Wastewater Pollution, Declining River Water Quality, and Its Socio-Economic Impact in NCT of Delhi

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Abstract

Historically, rivers have served as crucial life-lines for human settlements, by facilitating the growth of ancient civilizations worldwide. However, the advent of urbanization has brought about a profound shift: rivers that were once pristine sources of freshwater, now bear the burden of domestic and industrial pollutants which is emblematic of the swift economic and technological advancements of our time. This transformation has significantly degraded numerous rivers, including India's esteemed Ganga and its tributary, the Yamuna. Both these rivers endure severe pollution despite their cultural veneration as goddesses in Hindu mythology.

The Delhi NCR contributes significantly to the pollution load in the Yamuna River, causing it to function primarily as a channel for sewage discharge. This study meticulously scrutinizes the sources and repercussions of pollution in the Yamuna River ecosystem, particularly its impact on agricultural communities that are reliant on its waters. Physicochemical parameters—Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Faecal Coliform—were assessed using data from monitoring stations that were overseen by CPCB/ DPCC. The findings underscore the extensive river contamination and its detrimental socio-economic effects on local farmers.

This research underscores the imperative for inter-disciplinary collaboration across social and environmental sectors to drive innovative solutions for wastewater management. It advocates

emerging approaches such as decentralized wastewater treatment and Nature-based Solutions, to enhance water quality and bolster community well-being, thereby fostering broader social benefits. The effective rejuvenation of rivers like the Yamuna necessitates concerted efforts across sectors to implement sustainable water management practices, thus mitigating the profound impacts of pollution on ecosystems and human livelihoods.

Keywords: Wastewater, River Communities, Urban Agriculture, Nature-based Solutions, Decentralised Wastewater Treatment

Introduction

Rivers have always been at the heart of a society's development. All the world's ancient civilizations thrived along the banks of one or more rivers. Once the most important sources of freshwater, rivers became carriers of wastewater as cities grew. Rivers have paid the price for hasty economic and technological progress through various sources of pollution. Today's rivers are plagued by severe organic, inorganic, and/or pathogenic pollution, as well as low water levels. According to a UNEP report titled 'A Snapshot of the World's Water Quality: Towards a Global Assessment' (2016), one-third of all river stretches in Latin America, Africa, and Asia are affected by severe pathogenic pollution. Furthermore, severe organic pollution affects one-seventh of these river stretches, while salinity pollution affects one-tenth. Increased wastewater discharge into rivers has been identified as the primary source of water pollution (UNEP, 2016).

Water is necessary for the survival of all living things, but it is becoming increasingly scarce as human populations grow and the demand increases for high-quality water for domestic and commercial purposes. Freshwater scarcity is one of the most pressing environmental issues that India is facing in this century. The main obstacles to better water quality management in India are contamination and issues caused by treated, partially treated, and untreated wastewater from urban settlements, industrial operations, and irrigation run-off, as well as poor municipal solid waste management.

In India, wastewater treatment is a serious concern, particularly in rapidly increasing metropolitan regions. According to a 2015 report 'Inventorization of Sewage Treatment Plants' by the Central Pollution Control Board (CPCB), India generates 61,948 million gallons of urban sewage each day. However, every day over 38,000 million gallons of wastewater is discharged into major rivers which even percolates into the earth. Industrial wastewater also needs to be considered. This disconnect between sewage generation and treatment continues to be a major source of river contamination. Moreover, in a recent study done by the Centre for Science and Environment (CSE), 351 contaminated stretches were detected on 323 rivers. This was based on monitoring data in terms of biochemical oxygen demand, an indicator of organic pollution as shown in Table1 (Naraina, 2018).

BOD levels beyond a certain threshold are harmful for aquatic life. DO is digested by bacteria when significant biodegradable organics are present in water, as is the case with most wastewater. When this happens, the DO levels fall below a certain threshold, which has a detrimental influence on life since they are unable to maintain regular life-sustaining functions like growth and reproduction.

Furthermore, in many wastewater streams, eutrophication is caused by the abundance of nitrogen-containing chemicals. This causes algae blooms (the growth of plants in the aquatic ecosystem) and anoxic conditions which results in changes in dominant aquatic biota species, fishkills, and spread of water-borne diseases such as cholera and typhoid (Joshua N. Edokpayi, 2017).

Pollutants also reduce the quantity of usable water, raise the cost of purification, pollute aquatic resources, and impact food supplies. Pollution, in combination with human water demand, impacts biodiversity, ecosystem functioning, and the natural services that are provided by aquatic systems, all of which are important to society. Thus, it is critical to implement effective management approaches for improved water quality and biota conservation.

Table 1: State-wise Polluted Stretches of Rivers in India

States	Urban Sewage Generation (MLD)	Installed Treatment Capacity (MLD)	Polluted Stretches (in Km)
Andhra Pradesh	2871	247.27	6
Assam	703	0.51	28
Bihar	1876	124.55	5
Chhattisgarh	951	0	5
Daman & Diu	55	0	1
Delhi	4155	2693.7	1
Goa	145	74.56	8
Gujarat	4119	3062.92	20
Haryana	1413	852.7	2
Himachal Pradesh	110	114.72	8
Jammu and Kashmir	547	264.74	9
Jharkhand	1270	117.24	8
Karnataka	3777	1304.16	15
Madhya Pradesh	3214	482.23	21
Maharashtra	8143	5160.36	49
Manipur	132	0	12
Meghalaya	95	1	10
Nagaland	92	0	2

Odisha	1121	385.54	12
Punjab	1644	1245.45	2
Rajasthan	2736	865.92	8
Sikkim	24	31.88	5
Telangana	1671	685.8	7
Tripura	154	0.02	2
Uttar Pradesh	7124	2646.84	5
Uttarakhand	465	152.9	13
West Bengal	4667	416.9	17

Source: Naraina, 2018

Objectives of the Research

The research will provide insights and help with wastewater management and its effects on water quality and riverine populations in the study area at the city level. The study focuses on the farming communities in the site area that are dependent and interact with the river on a daily basis. Overall, it attempts to make a case for a more integrated spatial governance of the urban rivers at risk. The following objectives define the path of the study:

- To understand the importance and pollution status of urban rivers in India.
- To assess the existing wastewater management system and identify sources of pollution in the study area.
- To spatially assess the water quality parameters and detect the levels of pollution in the study area.
- To study the impact of river water quality on the livelihood of communities in the site area.
- To propose/recommend strategies for improvement of water quality of River Yamuna.

Study Area

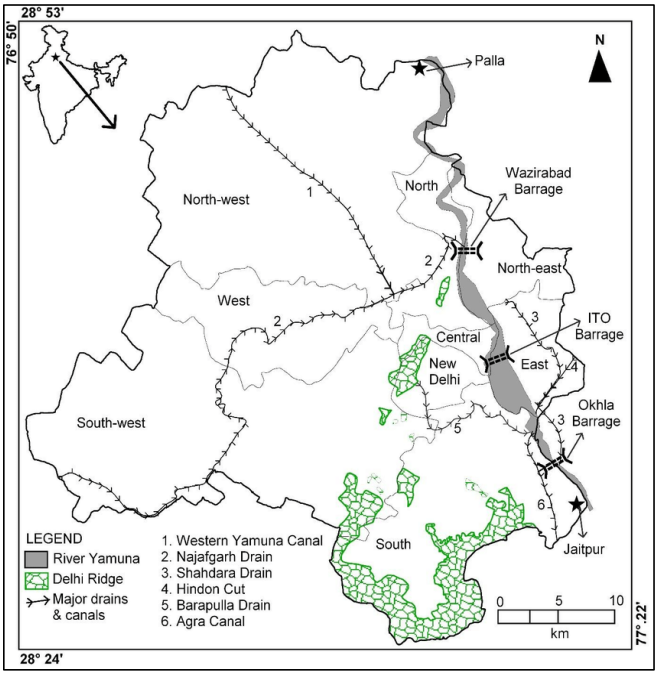
The National Capital Territory of Delhi (NCTD) has a total area of 1,483 square kilometres and is divided into nine census districts and 27 sub-divisions (Tehsils). River Yamuna flows for about 200-km from its source through a series of valleys in the Lower Himalayas before emerging into the Indo-Gangetic Plains. It draws water from several major streams in its upper 200-km stretch. To supply drinking water to Delhi, the river is first tapped via a barrage at Wazirabad. In general, no water is allowed to flow beyond the Wazirabad Barrage during the dry season because the available water is insufficient to meet the water supply-demand of Delhi.

After 22-kilometres downstream of Wazirabad Barrage, there is another barrage, the Okhla Barrage, which diverts Yamuna water into the Agra Canal for irrigation. During the dry season, no water is allowed to flow through this barrage as well. Whatever water that flows in the river beyond the Okhla Barrage comes from domestic and industrial wastewater that is generated in

East Delhi, Noida, and Sahibabad, which enters the river via the Shahdara drain.

The various human and industrial activities generate a large amount of garbage, which is discharged directly into the river without adequate treatment, thus lowering the river's water quality. The Yamuna River flows through the National Capital Territory for only 22-kilometres (or less than 1.6% of its total length). However, the wastes and toxins dumped into that narrow swath account for roughly 80% of all pollution in the 1,376-kilometre-long river (Sharma, 2017).

Figure 1: Flow of River Yamuna in the National Capital Territory of Delhi



Source: Singh et al., 2016

Methodology

The methodology of this study involves a comprehensive approach to understand and address urban river degradation, with the Yamuna River in Delhi as a case study. Initially, a literature review will critically examine the significance of urban rivers for communities, the impact of pollution on these communities, causes of river degradation, parameters that define the pollution status, and evaluation of pollution control proposals in urban master plans. Based on this review, the data collection focuses on assessing wastewater management systems and identifying the sources of pollution. This includes a detailed land use/land cover analysis to capture hydrological

variability and changes over the past decade, and pollution source analysis of sewer and non-sewer areas, drains discharging into the Yamuna, Sewage Treatment Plants (STPs), Common Effluent Treatment Plants (CETPs), and industrial clusters.

Wastewater analysis will evaluate the treatment capacity of STPs, pollution levels in treated effluents, and the end-use of treated wastewater. Spatial assessment of water quality parameters using IDW interpolation will provide a holistic view of pollution levels across the river. Finally, socio-economic surveys will explore the impact of river water quality on the livelihoods and health of riverine communities, integrate perspectives on basic facilities, household economies, awareness of water quality, and health perceptions.

This methodology aims to establish a clear link between rising pollution levels and urbanization pressures, thus informing effective strategies for sustainable river management and community well-being.

Table 2: Aims, Objectives, and Methodology

Formulation Stage	Aims & Objectives		Need of the Study
Literature Review	To critically understand the importance of urban rivers and the causes of their degradation	▪ Significance of urban rivers for cities and riverine communities ▪ Impact of pollution on the communities ▪ Cause of degradation of urban rivers ▪ Parameters to identify the pollution status of a river ▪ Assess proposals regarding river pollution in Master Plans	**Delhi as a Case Study** Identifying current issues, Status of Water Pollution, Impact on Communities
Data Collection & Selection of Study Area (Based on Literature Review)	To assess the existing wastewater management systems & identify pollution sources in the study area	▪ Land Use/Land Cover Analysis: ▪ LULC approach to capture hydrological variability of the Yamuna and changes in the LULC pattern over the previous decade ▪ Pollution Source Analysis: ▪ Sewered & unsewered areas ▪ Eighteen drains falling into Yamuna ▪ STPs and other treatment infrastructure ▪ CETPS & Industrial Clusters that it caters to ▪ Wastewater Analysis: ▪ Assess the treatment capacity of sewage treatment plants (Generation/Treatment Gaps) ▪ Pollution analysis of treated effluents (STPs, CETPs) ▪ End use of treated effluents from STPs	The overall study can help to find a link between rising pollution levels and the pressures of urbanization which may be attributed to increased wastewater generation/ discharge into the Yamuna

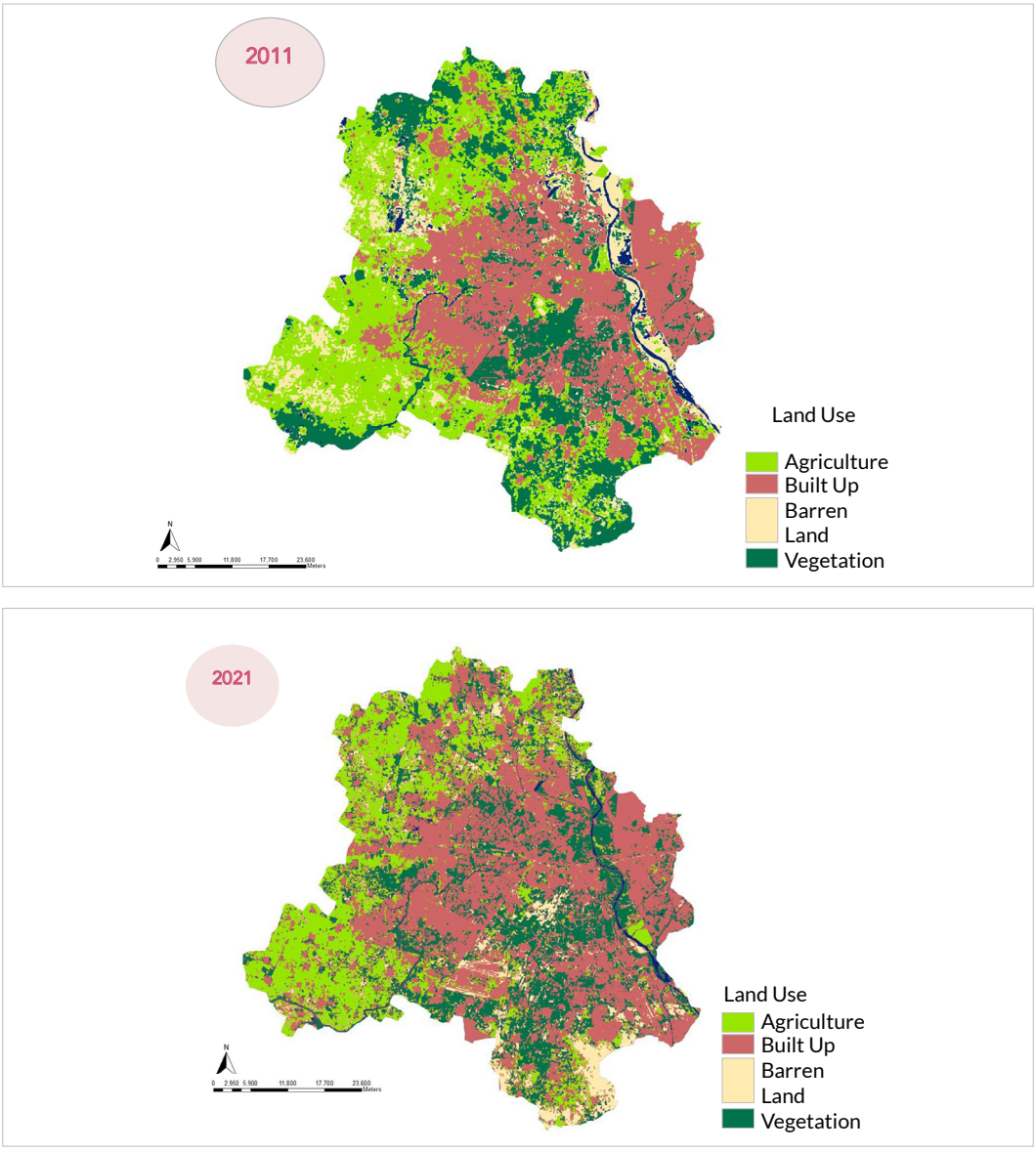
Analysis	To spatially assess the water quality parameters & detect the level of pollution in the study area	To assess the river water quality for pollution parameters, field datasets for the National Water Quality Monitoring Programme (NWMP) from monitoring stations of the Central Pollution Control Board (CPCB)	To assess water quality across the whole river flow area using **IDW interpolation**
Identification of Issues and Problems	To analyse the impact of river water quality on the livelihood & health of riverine communities	▪ Socio-economic Survey questionnaire: ▪ Questions related to basic facilities in households ▪ Livelihoods and Income: Questions related to household economy ▪ Perception of river water /Awareness and opinions about river water quality ▪ Questions related to health	Social research to evaluate the impact of pollution on the livelihoods and health of various riverine communities
Proposals	**To propose strategies for improvement of water quality of urban rivers.** This will incorporate the ecological and biodiversity concerns of poor water quality and support improvements of urban rivers and livelihoods.		

Analysis and Findings

Land Use/Land Cover Analysis

Land Use/Land Cover (LULC) Analysis was performed for year 2011 & 2021 as shown in Figure 2. This was done to highlight the pressures of haphazard development on floodplains and urbanization on River Yamuna's water quality. Almost 44% of major negative change was observed in the Yamuna area. Ignoring the river-flood-plain interactions which play significant roles in the ecology of a river, most of the floodplain has been reclaimed by constructing high levees.

Figure 2: Land Use and Land Cover in the National Capital Territory of Delhi (NCTD), 2011 – 2021



Source: Prepared by Author based on Google Imagery, 2022

Table 3: LULC Change between 2011-2021 in the National Capital Territory of Delhi (NCTD)

2011		2021		% Change (with respect to 2011)	
Area (m2)	Share of Area (% to Total)	Area (m2)	Share of Area (% to Total)		
Agriculture	545	36.62	405	27.24	**-26**
Built-Up	464	31.20	512	34.39	**10**
Barren Land	166	11.16	127	8.54	**-23**
Vegetation	277	18.65	424	28.51	**53**
Water Body	35	2.37	20	1.33	**-44**

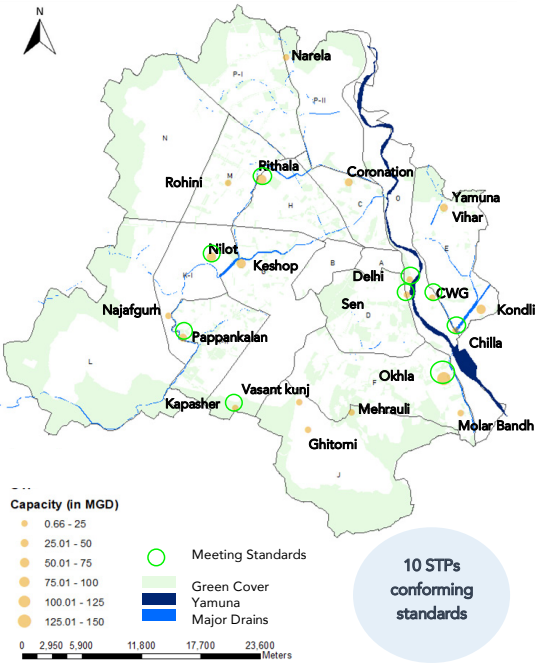
Source: Prepared by Author based on LULC Analysis, 2022

Developments like the Akshardham temple and the Commonwealth Games Village – which consist of multi-storey luxury apartments with a captive power plant – demonstrate how the government has actively encouraged new development by providing huge subsidies to corporate entities. Other concrete developments have followed suit, with the Akshardham temple on the eastern bank and a network of flyovers and wider roads built parallel to the eastern riverfront to accommodate the increased traffic. Within 300 metres from the bank of the river, the Delhi Metro Rail Corporation (DMRC) has built a Yamuna Bank metro station, a large train depot, and a retail mall near the Games Village, and the remaining property along the river has been earmarked for similar projects. Patches of agricultural land are being replaced by skyscrapers at a rapid pace. Instead of the ecological zone established in the Master Plan of Delhi- 2021 (MPD – 2021), these developments provide material expression to riverside development that reflects other western cities and ignores the fundamental socioeconomic and environmental challenges.

Availability and Utilisation of Sewage Treatment Plants

Delhi Jal Board (DJB), constituted under the Delhi Jal Board Act, 1998, has the responsibility of production and distribution of water as well as collection, treatment, and disposal of domestic sewage in the NCT Delhi. DJB is working in a phased manner to provide sewerage facilities to all the unsewered areas and cater to the requirement of unprecedented growth of population up to the year 2031. This is being done firstly, by extending the sewerage facilities to those command areas where outfall infrastructure exists.

Figure 3: Mapping STPs Conforming Standards in the NCTD



Source: Prepared by Author, 2022

Presently, Delhi generates around 744 million gallons per day (MGD) of sewage – considering 80% of the 930 MGD water supply. The 35 sewage treatment plants operational at 20 locations across Delhi treat up to 597.26 MGD of sewage. To tackle pollution, the environment ministry has strengthened rules for Sewage Treatment Plants (STPs) that discharge wastewater into rivers and other sites.

Furthermore, Delhi Pollution Control Committee releases a monthly report on the quality of treated water discharge. However, from the analysis of the December 2021 STP Monitoring Report, it was observed that 23 STPs (70%) do not discharge treated water as per standards (Delhi Pollution Control Committee, 2021). It was found that the main parameters that do not conform to the standards are TSS, BOD, and COD. Higher levels of BOD and COD indicate a higher amount of organic waste or sewage in the water/wastewater.

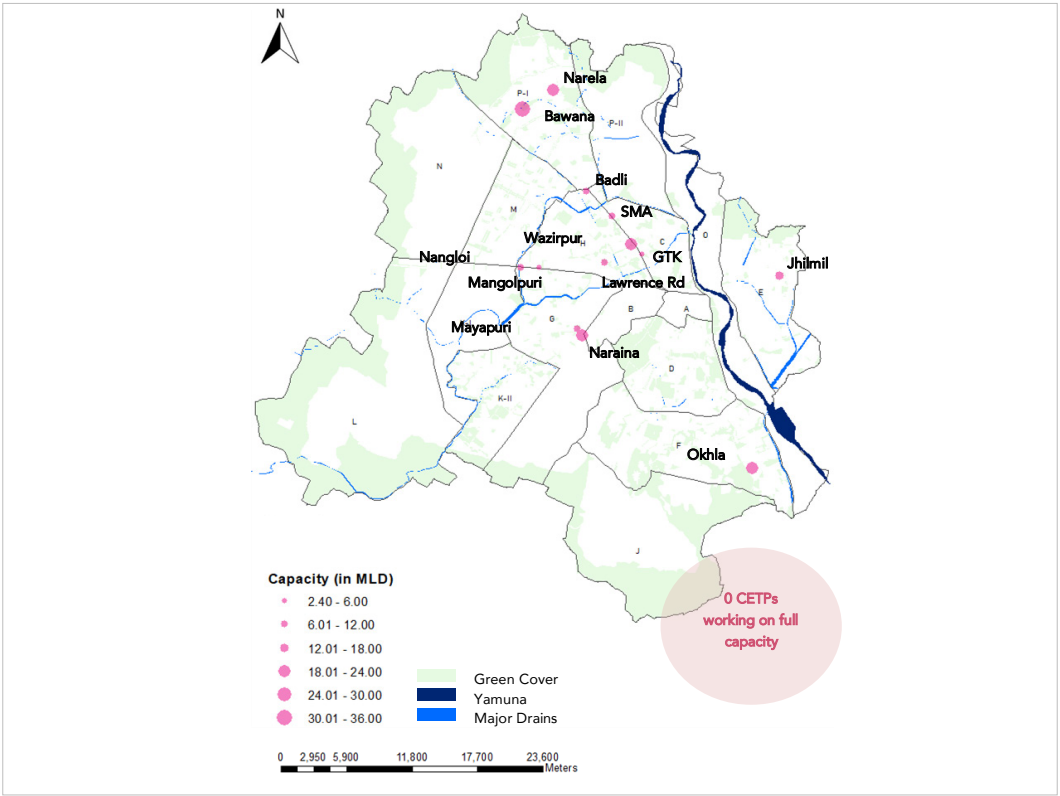
Availability and Utilisation of Common Effluent Treatment Plants

Delhi State Industrial and Infrastructure Development Corporation Ltd. (DSIIDC), a government organisation has been assigned the responsibility to establish, operate, maintain, and manage the Industrial Estates in Delhi. At present, 33 approved planned Industrial areas exist in Delhi. Out

of these, 17 are connected to 13 CETPs which are marked in Figure 4. The total Capacity of the 13 CETPs in Delhi is around 212.3 MLD. However, the total effluent flow generated is only 52.72 MLD. This shows that the utilization of CETPs is only 24.8 per cent.

This indicates that CETPs are not functioning up to the designed capacity probably because all industries have not taken connection to the CETPs. Thus, industrial waste from all the industries is not being treated and is being disposed directly into the drains. The main parameters that are not conforming to the standards are TSS in influent discharge and sulphide and BOD in effluent discharge. Higher levels of BOD indicate a higher amount of organic waste or sewage in water/ wastewater. However, the quality of the CETPs effluent standards (outlet) is monitored by Delhi Pollution Control Committee which shows that in July 2021, nine CETPs did not discharge the treated water as per standards (Delhi Pollution Control Committee, 2021).

Figure 4: Mapping of Common Effluent Treatment Plants in the NCTD

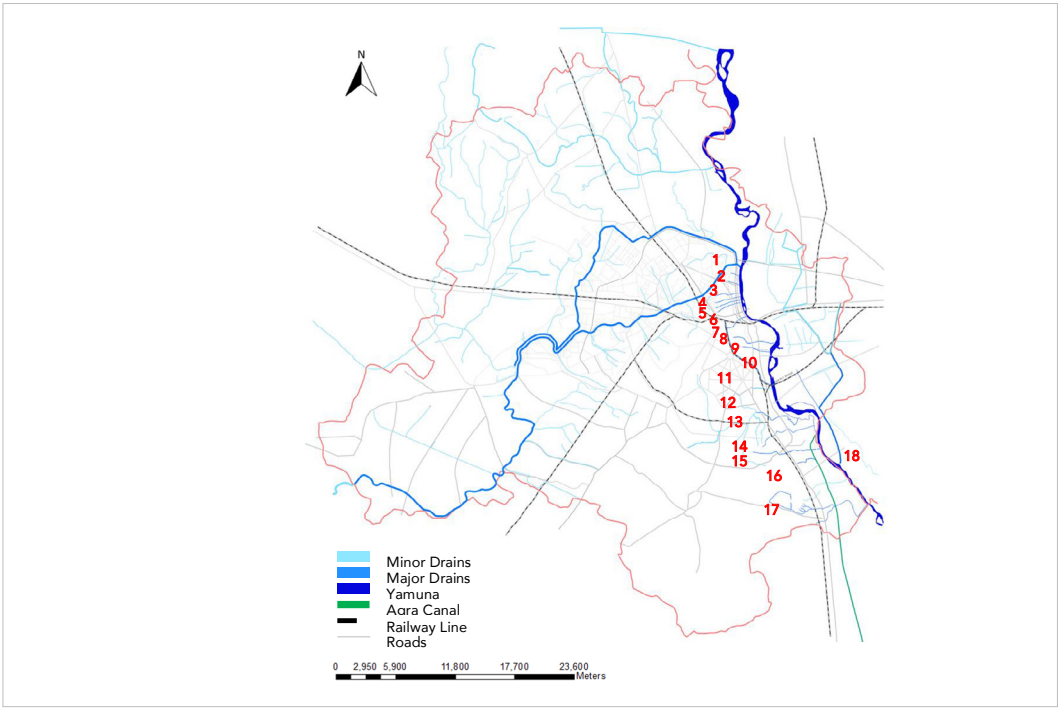


Source: Prepared by Author, 2022

Distribution of Drains and Unauthorised Colonies (UACs)

Total 18 drains of Delhi discharge the water flow into River Yamuna during both dry and rainy periods and contribute to around 80 per cent of pollution in the river. Furthermore, till now in Delhi, out of 1,799 UACs, only 561 (31%) have sewer lines laid. In non-sewered settlements, the household domestic wastewater is either collected in a septic tank or it is discharged directly into open drains (University of Virginia, 2018).

Figure 5: Distribution of Drains in the NCTD



Source: Prepared by Author using Google Imagery, 2022

Mapping Spatial Pollution

The mapping of spatial pollution along the Yamuna River in Delhi was conducted by using Inverse Distance Weighting (IDW) interpolation to analyze the Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and faecal parameters. This involved extrapolating pollution data from established monitoring points to create continuous maps that showed concentrations of pollutants. The BOD measurements indicated significant organic pollution, COD assessments highlighted the overall pollution levels, and faecal parameters provided insights into microbial contamination.

To analyze the river water quality as per the concerning pollution parameters, data for the years 2011 and 2021 was sourced from the National Water Quality Monitoring Programme (NWMP) at the monitoring stations that were managed by the Central Pollution Control Board (CPCB) and Delhi Pollution Control Committee (DPCC). By mapping these interpolated results, pollution hotspots were pinpointed along the river and this methodology enabled a comprehensive spatial analysis of the pollution dynamics which supported evidence-based decision-making for effective river management and environmental protection measures.

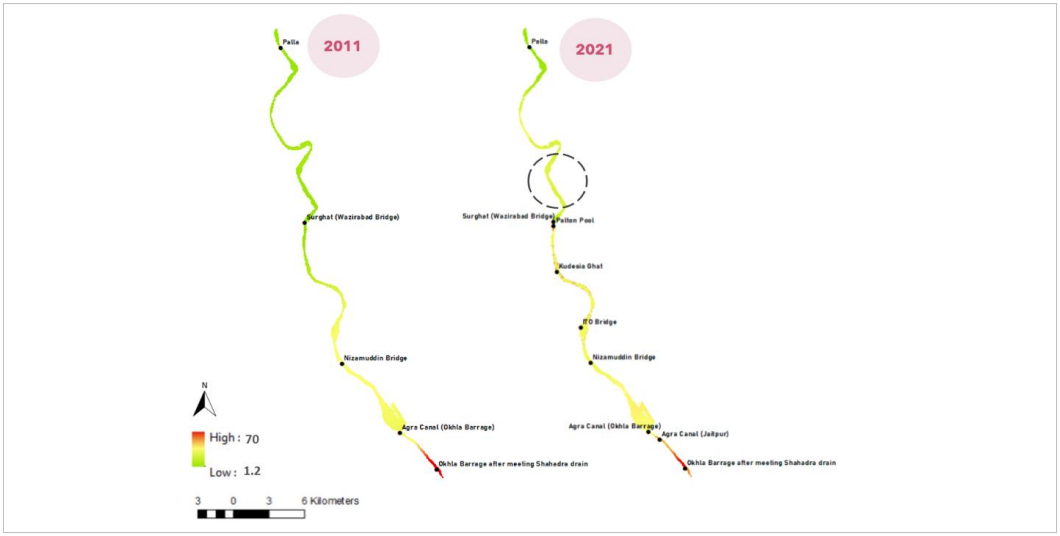
Biological Oxygen Demand

BOD gives an estimate of the organic pollution in water and wastewater. In both 2021 and 2011, the BOD levels remained under permissible limits only till the Wazirabad Barrage. Also, in Figure 6 it can be seen that in both 2021 and 2011, after the Wazirabad Barrage the values increased by almost 30 times as the river reached the Okhla Barrage. This led to decomposition of organic material and excess release of nutrients, such as nitrogen (N) and phosphorous (P) thus producing dense algal bloom which lowered the Dissolved Oxygen (DO).

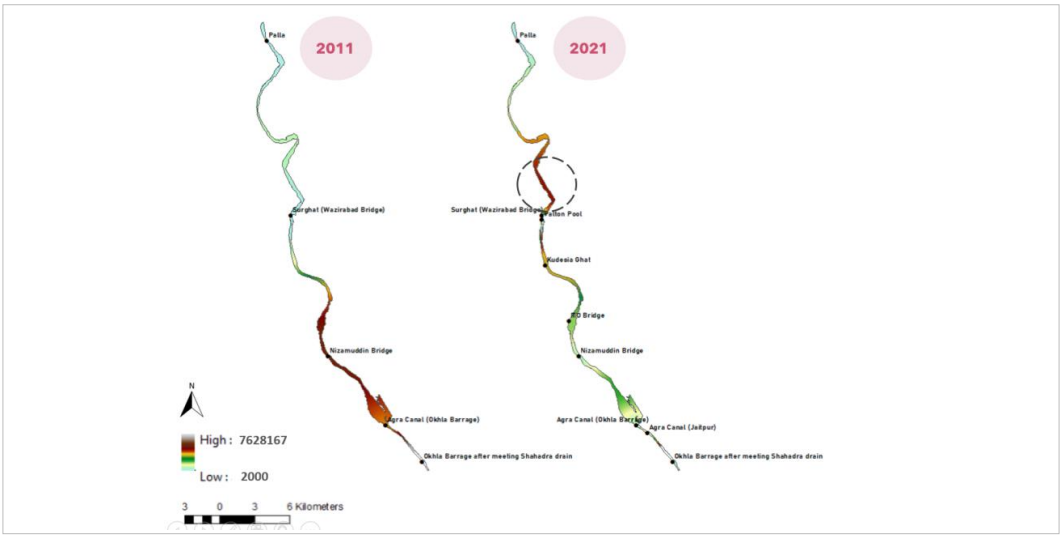
Faecal Coliform

Faecal Coliform gives an estimate of the biological pollution in water and wastewater. In both 2021 and 2011, faecal coliform was not within the permissible limits except at Palla (2020) as shown in Figure 6. Contact with such water results in exposure to pathogenic bacteria and is often associated with contamination by faecal material of humans or animal sources. Leaking sewage pipes or septic systems could be the sources for this.

Figure 6: Spatial Pollution Mapping of Biological Oxygen Demand (top) and Faecal Coliform (bottom) in the NCTD



Source: Prepared by Author using IDW Interpolation on ArcGIS, 2022

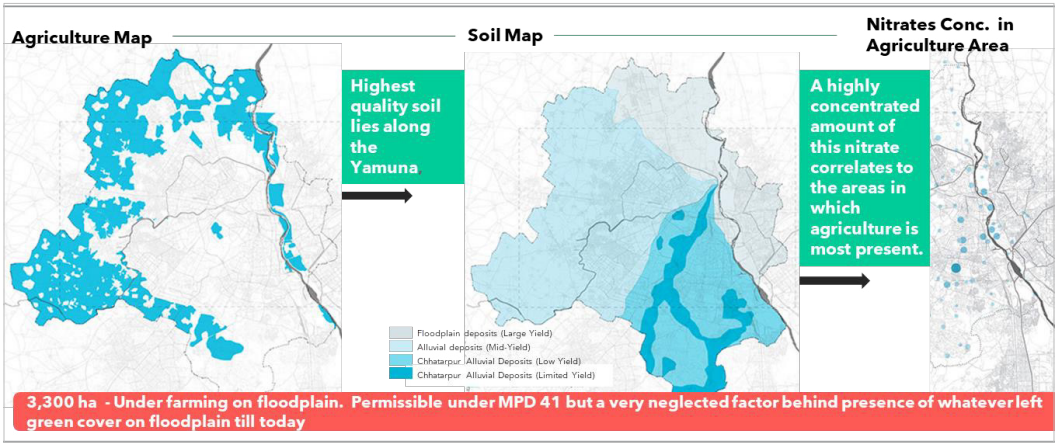


Source: Prepared by Author using IDW Interpolation on ArcGIS, 2022

Agricultural Run-off

While the highest quality soil lies along the Yamuna, most agricultural practices take place along the city's periphery and that too in low-quality soil because of limited access to the river. As a result of industrial effluents and untreated sewage water, Delhi's soil is highly contaminated with heavy metals and pesticides which are matters of concern regarding crop production and food safety. On the other hand, contamination of River Yamuna also occurs because of soil contamination through agricultural pesticides, fertilizer residue, and farmland waste that creates unhealthy run-off (University of Virginia, 2018).

Figure 7: Agriculture Mapping on Delhi's Floodplain



Source: University of Virginia, 2018

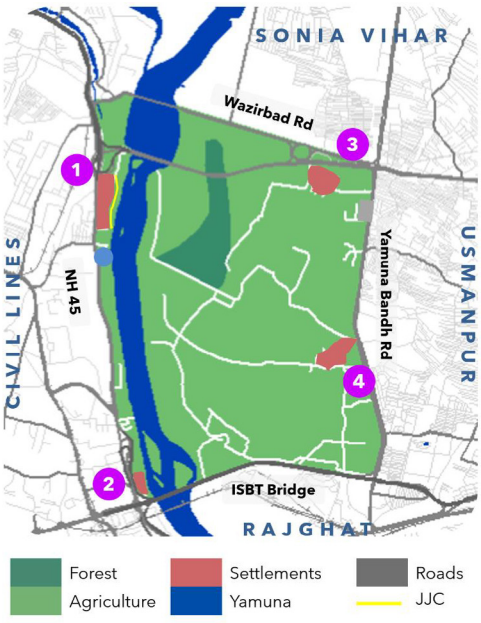
Site Selection and Analysis of Riverine Communities along Yamuna Bank

At site level, the study's main aim was to assess the condition of people living close to the River Yamuna and those who are directly dependent on it for their livelihood. The assessment would be in terms of living environment, availability of physical infrastructure, and impact on health. To conduct site-level research, the area between Wazirabad Barrage and ISBT Bridge was selected (Figure 8) as it is located downstream of the Najafgarh Drain in Sub-Zone II which contributes to about 60 per cent of the total pollution in the river.

The site consists of four residential colonies namely New Aruna Nagar Colony, Ladakh Vihar Colony, Gehri Mandu Village, and New Usmanpur. New Aruna Nagar was selected for a detailed study because of the diverse socio-economic profile of the area. Farmers are involved in agricultural activities in the river's floodplain behind New Aruna Nagar Colony. This community of farmers was also selected for research and all fifteen households were surveyed.

New Aruna Nagar was selected for detailed study because of the diverse socio-economic profile of the area with majority of the households involved in the commercial sector. Further, systematic sampling was conducted in this colony. Every fourth household was surveyed with a sample size of 100. In addition to the river's floodplains behind New Aruna Nagar Colony, farmers are involved in agricultural activities. This community of farmers on the floodplains has also been taken for the research and all 15 households were surveyed.

Figure 8: Site between Wazirabad Barrage and ISBT Bridge, Delhi selected for Survey



Source: Prepared by Author using Google Imagery, 2022

Basic Facilities in Households

There is piped water supply for all households in New Aruna Nagar Colony. However, during the dry season the water that is received by the households is dirty and it smells which forces them to buy bottled water. At present, there are no sewer connections; although one in every third household has a septic tank i.e. 47 per cent, but due to lack of regular pumping and proper drainage (sludge continues to build), it contaminates the nearby water bodies as well as the underground water.

Figure 9: Latrine Facility in New Aruna Nagar

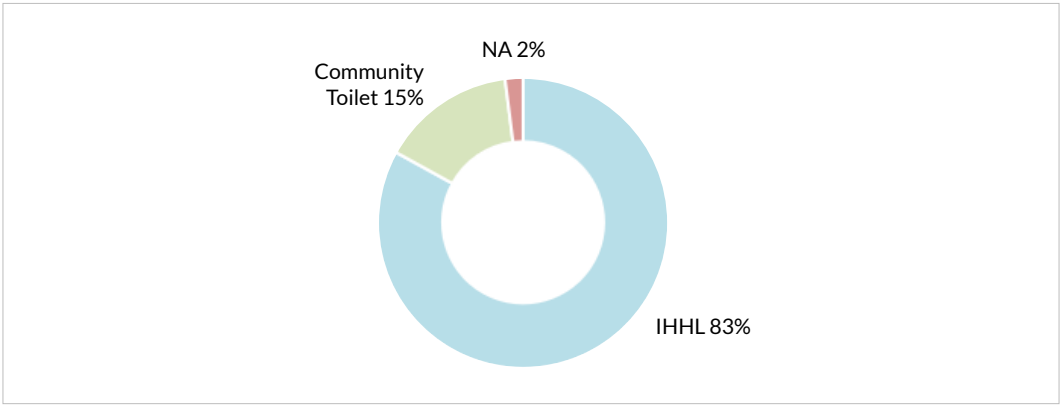
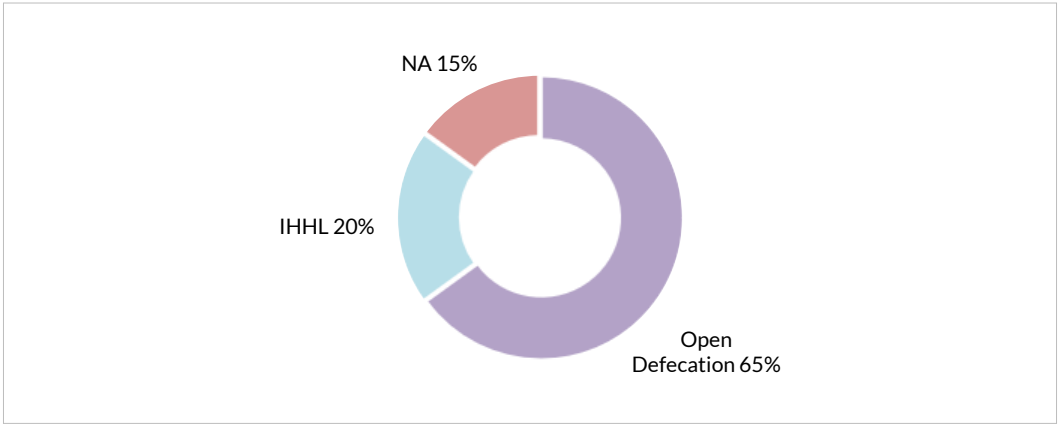


Figure: 10 Latrine Facility in Riverine Communities



Source: Primary Survey, 2022

It was observed that behind New Aruna Nagar Colony, facing the west bank of the river, the farmers were living at a bare-minimum level. These farmers did not even have access to proper sanitation facilities as shown in Figure 9. They practiced open defecation at makeshift arrangements that were installed on narrow drains which carry wastewater from Majnu Ka Tila to the river. However,

a government tap has been installed for drinking water purposes. Though most of the farmers also had a hand pump installed on their farmland, but they did not use its water for drinking because of high concentrations of fluoride that are present in the groundwater. Every morning, they fetch water from the government's public tap.

Health, Occupation, and Impact of Pollution

Occupation and Pollution Impacts

New Aruna Nagar Colony has extensive human activity like shops, eateries, vendors, and vehicles that are spread all over. No Impact on their Business is mentioned because as such the interaction of this community with River Yamuna is zero with respect to their occupation. Also, even though the polluted river does not affect their occupation to a large extent, these extensive human activities in return, affect the pollution levels of the river through discharging wastewater directly into it.

Figure 11: Occupation Type - New Aruna Nagar

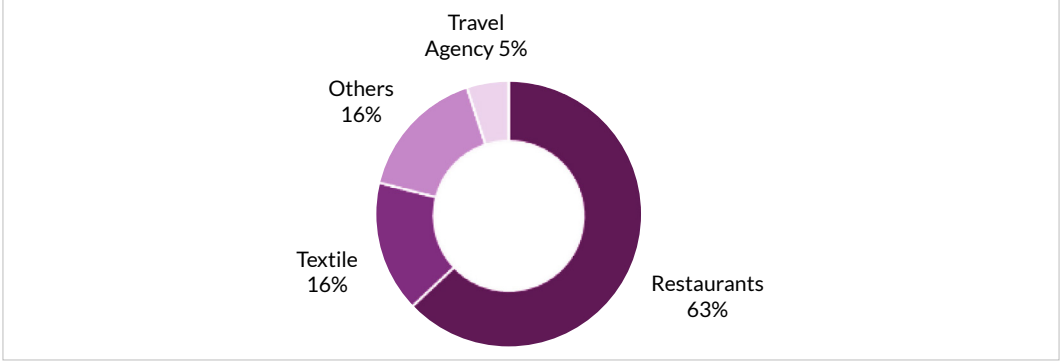
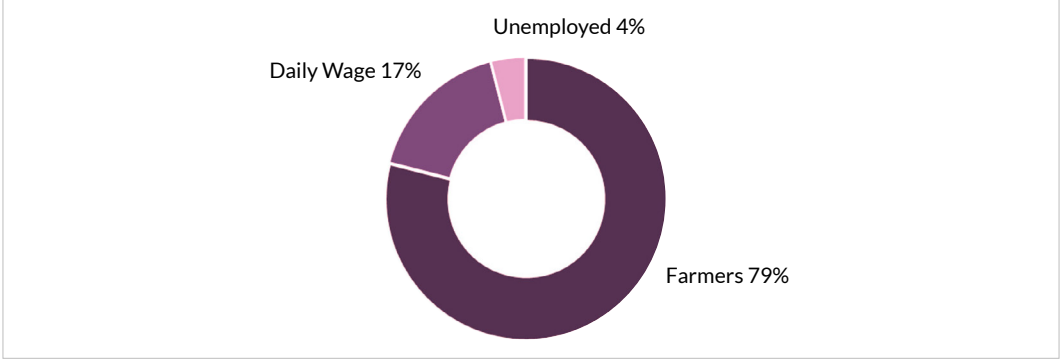


Figure 12: Occupation Type - Riverine Communities



Source: Primary Survey, 2022

In the farmer's communities, the major occupation source is farming which is around 79 per cent. The major vegetables that are produced include cucumber, and bottle gourd in summers and cauliflower, spinach, and lettuce in winters. However, due to lack of fresh and clean water sources for irrigation, wastewater discharge from drains/River Yamuna is used. Because of this, crops irrigated by the Yamuna River spoil sooner and this requires a high use of fertilizers. Such conditions also force them to change the type of crops grown over the year.

Health and Pollution Impacts

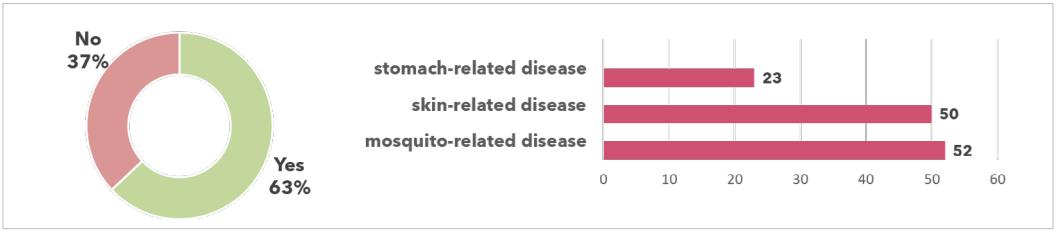
In New Aruna Nagar Colony, 95% of respondents said that River Yamuna's water quality had an impact on their health, especially on children. Of these, maximum cases recorded were of mosquito-related diseases which was followed by stomach and skin-related diseases, respectively, as shown in Figure 13.

Figure 13: Yamuna Water's Impact on Health & the Types of Diseases Reported - New Aruna Colony

Source: Primary Survey, 2022

In the farming communities, when asked about the Yamuna River's impact on their health, half the respondents did not answer. Only 34% respondents answered the question, out of these 63% believed that Yamuna's water quality had an impact on their health as shown in Figure 14. This was mostly because a majority of respondents were hesitant to think that river pollution could be the cause of any disease as they believed in the river's divinity. However, those who accepted, responded that they frequently suffered from mosquito related diseases, which were followed by skin and stomach related diseases. This is because they remain in close contact with the wastewater and the River Yamuna's polluted water for irrigation purposes.

Figure 14: Yamuna Water's Impact on Health & the Types of Diseases Reported – Riverine Communities



Source: Primary Survey, 2022

Issues

Land Use/Land Cover

In the last ten years, rapid urbanization has resulted in significant reduction of vegetation and the Yamuna area. This type of urban sprawl negatively impacts the quality of the river because more drains are built along these urban areas which outflow into the river.

STP & CETP Analysis

The existing sewerage treatment facilities are not sufficient:

- Inadequate coverage of sewerage results in wastewater flowing into the open Nallas causing pollution of the River Yamuna (only 31% UACs have sewers laid)
- Almost 20% wastewater that is generated by domestic users is discharged directly into the river
- It was noted that 23 STPs (70%) do not discharge treated water as per the given standards
- Nine CETPs do not discharge treated water as per the effluent standards (outlet)
- The generation-treatment gap continues to increase because of rapid population growth

Community Assessment

- Due to lack of tenure, space, and economic constraints the urban poor are unable to access safe sanitation
- People who use river water for their livelihood report diseases like joint pains, stomach aches, nausea etc
- Pollution of the river water affects the crop yields and farmers are forced to rethink about the types of crops to be grown for cultivation
- In turn, heavy use of fertilizers is also washed into the River Yamuna because of the use of wastewater for irrigation of crops

Discussion

Cross-Sectoral Collaboration and Wastewater Recycling at Different Levels

A combination of decentralized and in-situ treatment systems can be planned through Nature-based Solutions. This will help to tackle the issue of wastewater generation-treatment gap in a way that urban farming that is being practised on the river banks, can be preserved and promoted through reuse of recycled waste-water; thus, improving the quality of farming and the livelihood of farmers.

Table 4: A Strategic Combination of Decentralized and In-situ Treatment Systems

HARD To overcome the issue of connecting areas to centralised STPs		SOFT to overcome the issue of changing floodplain Land-Use		
APPROACH	HARD	SOFT		
Zone O II	Wastewater Treatment through DWWT in the Colonies	Nature Based Agriculture as Created Habitat	Riparian Restoration	Green Pathways
A combination of hard & soft measures can be planned through nature based solutions to tackle rising concerns on wastewater pollution.	Treat wastewater at a local level Reuse of Treated water in Agriculture Recovery of O & M Costs	Ecological Restoration of Floodplain through Natural Farming (Promote Green Jobs) Farmers trained to become guardians of parks along Yamuna.	Filtering Agricultural Run-off Restoring natural habitat along the river bank	Open space routes that are managed for both conservation and enjoyment. Forms river-people connect

Source: Prepared by Author, 2022 Site Level Proposals

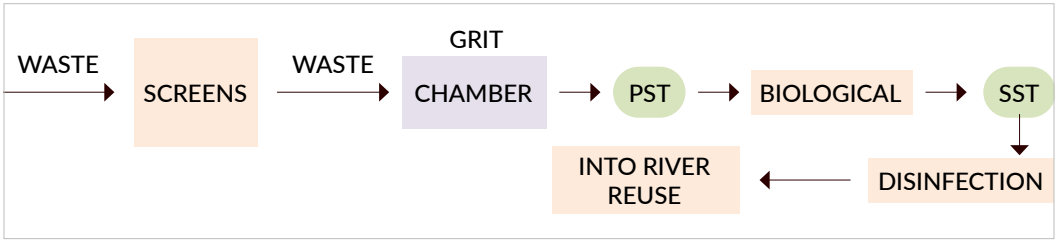
Decentralized Wastewater Management Systems

As per guidelines of the Ministry of Urban Development (MoUD), Decentralized Wastewater Management (DWWM) can be defined as "the collection, treatment, and disposal/reuse of wastewater from individual homes, clusters of homes, isolated communities, industries, or institutional facilities, as well as from portions of existing communities at or near the point of waste generation" (Guidelines for Decentralised Wastewater Management, 2012).

Advantages:

- At any point, the water flows remain small in the system
- Less environmental disturbances as smaller pipes are installed during the construction of the system
- Without routing more flows to the existing centers, new treatment centers can be added; making it easier to expand the system
- Less investment is required for laying down sewer pipelines
- The quality of treatment is more efficient as compared to the traditional system
- Efficient reuse of treated sewage for toilet flushing, irrigation, etc.
- Easier maintenance of sewerage system

Figure 15: Process of Decentralized Wastewater Technology (DWWT)



Source: Guidelines for Decentralised Wastewater Management, 2012

Selection of Technology to demonstrate Decentralized Wastewater Technology at Site Level

India has a number of efficient technologies to treat wastewater at the local level. However, factors to be considered while selecting technologies for DWWM are land required, capital cost, and operation & maintenance cost for unauthorized colonies. Land is the biggest constraint for any kind of wastewater treatment system. On the basis of these factors, CAMuS-SBT was specifically selected for the site as shown in Table 5. Further, this DWWT is the most suitable prototype for the selected area as it cannot be replicated in other areas. On the basis of varied factors, other suitable systems can be proposed for different areas.

Table 5: Factors for Selecting Technology at Site Level

FACTORS	CAMuS-SBT (600 KLD)
Land required	420 sq.m.
Capital Cost	Rs. 62.1 Lakhs
Operation & Maintenance costs	Rs. 6 Lakhs

Source: Calculations done by Author based on (Centre for Science and Environment, n.d.)

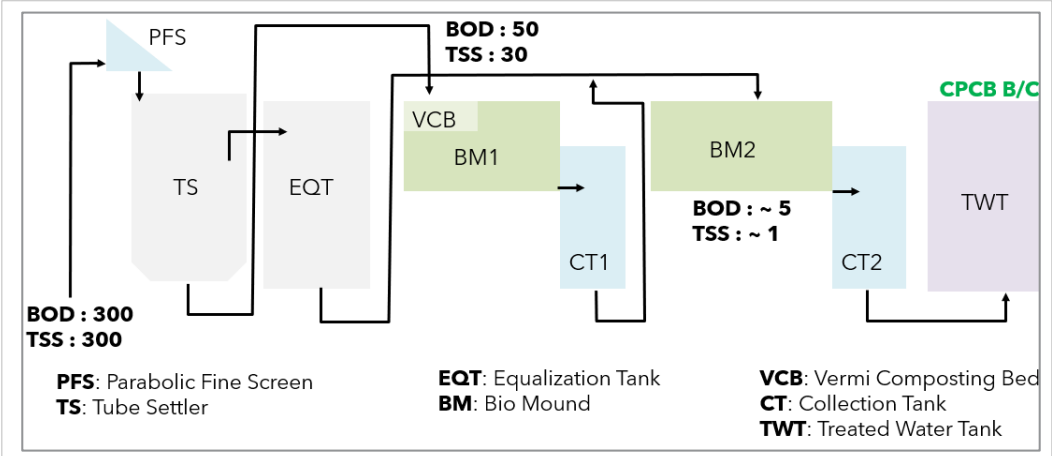
CAMuS-SBT

Continuous Advanced Multistage System – Soil Biotechnology (CAMUS-SBT) is an advanced technology that uses only local supplies and is an oxygen-supplying biological engine which can treat all wastewater - domestic, municipal, and industrial). Media used in the bio-reactors create a natural ecosystem that ensures a minimum lifespan - 25 years for desired hydraulic and organic loading (Shankar, P. H., n.d.).

Features:

- It's a green/clean technology
- No noise and odour
- Optimal usage of space
- No external aeration and no formation of bio-sludge
- One time media installation
- Low power consumption (1/3 of conventional STPs)
- Efficient removal of pollution
- Long life
- Creates green habitats

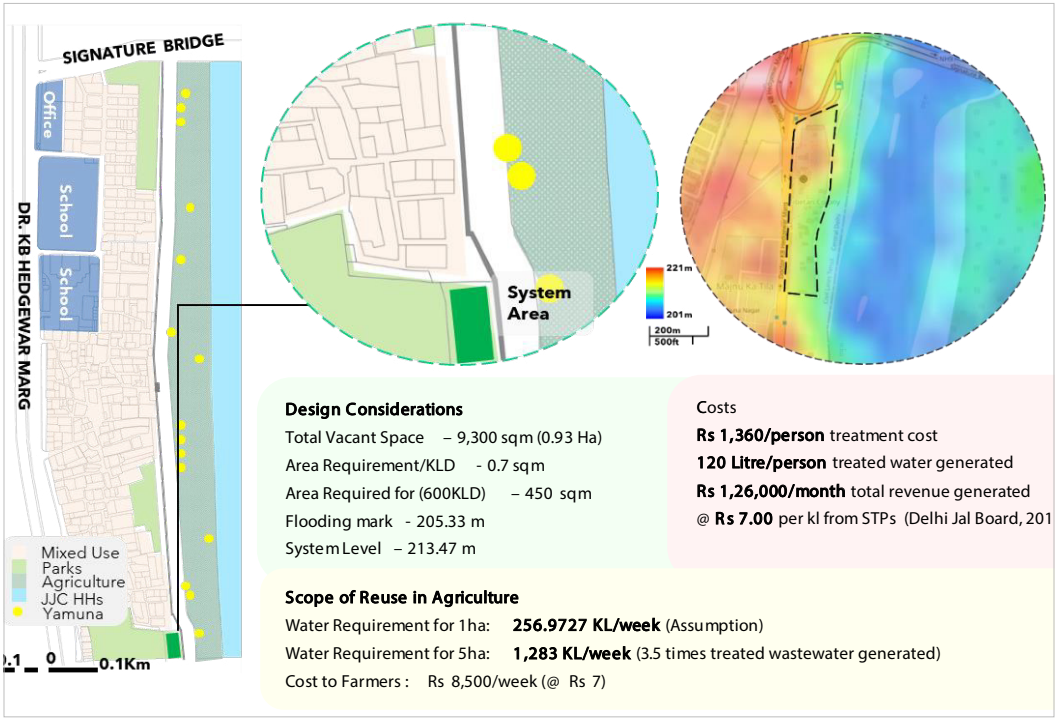
Figure 18: CAMuS-SBT Process



Source: Centre for Science and Environment, n.d.

Site Selection for Technology

Figure 19: System Area of Technology in New Aruna Nagar, Delhi



Source: Prepared by Author, 2022 based on standards recommended by Centre for Science and Environment, n.d.

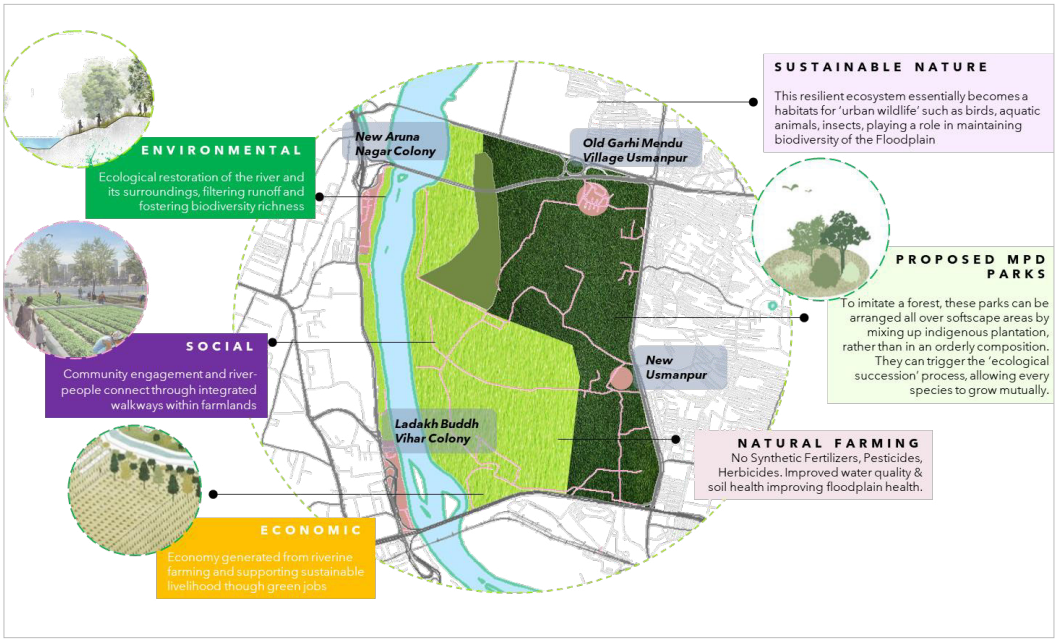
BOD and COD are less than five with the removal efficiency of both greater than 99%. Effluent can be used for construction, flushing, plantation, and irrigation as the discharged water is equivalent to CPCB designated Use Category 'B/C'.

Floodplain Level Proposal

The proposed Master Plan 2041 of Delhi Development Authority (DDA) places strong emphasis on the development of green belt and improving people's engagement with the city's "green and blue resources". The "Green-Blue strategy" which focuses on water bodies and the land around it, offers to give the city a unique shape (Rajput, 2020). Further, as per MPD-2041, agriculture is a permissible land use for Zone O. Integrating Nature-based Farming practices into it will not only help in tackling the agricultural run-off pollution but will also support the theme of re-imagining 'River Yamuna' and Delhi's floodplain image. Thus, the reframed vision for development should be along the lines where there is 'Integration of farming with the existing/proposed parks, and public spaces to improve floodplain health in terms of biodiversity, water quality, and soil health'. This will be done through interventions discussed below and can be replicated across the entire floodplain:

- Environmental: Through Riparian Buffer (30 M) - Ecological restoration of the river and its surroundings, filtering run-off, and fostering biodiversity richness.
- Social: Community engagement and river-people connect through integrated green walkways within the farmlands and proposed parks.
- Economic: Economy to be generated from riverine farming and supporting sustainable livelihood through green jobs.
- Sustainable Nature: This resilient ecosystem to essentially become a habitat for 'urban wildlife' such as birds, aquatic animals, insects, and play a role in maintaining biodiversity of the floodplain
- Proposed MPD Parks: To imitate a forest, these parks can be arranged all over the softscape areas by mixing up indigenous plantations. They can trigger the 'ecological succession' process, thereby allowing all species to grow mutually
- Natural Farming: No synthetic fertilizers, pesticides, or herbicides to be used. This will help in improving the water quality and soil health thus improving the health of the floodplain.

Figure 20: Floodplain Level Proposals based on Urban Agriculture at Site Level



Source: Prepared by Author on ArcGIS, 2022

Stakeholder Identification

Any planning vision for River Yamuna and its floodplains in Delhi must consider and reconcile the concerns and interests of all stakeholders. For successful implementation of community-based projects, stakeholder engagement is a main component. Stakeholders are involved in the planning and implementation stages so as to achieve consensus and take into account their needs and interests. This allows all stakeholders to understand the potential impacts of the proposed activity on the community and their contribution towards better implementation of the project.

Table 6: Stakeholders and their Contribution to the Project

Stakeholder Categories	Their Motives	Potential to Implement
Authorities DJB CPCB DDA NMCG	Respect for laws and regulations Public health Cleanliness of the city Conforming with Master Plans and other plans	Power for enforcement through regulatory framework in terms of connections and safe disposal of treated wastewater, and management of treatment units Link with other authorities can help in land transfer Training methods and materials to be developed with subject matter specialists and trainers to support integrated agro-ecosystem
NGOs (Rights of Farmers, Environmental Groups)	Clean environment Capacity building programs Transparency and Public Participation	Community awareness on effects of current farm practices Conducting workshops and creating awareness about Nature-based agriculture Collaboration between researchers and land users on the promotion of a productive and sustainable farming system
Potential end-users for Reuse Farmers DDA Forest Dept	Affordable and safe products Increase in yield	Increase DWWTs revenue through selling of end-products For irrigation For maintaining green spaces under various agencies
Households (users and owners)	Clean environment	Pressure on municipal authorities and service providers Better management of onsite systems

Conclusion

Although River Yamuna's water quality is at par with that of a healthy river, this study clearly demonstrates that the river is still an important part of many people's lives. The river's management in the city is more likely to create grey infrastructure and recreational areas in and around the river. However, the constant discharge of wastewater drains into the river has yet to be entirely addressed. Delhi also needs to address its unplanned urban growth and try to restore the river's natural ecological flow to allow wastewater to be diluted between Wazirabad and Okhla. Furthermore, Delhi must decentralize its wastewater management through in-situ treatment with focus on soft infrastructure, local reuse, and mainstream septage control, as new, illegal growth will emerge by the time the grey infrastructure covers the existing areas that are unsewered. This game of catch-up will continue until we acknowledge the problem, and move away from sewage and centralized systems and towards sanitation for all.

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Conflict of Interest

The authors declare no conflict of interest.

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