International Journal of Tropical Agriculture
Volume 44, Numbers (1-2) • 2026 : pp. 89-100
ISSN: 0254-8755
https://DOI:10.47509/IJTA.2026.v44i1-2.12

Decoding Yamuna Pollution: Sources, Quality Assessment and Health Consequences

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Abstract: The River Yamuna, a vital water resource for millions, faces severe pollution challenges exacerbated by industrial effluents and untreated sewage. According to the Central Pollution Control Board (CPCB), the river receives approximately 667 million gallons of sewage daily, with Delhi contributing a significant portion. Despite substantial investments in the Yamuna Action Plan (YAP), the biochemical oxygen demand (BOD) from the National Capital Territory has increased from 117 tons per day in 1982 to 260 tons per day in 2004. To achieve bathing class B water quality standards, nearly tenfold dilution of treated municipal wastewater is required. The Yamuna River, originating from Yamunotri and flowing through several states, is essential for transportation, irrigation, and cultural practices, yet it is recognized as one of India's most polluted rivers. As the river progresses downstream through Haryana and Uttar Pradesh, its water quality declines markedly. This degradation is largely driven by the influx of untreated municipal sewage and industrial discharges from densely populated urban areas. In Delhi alone, nearly 90% of domestic wastewater is discharged directly into the river without adequate treatment. The resulting contamination significantly elevates public health risks, particularly by increasing the prevalence of waterborne. Effective measures to combat industrial pollution include the mandatory installation of effluent treatment plants (ETPs), strict regulatory oversight, and the promotion of recycling and reuse of treated wastewater. Public awareness initiatives are crucial for engaging communities in pollution prevention efforts. Furthermore, implementing a water abstraction control policy and promoting water conservation practices through education and community participation are essential for sustainable management of the Yamuna. Despite substantial financial investments aimed at remediation, the persistent pollution issue underscores the complexity of achieving sustainable river health, highlighting the importance of systematic studies on anthropogenic impacts on river systems.

Keywords: River rejuvenation, Water quality, Microbial load, Heavy metals,

INTRODUCTION

Freshwater availability is crucial for societal, economic, political, and environmental development, particularly through river systems that are essential for the socioeconomic advancement of nations. However, contemporary river systems are increasingly polluted due to various factors such as urbanization, industrial activities, development projects, and high population density, which compromise water quality (Khondoker *et al*. 2023). Pollution primarily stems from industrial and agricultural practices, adversely affecting freshwater quality (Wato *et al.,* 2020). The major driving forces lead to water pollution, including construction, agricultural runoff, and urban and industrial waste, illustrating the interconnected nature of these factors. Seasonal variations in surface water runoff, precipitation, groundwater flow, and human water consumption significantly

Article History: Received: 10 March 2026; Revised: 09 April 2026; Accepted: 15 April 2026; Published: 20 May 2026

influence both the qualitative and quantitative characteristics of river water throughout the year. The Himalayan rivers play a vital role in sustaining life and significantly influence cultural practices, such as mass bathing during festivals, making them integral to Indian culture (Bhatt *et al.* 2022). Among the three major rivers originating from the Himalayas—Yamuna, Ganga, and Brahmaputra—these waterways are essential for transportation, irrigation, fishing, hydroelectric power generation, and cultural activities. This detailed study focuses on the Yamuna River, which begins at Yamunotri and flows through the states of Madhya Pradesh, Himachal Pradesh, Haryana, Delhi, and Rajasthan. The demand for clean drinking water is escalating globally, exacerbated by environmental degradation and increasing concerns about waterborne diseases (Chakraborti *et al.,* 2019; Sharma et al. 2020). Industrial regions are particularly problematic, as they have notably degraded water quality, posing health risks to both humans and animals (Chowdhary *et al.,* 2020). The water quality of the Yamuna River deteriorates as it flows downstream into Haryana and Uttar Pradesh, primarily due to the discharge of sewage and wastewater from major urban centres such as Panipat, Sonipat and Yamuna Nagar (Kumar *et al.,* 2020; Sharma *et al.,* 2024). This pollution has severely impacted various segments of the river, leading to a significant reduction in freshwater availability for drinking and irrigation. The cumulative release of industrial, residential, and agricultural wastewater has effectively transformed sections of the river into an open sewer (Jaiswal *et al.,* 2022; Kayastha, 2024). Moreover, the health of the river is further threatened by extreme climate events, including unprecedented heat waves and changing precipitation patterns (Sharma *et al.*, 2023; Rajan *et al.,* 2024; Yadav *et al.,* 2024). Addressing these challenges necessitates a comprehensive strategy to protect the water quality of the Yamuna and prevent the spread of diseases. This includes assessing water quality and identifying pollution sources such as agricultural runoff, industrial discharges, untreated sewage, and both commercial and household wastewater (Mohan, 2023). Identifying these pollution sources and evaluating their water quality is crucial. This study emphasizes the Yamuna river, recognized as one of India's most polluted rivers, rendering its water unsafe for drinking or bathing. Additionally, the consumption of contaminated fruits, vegetables, and other crops grown in its basin poses health risks due to the polluted water. Despite the clear pollution concerns, the issue remains complex and persistent, even after substantial financial investments which aimed at remediation. River Yamuna is also one of the most polluted rivers of India. It becomes very important to systematically study the status of pollution of the rivers in relation to various anthropogenic activities.

THE YAMUNA RIVER

The Yamuna River, the largest tributary of the Ganges, originates from the Yamunotri Glacier at an altitude of 6,387 meters, near the Banderpoonch peak in Uttarkashi district, Uttarakhand. Its catchment area spans several states, including Uttar Pradesh, Himachal Pradesh, Haryana, Rajasthan, and Madhya Pradesh, as well as the entire union territory of Delhi.The river flows a total length of 1,376 kilometres and covers a catchment area of approximately 366,220 square kilometers. Key tributaries of the Yamuna include Hindon, Chambal, Sind, Betwa, and Ken. The river's annual flow is about 10,000 cubic meters per second (cumecs), with 4,400 cumecs utilized annually, primarily for irrigation, which accounts for 96% of its usage. The catchment area of these tributaries is detailed in Figure 1 and Table 1. This perennial river is fed by groundwater, precipitation, and snowmelt runoff (Joshi *et al.,* 2023). Glaciers are among the primary natural sources of river water.

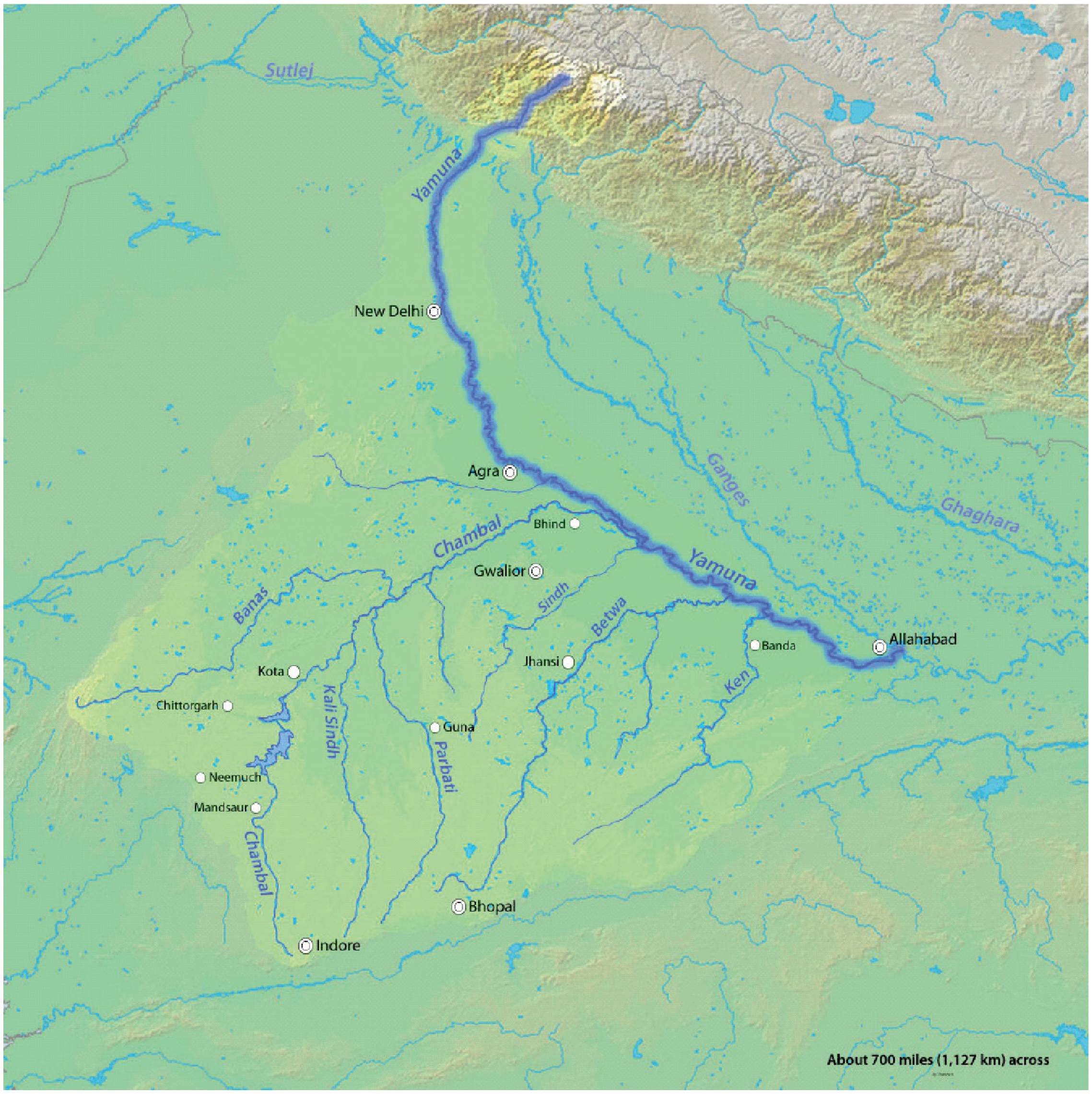

Fig. 1: Yamuna Basin *(Source: Google Earth)*

The Yamuna River is not only a vital water source but also holds immense religious and cultural significance. It sustains the livelihoods of communities residing in its basin and supports agriculture, industry, and urban areas, serving as the primary drinking water supply for many towns along its path. In fact, over 70% of Delhi's drinking water is sourced from the Yamuna, benefiting around 57 million people. However, the river faces severe pollution challenges due to rapid urban growth, industrialization, and insufficient infrastructure. Industrial towns along the river contribute significant waste, leading to its degradation, especially in the lower stretches where it primarily receives agricultural, industrial, and domestic effluents. As of 2023, approximately 359 industrial units were identified as directly polluting the river, including 22 in Haryana, 42 in Delhi, and 17 in Uttar Pradesh. These industries encompass various sectors such as paper, sugar, chemicals, leather, distilleries, and pharmaceuticals. Major cities located along the Yamuna's banks include Yamunanagar, Sonipat, Panipat, Delhi, Agra, and Mathura. The river's health is increasingly threatened by pollution and unsustainable water use, highlighting the urgent need for effective management and restoration efforts. The Yamuna River faces severe pollution due to the discharge of wastewater from various industries along its course. Key polluting sectors include pulp and paper mills, sugar factories, tanneries, steel plants, distilleries, textiles, leather processing, chemicals, pharmaceuticals, rubber, glass, oil refineries, thermal power plants, and food processing (fig 2). Delhi, in particular, contributes significantly to the river's degradation, with treated and untreated domestic and industrial effluents being discharged through numerous drains. Approximately 95% of the pollution in the Yamuna at Delhi is attributed to seven major drains: Najafgarh, Yamunapur, Sen Nursing Home, Barathpula, Maharanibag, Kalkaji, and Tuglakabad. The river's condition is so poor that beyond the Okhla barrage, it can hardly sustain any form of life. The pollution includes not only organic matter and nutrients but also alarmingly high levels of pesticides and heavy metals (Kumar *et al.*, 2020).

Causes of Yamuna River Pollution

The Yamuna River, a major tributary of the Ganges, is facing severe pollution issues. Despite accounting for only 2% of the entire catchment area, the National Capital Territory (NCT) of Delhi collects 79% of the river's total pollution in a 48-km stretch, making it the most polluted section. The primary cause of pollution in the river, accounting for around 85%, is domestic sources (Jha *et al,* 2023), these include:

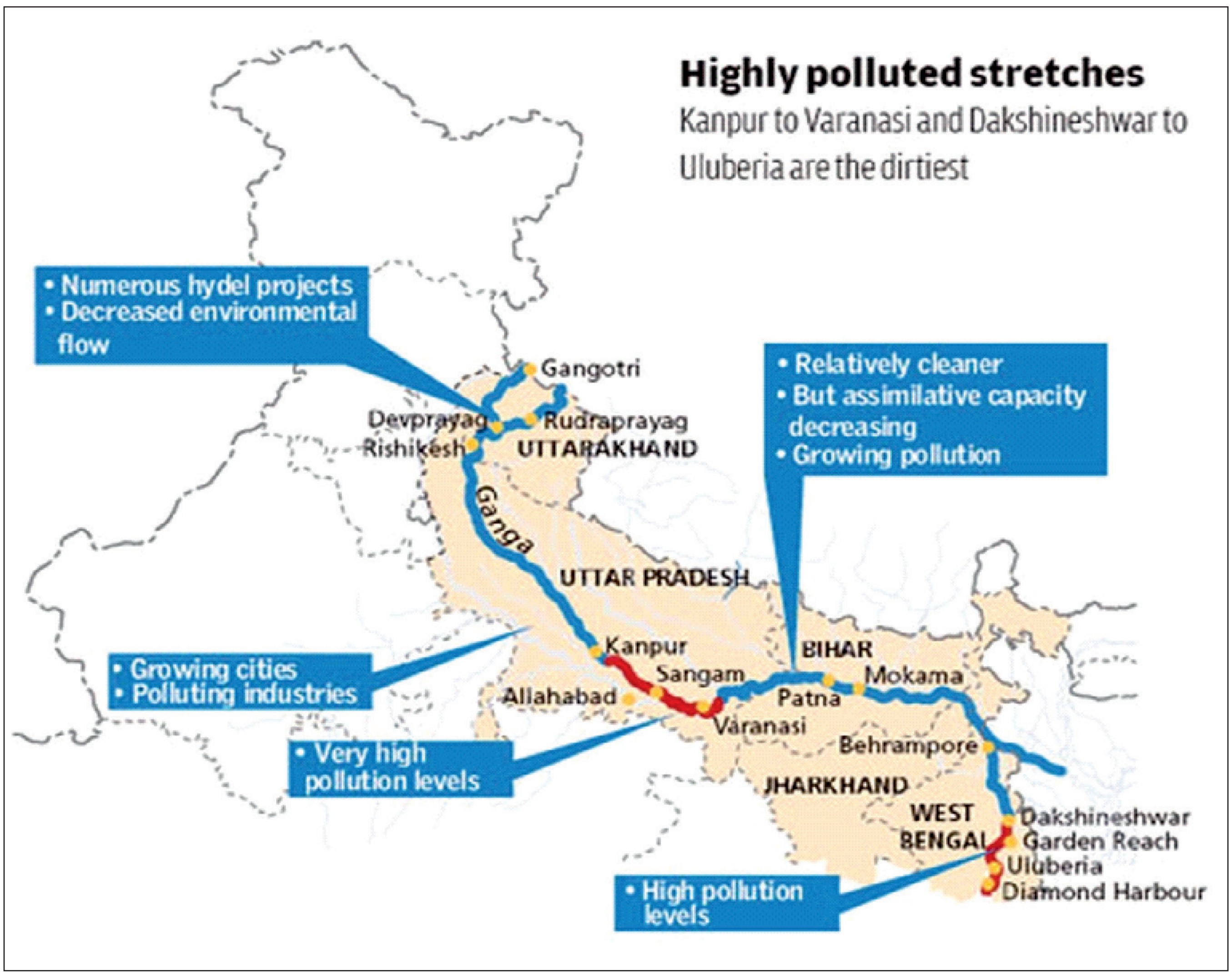

Fig. 2: Pollution level along the stream of Yamuna (Source: Centre of Science and Environment)

Table 1: State-wise Catchment Areas and Drainage Basin Contributions *(CGWB, 2024)*

S. No	*Location*	*Total Catchment Area (Km²)*	*Drainage Basin (Km²)*	*Percentage Drainage Basin (%)*	*Areas in major tributaries (Km²)*					
					Chambal	*Betwa*	*Hindon*	*Ken*	*Sind*	*Others*
1	Uttarakhand (UK)	3771	21769	33						3771
2	Uttar Pradesh (UP)	70437	166231	1	452	14438	748	3336	748	44380
3	Himachal Pradesh (HP)	5799	2320	1	-	-	-	-	-	5799
4	Rajasthan	102883	7422	19	79495	-	-	-	-	23388
5	Haryana	21265	34341	11	-	-	-	-	-	21265
6	Delhi	1485	1485	11	-	-	-	-	-	-
7	Madhya Pradesh (MP)	140208	72700	14	59838	33502	-	21090	25131	647

1. Industrial effluents
2. Raw manure
3. Waste and dead body disposal
4. Idol worship
5. Contaminants from water used in religious rituals

The river Yamuna is under serious threat from unprecedented escalation in urbanization and industrialization. Understanding the pollution sources is crucial for developing effective mitigation techniques. The deterioration of Yamuna's water quality is attributed to various parameters (Christopher *et al.*, 2012), including:

1. Biological pollutants
2. Heavy metals (HM)
3. Pollution from agriculture
4. Untreated domestic wastewater
5. Industrial effluents released by industries

Each source contributes substantially to the river's declining health. In the subsequent sections, each pollution source will be discussed in detail, highlighting the specific pollutants and their impact on the Yamuna's delicate ecosystem in detail.

The pollution in the Yamuna River is continuously escalating and the river water is unfit for any use. There are serious water quality problems in the, cities, towns and villages using Yamuna rivers as a source of their water.

The major sources of pollution in Yamuna River are:

(a) Industrial Effluents: The Yamuna River is often referred to as the "mailee" (dirty) river and the "river of sorrow" for the cities of Delhi, Mathura, and Agra. Water appears extremely black and resembles an industrial drain in Delhi due to the proximity of numerous industries that discharge untreated effluents directly into the river. For about nine months each year, the water in the Yamuna remains stagnant. Cities such as Faridabad, Mathura, Delhi, and Agra have many industrial facilities that release significant amounts of untreated water into the river. Reports indicate that 359 industrial facilities either directly or indirectly discharge their effluents into the Yamuna, with 42 industrial units in Delhi being major contributors to its pollution (Sharma, 2021; Syeed *et al.*, 2023; Yadav *et al.*, 2024).

(b) Domestic Waste Water: Yamuna River is recognized as one of the most polluted rivers in the world, particularly in the Delhi region, due to significant wastewater discharge. Delhi alone accounts for 23% of the total wastewater generated by Class I cities, which are cities with populations exceeding 100,000. Alarmingly, this figure rises to 47% when considering the waste produced by 101 Class I cities and 122 Class II cities (with populations between 50,000 and 99,999) within the Ganga basin. The untreated domestic wastewater discharged

into the Yamuna contains ammonia, which increases its concentration. Water becomes difficult to treat when ammonia levels reach 0.4 mg/L or higher (Sharma et al., 2024). Additionally, Usha and Singh (2024) reported that the phosphate content in the river was 0.51 mg/L, significantly above the standard range of 0.005 to 0.05 mg/L. This excess phosphate contributes to the formation of toxic froth on the river's surface. Ammonia levels in the Yamuna are often found to exceed 0.4 mg/L, particularly during the summer months. The river has become severely polluted due to the continuous discharge of domestic wastewater from Palla to Etawah (Mishra, 2010).

(c) Agriculture: Agricultural runoff is a major source of pollution in the Yamuna River, with chemical fertilizers, pesticides, nutrient-rich runoff, and soil erosion being the primary contributors. The extensive use of these substances in the river's basin leads to the introduction of various pollutants into the water system, exacerbating the already critical state of its water quality (Christopher et al., 2012). Agriculture is prevalent throughout the Yamuna River basin, including the catchment areas and along the entire riverbank. This agricultural activity leads to the drying up of river streams during the non-monsoon season and contributes to the presence of pesticide residues in the river (Mishra, 2010). The contaminated water poses health risks to consumers, as harmful substances can accumulate in crops irrigated with polluted water. Additionally, the polluted water can lead to reduced crop yields and economic hardships for farmers who rely on the river for irrigation (Sharma *et al.,* 2024).

(d) Anthropogenic activities: Heavy metal pollution in the Yamuna River is a major environmental hazard, mostly caused by human activity. Heavy metal contamination is most commonly caused by industrial discharges, untreated sewage, and agricultural runoff. The industrial sector plays a big role, with various plants along the river's banks emitting harmful metals such as chromium, lead, cadmium, nickel, and zinc. According to studies, a stretch of the river from Wazirabad to Okhla barrage accounts for more than half of the pollution load, highlighting the impact of both point and non-point sources, such as industrial discharge and agricultural runoff and untreated wastewater from drains (Kumar *et al.,* 2024). The flow of untreated sewage worsens the issue, with about 800 million litres of mostly untreated sewage entering the river every day. This sewage frequently contains heavy metals such as Cr, Cd, Zn, Cu, Ni, and Pb, as well as other contaminants that degrade water quality (Kr *et al.,* 2018). According to river quality monitoring, significant levels of several heavy metals have been identified in the Yamuna River's water. The most frequent element in Yamuna water is Fe, which exceeds the permissible limit. High amounts of heavy metals in water can cause a variety of health problems, including stunted growth and development, organ damage, cancer, nervous system impairment *etc* (Jaiswal *et al.,* 2022). According to Sehgal *et al.,* 2012, two locations between the Okhla and Wazirabad barrages that looked to be hotspots for river water deterioration have higher concentrations of numerous HMs. Yadav and Khandegar 2019 discovered that the large flow of industrial wastes into the Yamuna River was responsible for the changing content of HM. Contamination of the aquatic environment with HM has been a global problem in recent years due to their invulnerability and harmful effects on animals. Ni, Cd, and Pb, three HM, are rarely detected in high amounts (Malik., 2014). Despite the presence of sewage treatment plants, only a fraction of the sewage is adequately treated before being released into the river, leading to high concentrations of heavy metals and other contaminants. Additionally, agricultural practices contribute to heavy metal pollution through the runoff of fertilizers and pesticides,

which can contain harmful metals. The accumulation of these metals poses serious health risks to the local population, including potential damage to the nervous system, kidneys, and liver, as well as increased cancer risk. The combination of these factors has led to the Yamuna being classified as one of the most polluted rivers in the world, necessitating urgent intervention to mitigate heavy metal pollution and protect both human health and the river's ecosystem. Heavy metal exposure poses grave risks to human health, leading to a range of acute and chronic issues. Toxic metals like lead, mercury, cadmium, and arsenic can induce severe effects on various body systems (Malik *et al.,* 2014). Acute exposure may cause abdominal pain, diarrhoea, kidney damage, and neurological disorders, while chronic exposure can lead to organ damage, developmental problems, and cancer (Fiyadh *et al.,* 2023). Lead exposure is especially harmful to children, potentially causing cognitive impairments and behavioural issues due to its neurotoxicity. Cadmium exposure has been linked to kidney tubular damage, increased cancer risk, decreased semen quality, visual motor impairment, and loss of concentration (Okpara *et al.,* 2022). Mercury exposure can result in neurological and developmental deficits in foetuses and young children, while cadmium is associated with kidney dysfunction and bone fragility. Heavy metals can disrupt cellular processes, induce oxidative stress, and cause genomic instability, contributing to cancer risk (Mrozik *et al.,* 2021). The accumulation of these metals in the body, often through contaminated water, food, and air, underscores the urgent need for effective monitoring and intervention strategies to mitigate their harmful health effects (Fig 3).

Water Quality assessment of Yamuna River

Water quality assessment is a systematic process that involves evaluating the physical, chemical, and biological attributes of water

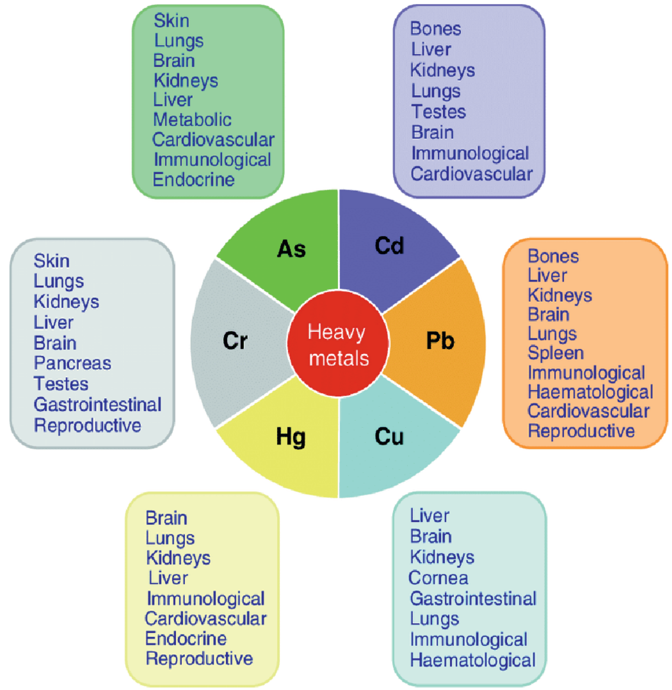

Fig. 3: Impact of Heavy metals on Human Health

to understand its natural state, the effects of human activities, and its potential uses. This evaluation is essential for determining whether water is safe for environmental purposes, human consumption, irrigation, and supporting aquatic ecosystems. Typically, this assessment compares the water's characteristics against established standards (Kumar, 2020).Key physicochemical parameters commonly analyzed in water quality studies include water temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), E coli, ammonia, nitrates, heavy metals (HMs), and chloride, among others. An overview of the acceptable limits for these parameters according to various standards is provided in Table 2.The water quality of the Yamuna River was evaluated using the Water Quality Index (WQI) and classified into different categories - "excellent-to-good", "good", "fair", "marginal", and "poor".- The upper zone of the river, from Paonta to Palla, had an "excellent-to-good" WQI. This indicates the water quality in this region was suitable for drinking after disinfection, as well as for irrigation and industrial uses. The middle region of the river, from Delhi to Etawah, was characterized by a "poor-to-marginal" WQI (Jaiswal *et al*., 2019). This was due to high pollution loads from urban and industrial sources, including discharges from major drains like Najafgarh and Shahdara. The lower zone of the river, from Auraiya to Pratappur, had a "good-to-excellent" WQI. This improvement in water quality was attributed to the dilution and depuration effects from tributaries like the Chambal, Betwa, and Ken rivers. The longitudinal pollution gradient along the river correlated with the oxygen sag curve (Fig 4), indicating the river's ability to assimilate and recover from the waste loads as it flows downstream, the water quality of the Yamuna River varied significantly from the upper to lower stretches, with the middle region being the most polluted due to urban and industrial influences, while the upper and lower zones had better water quality conditions.

Table 2: Water Quality Assessment of River Yamuna (CPCB, 2023)

Parameter	*Palla*	*Asgarpur*
Physico-Chemical Parameters		
Dissolved Oxygen (DO)	> 5 mg/L (9.2)	BDL
pH	6.5 - 8.5 (8.2)	7.4
Biochemical Oxygen Demand (BOD)	< 3 mg/L (16)	94
Ammonia (NH3-N)	--	5.5
Bacteriological Parameters		
Faecal Coliform	< 2500 MPN/100 ml ($17x10^3$)	$46x10^5$
Faecal Streptococci	< 500 MPN/100 ml ($16x10^3$)	$24x10^5$
Total Coliform	--	$54x10^3$
Heavy Metals		
Arsenic	--	BDL
Cadmium	--	BDL
Cobalt	--	BDL
Chromium	--	0.03
Copper	--	0.05
Iron	0.77	3.11
Manganese	0.14	0.59
Nickel	--	0.04
Lead	--	BDL
Zinc	0.04	0.11

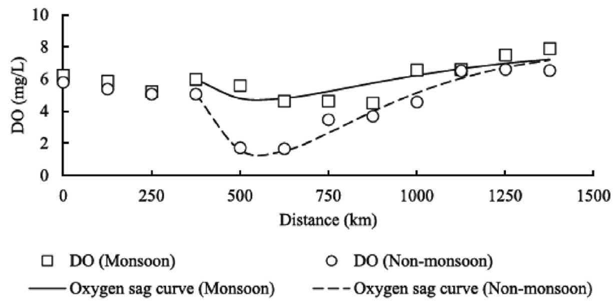

Fig. 4: DO profile along the Yamuna River and corresponding oxygen sag curve starting from Palla (Jaiswal *et al*., 2019)

Water quality of the Yamuna River in Dehradun for a 3-year period from 2017 to 2019 was studied by Sharma et al., 2020. The water quality index (WQI) was calculated for each year to assess the overall water quality. In 2017, the WQI was 42.87 indicating poor water qualities. However, the WQI improved to 40.47 in 2018 and 40.82 in 2019. Trend analysis was done to forecast the pollution levels in the Yamuna River from 2020 to 2024. The analysis showed that parameters like temperature, total coliform; TDS and hardness are increasing over time, while pH and dissolved oxygen are not rising significantly (Fig 5).The poor water quality is attributed to factors like high tourist activity, inadequate sewage facilities, and insufficient wastewater management in Dehradun and in the coastal areas of India.

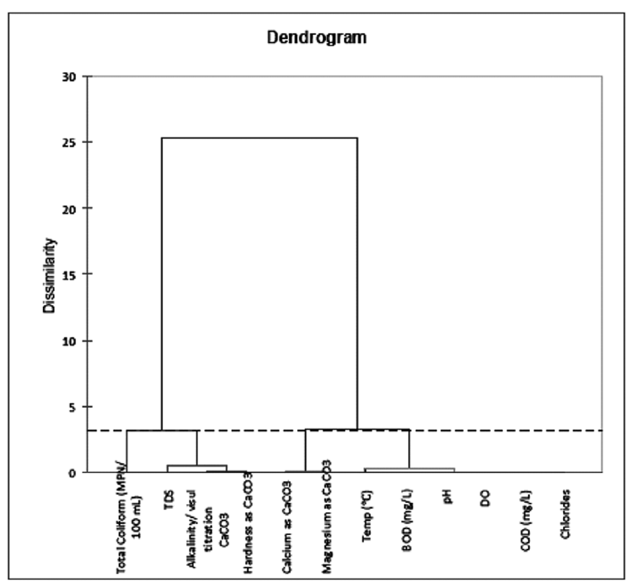

Fig. 5: Dendrogram for physicochemical parameter mean values for 2017, 2018, and 2019

Extent of Pollution in Yamuna River

The Central Pollution Control Board reported that approximately 667 million gallons of sewage, including industrial effluents, flow into the river daily. Of this, Delhi contributes around 3,270 million litres per day (MLD), accounting for 80% of the water supplied as sewage. The biochemical oxygen demand (BOD) at Okhla ranges from 31 mg/L to 64 mg/L, with virtually no dissolved oxygen (DO), while total coliform levels fluctuate between 1.3 million and 16 million most probable number (MPN) per 100 millilitres. The CPCB has set limits for the Delhi stretch at 3 mg/L for DO and 5,000 MPN/100ml for total coliform(CPCB, 2024). The Delhi Jal Board has raised concerns about intermittent pollution, particularly high levels of ammoniacal nitrogen detected at Wazirabad, which disrupt drinking water supplies in Delhi. The CPCB has identified sources contributing to elevated ammonia levels and is taking corrective measures. They are also establishing an institutional framework, including a Standard Operating Procedure, to address emergencies related to high toxicity in drinking water, which poses significant health risks to residents. To pinpoint the sources of high ammoniacal nitrogen, the Yamuna Management Committee (YMC) has tasked a committee of CPCB and NEERI scientists with providing advance alerts regarding water quality at Palla, especially when ammonia levels rise significantly, potentially affecting drinking water quality at Wazirabad (Ramadhan *et al.*, 2024). There is a pressing need for real-time online monitoring stations to measure water quality parameters such as pH, total suspended solids (TSS), BOD, DO, and ammoniacal nitrogen. This would enable early warnings to the DJB about pollutants in the river, allowing for proactive measures to protect the raw water being treated at the water treatment plants supplying drinking water to Delhi. The status of sewage treatment plants (STPs) in and around Delhi indicates that they are functioning at their best to treat the polluted water of the Yamuna. Five specific locations have been designated for water quality monitoring stations: Palla, Nizamuddin, Agra Canal at Kalindi Kunj, Okhla (downstream), and Agra Canal at Badarpur. Testing occurs monthly, and results are published on the CPCB website (Dar., 2024). Additionally, the CPCB generates reports on faecal coliform and total coliform, with monthly reports available for different years on the websites of both the Delhi Pollution Control Committee (DPCC) and the CPCB which can be used by scholar for simulating the real time data.

CONCLUSION

The dire situation of the Yamuna River necessitates immediate action and stringent regulations to protect the millions who rely on its waters and to restore the river's ecological health. The complexity of the pollution problem is underscored by various sources, including untreated domestic sewage, industrial discharges, and agricultural runoff. However, comprehensive policies targeting key areas—such as industrial regulations, wastewater management, sustainable agricultural practices, and public awareness campaigns propose hope for restoration. Effective wastewater management is crucial, involving the development of efficient sewage treatment plants (STPs) and decentralized solutions to address the significant untreated wastewater discharge, which accounts for about 80% of surface water pollution, particularly affecting cities like Delhi and other subordinate states. Implementing strict industrial regulations is essential to mitigate pollution, especially from unregulated enterprises. Coupled with incentives for greener production methods, these policies can significantly reduce harmful metals and other pollutants. Promoting sustainable agricultural practices, such as organic farming, is vital to decrease high nitrate and phosphate levels that contribute to eutrophication and fish mortality in the river. Public awareness initiatives are also critical, fostering community engagement and accountability through cleanup drives and reporting mechanisms for polluters.

FUTURE THRUST

As directed by the Hon'ble Supreme Court of India, a minimum water flow of 10 m^3/sec must be maintained throughout the River Yamuna (Paliwal et al. 2007). The CPCB has set standards for the discharge of treated effluent into water bodies, specifying limits of 30 mg/L for biochemical oxygen demand (BOD) and 250 mg/L for chemical oxygen demand (COD). Despite an investment of ₹1,187.54 to ₹1,443.84 crores in the Yamuna Action Plan (Srivastava, 2022), the BOD load from the National Capital Territory (NCT) has risen significantly, from 117 tons/day in 1982 to 260 tons/day in 2024 (CPCB, 2024). To adhere to the bathing class B water quality standards, nearly ten times dilution of fully treated municipal wastewater is necessary. To mitigate industrial pollution in the River Yamuna, several preventive measures are recommended:

- **Effluent Treatment Plants (ETPs)**: Industries must install ETPs to ensure that industrial waste is treated before being discharged into the river. Regulatory guidelines should be established for the operation and maintenance of these plants.
- **Separation of Effluents**: There should be a clear distinction between treated and untreated effluent, with an emphasis on recycling and reusing treated wastewater.
- **Monitoring Systems**: Strengthening systems and procedures is essential for accurately measuring both the quantity and quality of treated effluent in relation to prescribed standards.
- **Public Participation**: Preventing pollution in the Yamuna requires active involvement from the community. Raising awareness about the causes and consequences of river pollution is crucial, alongside educating the public on methods to reduce pollution levels.
- **Industrial Waste Management**: Measures must be taken to prevent industrial waste from entering the river, especially since many industries are located along its banks.
- **Water Abstraction Control**: A policy is needed to regulate the maximum and wasteful use of river water by industries.
- **Water Conservation Practices**: Implementing water conservation strategies through education and community engagement is vital for sustainable management of water resources.

This study aims to direct efforts toward restoring the previously thriving ecosystem of the Yamuna while identifying knowledge gaps for future research. It aligns with global conservation efforts, emphasizing the importance of protecting natural resources like the Yamuna river for future generations and honouring the cultural significance of the river.

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