' hill or terai regions include the Yamuna, Ghaghara, Gandak, Kosi, Burhi Gandak, and Gomati rivers. Significant tributaries from the Central India plateau include the Damodar, Tons, and Sone rivers.

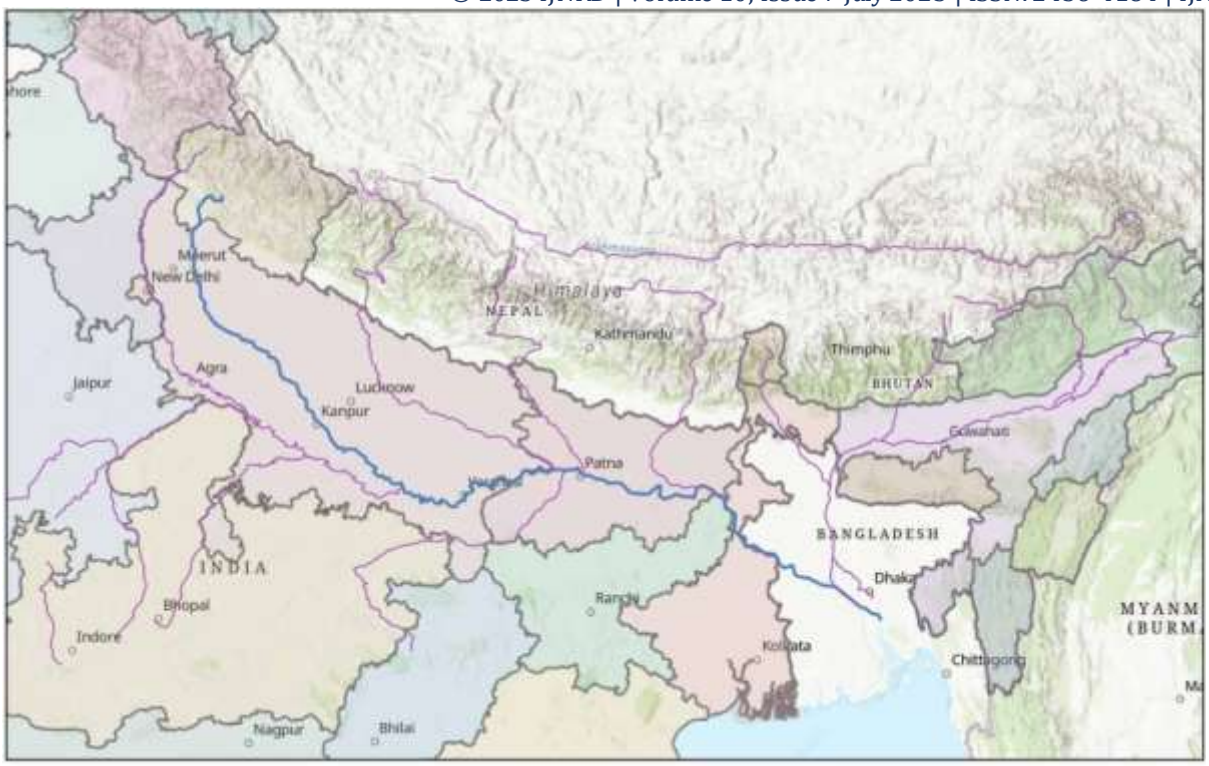

Figure 1 Ganga river

The Ganga River basin is one of the most productive ecosystems, comparable to the Brahmaputra River basin, another major river system in India. However, there is a great degree of complexity in the management of water and sediment due to the basin's high level of diversity, which includes the Himalayan mountains in the north, deserts in the west, heavily inhabited plains in the centre, and deltas in the east [7]. Vast population resides along the banks of the river Ganga and thus flow of domestic sewage is a huge factor that adds up to the misery. A lot of industrial activities also flourish along the bank of river Ganga that leads to direct discharge of effluent into the river [8]. Religious activities, bathings and disposal of the remains of the dead are other factors that add up to the woes of the Ganga. Rivers do have the natural ability to remediate themselves however the situation with Ganga is alarming because the rate of inflow of pollutants is way beyond its natural remediation capabilities [9]. A lot of previous studies have focused on increasing deterioration of Ganga River water quality [10-12].

The situation needs immediate action of researchers and policy planners because such contamination and pollution can lead to outbreak of water borne diseases like cholera, dysentery, hepatitis A and typhoid. People living on the bank of river Ganga use itswater for cooking and daily use that increases the health risk. Study by Indian Council of Medical Research (ICMR) says that the pollution in Ganga river has made people of Uttar Pradesh and Bihar highly prone to cancer [8]. Hence it is imperative to undertake more research activities to assess the real time pollution status of the Ganga river thereby facilitating the policy makers to formulate specific and goal oriented task plan.

In this paper, a comprehensive analysis of the variation of pollution levels in Ganga river water at five urban centres of Uttar Pradesh is reviewed. Four pollution parameters, i.e. Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Coliform (TC) and Fecal Coliform (FC) were used for the analysis. While DO levels represent if the water body is fit for the sustenance of aquatic life, the BOD levels signify the concentration of organic pollutants in the water body. Total coliform is a class of rod shaped bacteria whose presence in the river water body signifies the presence of pathogenic bacteria that may be harmful to the humans. Fecal coliform bacteria are the subset of total coliform bacteria and their presence shows that the water is polluted by the fecal matter of humans and animals. Fecal coliform bacteria are the thermoresistant total coliform bacteria and hence are harmful for the humans. Fecal coliform pathogens can cause health comorbities like diarrhea and stomach infections. Pathogens like E.Coli and Salmonella, that are subsets of Fecal Coliform Bacteria, can cause serious health implications like typhoid fever. The data from the monitoring results of Uttar Pradesh Pollution Control Board (UPPCB) was used for comparative analysis. Five urban centres were selected according to the route that the Ganga river follows in the state of Uttar Pradesh and the availability of data for upstream and downstream locations.

Need of the Study

- To investigate the potential parameters which impact the ecological activities of the Indian river Ganga from Prayagraj-to-Varanasi-regions of Uttar Pradesh
- To measure atmospheric deposition of nutrients (N and P) in the Ganga basin.
- To study the water quality characteristics of Ganga River.
- To study sediment characteristics under variable environmental conditions/anthropogenic disturbances in the Ganga fromPrayagraj-to-Varanasi-regions of Uttar Pradesh

Ecological challenges of Ganga river

Some important pilgrim centres, such as Rishikesh, Haridwar, Garhmukteshwar, Kannauj, Allahabad, Mirzapur, Varanasi, and Gangasagar are situated at the bank of the river, where various religious events take place throughout the year. Ritual bathing in the River Ganga is thought to purify the body and soul, therefore millions of people bathe at a specific stretch of the river during Kumbh [13]. In the 2013 Kumbh at Prayagraj, about 88.7 million people took a bath in the River Ganga within a 45-day event. The biggest gathering in human history was on 10 February 2013 when 30 million people took a holy dip in a single day [14]. A significant enhancement of Salmonella typhi in thewater and sediment of the River Ganga was reported during Kumbh 2013 at Prayagraj. Srivastava et al. found that the water quality of the river deteriorated during mass bathing during Kumbh 2013 at Prayagraj [14-15].The deterioration in water quality is mainly attributed to the use of soaps, shampoos, detergents, polythene, food, flowers, leaves, milk, curd, ghee, coins, etc. [16]. Ganga at Prayagraj is unsafe for bathing and can cause serious health problems due to extremely high levels of coliform bacteria [17].

The hydropower projects in Uttarakhand are threatening the ecological activities of the River Ganga, especially migrant species. There are around 17 migrant fish species found in Alaknanda and Bhagirathi basins including three species of long-distance migrant Mahseer. Therefore, the construction of a dam or a barrage across a river will not only hamper their migratory behaviour but also affect their breeding cycle[18]. The over-abstraction of groundwater in the Ganga basin has lowered the flow of the river and adversely affected the water quality of the river. This deterioration in the water quality of the river due to the reduction in the water flow is also a threat to aquatic life. Therefore, environmental flows of rivers should be maintained throughout the year to sustain freshwater and estuarine ecosystems as well as human livelihoods [19].

Most of the aquatic organisms are very sensitive to their environment and respond in different ways to the pollution. These include either death or migration to any other habitat, reduction in reproductive capacity or suppression of some enzyme systems needed to conventional metabolism [20]. The exponential growth of population, industrialisation, urban isation, and rising standards of living in Gangetic plains have exposed the River Ganga to various forms of degradation. It has been found that 90% of the river's natural discharge is extracted through dam and irrigation when the river reaches Kanpur [21]. Sewage pollution, industrial effluent, agricultural runoff, and religious activities are the four main sources of pollution in rivers, where municipal sewage is the main contributor followed by industrial effluents. Various organic and inorganic substances originating from these sectors are responsible for the pollution of rivers. Pollution due to religious activity is already discussed in the previous part, therefore effects of sewage, industrial effluent, and agricultural runoff are discussed in this section.

Urbanisation at such a scale is responsible for environmental problems such as water supply, wastewater generation, treatment and disposal. Kanpur, Prayagraj, Varanasi, Patna, and Kolkata are some major cities situated on the bank of the River Ganga. Although there are several STPs functioning in these cities, the water quality of the river Ganga is rapidly deteriorating due to thedischarge ofuntreatedsewagefromtheseurbancentres.Sewagewaterconstitutesheavymetals (Cr, As, Cd, etc.), organic matter (pesticides, detergent, etc.), nutrients (viz. N, P, K), inorganic matter (Ca, Mg, Na, K, etc.), and pathogens (bacteria, fungus, etc.) [21].Further, it was reportedthat 75% pollutionofthe RiverGanga is related to the discharge of millions of litres of sewage generated per day in the towns along the River Ganga [22]. According to CPCB's recent report, about 8,250 MLD (million litre per day) of wastewater is generated from 223 cities/towns along the River Ganga, out of which about 2,460 MLD is directly discharged into the River Ganga [23].This untreated sewagewaterisnotonlypolluting riversbut isalsocontaminatinggroundwaterduetopercolation.

Furthermore, municipal water treatment facilities generally do not remove traces of heavy metals which is also a concern for the riverine ecosystem.Kanpur (tanneries), Prayagraj (engineering), and Varanasi (carpets and locomotive) are the key industrial cities situated at the bank of the River Ganga in Uttar Pradesh. Industrial pollution significantly enhancing the concentration of toxic elements in the River Ganga [24-25]. The industrial waste includes hydrochloric acid, bleaches, dyes, pesticides, and other toxic heavy metals (As, Cd, Cr, Hg, Ni, and Pb). It has been reported in literature that the levels of carcinogenic elements like As, Cd, Cr, Hg, Ni, and Pb were exceeding the WHO permissible limit for potable water at many sites of the Ganga River [26-28].Industrial pollutants containing heavy metals are a major concern for healthy riverine ecosystems. Dutta et al. estimated that around 20% of the total volume of wastewater discharged in the River Ganga is from industrial sources [29].

The agricultural fertilisers and pesticides are harming the Ganga waters, and her water is harming their crops. Many cancer-causing chemicals, such as DDT or HCH, are sprayed as pesticides in agricultural farms which wash down into the river and thus pollute its water for drinking, bathing, or cooking [30]. Many pesticides, such as DDT, Aldrin and HCH, are still in agricultural use, although the Government of India has banned their use [31]. The13 banned and restricted organochlorine pesticides (OCPs) were found in the surface water of the River Ganga [32]

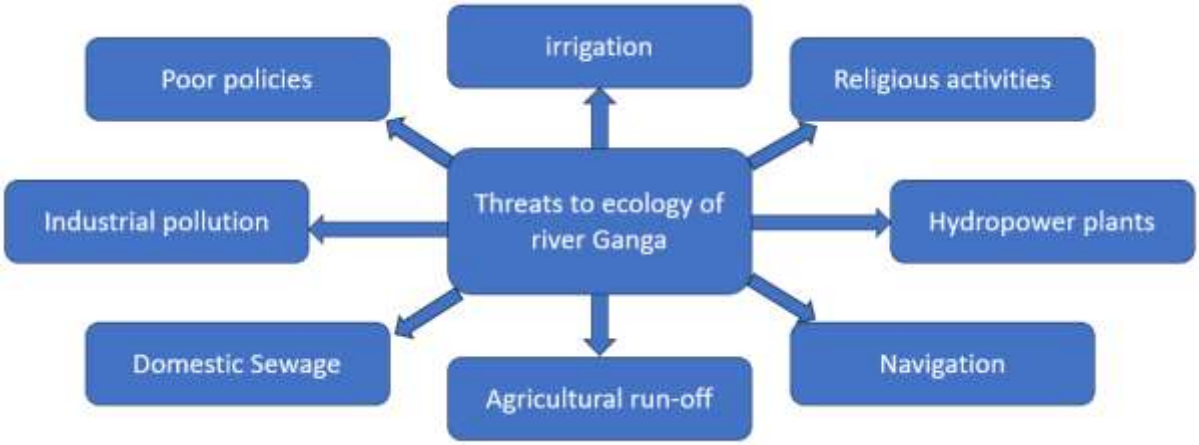

Figure 2. Challenges/threats to ecological actives of the ganga river

Methodology

This review aims to analyse valuates the threats to the ecology of the Ganga River and historical data on water quality in the Ganga River. The. The data used for this analysis were collected from available published literature and government project reports (UPPCB), which can be accessed through government websites. Ecological data were obtained from the public literature. Literature was sourced from internet platforms such as Google Scholar and ResearchGate, while pertinent offline publications were retrieved from the library of the Zoological Survey of India.The precise search phrases employed are "Ganga river", "Ecology of Ganga", "Ecological challenges", "water quality", "water pollution", "pollution-affected Ganga" etc.

Significant findings and discussion

In this section the trend of variation of the four parameters is represented for all the urban centres.

Kannauj

DO levels were found to be higher than the threshold limit of 4 mg/L that signified favourable condition for aquatic ecosystem. DO level slightly decreased in the year 2024 at the downstream side. BOD levels were higher at the downstream side for all the four years which showed the accumulation of organic pollutant. BOD levels were found to be consistently higher than 3 mg/L that meant substantial pollution of the river water. BOD level although decreased in the year 2024 at both the ends however it was still greater than 3 mg/L mark at the downstream side that signified presence of organic pollutants in the Ganga river in significant concentration. The TC and FC concentration were substantially higher at both the ends for all the four years. The coliform concentration was found to be higher at the downstream side which highlighted the active interference of human activities in the riverine system. The TC and FC concentration have significantly decreased since 2022 but still the absolute values are much higher than the permissible threshold.

Kanpur

Ganga river water was found to be highly polluted in Kanpur which can be attributed to direct industrial effluent discharge besides discharge of sewage and other pollutants. While the DO level at the upstream side was fairly constant and well above threshold limit, the DO level at the downstream side was quite low. However it was greater than the threshold of 4 mg/L and showed increasing trend in the year 2024. The BOD level at the downstream side was found to be well above 3 mg/L in all the four years and hence the river water is polluted with organic pollutants coming from industrial as well as residential areas. Vast difference between the BOD level at upstream and downstream sides signify accumulation of pollutants in the riverine system. The BOD level decreased in the year 2024 at the downstream side but was still at the higher side. Huge interference of industrial and human activities in the Ganga river system in Kanpur was evident from the TC and FC concentration. Presence of pathogenic bacteria in such high concentration can be detrimental for both animals and humans. The trend of TC and FC bacteria showed decline since 2022 but still a lot of work needs to be done both at administrative and community level. The absolute values of TC and FC are very high in Kanpur and thus the river water is highly unfit for any type of use by the humans.

Prayagraj

The DO and BOD level showed favourable trend in Prayagraj. While the DO increased since 2022, the BOD level decreased post 2022. Decreasing BOD level signified diminishing pollution level in the river water. The BOD level at both the sides reached the mark of 3 mg/L in 2024 from almost 5 mg/L in 2022 which is a commendable decline. Absolute values of TC and FC were found to be on a higher side however the trend showed that the pathogenic bacteria concentration is on a continuous decline in Prayagraj. This can be attributed to vigilant attitude and valiant efforts for Ganga rejuvenation. The absolute values of TC and FC in Prayagraj were less than that in Kanpur. The TC and FC concentration at the upstream and downstream sides were almost same that signified minimum accumulation of the pathogenic contaminates in the Ganga river water. This point must be appreciated and more community participation must be encouraged to lower down the absolute values of TC and FC bacteria concentration.

Mirzapur

Data analysis for the Mirzapur district showed alarming trends. The DO level was found to be on acontinuous decline while the BOD was found to be increasing continuously at the downstream side. DO and BOD at the upstream side was found to be fairly constant. This showed that the Ganga river water quality is getting degraded continuously in the Mirzapur district. The BOD level crossed the 3 mg/L mark in 2024 that showed significant contamination of the river water with decaying organic matter. Similar trend was seen in the case of TC and FC bacteria concentration. While TC and FC concentration at the upstream side remained fairly constant, the values at the downstream side kept on increasing at an alarming rate post 2022. The result was contrasting to other urban centres where decline in pollution level was evident after 2022. The gap between the TC and FC concentration at the upstream and downstream sides showed increasing trend that signified alrmingly increasing accumulation of pathogenic contaminants in the Ganga river water in Mirzapur. Such high gap can be attributed to lack of awareness among common mass or even to negligence. It is imperative to put in valiant efforts to control Ganga river water degradation in Mirzapur district before the condition becomes fatal.

Varanasi

The DO and BOD level at the upstream side in Varanasi were almost constant. DO at the downstream side was constantly lower than that in the upstream side while the BOD in the downstream side was consistently higher than that in the upstream side. Year 2024 witnessed increasing gap between the DO and BOD at the downstream side that indicates improving health of the riverine system. The DO at the downstream side showed increasing trend while the BOD at the downstream side showed declining trend signifying diminishing pollution level in the river water. However, absolute values of BOD at upstream and downstream side were higher than 3 mg/L with downstream values being much higher than the upstream values. This signifies accumulation of organic pollutants in the Ganga river water in Varanasi. The trend of TC and FC concentration was nearly same to that followed in Kanpur. TC and FC concentration in upstream side was fairly constant and comparatively low while the values in the downstream side were much higher and thus showed the presence of pathogenic contaminants in large concentration. The TC and FC concentration at the downstream side showed a declining trend post 2022 which is something to cheer about however the absolute values are still very high and need immediate attention of both policy makers and the general public.

Conclusion

This study concluded that Kannauj is polluted centre in which downstream values slightly higher than the upstream values that signified slight accumulation pollutants. Maximum difference in the BOD level and pathogenic concentration between the upstream and downstream side were observed at Kanpur and Varanasi signifying huge interference of human activities in the river ecosystem in Kanpur and Varanasi. Prayagraj showed continuous decline in pollution signifying improving water quality. However maximum TC and FC concentration at the upstream side was seen in Prayagraj which can be attributed to greater downstream values in Kanpur. The difference between the upstream and the downstream values at Prayagraj was comparatively less than that in Kanpur and Varanasi showing lesser accumulation of contaminants in the river stream. While all the centres showed declining trend of pollution owing to valiant government efforts and community participation, Mirzapur showed alarming and continuous increase in the organic and pathogenic pollutants. Therefore, effective measures are imperative, including reducing industrial and domestic effluent discharge, scrutinising sources of heavy metal contamination, and prioritising the restoration of the river's natural flow. Preserving the Ganges' ecological integrity is paramount, necessitating concerted efforts to ensure its health and vitality for future generations.

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