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Anthropogenic Impacts on River Ecosystemsin India- A Review

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Abstract

Rivers are most important part of our life, supporting ecosystems, agriculture, industry, and cultural heritage. However, growing human activities like dam construction, sand mining, and pollution from agriculture, industries, and untreated sewage have severely degraded river health in India. These changes have impacted water quality, biodiversity, and human well-being. This article highlights key issues using examples from rivers like the Ganga, Yamuna, Musi, and Chambal, and stresses that while the damage is serious, it is reversible. With public awareness, strong law enforcement, and sustainable practices, river restoration is possible. The aim is to promote collective responsibility in conserving river ecosystems.

Keywords: River Pollution, Ecosystem Degradation, Sand Mining, Industrial Effluents, River Restoration, India, Aquatic Biodiversity, Sustainable Development.

1. Introduction

Rivers have historically been a important element of India's natural and cultural legacy. Human societies have flourished alongside riverbanks throughout history, such as the Indus Valley Civilization along the Indus and the Gangetic plains, which facilitated the rise of important kingdoms and settlements. Rivers serve as more than mere bodies of water; they are vibrant ecosystems that sustain a wide range of biodiversity while delivering various ecosystem services, including water supply, food, energy, transportation, and opportunities for livelihoods. In many inland regions, rivers often represent the primary source of freshwater for agricultural, industrial, and household needs.

India boasts an extensive network of rivers, both perennial and seasonal. Inland rivers like the Mula-Mutha (Maharashtra), Yamuna (Uttar Pradesh, Delhi), Sabarmati (Gujarat), Musi (Telangana), and Gomti (Uttar Pradesh) have historically addressed the needs of millions. However, due to rising urbanization, industrial growth, population increase, and unsustainable farming methods, the condition of many of these rivers is beginning to decline. The Central Pollution Control Board reports that over 351 river stretches across India are in a critical state of pollution, primarily due to elevated levels of biochemical oxygen demand (BOD) resulting from untreated sewage and industrial effluents [1].

Human activities such as unregulated sand mining, dam construction, encroachment on river floodplains, disposal of untreated sewage, and the dumping of industrial waste have significantly disrupted the natural flow, sediment load, and ecological integrity of rivers. For example, the Yamuna River in Delhi receives around 3,800 million liters per day (MLD) of untreated residential and industrial wastewater, far surpassing its capacity for self-purification [2]. In a similar vein, the Mula and Mutha rivers in Pune have experienced a notable decline in water quality and aquatic biodiversity due to pollution stemming from household sewage, industrial waste, and inadequate solid waste management [3].

Pollution has not only changed the physicochemical properties of river water such as pH levels, dissolved oxygen (DO), and turbidity but has also resulted in the decline of aquatic ecosystems, alterations in microbial and plankton communities, and the accumulation of heavy metals in fish and other organisms living in water [4]. This environmental deterioration has both direct and indirect impacts on human health, food security, and the livelihoods of those, particularly from disadvantaged backgrounds, who rely significantly on rivers for their daily needs. While numerous laws and national action initiatives have been established to oversee and tackle river pollution such as the Water (Prevention and Control of Pollution) Act of 1974 and the Namami Gange Programme from 2014 their effectiveness is hindered by poor implementation, lack of inter-departmental collaboration, and inadequate community involvement [5].

This review article seeks to investigate the various human activities that contribute to the degradation of the health of inland rivers in India. It also addresses their ecological repercussions and emphasizes the need for an integrated approach to river basin management, rigorous law enforcement, sustainable practices, and collaborative efforts to safeguard and restore these essential water resources.

2. Human–River Relationship:

Since the beginning of civilization, rivers have been fundamental to the development and evolution of human societies. In the Indian subcontinent, numerous ancient cities like Varanasi, Haridwar, Prayagraj, and Patna developed and thrived alongside significant rivers, benefitting from the easy access to fresh water, nutrient-rich soil, and navigable routes that facilitated trade and travel. These rivers were not only regarded as crucial natural assets but were also honored as sacred beings. They became essential to the religious beliefs, cultural customs, and shared spiritual awareness of the community. However, as time has passed, the once respectful and harmonious relationship between humanity and rivers has diminished. Rapid urban growth, industrialization, and unsustainable development practices have drastically changed this relationship. Even though rivers remain important, they are increasingly seen as endless resources able to meet human needs indefinitely and absorb large amounts of waste. This misguided view has caused extensive overuse, pollution, and ecological harm.

Rivers are vital to human survival and advancement, fulfilling a wide range of crucial needs. They support agriculture by aiding irrigation and replenishing groundwater illustrated by the Indo-Gangetic Plain, one of the most fertile agricultural areas in the world, which heavily depends on rivers like the Ganga, Yamuna, and Ghaghara [6]. They also provide drinking water for millions. Cities such as Delhi, Pune, and Hyderabad rely on rivers like the Yamuna, Mula-Mutha, and Musi to satisfy their daily water requirements [7]. Rivers are equally important for industrial activities, supplying water for production, cooling, and cleaning processes. Nonetheless, this reliance has a negative aspect. Many rivers have become dumping sites for untreated industrial waste. For example, the Bandi River in Rajasthan has faced severe deterioration due to wastewater discharge from textile dyeing facilities in Pali, resulting in significant alterations in water color, chemical makeup, and aquatic health [8].

In numerous rural and peri-urban areas, rivers still serve domestic purposes, such as bathing, washing, and cleaning. Regrettably, the absence of adequate sanitation infrastructure often leads to the direct discharge of wastewater and detergents into river systems, exacerbating pollution. Besides their practical uses, rivers like the Ganga, Godavari, and Narmada are of immense religious and cultural importance. Ritual activities such as mass bathing, cremation, idol immersion, and the offering of ritual waste into rivers are prevalent. While these customs hold spiritual significance, they also contribute solid waste, ashes, and chemical residues, which adversely affect water quality and aquatic life [6]. The repercussions of the declining relationship between humans and rivers are already apparent.

For example, the Gomti River in Uttar Pradesh, which was once a clean tributary of the Ganga, has become severely polluted as it passes through Lucknow. It now transports significant amounts of untreated sewage and industrial effluent. Research indicates decreasing levels of dissolved oxygen (DO) and increasing biochemical oxygen demand (BOD), rendering the water unsuitable for both human consumption and aquatic organisms [4]. Another significant concern is the rampant and unregulated extraction of sand from riverbeds. Fueled by the growing demands of the construction sector, excessive sand mining disrupts river structures, leads to bank erosion, lowers groundwater levels, and devastates aquatic ecosystems. Rivers such as the Chambal and Narmada have experienced the negative ecological and socio-economic effects of this activity [9].

Consequently, the historical reverence for rivers has gradually shifted towards apathy and misuse. Although rivers continue to fulfill human needs across various sectors, the mutual obligation to safeguard and conserve them has considerably declined. This unsustainable and unbalanced reliance, if not addressed, threatens the ecological equilibrium and long-term sustainability of India’s inland river systems. There is an immediate need to restore this equilibrium through holistic river management, involvement from communities, and a revived cultural appreciation for rivers as both natural resources and spiritual lifelines.

2.1. Major Anthropogenic Pressures on Rivers:

Human-induced pressures on river systems have significantly increased over the last century, especially in developing countries such as India, where rapid population growth, urban development, and industrialization have outstripped sustainable environmental planning. The combined effects of various human activities have converted many of India's rivers from essential lifelines into polluted and degraded water bodies. These pressures not only disrupt the ecological balance of river ecosystems but also undermine their capacity to meet human needs.

a) Flow Regulation and River Engineering: Human-engineered structures like dams, barrages, and canals have dramatically changed the natural processes of river systems in India. Although these interventions have been important for supporting irrigation, hydroelectric power generation, and flood control, they have also resulted in significant ecological disruptions. By altering the timing, volume, and quality of water flow, these structures impede the natural flood pulse vital for floodplain agriculture and the rejuvenation of wetlands. The disruption of sediment transport causes downstream erosion and delta shrinkage, as evidenced by the Ganga-Brahmaputra delta, which loses land annually due to decreased sediment load [10]. Moreover, dam constructions fragment river habitats and block migratory routes for aquatic species such as the Hilsa fish and Gangetic dolphin, which depend on unobstructed connectivity for spawning and feeding [11]. Changes in flow regimes also diminish the rivers' capacity to flush out impurities, resulting in stagnation and heightened pollution in specific areas. The overall impact of these engineering interventions highlights the need for a more environmentally mindful approach to river management that reconciles developmental demands with ecological health.

b) Sand Mining: Unregulated and excessive sand mining from riverbeds poses a significant anthropogenic threat to the health and sustainability of river ecosystems in India. Sand is a important material for construction, creating high demand and leading to widespread extraction across various rivers, often occurring illegally. This activity drastically changes river morphology by deepening riverbeds, destabilizing banks, and altering flow patterns. The resulting erosion endangers nearby infrastructure and agricultural land while also resulting in habitat loss for many aquatic and riparian species. For example, rampant sand mining in the Chambal River has jeopardized nesting sites for the critically endangered gharial (Gavialis gangeticus) and severely impacted the natural spawning areas for native fish species. Furthermore, the removal of sand disrupts the natural recharge of aquifers, causing a decline in groundwater levels in surrounding regions [12]. In rivers such as the Narmada and Yamuna, unscientific sand extraction has been associated with diminished water quality and increased turbidity, further stressing aquatic life and the usability of water. Despite the presence of legal frameworks like the Sustainable Sand Mining Management Guidelines (2016), enforcement remains weak, and monitoring is often inadequate. A transition towards sustainable mining practices, stricter regulations, and community involvement is essential to alleviate the irreversible harm caused by unchecked sand mining [13].

c) Pollution: Pollution represents one of the most extensive and enduring human-induced challenges facing India's river ecosystems, stemming from agricultural, industrial, and domestic origins. The advancement of modern agriculture has resulted in a heightened application of chemical fertilizers and pesticides. These agrochemicals frequently seep into adjacent rivers through surface runoff, particularly during the monsoon season, leading to nutrient overload or eutrophication. This phenomenon triggers algal blooms, reduces dissolved oxygen levels, and causes mass die-offs among fish [14]. For example, the Yamuna River often encounters eutrophic conditions near Delhi due to agricultural runoff from the upper catchment region [15].

Industrial pollution presents an equally grave concern. Many factories situated along riverbanks release untreated or partially treated wastewater laden with heavy metals, dyes, organic chemicals, and other hazardous materials. This not only alters the chemical makeup of rivers but also accumulates within the aquatic food web, threatening both biodiversity and human health. A notable example is the Damodar River in Jharkhand and West Bengal, which is contaminated by effluents from coal washeries, steel manufacturing facilities, and thermal power plants, resulting in elevated levels of phenols, arsenic, and other pollutants. Urban sewage represents yet another significant contributor to river pollution, particularly in rapidly growing metropolitan areas [16]. Vast amounts of untreated or insufficiently treated domestic wastewater are released directly into rivers, drastically increasing biological oxygen demand (BOD), lowering dissolved oxygen (DO), and damaging aquatic habitats. The Musi River in Hyderabad and the Mithi River in Mumbai rank among the most polluted rivers in India due to ongoing sewage discharge. These contaminants not only jeopardize aquatic organisms but also diminish the usability of river water for drinking, irrigation, and recreational activities.

The combined impact of these pollutants results in a gradual decline in river health, rendering many sections of Indian rivers biologically sterile. Tackling river pollution necessitates strict enforcement of effluent regulations, enhancement of sewage treatment facilities, encouragement of organic farming practices, and active involvement from communities and industries.

d) Changes in Physicochemical Properties: The ongoing inflow of pollutants into rivers causes notable modifications in their physicochemical properties. These alterations directly affect water quality and pose risks to aquatic ecosystems. Among the parameters most significantly influenced are pH levels, dissolved oxygen (DO), turbidity, temperature, and concentrations of toxic metals.

Pollutants from industrial waste, agricultural runoff, and urban sewage frequently change the pH of river water, resulting in either acidic or alkaline conditions that surpass the tolerance limits for aquatic life. For example, acidic discharges from mining operations and tanneries lower pH levels, adversely affecting sensitive fish species and disrupting enzyme functions in aquatic organisms. Dissolved oxygen (DO) serves as a vital indicator of river health and is essential for the survival of fish and other aerobic species. The breakdown of organic waste from sewage and agricultural sources significantly reduces DO levels, leading to hypoxic environments that can result in extensive fish fatalities and loss of biodiversity. Rivers like the Yamuna and Sabarmati frequently report alarmingly low DO levels in urban segments [17].

Turbidity, which is often attributable to suspended solids from construction projects, soil erosion, and the discharge of untreated waste, limits light penetration in the water. This negatively impacts photosynthesis in aquatic vegetation and obstructs the gills of fish and invertebrates, hindering their respiration [18]. Variations in temperature within rivers are increasingly worrisome. Industrial effluents, especially from thermal power facilities, discharge warm water, changing the natural thermal patterns of rivers. Higher temperatures diminish oxygen solubility and disrupt the reproductive cycles of aquatic species [19].

In addition, rivers frequently transport hazardous metals like lead, arsenic, mercury, and cadmium, introduced via industrial and mining waste. These heavy metals accumulate in aquatic life, ascend the food chain, and create significant health hazards for people consuming contaminated water or fish. The overall effect of these physical and chemical changes destabilizes aquatic food webs, decreases biodiversity, and hampers the rivers' ability to self-purify. Consistent monitoring and scientific management of these factors are crucial for rehabilitating river ecosystems.

3. Biological Impacts and Bioaccumulation

The introduction of pollutants into river ecosystems has resulted in significant biological impacts, particularly through mechanisms such as bioaccumulation and biomagnification. When harmful substances, including heavy metals, persistent organic pollutants (POPs), and pesticides, are released into aquatic environments, they are taken up by microorganisms and small aquatic organisms at the foundation of the food web. These toxins then build up progressively in higher trophic levels, affecting fish, amphibians, and eventually humans, in a process called bioaccumulation [20]. For example, high concentrations of heavy metals such as mercury, cadmium, and lead have been detected in the tissues of fish from rivers including the Yamuna, Mithi, and Hooghly, with levels far surpassing safety thresholds. The health risks for communities relying on these rivers for sustenance and water supply are serious, leading to neurological and developmental issues as well as kidney and liver damage. Children and pregnant women face heightened risks from such toxic exposure [21].

Bioaccumulation also influences the reproductive, behavioral, and immune systems of aquatic species. Fish exposed to chemicals that disrupt endocrine function exhibit abnormal development, decreased fertility, and changed migration behaviors. In extreme cases, entire fish populations have diminished or vanished from contaminated river sections, as demonstrated in segments of the Musi and Bandi rivers [14]. The decline of essential species disrupts ecological balance and impacts the livelihoods of those reliant on river biodiversity, such as fishing communities. The loss of biodiversity also compromises ecosystem services, including natural water filtration, sediment transport, and stability within the food chain, resulting in long-term harm to river health.

4. Consequences to Humans

Ironically, the effects of river degradation extend beyond ecological limits they return to affect human health, well-being, and the economy in profound ways. As rivers deteriorate from pollution, changes in flow, and loss of biodiversity, the communities reliant on them for survival begin to experience a range of negative consequences [22]. One of the most immediate effects is the decline in drinking water quality. With numerous Indian urban and rural areas sourcing water directly from rivers, contamination by industrial waste, sewage, and agricultural runoff results in unsafe water supplies.

This has led to a rise in waterborne illnesses such as cholera, diarrhoea, and hepatitis A and E, particularly in densely populated, low-income regions lacking adequate water treatment facilities [17]. Using polluted river water for irrigation harms soil quality and results in the buildup of toxic substances in crops. This not only diminishes agricultural yields but also threatens food safety and public health. Frequent crop failures caused by tainted water sources also put financial pressure on farmers, exacerbating rural distress and driving migration [23].

Fisheries, both in freshwater and coastal areas, experience substantial economic downturns as fish populations decline due to habitat loss, pollution, and bioaccumulation. As a result, communities that rely on traditional fishing find themselves deprived of both their livelihoods and a vital source of protein [24]. Moreover, the modification of natural river flows resulting from dams, encroachments, and sedimentation has disrupted floodplains and wetlands that historically functioned as buffers against flooding. Consequently, areas such as Bihar and Assam are increasingly susceptible to devastating seasonal floods, leading to loss of life, displacement, and damage to infrastructure [25,26]. Ultimately, the human river relationship has become a contradiction in which overexploitation results in self-harm. Restoring river health is not just an environmental issue but also a critical matter for public health, food security, and economic stability.

River	Location	Major Issues (with Year/Period)	Consequences (with Year/Period)
Ganga	Kanpur, Varanasi, Patna	• Ongoing pollution for decades, worsened in **2000s–2020s.** • Untreated sewage and effluents from **tanneries in Kanpur.** • Ritual dumping of ashes, flowers, and idol immersions.	• By **2020**, levels of coliform bacteria were over **50 times the safe limit.** • Water is unsafe for drinking/ bathing. • Outbreaks of diarrhoea, skin diseases, and even cancers linked to toxic heavy metals.

Musi	Hyderabad	• Urban sewage and pharma-industrial effluents discharged directly into river since **1990s**, intensified in **2010s**. • Overflowing drains during monsoons.	• **2018–2022:** Contaminated irrigation water affected crop health. • Farmers reported **low yields and toxic produce.** • Slums near the river saw high cases of **gastroenteritis** and skin infections.
Yamuna	Delhi	• Over **80% untreated sewage** from Delhi enters the river, problem persists since **early 2000s.** • Religious waste and industrial runoff.	• By **2021**, dense foam layers formed; DO (Dissolved Oxygen) dropped to critical levels. • Known as a **"dead river"** in the Delhi stretch. • People bathing during festivals still suffer infections.
Chambal	Madhya Pradesh & Rajasthan	• **Illegal sand mining** increased since **early 2010s**. • Mining disrupts sediment balance, river ecology, and banks.	• **2015–2018:** Decline in population of **critically endangered gharial**. • Riverbank erosion damaged nearby **agricultural fields** and led to habitat loss.
Sutlej	Punjab	• Buddha Nullah discharge from **Ludhiana's industries since 1990s**. • Sewage from towns flows untreated. • Problem peaked in **2010s**.	• By **2019**, many districts like Bathinda showed a spike in **cancer cases**. • Entire zones labeled as part of **Punjab's Cancer Belt.** • Water unfit for domestic or agricultural use.
Godavari	Nashik, Maharashtra	• Pollution worsened post **2005**, especially during Kumbh Mela. • Idol immersion, dumping of religious waste, sewage discharge.	• **2015–2021:** Algal blooms and DO level drops observed. • Waterborne infections like **diarrhoea and jaundice** surged during post-festival weeks.
Mula-Mutha	Pune, Maharashtra	• Unchecked urbanization since **2000s**. • Untreated sewage, industrial pollutants, plastic waste. • River encroachment.	• By **2022**, high **BOD and ammonia** levels made water unfit for irrigation or consumption. • Complaints of **foul odor** and increased mosquito-borne illnesses nearby.
Panchganga	Kolhapur, Maharashtra	• Sugar mill effluent discharge since **early 2000s.** • Agricultural pesticide runoff during monsoons. • Mass idol immersions in river.	• **2017 & 2021:** Reports of **mass fish deaths.** • Water had strong odor, green tint due to pollution. • Local communities faced **drinking water shortages.**
Mithi	Mumbai, Maharashtra	• **2005:** Mithi's narrowing due to construction debris and solid waste. • Rampant slum encroachments on banks. • Choked flow and flooding potential.	• In **July 2005**, Mumbai saw **floods killing over 500 people**. • Losses worth thousands of crores. • Government initiated cleanup drives post-disaster, but challenges persist.

Table 1: Examples of River Disturbance and their Consequences in India

5. Conclusion

Rivers are more than just bodies of water they are vital ecosystems that sustain life, nature, and human society. In India, rivers are intertwined with our culture, beliefs, and everyday existence. However, nowadays, numerous rivers are threatened due to human exploitation and mismanagement. Rapid urbanization, population increase, and industrial activities have exerted immense pressure on our rivers. This article highlights how various human actions such as constructing dams and barrages, illegal sand extraction, and pollution from agriculture, industries, and urban areas have severely harmed river ecosystems. These activities disrupt the natural flow of rivers, jeopardize aquatic life, and alter water quality. Contaminated rivers pose risks not only to fish and plant life but also to people relying on the water for drinking, bathing, agriculture, and fishing.

The Ganga near Kanpur and Varanasi harbors dangerous bacteria and toxic heavy metals. The Yamuna in Delhi has become so contaminated that it produces white foam and resembles a lifeless river. In Hyderabad, the Musi River is inundated with sewage and chemicals that contaminate the water and agricultural produce. Pollution in the Sutlej River in Punjab has led to rising cancer rates. The Chambal River is suffering from illegal sand mining, which threatens endangered species like gharials. In Mumbai, the Mithi River was a significant cause of the 2005 floods due to waste disposal and encroachments. These cases shows that the degradation of rivers is not merely an environmental problem, it impacts human health, agriculture, livelihoods, and can even trigger natural disasters.

The encouraging news is that by taking action now, we can still repair the damage. Rivers can be cleansed and rejuvenated, but it will require collective effort. The government must rigorously enforce regulations to prevent pollution and illegal mining. Industries should be mandated to effectively treat their waste. The public must also be informed and accountable. Individuals should refrain from disposing of waste in rivers, engage in cleanup initiatives, and use water prudently. Farmers should be educated on minimizing chemical use, and construction practices should adhere to environmentally friendly guidelines.

Colleges should promote awareness about river conservation. Media, NGOs, and scientists also need to contribute to educating and advocating for river protection. Above all, we should begin to view rivers as integral members of our family not as resources to exploit and neglect. If we nurture them, they will continue to provide us with clean water and sustenance, beauty. The decision lies with us, either we take action now to protect our rivers or we wait and risk losing them forever.

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