Final Report

Study on Yamuna Frothing in Delhi

Department of Environment
Government of NCT of Delhi

NMCG-TERI Centre of Excellence on Water Reuse

THE ENERGY AND RESOURCES INSTITUTE
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We are thankful once again and we look forward to having a continued association with the Govt. of NCT of Delhi in whatever possible manner in rejuvenation of our sacred River Yamuna.

Name: Dr. Nupur Bahadur, Principal Investigator & Project Director

Place: New Delhi

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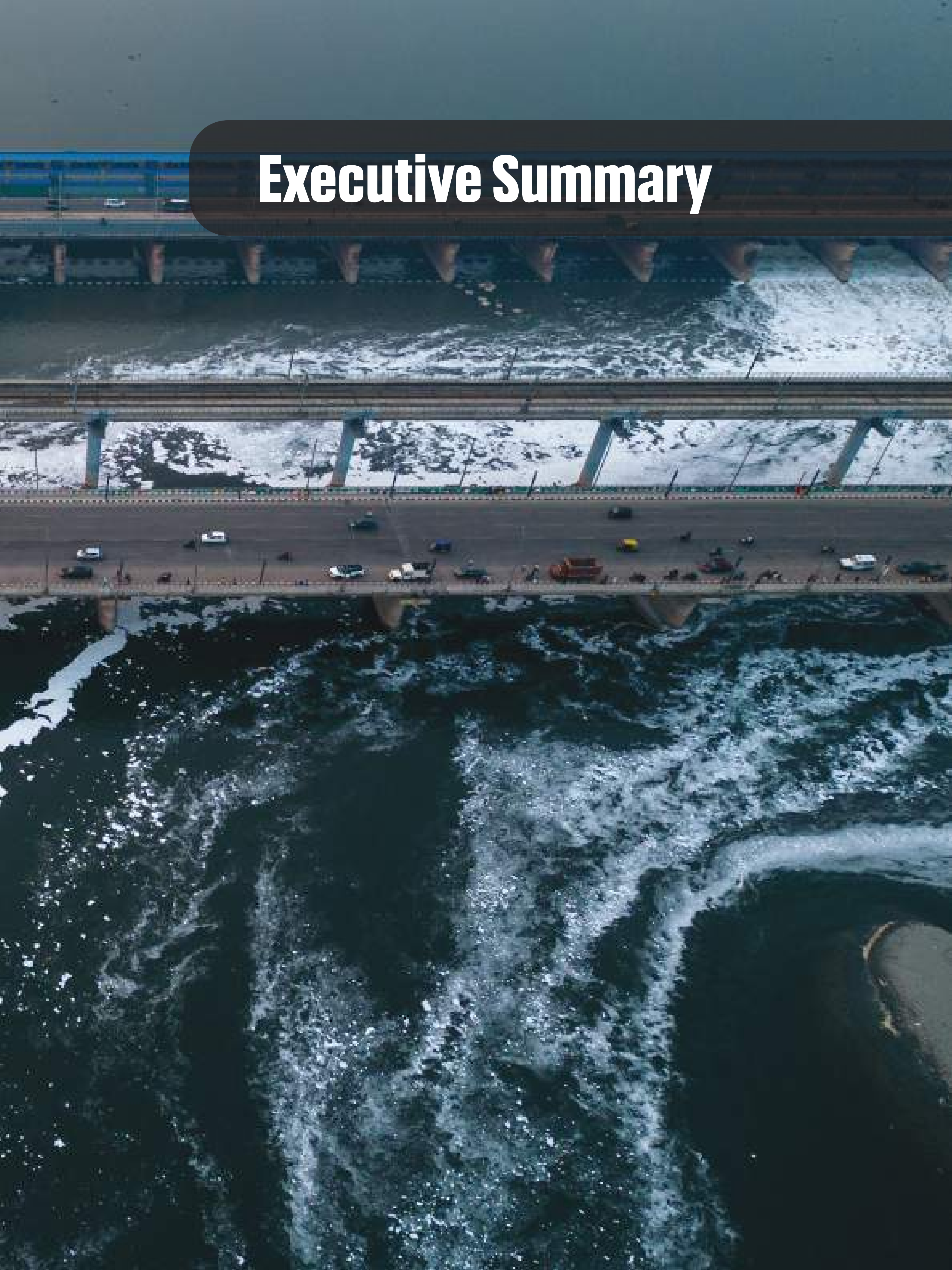
ABBREVIATIONS

APHA	American Public Health Association
BIS	Bureau of Indian Standards
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
DJB	Delhi Jal Board
DO	Dissolved Oxygen
DPCC	Delhi Pollution Control Committee
GIS	Geographic Information System
HLC	High-Level Committee
MGD	Million Gallons Per Day
NGT	National Green Tribunal
SDS	Sodium Dodecyl Sulphate
SLS	Sodium Lauryl Sulfate
STPP	Sodium Tri-Polyphosphate
STPs	Sewage Treatment Plants
TDS	Total Dissolved Oxygen
TERI	The Energy and Resources Institute
TSS	Total Suspended Solids
GPIs	Grossly Polluting Industries
CETP	Common Effluent Treatment Plant
MLD	Million Liters Per Day
USEPA	United States Environmental Protection Agency
NABL	National Accreditation Board for Testing and Calibration Laboratories

Executive Summary



The Project titled "***Study of Yamuna Frothing in Delhi***" was awarded by Department of Environment, Government of NCT of Delhi (GNCTD) and work completed during 2024–2025. **The Five key objectives of the study** were: (1) To find out the reasons behind the foaming/frothing in River Yamuna and correlate it with the outflow of different drains, (2) To assess and identify froth sources in Najafgarh Drain (upstream Dhansa Regulator to Wazirabad) and supplementary drains, (3) To identify major drains accounting for maximum pollution, load responsible for froth and finding out parameters exceeding the standard/permissible limits, (4) To identify area sources such as colonies, industrial areas, etc., contributing to the pollution load responsible for frothing in Yamuna and finding out the relative quantification, nature, source and characteristic of the pollutants and identify hot spots as far as sources are concerned, (5) To develop short-term, medium-term and long-term action plan including clear enforcement strategies for minimizing frothing/foaming in the river Yamuna including possible alternatives to household products responsible for frothing.

The study was conducted in two phases, the pre-monsoon phase (May-June 2024) and the post-monsoon phase including festive season (Nov-Jan 2025), **covering 52 locations** in each season, which includes 7 River stretch and Barrages, 19 Drains, 12 STPs, 6 CETPs, 5 Dhobi Ghats/Laundry Clusters and 3 additional locations covering the Najafgarh Stretch and have been depicted in Figure 1.

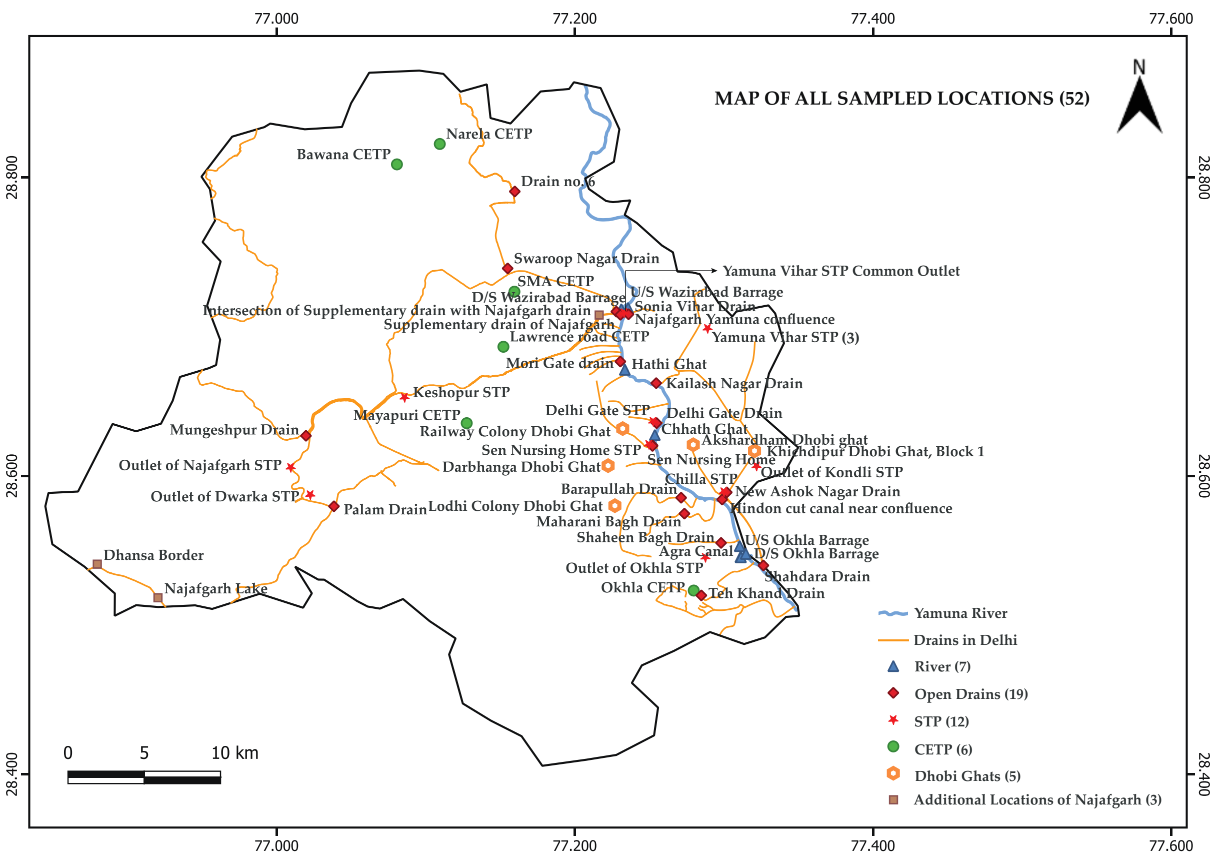


Figure 1: Delhi Map with 52 Sampling Locations

The testing and analysis focused on 33 parameters in each sample encompassing physicochemical, microbial, and surfactant characteristics to develop comprehensive understanding of the foaming phenomenon.

Findings reveal that Froth formation is triggered mainly by the poor water quality of the river, which results from various factors such as effluent coming from **Dhobi Ghats/Laundry Clusters**, which contains high ammonia and phosphate, released from anionic surfactants used in industrial grade detergents at these places. In particular, Akshardham, Khichdipur, and Railway Colony Dhobi Ghats were found, discharging white, turbid and untreated wastewater directly into the Yamuna through Ganesh Nagar Drain, Shahdara Drain, and 12A Drain, respectively.

Assessments of **CETPs** showed that while these facilities achieved good removal efficiencies for Fecal coliform (up to 99%) but moderate to good removal efficiencies for BOD and COD (50–95%) and poor removal efficiency for ammonia, phosphate and surfactants (<50%), emphasizing the urgent need for advanced treatment including Zero Liquid Discharge (ZLD) Compliance, upgradation and polishing units in various CETPs, particularly Lawrence Road, Okhla and Mayapuri CETPs.

STP evaluation also indicated effective reduction of Fecal Coliform (up to 99%) in almost all STPs visited during this study, but poor treatment efficiency in reducing BOD, COD, nitrate and phosphate, particularly in Yamuna Vihar Phase 1, Phase 2 and Phase 3 STPs, from where froth laden wastewater, is directly discharged into the Yamuna, through a combined outlet at the downstream of Wazirabad. This suggests incomplete nutrient removal and the need for process optimization for efficient BOD and COD removal.

In case of most of **Drains**, pre-monsoon witnessed 9×10^6 MPN / 100 ml. Fecal coliform which reduced to ~5×10^5 MPN/100ml in post monsoon, indicating very high values despite dilution effect. The drains particularly contributing to poor water quality of Yamuna are Drain no. 6, Delhi Gate, Sen Nursing Home, Barapulla, Ashok Nagar, Maharani Bagh, Shahdara, Teh Khand, Palam drain, Soniya Vihar, Najafgarh and Supplementary drain.

Seasonal variation across the **River** stretch demonstrated that post-monsoon improvement in water quality was largely due to dilution from higher rainfall (1029.9 mm in 2024 vs. 660.8 mm in 2023), though the persistence of high nitrate (8.6–64.83 mg/L), high ammonia (12.5–30.6 mg/L), high phosphate (2.637–8.971 mg/L) and Fecal coliform (10^4 MPN/100mL) levels in the river indicated continued contamination, underscoring significant microbial pollution linked to untreated sewage inflow. Also, higher concentrations of anionic surfactants (up to 31.8 mg/L at Hathi Ghat, far exceeding the CPCB limit of <1 mg/L) and biogenic surfactants (saponins ranging from 400–700 mg/L) coming from water hyacinth and algal blooms, which intensified with high organic load, indicates both synthetic and natural contributions to foam formation. With this poor water quality, when the river reaches the Okhla Barrage, together with sudden opening of barrage gates and the fall of water from significant height of barrage leads to the disturbance of water and sludge beds, creating high turbulence, **exhibiting the most severe foaming**, which further stabilizes with the winter season setting in during this time of the year.

Thus, the study proposed **Department wise comprehensive Plan with short-, medium, and long-term measures** to mitigate foaming and restore river health. The key recommendations involve, a call for a coordinated approach across departments, starting with strengthening a centralised mechanism like the State Mission for Clean Yamuna (SMCY) to ensure inter-agency coordination. For pollution monitoring, the **Delhi Pollution Control Committee (DPCC)** has been advised to expand water testing to include ammonia and phosphate—key contributors to detergent-induced froth—beyond the existing parameters. The report also calls for regular inspections and installation of micro sewage treatment plants (STPs) at Dhobi Ghats/Laundry Clusters, and stricter enforcement of eco-friendly detergent standards. DPCC is urged to collaborate with the **Bureau of Indian Standards (BIS)** to promote zeolite- and enzyme-based detergents over phosphate-heavy alternatives.

The **Irrigation and Flood Control Department (IFCD)** has been tasked with installing aerators in low-flow areas, particularly upstream of Okhla barrage, to maintain dissolved oxygen levels and improve water quality. The study also proposes webcams at barrage gates for real-time monitoring and regular removal of water hyacinth, which contributes to foam formation. It recommends IFCD and **Urban Development Department (UD)** to revisit the 1994 Yamuna water-sharing agreement to ensure minimum environmental flow and present this Report in the upcoming winter session of the Delhi Assembly as part of a broader public awareness campaign.

Delhi Jal Board (DJB) has been advised to expand STP capacity, improve efficiency and compliance of 12 STPs by adopting advanced treatment technologies such as Biological Nutrient Removal (BNR) and Advanced Oxidation Photocatalysis Processes (AOP-PC).

Other directives include online water quality monitoring at drains, flow meter installation, and curbing illegal discharges by the **Municipal Corporation of Delhi (MCD)**; strict performance checks and new CETPs by the **Delhi State Industrial and Infrastructure Development Corporation (DSIIDC)** and decentralized or micro-STPs for unauthorized colonies and JJ clusters by **Delhi Development Authority (DDA).**

It is expected that if action taken by each department appropriately and timely then not just the frothing issue be addressed but also pollution in Yamuna could be controlled and the cleaning and rejuvenation of Yamuna is also possible in a time-bound manner.

Introduction & Literature Review

1. Introduction

1.1 River Yamuna in Delhi

The Yamuna River, originating from Yamunotri in Uttarakhand (31°01′N, 78°46′E), is the second-largest tributary of the Ganga River and holds immense cultural and ecological significance in India. Spanning a total length of 1,376 km, the river traverses multiple states Uttarakhand, Haryana, Delhi, and Uttar Pradesh before merging with the Ganga at Prayagraj, Uttar Pradesh[1]

Despite its sacred status, Yamuna has become one of the most polluted rivers in the country, particularly along its middle stretch. Major urban centers such as Sonipat, Panipat, Delhi, Ghaziabad, Agra, Mathura, Etawah, and Prayagraj contribute heavily to this pollution. Decades of unchecked discharge of untreated domestic and industrial wastewater from both point and non-point sources have critically disrupted the river's biological balance[2].

The Yamuna enters Delhi at Palla village, bordering Haryana in the north, and flows through the city for about 52 km before exiting at Jaitpur village near the Uttar Pradesh border in the south as shown in Figure 2. The 22 km stretch between Wazirabad and Okhla, which is recognized as one of the most severely polluted segments of the river is of particular concern. This stretch receives inflows from several sewage drains in Delhi, most notably the Najafgarh Drain. The unchecked intrusion of untreated sewage and industrial effluents has drastically degraded the ecological health of the river. High levels of Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Ammonia, Phosphates, and other pollutants both anthropogenic and natural (e.g., biosurfactants) underscore the river's deteriorating water quality. The Delhi stretch of the Yamuna has thus become a critical case study in river pollution in northern India.

Delhi's rapid urbanization and population growth—primarily driven by migration from neighboring states—have exerted tremendous pressure on its water resources. According to the Monthly Progress Report submitted by the Delhi Government to the National Green Tribunal (NGT) in OA No. 673 of 2018 and compiled by the National Mission for Clean Ganga (NMCG)[3], Delhi's total water consumption is approximately 990 Million Gallons per Day (MGD), sourced from both surface and groundwater. Assuming that 80% of this freshwater supply returns as wastewater, the estimated sewage generation stands at 792 MGD.

1 Kaur, Rajveer, and Puneeta Pandey. "Air pollution, climate change, and human health in Indian cities: a brief review." Frontiers in Sustainable Cities 3 (2021): 705131.

2 Kumar, Sumit, et al. "Composition of heavy metals in sediment, water, and fish of the Ganga and Yamuna Rivers in two major cities of India." Environmental Monitoring and Assessment 196.7 (2024): 612.

3 59_Delhi – MPR June 2025.pdf

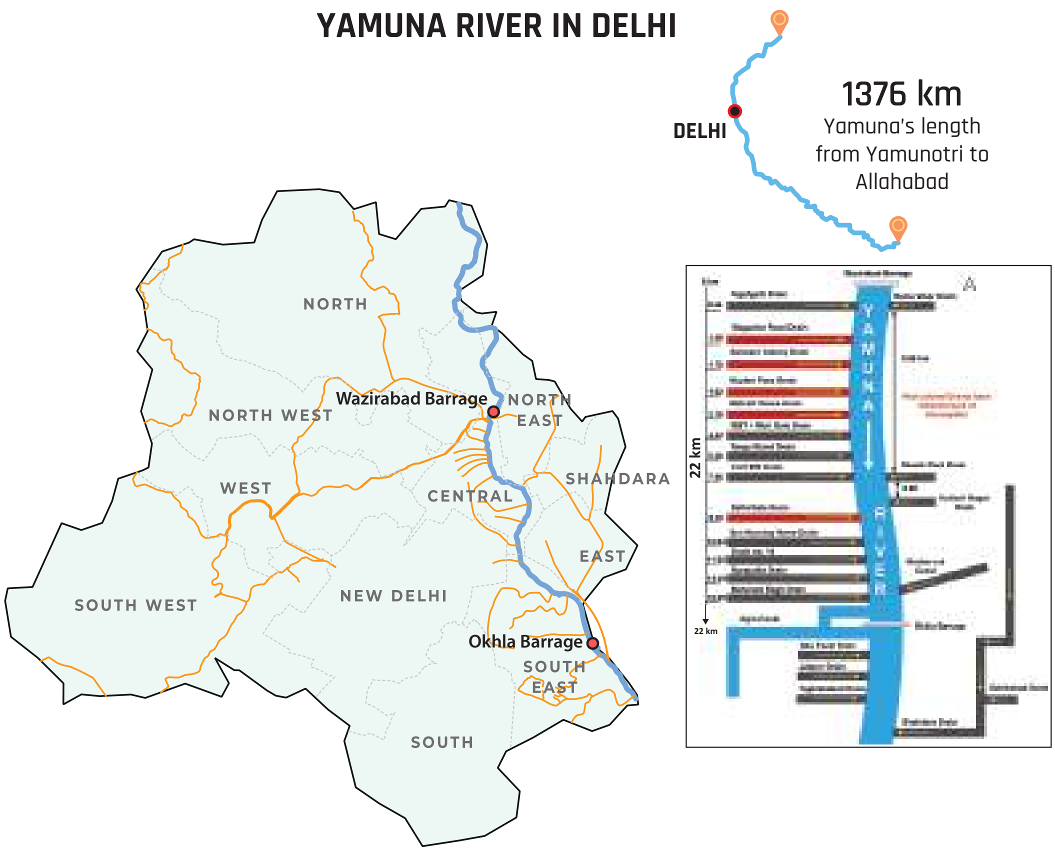


Figure 2: Yamuna Stretch in Delhi and Associated Drains

However, as per data from the Delhi Pollution Control Committee (DPCC), only 650 MGD of sewage is currently being treated. The remaining 142 MGD flows untreated into the Yamuna River, contributing significantly to its pollution. One of the most visible and alarming manifestations of this pollution is the foaming observed near the Okhla Barrage, especially around Kalindi Kunj. While foaming can occur naturally under certain conditions, its intensity and frequency in Delhi are indicative of extreme contamination from untreated sewage and industrial discharges. The following section explores global foaming incidents in rivers and water bodies, analyzing how similar issues have been addressed and mitigated in different regions.

1.2 Impact of Pollution on Surface Water Bodies

Natural water bodies are essential freshwater resources, which have been overexploited in recent decades, resulting in contamination, depletion, and degradation of rivers, lakes, reservoirs, and groundwater sources. Developing countries like India, experiencing rapid vertical industrial growth and urban expansion, are particularly vulnerable to surface water pollution due to the diverse nature of polluting sources and the lack of adequate wastewater treatment and management infrastructure. One visible manifestation of this pollution is foam formation on surface water bodies, which has emerged as a significant environmental concern. Foaming incidents in rivers and lakes are a visible and alarming sign of severe water pollution. It is caused by organic matter, excess nutrients, heavy metals, and emerging pollutants, introduced by untreated sewage, industrial effluents, and agricultural runoff, which contaminate aquatic ecosystems and lead to the formation of foam in natural water bodies.

Foaming agents directly responsible for the formation of foam in natural water bodies can be broadly classified into two categories based on their origin: natural (bio-surfactants) and synthetic surfactants. Natural surfactants are present in water bodies due to the degradation of organic materials such as humic substances, lipids, and proteins, which originate from aquatic plants like phytoplankton, algal blooms, and microorganisms within the natural ecosystem. In contrast, synthetic surfactants, often phosphate-based derivatives are typically introduced through point or diffused sources of pollution, resulting from various anthropogenic activities.

Foaming is primarily triggered by the excessive accumulation of these surfactants, along with other organic and inorganic pollutants, particularly under conditions of increased turbulence caused by disturbance in flowing water. This combination of various factors significantly reduces the surface tension of water, leading to the formation of thick, persistent layers of froth on the surface.

Although foaming incidents are typically localized, they have been reported worldwide. Several urbanized water bodies, both in India and across the globe, have experienced such events, raising serious ecological and public health concerns. The following section highlights prominent case studies of foaming issues in rivers and lakes at both national and international levels. Figure 3 displays the foaming incidents reported worldwide.

1.3 Foaming Incidents Reported Worldwide

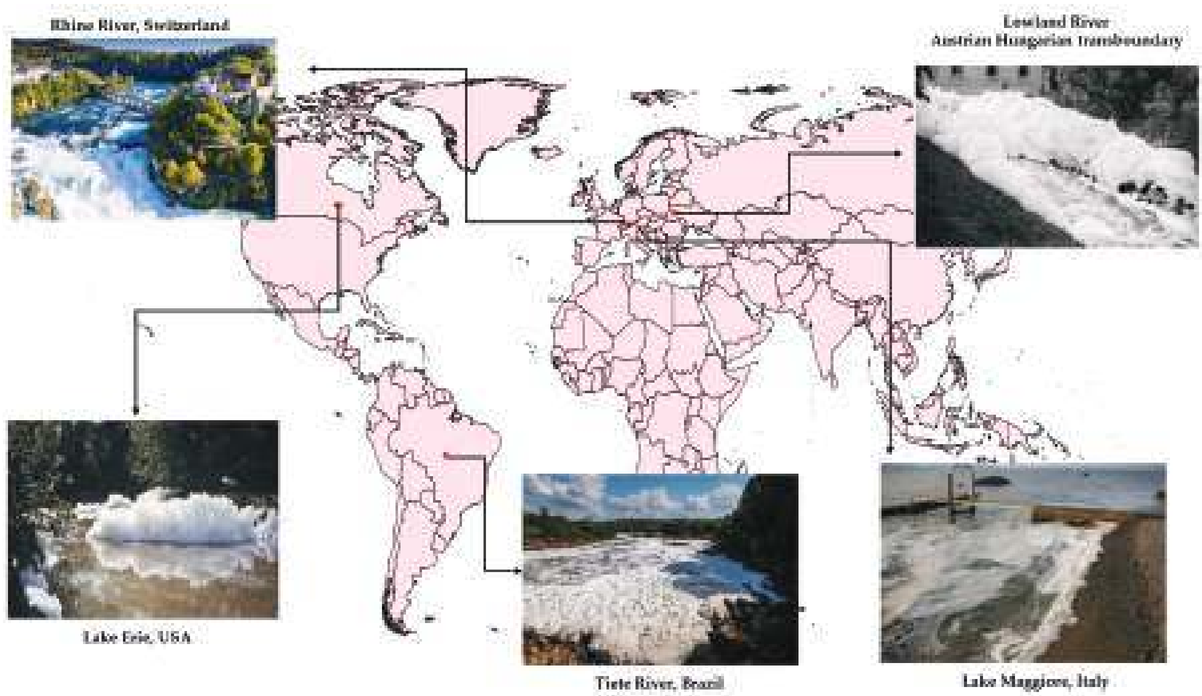


Figure 3: Foaming Cases Reported worldwide

1.3.1 Rhine River Switzerland (1960–2002):

Background: During the period of 1970–2002, a persistent foam cover was observed during the summer months in the Rhine River, occurring especially beneath the Rhine Fall, a waterfall near Schaffhausen, Switzerland. This phenomenon has become a matter of public concern ever since its first appearance. Large quantities of Ranunculus (a kind of aquatic plant) biomass were found to accumulate near the Schaffhausen hydroelectric dam, just upstream of the Rhine Falls, which was releasing large quantities of natural surfactant in the river.[4]

Solution:

i. **Advanced Monitoring Techniques:** Use of advanced analytical techniques like electrospray liquid chromatography–mass spectrometry (LC-MS) to identified and the presence of triterpene saponins and galacto-syldiacyl-glycerolipids (MGDAG and DGDAG)—natural surfactants released from aquatic plants like *Ranunculus fluitans* as foaming agents in river

ii. **Policy Shift Towards Nature-Based Foam Causes and Solutions:** Earlier assumptions focusing on synthetic pollution were revised. Authorities adopted a more holistic policy approach, recognizing natural sources like aquatic plants as major contributors of foam formation and incorporating their ecological monitoring and targeted removal efforts into river management practices.

iii. **Evidence-Based Water Quality Strategies:** Systematic monitoring of saponin concentrations in water and foam samples during 1998 and 2000 helped establish a clear link between natural plant compounds and foam formation. Insights from long-term monitoring data influenced local water quality management policies, promoting targeted interventions at specific locations and times (e.g., during summer months).

1.3.2 Austrian Hungarian Transboundary Lowland River (2009):

Background: As reported by Schilling et al. (2012,2014)[5],[6] the appearance of foam in a lowland river in Austria, extending to areas just across the Austrian Hungarian border, triggered public protests in Hungary. In this response, a year-long monitoring program was initiated. This programme involved:

a. Surface water sampling along the affected stretch.

b. Inspection and analysis of 13 municipal and industrial wastewater treatment plants, focusing on potential sources of foam-forming compounds.

The investigations revealed that three tanneries—despite employing best available treatment technologies (biological treatment with nitrification and denitrification, sludge retention time >20 days, temperature in the activated sludge tank >20 C) were the primary contributors to foam formation due to the presence of poorly degradable surfactants like Quaternary Ammonium Compounds (QUACs), Nonylphenols (NPs), Nonylphenolethoxylates (NPEOs), Linear Alkylbenzolsulfonates (LAS)

Solution:

1. **Regulatory Intervention:**

a. Amendment of Austrian Rules to include surface tension as a new emission parameter.

b. Two emission limits for surface tension were defined based on river flow: 60 mN/m when river discharge is > 4.6 m^3/s and 65 mN/m when discharge is < 4.6 m^3/s

4 Wegner, Christian, and Matthias Hamburger. "Occurrence of stable foam in the upper Rhine River caused by plant-derived surfactants." *Environmental science & technology* 36.15 (2002): 3250–3256.

5 Schilling, Katerina, Ulrike Bletterie, and Matthias Zessner. "Assessment of instream foam formation and quantification of foam in effluents." Environmental Science and Pollution Research 21 (2014): 7187–7193.

6 Schilling, Katerina, et al. "Adapting the Austrian Edict on wastewater emissions for tanneries as consequence of foam formation on surface waters." Environmental science & policy 23 (2012): 68–73.

2. **Technological Solution:** Advanced oxidation technique- **ozonation** was evaluated as a post-treatment for tannery effluents. The process effectively oxidized surface-active substances, increasing surface tension and reducing foam potential. Ozone dosages between 100–190 mg/l were required to meet the emission standards of 60–65 mN/m, depending on effluent composition. This demonstrated ozonation as a viable solution to control foaming
3. **Monitoring and Analytical Tools:** Continuous monitoring through online webcams was performed and foam index was developed for quantification of foam at the location

1.3.3 Tiete River Brazil (2021)

Background: In the Tietê–Pinheiros river system of São Paulo, Brazil, persistent foam formation at the Pirapora reservoir has been a significant environmental concern. This phenomenon has been directly linked to intense organic pollution and anoxic (oxygen-depleted) conditions, primarily due to the discharge of untreated municipal and industrial wastewater into the river system. Investigations revealed that foaming is closely associated with high concentrations of acid volatile sulfides (AVS), elevated organic carbon in sediments, and decreased microbial activity under low-oxygen conditions. The affected stretches exhibited dark-colored water, strong odors of methane and hydrogen sulfide, and the presence of reactive heavy metals—making foam a visible indicator of severe chemical and microbial contamination in the river ecosystem.

Solution: A comprehensive solution to the problem is still being explored.

1.3.4 Lake Maggiore, Italy (2007- 2013):

Background: As reported by Stefani et al. (2016)[7], recurring foam events were observed in Lake Maggiore, a subalpine lake in northern Italy, after a period of 2–3 decades. Notably, foaming occurred in 2007, 2008, and 2010, prompting investigations into the possibility of a natural, endogenous origin of the foam under newly established ecological conditions.

Problem Identification: The analysis of foam samples revealed that while blooms of the diatom *Tabellaria flocculosa (type of algae)* showed strong correlation with foam formation, the overall algal biomass was a more consistent predictor of foaming risk. Chemical assessments further ruled out industrial pollution, as no significant enrichment of synthetic surfactants was detected.

The study also highlighted that foam events were also driven by a combination of factors, including spring phytoplankton blooms, residual thermal stratification, and increased wind activity in autumn.

Solution:

i. **Monitoring of algal biomass:** Regular monitoring of Tabellaria flocculosa and overall algal biomass was included as a consistent predictor of foaming risk.
ii. Wetlands and other buffer strips were constructed around the lake to trap nutrients runoffs.
iii. Regulations were implemented to reduce phosphate usage in households and industries

7 Stefani, F., et al. "Endogenous origin of foams in lakes: a long-term analysis for Lake Maggiore (northern Italy)." *Hydrobiologia* 767 (2016): 249–265.

1.3.5 Lake Erie USA (2011)

Background: In Lake Erie (USA), foam formation has been periodically observed, especially during and after harmful algal blooms (HABs) dominated by cyanobacteria like Microcystis. These blooms, fueled by excessive nutrient runoff (particularly phosphorus from agricultural sources), release organic compounds that, with wind and wave action, lead to foam formation along shorelines. Studies have shown that foam often contains cyanotoxins, posing ecological and public health risks[8].

Solution:

i. **Regulatory Controls and Monitoring:** Stricter regulatory controls are applied to industries, including effluent discharge limits, alongside continuous monitoring and nutrient management plans to mitigate harmful algal blooms and associated foam formation.

ii. **Watershed Management:** Comprehensive watershed management strategies are implemented to address nutrient load and improve water quality in the lake.

iii. **Agricultural Practices:** Fertilizers (especially nitrogen and phosphorus) were applied based on soil testing and crops needed to minimize nutrient runoff into water bodies.

1.3.6 Northern U.S. Lakes (2020)

Background: Foam formation incidents were recurrently observed across several northern U.S. lakes. Notable events have occurred in lakes such as Lake Michigan, Lake Superior, and Lake Champlain, where thick, white to brownish foams have appeared along shorelines and open water zones. These foams are often reported in late spring and tend to accumulate in windward covers, bays, or near river inlets. These events raised public concern due to their sudden appearance, prompting local authorities to investigate their nature and frequency[9].

Problem Identification: In these lakes, surface foam showed extremely high PFAS levels—especially PFOS—far above EPA limits. Though PFAS made up less than 0.1% of dissolved organic carbon, they were highly concentrated in foam, with enrichment factors up to 2830 times. Natural organic matter also drives foam formation in these lakes. This study also highlights potential health risks from foam ingestion, particularly for children.

Solution: As of now, specific remedial or regulatory actions are still in progress.

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8 Steffen, Morgan M., et al. "Ecophysiological examination of the Lake Erie Microcystis bloom in 2014: linkages between biology and the water supply shutdown of Toledo, OH." *Environmental science & technology* 51.12 (2017): 6745–6755.

9 Schwichtenberg, Trever, et al. "Per-and polyfluoroalkyl substances enrichment in the surface microlayer of a freshwater system impacted by aqueous film-forming foams." *ACS ES&T Water* 3.4 (2023): 1150–1160.

1.4 Foaming Incidents Reported in India

In India, foaming in rivers and lakes is increasingly being reported in major urban centers. Figure 4 shows few major incidents of foaming observed in surface water bodies in India

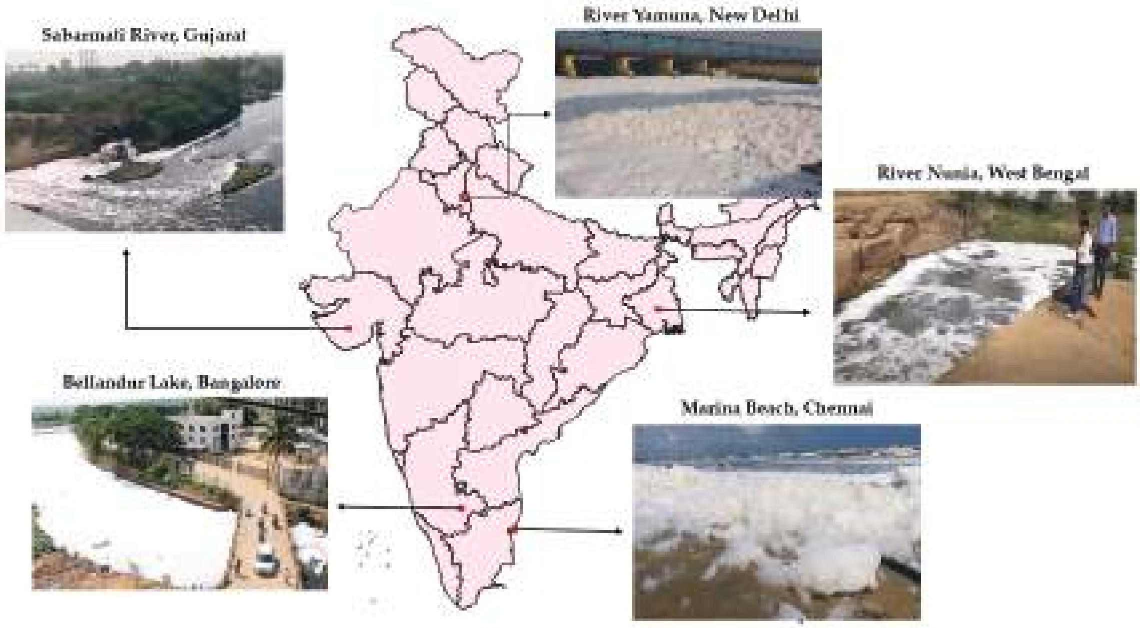

Figure 4: **Foaming Incidents Reported in India**

1.4.1 The Bellandur Lake and its Downstream Lakes (Varthur and Kolar) in Bengaluru (2023)

Background: As per reported study by Rashmi Das et al (2023)[10] the foaming events at Bellandur Lake in Bangalore, India, have gained international attention due to their dramatic and persistent nature. The lake experiences severe foaming, with foam reaching heights of 2.5–3 meters and lasting for 6–7 days. These events are seasonal, typically occurring after moderate to intense rainfall. One of the most striking incidents involved the foam catching fire, producing smoke-laden aerosols that covered the neighborhood for hours, disrupting traffic and degrading the aesthetic and environmental quality of the area.

Problem Identification: As reported in study Rashmi Das et al (2023 b)[11] Bellandur Lake receives 530–548 million liters of untreated sewage daily, with only 54% being treated. Household laundry and personal care products introduce anionic surfactants like (Sodium Dodecyl Benzene Sulphonate (SDBS) and Linear Alkylbenzene Sulfonates (LAS)) in lake which was considered the primary cause of foaming. These Surfactants adsorbed onto lake sediments (up to 3.4 g/kg dry sediment) and (53.5 ± 4 mg/g SS) on suspended solids Contrary to expectations rainfall events triggered the desorption from SS and sediments, increasing free surfactant concentration by 43% leading to severe foam formation (2.5–3 m high).

10 Das, Reshmi, Chanakya Hoysall, and Lakshminarayana Rao. "Unveiling the origin, fate, and remedial approaches for surfactants in sewage-fed foaming urban (Bellandur) Lake." *Environmental Pollution* 339 (2023): 122773.

11 Das, Reshmi, H. N. Chanakya, and Lakshminarayana Rao. "Unravelling the reason for seasonality of foaming in sewage-fed urban lakes." *Science of the Total Environment* 886 (2023): 164019.

Solution Proposed:

i. **Source Control and Infrastructure Improvements:** It was suggested to divert and treat all sewage before it enters the lake to significantly reduce the surfactant load responsible for foaming. Also, stringent regulations on industrial and domestic wastewater discharge were recommended to prevent further contamination.

ii. **Sediment and Stormwater Management:** It was proposed to dredge the polluted sediments that store high levels of adsorbed surfactants, with a caution that sustainable disposal methods must be developed due to the pollutant concentration. Also to minimize surfactant desorption during rainfall, it was suggested to control stormwater runoff rather than allow direct dilution of lake water.

iii. **Lake Restoration Measures:** Enhanced aeration was recommended to improve dissolved oxygen levels in the lake, which can facilitate natural biodegradation of surfactants.

iv. **Policy Measures:** Emphasis was placed on strengthening policy enforcement to ensure compliance with wastewater treatment and disposal standards.

1.4.2 River Nunia, West Bengal (2023):

Background: The River Nunia, a tributary of the Damodar River in Asansol, West Bengal, has recently gained attention due to persistent foam formation near the Ghagarburi site, a culturally significant area adjacent to a temple and tourist spot. Local residents and authorities have raised concerns as the dense, unnatural foam accumulates along the riverbanks, particularly during summer and winter months[12].

Problem Identification: Foam formation is driven by a combination of chemical pollutants and physical landscape features. Elevated phosphate (3.6 mg/L) and sulphate (61.2 mg/L) levels, primarily from detergents and effluents, reduce water surface tension and contribute to foam stability. High BOD (29 mg/L) and COD (100 mg/L) values contribute to the presence of untreated sewage or industrial discharges. Additionally, nitrate concentrations (54.2 mg/L) originating from agricultural runoff stimulate algal blooms, and the subsequent decomposition of algal biomass releases organic matter that further promotes foam formation. The region's rocky topography, especially cascading sections, enhances water turbulence and traps air, physically facilitating foam generation.

Solution: The problem is still being assessed.

1.4.3 Sabarmati River, Gujarat (2023)

Background: As per the literature report (Khan et al, 2021) foaming events in the Sabarmati River, particularly near Ahmedabad's Gandhi Bridge, have been increasingly observed during the winter months (November to February). These incidents are characterized by thick, white foam floating along the river surface, often creating visually disturbing scenes resembling toxic bubble baths. The foam is especially prominent during low-flow periods when the dilution capacity of the river is minimal. Although monsoon rain temporarily washes away the foam, the issue reemerges annually, making it a persistent seasonal phenomenon in the urban stretches of the river.

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12 Mukherjee, Sagarika, and Manas Paramanik. "Discussion and evaluation of water quality in river systems of West Bengal, India: An assessment of physicochemical and biological parameters as markers of water quality." *J. Biodivers. Environ. Sci* 24.5 (2024): 8–23.

Problems Identified: The primary sources of foam in the Sabarmati River are untreated domestic sewage, laundry detergents—notably Linear Alkylbenzene Sulfonate (LAS) and Sodium Dodecylbenzene Sulfonate (SDBS). The discharge of these substances without adequate treatment results in the accumulation of surface-active agents, which lower surface tension and promote foam formation. Additionally, religious offerings further contribute to organic and chemical load in the river. The lack of effective wastewater treatment and continuous pollution inflows during dry seasons intensify the problem, raising significant concerns about riverine health, aesthetics, and potential public exposure to toxic compounds.

1.4.4 Marina Beach Foaming (2023–2024)

The iconic Marina Beach in Chennai has been experiencing recurring foam formation along its shoreline, particularly near river mouths and drainage outlets, with incidents peaking during the Northeast monsoon (October-December). This phenomenon stems from a combination of untreated sewage and industrial effluents from the Cocoum and Adyar rivers, laden with surfactants (2.5–4.2 mg/L) and phosphates (3.8–6.1 mg/L), mix with seawater, while wave action and algal blooms further stabilize foam. The foam's persistence—often lasting 12–48 hours—has raised alarms due to its ecological and aesthetic impact on India's longest urban beach, which sees over 20,000 daily visitors[13].

Problems Identified: Seasonal monsoon flows is the primary cause of the issue by flushing accumulated pollutants into the sea, creating expansive foam patches (50–100 meters long). Compounding the problem, Chennai's inadequate sewage treatment capacity (only 530 MLD against a 750 MLD need) and industrial discharge violations highlight systemic gaps in pollution control, threatening both marine biodiversity and the beach's recreational value[14]

1.5 Frothing in Yamuna River in Delhi

Background: The Yamuna River, particularly its Delhi stretch, is a critical example of such an issue in northern India. The phenomenon of foaming, especially around the Okhla Barrage, has drawn public and media attention due to its alarming visuals and underlying pollution crisis (Figure 5). The foam usually covers up to half of the river's surface and gradually disappears several kilometers downstream.

13 Battaglia, Steven M. "Are Ocean Shorelines Getting Frothier?" *Weatherwise* 76.1 (2023): 27–34.

14 https://www.tnpcb.gov.in/PDF/Citizen_corner/ph/ExeSumEngMarine4823.pdf

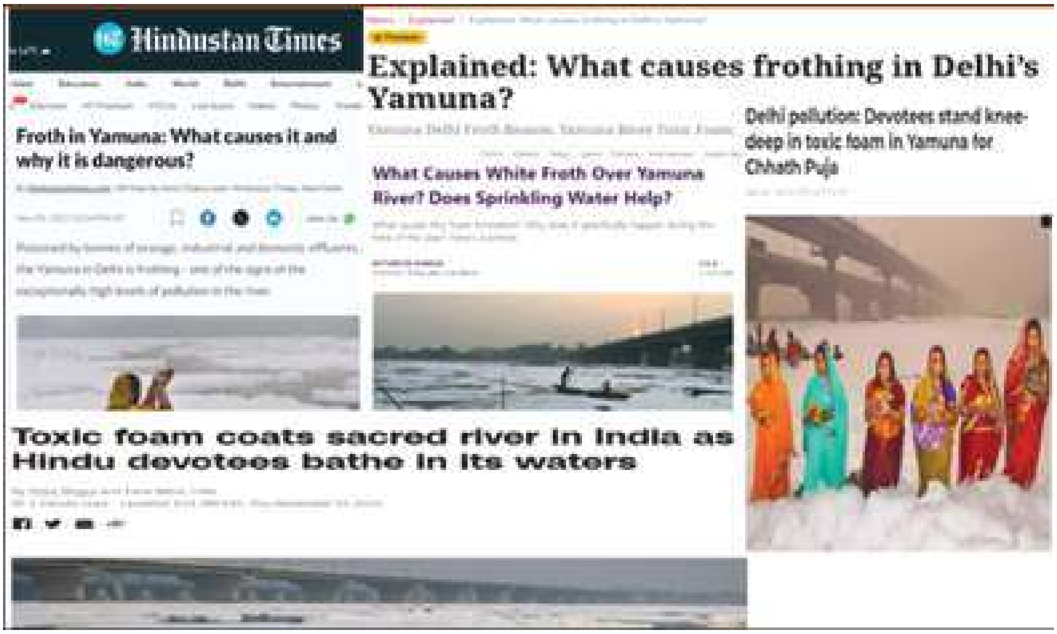


Figure 5: **Persistent Problem of Froth in Yamuna reported widely on Print Media**

Problem Identification:

This recent study by Sejwal and Singh (2023)[15], shed light on several overlooked or unquantified dimensions of foaming issue in Yamuna.

Drawing from their analysis, it was evident that foam formation in the Yamuna is not solely due to synthetic surfactants but may also be influenced by biogenic inputs, especially from invasive aquatic species like *Eichhornia crassipes* (water hyacinth).

These plants are known to release surface-active compounds such as saponins and phosphates that can contribute to natural foaming.

Moreover, the study highlights the potential role of eutrophication-induced plankton blooms, long-chain fatty acids, nitrogen gases, and even proteins in enhancing foam stability.

The turbulence caused by the Okhla Barrage also plays a physical role in promoting foam generation by injecting gas bubbles into the surfactant-laden water column.

Solutions Proposed:

Sejwal and Singh emphasize the importance of investigating the contribution of invasive aquatic species—particularly *Eichhornia crassipes* (water hyacinth)—to the foam formation process. They hypothesize that such species may release natural surfactants like saponins, which could significantly influence foam generation and stability.

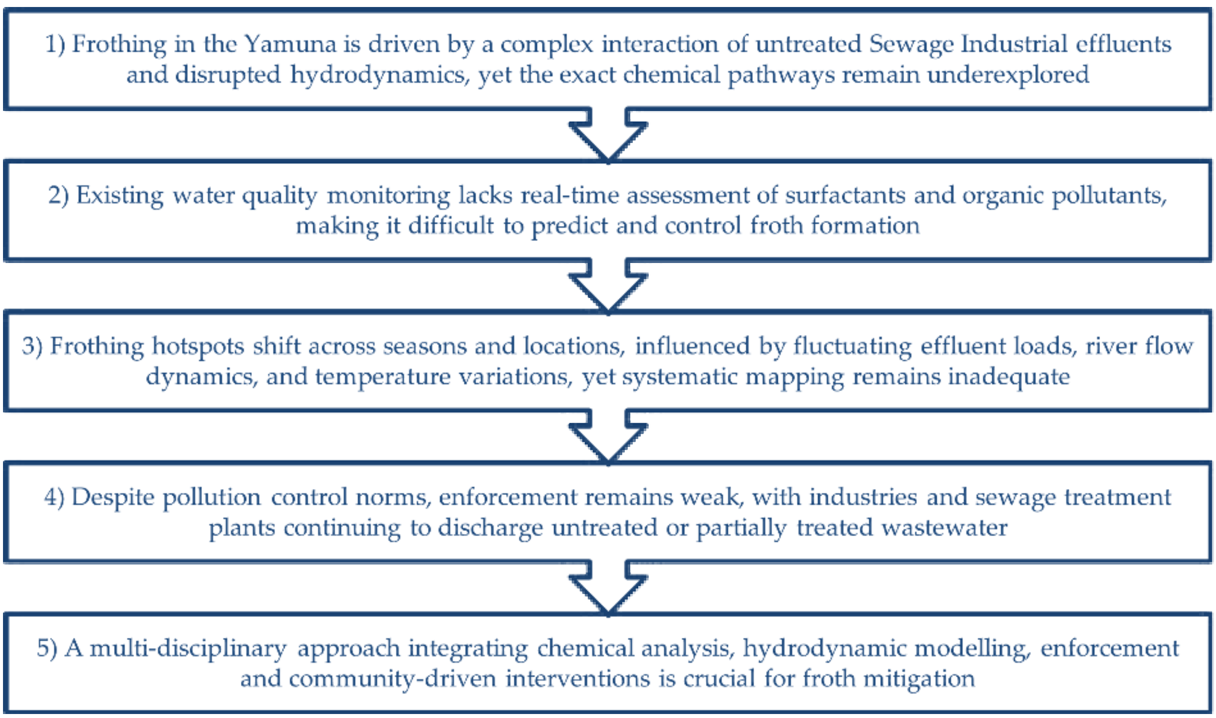
They also drew attention to the need for monitoring seasonal variations in nutrient influxes, such as nitrogen and phosphorus. These nutrients are known to promote eutrophication, potentially leading to the development of biogenic surface-active compounds that can further enhance foaming events.

15 Sejwal, Garima, and Santosh Kumar Singh. "Perspective: The unexplored dimensions behind the foam formation in River Yamuna, India." *Environmental Science and Pollution Research* 30.39 (2023): 90458–90470.

The study lastly strongly advocates for laboratory-based experimental approaches to quantify the concentrations of various contributing agents—both synthetic (e.g., detergents) and natural (e.g., fatty acids, proteins, and phytochemicals)—in both river water and foam samples. This is proposed to establish a clearer causal relationship between pollutants and foam occurrence.

Despite policy-level interventions under the Yamuna Action Plan and Namami Gange Programme, gaps remain in enforcement and integrated watershed management. Addressing these unexplored drivers holistically is essential for restoring the ecological health of Yamuna and preventing future foaming events.

1.6 Research Gaps



1.7 Scope of Work as mentioned in RFP

The primary objectives of the project are:

1. To find out the reasons behind the foaming/frothing in Yamuna River and correlate it with the outflow of different drains.
2. To assess and identify froth sources in the Najafgarh Drain (upstream Dhansa Regulator to Wazirabad) and supplementary drains.
3. To identify major drains accounting for maximum pollution, load responsible for froth, and finding out parameters exceeding the standard/permissible limits.
4. To identify area sources such as colonies, industrial areas, etc., contributing to the pollution load responsible for frothing in Yamuna, find out the relative quantification, nature, source, and characteristic of the pollutants, and identify hot spots as far as sources are concerned.
5. develop short-term, medium-term, and long-term action plans including clear enforcement strategies for minimizing frothing/foaming in the river Yamuna including possible alternatives to household products responsible for frothing.

Approach & Methodology

2. Approach & Methodology

2.1 Mapping of Locations

A total of 52 locations were visited, and 99 samples were collected during the yearlong study. These locations comprise of River Ghats and Barrages (7), Open Drains (19), STPs (12), CETPs (6), Dhobi Ghats (5) and additional locations covering the Najafgarh Stretch (3). Marked locations are projected using Geographic Information System (GIS) maps in Figure 6.

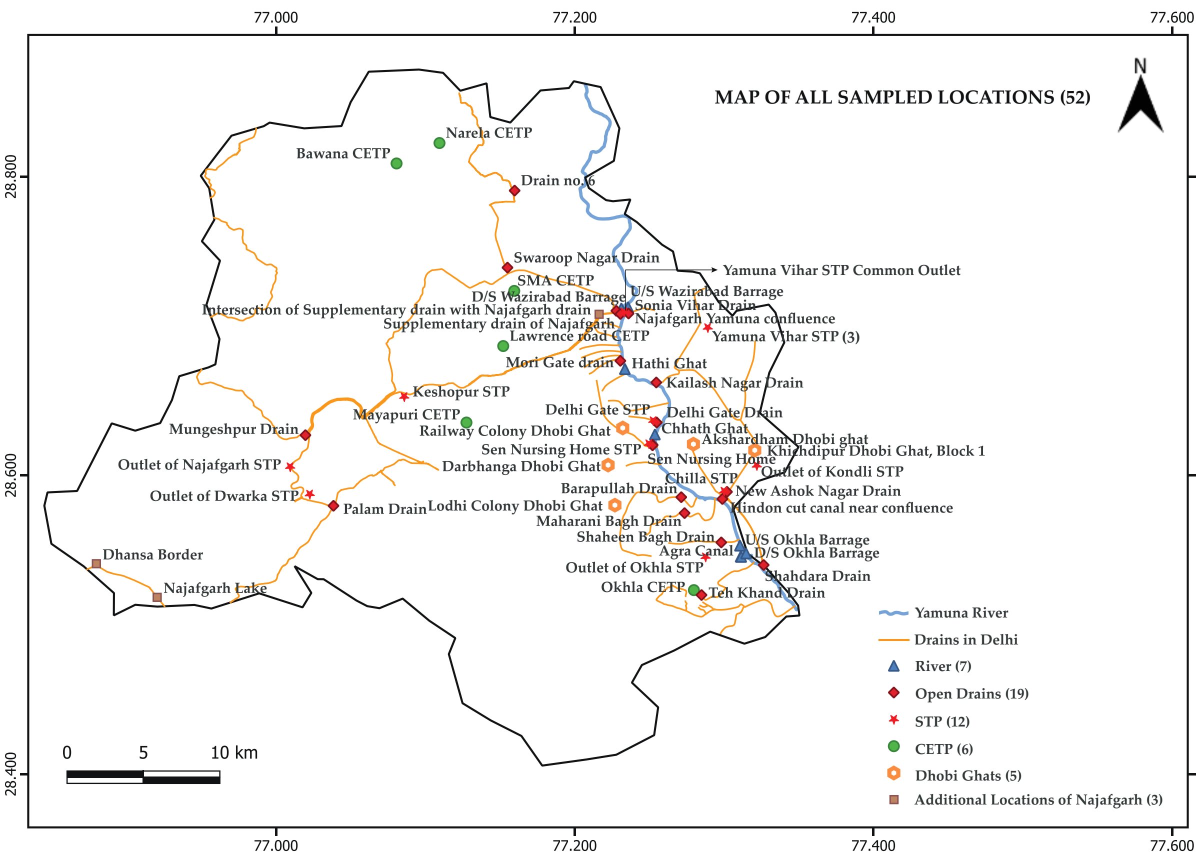


Figure 6: Study Area Map Projecting 52 Sampling Locations over the Stretch of Yamuna River in NCT Delhi

2.2 Sampling Approach

Total of 99 samples were collected during Pre- and Post-Monsoon Sampling. The sites for sample collection were selected based on their direct contribution to the river's water flow, pollution, and recommendations received during the 1st interim report held on 26 Nov 2025. These locations comprised of River ghats, major drains directly out falling in the Yamuna River, and sub drains contributing to these major drains carrying pollutants from unauthorized colonies. Additionally, Okhla Barrages near Kalindi Kunj, where extensive foaming has been reported, was focused on capturing a comprehensive view of potential pollution hotspots and point sources leading to persistent foaming at the barrage. The detailed list of pre- and post-monsoon sampling locations is given in Table 1.

Table 1: Locations Visited, and Samples Collected during Pre- and Post-Monsoon Season

S. No.	Locations	Latitude	Longitude
DHOBHI GHATS	**Sampling Location Visited – 5** **Total No of Samples Collected – 3**		
1.	Akshardham Dhobi ghat	28.620911N	77.279431E
2.	Khichdipur Dhobi Ghat, Block 1	28.616831N	77.320506E
3.	Lodhi Colony	28.58007N	77.226864E
4.	Darbhanga Dhobi Ghat	28.6069N	77.222306E
5	Railway Colony Dhobi Ghats	28.631743N	77.232108E
STPs	**Sampling Location Visited – 12** **Total No of Samples Collected – 19**		
1.	Najafgarh STP Outlet	28.605766N	77.009416E
2.	Dwarka STP Outlet	28.587447N	77.022526E
3.	Okhla STP Outlet	28.545453N	77.287545E
4.	Kondli STP Outlet	28.60663N	77.321837E
5.	Yamuna Vihar Final Outlet	28.69896N	77.28902E
6.	Yamuna Vihar Phase 1 Inlet & Outlet	28.69896N	77.28902E
7.	Yamuna Vihar Phase 2 Inlet & Outlet	28.69896N	77.28902E
8.	Yamuna Vihar Phase 3 Inlet & Outlet	28.69896N	77.28902E
9.	Keshopur STP Inlet & Outlet	28.6527N	77.08579E
10.	Chilla STP Inlet & Outlet	28.58946N	77.29997E
11.	Delhi Gate Inlet & Outlet	28.63661N	77.25253E
12.	Sen Nursing Home STP Inlet & Outlet	28.62121N	77.24962E
CETPs	**Sampling Location Visited- 6** **Total No of Samples Collected – 12**		
1.	Lawrence Road CETP Inlet & Outlet	28°.68659N	77.15209E
2.	Bawana CETP Inlet & Outlet	28°.80884N	77.08068E
3.	Narela CETP Inlet & Outlet	28°.82252N	77.10942E
4.	Okhla CETP Inlet & Outlet	28°.52318N	77.28071E
5.	Mayapuri CETP Inlet & Outlet	28°.63537N	77.12748E
6.	SMA CETP Inlet & Outlet	28°.72351N	77.15948E
Drains	**Sampling Location Visited for Major Drains – 19** **Total Samples Collected during Pre & Post Monsoon – 37**		
1.	Drain no. 6	28.790674N	77.159728E
2.	Swaroop Nagar Drain	28.739118N	77.154943E
3.	Supplementary Drain of Najafgarh	28.710166N	77.227830E
4.	Soniya Vihar Drain	28.708382N	77.235998E
5.	Najafgarh Yamuna Confluence	28.708046N	77.230538E
6.	Mori Gate drain	28.669500N	77.234028E
7.	Kailash Nagar Drain form Shastri Nagar	28.662197N	77.254574E

S. No.	Locations	Latitude	Longitude
8.	Delhi Gate Drain	28.6354N	77.254859E
9.	Sen Nursing Home	28.620458N	77.252103E
10.	New Ashok Nagar Drain	28.588991N	77.301909E
11.	Drain 12A	28.620139N	77.252075E
12.	Barapullah Drain	28.585401N	77.27129E
13.	Shaheen Bagh Drain	28.542728N	77.299868E
14.	Hindon cut canal near confluence	28.584194N	77.298805E
15.	Maharani Bagh Drain	28.57474N	77.273509E
16.	Teh Khand Drain	28.524755N	77.283639E
17.	Shahdara Drain	28.544612N	77.318462E
18.	Palam Drain	28.579645N	77.03844E
19.	Mungeshpur Drain	28.62693N	77.019655E
Najafgarh Stretch	**Additional Locations around Najafgarh Drain – 3** **Total Samples Collected during Pre & Post Monsoon – 6**		
1.	Dhansa Border	28.540135N	76.879545E
2.	Najafgarh Lake	28.5178483N	76.9204186E
3.	Intersection of Supplementary drain with Najafgarh drain	28.710011N	77.217761E
River Yamuna	**Sampling Locations Visited – 7** **Total Samples Collected during Pre & Post Monsoon – 12**		
1.	Upstream Wazirabad Barrage (East)	28.712585N	77.235719E
2.	Downstream Wazirabad Barrage	28.71181N	77.23118E
3.	Hathi Ghat	28.671222N	77.233528E
4.	Chhath Ghat	28.627427N	77.253650E
5.	Agra Canal	28.545611N	77.311055E
6.	Upstream Okhla Barrage East Side	28.545488N	77.311411E
7.	Downstream Okhla Barrage	28.54781N	77.314673E
Additional Samples Collected – 10			
1.	Okhla Barrage –Multiple Time – 6	28.712585N	77.235719E
2.	Soil Samples – 2	28.712585N	77.235719E
3.	Plant Samples – 2	28.56748N	77.2943533E
Total Sampling locations visited=52 **Total Samples collected=99**			

2.3 Testing & Analysis Laboratory

2.3.1 Selection of Analytical Laboratory

TERI undertook a transparent and comparative process to identify a suitable NABL-accredited laboratory for the testing and analysis of water samples collected from multiple locations along the Delhi stretch of the Yamuna River. Quotations were invited from reputed NABL-accredited laboratories covering a comprehensive set of physico-chemical, microbiological, and surfactant-related parameters crucial for understanding the frothing phenomenon.

Upon detailed comparative evaluation, **Eureka Testing & Analysis Laboratory, Sonipat** emerged as the most comprehensive and technically competent option, offering complete analytical coverage of all required parameters at competitive rates with one laboratory. And within Delhi-NCR. The other laboratories either did not include essential parameters such as surfactants (Anionic/Cationic), Sodium Lauryl Sulphate (SLS), Sodium Tri-Polyphosphate (STPP), or microbial indicators, which were vital for assessing the causative factors of frothing and also did not agree for sample collection as scope of work.

Eureka Testing & Analysis Laboratory is a **NABL-accredited (ISO/IEC 17025:2017)** facility located in **Sonipat, Haryana**, recognized for its precision, reliability, and adherence to national and international analytical standards. The laboratory specializes in the testing of **water, wastewater, soil, air, and industrial effluents**, supporting regulatory, research, and environmental monitoring programs across India. Eureka is equipped with advanced instrumentation, including:

1. **Thermo ICP-OES (**Inductively Coupled Plasma – Optical Emission Spectrometer, iCAP **7000 Series)** for trace metal and nutrient analysis (Phosphates, STPP, Heavy Metals).

Figure 7: **ICP-OES**

2. **UV-Vis Spectrophotometer** for colorimetric determinations

Figure 8: **Ultraviolet-Visible spectrophotometer**

3. **High-Precision pH, DO, TDS, BOD, and COD Analyzers**
4. **Microbiological Testing Facilities** for filamentous bacteria (*Nocardia amarae*, *Gordonia amarae*) following *The Microbiology of Wastewater Treatment (USEPA Webinar Series, 2020)*
5. **Surfactant and Organic Compound Analysis Systems** using validated in-house methods (EKA-SOP-156 and EKA-MB-SOP-44).

All analyses were performed in accordance with **Eureka's Standard Operating Procedures (SOPs),** supported by traceable calibration standards and internal quality assurance practices. Their methodical approach and adherence to NABL guidelines ensured high precision and reproducibility, lending strong scientific credibility to the analytical results generated under this study.

2.3 Sampling Methodology

- ➢ Composite water samples were collected over a period from May and June 2024 in Pre-monsoon and December and January 2025 in Post-Monsoon in from all 52 locations mentioned in Table 1.
- ➢ The river water samples were collected from the middle of the river to ensure homogeneity of the pollutants in the samples.
- ➢ The water samples were collected in pre-cleaned, sterilized bottles of varying capacities (500 mL, 1000 mL, and 5000 mL), and with a total of 10 L of water collected at each sampling site. This quantity was deemed sufficient for the analysis of all proposed parameters, including physical, chemical, and biological indicators.
- ➢ The samples were promptly transported to NABL-accredited Eureka Labs, located in Kundli, Sonipat, on the same day of collection for analysis.
- ➢ Eureka Labs was selected after receiving and evaluating quotations from various NABL-accredited labs across the country based on the criteria of availability in Delhi NCR, cost competition, having all testing parameters under one roof and good experience, and well-established setup and credibility of results lead to the selection of the lab for this study.
- ➢ The samples were stored in freezers below 4 °C at the Eureka Labs facility to ensure that there was no degradation or alteration of the sample properties.

2.4 Analytical Procedures

- ➢ The collected samples were analyzed for the parameters, as outlined in Table 2 to identify froth causing factors.
- ➢ These parameters included standard polluting parameters in line with DPCC/CPCB monitoring, anthropogenic compounds that are indicators of industrial effluent, pharma products, and parameters that are directly and indirectly responsible for foam formation in the river, as identified from the extensive literature study.
- ➢ **Microbial Analysis:**

  Identification of **filamentous bacteria** such as *Nocardia amarae* and *Gordonia amarae* was conducted using microscopic examination and biochemical characterization following EKA-MB-SOP-44 and USEPA guidelines.
- ➢ **Surfactants and Organic Compounds:**
  1. **Saponin and Sodium Lauryl Sulphate (SLS)** were determined through methanol extraction and titrimetric analysis, respectively, as per EKA-SOP-156 and Aziz et.al (2019).

2. The extraction process involved methanol reflux, acetone precipitation, and gravimetric quantification for saponin.
3. SLS concentration was determined using benzathine chloride titration method with methyl blue as an indicator.

- **Nutrient and Phosphate Analysis:**
  1. **Sodium Tri-Poly Phosphate (STPP)** was analyzed using **ICP-OES** as per EKA-SOP-99.
  2. Samples were filtered through **0.45 µm membranes**, acidified to **pH < 2**, and digested with **nitric acid** and **hydrochloric acid** before analysis.
  3. Results were expressed as phosphorus (P), applying a **conversion factor of 3.96** to calculate STPP concentration.
- **Heavy Metal Analysis:**
  1. Determination of **heavy metals** was conducted using **Thermo ICP-OES (iCAP 7000 Series)** as per **EKA2-CHE-SOP-099**.
  2. were filtered, acid-digested, and analyzed to quantify metal ions contributing to frothing and surface tension variation.
- The analysis of the samples collected was conducted within 24 hours of sample collection. The American Public Health Association (APHA) and other established methods, such as USEPA, were followed in the analysis of selected parameters.
- Analytical-grade chemicals were used, and all tests were performed in triplicate to ensure precision, utilizing advanced techniques like Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) for elemental analysis and various chromatographic methods (HPLC, GC, and MS) available in Eureka Labs.
- The concentration of saponin in the samples was provided in g/100g by the lab, which has been reported in mg/L as per literature and to maintain the uniformity in reporting of data and analysis.
- **Reporting of Error:** As the sample size varied, the standard deviation was high. Therefore, an error margin of ±5% has been considered.

Table 2: Summary of all 33 Parameters used for Analysis

S. No	Parameters	Standard Testing Method
1	**Standard Parameters**	
1.1	pH	APHA 4500-H
1.2	Dissolved Oxygen	APHA 4500-O
1.3	Total Hardness	APHA 2340
1.4	Alkalinity	APHA 2320
1.5	TSS	APHA 2540
1.6	TDS	APHA 2540C
1.7	BOD	IS 3025 Pt 44
1.8	COD	APHA 5220
1.9	Ammonia	APHA 4500-NH3

S. No	Parameters	Standard Testing Method
1.10	Nitrate	APHA 4500-NH3
1.11	Phosphate as P	USEPA 200.7
1.12	Surfactants	APHA 5540
1.13	Oil & Grease	APHA 5520
2	Microbial Parameters	
2.1	Total Coliform	IS 1622
2.2	F. coliform	IS 1622
2.3	E. coli	IS 1622
3	**Filamentous Bacteria**	
3.1	Nocardia Amarae	Waste Water Microbiology, American Water Works Association.
3.2	Gordonia Amarae	Manual on the Causes and Control of Activated Sludge Bulking, FOAMING and other solids Separation problems by David, Michael & Glen)
4	**Bio-genic Origins/Compounds such as food products, aquatic plants**	
4.1	Saponin*	El Aziz, et.al (2019)
4.2	Lipids	AOAC 922.06: 2023
4.3	Proteins	IS 7219: 1973 (Revised 2020)
4.4	Carbohydrates	IS 1656: 2022
4.5	Fatty Acids	AOAC 996.06
4.6	Monosaccharide (as glucose & fructose)	AOAC 982.14
5	**Heavy Metals**	
5.1	Arsenic	USEPA 200.7
5.2	Mercury	USEPA 200.7
5.3	Chromium	USEPA 200.7
5.4	Lead	USEPA 200.7
5.5	Magnesium	USEPA 200.7
5.6	Iron	USEPA 200.7
5.7	Calcium	USEPA 200.7
6	**From Activators**	
6.1	Sodium Lauryl Sulphate	IS 4956 2002
6.2	Sodium tri-poly-phosphate as P	IS 3025 part -65/Part -2
	TOTAL	**33 Parameters**

Theory of Saponin

Saponins are naturally occurring bioorganic compounds having at least one glycosidic linkage (C-O-sugar bond) at C-3 between aglycone and a sugar chain. Hydrolysis of saponin molecule produces two portions, aglycone and a sugar moiety. Isolated amorphous solid saponins have a high molecular weight, and containing 27 to 30 carbon atoms in the non-saccharide portion. Figure 9 shows the chemical structure of Saponin[16].

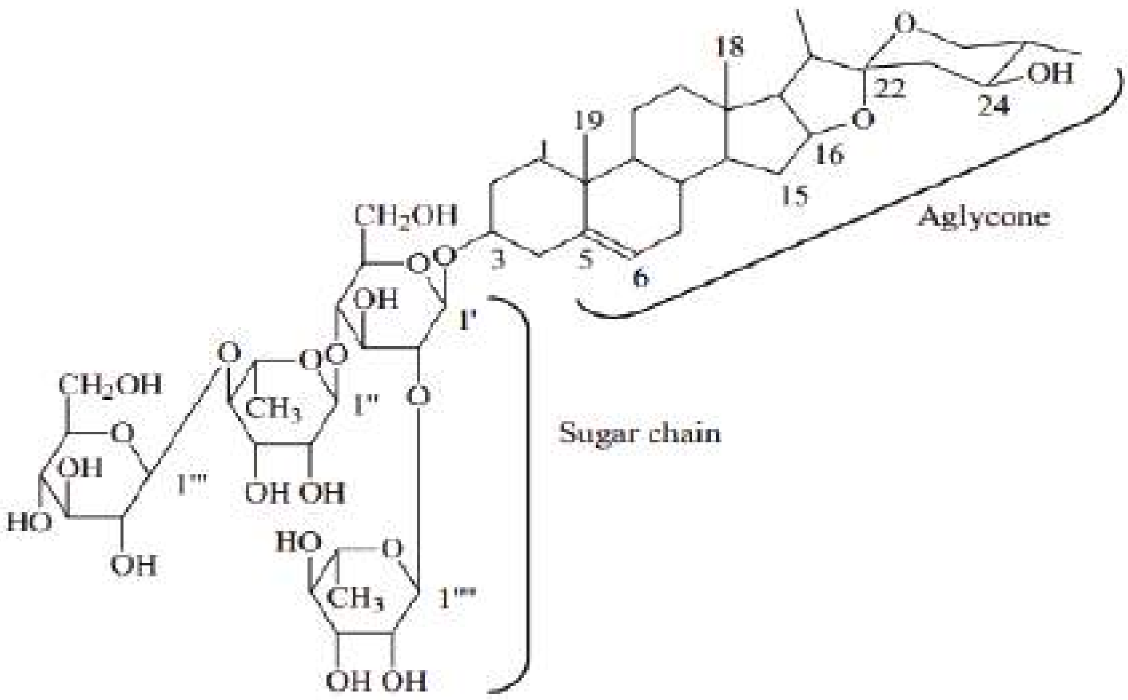


Figure 9: The Chemical Structure of Saponin

Molecular Formula: $C_{58}H_{94}O_{27}$

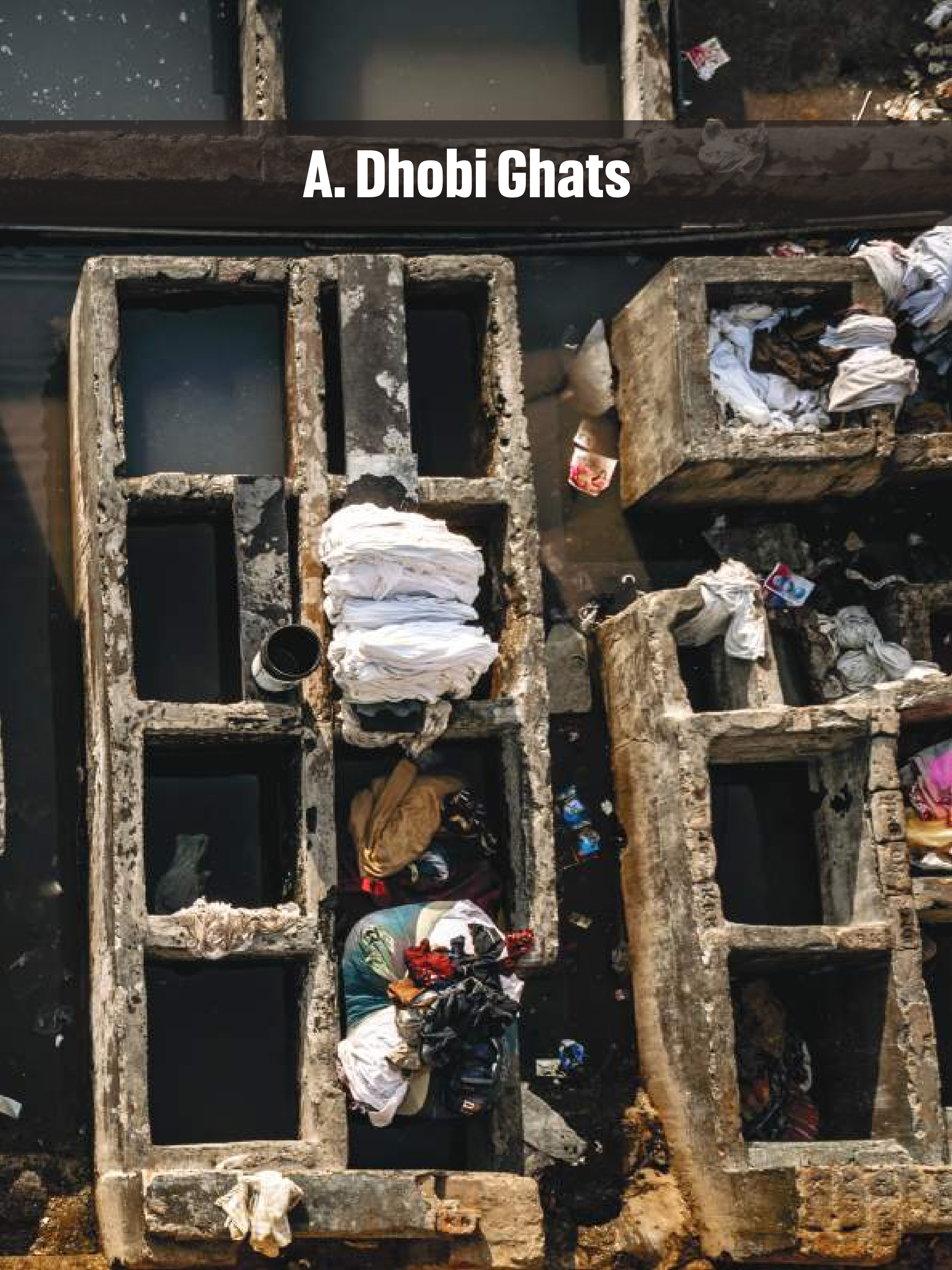
The triterpenoid saponin (from water hyacinth) can significantly increase surface elasticity, even at meagre rates of surface deformation, by forming the viscoelastic adsorption layers. The saponin molecules are larger, and their desorption from bubble surfaces is reduced by strong intermolecular attraction inside the adsorbent layer. The H-bond formation between the head groups of the adsorbate surfactant molecules induces short-range attraction, increasing the rigidity and elasticity of the surfactant adsorbent layer. Detailed investigations revealed that natural surface-active compounds particularly saponin released by the aquatic plant Ranunculus fluitans—were strongly correlated with seasonal foam formation, especially near high-energy sites such as the Rhine Falls in Schaffhausen, Switzerland. Synthetic detergents, in contrast, were found to have minimal association with the observed foaming[17].

16 JNMR-08–00199.pdf

17 *The unexplored dimensions behind the foam formation.pdf

Results & Discussion

A. Dhobi Ghats



3 Result & Discussion

A. Dhobi Ghats

Major dhobi ghats have been identified and surveyed for this study and may be divided into two categories, **Category A** involved those Dhobi ghats, which were visited but samples not collected, which includes Darbhanga Dhobi Ghat and Lodhi Colony Dhobi Ghat. Samples were not collected from these Dhobi Ghats because the wastewater here has been discharged into the tapped drains, reducing the likelihood of direct environmental contamination in the river.

Category B where Dhobi ghats which were visited and samples were collected, which includes Akshardham Dhobi Ghat, Khichdipur Dhobi Ghat and Railway Colony Dhobi ghat that discharge wastewater directly in Ganesh Nagar Drain, Shahdara drain and 12A drain respectively. Details of all Dhobi Ghats visited and sample collected have been provided in Table 3.

The wastewater generated at these sites is predominantly whitish, likely due to the high presence of detergents. We were also informed that groundwater is used for washing activities, but no data on water usage and discharge was available. Most dhobi ghats were using industrial grade detergents like TEEPOL for washing clothes. Direct discharge of laundry wastewater from Dhobi Ghats is a concern, as it contributes inorganic pollutant loads and potential amounts of surfactants that exacerbate water quality issues. The details of Dhobi Ghats visited and surveyed are given in Table 4 and marked locations are projected through Figure 10.

Table 3: Details of Dhobi Ghats Visited and Samples Collected.

S. No.	Locations	Latitude	Longitude	Observations
Category A: Dhobi Ghats Visited but Samples not Collected				
1.	Darbhanga Dhobi Ghat	28.6069°N	77.222306°E	Manual handwashing without electrical machinery; washing liquid used at Rs. 200/kg with 5–10 L/week consumption. Freshwater sourced from NDMC supply.
2.	Lodhi Colony	28.58007°N	77.226864°E	Water source: Borewell water, Water dumped in Sewa Nagar Drain (Lajpat Nagar)
Category B: Dhobi Ghats Visited and Samples Collected				
3.	Akshardham Dhobi Ghat	28.620911°N	77.279431°E	Established in 2010 by MCD; consists of 40 counters (50×27 inches each); detergents used include Surf Excel, Ghadi, Fena, and 555; wastewater drains into Ganesh Nagar Drain and eventually into Hindon cut canal.
4.	Khichdipur Dhobi Ghat, Block 1	28.616831°N	77.320506°E	Water sourced from borewell; used water is discharged into the Shahdara Drain.
5.	Railway Colony Dhobi Ghats	28.631743 °N	77.232108 °E	Water sourced from MCD; mixed use of liquid and powder detergents (Surf Excel, Ghadi); washing done both manually and by machine; wastewater discharged into Drain 12A, which directly flows into the Yamuna River.

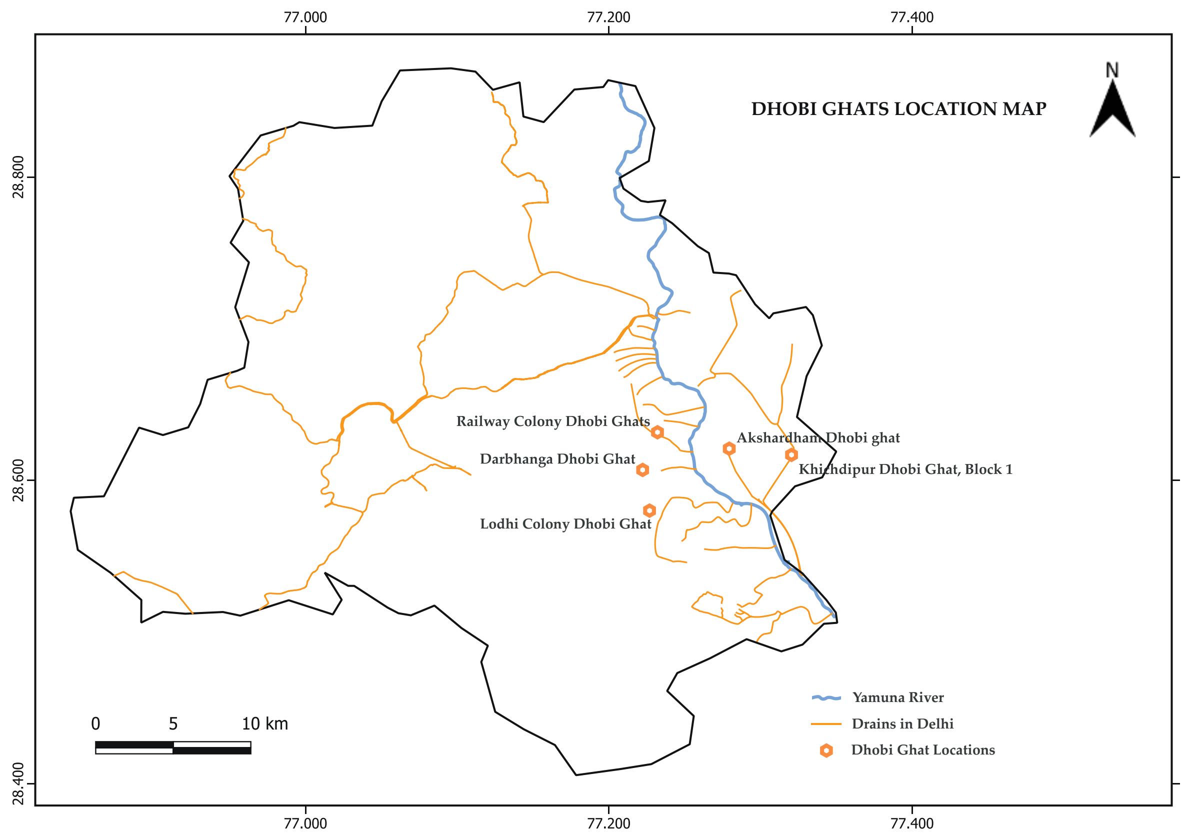


Figure 10: Dhobi Ghats Locations Marked on the Map of Delhi

Category A: Dhobi Ghats which were Visited but Samples not Collected for Analysis.

Category A includes Darbhanga Dhobi Ghat (Figure 11) and Lodhi Colony Dhobi Ghat (Figure 12). Samples were not taken from these Dhobi Ghats because the wastewater here has been discharged into the tapped drains, reducing the likelihood of direct environmental contamination. These tapped drains are directed to nearby STPs where the treatment might take place.

Figure 11: Darbhanga Dhobi Ghat, near Man Singh Road Area

Figure 12: **Lodhi Colony Dhobi Ghat**

Category B: Dhobi Ghats which were Visited, and Samples Collected for Analysis.

Category B includes Akshardham Dhobi Ghat (Figure 13), and Khichdipur Dhobi Ghat (Figure 14) and Railway Colony Dhobi ghat (Figure 15) where samples were taken from these Dhobi Ghats because the detergent-rich wastewater was directly falling into the open drains which ultimately make their way to River Yamuna. The effluent from Khichdipur Dhobi Ghat flows into the Shahdara Drain. The wastewater from Akshardham Dhobi Ghat is released into the Yamuna River via the Ganesh Nagar Drain, eventually flowing into the Hindon Cut Canal. Railway colony dhobi ghat was found connected to the Drain 12 A that meets Yamuna River after Chhath ghat.

Figure 13: **Akshardham Dhobi Ghat, Patparganj**

Figure 14: **Khichdipur Dhobi Ghat, Mayur Vihar Phase 1**

Figure 15: **Railway Colony Dhobi Ghat**

The analysis results of these Dhobi Ghats are presented in Table 4 in the following section, and Figure 16 provides a graphical representation of levels of major pollutants recorded from the samples collected at the out of Dhobi Ghats.

Table 4: Analysis of Various Wastewater Parameters of Samples Collected from Dhobi Ghat

S.No.	Sample Location/ Date of Sample Collection	pH	TSS	BOD	COD	NH_3	NO_3^{-2}	PO_4^{-3}	Anionic Surfactants	Oil & Grease
		-	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1	Akshardham Dhobi Ghat 7/6/2024	9.13	549	96	372	28	32	<1	0.31	16
2	Khichdipur Dhobi Ghat 24/6/2024	9.99	28	67	260	53	36	<1	0.61	ND
3	Railway Colony Dhobi Ghat	7.19	51	34	127.5	11.76	NA	NA	107.14	<5

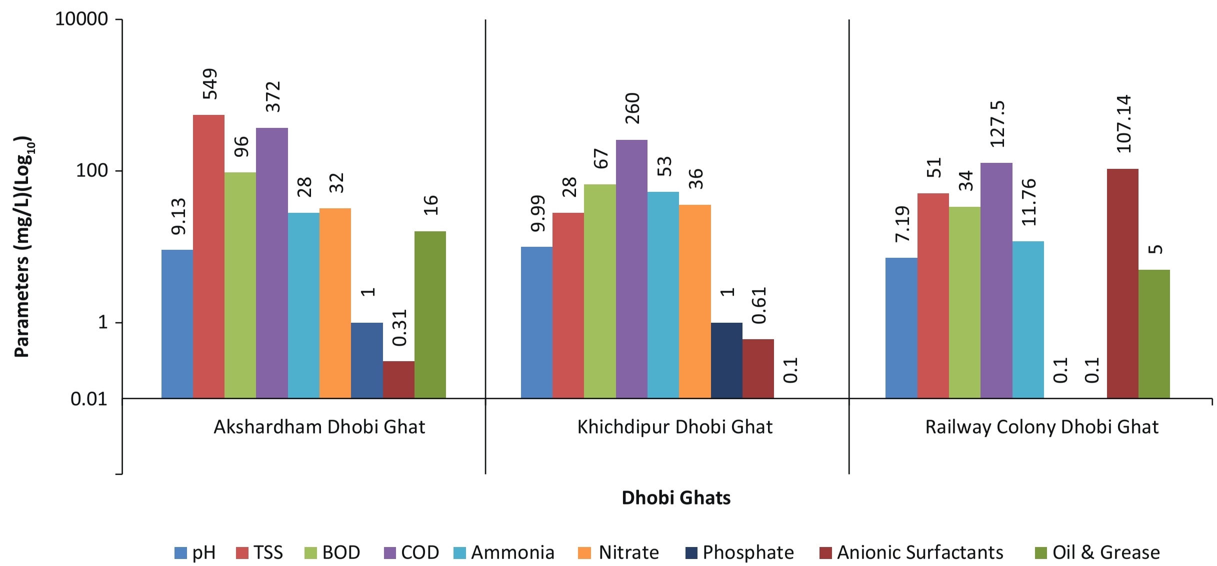


Figure 16: **Graphical Representation of Pollutant concentration in Samples taken from Dhobi Ghats**

Result & Analysis

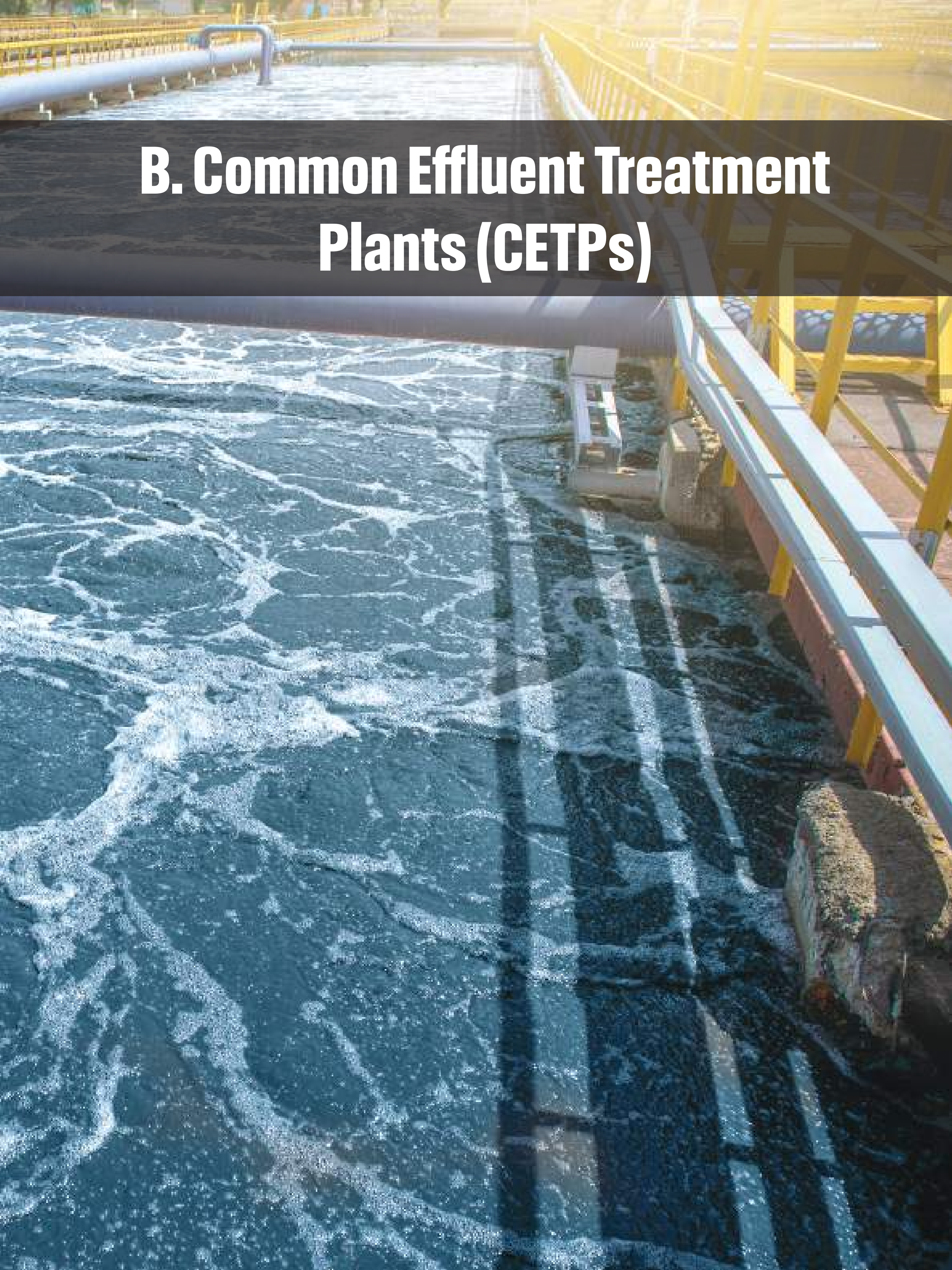
1. **Organic Load (BOD & COD): T**he wastewater from **Akshardham Dhobi Ghat** exhibited the **highest organic pollution**, with BOD and COD levels at **96 mg/L** and **372 mg/L**, respectively. While, K**hichdipur** and **Railway Colony** also showed organic contamination (BOD: 67 and 34 mg/L; COD: 260 and 127.5 mg/L), pointing to incomplete degradation of detergents and organic matter.
2. **Ammonia and Phosphate Presence:** Ammonia levels were especially elevated at Khichdipur (53 mg/L) and Akshardham (28 mg/L), indicating either domestic wastewater intrusion or detergent breakdown byproducts. Though Phosphate levels were below detection (<1 mg/L) at all location.
3. **Anionic Surfactant Concentration:** The anionic surfactant concentration was found to be 107 mg/L at railway colony dhobi ghat, which was significantly high. However, the synthetic surfactant concentration was found <1 mg/L at other two dhobi ghats.
4. **Saponin (Biosurfactant) Concentration:** Saponin, a natural foaming agent, was recorded at 150 mg/L in Akshardham and 60 mg/L in Khichdipur. Alarmingly, the Railway Colony Dhobi Ghat reported very high saponin levels (1000 mg/L)—over 6 times higher than Akshardham—strongly suggesting direct discharge of untreated sewage into Drain 12A, which flows into the Yamuna.

Need for Intervention: The data highlights the urgency of **monitoring informal discharge points**, such as Railway Colony's drain outlet, and **enforcing proper wastewater treatment** at all Dhobi Ghats.

It is proposed that the wastewater discharge from Dhobi Ghats, such as the Railway Colony Dhobi Ghat, be redirected to the nearest Sewage Treatment Plant (STP) instead of being released directly into drains and then drictly into Yamuna river. This intervention aims to ensure proper treatment of effluents containing high loads of surfactants, detergents, and other pollutants, thereby mitigating their impact in Yamuna River.

If not able to be connected to STPs then . installing onsite micro STPs (based on flow) will ensure proper treatment before discharge. TERI's TADOX® (Advanced Oxidation Technology) could serve as a decentralized micro STP (50–200 KLD capacity) for Dhobi Ghats.

B. Common Effluent Treatment Plants (CETPs)



B. Common Effluent Treatment Plants (CETPs)

Common Effluent Treatment Plants (CETPs) are established to treat industrial wastewater generated by clusters of Small and Medium Enterprises (SMEs). According to the report submitted to NMCG, 17 approved industrial areas are connected to 13 CETPs, collectively serving 26,404 SMEs[18]. The total quantity of effluent generated from the industries/units in 17 approved industrial areas (out of 28 approved industrial areas) is 25.89 MLD.

The TERI team conducted site visits to 6 out of the 13 CETPs, listed in Table 5 and represented in Figure 17.

Table 5: CETP visited during Sampling

S. No	Sampling Locations/Capacity	Latitude	Longitude	Date
1.	Lawrence road CETP/ 12 MLD	28.68659	77.15209	19/02/2025
2.	Bawana CETP / 35 MLD	28.80884	77.08068	19/02/2025
3.	Narela CETP/ 22.5 MLD	28.82252	77.10942	19/02/2025
4.	Okhla CETP/ 24 MLD	28.52318	77.28071	24/02/2025
5.	Mayapuri CETP/ 12 MLD	28.63537	77.12748	24/02/2025
6.	SMA CETP/ 12 MLD	28.72351	77.15948	24/02/2025

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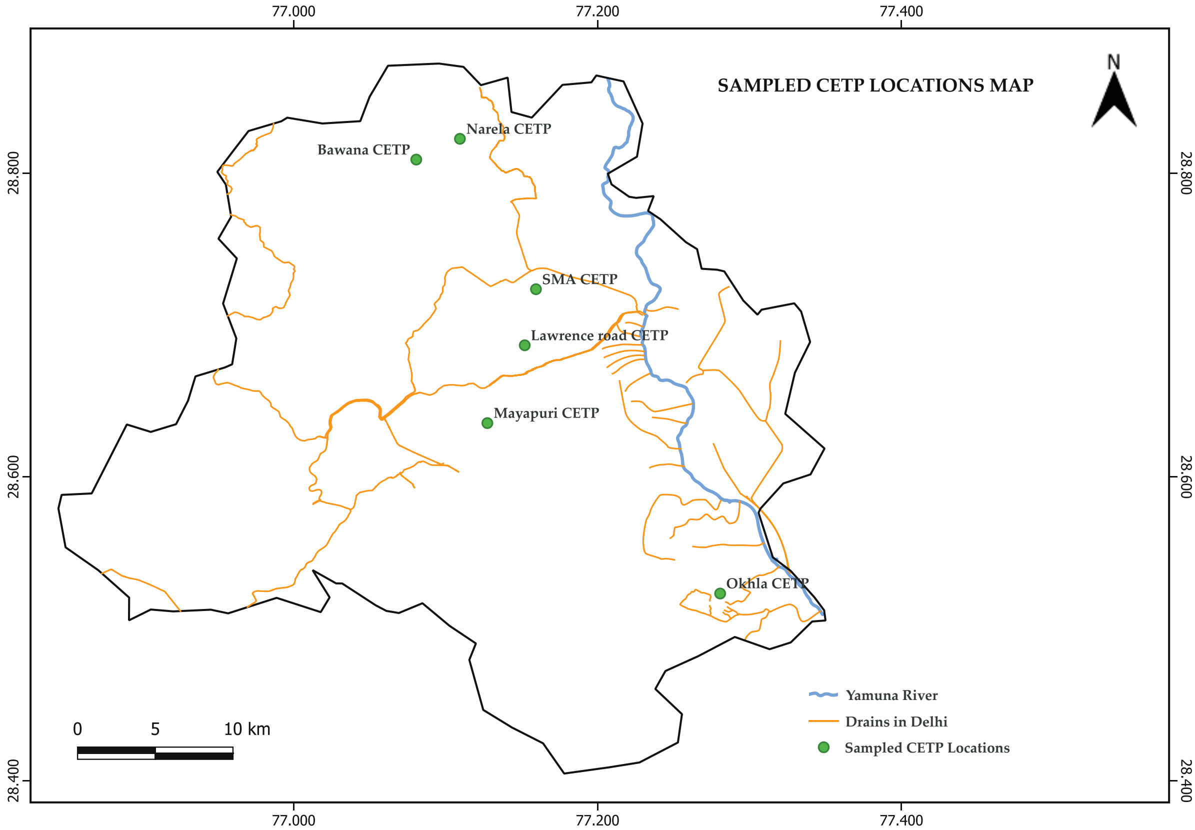


Figure 17: CETPs visited during Sampling

Based on the inlet and outlet water quality results, the pollutant removal performance of six CETPs is summarized and presented in terms of the percentage change, as shown in Table 6. The percentage removal of various pollutants, BOD, COD, Ammonia, Anionic and Cationic Surfactants, *F. coli*, Saponin, and STPP, at the six sampled CETP locations, namely Lawrence Road, Bawana, Narela, Okhla, Mayapuri, and SMA, is presented in Figure 18.

Table 6: Inlet & Outlet Water Quality Parameter with Percentage Pollutant Removal across 6 CETPs

S. No	CETP	COD			BOD			Ammonia			Anionic Surfactants			Cationic Surfactants			Fecal Coliform			STPP		
		mg/L			mg/L			mg/L			mg/L			mg/L			MPN/100mL			mg/L		
		Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%	Inlet $x10^5$	Outlet $x10^3$	%	Inlet	Outlet	%
1.	Lawrence Road	588.2	215.7	63.32	180	58	67.77	40	21.9	82.64	37.39	26.37	41.78	11.94	8.59	38.99	340	170	99.5	23.96	3.56	85.11
2.	Bawana	735.3	137.3	81.32	220	35	84.09	32.2	21.1	34.47	108.25	47.15	56.44	21.2	10.32	51.32	340	540	98.41	19.62	9.88	49.62
3.	Narela	833.3	58.8	92.94	260	14	94.61	26.2	8.2	68.70	81.19	64.03	21.13	12.3	9.32	31.97	340	17	99.95	21.30	10	53.05
4.	Okhla	1029.4	245.1	76.19	310	78	74.83	66.08	63.28	4.42	102.11	72.4	29.09	18.3	11.2	63.39	54	2.2	99.95	54.37	6.54	87.96
5.	Mayapuri	784.3	284.3	63.75	213	90	57.74	46.48	31.92	45.61	21.34	12.9	65.42	4.12	1.23	70	24	0.07	99.99	31.97	7.17	77.54
6.	SMA	1225.5	137.3	88.79	340	44	87.05	34.72	19.044	45.16	3.99	2.15	46.11	0.1	0.1	0	24	0.02	99.99	71.43	3.73	94.77

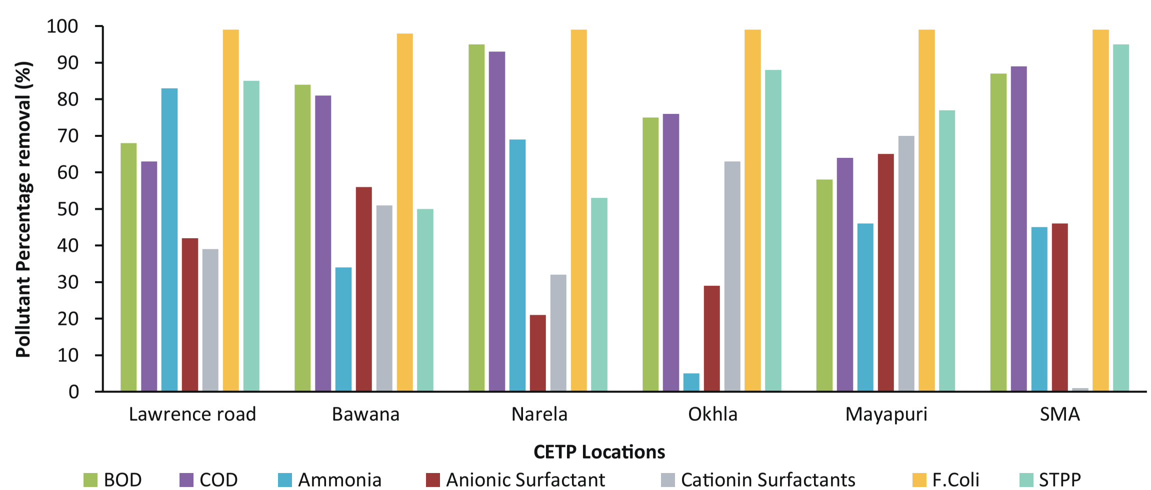


Figure 18: Removal Percentage (%) of Various Pollutants in 6 CETPs

Given these observations, each phase of the CETPs was examined individually to assess its operational performance. Wastewater samples were collected from both the inlet and outlet of each phase for detailed physio-chemical analysis. The results and interpretations of these analyses are provided in the subsequent section, offering insights into the performance of each CETP phase with respect to compliance with effluent discharge norms.

1. Lawrence Road CETP:

Inlet

Outlet

Observations:

i. Influent quality shows variability due to mixed industrial and domestic sources, though the CETP effectively manages the load as reflected in its overall satisfactory pollutant removal.

ii. Some infrastructure components appear aged, indicating the need for routine maintenance and minor upgradation to sustain consistent treatment performance.

iii. Localized foaming was observed at the outlet, likely due to residual surfactants, suggesting the benefit of incorporating a polishing step to further improve effluent quality.

iv. Overall treatment processes are functioning well, and targeted tertiary enhancements could further improve removal of persistent compounds such as surfactants.

Experimental Results

i. Lawrence Road CETP demonstrates reasonably good treatment performance, achieving BOD removal of 68%, COD removal of 63%, and Ammonia removal of 83%. Although the plant shows effective reduction of organic and nitrogenous pollutants, further optimization is required to enhance BOD and COD removal efficiencies to meet stricter discharge standards.

ii. The CETP shows baseline surfactant removal, achieving 42% reduction of anionic and 39% reduction of cationic surfactants. Ammonia removal stands at 34%, reflecting partial nitrification that would benefit from process optimization.

iii. The CETP achieves 100% removal of Fecal Coliform (F. coli), demonstrating a highly effective and well-functioning disinfection process as observed during the visit also.

iv. CETP demonstrates strong removal of STPP at 85%, indicating effective handling of phosphate-based detergent compounds, with only minor scope for further optimization through tertiary polishing processes.

Inference:

The CETP demonstrates generally effective treatment performance across key parameters; however, selective infrastructure strengthening and the addition of targeted tertiary treatment units would help address residual surfactants and further enhance effluent quality in response to evolving industrial discharge characteristics.

2. Bawana CETP:

Inlet

Outlet

Visit Observations:

i. Routine maintenance and periodic upgrades of treatment units appear to be in place, supporting stable operations and contributing to consistent treatment efficiency.

ii. Noticeable foaming was observed at the CETP outlet, indicating the presence of residual surfactants or other foam-forming compounds in the treated effluent.

Experimental Results:

i. The CETP demonstrates high removal efficiency for organic and microbial pollutants, achieving 84% BOD removal, 81% COD removal, and 98% reduction in Fecal Coliform, reflecting effective core biological treatment performance.

ii. However, nutrient and surfactant removal remains inadequate, with cationic surfactants removed at only 34%, indicating poor treatment of industrial surfactant inputs.

iii. Anionic surfactants show moderate removal at 56%, while STPP removal is low at 50%, suggesting insufficient control of phosphate-based detergent compounds.

iv. These results collectively indicate that the CETP primarily depends on biological processes and lacks advanced tertiary treatment mechanisms required for efficient removal of industrial surfactants and phosphorus-bearing compounds.

Inference:

The presence of visible foaming at the outlet, coupled with low experimental removal efficiencies for surfactants and STPP, clearly indicates a treatment gap. Integrating surfactant-targeted tertiary technologies such as activated carbon polishing, advanced oxidation processes (AOPs), or specialized membrane systems would significantly improve effluent quality and effectively address persistent foam-forming contaminants in the discharge.

3. Narela CETP:

Inlet

Outlet

Visit Observations:

i. At Narela CETP, all treatment units have been upgraded, and regular maintenance activities are being carried out, ensuring operational continuity and effective treatment functionality.

ii. The facility maintained good housekeeping practices, with clear demarcation of units.

Experimental Results

i. The CETP exhibits excellent removal of organic and microbial pollutants, achieving 95% BOD removal, 93% COD removal, and 99% Fecal Coliform reduction, indicating robust biological treatment performance.

ii. Ammonia removal at 69% reflects satisfactory nitrification efficiency under existing operational conditions.

iii. Surfactant removal, however, remains insufficient, with cationic surfactants reduced by only 32% and anionic surfactants by 21%, highlighting limitations in removing foam-forming industrial contaminants.

iv. STPP removal is modest at 53%, suggesting limited tertiary treatment capability and the need for additional polishing processes to target phosphate-based and detergent-derived compounds.

Inference:

While the CETP performs strongly in removing organic matter and pathogens, the low removal of surfactants and STPP indicates a gap in advanced treatment capability. Integration of targeted tertiary units such as activated carbon adsorption, advanced oxidation processes, or membrane-based polishing would enhance the removal of persistent surfactant fractions and reduce the risk of downstream foaming in the river.

4. Okhla CETP:

Inlet

Outlet

Visit Observations

i. Influent parameters were far exceeding the designed parameters, pointing to the need for rehabilitation or upgradation
ii. Treatment units like bleaching tanks and activated carbon filters were under maintenance
iii. The sludge storage house had been destroyed, rendering it non-operational and compromising proper sludge management at the site.
iv. Signs of aging infrastructure were evident across the facility, pointing to the need for rehabilitation or upgradation efforts
v. Very high foaming was observed at the outlet of the facility.

Experimental Results

i. Organic load reduction was moderate, with 75% BOD removal and 76% COD removal, reflecting partially effective biological treatment.
ii. Ammonia removal was critically low at 5%, indicating inadequate nitrification.
iii. Surfactant removal was poor, with cationic surfactants removed at only 16% and anionic surfactants at 29%, highlighting insufficient treatment of detergent-derived pollutants.

iv. In contrast, microbial removal was excellent, with F. Coli reduced by 99%, indicating effective disinfection.
v. STPP removal efficiency was relatively high at 88%, suggesting partial chemical treatment effectiveness in managing phosphate-based compounds.

Inference:

Although the CETP demonstrates satisfactory removal of pathogens and phosphates, its performance in treating ammonia and surfactants is significantly inadequate. The combination of low nutrient and surfactant removal, high influent loading, and visibly deteriorated infrastructure indicates that the existing treatment processes are insufficient for current effluent characteristics. Upgradation of treatment units and integration of targeted tertiary processes such as nitrification enhancement and surfactant-specific polishing are essential to improve overall treatment efficiency and address persistent foaming at the outlet.

5. Mayapuri CETP:

Inlet

Outlet

Visit Observations:

i. The CETP, operational since 2002, has not been upgraded, resulting in aged and partially non-functional infrastructure. Meanwhile, the number and nature of contributing industries have significantly changed, potentially affecting treatment efficiency.
ii. Although CETPs are designed to treat industrial effluents, it was observed that the influent is significantly impacted by discharges from unauthorized colonies, such as JJ clusters, and Banquet halls compromising the plant's treatment efficiency.
iii. Filtration units (DMF and ACF) were not maintained due to high-tension wires overhead, hindering safe access and routine upkeep.
iv. Foaming observed at outlet of the CETP

Experimental Results

i. The CETP exhibited excellent F. coli removal reducing it by 100%, indicating effective disinfection.

ii. Organic load reduction was moderate, with 58% BOD and 64% COD removal, reflecting partial effectiveness of biological processes.

iii. Nutrient removal was limited, with ammonia removal at only 46%, indicating incomplete nitrification.

iv. Surfactant removal showed mixed performance: anionic surfactants removed at 65% (moderate), while cationic surfactants showed higher removal at 70%, indicating relatively effective chemical and adsorption processes.

v. STPP removal at 77% suggests partial effectiveness in handling phosphate-based detergent compounds, though scope for improvement remains.

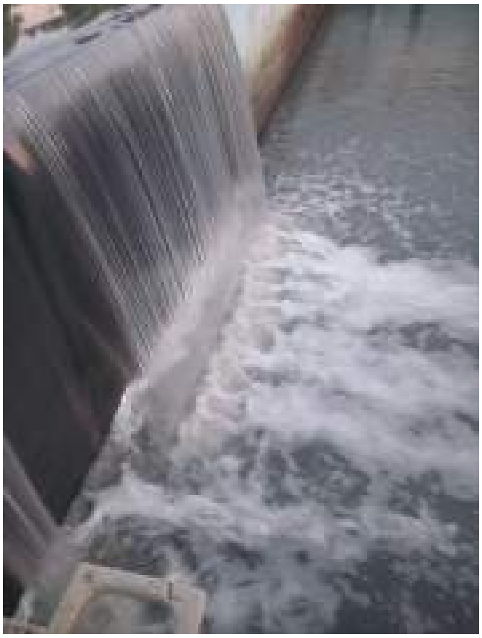
vi. Overall, the results show inconsistent treatment performance across parameters.

Inference:

While the CETP demonstrates strong F.Coliremoval and relatively better performance for cationic surfactants and STPP, overall treatment efficiency remains inconsistent. Moderate BOD and COD reduction, limited ammonia removal, and variability in surfactant treatment indicate the need for infrastructure strengthening, improved operational control, and integration of targeted tertiary processes to enhance overall treatment reliability.

6. SMA CETP:

Inlet



Outlet

Visit Observations:

i. Foaming was observed at both the inlet and outlet of the CETP, indicating potential issues with the treatment process or improper handling of surfactants and organic load.

ii. The aerators in one of the equalization tanks was found to be non-functional, which could adversely affect the mixing and aeration required for optimal treatment.
iii. High foaming was observed at outlet, liquid defoamers were used at outlet to mitigate the problem.

Experimental Results

i. The CETP exhibited excellent microbial removal, with F. coli reduced by 99%, indicating effective disinfection.
ii. Organic load reduction was high, with 87% BOD and 89% COD removal, demonstrating strong biological treatment performance.
iii. Nutrient removal was moderate, with ammonia removal at 45%, indicating incomplete nitrification and the need for enhanced aeration or advanced nutrient removal steps.
iv. Surfactant removal was inadequate: anionic surfactants showed only 46% removal (low), while cationic surfactants exhibited 0% removal, highlighting the absence of effective chemical or adsorption-based surfactant treatment processes.
v. STPP removal at 95% indicates strong phosphate removal capability, reflecting efficient handling of detergent-derived phosphorus loads.

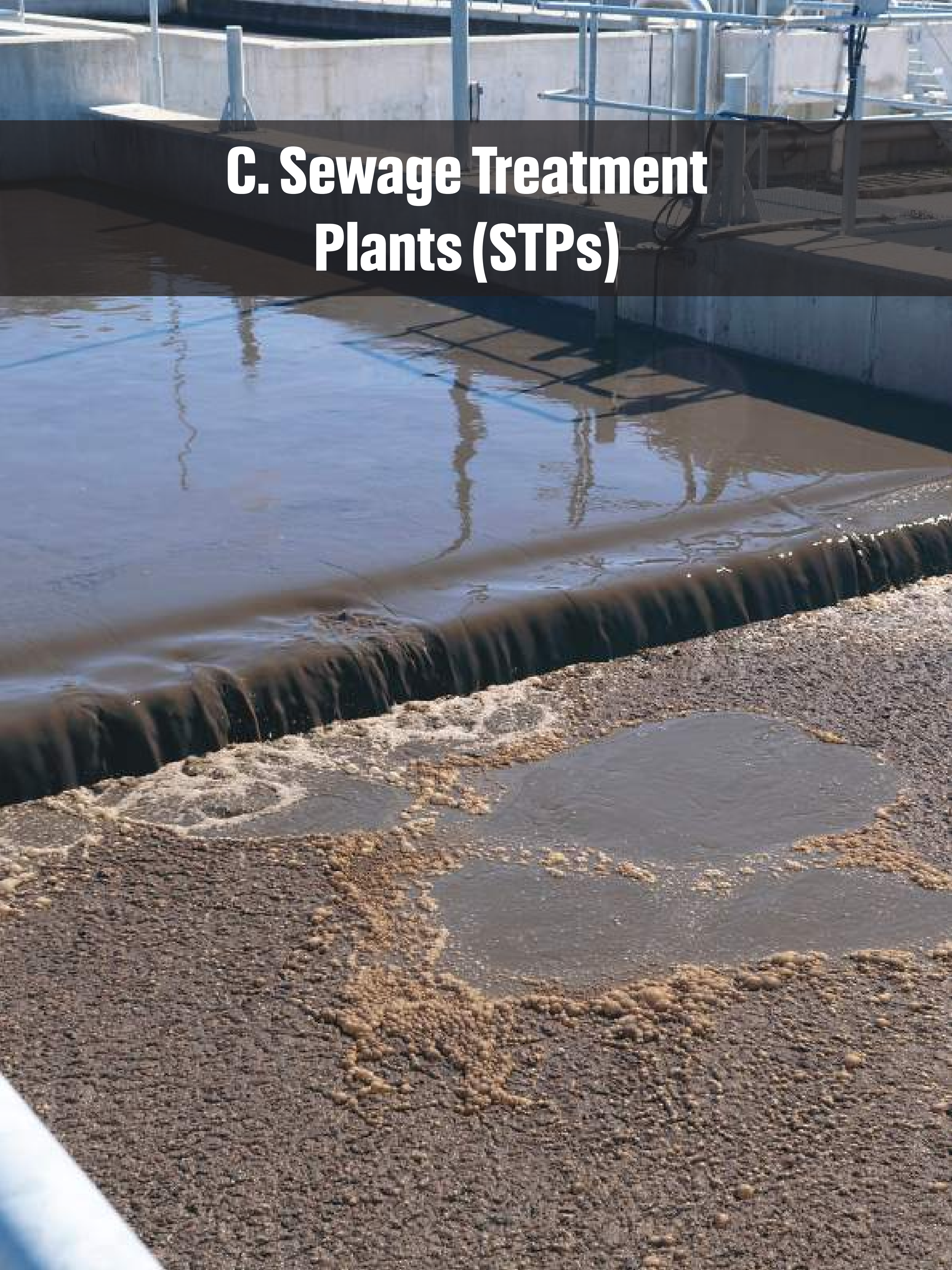
Inference:

The SMA CETP exhibited moderate treatment performance for conventional pollution parameters but performed poorly in surfactant removal. Persistent foaming at the outlet, coupled with operational issues such as uneven aeration and sludge accumulation, highlights the need for enhanced tertiary treatment and improved process control.

Key Takeaways from 6 CETPs:

i. Aging infrastructure and inadequate maintenance limit treatment performance, indicating a need for systematic upgradation.
ii. Influent loads frequently exceed design capacity, especially due to mixed and unauthorized discharges, reducing process efficiency.
iii. Foaming is a recurring issue, driven by high surfactant loads and insufficient tertiary polishing.
iv. Organic load removal is generally satisfactory, but nutrient removal—particularly ammonia is consistently poor.
v. Surfactant removal remains weak, reflecting the absence of advanced or specialized treatment units.
vi. Microbial removal is consistently strong, demonstrating effective disinfection despite upstream limitations.
vii. Sludge management practices are inadequate, indicating operational and infrastructural gaps.
viii. Advanced treatment integration is essential to manage evolving industrial effluent characteristics and improve overall system performance.

C. Sewage Treatment Plants (STPs)



C. STPs in Delhi region

The rapid pace of urbanization and population growth in the National Capital Territory (NCT) of Delhi has placed significant stress on the region's limited water resources. According to the Monthly Progress Report of June 2025 from the Government of Delhi submitted by the DPCC to the NMCG, Delhi currently generates approximately 800 million gallon of wastewater per day[19]. Of this, approximately 650 MGD is treated in 37 operational Sewage Treatment Plants (STPs), which together have a total installed treatment capacity of 764 MGD. However, despite this substantial infrastructure, a shortfall remains, with nearly 28 MGD of untreated or partially treated wastewater continuing to enter the Yamuna River through various stormwater and open drains. This untreated discharge contributes significantly to the river's pollution load and poses serious environmental and public health challenges.

In order to evaluate the performance and efficiency of the existing STPs in Delhi, 12 critical STP location (presented in Table 7 and Figure 19) were identified for detailed on-ground assessment. These plants were selected based on factors such as capacity, geographical coverage, inflow characteristics, and their impact on major drainage outfalls leading to Yamuna.

Table 7: List of STPs Visited during the Project Tenure

S. No	Sampling Locations/ Capacity	Latitude	Longitude	Date
1.	Najafgarh STP Outlet/ 5 MGD	28°605766"N	77°009416"E	5/6/2024
2.	Dwarka STP Outlet/ 10 MGD	28°587447"N	77°022526"E	5/6/2024
3.	Okhla STP Outlet/ 16 MGD	28°545453"N	77°287545"E	24/6/2025
4.	Kondli STP Outlet/ 10 MGD	28°60663"N	77°321837"E	24/6/2024
5.	Yamuna Vihar Phase 1 Outlet / 10 MGD	28.69896N	77.28902E	30/01/2025
6.	Yamuna Vihar Phase 2 Outlet / 10 MGD	28.69896N	77.28902E	30/01/2025
7.	Yamuna Vihar Phase 3 Outlet / 25 MGD	28.69896N	77.28902E	30/01/2025
8.	(Yamuna Vihar STP Common Outlet) directly out falling across D/S Wazirabad Barrage into Yamuna	28.708382N	77.235998E	30/01/2025
9.	Keshopur Outlet / 20 MGD	28.6527N	77.08579E	30/01/2025
10.	Chilla Outlet / 9 MGD	28.58946N	77.29997E	08/02/2025
11.	Delhi Gate Outlet / 2.2 MGD	28.63661N	77.25253E	08/02/2025
12.	Sen Nursing Home Outlet / 2.2 MGD	28.62121N	77.24962E	08/02/2025

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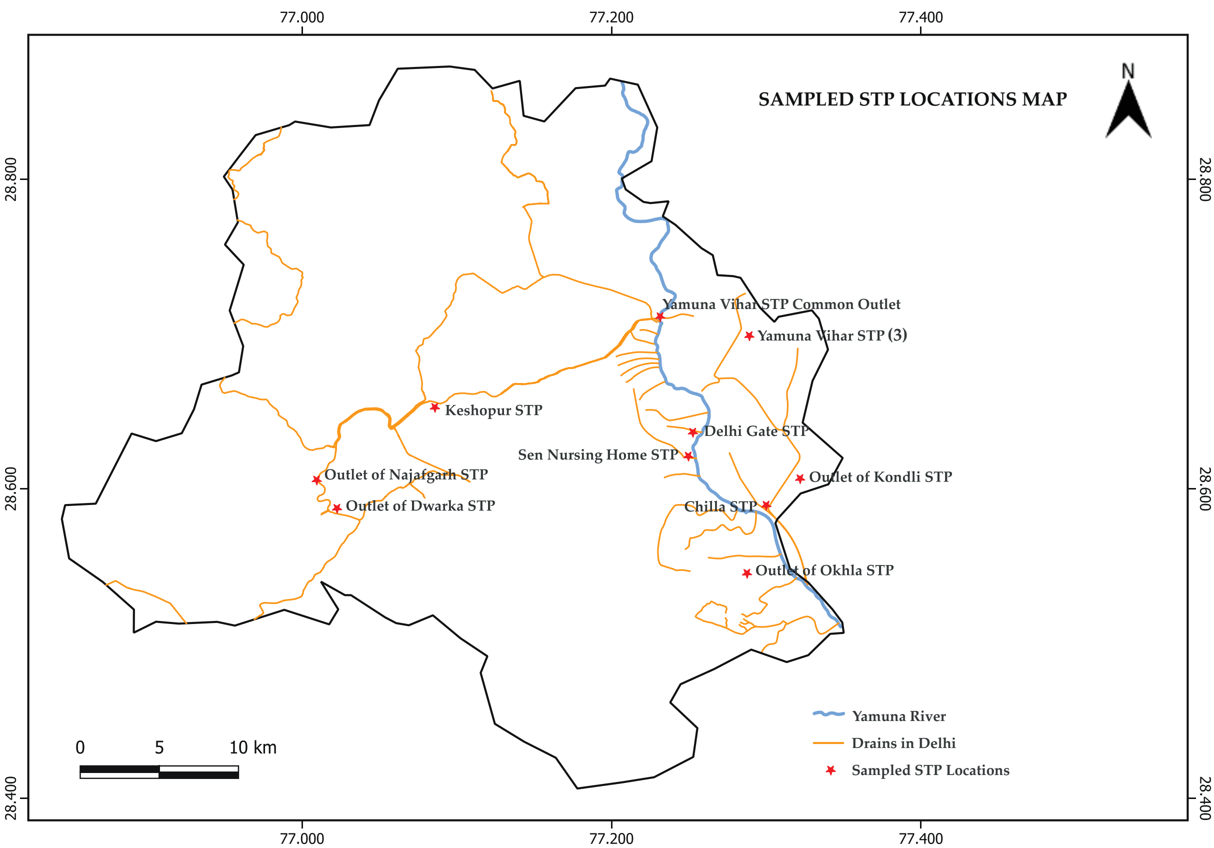


Figure 19: **STPs Visited during Sampling marked on Delhi Map**

STPs Visited during Pre-Monsoon Sampling:

Table 8: Location Details of STPs visited in Pre-Monsoon Sampling

S. No	Sampling Locations	Latitude	Longitude	Date
1.	Outlet of Najafgarh STP	28°605766"N	77°009416"E	5/6/2024
2.	Outlet of Dwarka STP	28°587447"N	77°022526"E	5/6/2024
3.	Outlet of Okhla STP	28°545453"N	77°287545"E	24/6/2025
4.	Outlet of Kondli STP	28°60663"N	77°321837"E	24/6/2024

Four major STPs have been selected i.e., Kondli STP, Okhla 30MGD STP, Dwarka STP Phase 2, and Najafgarh STP, and the treated water has been collected from their respective outlet. Samples were analyzed for standard parameters as well as for the parameters of concern. The sampling locations are marked on the map as shown in Figure 19. The details and pictures of sampling locations are given in Figure 20.

(a) Okhla 30 MGD STP

(b) Kondli STP

(c) Najafgarh STP

(d) Dwarka STP Phase 2

Figure 20: Sampling at STPs in Pre-Monsoon

Table 9: Chemical Analysis Results of Treated Water Collected from STP Outlet

S.No	Sample Location	pH	TSS	BOD	COD	Fecal Coliform	NH_3	NO_3^{-2}	PO_4^{-3}	Anionic Surfactants	Hardness	Alkalinity
	Units	unit	mg/L	mg/L	mg/L	MPN/ 100 mL	mg/L	mg/L	mg/L	mg/L	mg/L as $CaCO_3$	mg/L as $CaCO_3$
1	Kondli STP	7.2	12	5.3	22	1700	<0.5	12.4	<1.0	<0.1	277.68	207
2	Okhla 30MGD STP	7.54	<5	<1	<4	2200	6.3	16.2	12.84	<0.1	331.08	362.25
3	Dwarka STP Phase 2	7.64	14	<1	<4	49	12.2	13.5	5.63	<0.1	437.88	238.05
4	Najafgarh STP	7.79	13	<1	<4	110	<0.5	53	12.42	<0.1	544.68	248.4

Most of the parameters lie under the prescribed permissible limit. Analysis results are given in Table 9. All locations have pH within neutral to slightly alkaline ranges, which is generally favorable for aquatic ecosystems. The other three STPs especially Okhla and Dwarka, have adequate DO levels, supporting aquatic life, while Kondli's DO is low. BOD and COD values are under permissible limits. Nitrate concentrations are found to be significant, with Najafgarh STP-treated water showing the highest (53.0 mg/L) concentration.

STPs Visited during Post-Monsoon Sampling:

Table 10: The Physicochemical Parameter of STPs for which sampling was done during post -monsoon season

S. No	Sample Location	pH		BOD			COD			TSS			[Fecal Coliform]		
		mg/L		mg/L			mg/L			mg/L			MPN/100 mL		
		Inlet	Outlet	Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%	Inlet (x 10^5)	Outlet	%
1.	Yamuna Vihar Phase 1 STP	6.77	7.09	90	21	76.66	242.7	77.7	67.98	200	28	86	240	22	99.99
2.	Yamuna Vihar Phase 2 STP	6.51	6.78	140	117	16.42	504.8	339.8	32.68	324	13	95.98	34	17	99.99
3.	Yamuna Vihar Phase 3 STP	6.68	6.84	83	39	53.02	262.1	165	37.04	153	49	67.97	34	5400	99.84
4.	Keshopur STP	6.53	6.9	144	2	98.61	475.4	19	96.00	214	9	95.79	34	3400	99.9
5.	Chilla STP	7.14	7.28	480	14	97.08	1618.4	57.1	96.47	332	8	97.59	54	490	99.99
6.	Delhi Gate STP	7.13	7.25	370	10	97.29	1380.4	38.1	97.23	404	5	98.76	54	50	99.99
7.	Sen Nursing Home STP	7.06	7.34	270	3	98.88	904.4	19	97.89	516	5	99.03	34	490	99.98

Table 11: The Physicochemical Parameter of STPs for which sampling was done during post -monsoon season (Continued)

S. No	Sample Location	Ammonia			Nitrate			Phosphate			Anionic Surfactants		
		mg/L			mg/L			mg/L			mg/L		
		Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%	Inlet	Outlet	%
1.	Yamuna Vihar Phase 1 STP	47.4	33	30.37	5.98	0.5	91.63	19.40	10.10	47.91	1.45	0.1	93.10
2.	Yamuna Vihar Phase 2 STP	43.8	25.7	41.32	5.18	0.8	84.55	22.02	9.38	57.40	14.37	0.1	99.30
3.	Yamuna Vihar Phase 3 ST	47.8	36.4	23.84	15.14	13.95	78.59	29.90	16.54	44.66	11.44	4.02	64.86
4.	Keshopur STP	4.6	0.5	89.13	44.23	2.39	94.79	18.53	9.23	50.16	19.81	0.17	99.14
5.	Chilla STP	44.7	0.5	98.88	27.9	18.33	34.30	22.78	11.16	50.98	45.76	0.1	99.78
6.	Delhi Gate STP	50.8	0.5	99.01	8.77	4.78	45.49	26.31	1	96.19	68.63	0.1	99.85
7.	Sen Nursing Home STP	36.1	1.6	95.56	11.96	7.17	40.05	34.72	1.89	94.55	27.62	0.1	99.63

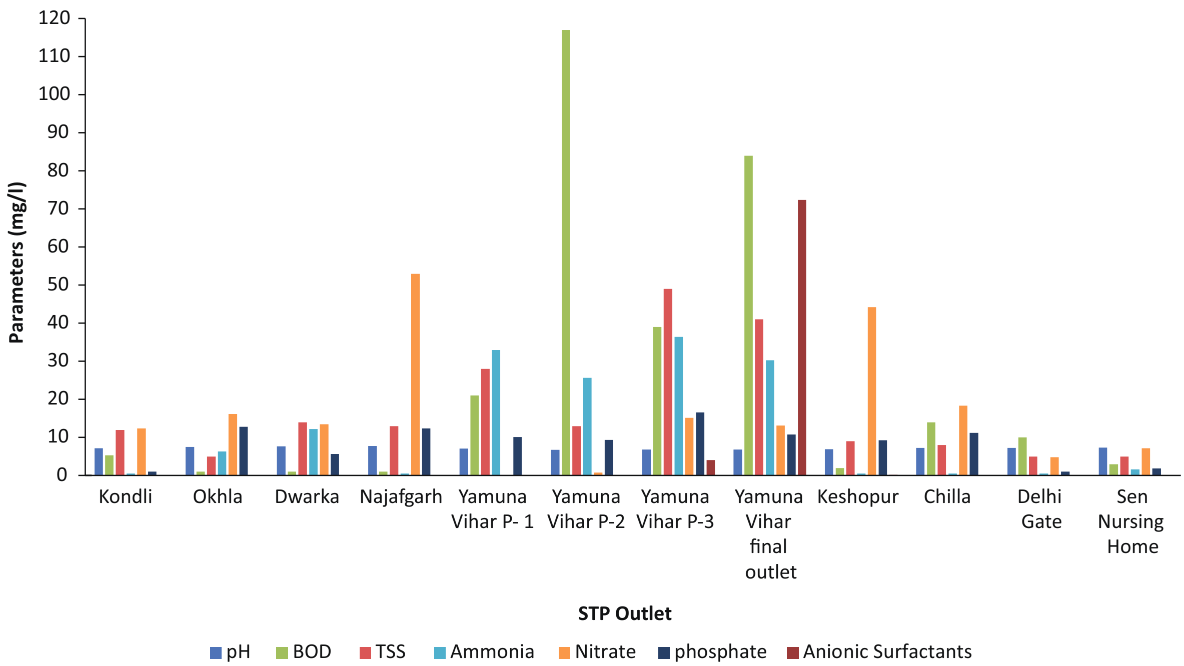


Figure 21: Concentration of Pollutant Parameters at the Outlet of STPs visited during the Project

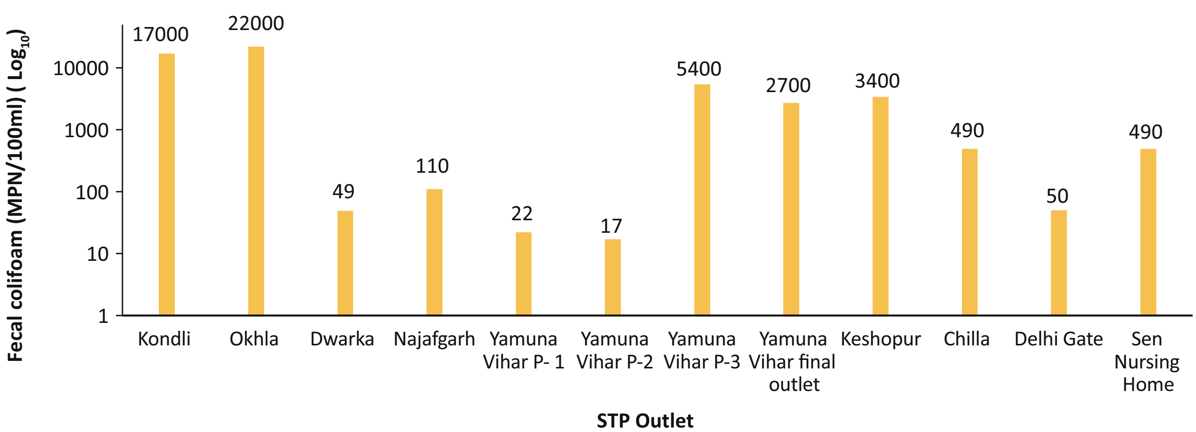


Figure 22: Fecal Coliform Concentration at the Outlet of Visited STPs

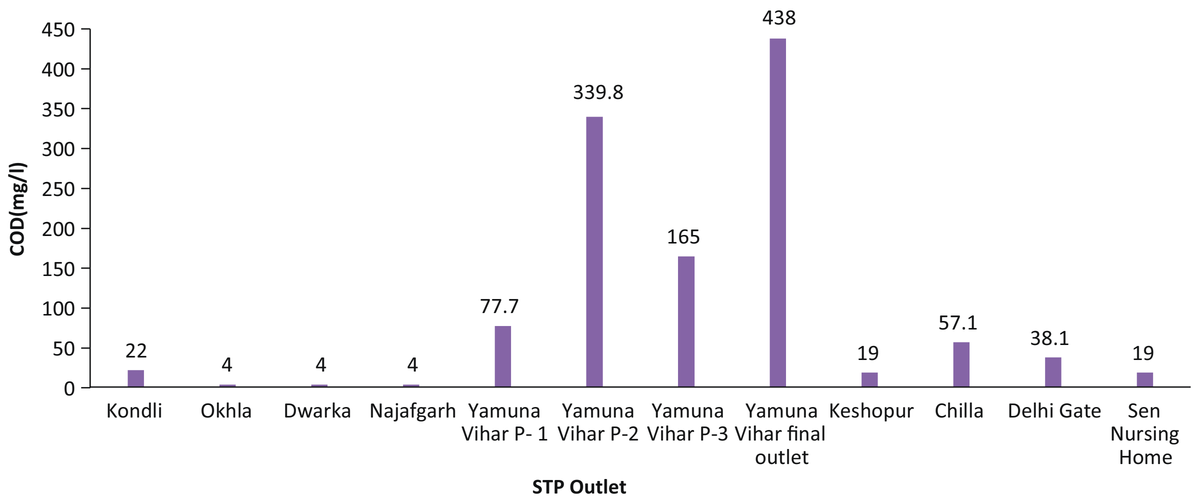


Figure 23: COD Concentration at the Outlet of Visited STPs

For each STP visited during post-monsoon study, key operational observations have been documented, and the analytical results of key outlet parameters along with froth causing parameters have been discussed in detail in the subsequent section. These findings are intended to provide insights into the current status of wastewater treatment in Delhi and to highlight areas requiring improvement for enhancing overall treatment efficiency and safeguarding river water quality.

1) Yamuna Vihar STP

The Yamuna Vihar STP has been developed in three phases, with Phase I having a capacity of 10 MGD, Phase II 10 MGD, and Phase III 25 MGD. The treated effluent from this STP is discharged into the downstream stretch of the Yamuna River. During the field visit, it was observed that the outlet was releasing foaming water into the river, indicating possible issues with treatment efficiency or the presence of surfactants, as shown in Figure 24.

Figure 24: Treated Effluent from Yamuna Vihar STP being discharged in Yamuna

Given these observations, each phase of the STP was examined individually to assess its operational performance. Wastewater samples were collected from both the inlet and outlet of each phase for detailed physio-chemical analysis. The results and interpretations of these analyses are provided in the subsequent section, offering insights into the performance of each phase with respect to compliance with effluent discharge norms.

1. Yamuna Vihar STP Phase-I

The inlet and outlet sample analysis of the STP is provided in Figure 25. The inlet BOD/COD ratio is 0.37, indicating that the sewage is primarily of domestic origin and does not show any significant intrusion of inorganic load from nearby industries. However, frothing was observed at the outlet indicating inefficient phosphate and surfactant removal.

Inlet **Outlet**

Figure 25: Inlet and outlet of Yamuna Vihar STP Phase-I

Visit Observation:

i. Foaming and odour issues were observed near the aeration tanks, indicating potential process inefficiencies or operational imbalances.

ii. Mechanical screens were found to be operational; however, a noticeable buildup of solids was observed, suggesting a need for improved maintenance.

iii. Minor scum accumulation was noted in the clarifiers, which may require periodic removal to maintain efficiency.

iv. Signs of aging infrastructure were evident across the facility, pointing to the need for rehabilitation or upgradation efforts.

Experimental results:

i. The analysis of inlet and outlet samples (refer Table 10–11) indicates a 77% removal efficiency for BOD and 68% for COD, suggesting suboptimal performance of system design and biological treatment process.

ii. The observed 30% removal of ammonia and 92% removal of nitrate indicate that the treatment process requires improved aeration to achieve complete nitrification

iii. The poor removal efficiency of biosurfactants highlights the need for the integration of advanced treatment modules. However, the 93% removal of anionic surfactants reflects effective conventional treatment performance.

Inference:

i. The aeration system and mixing zones must be redesigned to improve oxygen transfer efficiency and ensure uniform microbial activity for effective BOD and COD removal.

ii. An advanced treatment processes must be integrated for inadequate removal of surfactants and saponins.

2. Yamuna Vihar Phase 2 STP:

The inlet and outlet sample analysis of the STP is provided in Figure 26. The inlet BOD/COD ratio is 0.27 having COD 504.8 mg/L at the inlet, indicating significant intrusion of inorganic load from nearby industries.

Visit Observation:

i. Grease and oil trap mechanisms found inadequate, possibly contributing to surfactant-rich wastewater entering biological treatment stages

ii. The settling tank showed signs of poor sludge removal and surface scum accumulation

iii. Poor retention time and improper desludging frequency noted.

iv. Frothing was observed at the outlet indicating inefficient phosphate and surfactant removal

v. Signs of aging infrastructure were evident across the facility, pointing to the need for rehabilitation or upgrading efforts.

Inlet

Outlet

Figure 26: Inlet and outlet of Yamuna Vihar STP Phase-II

Experimental Results:

i. The analysis of inlet and outlet samples indicates a 16% removal efficiency for BOD and 33% for COD, suggesting low treatment efficacy or possible operational breakdowns in treatment process.

ii. Ammonia removal remains low at 41%, while nitrate removal is 85%, indicating that nitrification is occurring but remains incomplete due to inadequate aeration or limited microbial activity.

iii. The removal efficiencies of anionic (99%) and cationic (62%) surfactants demonstrate fair treatment performance; however, saponin removal remains limited (50%), highlighting the need for advanced treatment modules or process optimization to address persistent organic foaming agents.

iv. The comparable removal efficiencies of phosphate and STPP (both 57%) suggest that the system relies primarily on biological processes without chemical precipitation support. However, the complete (100%) removal of fecal coliforms indicates an effective disinfection stage.

Inference:

The STP exhibited operational inefficiencies, including poor grease/oil trapping, inadequate sludge removal, and limited surfactant and saponin removal. While BOD and COD levels showed moderate improvement, high ammonia and suboptimal nutrient removal highlight the need for the installation of advanced treatment modules.

3. Yamuna Vihar Phase 3 STP

The inlet and outlet sample analysis of the STP is provided in Figure 27.

Inlet **Outlet**

Figure 27: Inlet and outlet of Yamuna Vihar STP Phase-III

Visit Observation:

i. Screening and grit removal units were partially operational and poorly maintained, allowing fine particles and frothing agents to pass through.
ii. Minor scum accumulation was noted in the clarifiers, which may require periodic removal to maintain efficiency.
iii. Disinfection using chlorination was inconsistent, possibly allowing microbial contaminants and active surfactants to persist.
iv. Frothing was observed at the outlet indicating inefficient phosphate and surfactant removal
v. Logbooks and maintenance records were either missing or incomplete

Experimental Results:

i. Evaluation of inlet and outlet samples (refer Table 8) reveals 53% BOD and 37% COD removal, ndicating limited treatment efficiency that may result from low Mixed Liquor Volatile Suspended Solids (MLVSS) within the aeration tank.
ii. Ammonia and nitrate removals of 24% and 9%, respectively, suggest that aeration is inadequate and the nitrification process remains incomplete.
iii. Although Anionic surfactant removal efficiency is appreciable (65%), the poor reduction of saponins (16%) points to challenges in degrading complex organic compounds and biosurfactants.
iv. Anionic surfactant removal (65%) is comparatively low, implying the need for improved operational control or the inclusion of polishing stages to enhance surfactant elimination.

Inference:

The STP shows limited treatment efficiency, with moderate organic matter removal and poor nutrient and surfactant reduction. Incomplete nitrification and low saponin removal indicate inadequate aeration and weak degradation of complex organics. Overall, process optimization and inclusion of advanced treatment modules are required to improve performance

4. Keshopur STP

The inlet and outlet sample analysis of the STP is provided in Figure 28. The inlet BOD/COD ratio is> 0.3, indicating that the sewage is primarily of domestic origin and does not show any significant intrusion of inorganic load from nearby industries.

Inlet

Outlet

Figure 28: Inlet and Outlet of Keshopur STP

Visit Observation:

i. The plant was under rehabilitation for capacity enhancement
ii. Screens were found to be non-operational, allowing noticeable buildup of solids, suggesting a need for improved maintenance.
iii. Few aeration tanks were non-functional, indicating potential process inefficiencies or operational imbalances.
iv. Signs of aging infrastructure were evident across the facility

Experimental results:

i. The analysis of inlet and outlet samples (refer Table 8) shows extremely high BOD (99%) and COD (96%) removal indicating proper treatment efficiency
ii. Surfactant removal is also notably efficient, with anionic removal rates of 99% and 93%, respectively, indicating good performance of the secondary treatment process for these compounds.
iii. Saponin removal (33%) and phosphate/STPP removal (50%) remain modest, reflecting limited capacity for complex organic and nutrient removal.
iv. Fecal coliform elimination (100%) indicates effective disinfection performance

Inference:

The STP, under rehabilitation, faces significant inefficiencies. The treatment plant demonstrates excellent efficiency in organic load and microbial removal but shows limited effectiveness in removing complex organics and nutrients such as saponins and phosphates.

5. Chilla STP

Inlet **Outlet**

Figure 29: The Inlet and Outlet Sample Analysis of the STP

Visit Observation:

i. Foaming and odor issues were observed near the aeration tanks, indicating potential process inefficiencies or operational imbalances.
ii. Mechanical screens were found to be operational; however, a noticeable buildup of solids was observed, suggesting a need for improved maintenance.
iii. The settling tank showed signs of poor sludge removal and surface scum accumulation

Experimental Results:

i. The high removal efficiency of BOD (97%) and COD (96%) indicates effective degradation of organic matter through the treatment process.
ii. Ammonia removal is highly efficient (99%), while nitrate removal remains moderate (34%), suggesting limited denitrification.
iii. The treatment shows excellent performance in removing surfactants, with complete elimination of both anionic and cationic types.
iv. Nutrient removal is partial, with phosphate and STPP removal at 51%, indicating a need for chemical or advanced treatment to enhance nutrient reduction.
v. Fecal coliform removal is satisfactory, reflecting adequate disinfection efficiency.

Inference:

The treatment system exhibits excellent organic load, ammonia, and surfactant removal, along with effective disinfection, though nutrient and nitrate removal remain limited, indicating scope for process optimization.

6. Delhi Gate STP

The inlet and outlet sample analysis of the STP is provided in Figure 30.

Inlet

Outlet

Figure 30: Inlet and Outlet of Delhi gate STP

Visit Observation:

i. Mechanized bar screens (coarse & fine) and automated grit chambers to ensure effective removal of debris and grit were installed.
ii. Presence of sludge digesters, drying beds, or mechanical dewatering systems (e.g., centrifuge, belt press).
iii. Minor scum accumulation was noted in the clarifiers, which may require periodic removal to maintain efficiency.
iv. Log books and maintenance records were either missing or incomplete

Experimental Results:

i. High BOD and COD removal efficiency (97% each) suggest good in organic removal.
ii. Ammonia (99 %) is effective whereas nitrate (45 %) levels again confirm ineffective nitrate removal.
iii. Surfactants are removed efficiently (Anionic and Cationic: 100%), but saponin removal is 0%, indicating resistance of these compounds to current treatment.
iv. Highest phosphate and STPP removal among the STPs (96% and 71%) suggest the possible inclusion of chemical treatment steps.
v. Pathogen removal was found 100%.

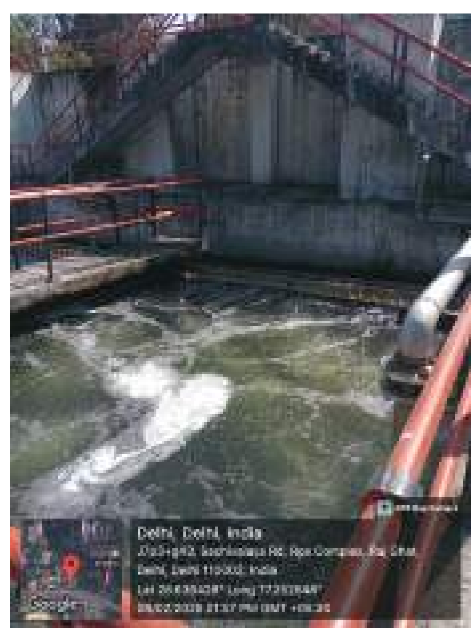
Inference:

The infrastructure and an effective treatment process, reflecting good operational management and consistent performance across key treatment parameters.

7. Sen Nursing Home STP

The inlet and outlet sample analysis of the STP is provided in Figure 31.

Inlet



Outlet

Figure 31: Inlet and outlet of Sen-nursing home STP

Visit Observation:

i. Diffused aeration systems with fine bubble diffusers evenly spaced for uniform oxygen supply in aeration tanks.

ii. Minor scum accumulation was noted in the clarifiers, which may require periodic removal to maintain efficiency

iii. Logbooks and maintenance records were either missing or incomplete

Experimental Results:

i. BOD and COD removal is very good (99% treated), indicating sufficient treatment.

ii. High ammonia removal (96 %) with low nitrate removal (40 %).

iii. Surfactant removal is efficient (Anionic and Cationic: 100%, 99%), but saponin removal (67%) is moderate.

iv. Phosphate (95%) are among the best recorded, indicating more advanced nutrient management.

v. 100% fecal coliform removal is recorded.

Inference:

This STP also showed proper infrastructure and efficient treatment process but nitrate and saponin removal was inefficient, requiring advanced treatment upgradation. The treatment system exhibits excellent organic load, ammonia, and surfactant removal, along with effective disinfection, though nutrient and nitrate removal remain limited, indicating scope for process optimization**.**

Conclusion:

1. Most STPs showed efficient BOD and COD removal, indicating good performance in organic load reduction.
2. Saponin removal was consistently poor in most STPs, despite good removal efficiency for synthetic surfactants (anionic and cationic) in most of STPs.
3. The common outlet of Yamuna Vihar STP at Wazirabad barrage was having excessive foaming as observed during our visit. It was related to underperformed infrastructure and its noncompliance with ammonia, STPP and Saponin removal standards.
4. Keshopur and Chilla STPs showed inefficiency in Nitrate and Phosphate removal, though showing good surfactant removal efficiency.
5. Delhi Gate and Sen Nursing Home STPs showed better surfactant removal yet failed to address surfactant (Saponin and STPP) removal effectively.
6. Foaming, scum accumulation, and aging infrastructure were common operational issues across multiple sites.

D. Drains

D. Drains

Across the stretch of River Yamuna in Urban Delhi, there are 24 drains discharging wastewater to River Yamuna[20]. Of these, 19 major drains, spanning from Wazirabad Barrage to the Okhla Barrage, were identified through a literature review for their significant contribution to the pollution load in the Yamuna (detailed sampling locations are listed in Table 12). The sampling locations of major drains and sub-drains discharging into the Yamuna River are marked in Figure 32 and photographs taken during sampling have been shown in Figures 33. The sampling also includes the entire stretch of Najafgarh Drain. Once known as the Sahibi River, a natural watercourse, it has transformed into a drain due to the urbanization and industrialization along its course, particularly in the Delhi region. This drain is a major contributor to pollution in the Yamuna River, collecting large volumes of untreated sewage, industrial waste, and runoff throughout its 51 km course through the city before merging with the Yamuna.

Table 12: Details of Drains falling into River Yamuna

Major Drains directly out falling in Yamuna River

S. No.	Sampling Location	Pre-Monsoon	Post- Monsoon	Latitude	Longitude
1.	Drain no. 6	27/6/2024	17/12/2024	28.790674N	77.159728E
2.	Swaroop Nagar Drain	27/6/2024	17/12/2024	28.739118N	77.154943E
3.	Supplementary drain	4/6/2024	17/12/2024	28.710166N	77.227830E
4.	Soniya Vihar Drain	-	30/01/2025	28.708382N	77.235998E
5.	Najafgarh Yamuna confluence	4/6/024	17/12/2024	28.708046N	77.230538E
6.	Mori Gate drain	4/6/2024	14/12/2024	28.669500N	77.234028E
7.	Kailash Nagar Drain form Shastri Nagar	-	30/12/2024	28.662197N	77.254574E
8.	Delhi Gate Drain	3/6/2024	30/12/2024	28.6354N	77.254859E
9.	Sen Nursing Home	3/6/2024	14/12/2024	28.620458N	77.252103E
10.	New Ashok Nagar Drain	7/6/2024	-	28.588991N	77.301909E
11.	Drain 12A	-	24/02/2025	28.620139N	77.252075E
12.	Barapullah Drain	3/6/2024	30/12/2024	28.585401N	77.27129E
13.	Shaheen Bagh Drain	24/6/2024	-	28.542728N	77.299868E

20 https://greentribunal.gov.in/sites/default/files/news_updates/REPORT%20BY%20CPCB%20IN%20OA%20NO.%2021%20of%202023%20Ashwani%20Yadav%20Vs.%20Govt.%20of%20NCT%20of%20Delhi.pdf

S. No.	Sampling Location	Pre-Monsoon	Post- Monsoon	Latitude	Longitude
14.	Hindon cut canal near confluence	-	13/12/2024	28.584194N	77.298805E
15.	Maharani Bagh Drain	3/6/2024	30/12/2024	28.57474N	77.273509E
16.	The Khand Drain	30/5/2024	-	28.52475506N	77.283639E
17.	Shahdara Drain	-	13/12/2024	28.544612N	77.318462E
18.	Palam Drain	5/6/2024	24/12/2024	28.579645N	77.03844E
19.	Mungeshpur Drain	5/6/2024	24/12/2024	28.62693N	77.019655E
Additional Locations of Najafgarh					
S. No.	**Sampling Locations**	**Pre-Monsoon**	**Post- Monsoon**	**Latitude**	**Longitude**
1.	Dhansa Border	5/6/2024	24/12/2024	28.540135N	76.879545E
2.	Najafgarh Lake	27/6/2024	24/12/2024	28.5178483N	76.9204186E
3.	Inception of Supplementary drain	5/6/2024	24/12/2024	28.710011N	77.217761E

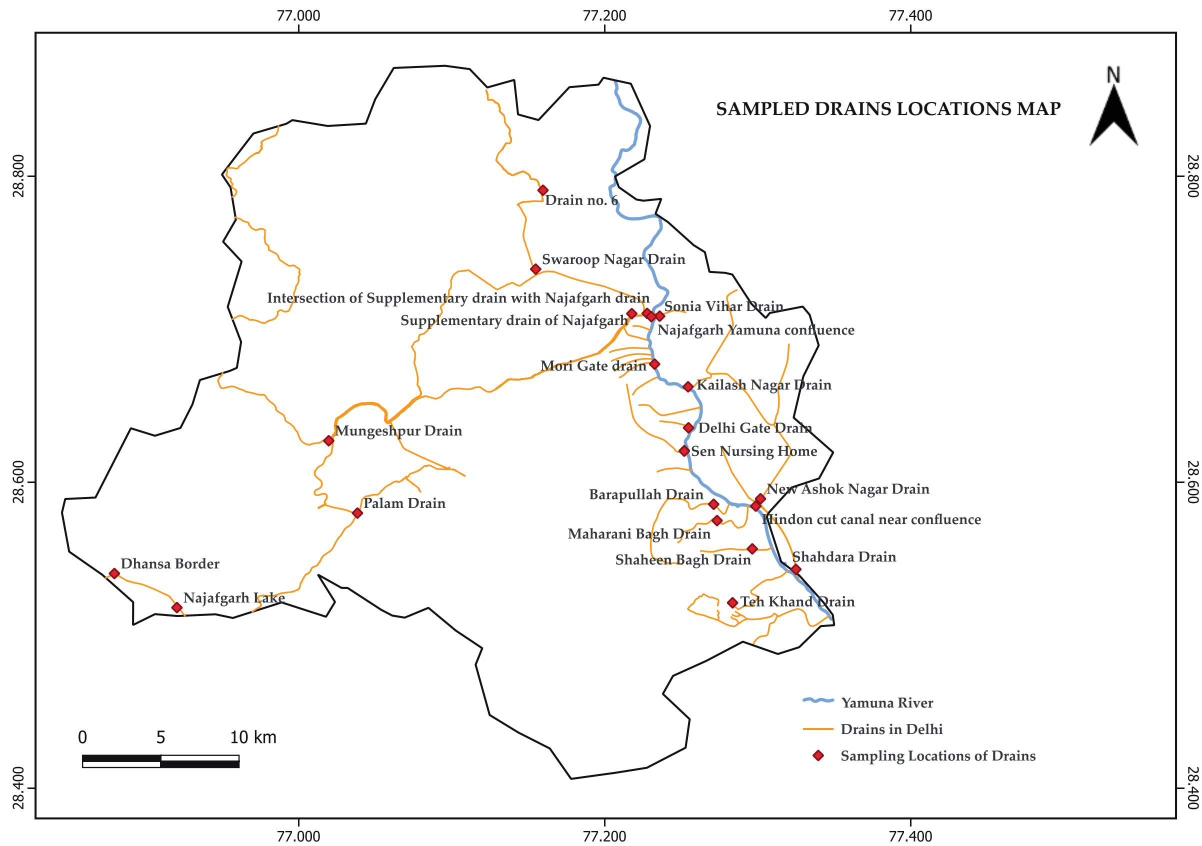


Figure 32: Sampling Locations of Drains out falling in Yamuna River

Referring to Figure 32, the section of the Yamuna between Wazirabad and Hathi Ghat is particularly impacted by the Najafgarh Drain, which emerges as the primary source of pollution in the river after Wazirabad Barrage. This drain collects effluents from multiple sources, including Drain No. 6, which flows through Mukhmelpur and Swaroop Nagar before ultimately joining the Supplementary Drain. The Supplementary Drain further meets the Najafgarh Drain near Mukherjee Nagar and falling in Yamuna at downstream of Wazirabad. Between Hathi Ghat and Chhath Ghat, two major drains, the Mori Gate Drain (also known as the Kashmiri Gate Drain) and the Delhi Gate Drain, discharge into the river. The Yamuna reaches Chhath Ghat near the ITO Bridge. From this point to the Okhla Barrage, the river receives wastewater from several additional drains, including the Sen Nursing Home Drain, Barapullah Drain, (which carries effluent from the Akshardham Dhobi Ghat), Shahdara Drain, Shaheen Bagh Drain, and Maharani Bagh Drain. The physicochemical parameters of the wastewater from these drains during pre and post monsoon sampling have been presented in Table 13 and 14 respectively.

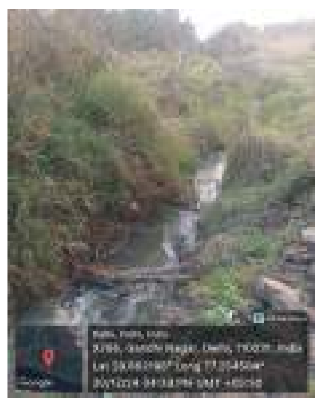
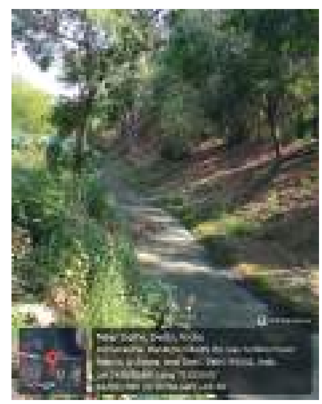
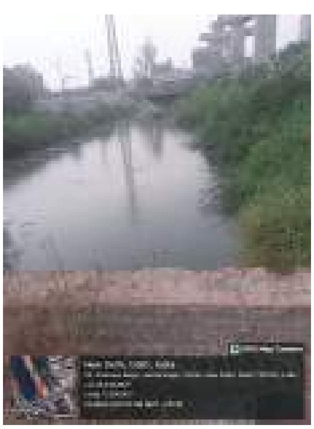
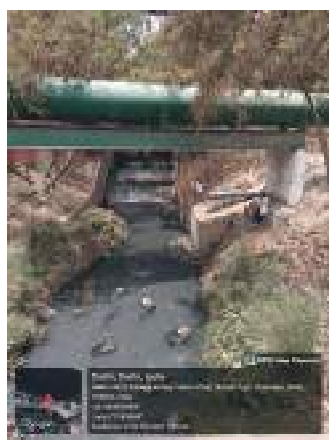
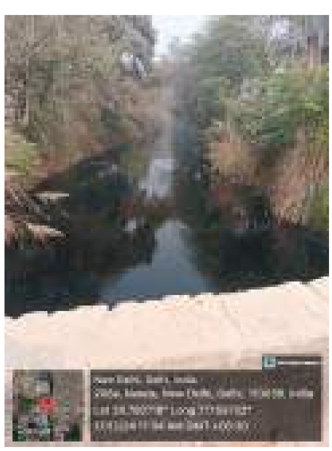
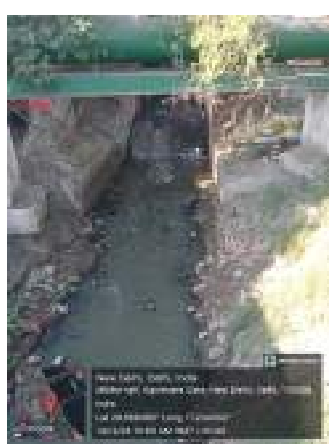
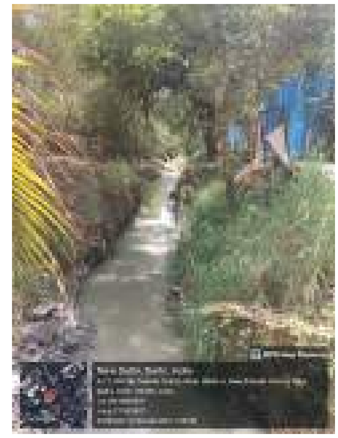
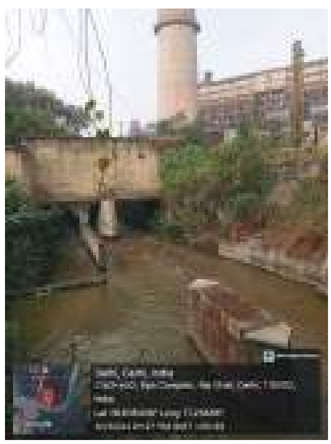
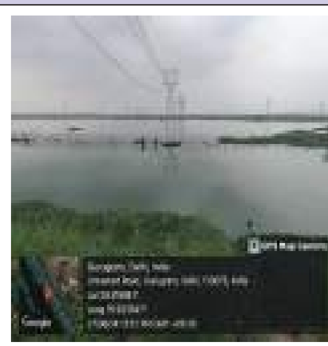
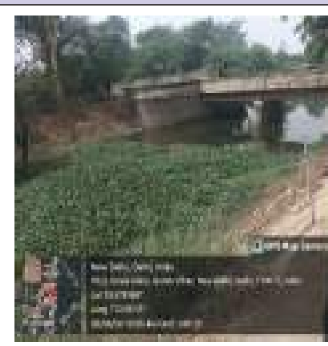
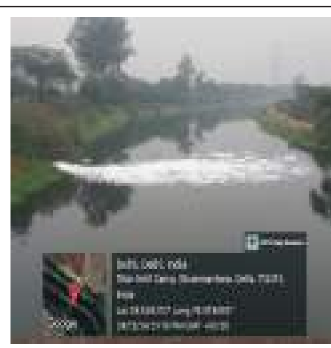
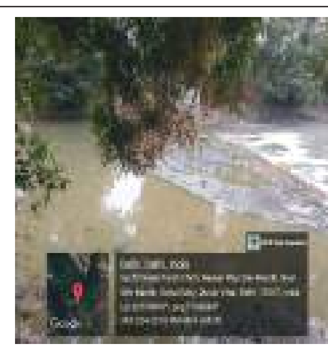
Sonia Vihar Drain	Kailsah Nagr Drain /Shastri Nagar	Drain 12A
		
Shaheen bagh Drain	**Teh khand Drain**	**Shahdara drain**
		

Figure 33: Sampling of Drains Locations during Pre- and Post-Monsoon study

New Ashok Nagar Drain	Hindon Cut Canal
	

	Drain No. 6, near Mulkmelpur	Mori Gate Drain/ Kashmiri gate	Barapullah Drain
Pre-Monsoon			
Post- Monsoon			

	Delhi gate Drain	Sen Nursing home Drain	Maharani Bagh Drain
Pre-Monsoon			
Post- Monsoon			

	Dhansa Border	Najafgarh Lake	Palam Drain
Pre-Monsoon			
Post- Monsoon			

	Mungeshpur drain	Supplementary drain to Najafgarh drain
Pre-Monsoon		
Post- Monsoon		

Table 13: The Physicochemical Parameter Data of Drains Out falling in River Yamuna during Pre – Monsoon Season

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring				Anthropogenic Compounds, Foam Activators, and Activators							
		pH	TSS	COD	BOD	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Fecal Coliform	Saponin	Hardness	Sodium Tri-Poly-Phosphate
	CPCB Standard Limit[21]	**5.5-9.0**	**<100**	**< 250**	**<30**	**< 100**	**<10**	**< 5**	**< 1**	<2500	-	**-**	**-**
	Unit	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/ 100 mL	mg/ L	mg/L as $CaCO_3$	mg/L
1.	Drain No 6	7.6	155	216	51	6.2	23.3	5.035	<0.1	9.2×10^6	700	491.28	6.49
2.	Swaroop Nagar	7.57	56	96	23	3.2	27.6	7.65	<0.1	9.2×10^6	700	672.84	9.87
3.	Supplementary	7.61	43	61	17	9.4	20.0	8.44	0.21	9.2×10^5	700	405.84	10.89
4.	Najafgarh	7.73	126	138	38	18.7	13.4	8.24	0.52	3.5×10^6	1200	480.6	16.01
5.	Mori Gate	7.54	94	146	40	20.9	7.6	5.71	0.39	9.2×10^6	1000	331.08	7.36
6.	Delhi Gate	7.20	206	379	105	18.7	<0.5	8.17	0.62	2.8×10^6	1200	352.44	
7.	Sen Nursing Home	7.14	23	475	132	25.9	11.6	8.88	0.72	7.9×10^5	1100	416.52	11.45
8.	Barapullah	7.41	25	146	40	15.1	<0.5	7.78	0.51	9.2×10^6	900	384.48	10.03

21 Annexure-I

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring				Anthropogenic Compounds, Foam Activators, and Activators							
		pH	TSS	COD	BOD	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Fecal Coliform	Saponin	Hardness	Sodium Tri-Poly-Phosphate
9.	Ashok Nagar	7.2	720	325	84	30.2	46.3	13.82	0.72	5.4×10^{6}	1100	416.52	17.83
10.	Maharani Bagh	7.29	166	257	71	20.9	7.8	10.67	0.62	9.2×10^{6}	1100	4.5.84	13.76
11.	Shaheen Bagh	7.38	22	88	19	4.3	24.2	13.775	<0.1	3.5×10^{5}	700	736.92	17.77
12.	Shahdara	7.28	26	243	62	17.3	4.2	<1.0	-	6.4×10^{7}	-	437.88	NA
13.	Teh Khand	7.20	306	314	87	47.5	3.3	12.12	0.83	9.4×10^{5}	600	672.84	15.63
14.	Dhansa Regulator	7.48	26	56	14	4.32	23.1	3.144	<0.1	3.5×10^{5}	600	651.48	4.06
15.	Najafgarh Lake	7.44	42	60	15	14.2	16.7	15.301	<0.1	3.5×10^{5}	800	288.36	19.74
16.	Palam Drain Meeting Najafgarh Drain/Sahibi River	7.51	36	176.27	48.96	22.31	<0.5	13.94	0.82	5.4×10^{5}	1100	437.88	17.97
17.	Drain parallel to Najafgarh/ Sahibi River	8.41	241	141.78	39.39	16.55	<0.5	4.96	0.71	70	900	448.56	6.40
18.	Intersection with Mungeshpur Drain	7.8	549	149.45	41.51	33.82	<0.5	9.05	0.21	2.4×10^{6}	1000	1132.08	11.68

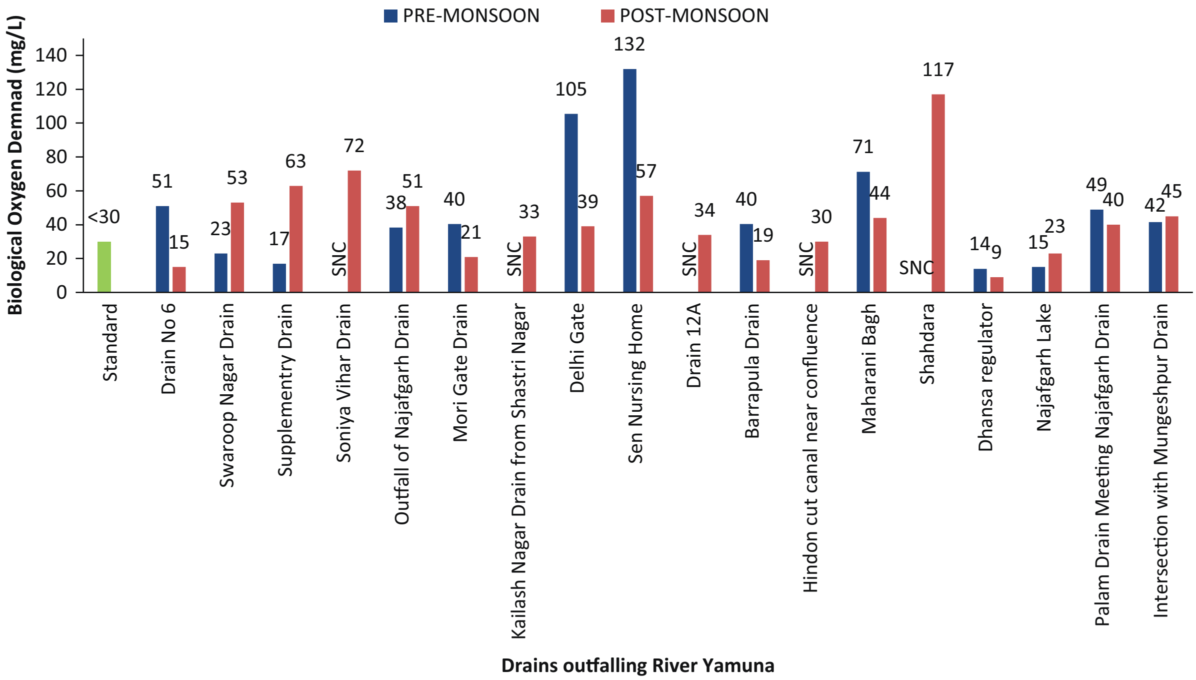
Table 14: The Physicochemical Parameter Data of Drains Out falling in River Yamuna Post – monsoon season

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring				Anthropogenic Compounds, Foam Activators, and Activators							
		pH	TSS	COD	BOD	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Fecal Coliform	Saponin	Hardness	Sodium Tri-Poly-Phosphate
	CPCB Standard Limit[22]	5.5–9.0	<100	< 250	<30	< 100	<10	< 5	< 1	<2500	-	-	-
	Unit	units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/ 100 mL	mg/ L	mg/L as $CaCO_3$	mg/l
1.	Drain No 6	7.58	77	40	15	21.3	56.6	13.195	4.87	3.3×10^5	500	529.2	17.02
2.	Swaroop Nagar Drain	7.55	98	162	53	20.1	60.27	12.452	7.31	4.1×10^5	400	848.4	16.06
3.	Supplementary drain to Najafgarh	7.54	200	192	63	22.8	38.81	15.832	10.9	8.4×10^5	1300	525.2	20.42
4.	Soniya Vihar Drain	6.74	356	223.3	72	18.3	3.19	8.031	78.68	2.1×10^5	1500	316.2	10.36
5.	Najafgarh Yamuna Confluence	7.6	135	162	51	24.5	55.13	15.454	7.06	1.2×10^5	800	464.6	19.93
6.	Mori gate	7.77	100	61	21	29.1	30.5	10.005	23.05	1.4×10^5	700	319	12.91
7.	Kailash Nagar Drain form Shastri Nagar	7.32	184	135.7	33	10.4	12.1	12.796	56.64	9.2×10^5	1600	308	16.51

22 Annexure-I

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring				Anthropogenic Compounds, Foam Activators, and Activators							
		pH	TSS	COD	BOD	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Fecal Coliform	Saponin	Hardness	Sodium Tri-Poly-Phosphate
8.	Delhi gate Drain	7.15	49	116.3	39	35.4	15.5	14.266	6.98	7.9×10^5	2300	297	18.40
9.	Sen Nursing Home	7.93	302	202	57	25.6	58.43	19.937	15.73	2.2×10^5	300	363	25.72
10.	Drain 12A	7.19	51	127.5	34	11.76	NA	NA	107.14	5.4×10^5	1000	NA	8,91
11.	Barapulla Drain	7.25	23	87.2	19	28.1	23.9	10.091	14.56	7×10^5	1400	302.5	13.02
12.	Hindon cut canal near confluence	7.81	35	87	30	22.8	15.44	1.741	1.61	6.8×10^5	700	192.5	<10
13.	Maharani Bagh Drain	7.02	226	116.3	44	8	19.7	13.318	13.78	2.4×10^5	1500	291.5	17.18
14.	Shahdara Drain confluence	7.61	64	369	117	24.2	9.04	20.514	24.7	4.9×10^5	900	379.5	26.46
15.	Dhansa Border	7.3	<5	39.6	9	<0.5	38.22	<1	0.94	3.3×10^3	1700	797.9	<1
16.	Najafgarh Lake	7.18	26	69.3	23	16.9	30.5	7.89	4.73	3.3×10^3	1200	402	10.17733
17.	Palam Drain	7.06	113	128.7	40	41.6	36.02	18.288	52.25	4.3×10^5	1900	298	23.58973
18.	Mungeshpur Drain	7.15	56	138.6	45	26.5	47.15	8.817	57.75	17×10^5	3200	1419.1	11.37307
19.	Intersection of Supplementary drain with Najafgarh drain	7.16	73	59.4	18	13.9	28.3	11.46	3.47	3.3×10^5	200	416.1	14.78228

1. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)



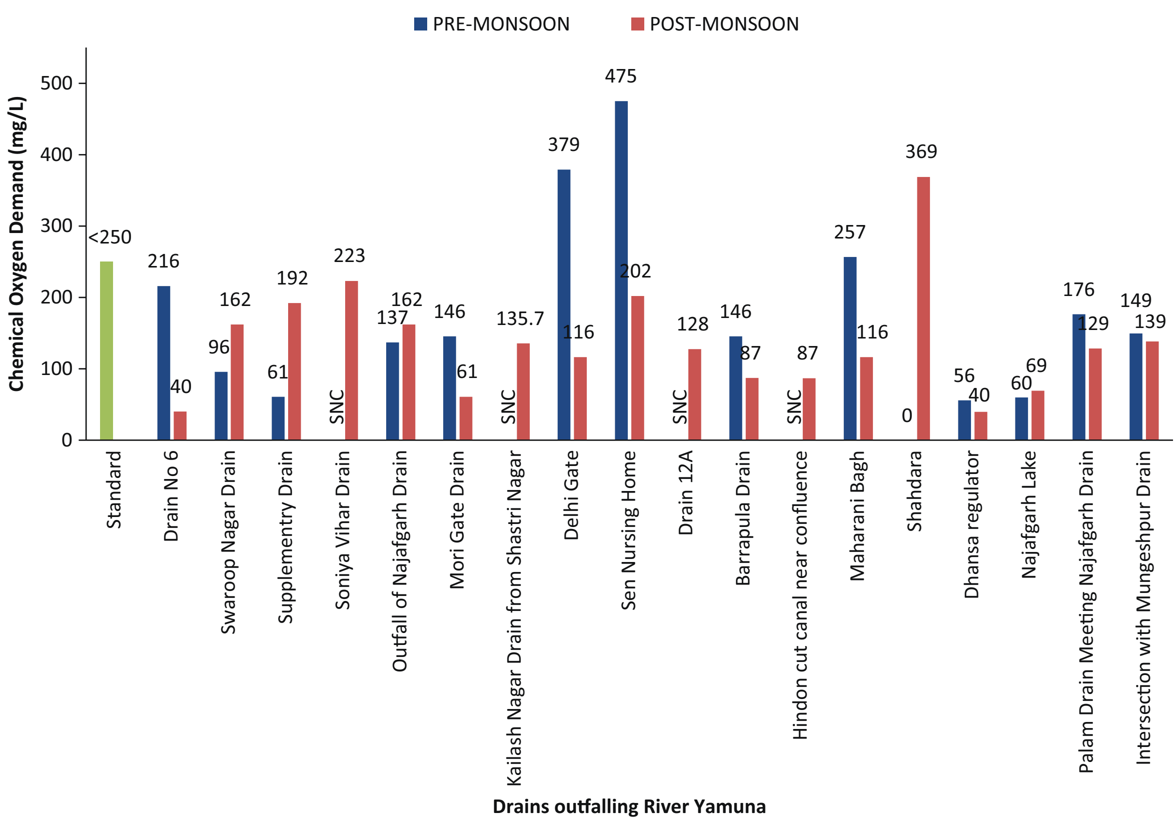


Figure 34: BOD and COD of the Wastewater carried by Open Drains

1. The BOD and COD levels in the drains vary, ranging from 15 to 132 mg/L and 40 to 475 mg/L, respectively. Both parameters peak at the Sen-nursing home Drain near Delhi gate, which indicates the possibility of intrusion of industrial effluent in the drain (Figure 34).
2. Compared to pre-monsoon sampling, the BOD & COD levels have decreased in the drains, which may be attributed to the urban runoff leading to dilution of organic pollutants in the river during the monsoon season.
3. **Najafgarh and associated Drain:** The Najafgarh drain enters Delhi at Dhansa regulator having BOD less than 15 mg/L, but this increases to 51 mg/L at the outfall at Yamuna which may be attributed to higher concentration of pollutants, particularly from untreated sewage entering from the Palam Drain, Mungeshpur Drain, and Supplementary Drain meeting Najafgarh at various locations with high BOD and COD values as observed in Figure 34.

2. Suspended Solids

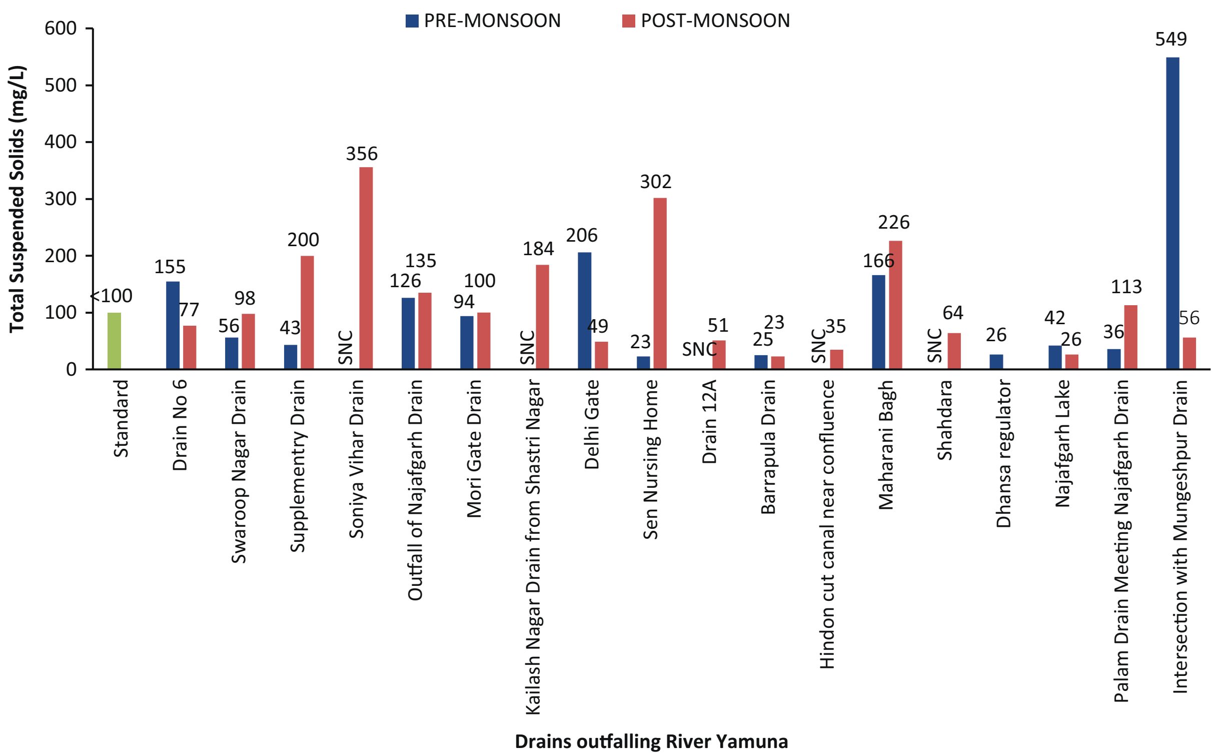


Figure 35: Total Suspended Solids carried by drains to Yamuna

1. The suspended solids levels of drains that are out falling in Yamuna River directly were found ranging from 23–356 mg/L as shown in Figure 35, the minimum in Barapulla Drain and the maximum in Soniya Vihar drain during post monsoon season. The very high concentration observed at the Soniya Vihar drain may be due to some construction activity & cremation site near the drain and the location of sample collection.
2. TSS at various locations has no trend & has increased at some locations & decreased at a few locations. However, compared to pre-monsoon data, the TSS has increased at most locations, which may be attributed to the rainfall runoff that bring huge amount of debris into the drains.

3. **Najafgarh and associated Drain:** The TSS level of Najafgarh Drain at Dhansa Regulator is <5 mg/L, which increases significantly to 135 mg/L at the outfall of the drain in Yamuna River as indicated in Figure 35. This sharp rise indicates a substantial addition of suspended matter as the drain progresses, most likely from the intersection of subdrains like the Mungespur drain and the supplementary drain entering the Najafgarh.

3. Nutrient Levels

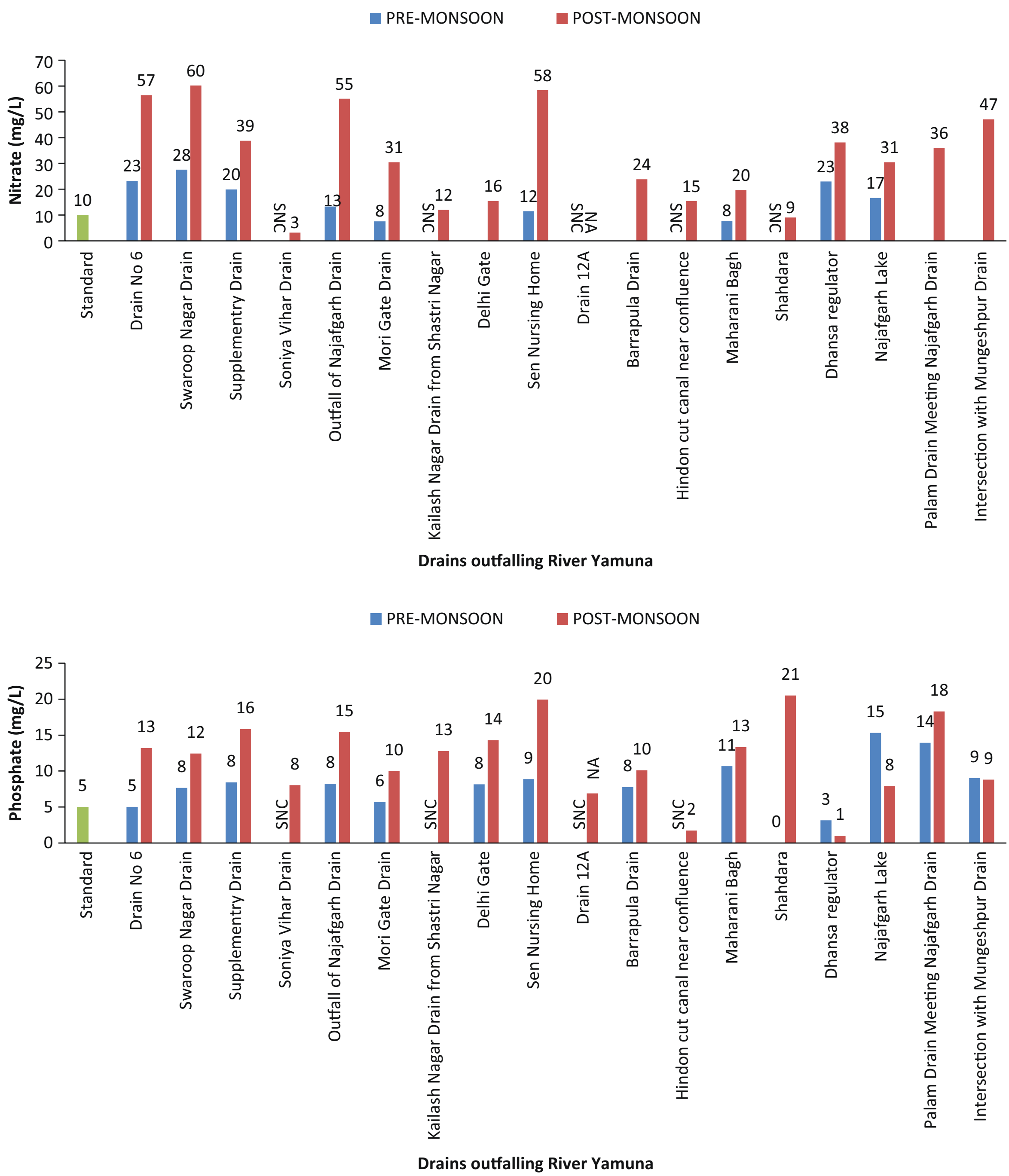


Figure 36: **Concentration of Nitrate-N and Total Phosphate Carried by Drains to Yamuna**

- The Nitrate and phosphate concentration recorded during pre and post monsoon sampling that has been presented in Figure 36, clearly indicates that drains are carriers of nutrients in the form of Nitrate-N and Phosphate.
- It is important to note that the concentration of nitrates and phosphates in all location increases significantly during post-monsoon season. This may be attributed to the surface runoff from agricultural fields, as monsoon rains often wash fertilizers (rich in nitrates and phosphates) from agricultural fields into nearby water bodies and drains, leading to nutrient enrichment.
- The high Nitrate and phosphate levels at the Swaroop Nagar drain may result from contamination from the landfill site and at and Shahdara drain confluence to various anthropogenic activities, respectively.
- **Najafgarh and associated Drain:** Excessive levels of Nitrates and Phosphates were also found in the entire stretch of Najafgarh drain and associated drains, which may also be responsible for excessive algal blooms and hyacinth growth in the stretch of Najafgarh which was observed during the sampling process.

4. Fecal Coliform

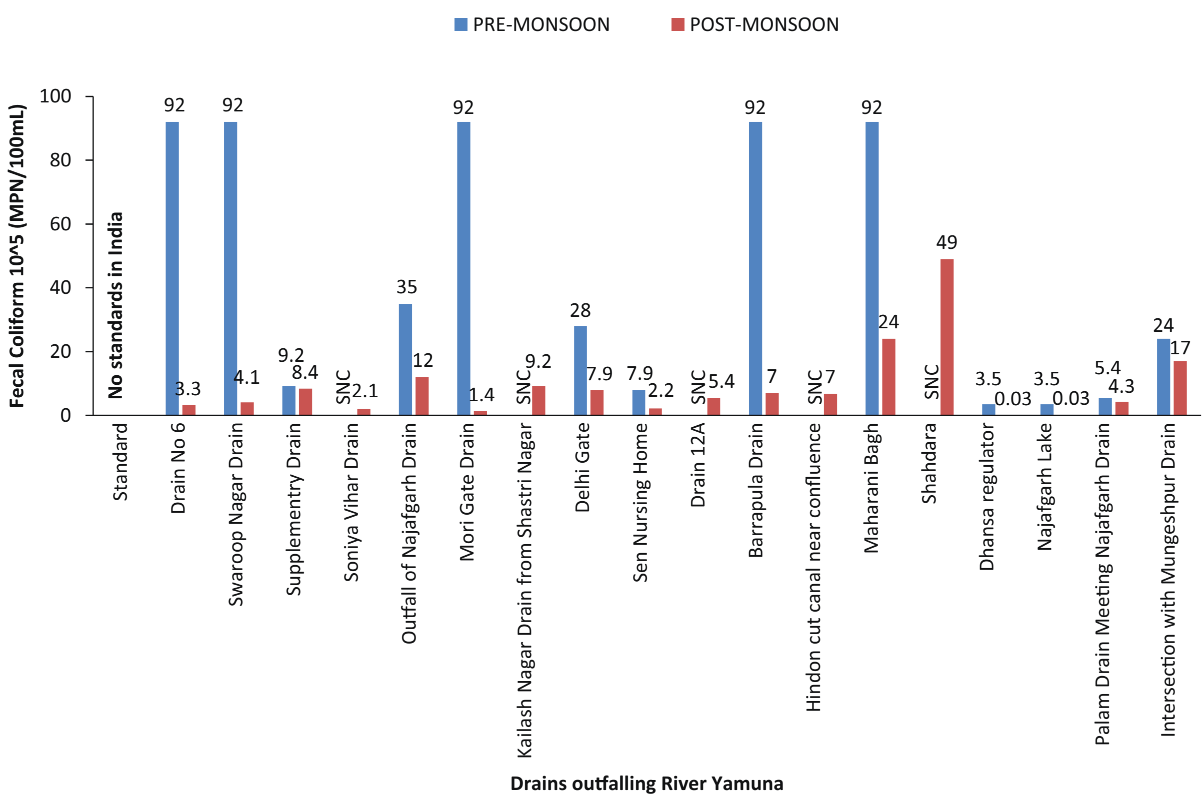


Figure 37: Fecal Coliform Count in Drains entering River Yamuna

- The low Fecal Coliform count (70 MPN/100 ml) recorded at Drain Parallel to Najafgarh during pre-monsoon is due to the fact that this point is the origin of tis drain having no intrusion of any kind.
- The Fecal coliform count recorded in the post-monsoon is significantly low compared to the pre-monsoon (Figure 37). This may be explained by the dilution resulting from the rainfall runoff & increased flow resulting from the monsoon season.

- Drains intrusion into River Yamuna carries different strains of Bacteria, which release a variety of natural/bio-surfactants for example Rhamnolipid, Glycolipopeptide, Glycolipid, Lipopeptide, etc., as Das et al., 2024 mentioned[23] leading to possible froth formation in river.[24]
- The sources of high Fecal coliform count in the drains could be attributed to the intrusion of untreated sewage, septage and animal faeces in these open drains coming from nearby areas.

5. Saponin Content

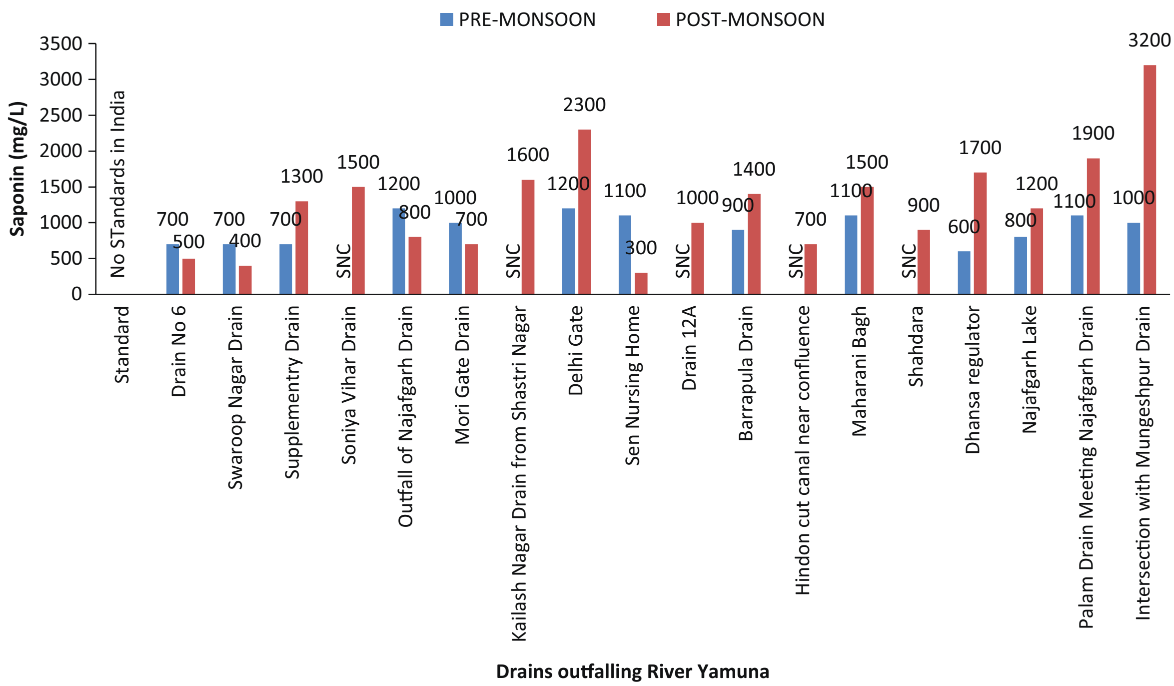


Figure 38: Saponin Concentration in the wastewater carried by Drains

- There are no prescribed standards for saponin concentration in India. However, as per literature saponin concentration greater than ~1800 ng/L max (0.0018 mg/L) As discussed earlier, 0.0018 mg/L (1800 ng/L) of Saponin concentration can cause froth.
- In analysis, we found that the range of saponin concentration in wastewater carried by drains lies between 1000 – 2300 mg/L (Figure 38).

23 Reshmi Das, Chanakya Hoysall, Lakshminarayana Rao, Insights on foaming in surface waters: A review of current understandings and future directions, Chemical Engineering Journal, Volume 493, 2024, 152472, ISSN 1385-8947, https://doi.org/10.1016/j.cej.2024.152472.

24 Reshmi Das, Chanakya Hoysall, Lakshminarayana Rao, Insights on foaming in surface waters: A review of current understandings and future directions, Chemical Engineering Journal, Volume 493, 2024, 152472, ISSN 1385-8947, https://doi.org/10.1016/j.cej.2024.152472.

- Majority drains contain saponin >1000 mg/L of wastewater, which may be considered the major source of saponin in the Yamuna River. The high saponin values can be attributed to the high bacterial contamination found in the drain water.
- At Delhi Gate drain, the saponin concentration has doubled from 1200mg/L to 2300mg/L from pre-monsoon to post-monsoon sampling, this can be correlated with the high concentration of fecal coliform at Delhi gate drain and Kailash Nagar drain passing from Shastri Nagar.
- **Najafgarh and associated Drains**: In the post-monsoon sampling, the saponin concentration at Dhansa Border increased from 600 mg/L to 1700 mg/L, with a significant presence of water hyacinth observed. In contrast, the saponin concentration at the Najafgarh-Yamuna confluence decreased from 1200 mg/L to 800 mg/L. This decline can be attributed to the flow of the Najafgarh drain merging with the Yamuna during the monsoon.

6. Concentration of Synthetic Surfactant (Anionic surfactants & STPP)

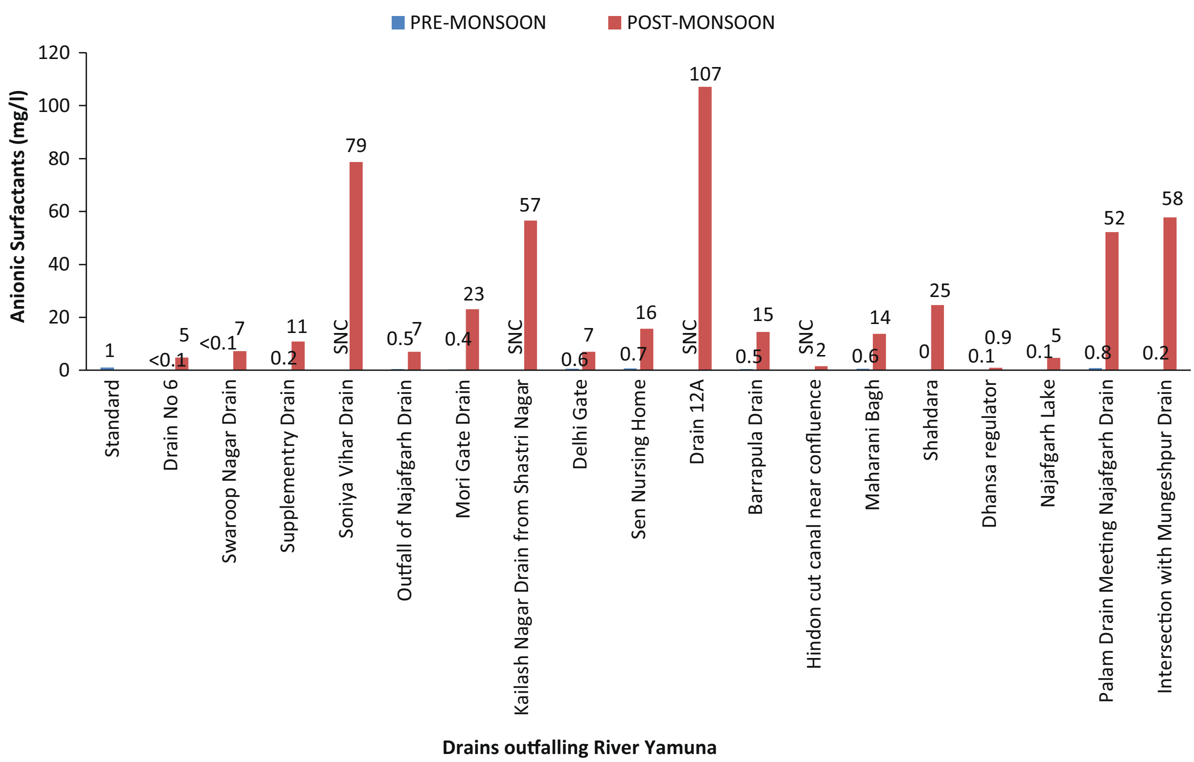


Figure 39: Concentration of Suspended solids and Anionic surfactants in Drains out falling River Yamuna

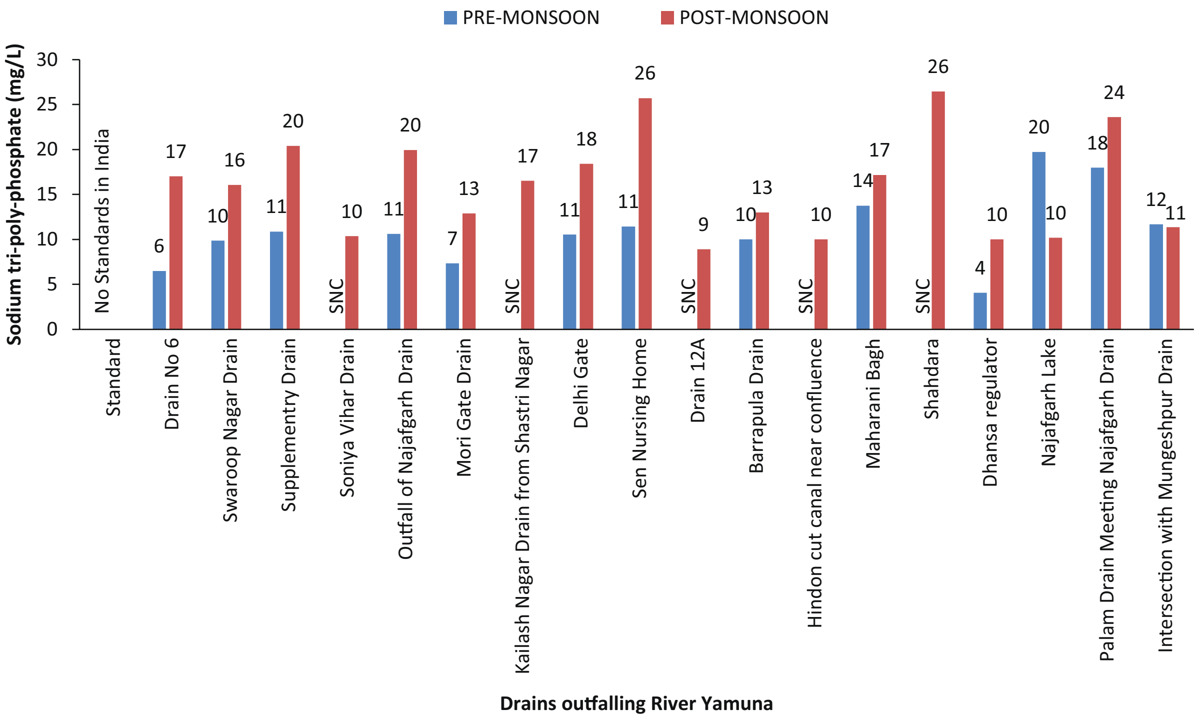
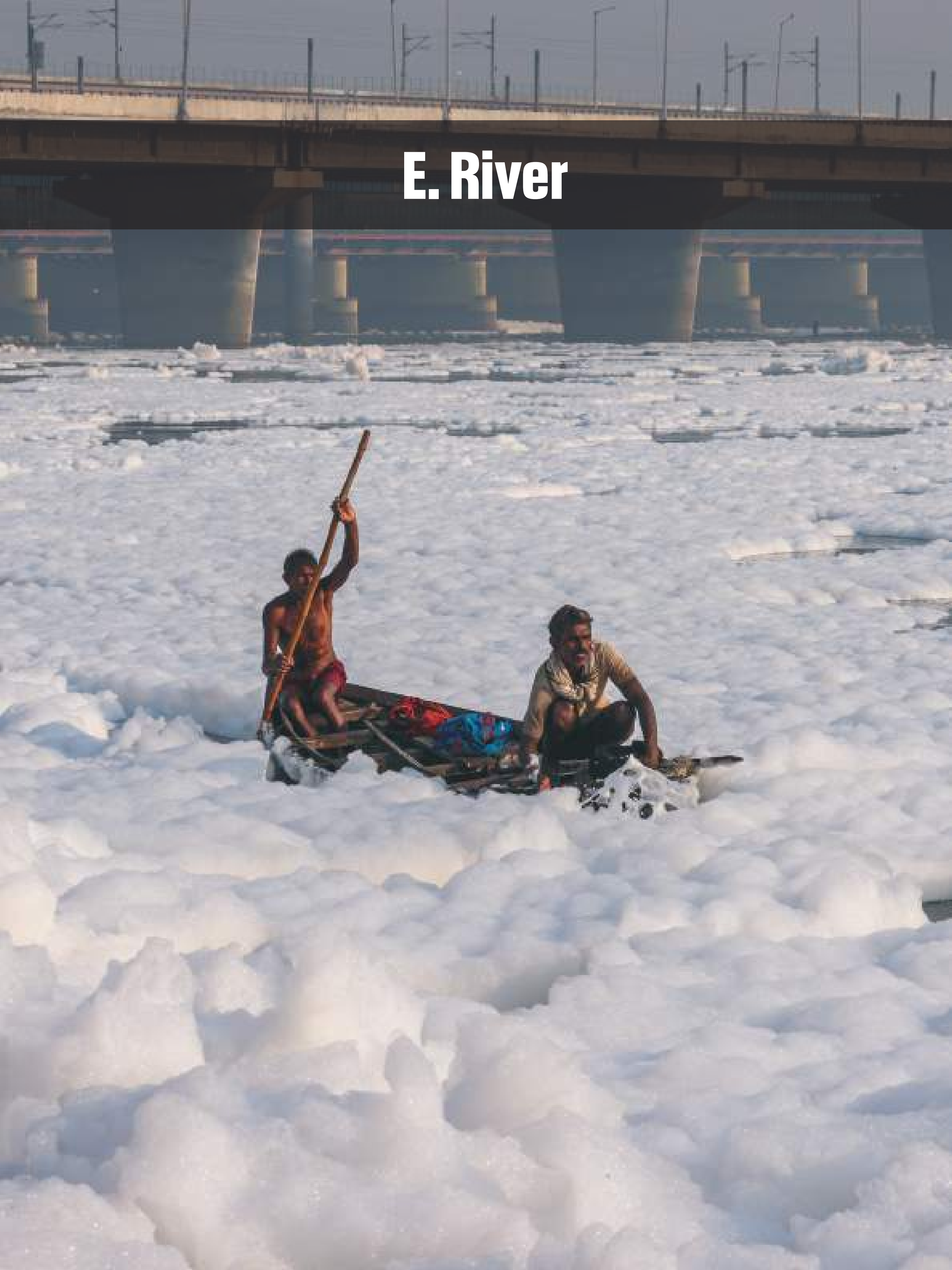


Figure 40: Sodium tri-poly-phosphate (STPP) Concentration in Drains

1. Anionic surfactants are commonly used in cleaning products due to their excellent lathering properties, may be responsible for frothing in surface waters. Also, STPP is a stable chemical agent commonly used as an ingredient in detergents and cleaning agents and enhances the performance of surfactants, which are primary agents responsible for foam production.
2. An important observation in the pre-monsoon sampling was that the anionic surfactant concentration (Figure 39) was recorded at <1 mg/L at all locations in the drains. However, this value increased significantly during the post monsoon sampling period reaching as high as 107 mg/L at the outlet of Drain 12 A. The possible reason of high anionic surfactant can be attributed to:
   a. High flow during monsoon can stir up previously settled pollutants, including surfactants bound to organic matter or sediments, causing a spike in measured concentrations.
   b. Many sewage treatment plants (STPs) may be bypassed, overloaded, or underperformed during the monsoon, leading to the release of untreated or partially treated wastewater rich in surfactants.
3. The concentration of STPP has a similar trend to the anionic surfactants (Figure 40).

E. River



E. River

Along a 22 km stretch of the Yamuna River flowing through urban Delhi, various key locations were selected to assess water quality and the impact of drain intrusions. The first sampling site was just upstream of the Wazirabad Barrage, where the river enters urban Delhi, followed by the downstream of the Wazirabad barrage. It was noted that the upstream section of the barrage was covered with water hyacinth, with minimal water flow through the barrage gates. The next sampling location was Hathi Ghat, also known as Qudsia Ghat, where the intrusion of the Mori Gate drain was observed downstream. The subsequent sampling took place at Chhath Ghat, near the ITO Bridge. The Delhi Gate drain falls at the upstream of Chhath Ghat. Both Hathi Ghat and Chhath Ghat showed significant visible pollution from plastic and other solid waste accumulation, primarily due to religious activities, such as poojas and offerings made by locals into the river. The remaining locations at Okhla Barrage were upstream of Okhla Barrage and downstream of Okhla Barrage, as listed in Table 15 and Figure 41. Through visual inspection, the growth of water hyacinth was prominent at all locations and can be seen in Figure 42–48.

Table 15: Details of Sampling Locations from River Yamuna

S. No	Sampling Locations				
	Sampling Location	**Pre-Monsoon**	**Post- Monsoon**	**Latitude**	**Longitude**
1.	Upstream Wazirabad Barrage (East)	-	17/12/2024	28.712585N	77.235719E
2.	Downstream Wazirabad Barrage	4/6/2024	17/12/2024	28.71181N	77.23118E
3.	Hathi Ghat	4/6/2024	14/12/2024	28.671222N	77.233528E
4.	Chhath Ghat	4/6/2024	14/12/2024	28.627427N	77.253650E
5.	Agra Canal	30/5/2024	13/12/2024	28.545611N	77.311055E
6.	Upstream Okhla Barrage East Side	-	13/12/2024	28.545488N	77.311411E
7.	Downstream Okhla Barrage	7/6/2024	13/12/2024	28.54781N	77.314673E

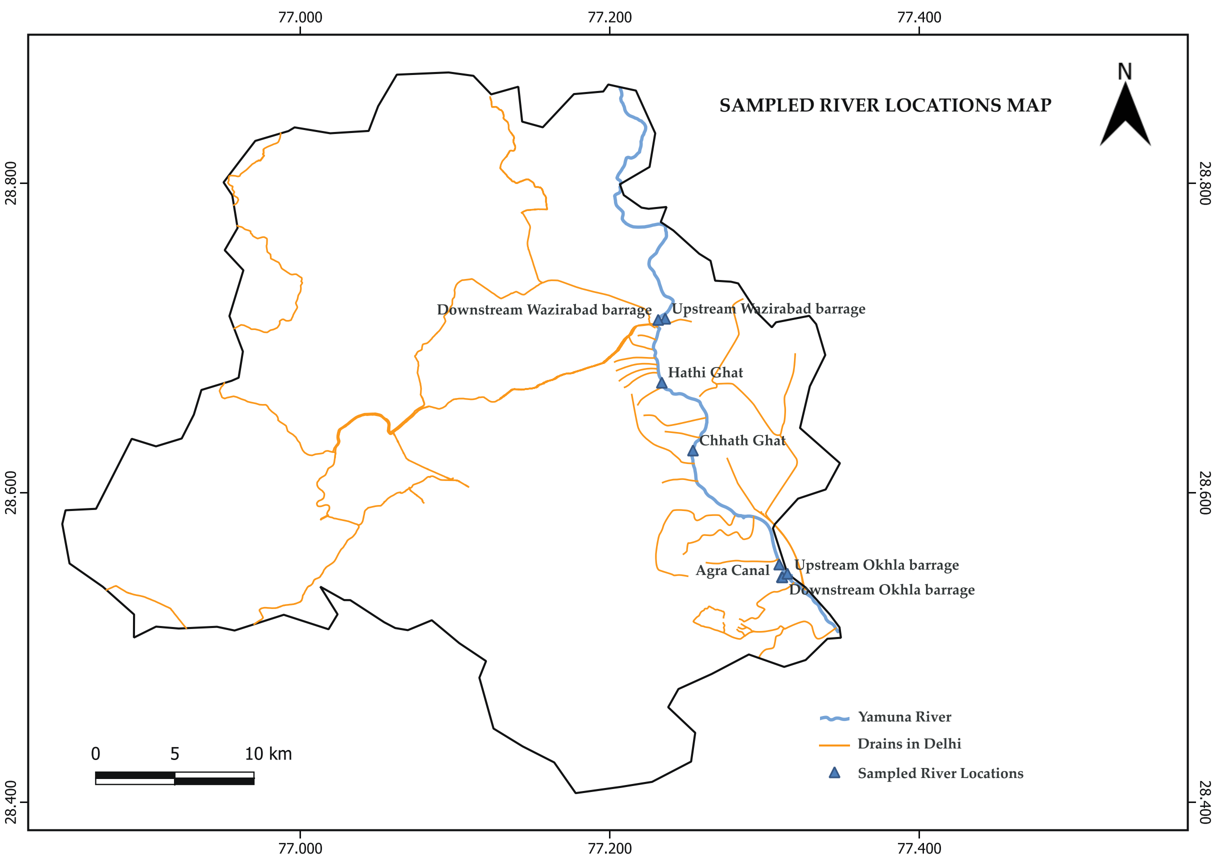


Figure 41: Locations of Samples collected from River Yamuna

Post-monsoon

Figure 42: Post monsoon sampling at Upstream Wazirabad barrage (East)

Pre-monsoon

Post-monsoon

Figure 43: **Pre and Post monsoon sampling at Downstream Wazirabad barrage**

Pre-monsoon

Post-monsoon

Figure 44: **Pre and Post monsoon sampling at Hathi ghat**

Pre-monsoon

Post-monsoon

Figure 45: **Pre and Post monsoon sampling at Chhath Ghat**

Pre-monsoon **Post-monsoon**

Figure 46: **Pre and Post Monsoon Sampling at Upstream Okhla Barrage**

Pre-monsoon **Post-monsoon**

Figure 47: **Pre and Post Monsoon Sampling at Agra Canal**

Pre-monsoon **Post-monsoon**

Figure 48: **Pre and Post Monsoon Sampling at Downstream Okhla Barrage**

The standard water quality parameters in line with those monitored by DPCC, along with the key pollutant parameters identified from the analysis of foam-causing factors at seven (7) locations along the Yamuna River during pre and post monsoon, are summarized in Table 16 and 17 respectively.

The parameters deemed significant in relation to froth formation are discussed in this chapter. Based on the water quality observations and analysis results, the following conclusions have been drawn.

Table 16: Physio-Chemical Parameters for Assessing Water Quality at five Locations along the Yamuna River during Pre-Monsoon Sampling

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring						Anthropogenic Compounds, Foam Activators, and Stabilizers						
		pH	DO	BOD	COD	Fecal Coliform	TSS	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Saponin	Hardness	Alkalinity
	CPCB Standard for River[25]	6.5-8.5	>5	<3	-	<2500	<100	-	<10	<0.1	<1	-	-	-
	Units	-	mg/L	mg/L	mg/L	MPN/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1.	Wazirabad Barrage (downstream)	8.1	Nil	17	61	1.7×10^{4}	55	22.3	6.5	<1.0	0.41	500	245.6	186.3
2.	Hathi Ghat	7.7	0.4	19	69	5.4×10^{6}	61	28.1	5.4	5.83	0.62	700	437.9	320.9
3.	Chhath Ghat	7.6	0.6	35	126	3.5×10^{6}	38	10.8	103	6.47	0.73	500	469.9	279.5
4.	Okhla Barrage (Up-stream)	7.3	Nil	15	54	5.4×10^{6}	8	17.3	6.3	6.11	0.62	400	354.4	217.4
5.	Okhla Barrage (Down-stream)	7.4	3.2	12	52	3.5×10^{5}	13	15.1	15	4.78	<0.1	70	288.4	196.7

25 Schedule – VI – The Environment (Protection) Rules, 1986

Table 17: Physio-Chemical Parameters for Assessing Water Quality at Seven Locations along the Yamuna River during Post-Monsoon Sampling

S. No.	Sample Location	Basic Water Quality parameters in line with DPCC monitoring						Anthropogenic Compounds, Foam Activators, and Stabilizers						
		pH	DO	BOD	COD	Fecal Coliform	TSS	Ammonia	Nitrate	Phosphate	Anionic Surfactants	Saponin	Hardness	Alkalinity
	CPCB Standard for River[26]	6.5-8.5	>5	<3	-	<2500	<100	-	<10	<0.1	<1	-	-	-
	Units	-	mg/L	mg/L	mg/L	MPN/100mL	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
1.	Upstream Wazirabad barrage (East)	7.93	4.4	4.3	20	2.5×10^4	10	27.4	20.51	2.73	0.6	400	238.4	261
2.	Downstream Wazirabad barrage	7.88	6.2	<1	10	3.2×10^4	<5	30.6	16.24	2.63	2.14	400	226.2	232
3.	Hathi Ghat	7.9	2.8	18	51	2.2×10^4	63	25.9	43.37	8.35	31.8	700	418	324.8
4.	Chhat Ghat	7.95	3.3	19	51	1.1×10^4	41	28.8	64.83	8.97	19.9	400	440	351.5
5.	Agra Canal	7.87	3.2	27	78	6.8×10^4	19	25.8	17.64	4.45	5.72	400	280.5	207.7
6.	Upstream Okhla barrage	8.23	4.2	5	19	0.11×10^4	15	12.5	9.56	2.21	1.12	400	209	154.4
7.	Downstream Okhla barrage	8.05	3.5	16	49	8.3×10^4	187	24.3	8.6	6.70	8.03	500	357.5	255.6

26 Schedule – VI – The Environment (Protection) Rules, 1986

1. Dissolved Oxygen

- It has been observed that during both pre- and post-monsoon sampling, DO levels at all sampling points in the River Stretch were not complying with the standard criteria prescribed by CPCB, i.e., >5 mg/L in the river (Figure 49), with an exception observed at Wazirabad barrage during post monsoon sampling, where DO levels were 6 mg/L.
- Though, the DO has been found to improve compared to the results obtained during pre-monsoon sampling, which is indicative of the improved river health due to increase in environmental flow (E-Flow) during monsoon period.

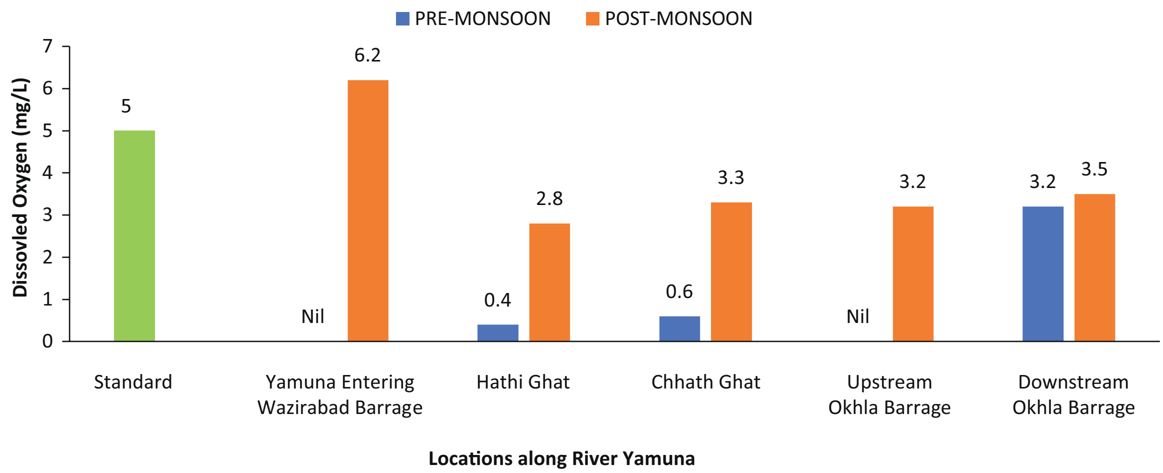
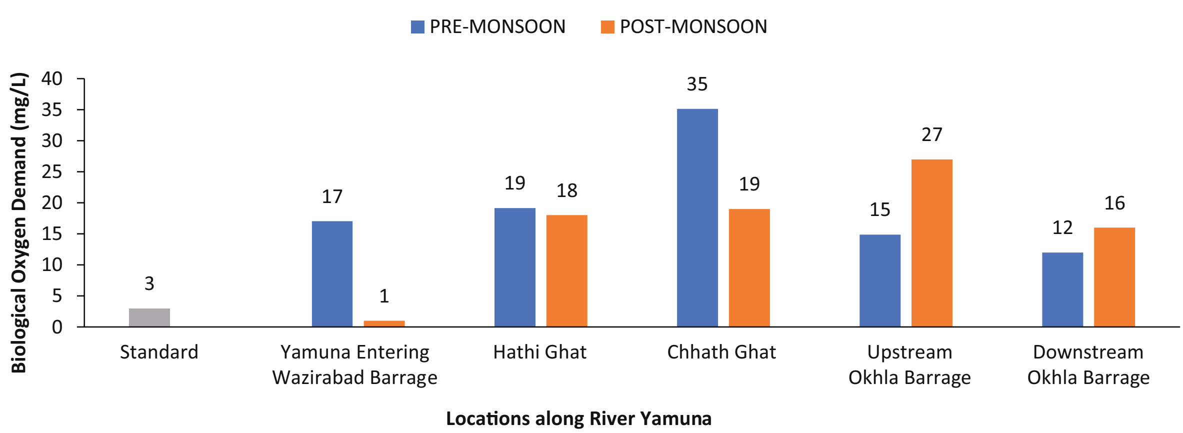


Figure 49: **Dissolved Oxygen Levels of River Yamuna at Different Locations**

2. Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)



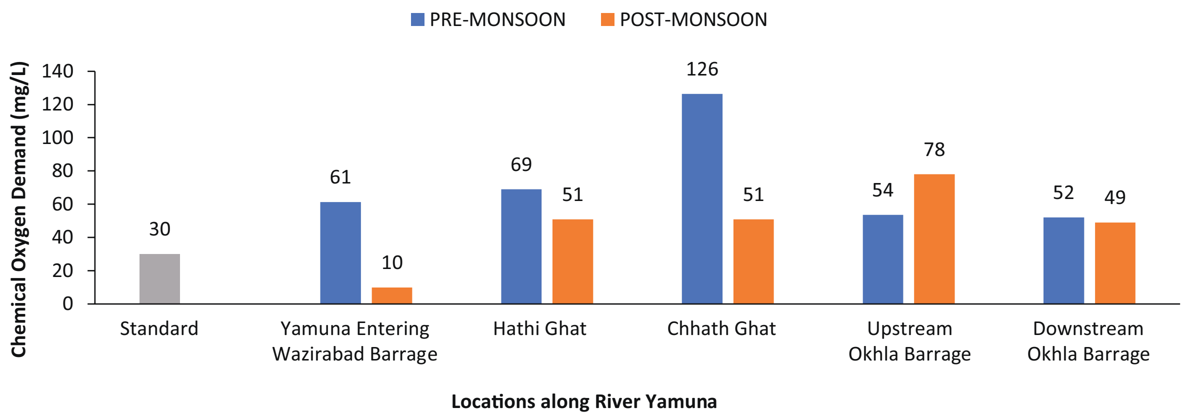


Figure 50: BOD and COD of River Yamuna at Different Locations

- It is indicative from the data that the BOD of the river has improved during the post-monsoon period.
- An interesting observation was made during the post-monsoon season. The samples collected from the western side of Yamuna River at upstream Okhla Barrage i.e. the inlet to Agra Canal, the recorded BOD and COD were 27 mg/L and 78 mg/L respectively. In contrast, samples from the eastern side of Yamuna River, near the Okhla Bird Sanctuary, showed significantly lower BOD (5 mg/L) and COD (19 mg/L), meeting CPCB standards for bathing water quality (refer to Table 15).
- This variation may be attributed to the intrusion of multiple drains and human activities on the western side, contributing to pollution, whereas the eastern bank remains relatively unaffected due to the presence of the Okhla Bird Sanctuary, which limits anthropogenic activities.
- The COD levels in the river water have also shown improvement during the post-monsoon season.
- This improvement in both BOD and COD during post monsoon sampling can be attributed to the dilution effect caused by increased river flow. Notably, Delhi received significantly higher rainfall in 2024 (1,029.9 mm) compared to 2023 (660.8 mm), which has contributed to this enhanced dilution. (Source: IMD Rainfall Data)[27].

27 https://mausam.imd.gov.in/responsive/rainfallinformation_swd.php

3. Total Suspended Solids

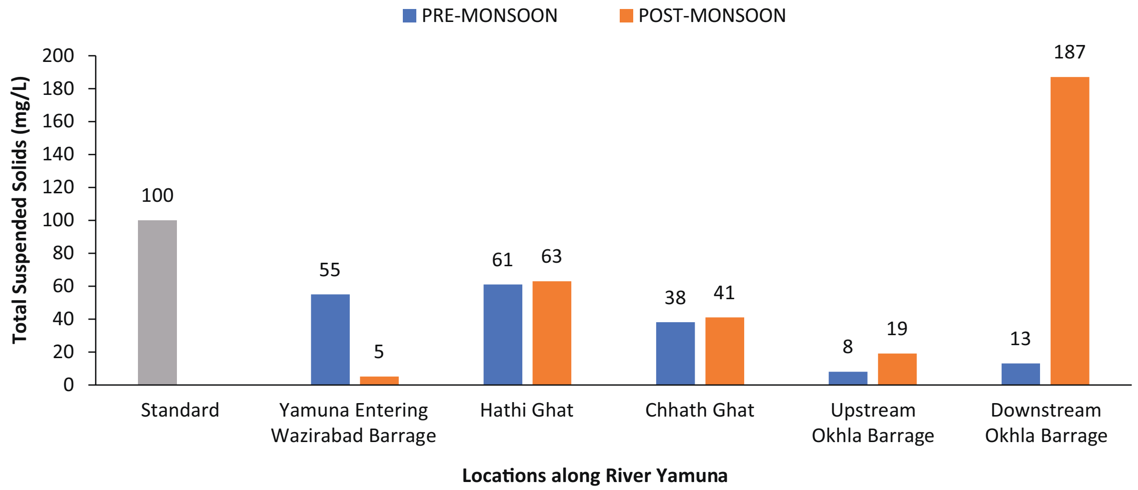
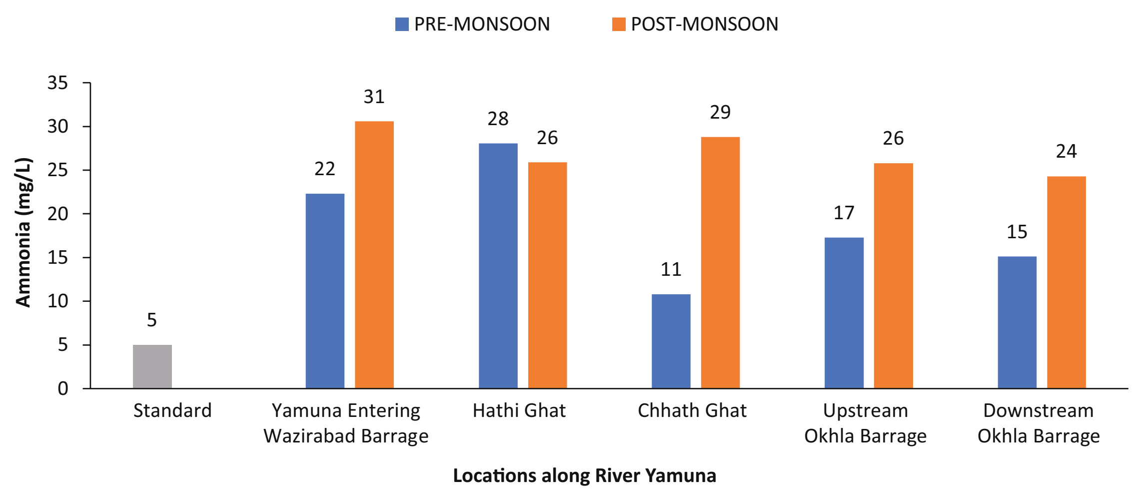


Figure 51: Concentration of Suspended Solids of River Yamuna at Different Locations

- The total suspended solids at different locations in River Yamuna have been found ranging from 5–187 mg/L (as shown in Figure 51), indicating all location comply with the limits prescribed by DPCC having TSS <100 mg/L, except at the downstream of Okhla barrage during post monsoon season.
- Compared to the pre-monsoon results, TSS at downstream Okhla Barrage increased from 13 mg/L to 187 mg/L (approx. 15 time), likely due to higher inflow and the accumulation of solid waste from rainfall runoff near the barrage.

4. Nutrient Levels (Ammonia & Phosphate Concentration)



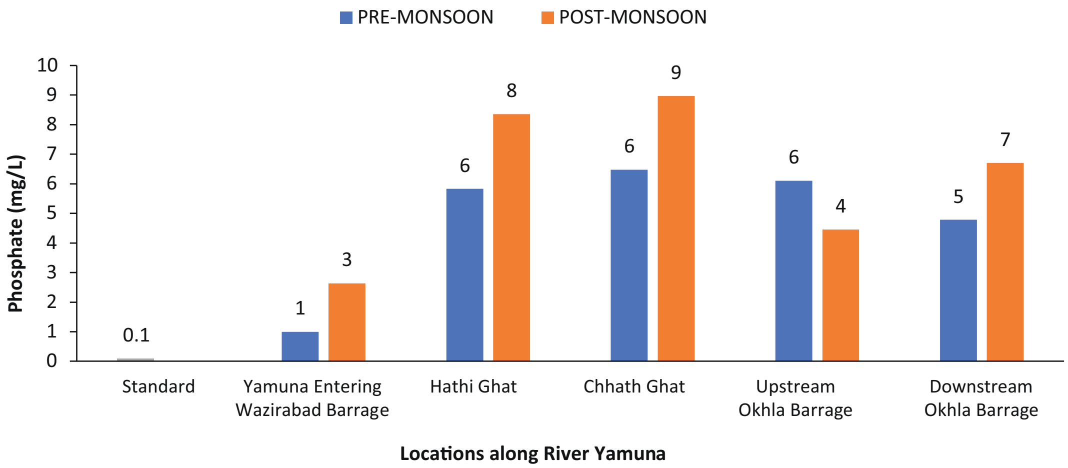


Figure 52: Concentration of Ammonia and Phosphate in River Yamuna at Different Locations

- The ammonia concentration in the river water was found increased during post-monsoon sampling period and exceeds from the prescribed limits of 5 mg/L as per CPCB standards (Figure 52).
- Phosphate concentration was also found to be increased during the post-monsoon period. The high phosphate concentration observed at Hathi Ghat and Chhath Ghat may be connected to the various religious activities and other human activities of bathing and washing at these ghats.
- The elevated levels of ammonia and phosphorus, acts as nutrients and can stimulate the growth of algae, aquatic plants like water hyacinth, and other microorganisms leading to algal blooms. The decomposition of these aquatic plans and micro-organism in natural system can release organic compounds and bio-surfactants, contributing to foam.[28]

5. Sodium Tri-Poly-Phosphate (STPP)

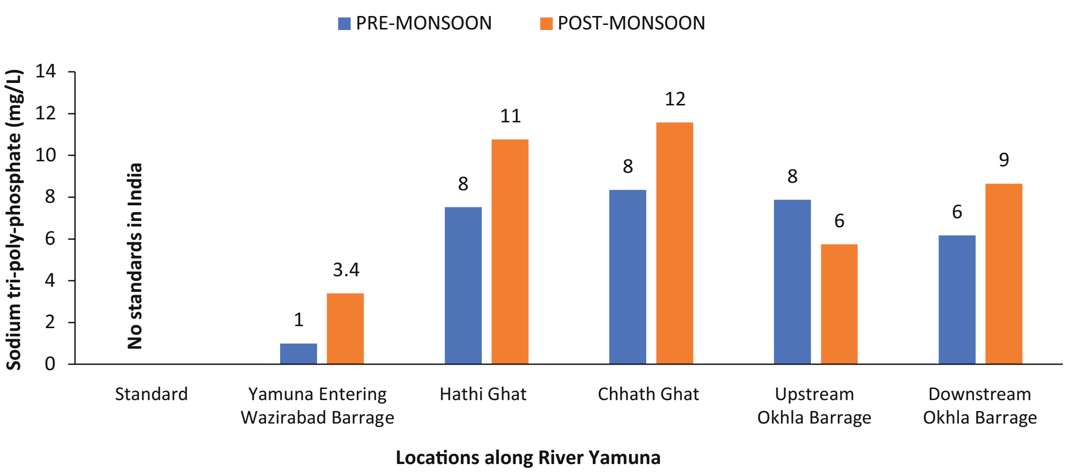


Figure 53: Sodium tri-poly-phosphate (STPP) concentration along River Yamuna

28 R. Das, H.N. Chanakya, L. Rao, Study towards understanding foaming and foam stability in urban lakes, J. Environ. Manage. 322 (2022), https://doi.org/ 10.1016/j.jenvman.2022.116111.

➢ Sodium Tri-poly-phosphate (STPP) is a stable chemical agent commonly used as an ingredient in detergents and cleaning agents. It is a phosphorus-containing compound widely used in detergents and cleaning products when discharged into waterways through sewage, STPP breaks down into phosphate, which are the primary agents responsible for foam production[29].

➢ During the post-monsoon sampling, elevated concentrations of STPP (Sodium Tripolyphosphate) were observed at all locations along the river stream (Figure 53). This increase can except upstream of Okhla barrage which can be attributed to enhanced streamflow during the monsoon, which disturbs the bottom sediments. As a result, phosphate ions previously adsorbed onto these sediments are resuspended and released back into the water column, leading to higher STPP levels.

6. Fecal Coliform

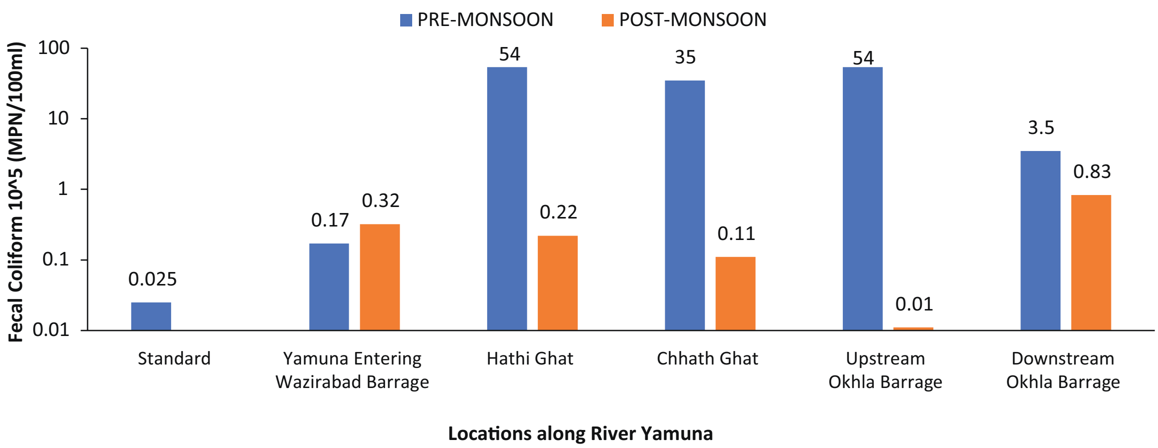


Figure 54: Trend of Fecal Coliform Count along River Yamuna.

➢ The Fecal coliform count (Figure 54) in the Yamuna River at all locations except Upstream Okhla barrage has been found to be exceeding the prescribed limit of 2500 MPN/100 mL as per CPCB norms.[30]

➢ Though, the fecal coliform count has significantly decreased in the post-monsoon sampling, yet the prevalence of fecal coliform bacteria at these recorded levels may contribute to foam formation. These bacterial colonies produce biosurfactants from the degradation of organic materials, releasing surface-active compounds responsible for producing biosurfactants and hence contributing to foam formation.[31]

29 Li, Meng, et al. "The significance of phosphorus in algae growth and the subsequent ecological response of consumers." Journal of Freshwater Ecology 37.1 (2022): 57-69.

30 Annexure-I

31 Reshmi Das, Chanakya Hoysall, Lakshminarayana Rao, Insights on foaming in surface waters: A review of current understandings and future directions, Chemical Engineering Journal, Volume 493, 2024, 152472, ISSN 1385-8947

7. Synthetic/Anionic Surfactant Concentrations

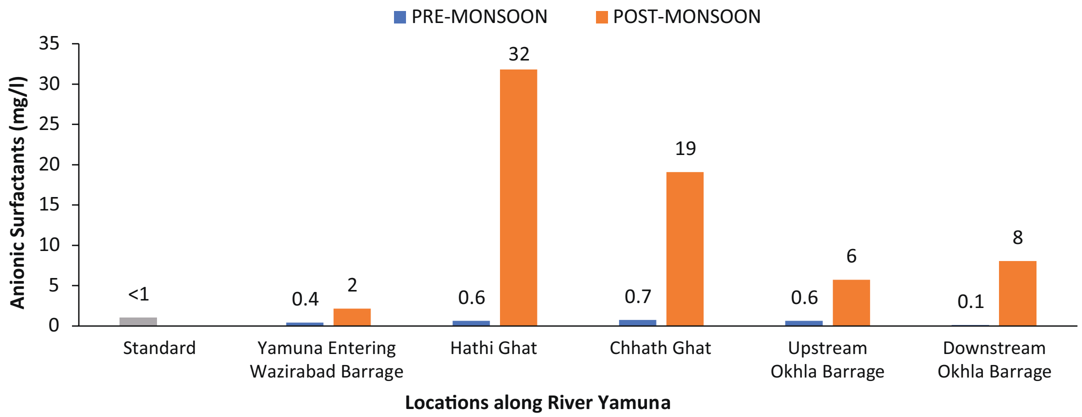


Figure 55: Concentration of Anionic Surfactants in River Yamuna

- Anionic surfactants are widely used in various cleaning, detergent, and personal care products due to their excellent ability to produce rich lather and effectively remove grease, oil, and other contaminants.
- The concentration of anionic surfactants recorded in the river stretch (Figure 55) indicates that, except for Upstream Wazirabad Barrage (East), all locations exceeded the limit of <1 mg/L. Notably, the concentration increased during the post-monsoon period, suggesting slower degradation of anionic surfactants in the river ecosystem due to temperature changes. This also indicates the possibility of persistent foam formation, which is exacerbated during winter seasons.

8. Natural Surfactant (Saponin) Concentration

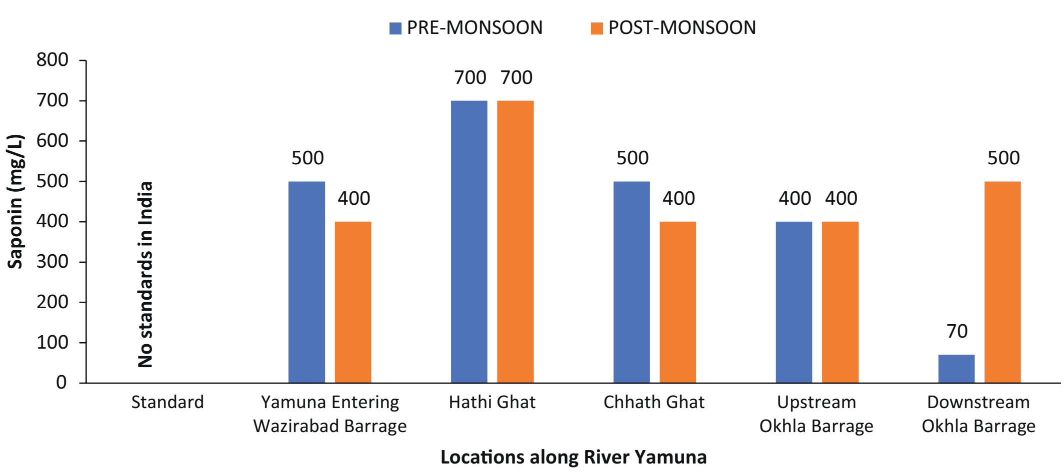


Figure 56: Saponin concentration in water carried by River Yamuna

- In the river water, the concentration of saponin ranges from 400–700 mg/L sample as shown in Figure 56. There are no prescribed standards for saponin concentration in India. However, as per literature saponin concentration greater than ~1800 ng/L max[32] (0.0018 mg/L) in Rivers can cause foaming.

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32 Insights on foaming in surface waters: A review of current understandings and future directions – Science Direct

- At Hathi ghat, high saponin concentrations 700 mg/L; is the indicator of bio-surfactants which are released due to the decomposition of aquatic and microorganisms present in the river water.
- A type of aquatic plant *Eichhornia crassipes* aka Water hyacinth has been visually observed in the entire stretch of the river and in large volumes nearby Hindon cut canal i.e. eastern side of the river, Upstream of Wazirabad barrage which may be responsible for the presence of high concentration of saponin in Yamuna River.
- Though efforts have been undertaken for hyacinth removal, it must be noted that the source of hyacinth is continuously incoming from the Najafgarh and associated drains which are infested with this aquatic plant growth.

Mapping and Analysis of Water Pollution Sources and Outbreak Incidents in Delhi

4 Mapping and Analysis of Water Pollution Sources and Outbreak Incidents in Delhi

4.1 Introduction

Within the National Capital Territory (NCT) of Delhi, the Yamuna functions as the city's principal freshwater lifeline yet also bears the brunt of escalating wastewater discharges. The 48 km stretch through Delhi is particularly stressed due to the mismatch between rising water demand, inadequate treatment infrastructure, and unchecked industrial activity.

Delhi's semi-arid subtropical climate and dense population exert additional pressure on its water system. Despite a raw water supply of 953 MGD distributed across nine Water Treatment Plants (WTPs), persistent shortfalls are evident. For instance, the Sonia Vihar WTP zone faced the largest deficit at 154 MGD, while Nangloi recorded a shortfall of 124 MGD under realistic demand conditions. These supply-demand imbalances extend into wastewater management as well[33].

According to the Monthly Progress Report of the Government of Delhi submitted by the DPCC to the NMCG, the city generates nearly 792 MGD of sewage[34], far surpassing existing treatment capacity. Spatial disparities are stark: the Okhla STP zone received 160–173 MGD of sewage inflow but treated only 140 MGD, whereas Najafgarh generated 105–112 MGD against a capacity of 45 MGD. Khanjawala had no treatment facility at all, discharging 102 MGD of untreated sewage directly into the river. Across zones, untreated sewage loads ranged between 217–325 MGD, with unauthorized colonies and slums contributing disproportionately.

Industrial effluents compound this stress. Numerous small and medium-scale enterprises in electroplating, steel processing, textile dyeing, printing, and battery manufacturing release inadequately treated wastewater. Much of this enters the river via stormwater drains and unlined channels, culminating in nineteen major drains that discharge into the Yamuna. Among them, the Najafgarh, Shahdara, and Supplementary drains remain the most significant conduits of pollution.

Figure 57: Foaming in Yamuna due to Excessive Pollution

33 Urban Water System of the National Capital Territory (NCT) of Delhi: A Comprehensive Study | Water Supply | IWA Publishing

34 59_Delhi – MPR June 2025.pdf

The recurring mismatch between water demand and supply, coupled with gaps in sewage treatment, has made Delhi highly vulnerable to water pollution outbreaks. Episodes of foam formation, ammonia spikes that disrupt drinking water treatment plants, and periodic fish kills exemplify the ecological and health consequences of this persistent problem. Against this background, mapping and analyzing pollution sources and outbreak incidents becomes essential for identifying hotspots, assessing systemic failures, and guiding evidence-based interventions for improved water governance.

4.2 Water Pollution Sources in Delhi

The overlay of Grossly Polluting Industries (GPIs), Sewage Treatment Plants (STPs), Common Effluent Treatment Plants (CETPs), hospitals, and major drains on the composite map reveals a highly clustered distribution of pollution sources across Delhi (Figure 58). A particularly dense aggregation of GPIs is observed in the Western and North-Western industrial belts, including clusters around Wazirpur, Naraina, Anand Parbat, and Bawana. These regions correspond to well-documented water quality degradation zones in the Yamuna, particularly along the Najafgarh and supplementary drains as also observed in this study.

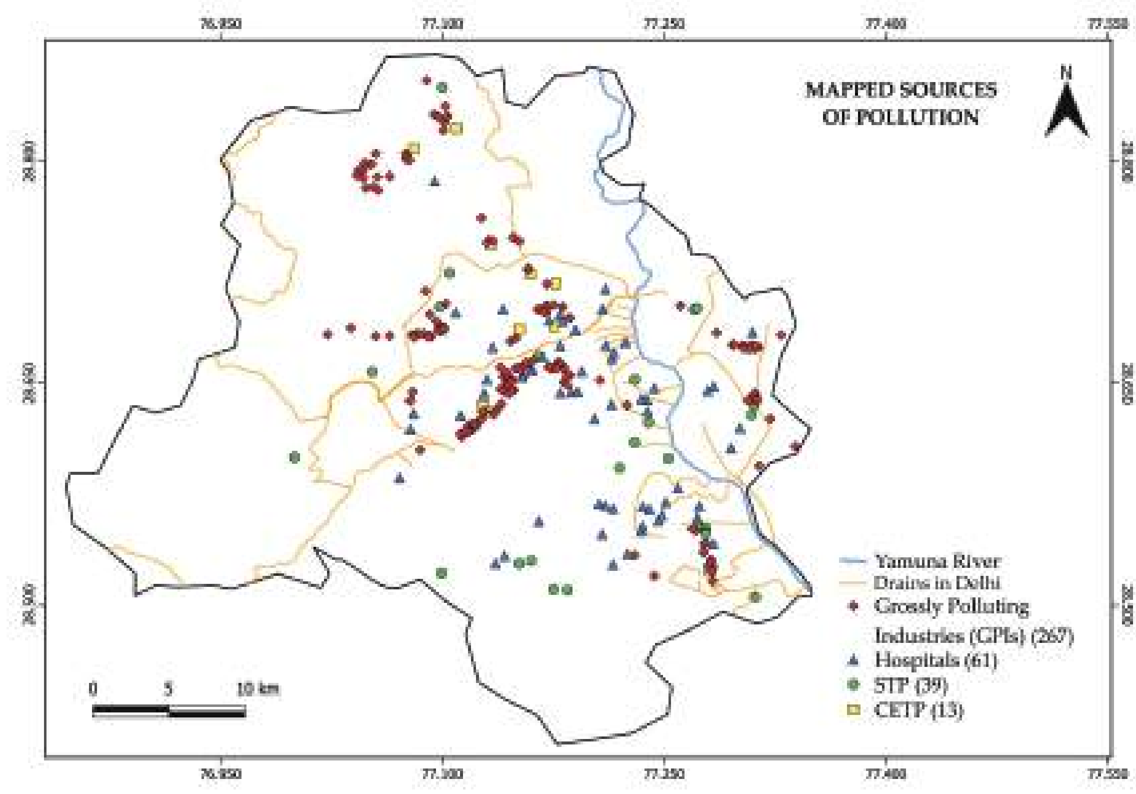


Figure 58: **Major Water Pollution Sources in Delhi**

The proximity of GPIs to major drains suggests a direct pathway for industrial effluents into the Yamuna. Many of these drains were originally designed for stormwater conveyance but are now heavily burdened with untreated industrial and domestic wastewater. This results in high loads of organic matter, surfactants, heavy metals, and nutrients entering the river system at concentrated nodes, leading to localized hotspots of contamination.

4.2.1 Sewage Treatment Plants (STPs) and Common Effluent Treatment Plants (CETPs)

While STPs and CETPs were established to mitigate wastewater discharges, they show uneven distribution and limited efficiency across Delhi. A total of 39 STPs are mapped in the city, but their placement does not adequately correspond with the highest density of polluting sources. Similarly, 13 CETPs cater to 17 approved industrial estates, yet they often operate below capacity or inconsistently, failing to meet prescribed standards. The mismatch between the geographic spread of polluting industries and the available treatment infrastructure underscores a structural gap in wastewater management. Despite expansions in capacity, the sewage treatment deficit remains severe, with nearly 142 MGD of sewage still flowing untreated into the Yamuna through 22 major drains, against a total wastewater generation of approximately 800 MGD

Figure 59: **Sewage Treatment Plant**

4.2.2 Hospitals

Hospitals, though fewer in number compared to industrial sources, contribute significantly to water pollution. Approximately 61 hospitals in Delhi release biomedical effluents, much of which enters sewerage systems or open drains untreated. Their clustering in central and eastern parts of Delhi increases the chemical and microbiological burden on downstream stretches of the Yamuna. Biomedical discharges—often containing pharmaceuticals, pathogens, and hazardous chemicals—pose public health risks while further degrading the river's ecological balance as shown in Figure 60.

Figure 60: Various Types of Hospital Waste

4.2.3 Drains

The 22 major drains emptying into the Yamuna were originally designed for storm water conveyance, but they are now heavily burdened with untreated domestic and industrial wastewater. This has transformed the drains into direct conduits for pollutants, carrying organic matter, surfactants, heavy metals, and nutrients into the river system at concentrated nodes. These inputs have created localized hotspots of contamination, severely impairing water quality downstream of Wazirabad and Okhla barrages. The persistent discharge of untreated sewage through these drains remains one of the primary drivers of Yamuna's deterioration.

4.2.4 Grossly Polluting Industries (GPIs)

The proximity of Grossly Polluting Industries (GPIs) to major drains provides a direct pathway for industrial effluents to reach the Yamuna. Many GPIs, including small- and medium-scale enterprises engaged in dyeing, electroplating, and metal processing, and discharge effluents directly into storm drains or unlined channels. While the Delhi State Industrial and Infrastructure Development Corporation (DSIIDC) monitors 28 approved industrial estates, enforcement remains weak: no systematic data exists on unauthorized industries, many of which are suspected to discharge untreated effluents into drains, bypassing CETPs. This constitutes a major regulatory blind spot that undermines pollution control. Furthermore, legacy industrial pollution persists in the form of toxic riverbed sludge, with elevated concentrations of chromium, copper, lead, nickel, and zinc detected at sites such as Old Iron Bridge, Geeta Colony, and the DND Barrage. Though controlled dredging has been recommended to remove this sludge, concerns remain over potential ecological destabilization.

Figure 61: Grossly polluting industries in Delhi

4.3 Pollution Outbreak Incidents in Delhi

4.3.1 Case Study: Sewage Contamination in Janakpuri's A1 Block

In May 2024, the National Green Tribunal (NGT) pulled up the Delhi Jal Board (DJB) for failing to address severe water contamination in Janakpuri's A1 Block. Water quality testing revealed that 30% of drinking water samples were contaminated with E. coli and fecal coliform bacteria, indicating direct mixing of untreated sewage with potable water supplies. A Central Pollution Control Board (CPCB) report further confirmed that coliforms and E. coli were detected in six out of 20 households sampled, far exceeding permissible limits (which mandate complete absence in drinking water).

The contamination was traced to corroded drinking water pipelines that had been compromised by a choked sewer line, allowing untreated sewage to enter the potable water distribution system. Residents reported chronic issues of foul-smelling and visibly polluted water, and the local Residents' Welfare Association (RWA) filed a plea before the tribunal seeking urgent relief.

The NGT directed the Delhi Jal Board to immediately ensure the supply of clean drinking water to residents through alternate arrangements until the contamination issue was resolved. It further mandated fresh sampling of water on June 30, with a compliance report to be submitted ahead of the next hearing scheduled for July 16. In addition, the tribunal required DJB officials, including the Chief Engineer, to submit an undertaking guaranteeing the implementation of remedial measures, with personal liability in case of failure. The bench strongly criticized the DJB's casual and delayed response to a problem that had already persisted for over three months, noting that such inaction in the face of confirmed E. coli and fecal coliform contamination posed a direct and unacceptable threat to public health.

4.3.2 Case Study: Illegal Denim Dyeing Units at Meethapur, Delhi

This case study examines the environmental and health impacts of illegal denim dyeing units operating in Meethapur village, located near the Delhi–Mumbai Expressway in southeast Delhi. Although these units are hidden behind locked gates, evidence of their activities can be observed through freshly dyed jeans drying on rooftops and drains running deep blue with untreated effluents. The dyeing process, while producing fashionable blue denim, is highly resource-intensive and environmentally unsustainable. It consumes thousands of litres of water and relies on synthetic indigo dye, which does not dissolve naturally and must be treated with strong chemicals such as hydrochloric acid, hydrogen peroxide, sulfuric acid, caustic soda, formic acid, surfactants, and salts. Without effluent treatment plants, these units discharge their chemical-laden wastewater directly into the village drains, which eventually converge into Bhatte Johad pond and later find their way into the Yamuna River.

Figure 62: Illegal Dying units in Meethapur[3]

The discharge of such toxic effluents has had multiple environmental consequences. The drains and pond in Meethapur have turned visibly blue, while contaminated wastewater has seeped into the soil and groundwater. The presence of heavy metals, carcinogenic substances, and phosphates not only deteriorates water quality but also contributes to the foaming and frothing observed in certain stretches of the Yamuna. Colloidal matter and chemical residues increase turbidity, inhibit sunlight penetration, and reduce the self-purifying capacity of the river. These factors have severely disrupted aquatic ecosystems and undermined the carrying capacity of the Yamuna.

Residents of Meethapur have reported a range of health issues linked to this pollution. People frequently complain of itchy throats, burning eyes, skin irritation, coughing, and nausea when passing near the contaminated drains. A foul odour lingers in the locality, and during rainfall, roads become inundated with dark, ink-like wastewater, intensifying human exposure to toxic chemicals. Despite some earlier crackdowns in 2006, new units continue to emerge, with landlords renting out premises at high rates to operators of such units.

Regulatory agencies and environmental groups have acknowledged the gravity of the situation. The Delhi Pollution Control Committee (DPCC) has officially declared denim dyeing and washing units as highly polluting industries and claims to seal one or two such units daily, though enforcement remains inconsistent and ineffective. Experts from the Centre for Science and Environment (CSE) stress that sewage treatment plants in Delhi lack the capacity to treat chemical effluents, meaning untreated toxic substances flow directly into the Yamuna. Activists, including members of the South Asia Network on Dams, Rivers, and People, emphasize that these pollutants damage aquatic life and worsen frothing in the river.

Recognizing the seriousness of the problem, the National Green Tribunal (NGT) directed a joint inspection by the DPCC and the Central Pollution Control Board (CPCB) in Meethapur and nearby areas, and ordered action against polluting units. However, recurring violations indicate that regulatory actions are piecemeal and that illegal operations persist.

The case highlights the urgent need for stronger enforcement of environmental regulations, relocation of dyeing activities to designated industrial zones, and the establishment of common effluent treatment plants (CETPs) specifically for textile industries. Continuous monitoring of surface and groundwater in the region is essential, along with community awareness programmes to inform residents about health hazards. Unless strict and sustained measures are implemented, Meethapur's illegal dyeing units will continue to threaten human health, degrade soil and water quality, and further burden the fragile Yamuna ecosystem.

4.3.3 Case Study: Illegal Denim Dyeing Units in Shiv Vihar and Shanti Nagar (Delhi–UP Border)

This case study examines the environmental and health impacts of illegal denim dyeing units operating in Shiv Vihar, East Delhi, and adjacent Shanti Nagar in Uttar Pradesh. While these factories were officially sealed following Delhi High Court orders and a Central Bureau of Investigation (CBI) inquiry into regulatory lapses, evidence of their activities persists. Though their front entrances remain shut and sealed, hidden backdoors in adjoining lanes of Uttar Pradesh allow operations to continue. The drains in Shiv Vihar still run deep blue the unmistakable pigment of denim dye indicating ongoing effluent discharge.

The dyeing process, while producing the globally popular blue denim, is highly resource-intensive and environmentally destructive. It requires thousands of litres of freshwater and the use of synthetic indigo dye, which is not naturally soluble and therefore treated with hazardous chemicals such as hydrochloric acid, hydrogen peroxide, sulfuric acid, caustic soda, formic acid, surfactants, and salts. With no effluent treatment plants (ETPs) in place, the untreated wastewater is discharged directly into narrow drains that flow into the Yamuna River. The continued discharge of effluents from these units has turned local drains visibly blue and caused severe contamination of both surface and groundwater. Heavy metals, persistent organic compounds, and phosphates present in the wastewater not only degrade water quality but also contribute to foaming and frothing observed in certain stretches of the Yamuna.

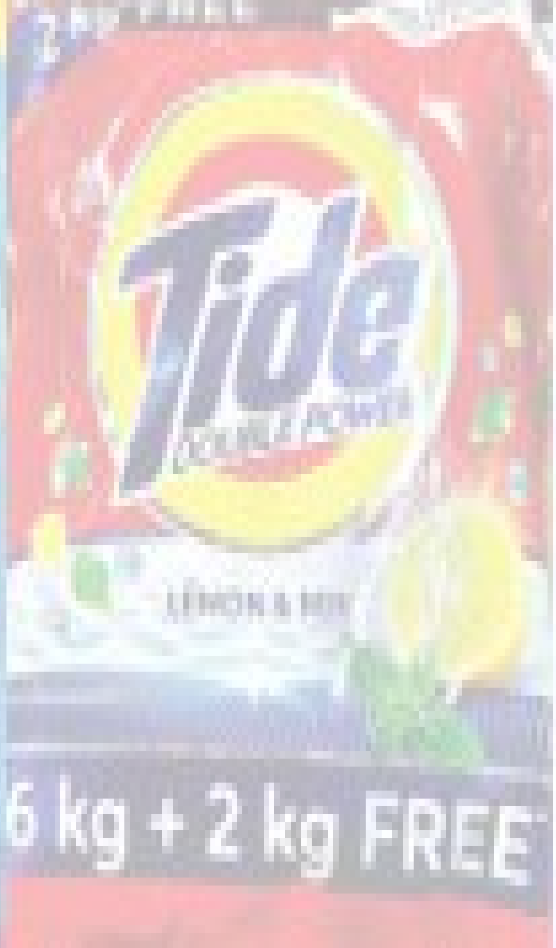
Figure 63: Drain in Shiv Vihar Carrying Dye Effluent[35]

Chemical residues increase turbidity, reduce light penetration, and suppress the river's self-purification capacity, thereby undermining aquatic ecosystems. The local workforce, primarily composed of migrant labourers, operates under unsafe and exploitative conditions. Workers handle chemicals with bare hands and without protective gear, resulting in frequent cases of skin irritation, respiratory problems, and other health disorders. For nearby residents, exposure to contaminated drains has caused complaints of burning eyes, itching, coughing, and nausea. Groundwater pollution further exacerbates risks by threatening potable water sources.

While Delhi's Master Plan prohibits industrial activity in unauthorized or unregularised colonies, enforcement remains weak in practice. The Delhi High Court's crackdown forced units to relocate—not to formal industrial zones, but just across the border into Uttar Pradesh, effectively beyond Delhi regulators' jurisdiction. This jurisdictional loophole has allowed operators to bypass enforcement while continuing to discharge effluents into the same shared drainage channels. The Delhi Pollution Control Committee (DPCC) and Central Pollution Control Board (CPCB) have acknowledged the problem but face limitations in regulating illegal and cross-border operations. The reasoning often cited is that "illegal factories do not exist in records," and therefore notices or compliance measures cannot be formally issued—leaving entire settlements like Shiv Vihar and Shanti Nagar outside the enforcement net.

35 Narain, S. (2019, February 14). Pollution's underbelly. Down To Earth. Retrieved [date of access], from Down To Earth website


Henko


Tide
LEMON & MINT
6 kg + 2 kg FREE


Rin
5 kg BUDGET PACK


Rin

Detergents and Its Environmental Impact -Indian Perspective

5 Detergents and Its Environmental Impact -Indian Perspective

5.1 Detergents and their Impact on Aquatic Life

Detergents are complex chemical formulations primarily composed of surfactants, which can be anionic (e.g., linear alkylbenzene sulfonate – LAS), cationic (e.g., benzalkonium chloride), or non-ionic (e.g., alkyl polyglycosides)[36]. They also include additives such as polyphosphates, silicates, enzymes, bleaching agents, dyes, and perfumes to enhance cleaning performance[37]. These detergents are widely used in households and industries, with significant quantities eventually entering aquatic environments through wastewater discharges. The presence of detergents in aquatic environments leads to chronic exposure for a wide range of organisms across different trophic levels, causing significant ecological harm. Toxicity assessments using LC_{50}R and EC_{50} values have demonstrated that detergents adversely affect aquatic organisms. The anionic surfactant LAS exhibited the highest toxicity, with LC_{50} values as low as 0.263 mg/L, followed by commercial detergents formulated for dishwashing and laundry. Moreover, detergent additives such as polyphosphates promote eutrophication, while enzymes, perfumes, and dyes have been linked to genotoxic effects and tissue damage in aquatic species[38].

As Detergents have become an indispensable part of modern life, with India's detergent industry being worth thousands of crores of rupees (Singh et al., 2014). The Indian context presents unique challenges due to rapid urbanization, increasing detergent consumption, and inadequate regulatory enforcement of detergent quality standards[39].

36 Bajpai, Divya. "Laundry detergents: an overview." *Journal of oleo science* 56.7 (2007): 327–340.

37 Kogawa, Ana Carolina, et al. "Synthetic detergents: 100 years of history." *Saudi pharmaceutical journal* 25.6 (2017): 934–938.

38 Sobrino-Figueroa, A. "Toxic effect of commercial detergents on organisms from different trophic levels." *Environmental Science and Pollution Research* 25 (2018): 13283–13291.

39 A Critical Analytical Study on Certain Popular Indian Detergent Powders with Respect to the Related BIS Specifications and Their Environmental Impact

5.2 Composition and Environmental Impact of Conventional Detergents in India

The study by Singh et al. (2014)[40] analysed eleven popular Indian detergent brands and found several concerning components with environmental consequences shown in Figure 64.

S. No.	Brand Name	% Active Ingredient	Total Alkalinity (as % Na2CO3)	Insoluble Matter (Calcite, Kaolin, Pyrophyllite, etc.)	Presence of Phosphate
1	Tide	10.1	22	3.1	Nil
2	Surf Excel	18	22	11.56	Nil
3	Rin	15.87	26.28	17.12	Nil
4	New Super Check	9.37	32.25	26.56	Nil
5	Active Wheel Lemon	12.9	27	32.2	Nil
6	Nirma Advance	14.01	39.6	16.08	Present
7	Patanjali (Herbal)	12	37.2	26.25	Nil
8	Superior Plus	9.9	27.6	27.95	Present
9	Ghadi	11.45	35.14	17.62	Nil
10	Surf Excel Quick Wash	21.13	38.3	20.27	Present
11	Teen Ikke	11.1	32.21	33.35	Nil

Figure 64: Analysis of Various Commercial Detergent Based on their Composition of Active Ingredients, Insoluble Matter and Presence of Phosphates

Source: Singh et al., 2014

40 Singh, Johar Sarabjeet, et al. "A Critical Analytical Study on Certain Popular Indian Detergent Powders with Respect to the Related BIS Specifications and Their Environmental Impact." *Universal Journal of Environmental Research & Technology* 4.4 (2014).

Researcher Singh et al. in his study highlighted several critical environmental concerns associated with detergent constituents in Indian market formulations. Active matter (surfactants), present at concentrations between 10.10% and 21.13%, were identified as foam-producing agents and can also adversely impact the aquatic life even at concentrations as low as 5 ppm. Chronic exposure to surfactants at 0.01 mg/L has been found to cause toxicity in various aquatic organisms[41]

The study also detected phosphates in 3 out of 11 detergent samples, notably in Nirma Advance, Superior Plus, and Surf Excel Quick Wash. Phosphate based detergents contribute significantly to eutrophication, stimulating excessive algal growth that leads to oxygen depletion and the potential collapse of aquatic ecosystems. Such consequences were observed in the Lower Ganga Canal near Kanpur, where algal blooms and fish mortality were linked to phosphate pollution[42]. Furthermore, water-insoluble mineral matter—comprising fillers such as calcite, kaolin, and pyrophyllite—was found in 10 out of 11 samples, ranging from 3.10% to 33.35%. These fillers accumulate in riverbeds, causing sedimentation, reducing water depth, and increasing the risk of flooding. All detergent samples also exhibited high alkalinity, with pH values between 10 and 11 and total alkalinity (as Na_2CO_3) ranging from 22.00% to 39.60%. Such elevated alkalinity can disrupt the natural pH balance of aquatic systems, affecting aquatic life and biodiversity.

41 Qing, Qing, Bin Yang, and Charles E. Wyman. "Impact of surfactants on pretreatment of corn stover." *Bioresource technology* 101.15 (2010): 5941–5951.

42 Singh, Johar Sarabjeet, et al. "A Critical Analytical Study on Certain Popular Indian Detergent Powders with Respect to the Related BIS Specifications and Their Environmental Impact." *Universal Journal of Environmental Research & Technology* 4.4 (2014).

Requirements for Laundry Detergent Bars (*Clauses* 5.4, 7.3.1 *and* 8.1)							
Sl No.	**Requirements**	**Requirements**				**Method of Test, Ref**	
	Characteristics	**Grade 1**	**Grade 2**	**Grade 3**	**Grade 4**	Annex to IS 4955	Annexof this standard
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Active ingredient percent by mass, Min	16	14	12	10	B	-
ii)	Total phosphate (as P_2O_5), percent by mass Max (See notes 1 and 2)	5	8	5	5	D	-
iii)	Active alkalinity (ml of 0.1 N HCl to titrate 50 ml of 1% product solution to phenolphthalein end point), Max	10	12	15	20	-	B
iv)	Percent detergency, Min	65	55	45	35	G	-
v)	Ash built up, percent, Max	1	5	10	12	H	-

NOTES:

1. Total phosphate content including phosphate-based builder (as recommended in Annex A) shall not exceed 5% by mass for Grade I, Grade III, and Grade IV 10% by mass for Grade II
2. Use of Zeolite (see IS 15267) is recommended as an alternative and substitute for phosphate-based builder.

Figure 65: Requirements of Laundry Detergent as per BIS standards

(Source: BIS 8480:2020)

5.3 Alternatives of Phosphate and Sulphate Based Detergents

The majority of commercially available detergents do not disclose their complete ingredient composition, which makes it difficult to ascertain the type of builder base or surfactants used in their formulation. However, based on available literature and market analysis, it is evident that most of these detergents are phosphate or sulphate-based. Such chemical formulations are known to pose significant environmental threats, particularly to aquatic ecosystems. Phosphates, for instance, are a major contributor to eutrophication, a process that leads to excessive algal blooms, oxygen depletion, and the eventual degradation of water bodies. Sulphates and other synthetic chemicals used in detergents further exacerbate water pollution by affecting aquatic life and compromising water quality. A review of commonly used detergent brands in the Indian market (Table 18) reveals that widely used products such as Tide, Surf Excel, Rin, Ariel, Henko, and even herbal variants like Patanjali's detergent are either phosphate or sulphate-based. These products, although economically priced and readily available, contribute to the growing load of chemical pollutants in stewater, which ultimately finds its way into rivers, lakes, and groundwater sources.

Figure 66: **Packaging of Commercially Available Laundry Detergents that are Sold in the Market Without any BIS mark.**

Table 18: Cost Comparison of Various Commercial Phosphate-based Detergents and their Alternatives using Eco-Friendly Compositions

Phosphate and Sulphate-Based Detergents			
S. No.	**Brand Name**	**Manufactured by**	**Cost/kg**
1	Tide	Procter & Gamble, Mumbai	110
2	Surf Excel	Hindustan Unilever Ltd. (HUL) Mumbai	128
3	Rin	Hindustan Unilever Ltd. (HUL) Mumbai	96
4	Ariel	Procter & Gamble, Mumbai	190
5	Patanjali (Herbal wash)	Patanjali Ayurveda Ltd., Haridwar	70
6	Henko	Jyothi Labs Limited	130
Eco-Friendly alternative options			
1	Coco Custo	Custo Home India Pvt. Ltd.	395
2	Beco	Kaps Hygiene Pvt Ltd.	199

In contrast, a new segment of alternative, eco-friendly detergents, is gradually emerging in the market. Brands such as Coco Custo and Beco have introduced plant-based formulations made from renewable sources such as coconut and corn, and incorporate natural enzymes for effective cleaning. These products emphasize transparency by listing their ingredients openly on their websites. Notably, Beco has been certified by "Ecocert", an international certification body that ensures products are derived from natural and sustainable resources, and are free from petrochemical and synthetic compounds.

Despite their clear environmental advantages, these eco-friendly detergents are often priced significantly higher than their conventional counterparts. Coco Custo, for instance, is priced at ₹395 per kilogram, while Beco is available at ₹199 per kilogram, substantially higher than mainstream brands that range between ₹70 to ₹190 per kilogram (Figure 67). The elevated cost of eco-friendly detergents can be attributed to several factors. Firstly, the market for such products remains niche, with limited consumer awareness and demand. Secondly, the sourcing of natural, sustainable raw materials, as well as the certification processes involved, can be relatively expensive. As a result, the economies of scale that benefit mass-produced chemical detergents are not yet applicable to eco-friendly alternatives.

To ensure a wider adoption of environmentally sustainable cleaning products, it is imperative to promote such alternatives through public awareness campaigns, policy support, and market incentives. Government and regulatory bodies can play a significant role by offering subsidies or tax benefits to manufacturers of eco-friendly products and encouraging green labelling and certification standards. Additionally, consumers must be educated about the long-term environmental costs associated with phosphate and sulphate-based detergents, and the need to shift towards more sustainable options. Hence, while eco-friendly detergents currently face challenges in terms of pricing and market penetration, their promotion and incentivization are essential steps toward reducing chemical pollution in our water systems and fostering a circular, environmentally conscious approach to everyday household practices.

Figure 67: Eco-Friendly alternative options available in the Indian Market

SPECIAL CASE: Okhla Barrage

6. Special Case: Okhla Barrage

The stable foam presence and persistence at the downstream of Okhla Barrage on the Yamuna River in Delhi, India, has been a recurring phenomenon since last decade. Large masses of froth accumulate at the downstream of Okhla barrage, often covering significant portion of the river's surface, gradually disappearing several kilometres downstream.

A comprehensive study was conducted for the analysis of water quality parameters upstream and downstream of the Okhla Barrage on the Yamuna River to investigate the underlying causes of foam formation, a persistent environmental issue specific to this location. Sampling was conducted over five months, spanning from 30th May 2024 to 13th December 2024, to capture seasonal variations in pollutant concentrations. There is a visible variation in the location can be observed at the Okhla barrage. While during summer seasons, a huge accumulation of hyacinth can be observed at the barrage, it clears up during October and early November. However, the hyacinth starts to build up again during December. This indicates that hyacinth is incoming from upstream of the river and should be removed regularly from the river stream.

A continuous stream of lean foam is observed downstream of the barrage, even when the barrage gates remain closed, indicating persistent pollution at the upstream stretch. However, the extent of foaming significantly increases when the barrage gates are opened to release excess water from the upstream side.

Visual documentation of the site across different dates demonstrates this seasonal variability in both upstream and downstream conditions shown in Figure 69–70. On 30th May 2024 and 26th July 2024, the upstream region is visibly clogged with dense growth of water hyacinth, indicating prolonged stagnation and eutrophication.

However, by 25th October 2024, upstream hyacinth has been cleared, and correspondingly, the downstream area exhibits intense foaming—suggestive of the release of accumulated organic matter. This foaming condition is extreme and widespread again on 6th November 2024, when water is visibly frothy under the barrage bridge and farther downstream.

Figure 69: **Upstream and Downstreams of Okhla Barrage Observed on Various Sampling Dates**

Figure 70: **Upstream and Downstreams of Okhla Barrage Observed on Various Sampling Dates (Contd.)**

The situation moderately improves by December 2024, but the reappearance of hyacinth on the upstream, and accumulation occurs. The pollutant parameters analysed for upstream and downstream of Okhla Barrage River water samples have been provided in Table 19–20, and analysis of results have been provided in Figure 71–72.

Results and Inference

1) Okhla Upstream River Water Samples

Table 19: Pollutant Parameters Analysed for Upstream Okhla Barrage River Water Samples

Sampling Date	DO	BOD	COD	TSS	Ammonia	Nitrate	Phosphate	Fecal Coliform	Saponin	SLS	STPP	Anionic Surfactant
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100 mL	mg/L	mg/L	mg/L	mg/L
30-05-2024	Nil	15	54	8	17.3	6.3	6.11	5.4×10^6	400	<10	7.8	0.62
26-07-2024	0.1	18	107.8	16.5	13.9	2.28	1.78	-	700	<10	2.3	0.07
25-10-2024	3.1	15	61.2	299	18.2	12.3	8.34	2.2×10^5	100	<10	10.81	0.19
06-11-2024	3.4	12	51	12	12.2	8.4	4.215	-	500	<10	5.44	<0.1
13-12-2024	3.2	27	78	19	12.5	17.64	4.455	6.8×10^4	400	<10	<10	5.72

Table 20: Pollutant Parameters Analysed for Downstream Okhla Barrage River Water Samples

Sampling date	DO	BOD	COD	TSS	Ammonia	Nitrate	Phosphate	Fecal Coliform	Saponin	SLS	STPP	Anionic Surfactant
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100 mL	mg/L	mg/L	mg/L	mg/L
30-05-2024	3.2	12	52	13	15.1	15	4.78	3.5×10^5	700	<10	6.17	<0.1
26-07-2024	4.4	26	78.4	24	14.6	1.96	1.67	-	500	<10	2.15	<0.1
25-10-2024	3.5	12	51	353	18.2	14.3	7.19	9.2×10^5	100	<10	9.28	0.24
06-11-2024	3.8	11	40.8	16	13.4	11.2	4.187	-	510	<10	5.4	<0.1
13-12-2024	3.5	16	49	187	24.3	8.6	6.705	8.3×10^4	500	<10	<10	8.03

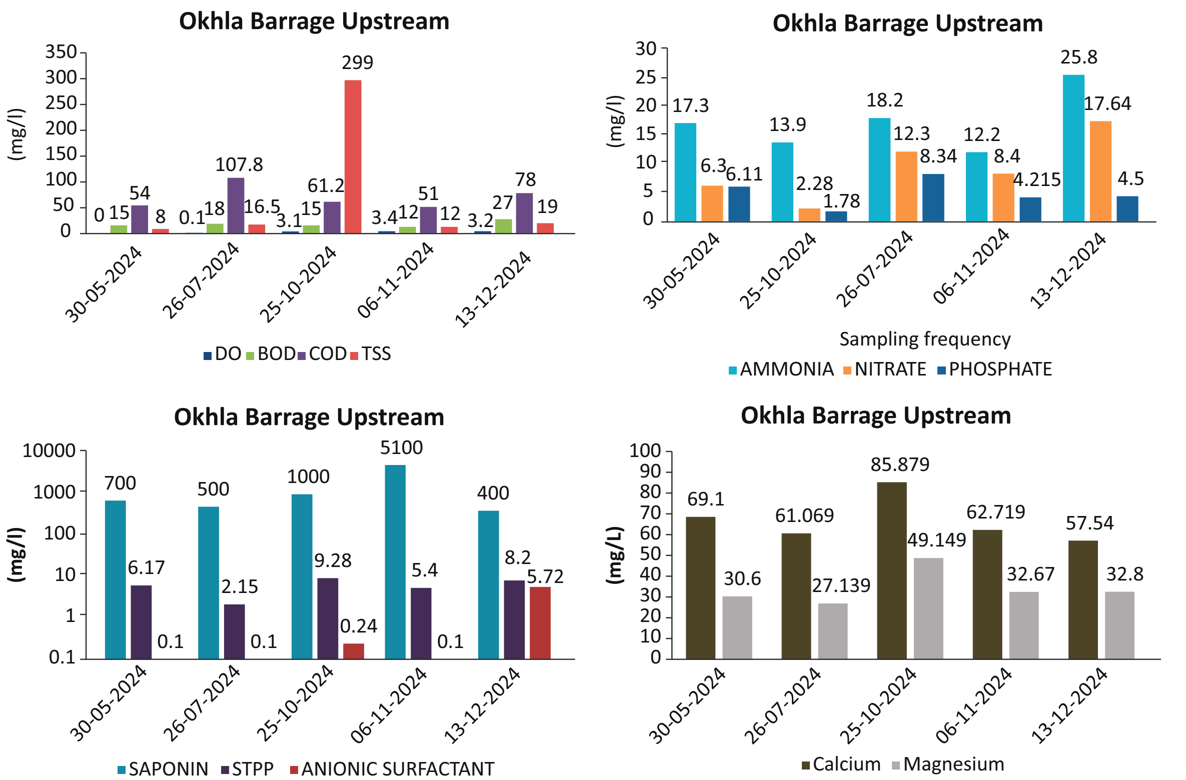


Figure 70: Pollutant Parameters in Upstream of Okhla Barrage

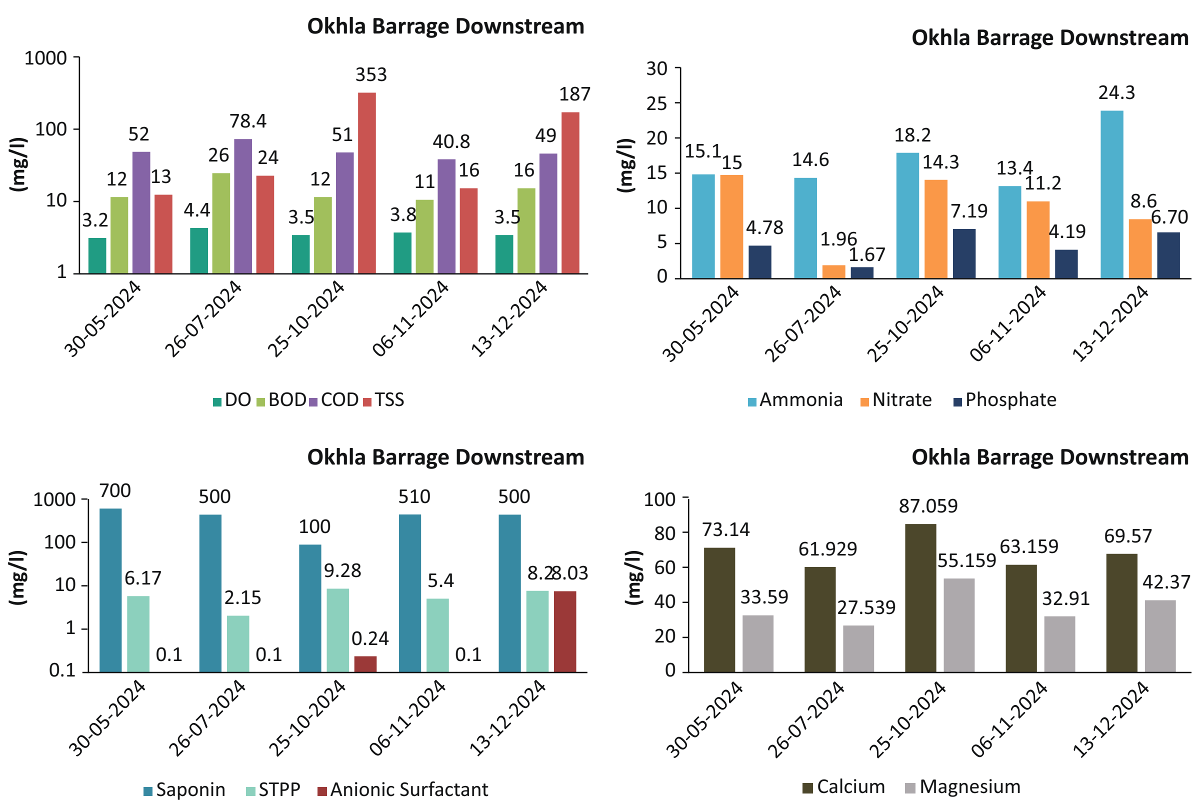


Figure 71: Pollutant Parameters in Downstream of Okhla Barrage

Analysis of Pollutant Parameters in Upstream and Downstream of Okhla Barrage.

Sr. No	Analysis Parameters	Upstream Okhla Barrage	Downstream Okhla Barrage
1.	Dissolved Oxygen (DO)	**Trend**: DO levels show a gradual increase over time, starting from 0 mg/L on 30th May 2024 and reaching >3 mg/L by 13th December 2024. **Analysis**: The DO level improves due to enhanced water flow in the river and pollutant dilution during the post-monsoon period.	**Trend**: DO levels at the downstream has been >3 mg/L during all 5 sampling dates. **Analysis**: The comparative high DO in the downstream is due to turbulence caused from flow from small openings and fall of water from a height at the barrage.
2.	Biochemical Oxygen Demand (BOD)	**Trend**: The BOD levels almost doubles during post -monsoon period reaching to 27 mg/L. **Analysis**: The peak BOD level on 6th July 2024 coincides with the onset of the monsoon, suggesting increased runoff carrying organic pollutants into the river. The decline in BOD levels during the post-monsoon period (5 mg/L by December) may reflect dilution effects from increased water flow because of increased rainfall this year and reduced pollutant inputs.	**Trend**: BOD levels downstream show significant fluctuations, starting at 12 mg/L on 30th May 2024, peaking at 26 mg/L on 26th July 2024, **Analysis**: The peak BOD level on 26th July 2024 (26 mg/L) coincides with the monsoon onset, suggesting increased inputs of organic pollutants from runoff. The decline in BOD levels during the post-monsoon period (16 mg/L by December) may reflect dilution effects and reduced pollutant inputs
3.	Chemical Oxygen Demand (COD)	**Trend**: The COD ranges between 50–80 mg/L. **Analysis**: The peak COD level on 26th July 2024 aligns with the monsoon onset, suggesting increased inflow of pollutants due to operation of Wazirabad and Okhla barrage, due to sudden flow from heavy rainfall during this period.	**Trend**: COD levels downstream show is found diluted compared to upstream. **Analysis**: The peak COD level on **26th July 2024** (78.4 mg/L) aligns with upstream results.
4.	Total Suspended Solids (TSS)	**Trend**: The TSS is approx. 8–16 mg/L, except observed 299 mg/L on a specific date. **Analysis**: The peak TSS level on **25th October 2024** (353 mg/L) suggests increased silt and particulate matter inputs during the post-monsoon period.	**Trend:** The TSS increases in the downstream **Analysis:** This sudden influx in the flow in specific dates caused disturbance in the flow resulting in re-suspension of riverbed resulting in high TDS

Sr. No	Analysis Parameters	Upstream Okhla Barrage	Downstream Okhla Barrage
5.	Saponin	**Trend**: Saponin levels ranges from 400–700 mg/L in both upstream and downstream of Okhla barrage and does not show a seasonal trend. **Analysis**: The saponin levels in the river is resultant of the natural degradation of aquatic plants and filamentous bacteria present in the river. As these are natural sources, they don't particularly show any major seasonal variation	
6.	Anionic Surfactant	**Trend**: Anionic surfactant levels remain <1 mg/L during all season but shows sudden surge in both upstream and downstream during post -monsoon sampling. **Analysis**: At lower temperatures (15–20°C), anionic surfactant degradation slows down, allowing them to persist longer. Winter also sees increased industrial discharge from textile, pharmaceutical, and dairy sectors, along with pollutants from religious activities like mass bathing and idol immersion, Chhath puja etc. further contaminating the banks of Yamuna near Okhla.	

It is important to note that the year 2024 experienced significantly higher rainfall compared to the previous year provide in Figure 73. June 2024 recorded exceptionally high rainfall, exceeding the normal levels by 228% compared to June 2023. Additionally, August 2024 received more than three times the rainfall observed in August 2023, while September 2024 witnessed an even greater surge, with rainfall levels four times higher than those recorded in September 2023. The effect of this rainfall has been observed on the concentration of pollutants.

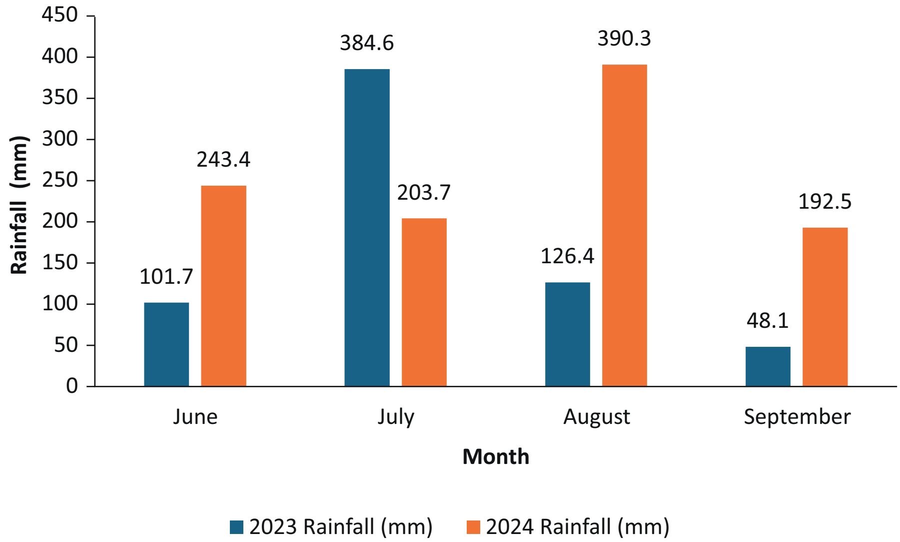


Figure 72: **Rainfall trends observed during year 2023 and 2024**

Role of Water Hyacinth and Yamuna Riverbed on Foaming

To better understand the causes behind the persistent foaming observed downstream of the Okhla Barrage, a focused investigation was carried out involving the collection and analysis of water hyacinth plants and soil samples from the Yamuna riverbed. The aim was to identify both natural and pollutant-based sources of surfactants that contribute to foam formation in the river.

Water hyacinth, a common aquatic plant found extensively along the Yamuna, was analysed for its chemical constituents. The results revealed an alarmingly high concentration of saponin, measured at 32,700 mg/kg. Saponin is a naturally occurring surfactant, and existing literature supports the fact that the decomposition of water hyacinth in aquatic ecosystems releases saponins into the surrounding water. These compounds can significantly increase the surfactant load in the river and may also deposit within the sediments on the riverbed, creating a potential long-term source of natural surfactants.

In parallel, soil samples collected from the Yamuna riverbed on 24th August 2024 were analyzed to assess the level of pollutant deposition. The results highlighted substantial concentrations of substances known to promote foaming. Phosphate levels were recorded at 3,800 mg/kg of soil, while natural surfactant concentrations reached 5,900 mg/kg (on a dry weight basis). In addition, Sodium Tripolyphosphate (STPP), a common industrial and household cleaning agent, was detected at 4,904 mg/kg. These findings indicate a considerable buildup of both natural and synthetic surfactants in the riverbed. When disturbed or resuspended due to changes in water flow or turbulence, these sediments can reintroduce these compounds into the water column, triggering excessive frothing downstream.

Together, the analysis of aquatic vegetation and sediment pollution underscores the combined impact of natural decomposition processes and anthropogenic pollutants in contributing to the foam observed in the Yamuna River. A better understanding of these sources is essential for devising effective strategies to mitigate such environmental issues.

Structure of Barrage & Barrage Gate operation

Beside the accumulation of pollutants at Okhla barrage due to closed gate operation, the structure of the barrage and operation of gates also plays a major role in the foaming incidents. The excessive foaming has been observed particularly when large volume of water is released from the barrage, leading to disturbance of the sludge beds. This causes suspension of high concentration of pollutants including bio-surfactant (saponin) that otherwise remains deposited in the sludge beds leading to high concentration in the downstream water. This combined with high turbulence at the gates due to fall of water at almost height more than 1 m (Figure 74). As per literature[43] the fall due to full opening of barrage may go up to 8.24 m, resulting in very high turbulence, leading to formation of air bubbles. These air bubbles in presence of the high surfactant concentration produce stable foam at the downstream of the barrage. During regular operation of the gates, the slope at the end constructed barrage is responsible for the extended fall of 1m, further leading to the foaming activities.

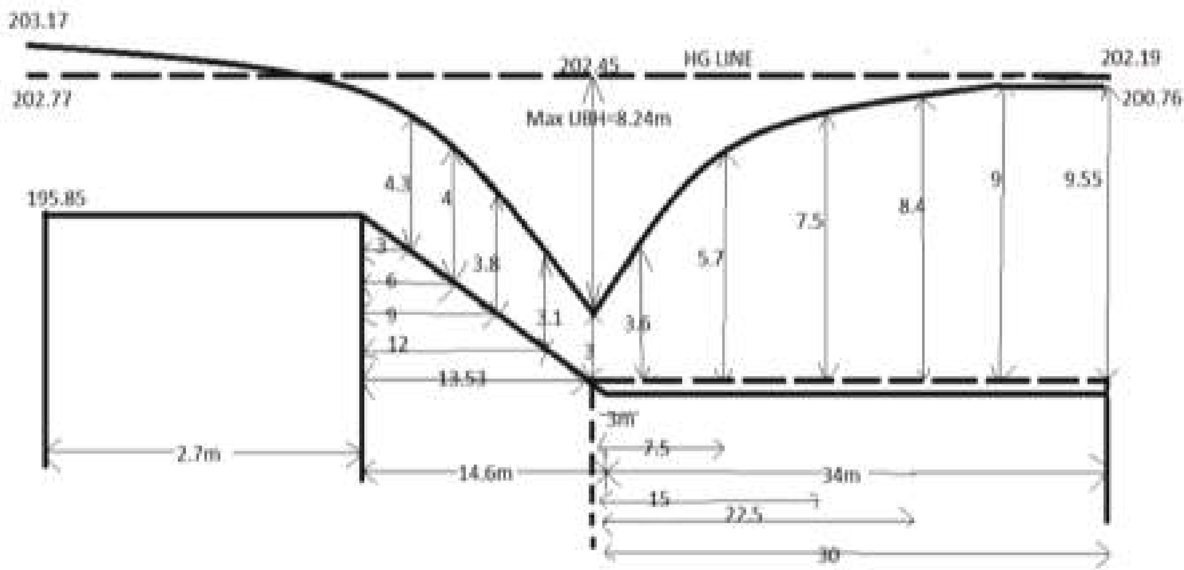


Figure 73: **Barrage Structure and Fall of Water at Barrage due to Artificial Construction[44]**

43 https://www.ijsr.net/archive/v8i11/ART20202521.pdf

44 https://www.ijsr.net/archive/v8i11/ART20202521.pdf

7. Department-Wise Strategic Action Plan under the Project; Study on Yamuna Frothing In Delhi

Froth formation is triggered mainly when three factors come together like poor water quality with high pollution load, higher concentration of surfactants (either bio-surfactant or synthetic surfactants or both), and high-water flow rates due to seasonal variation. Together with the sudden opening of barrage gates at Okhla Barrage and the fall of water from significant height of barrage leads to the disturbance of sludge bed, high turbulence and churning effect in the form of froth in the Yamuna River.

Based on the study and meticulous work carried out by TERI Team, a detailed Strategic Plan for each Department of GNCTD is presented as follows**:**

S. No.	Department/ Agency	Role, Responsibilities and Action Plan
1	Dept. of Environment (DoE), GNCTD	1) This report and key findings could be part of public awareness campaigns, Delhi School & College Curriculum etc. 2) Fund more such projects to address such environmental challenges. 3) Involve research institutions like NMCG-TERI CoE on Water Reuse (NTCoEWR) and their Experts for further studies, pollution control, treatment, monitoring and implementation of the recommendations of this report.
2	Delhi Pollution Control Committee (DPCC)	1) Parameters like ammonia and phosphate need to be added to the current list of five water quality parameters viz. pH, DO, BOD, COD and fecal coliform, which forms part of monthly water quality monitoring exercise from DPCC & CPCB. 2) Detergent formulations should adhere to regulatory standards keeping environmental considerations, and appropriate actions should be taken in case of any violations. 3) It is recommended to display water quality data of Yamuna on the sign boards across major crossings in Delhi just like display of AQI Parameters. 4) To regularly inspect and check operations of Dhobi Ghats which directly discharge laundry wastewater into the Yamuna through specific drains. Decentralized treatment options (DETPS) should be explored with advance wastewater treatment processes such as AOPs, MBR,BNR and membrane filtration. 5) To work closely with BIS towards amendments, quality standards and compliances.

S. No.	Department/ Agency	Role, Responsibilities and Action Plan
3	DPCC along with **Bureau of Indian Standards (BIS), Ministry of Consumer Affairs, Food and Public Distribution**, Government of India & **Association of Detergents Manufacturers**	1) To make a legal binding for all detergent manufacturers that products display the ISI mark only after verification by certified standardization and certification from BIS. 2) There should be mandatory disclosure of entire composition including clear labelling of critical ingredients (including surfactants, builders, fillers, enzymes) over the packaging material of detergents and washing powders. 3) To encourage greener formulations such as use of environmentally benign detergent formulations & builders like zeolite (IS 15267), enzyme-based and trisodium citrate, which are already recommended in IS 8180:2020, incentives such as tax benefits and fast-track approvals for ECO Mark-certified products be provided to the manufacturers & suppliers. 4) Reinstate BIS filler limit of 5% to curb aquatic pollution from excess detergent fillers.
4	Irrigation & Flood Control Department (IFCD), GNCTD	1) To ensure minimum environmental flow and revisit 1994 water sharing agreement between Yamuna basin States. 2) Aerators may be installed at specific locations where the flow in the river Yamuna is poor and/or where water is stagnant like the upstream Okhla Barrage to improve and maintain DO levels >5 mg/l and reduce GHG emissions. 3) High-resolution webcams should be installed at all the barrage gates at Wazirabad and Okhla Barrage to study site-specific factors including the operation of barrage gates, turbulence and incidences of frothing. 4) Remove water hyacinth on regular basis as its presence contributes to very high concentrations of biosurfactants, which together with existing pollution in the river and higher water flows from significant height of barrage, churns out as froth/foam in the river. Also, it is recommended to explore additional, sustainable strategies for their long-term control and possible reuse into some useful materials etc. 5) Conduct regular desilting and waste removal around River Yamuna stretch in Delhi. 6) Implement online water quality monitoring and install flow meters at all drains to prevent untreated sewage discharge. 7) Complete drain tapping projects, curb illegal discharges, and strengthen solid waste management. 8) In drains where tapping is not technically feasible, point source pollution abatement strategies be strictly adhered, which include Decentralized wastewater system (DETPs) and advanced technology interventions etc.

S. No.	Department/ Agency	Role, Responsibilities and Action Plan
5	Delhi Jal Board (DJB), GNCTD	1) As per June 2025 DPCC data (References\DPCC- Monthly Progress Report-June 2025.pdf) ; Delhi has sewage generation of 792 MGD, with an installed capacity of treatment of 764 MGD (96.5%) while treated is 650 MGD (83%). Thus, capacities of STPs could always be augmented with additional infrastructure and Decentralized STPs. 2) Out of 37 operational STPs, 23 are compliant while 12 are non-compliant with regard to Standards prescribed by DPCC (BOD/TSS: 10/10 mg/l) hence it is essential to understand and address non-compliance issues. 3) Assessment of all 37 STPs is required with regular 3rd party assessments and penalised actions should be taken against non-compliant STPs. 4) To enhance efficiency of non-compliant STPs, it is advised to integrate in current STPs advanced technological interventions like Biological Nutrient Removal (BNR). 5) To enhance augmentation capacity of STPs, it is advised to integrate advanced wastewater treatment technologies like Advanced Oxidation Processes (AOPs) based Photocatalysis technology, MBBR and BNR etc. 6) To maintain accurate wastewater data, use of IOTs and digital twins be encouraged, especially during high flow in rainy season and/or bypass events in STPs.
6	Municipal Corporation of Delhi (MCD), GNCTD	1) Implement online water quality monitoring and install flow meters at all drains to prevent untreated sewage discharge. 2) Complete drain tapping projects, curb illegal discharges, and strengthen solid waste management.
7	Delhi State Industrial and Infrastructure Development Corporation (DSIIDC), GNCTD	1) To ensure performance and compliance of all 13 CETPs, to which 17 approved Industrial Areas are connected, it is required to carry out annual adequacy assessment with strict compliance as per Consent to Operate protocols . 2) It is observed that CETPs have heterogeneous nature of effluent as different nature of industries are present in industrial clusters. Advanced wastewater treatment technological like Advanced Oxidation Photocatalysis (AOP), BNR integration should be explored to achieve suitable, sustainable and economical compliance. 3) Illegal dyeing and denim washing units operating in areas such as Meethapur and Peeragarhi contribute significantly to water pollution (Source:Sunday Times of India, New Delhi/Gurgaon, July 28, 2024). A geo-tagged inventory of these units should be developed. These units may either be regularized and equipped with decentralized AOPbased wastewater treatment systems for point-source pollution control.

S. No.	Department/ Agency	Role, Responsibilities and Action Plan
8	Delhi Development Authority (DDA), GNCTD	1) To regularly check direct discharge of untreated sewage from unauthorized colonies and JJ clusters. 2) In areas with limited space and unauthorized clusters, decentralized advanced wastewater treatment options such as Advanced Oxidation Photocatalysis (AOP) technology may be explored. AOP based systems can directly treat municipal or mixed sewage without stream segregation and biological processes, thereby reducing land footprint, treatment time, and overall cost.
9.	**Public Works Departments (PWD), GNCTD**	1) Implement online water quality monitoring and install flow meters at all drains under their jurisdiction to prevent untreated sewage discharge into Yamuna. 2) Complete drain tapping projects, curb illegal discharges, and strengthen solid waste management.
10.	New Delhi Municipal Council (NDMC) / Delhi Cantonment Board (DCB) / Municipal Corporation of Delhi (MCD)	1) To ensure that municipal solid waste is not thrown into the drains and ultimately in river Yamuna.
11.	**Urban Development Department (UDD), GNCTD** in coordination with **Central Water Commission**, MoJS, GoI	1) Strengthen centralized mechanisms like State Mission for Clean Yamuna (SMCY) to coordinate all agencies. 2) On the lines of NMCG in objectives of better coordination amongst different departments of GNCTD

Conclusion & Way Forward

From the study, it may be concluded that the issue of frothing is not limited to the Yamuna River in Delhi but is a widespread phenomenon observed in many prominent rivers across the world. Frothing has also been reported in several parts of India, including rivers, lakes, beaches and other water bodies. After in-depth analysis, it was found that a common factor in all these cases is the presence of excessive pollutants, which leads to severely degraded water quality, whether in rivers, lakes, or beaches in coastal areas. Although the reasons behind froth formation are largely similar, they are often influenced by localized environmental and anthropogenic factors.

Froth formation is triggered mainly when three factors come together like poor water quality with high pollution load, higher concentration of surfactants (either bio-surfactant or synthetic surfactants or both), and high-water flow rates due to seasonal variation. Together with the sudden opening of barrage gates at Okhla Barrage and the fall of water from significant height of barrage leads to the disturbance of sludge bed, high turbulence and churning effect in the form of froth in the natural riverine system.

The study can be expanded in future phases through the inclusion of quantitative measurements of surfactant and BOD loads (mg/L × flow) to establish pollutant mass fluxes across different stretches of the Yamuna. A temporal analysis of monthly variations in water quality and frothing intensity would help in identifying critical periods and linking them with hydrological and anthropogenic factors. Incorporating a hydrological mass balance or model validation through tools such as QUAL2K will enhance predictive accuracy and scenario planning. The integration of enhanced visual datasets—such as GIS-based spatial maps, trend graphs, and chemical concentration tables—will improve the interpretability of results for decision-makers. Finally, establishing explicit linkages with national policy frameworks such as the Namami Gange Programme (NMCG), River Rejuvenation Committee (RRC), and Central Pollution Control Board (CPCB) guidelines will ensure that the findings directly inform actionable interventions and regulatory planning for sustainable river management

Thus, this final report is a collation of all data points comparing variation in parameters across all the identified locations during pre and post monsoon sampling periods. Based on the observations, detailed short-, medium- and long-term strategies, which are proposed to the DoE, GNCTD, it is expected that if action taken appropriately and timely then not just the frothing issue be addressed but also pollution in Yamuna be controlled and the cleaning and rejuvenation of Yamuna is also possible in a time-bound manner.

References

1. A. Bera, T. Kumar, K. Ojha, A. Mandal, Adsorption of surfactants on the sand surface in enhanced oil recovery: isotherms, kinetics, and thermodynamic studies, Appl Surf Sci 284 (2013) 87–99.
2. The Environment (Protection) Rules (1986). https://cpcb.nic.in/displaypdf.php?id=SW5kdXN0cnktU3BlY2lmaWMtU3RhbmRhcmRzL0VmZmx1Z W50LzQ4NC0xLnBkZg==.
3. L. Peperzak, R. van Wezel, Human fatalities related to a Phaeocystis harmful algal bloom in the North Sea, Harmful Algae 130 (2023) 102545, https://doi.org/ 10.1016/j.hal.2023.102545.
4. Manisha, M., Verma, K., Ramesh, N., Anirudha, T. P., Santrupt, R. M., Das, R., Mohan Kumar, M. S., Chanakya, H. N., & Rao, L. (2023). Socio-economic impact assessment of large-scale recycling of treated municipal wastewater for indirect groundwater recharge. *Science of The Total Environment*, *859*(August 2022), 160207. https://doi.org/10.1016/j.scitotenv.2022.160207.
5. Reshmi Das, Chanakya Hoysall, Lakshminarayana Rao, Insights on foaming in surface waters: A review of current understandings and future directions, Chemical Engineering Journal, Volume 493, 2024, 152472, ISSN 1385-8947, https://doi.org/10.1016/j.cej.2024.152472.
6. Katerina Schilling and Matthias Zessner. "Foam in the Aquatic Environment." *Water Research*, vol. 45, no. 15, 2011, pp. 4355–4366. *ScienceDirect*, https://doi.org/10.1016/j.watres.2011.06.004.
7. Ramachandra TV, Asulabha K S, Sincy V, Vinay S, Bharath H. Aithal, Sudarshan P. Bhat, and Durga M. Mahapatra, 2015. Pathetic status of wetlands in Bangalore: Epitome of inefficient and uncoordinated Governance, ENVIS Technical Report 93, CES, Indian Institute of Science, Bangalore 560012.
8. Bashir I, Lone FA, Bhat RA, Mir SA, Dar ZA, Dar SA. Concerns and Threats of Contamination on Aquatic Ecosystems. Bioremediation and Biotechnology. 2020 Jan 27:1–26. doi: 10.1007/978-3-030-35691-0_1. PMCID: PMC7121614.
9. Lee, Chang-Gu & Song, Mi-Kyung & Ryu, Jae-Chun & Park, Chanhyuk & Choi, Jae Woo & Lee, Sang-Hyup. (2016). Application of carbon foam for heavy metal removal from industrial plating wastewater and toxicity evaluation of the adsorbent. Chemosphere. 153. 1-9. 10.1016/j.chemosphere.2016.03.034.
10. Eras-Muñoz E, Farré A, Sánchez A, Font X, Gea T. Microbial biosurfactants: a review of recent environmental applications. Bioengineered. 2022 May;13(5):12365-12391. doi: 10.1080/21655979.2022.2074621. PMID: 35674010; PMCID: PMC9275870.
11. Wegner C, Hamburger M. Occurrence of stable foam in the upper Rhine River caused by plant-derived surfactants. Environ Sci Technol. 2002 Aug 1;36(15):3250-6. doi: 10.1021/es025532p. PMID: 12188349.
12. C Ng Patrick and **Long Brit. Hydrogen Sulfide Toxicity: More than just a rotten egg smell. emDocs. 2016 Sept. 14**. https://www.emdocs.net/hydrogen-sulfide-toxicity-just-rotten-egg-smell/.
13. Parveen, Adeeba, and Syed Naushad Ahmad. "Urban Water System of the National Capital Territory (NCT) of Delhi: A Comprehensive Study." *Water Supply* 24, no. 11 (2024): 3639–51. https://doi.org/10.2166/ws.2024.233.