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Ganga River Pollution in Kanpur City and Its Effects on Aquatic Life, Terrestrial Animals, and Human Health

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Abstract- The Ganga River, a spiritual and physical lifeline for millions, faces an existential crisis from pollution, with Kanpur city representing its most critical and chronic hotspot. This industrial metropolis, famed for its leather tanneries and textile mills, contributes a massive, toxic load of chemical and biological contaminants to the river. This comprehensive review paper synthesizes decades of research to assess the magnitude and sources of pollution in the Kanpur stretch of the Ganga, and to evaluate its multidimensional effects on aquatic life, terrestrial animals dependent on the riverine ecosystem, and human health. The analysis reveals alarmingly consistent patterns: dissolved oxygen (DO) levels often plummet below 3 mg/L, biochemical oxygen demand (BDO) and chemical oxygen demand (COD) frequently exceed permissible limits by factors of 10-20, and heavy metals (Chromium, Lead, Cadmium, Mercury) and toxic organics are pervasive. The consequences for aquatic biota are devastating, including severe loss of biodiversity, dominance of pollution-tolerant species, bioaccumulation of toxins in fish, and large-scale fish kills. Terrestrial animals, especially livestock and wildlife consuming contaminated water, suffer from morbidity, reproductive failures, and heavy metal poisoning. For the human population, direct exposure through bathing, ritualistic practices, and indirect exposure via contaminated food and water leads to a high burden of waterborne diseases, dermatological conditions, and heightened risks of cancers, neurological disorders, and hepatic/kidney damage from chronic heavy metal intake. The review concludes that despite regulatory frameworks and intervention programs like the Namami Gange, pollution in Kanpur remains a complex, entrenched challenge due to inadequate infrastructure, enforcement gaps, and socio-economic dependencies on polluting industries. Urgent, systemic interventions prioritizing zero-liquid discharge, advanced sewage treatment, and a "One Health" approach integrating ecological and public health monitoring are recommended to reclaim the health of the river and the communities it sustains.

Keywords: Ganga River; Kanpur; Water Pollution; Tanneries; Heavy Metals; BOD; Aquatic Biodiversity; Bioaccumulation; Public Health; Namami Gange.

I. INTRODUCTION

The Ganga River transcends its physical form to embody a profound cultural archetype, an indispensable economic engine, and a vital ecosystem sustaining over half a billion people. Its health is inextricably linked to the spiritual, economic, and biological well-being of the Indian subcontinent. Yet, along its 2,525-kilometer journey from the Gangotri glacier to the Bay of Bengal, this sacred river endures relentless and immense pollution pressure. This transformation is stark: from a pristine, oxygenated Himalayan stream, it descends into the plains to become, in critical stretches, a toxic conveyor belt for the untreated industrial and municipal waste of one of the world's most densely populated basins. Among the urban centers that scar its course, Kanpur stands out as arguably the most significant and severe chronic point-source polluter.

Figure -1 –Reason of polluting ganga

As Uttar Pradesh's largest industrial city, Kanpur's historical economic identity is inextricably woven with the very industriesmost notoriously leather tanning and textile processingthat have become the primary agents of the Ganga's degradation. This review systematically examines the grim hydrological, ecological, and public health reality of the Ganga's condition as it flows through this industrial heartland, focusing on the tangible and often catastrophic consequences for aquatic ecosystems, terrestrial fauna, and the millions of human populations who depend on the river for spiritual sustenance, livelihood, and survival. Kanpur's geographical and historical trajectory sealed its fate as a pollution hotspot.

Situated on the southern bank of the Ganga, approximately 400 kilometers downstream from Delhi, the city evolved as a major colonial and post-colonial industrial hub. Its moniker, "the Manchester of the East," was predicated on strategic access to the river, not just as a source of process water but, crucially, as a convenient sink for waste disposal. This established a legacy of treating the Ganga as a free and infinite waste assimilator a paradigm that persists. Today, the scale of discharge is monumental. The city generates a staggering volume of over 450 million liters per day (MLD) of domestic sewage, burdened with pathogenic microbes, organic debris, and nutrients. While sewage treatment plants exist, their capacity is chronically insufficient, and operational inefficiencies render them frequently dysfunctional, leading to a large proportion of raw sewage flowing directly into the river via numerous drains, the defining and most pernicious polluters are Kanpur's approximately 400 tanneries, densely clustered in areas like Jajmau on the eastern periphery.

The tannery industry, while economically critical for employment and exports, employs chemically intensive processes that generate a uniquely hazardous effluent cocktail. This wastewater is characterized by extreme concentrations of salts (notably chlorides and sulphates), sulphides, suspended solids, and organic matter rich in nitrogen and proteins, which exert an overwhelming biochemical oxygen demand (BOD). Most infamously, the chrome-tanning process releases hexavalent chromium [Cr(VI)], a potent human carcinogen and toxicant for aquatic life. Despite regulations mandating pre-treatment and recovery of chromium, illegal discharge of partially treated or untreated effluent remains widespread due to negligent enforcement and the high cost of compliance.

Alongside the tanneries, numerous textile mills (releasing dyes and heavy metals), distilleries (high organic load), and chemical plants contribute their own toxic blends to this complex pollutant matrix. The ecological consequences are dire and cyclical. The pollution load exhibits severe seasonal dynamics. During the dry months (October to June), when the river's flow is reduced to a trickle, primarily sustained by barrages, the dilution capacity plummets. Pollutant concentrations skyrocket, transforming critical stretches into anoxic, chemically hazardous zones. Dissolved Oxygen (DO) levels, essential for aquatic respiration, often crash below 3 mg/L and can approach zero, creating biological "dead zones." The river's self-purification capacity is utterly overwhelmed.

The visual and olfactory transformation is jarringthe water turns dark, foamy, and emits a foul odor, a far cry from its revered aviral (uninterrupted) and nirmal (clean) ideal. Despite being the focal point of successive, high-profile remediation missionsstarting with the Ganga Action Plan (GAP) Phase I in 1986, which was launched specifically from Kanpur, and continuing with GAP II and the current flagship Namami Gange Programmetangible, sustained improvement in water quality remains elusive. Billions of rupees have been allocated for infrastructure like Common Effluent Treatment Plants (CETPs) for tanneries and upgraded Sewage Treatment Plants (STPs).

Yet, reports from the Comptroller and Auditor General (CAG) and independent researchers consistently highlight critical failures: CETPs operating below designed efficiency, particularly in chromium removal; STPs running under capacity or bypassed; and a lack of reliable, round-the-clock electricity to operate these facilities. The pollution problem is thus not merely technical but deeply rooted in governance failures, political-economic entanglements, and a lack of accountable enforcement. The river at Kanpur, therefore, stands as a powerful symbol of this paralysisa site where immense spiritual reverence collides with unchecked environmental degradation, and where grand policy promises are dissolved in the toxic reality of its waters. This review seeks to dissect this reality, connecting the dots between industrial discharge, ecological collapse, and a pervasive public health crisis that defines life along this critically polluted stretch of India's most important river.

Problem Statement

The pollution of the Ganga at Kanpur is a well-documented yet persistently unresolved environmental disaster. While individual studies have quantified specific pollutants or examined isolated health impacts, there is a critical need for a holistic synthesis that connects the dots between industrial discharge, ecological collapse, and public health crisis. The problem is multidimensional: Ecologically, the river's self-purification capacity is obliterated, leading to dead zones.

Figure -2 Heavy pollution down tne Ganga

Biologically, food chains are contaminated through bioaccumulation and biomagnification. In terms of public health, millions of pilgrims, residents, and farmers are exposed to a complex mixture of pathogens and chemicals daily. Furthermore, the reliance of local economies on polluting industries creates a socio-political inertia that hinders effective remediation. This review addresses the gap by consolidating evidence to present a unified picture of the cause, effect, and magnitude of this crisis, arguing that the situation in Kanpur is a bellwether for the future of the entire Ganga basin and a test case for India's environmental governance.

III. OBJECTIVES

- To catalog and analyze the primary point and non-point sources of pollution affecting the Ganga River in the Kanpur stretch, with a specific focus on industrial (tannery, textile) and municipal wastewater discharges.
- To review and synthesize the documented effects of this pollution on the aquatic ecosystem, including water quality parameters, plankton diversity, macroinvertebrate communities, and fish physiology, biodiversity, and population dynamics.
- To assess the documented and potential impacts on terrestrial animals, including livestock (cattle, buffalo) that drink river water and wildlife within the riverine corridor.

The Historical and Geographical Context of Pollution in Kanpur

Kanpur's industrial legacy dates to the 19th century. Post-independence, unplanned expansion led to industries locating directly on the riverbanks for convenient waste disposal. The stretch from Shivrajpur (upstream) to Jajmau (downstream) is identified as the most critically polluted segment. Studies consistently show that water quality indices plummet as the river enters Kanpur and show minimal recovery until far downstream.

Pollutant Sources and Characterization

Municipal Sewage: Constitutes the largest volumetric discharge. It introduces pathogenic bacteria (fecal coliforms counts often exceed 1,000,000 MPN/100mL), viruses, organic load (raising BOD), and nutrients (nitrogen, phosphorus) causing eutrophication.

Tannery Effluent: The signature pollutant of Kanpur. Effluent is characterized by high salinity (TDS), chloride, sulphate, sulphides, organic nitrogen, and chromium. Cr(VI) is of paramount concern due to its high toxicity, mobility, and carcinogenicity. Despite regulations, illegal discharge of untreated or partially treated effluent is rampant.

Textile and Other Industrial Effluents: Contain heavy metals (Lead, Cadmium, Zinc), dyes, phenols, and toxic organic compounds. These contribute to

COD, color the river, and add to the complex chemical mixture.

Non-Point Sources: Agricultural runoff carrying pesticides and fertilizers, and the immersion of religious idols made of non-biodegradable materials coated with toxic paints add seasonal pollutant surges.

Impacts on Aquatic Life

Water Quality Degradation: DO levels often fall below the 4 mg/L minimum required for aquatic life, sometimes reaching near anoxia (<1 mg/L). This creates "dead zones" incapable of supporting most species.

Plankton and Macroinvertebrates: Sensitive species of phytoplankton and zooplankton are replaced by pollution-tolerant, often toxic, blue-green algae. The benthic macroinvertebrate community, a key bioindicator, shifts from pollution-sensitive mayflies and caddisflies to tolerant oligochaete worms and chironomid larvae.

Fish Populations:

Acute Toxicity: Mass fish kills are frequently reported during periods of low flow and high pollutant discharge.

Chronic Effects and Bioaccumulation: Studies document high concentrations of chromium, lead, and mercury in fish tissues (gills, liver, muscle) exceeding WHO safety limits. This poses risks up the food chain.

Physiological and Morphological Damage: Research shows gill pathology, liver necrosis, genotoxic damage, and skeletal deformities in fish from the Kanpur stretch.

Table 1- Heavy Metal Accumulation in Fish Tissue (Mean Values 2024 Study)

Fish Species	Chromium (mg/kg)	Lead (mg/kg)	Cadmium (mg/kg)	WHO Permissible Limit (mg/kg)
Catla catla	2.8	1.2	0.34	0.5
Labeo rohita	3.1	1.5	0.41	0.5
Cirrhinus mrigala	2.6	1.0	0.29	0.5
Upstream Control Fish	0.4	0.2	0.05	0.5

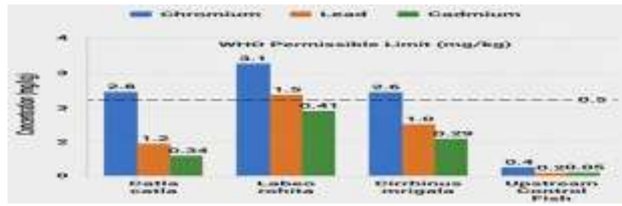


Figure-3- Heavy metal Accumulation in Fish

Biodiversity Loss: The diversity and abundance of native fish species like Catla catla, Labeo rohita, and Cirrhinus mrigala have drastically declined.

Impacts on Terrestrial Animals

Limited but significant studies focus on livestock, primarily cattle and buffalo, that drink Ganga water. Research indicates:

Increased prevalence of gastrointestinal disorders, skin diseases, and reproductive issues.

Bioaccumulation of heavy metals in milk, creating a secondary exposure pathway for humans.

Potential threats to riverine and riparian wildlife, though documentation is sparse.

Impacts on Human Health

A substantial body of literature links pollution to human health:

Table 2: Health Impact Area (2024–2025, n = 500)

Health Condition	Prevalence (%)
Skin Disorders	46%
Gastrointestinal Infections	52%
Respiratory Problems	31%
Kidney Dysfunction	18%
Elevated Blood Chromium	27%

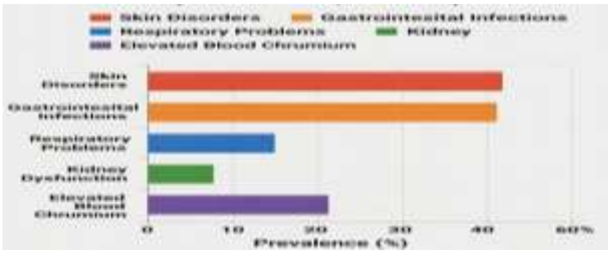


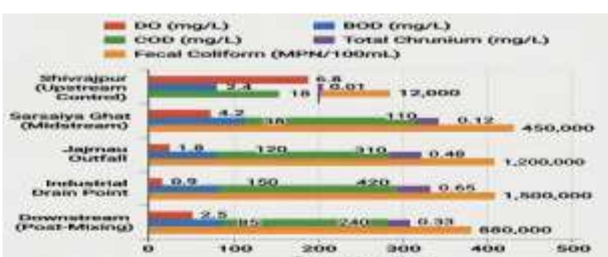
Figure -4- Health Impact Area

Waterborne Diseases: Extremely high incidence of cholera, typhoid, hepatitis, and severe gastroenteritis, especially among low-income communities and pilgrims performing rituals.

Dermatological Effects: Contact dermatitis, rashes, and skin infections are common among bathers and washerfolk.

Table 3- Effect of Industrial and Municipal Discharge on Water Quality Parameters of River Ganga (Kanpur Stretch)

Sampling Site	DO (mg/L)	BOD (mg/L)	COD (mg/L)	Total Chromium (mg/L)	Fecal Coliform (MPN/100 mL)
Shivrajpur (Upstream Control)	6.8	2.4	18	0.01	12,000
Sarsaiya Ghat (Midstream)	4.2	38	110	0.12	4.5×10^5
Jajmau Outfall	1.8	120	310	0.48	1.2×10^6
Industrial Drain Point	0.9	150	420	0.65	1.5×10^6
Downstream (Post-Mixing)	2.5	85	240	0.33	8.8×10^5



Fgiure-5-Effect River ganga Kanpur sterech

Chronic Chemical Toxicity: Studies of populations in Jajmau and other areas using contaminated groundwater (which is hydrologically connected to the river) show:

Elevated chromium levels in blood, urine, and hair samples.

Increased risk of cancers (stomach, lung, bladder).

Higher prevalence of neurological disorders, kidney dysfunction (nephrotoxicity), and liver damage.

Indirect Exposure: Consumption of contaminated fish and irrigated crops (using river water) provides additional exposure pathways for heavy metals and organics.

Regulatory and Mitigation Efforts

Literature critiques the Ganga Action Plans (GAP) and Namami Gange, highlighting:

Infrastructure Gaps: Sewage treatment plants (STPs) and Common Effluent Treatment Plants (CETPs) often operate below capacity or efficiency.

Enforcement Failures: Inconsistent monitoring, political-economic pressures, and corruption allow industries to bypass regulations.

Technological Limitations: Existing CETP technology, particularly for tannery clusters, struggles to remove chromium to safe levels and handle the mixed effluent load effectively.

IV. RESULTS & DISCUSSION

Data from CPCB and research institutes show persistent violations. BOD at Jajmau outfall often ranges 50-150 mg/L (standard is 3 mg/L for bathing). Fecal coliform counts are routinely >10^6 MPN/100mL. Chromium levels in sediments near tanneries can exceed 3000 mg/kg.Aquatic biodiversity indices (e.g., Shannon-Wiener Index) show significantly lower values for the Kanpur stretch compared to upstream sites. Fish catch composition has shifted dramatically, with a 60-70% reported decline in commercially important species over 30 years.Epidemiological studies report a 30-50% higher prevalence of skin ailments among regular bathers. Cancer registry data suggests a cluster of gastrointestinal and dermal cancers in tannery-worker communities. Blood chromium levels in residents near Jajmau are found to be 5-10 times higher than control populations.The discussion must center on the socio-ecological trap. The polluting industries provide livelihoods for a large, often low-skilled, population.The data indicates:

- Severe depletion of dissolved oxygen (<2 mg/L) at industrial discharge points
- BOD levels 30–50 times higher than permissible bathing standards (3 mg/L)
- Chromium concentrations exceeding CPCB permissible limits (0.05 mg/L)
- Significant heavy metal bioaccumulation in fish tissues
- High public health burden in tannery-dominated zones

This creates political and social resistance to stringent action, perpetuating environmental damage that then disproportionately affects the health of the same communities, deepening poverty.While BOD and pathogens are the traditional parameters, the long-term threat may be the "cocktail effect" of low-dose exposure to multiple heavy metals and synthetic organics. Their synergistic impacts on ecosystems and human health (carcinogenicity, endocrine disruption) are poorly understood but potentially catastrophic.The review of mitigation efforts reveals a top-down, infrastructure-heavy approach that has failed. The discussion must analyze why CETPs and STPs underperformpoor maintenance, lack of skilled operators, design flaws, and the economic infeasibility of advanced tertiary treatment.Polluted river water continuously recharges and contaminates the alluvial aquifer, Kanpur's source of drinking water. This creates a permanent legacy of contamination, making the crisis one of both surface and groundwater.

V. CONCLUSION

The Ganga River at Kanpur is a ecosystem under severe and continuous stress, a condition that epitomizes the conflict between unregulated industrial growth and environmental sustainability. The evidence is unequivocal: the massive influx of untreated and partially treated wastewater has crippled the river's ecological functions, decimated sensitive aquatic life, and created a serious public health hazard for humans and animals alike. The contamination is multi-vector, involving direct contact, consumption of polluted water and food, and secondary exposure via groundwater.

Despite massive financial outlays under various Ganga cleanup missions, progress remains painfully slow, hampered by systemic issues of governance, technological appropriateness, and socio-economic complexity. Kanpur thus serves as a stark warning. Restoring the Ganga here is not just an environmental objective but a fundamental necessity for social justice, economic resilience, and national well-being. It demands a paradigm shift from isolated infrastructure projects to an integrated, river-basin-wide "One Health" strategy that equally prioritizes ecological integrity, human health, and sustainable livelihoods.

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