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Nitrate/Nitrite in the Lotic System of Yamuna and Ganga

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Abstract

The pollution of the Ganga and Yamuna rivers has become a serious environmental challenge in India. Despite the implementation of several government initiatives aimed at river conservation, these rivers continue to receive large quantities of untreated industrial effluents, municipal sewage, and agricultural runoff. Such contamination has resulted in the degradation of aquatic ecosystems and poses significant health risks to millions of people who depend on these rivers for drinking water, irrigation, and other domestic purposes. The Yamuna River originates from the Yamunotri Glacier and flows approximately 1,376 km before joining the Ganga at Prayagraj. The river basin covers about 366,223 km² across several northern Indian states. The hydrological characteristics of the river vary considerably between monsoon and non-monsoon seasons, with nearly 80% of the annual flow occurring during the monsoon period. During the dry season, extensive diversion of water through barrages for irrigation, domestic supply, and industrial use significantly reduces the natural flow of the river. Pollution in the Yamuna River arises from both point and non-point sources, with domestic sewage representing the major contributor. A critically polluted stretch of approximately 580 km exists between the Wazirabad Barrage and the confluence with the Chambal River, with the 22 km stretch passing through Delhi being the most severely affected. Monitoring studies indicate that water quality is comparatively better in upstream regions but deteriorates sharply after the river enters Delhi. Elevated organic pollution increased biochemical oxygen demand, and significant fluctuations in dissolved oxygen levels suggest severe contamination and persistent eutrophic conditions in this section of the river.

Keywords: NEDA, sulphanilamide, arginine, nitrate, Ganga, Yamuna

INTRODUCTION

Water pollution occurs when harmful substances enter natural water systems and alter their physical, chemical, or biological characteristics. Water is considered polluted when the presence of contaminants makes it unsuitable for human use, such as drinking or domestic purposes, or when it disrupts aquatic ecosystems and affects organisms, such as fish and other aquatic life. Pollution can result from the presence of chemical substances, organic waste, or other contaminants [1].

Although nearly two-thirds of the Earth's surface is covered with water, most of it is not suitable for human consumption. Approximately 98% of the total water available on Earth is saline seawater. Only about 2% is freshwater, of which a large proportion is locked in glaciers and polar ice caps. A smaller fraction is stored as groundwater in aquifers, leaving only a very limited amount available in rivers and lakes for direct human use. Therefore, the availability of clean and safe freshwater resources is extremely limited [1, 2].

The quality and availability of water resources are strongly influenced by environmental conditions, regional distribution, and seasonal variations. In recent decades, rapid population

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growth, urban expansion, agricultural development, and industrial activities have significantly affected water quality [3]. These activities introduce pollutants into water bodies, leading to the gradual degradation of surface and groundwater resources. Contaminated water not only affects the current population but also poses long-term risks to future generations because pollutants can persist in the environment for extended periods. Communities that depend on contaminated water sources may experience serious health problems, including damage to vital organs, such as the liver, kidneys, lungs, and brain, as well as increased risks of cancer, birth defects, and other diseases [4].

Nitrate contamination in drinking water is particularly concerning due to its direct impact on human health. Elevated concentrations of nitrate in drinking water have been associated with several health disorders, including methemoglobinemia (commonly known as blue baby syndrome), gastrointestinal cancers, and other health complications. Apart from its effects on human health, high nitrate concentrations also affect aquatic ecosystems. Excess nitrate in surface waters can promote excessive growth of algae and aquatic plants, leading to eutrophication. This process reduces water quality and may cause oxygen depletion, which negatively affects aquatic organisms and reduces the ecological and economic value of water bodies [5].

Nitrates naturally occur in water at low concentrations as part of the nitrogen cycle. However, intensive agricultural practices involving the heavy use of nitrogen-based fertilizers, particularly those containing urea, can significantly increase nitrate concentrations in surface and groundwater. When applied in excess, these fertilizers can leach into nearby water bodies through runoff and infiltration, creating potential environmental and health risks.

Rivers are especially vulnerable because they receive runoff from agricultural lands, industrial effluents, and domestic wastewater. The Ganga River is one of the most significant rivers in India and supports millions of people who depend on it for domestic, agricultural, and cultural purposes. However, increasing pollution levels are posing serious threats to its biodiversity and long-term ecological sustainability [6].

To assess nutrient pollution and eutrophication risk, water samples collected from multiple locations along the Ganga and Yamuna rivers in Uttar Pradesh were analyzed for nutrient concentrations. The results indicated that the average concentrations of nitrogen and phosphorus were higher than the levels typically observed in unpolluted rivers, suggesting a strong influence of human activities. In addition, a relatively low ratio of dissolved silica to dissolved inorganic nitrogen (DSI/DIN) indicated conditions favorable for algal growth, particularly in the Yamuna River. Based on trophic status indicators, the Yamuna River exhibited poor water quality and was characterized by hypereutrophic conditions, indicating severe nutrient enrichment and ecological imbalance [7].

LITERATURE REVIEW

The condition of river ecosystems is strongly influenced not only by natural processes but also by external inputs such as agricultural runoff, industrial discharge, and municipal waste. Nutrients present in river systems may originate from external sources, including weathering of rocks, precipitation, and runoff from domestic and agricultural activities, or from internal processes such as biological production and the decomposition of organic matter within the water body. In recent decades, rapid population growth has accelerated industrialization and urban expansion [4]. These developments, along with changes in land-use patterns, fossil fuel combustion, and residential runoff, have disrupted the natural nutrient balance of many rivers. A considerable proportion of the average annual river flow is also influenced by discharges from treatment facilities. Furthermore, modern agricultural practices that rely heavily on chemical fertilizers and agrochemicals have intensified nutrient enrichment in river systems [8].

During the past twenty years, the extensive use of fertilizers and pesticides has significantly increased nutrient concentrations in rivers, particularly compounds such as nitrate, potassium, and phosphate.

Among these nutrients, nitrogen, and phosphorus enrichment is of particular concern in aquatic ecosystems. Regions dominated by dense urban settlements or intensive agriculture often contribute large quantities of nutrients through diffuse runoff, which eventually enters river channels. Controlling such diffuse nutrient inputs is challenging because it requires integrated management strategies implemented at both watershed and river-reach levels [1]. Excessive nutrient loading can disturb the ecological balance of aquatic environments by altering the natural ratios of carbon, nitrogen, phosphorus, and silicon. Such imbalances may promote eutrophication, excessive algal growth, and the formation of oxygen-deficient zones that threaten aquatic life [9].

The Ganga and Yamuna rivers are among the most important river systems in northern India. Several densely populated cities are situated along their banks, and millions of people depend on these rivers for domestic, agricultural, and industrial purposes [10]. Despite this cultural reverence, increasing human activities have led to severe deterioration in their water quality, and the rivers have been ranked among the most polluted globally. The Yamuna, one of the major tributaries of the Ganga, is considered one of the most polluted rivers in India. A substantial proportion of the pollution load entering this river originates from the Delhi-NCR region, where untreated or partially treated wastewater discharges have transformed parts of the river into channels resembling sewage drains [2].

Numerous industries operate along the river, and many of them are categorized as highly polluting due to the nature of their effluents. Agricultural activities further contribute to nutrient enrichment, as a fraction of the phosphorus and nitrogen applied to croplands eventually reaches surface water bodies through runoff and leaching processes. Globally, large quantities of anthropogenic nitrogen from agricultural lands enter freshwater systems each year. Many freshwater ecosystems are naturally limited by phosphorus availability, and an increase in nutrient concentrations can disrupt ecological balance by altering the composition and diversity of aquatic plants and microorganisms that play essential roles in maintaining ecosystem health.

Nutrient pollution, therefore, remains a serious environmental concern because it can lead to deterioration of water quality, disruption of aquatic food chains, and adverse impacts on the health of humans and other living organisms. To address the growing problem of river pollution, the Government of India has implemented several river conservation initiatives, including the Ganga Action Plan, Namami Gange Programme, and the Yamuna Action Plan [5].

The Ganga Action Plan was implemented in two phases over several decades with substantial financial investment aimed at reducing pollution and improving water quality. Despite these efforts, the expected level of improvement was not achieved, highlighting the need for a more comprehensive and basin-wide management strategy. Consequently, the Namami Gange Programme was launched with the objective of restoring and conserving the entire Ganga river basin rather than focusing solely on specific river stretches. A significantly larger budget has been allocated under this programme to support pollution control measures, infrastructure development, and river rejuvenation activities [10].

Similarly, the Yamuna Action Plan was initiated as a collaborative effort between the governments of India and Japan to reduce pollution levels in the Yamuna River. The programme has been implemented in multiple phases, focusing on wastewater treatment, sewerage infrastructure, and pollution control measures. The current phase continues to address pollution abatement in the river with dedicated financial support [3].

However, despite the implementation of these large-scale restoration programmes, the water quality of both the Ganga and Yamuna rivers has not improved to the desired level. Nutrient pollution continues to pose a significant challenge to the ecological health of these rivers. Therefore, monitoring nutrient concentrations and understanding their dynamics in these river systems is essential, particularly in regions, such as Uttar Pradesh, where intensive agricultural activities dominate the landscape. Most previous studies conducted in this region have primarily focused on conventional physicochemical parameters such as dissolved oxygen, biochemical oxygen demand, heavy metals, and fecal coliform contamination. Comparatively fewer studies have examined nutrient loading patterns, their relationship with eutrophication risk, and the trophic status of these river systems.

In view of these knowledge gaps, the present study was undertaken to evaluate nutrient dynamics and eutrophication potential in the Ganga and Yamuna rivers. The specific objectives of the study were: (1) to assess the spatial and seasonal variation in dissolved nutrient concentrations in both rivers; (2) to examine nutrient chemistry and identify the major factors influencing it using multivariate statistical analysis; (3) to estimate dissolved nutrient ratios and nutrient loads in the river systems; and (4) to evaluate the eutrophication potential of the rivers using indicators such as the Indicator for Coastal Eutrophication Potential (ICEP) and the Trophic State Index (TSI).

MATERIALS AND METHODS

Sampling and Distribution

Water samples were collected and analyzed to determine the chemical composition and the biological and physical characteristics of the water bodies to evaluate their suitability for domestic, industrial, and agricultural use. Accurate sampling is essential to obtain reliable and representative results throughout the data collection process.

Water samples were collected from different locations of the Ganga River, including upstream, midstream, and downstream sites at Rishikesh, Anupshahr, Garh Ganga, and Prayagraj. In addition, water samples were collected from the midstream of the Yamuna River at Mathura.

Sample Collection Method

The following procedure was followed during sample collection:

- A sampling tap located after treatment but before the water entered the distribution system was selected.
- Any attachments from the tap, such as hoses, filters, screens, or aerators, were removed.
- The water was flushed for approximately 5 minutes or until a constant temperature was reached.
- The sample container was then filled up to the shoulder of the bottle.
- After collection, all samples were properly labeled and refrigerated.
- The collected samples were analyzed within 24 hours.

Chemical Used

Chemicals used in the study were purchased from Sigma-Aldrich Chemical Company, Missouri (USA). The main reagents used for nitrate analysis included:

- NEDA (N-(1-Naphthyl) Ethylenediamine Dihydrochloride).
- Sulfanilamide.
- Arginine.

Water Quality Test Results

The water quality of the collected samples was analyzed using parameters such as pH, conductivity, and nitrate concentration. The pH of the samples was measured using a pH meter. The pH scale ranges from 0 to 14 and indicates the acidic or basic nature of water. A pH of 7 is neutral, values below 7 are acidic, and values above 7 are alkaline. According to Bureau of Indian Standards (BIS) guidelines, the acceptable pH range for drinking water is 6.5–8.5. In the present study, the pH values of all samples ranged from 7.29 to 8.04, indicating that the water was slightly alkaline but still within the permissible limits.

Electrical conductivity was measured to determine the concentration of dissolved ionic substances present in the water. Conductivity generally increases in rivers receiving sewage or industrial discharge due to the presence of ions such as chlorides and phosphates from household and industrial products.

Higher conductivity values indicate a greater proportion of dissolved inorganic salts, while lower values suggest relatively cleaner water with fewer ionic impurities. In this study, the conductivity values recorded at different sampling sites ranged from –025 to –058 millivolts, showing variations in the ionic content of the water.

The nitrate concentration was measured using a nitrate meter. Nitrates are naturally present in water and are usually harmless at low concentrations. However, excessive nitrate levels can negatively affect aquatic ecosystems and human health. Drinking water containing nitrate concentrations above 10 mg/L may cause health problems, such as methemoglobinemia, commonly known as "blue baby syndrome." In the present study, the nitrate concentration in all water samples ranged from 0.014 to 0.031 mg/L, which is well below the harmful limit. This indicates that nitrate pollution in the sampled sites was relatively low during the study period.

RESULT

The physicochemical analysis of river water samples collected from different locations of the Ganga and Yamuna rivers showed variations in pH, conductivity, and nitrate concentration. The pH values of the samples ranged from 7.29 to 8.04, indicating slightly alkaline water conditions. The lowest pH value was observed at Anupshahr Ganga (7.29), while the highest pH value was recorded at Yamuna (Mathura) and Prayagraj (8.04). These values fall within the acceptable range for natural river water.

The conductivity values also varied among the sampling sites, indicating differences in dissolved ionic content in the water. The conductivity ranged from –025 mV to –058 mV, with the highest value observed in Yamuna (Mathura) and Prayagraj, suggesting a relatively higher concentration of dissolved salts and pollutants compared to other sites.

The nitrate concentration in the water samples ranged from 1.4 to 2.5 µmoles/L. The highest nitrate concentration was recorded in Yamuna (Mathura) (2.5 µmoles/L), followed by Garh Ganga (2.4 µmoles/L), while the lowest value was found in Anupshahr Ganga (1.4 µmoles/L). Moderate nitrate levels were observed in Rishikesh (2.0 µmoles/L) and Prayagraj (1.8 µmoles/L). These variations may be attributed to agricultural runoff, domestic sewage, and other anthropogenic activities affecting the water quality of these rivers.

Overall, the results indicate spatial variation in water quality parameters, with relatively higher nutrient and conductivity levels observed in regions influenced by human activities.

CONCLUSION

The present study evaluated the water quality of selected sites of the Ganga and Yamuna rivers by analyzing parameters, such as pH, conductivity, and nitrate concentration. The results showed that the pH values ranged from 7.29 to 8.04, indicating slightly alkaline water but within the permissible limits recommended for drinking water. The conductivity values suggested the presence of dissolved ions, which reflect the mineral content of the water. The nitrate concentration in all samples was found to be very low (0.014–0.031 mg/L) and well below the permissible limit of 10 mg/L, indicating that the water is not significantly affected by nitrate pollution.

Overall, the findings suggest that the water quality of the studied river sites is within acceptable limits with respect to nitrate levels. However, continuous monitoring of water quality is necessary to prevent future contamination and to ensure the safety of water for domestic, agricultural, and ecological purposes.

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