

YAMUNA ACTION PLAN AND SUSTAINABLE RIVER POLLUTION CONTROL: A POLICY AND GOVERNANCE REVIEW

A PROJECT REPORT

**SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR
THE AWARD OF DEGREE**

**OF
MASTERS OF TECHNOLOGY**

IN

ENVIRONMENTAL ENGINEERING

Submitted by:

**KRISH SHOKEEN
24/ENE/07**

Under the supervision of

Prof. Anil Kumar Haritash



DEPARTMENT OF ENVIRONMENTAL SCIENCE AND ENGINEERING

**DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi college of engineering) Bawana
Road, Delhi-110042**

MAY, 2026

**DEPARTMENT OF ENVIRONMENTAL SCIENCE AND
ENGINEERING
DELHI TECHNOLOGICAL UNIVERSITY
(Formerly Delhi College of Engineering)
Bawana Road, Delhi-110042**

CANDIDATE'S DECLARATION

I, **Krish Shokeen**, Roll No–24/ENE/07 student of M.Tech (Environmental Science and Engineering), hereby declare that the work which is presented in the thesis titled **“YAMUNA ACTION PLAN AND SUSTAINABLE RIVER POLLUTION CONTROL: A POLICY AND GOVERNANCE REVIEW”** which is submitted by us to the Department of Environmental Science and Engineering, Delhi Technological University, Delhi in fulfilment of the requirement for the award of degree of Masters of Technology under supervision of **Prof. Anil Kumar Haritash**, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associateship, Fellowship or other similar title or recognition.

Place: Delhi

Date: MAY, 2026

Krish Shokeen (24/ENE/07)

This is to certify that student has incorporated all the corrections suggested by the examiner in thesis and statement made by candidate is correct best to our knowledge

Signature of Supervisor

Signature of External Examiner

**DEPARTMENT OF ENVIRONMENTAL SCIENCE AND
ENGINEERING**

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

CERTIFICATE

I hereby certify that the Project Dissertation titled “**YAMUNA ACTION PLAN AND SUSTAINABLE RIVER POLLUTION CONTROL: A POLICY AND GOVERNANCE REVIEW**” which is submitted by Krish Shokeen, Roll No’s – 24/ENE/07 of Environmental Science and Engineering ,Delhi Technological University, Delhi in fulfilment of the requirement for the award of the degree of Masters of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place: Delhi
Date: MAY, 2026

Prof. Anil Kumar Haritash
SUPERVISOR

**DEPARTMENT OF ENVIRONMENTAL SCIENCE AND
ENGINEERING**

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-110042

ACKNOWLEDGEMENT

I wish to express my sincerest gratitude to Prof. Anil Kumar Haritash for his continuous guidance and mentorship that he provided me during the project. He showed me the path to achieve my targets by explaining all the tasks to be done and explained to me the importance of this project as well as its industrial relevance. He was always ready to help and clear any doubts regarding any hurdles in this project. Without his constant support and motivation, this project would not have been successful.

Place: Delhi

Date: MAY, 2026

Krish Shokeen (24/ENE/07)

Abstract

The Yamuna River maintains its position as one of the most polluted water bodies in northern India despite multiple decades of intervention efforts. Recently, the Yamuna River has been subjected to heavy pollution loads caused by the discharge of untreated or partially treated wastewater and industrial effluents. This necessitates the need for managing the pollution caused in the rivers. So, the Yamuna Action Plan is initiated for the effective control of river pollution.

The research evaluates Yamuna Action Plans YAP I–III through their policy design elements, their governance systems, and public–private partnership structures. The methodology involves the use of the Weighted Average Water Quality Index (WAWQI), which is calculated using the quality scores and standardization of it into a 0 to 5 Water Quality Score (WQS) and the Efficiency Ratio (ER) is normalized for the dynamics of the cost-policy equation using logarithmically scaled funds. This reveals the continued disparity between infrastructure investment and actual improvements in river health, including constant high BOD concentrations in the 22 km reach of the river in Delhi. Although there has been improvement in the treatment facilities for sewage waste (from 726 MLD in YAP I to over 2,893 MLD at present), institutional fragmentation, upstream pollutants, and lax enforcement have led to setbacks, as indicated by the Priority-I status of pollution. The review uses data from the Central Pollution Control Board (CPCB 2024) and Delhi Pollution Control Committee (DPCC 2025) and academic research to demonstrate that sewage infrastructure development and technological advancements have increased substantially, yet weak governance and insufficient enforcement continue to block environmental restoration. The Delhi section of the Yamuna River maintains Biochemical Oxygen Demand levels exceeding 40 mg/L, which exceeds the required standards for bathing water quality.

The thesis supports three essential recommendations for Yamuna River sustainability through the establishment of basin-wide governance, performance-based funding, and permanent community engagement. From that, the significance of YAP, importance, and the plans for sustainable river pollution management are explored in this review.

Table Of Contents

Candidate's declaration.....	i
Certificate	ii
Acknowledgement.....	iii
Abstract.....	iv
Table Of Contents	v
List of Tables	vii
List of Figures.....	viii
CHAPTER 1 INTRODUCTION	1
1.1 Yamuna Action Plan-.....	1
1.1.1 Assess Economic Implications:	2
1.1.2 Evaluate Regulatory and Policy Frameworks:	2
1.1.3 Focus On Environmental Sustainability:	3
1.2 Problem Statement.....	3
CHAPTER 2 METHODOLOGY AND LITRATURE REVIEW	5
2.1 Literature Review	5
2.2 PRISMA- Four-Phase Flow Diagram	5
2.2.1 Data Collection:	7
2.2.2 Selection Criteria:.....	7
2.2.3 Analysis:	7
2.3 Policy Efficiency Framework	8
2.3.1 Computation of Quality Rating (Qi)	8
2.3.2 Computation of WAWQI and WQS	8
2.3.3 Efficiency Ratio (ER) and Policy Grade	9
CHAPTER 3 EVOLUTION AND FRAMEWORK OF YAMUNA ACTION PLAN..	10

3.1 Yamuna Action Plan Phase I (1993–2003)	10
3.2 Yamuna Action Plan Phase II (2003–2015).....	11
3.3 Yamuna Action Plan Phase III (2015–Present)	11
3.4 Institutional and Financial Framework.....	12
CHAPTER 4 POLICY AND GOVERNANCE ANALYSIS.....	15
4.1 Policy Design and Objectives	15
4.2 Institutional Coordination and Administrative Mechanisms	15
4.3 Legislative and Regulatory Framework.....	16
4.4 Governance Challenges and Accountability Gaps.....	16
4.5 Expenditure Spent for Yamuna Rejuvenation-.....	18
CHAPTER 5 PUBLIC-PRIVATE PARTNERSHIP.....	20
5.1 Evolution of PPPs in River Management	20
5.2 Major PPP Initiatives under YAP III	20
5.3 Stakeholder Participation and Community Engagement.....	21
5.4 Evaluation of PPP and Participation Outcomes.....	21
CHAPTER 6 RESULT AND DISCUSSIONS.....	23
6.1 Environmental and Technical Outcomes	24
6.2 Institutional and Policy Outcomes	25
6.3 Socio-Economic and Community-Level Outcomes	25
6.4 Policy Score-	26
6.5 Challenges.....	28
CHAPTER 7 CONCLUSION AND POLICY RECOMMENDATIONS.....	29
7.1 Conclusion	29
7.2 Policy Recommendations	29
REFERENCES-	31
ANNEXURE A- Data Summary for R Analysis	35
ANNEXURE B – Full R Code Used	36

List of Tables

Section	Table	Page No
2.3	Water Quality Parameters- Standard Values and Assigned Unit Weights.....	8
2.3	Policy Performance Grade Classification.....	9
3.4	Evolution and Framework of the Yamuna Action Plans.....	13
4.4	Policy and Governance analysis of YAP.....	17
4.5	Funds Spent each Financial Year.....	18
6.4	Policy score and Grade calculation.....	26

List of Figures

Section	Figure	Page No.
1.1	Map of river Yamuna through Delhi stretch	2
2.2	PRISMA Framework.....	6
6	BOD Prediction using R-studio.....	23
6	DO Prediction using R-studio.....	23
6	Fecal Coliform Prediction using R-studio.....	24

CHAPTER-1

INTRODUCTION

1.1 Yamuna Action Plan-

Rivers have always been a source of life for civilisations. They are essential to support agriculture and urbanisation as well as culture (Pandey & Pandey 2013). India's rivers are vital to the nation due to rapid urbanization and intensive agricultural activities. The country has 14 major rivers that account for 85% of total surface water flow, serving crucial environmental, historical, social, and economic functions. The Yamuna River is particularly significant, supporting irrigation for millions across the Delhi and Uttar Pradesh regions (Jaiswal et al., 2019). The Yamuna River originates from the Yamunotri glacier in Uttarakhand and flows approximately 1,370 km through Himachal Pradesh, Haryana, Delhi, and Uttar Pradesh before converging with the Ganga River at Prayagraj (formerly Allahabad). This river sustains more than 50 million people over its course. For decades, rapid urbanization, industrial release, and poor sewage treatment have made this sacred river one of India's most polluted (CPCB 2024). The river receives almost 80 percent of its pollution load from untreated domestic sewage. Furthermore, the short Delhi segment, not exceeding 2 percent of the river's length, contributes almost 75 percent of the total contaminants (DPCC 2025). The pollution load discharged within the Delhi stretch significantly deteriorates river water quality, as evidenced by the increase in chemical oxygen demand (COD) from 70 mg/L at Palla to 430 mg/L at the Okhla Barrage (Nehra and Singh, 2020).

Recognizing the severity of the river pollution problem, the Government of India introduced the Yamuna Action Plan (YAP) in 1993, with funding assistance from the Government of Japan facilitated through the Japan International Cooperation Agency (JICA). The initiative expanded into YAP II (2003) and YAP III (2015 onwards) under the NMCG. The different phases of the program worked to enhance sewage interception systems and treatment facilities and solid waste management and public education programs (MoEFCC 2018). The total investment of more than ₹5,000 crores has not led to better water quality (Rani & Kumar, 2020). There are still gaps between infrastructure growth and environmental restoration indicate that Indian urban river management faces multiple governance and policy challenges.

Therefore, this review explores the YAP, its significance, and Sustainable River Pollution Control schemes, policies, and governance strategies. Also, this review explores the challenges, legislative frameworks, and policies related to the YAP and its impact on people and the river. This review is undertaken due to the limited exploration of the YAP program, legislative framework, and the evolution of YAP and its impacts on the river Yamuna. Moreover, this review is significant because it highlights the significance and the impacts of the YAP and the government policies, which are underexplored in the existing studies. Along with this, the organizations and institutions helping with the YAP plans are also explored. However, some challenges and limitations in YAP still persist. Some of the challenges are improper governance, improper sewage control, etc.

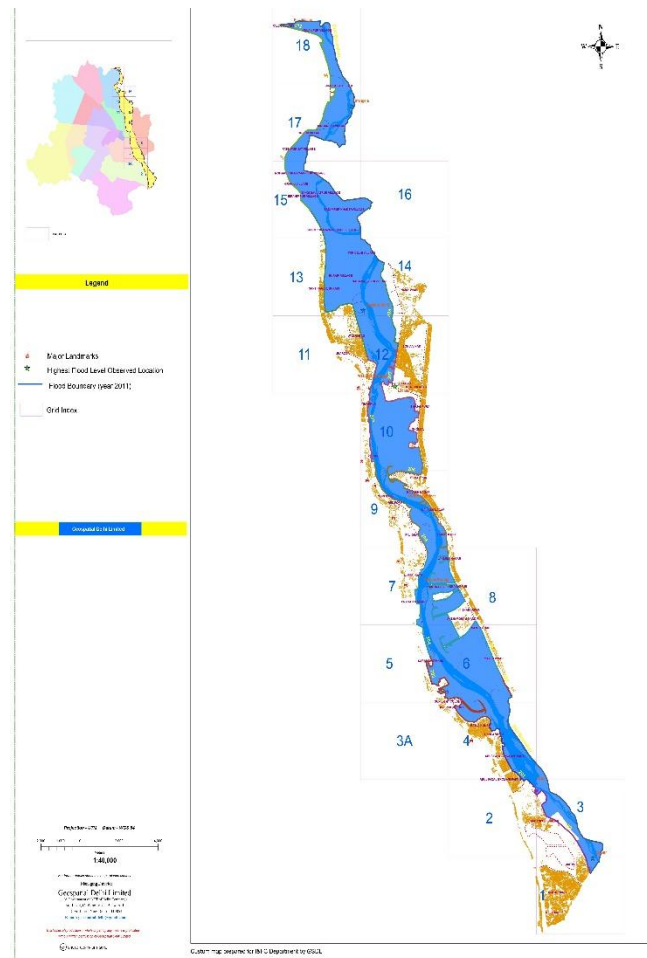


Figure1: Map of river Yamuna through Delhi stretch

1.1.1 Assess Economic Implications:

The government has poured billions into constructing sewage treatment plants (STPs) and interceptors, expecting biochemical oxygen demand (BOD) to drop below the mandated 3 mg/L primary water quality standard. Still the Delhi's 22-km Yamuna stretch consistently registers BOD >40 mg/L, with total coliforms exceeding 10,000 MPN/100ml—which depicts level of water which are unfit even for bathing.

The Yamuna's restoration projects have taken a huge toll on the budget and not only that it still hasn't wielded a desirable result. Public health burdens from waterborne diseases (cholera, jaundice) rack up ₹1,500 crore yearly in Delhi alone, according to health ministry estimates, from 20,000+ cases being tied to river contamination. Ecosystem losses compound like fisheries collapsed leading to reduced livelihood from them, biodiversity hotspots like floodplain wetlands vanishing in the surroundings, slashing services worth ₹500 crore annually (carbon sequestration, flood buffering), factory polluting a river without paying for downstream cleanup, perpetuating market failure.

1.1.2 Evaluate Regulatory and Policy Frameworks:

- **YAP I (1993-2003):** It mainly focused on infrastructure like STPs and interceptors (₹686 crore), it ignored factors like urban sprawl fueling sewage surges or farmers' runoff. They were essentially treating symptoms and not root cause.
- **YAP II (2003-2012):** The YAP expanded and started to spread public awareness campaigns and solid waste management (₹1,700 crore), yet the implementation lagged, only 55% of targets were able to meet due to siloed funding.

- **YAP III (2017-2026):** At this stage we started Integrated Basin Management (aligning SDG 6: clean water). Incorporating reuse and monitoring technology to device the favoured results and increase efficiency. But the policy was not properly implemented due to COVID and other delays.

Agency Overload

We have a multi-agency model which has lead to multiple sources for reporting and implementation. Now this might be effective if agencies like National Mission for Clean Ganga (NMCG) for strategy, Central Pollution Control Board (CPCB)/Delhi Pollution Control Committee (DPCC) for data, Urban Local Bodies (ULBs) like DJB for groundwork worked in harmony but they overlaps and contradict each other. NMCG approves funds, but ULBs execute. Conflicting reports between agencies (CPCB logs 70% STP uptime, CAG says 60%) sometimes spark blame games. This "multi-agency muddle" echoes India's federal water woes, delaying decisions and creating confusion.

1.1.3 Focus On Environmental Sustainability:

Delhi is the major culprit, responsible for polluting Yamuna- 70-80% of its annual pollution load squeezes into a mere 2% stretch (22 km) of Delhi which leads to dissolved oxygen (DO) levels going lower than 4 mg/L signaling ecological collapse, phosphates increase and forms frothy eutrophication that chokes aquatic breath. It's a river which is being reduced to just a drain over Delhi stretch. Yamuna needs holistic healing and rejuvenation.

Delhi generates about 3,400 million liters per day (MLD) of sewage, but the treatment capacity installed hovers at about 2,893 MLD leaving an approximate of 500-800 MLD gap which is being flushed untreated into the river. End-of-pipe STPs contribute to 70% of point sources but ignores the non-point sources such as 40% agricultural runoff laden with pesticides, 20% industrial effluents evading monitors. This linear approach to control the sources in visible site only sustains a vicious loop, ignoring upstream sludge that is being discharged from 1,500+ illegal drains and industries .

Current policies majorly focus on grey infrastructure that dominates the treatment and is priority focused solution but nature-based solutions offers salvation. For example constructed wetlands at Keshopur treat 20 MLD at 1/5th STP cost while polishing effluents naturally, floodplain reconnection (e.g., 500-ha Yamuna Biodiversity Park model) restores aquifers and fisheries, bioremediation with native microbes' cuts BOD 60% in pilots, riparian planting buffers banks against erosion. Natural based solutions deliver co-benefits, flood resilience amid climate change, biodiversity rebounds with lesser cost and more environmentally sustainable.

1.2 Problem Statement

India has spent over ₹5,400 crore and more than three decades on the Yamuna Action Plans (YAP I–III), which were first funded by JICA and later by NMCG. However, the sacred Yamuna River is still ecologically devastated, especially in Delhi's 22-km stretch (2% of its 1,370 km course), where 70-80% of pollution loads (including 75% of total contaminants) raise BOD >40 mg/L, COD from 70 to 430 mg/L, and DO <2 mg/L, making it biologically dead (CPCB 2024; DPCC 2025; Nehra & Singh 2020).[from before] This important lifeline, which supports more than 50 million people, 90% of regional irrigation, and a rich cultural heritage (Jaiswal et al. 2019; Pandey & Pandey 2013), gets 80% of its pollution from untreated sewage (3,400 MLD generated vs. 2,893 MLD treated). This is made worse by industrial waste, agricultural runoff, and a lack of ecological flows.

YAP phases have grown from engineering-focused STPs and interceptors (YAP I) to

awareness, solid waste, and basin integration (YAP III; MoEFCC 2018), but systemic failures keep water quality from improving: 40% of STPs don't work because of problems with operation and maintenance (CAG findings), institutional fragmentation across NMCG/CPCB/ULBs/DPCC, disputes over state borders (Haryana/UP vs. Delhi), weak enforcement of the Water Act 1974 and EPA 1986, and a linear "treat-and-dump" model that doesn't take into account costs like ₹1,500 crore per year in health care, fishery collapses, and property devaluation (Rani & Kumar 2020). No basin authority enforces IWRM, which keeps a governance paradox going where expensive infrastructure doesn't pay off and policy evolution and sustainability gaps aren't fully explored.

The study tackles this important gap: even though YAP investments show commitment, there hasn't been much research on their economic inefficiencies, broken governance, and environmental problems, which make it hard to restore urban rivers in India on a large scale. By looking at YAP's effects over time, the laws that govern it, the roles of institutions, and the connections between people and rivers, it shows why technological solutions don't work without changes to the economy, policies, and the environment. This is a plan for cleaning up the Yamuna and other polluted waterways.

CHAPTER-2

METHODOLOGY AND LITERATURE REVIEW

2.1 Literature Review

As defined by Singh & Kansal (2018), this review follows the systematic-thematic approach that corresponds with general standards followed by environmental policy journals. The methodology of this review has some stages: i) Literature review and Data Collection, ii) Article Selection Criteria, and iii) Analysis. This is done to effectively classify and select the articles for effective analysis and research. Moreover, the selection and eligibility of the articles are represented as a Preferred Reporting Items for Search Strategy and Meta Analyses (PRISMA) framework in Figure 2.

PRISMA, short for Preferred Reporting Items for Systematic Reviews besides Meta Analyses, offers a fixed set of rules for how researchers should describe every step of a systematic literature review, especially in environmental policy studies. Singh & Kansal (2018) use the PRISMA flow diagram to show, box by box, how they found papers, removed duplicates, read titles and abstracts, applied inclusion rules and ended with the final corpus. Each arrow in the diagram matches a stage in your systematic thematic plan - the initial search string, the first screen, the full text check plus the final list of accepted studies - any reader could repeat the same sequence.

The checklist forces authors to report 27 separate items that cover the title, the abstract, how the search was done, what came out of it and how the findings were interpreted. Because every rejected article is logged with a reason, hidden or convenient omissions become impossible. The approach supports "effective classification and selection" - turning each choice into a countable entry - the raw hits from each database, the number after duplicate removal, the count left after title abstract screening, the full texts assessed and the final set retained.

A PRISMA flow diagram is required for every thesis because it forces every author to describe the hunt for literature in the same way. The chart turns private choices into public numbers that any reader can repeat - environmental policy journals will not accept a methods section that lacks those numbers.

2.2 PRISMA- Four-Phase Flow Diagram

PRISMA 2020 keeps the same four part picture that earlier versions used. The picture follows each record through three thesis stages: (i) gathering literature and data, (ii) choosing articles and (iii) analysing the final set. Boxes list how many records enter or leave each step - arrows show where they go. Because every total is written down, later readers see how many items vanished and why - the risk of a hidden bias charge falls.

1. Identification - List every record found in each database - Scopus, Web of Science, Google Scholar for environmental policy work - but also add records from grey literature or citation lists. Remove duplicates with software like EndNote - duplicate removal usually erases ten to twenty percent of the first list. Report the final count of unique records. Example: "1,500 records identified; 300 duplicates removed → 1,200 proceed" This number feeds directly into stage i) and proves that the data gathering step was

exhaustive.

2. Screening- It begins when titles and short summaries are checked against wide entry rules, for example if the work touches climate governance or similar policy topics. Each excluded item is logged with its reason, like "900 irrelevant to environmental policy". Two reviewers carry out the check separately - when their decisions differ, they talk until they agree. The works that pass, say 200, move on - this step matches the first filter named in section ii).
3. Eligibility requires the full document to meet tighter rules - it must be peer reviewed, published after 2000, contain evidence about policy results and be written in English. Every rejection is written in a table together with its exact motive, for instance "no methodology: n=120; wrong geography: n=30". Only the documents that satisfy all rules, perhaps 50, enter the synthesis - this step gives the grounds for omissions listed in sections ii) and iii).
4. Inclusion- Inclusion ends with the final pool chosen for thematic analysis. Policy reviews often keep 20 - 50 articles or reports. Each retained study is listed with full details, like "40 articles synthesized". This final pool feeds the analysis chapter and the flow diagram shows that no selective picking took place.

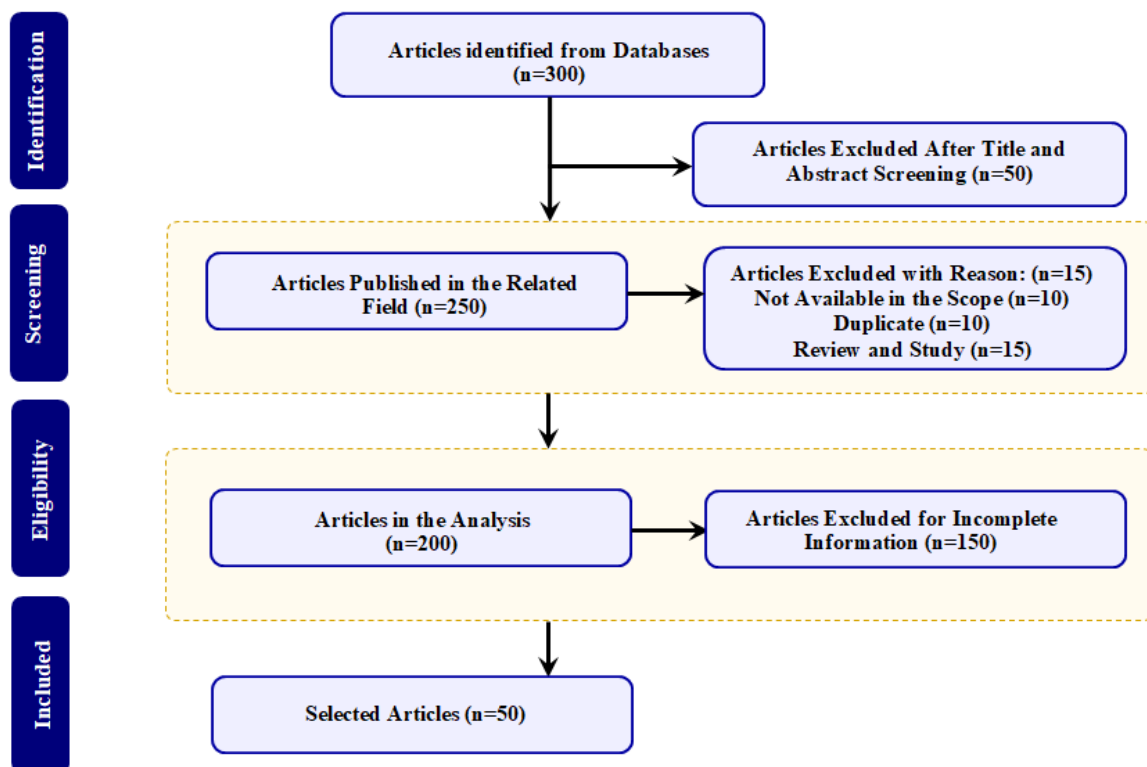


Figure 2: PRISMA Framework

2.2.1 Data Collection:

In this review, articles, journals, and reports from governmental agencies like CPCB 2024, DPCC 2025, MoEFCC 2018, NMCG 2024, and JICA progress documents and news updates from “The Indian Express” 2025 were used throughout the review.

2.2.2 Selection Criteria:

Studies that centered on either of the Yamuna Action Plans or other Indian river-cleaning projects, or dealt with policy, governance, or institutional mechanisms where there was empirical data on implementation, were included. Purely chemical or site-specific papers with no policy insight were excluded. Also, the literature from the significant databases like “Science Direct, Web of Science, IEEE, etc.,” was selected between the years 2016 and 2026. Also, the keywords like “Yamuna Action Plan (YAP), Environmental Governance, Public–Private Partnerships, and Sustainable River Management” were used for the search strategy.

2.2.3 Analysis:

All data were qualitatively coded for emergent themes: policy design, governance gaps, stakeholder engagement, and sustainability. Additional reliability was provided in the reliability coding process effort due to utilizing multiple data sources. Trends expressed in older studies, for instance, were validated by using CPCB readings from 2024 and DPCC readings from 2025.

Trends were assessed using time-series and faceted seasonal plots generated in R. The empirical outcomes were then compared against governance and infrastructure developments under the Yamuna Action Plans to evaluate their effectiveness.

For each Station $\times$ Season $\times$ Parameter, the following equation was used:

$$\text{Predicted Value} = a + b \times (\text{Future Year})$$

1. a = intercept (the baseline value of the parameter when Year = 0)
2. b = slope (rate of change of the parameter per year)
3. Future Year = 2026, 2027, 2028

Slope:

$$b = \frac{\sum(X - \bar{X})(Y - \bar{Y})}{\sum(X - \bar{X})^2}$$

Intercept:

$$a = \bar{Y} - b \cdot \bar{X}$$

Where-

1. X = observed years (2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025)
2. Y = observed values for a parameter (e.g., pH, BOD, COD, etc.)
3. $\bar{X}$ = mean of years
4. $\bar{Y}$ = mean of parameter values

2.3 Policy Efficiency Framework

Weighted average water quality index (WAWQI) Framework is utilized in this study to understand and access the water quality parameter of Yamuna River across Delhi Stretch. Generally, this method integrates the multiple parameters into a single composite index, which is relatively easier to understand the overall quality of the river.

WAWQI is converted into Water Quality Score (WQS) that helps to evaluate the overall performance of the policy on the river quality. On the other hand, we calculate the Efficiency ratio (ER) which depend on the overall estimated funds spent on the river to cleaning and couple it with the WQS to calculate the performance of policy. The score obtained is categorized accordingly to, evaluate the annual performance of the government policy implementation and find the calculative ways to improve.

Primary water quality data that is included are Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO) and Fecal Coliform (FC). They were sourced from annual monitoring reports published CPCB and DPCC. The annual financial expenditure data pertaining to Yamuna remediation initiatives (including the Yamuna Action Plan phases I–III and the Delhi Government's river rejuvenation budget) were compiled from DJB annual reports and the Ministry of Jal Shakti allocations.

2.3.1 Computation of Quality Rating (Qi)

The quality rating for each parameter was computed using the standard sub-index formulation as follows:

$$Q_i = \frac{(Actual\ Conc.-Ideal\ Conc.)}{(Con.\ Standard-Ideal\ Conc.)} \times 100 \quad \dots (1)$$

Where:

Actual Conc. = measured concentration from the report of CPCB and DPCC after calculating mean.

Ideal Conc. = ideal value according to the parameter being measured

Conc. Standard = WHO permissible standard set for the particular parameter

2.3.2 Computation of WAWQI and WQS

Unit weights were assigned to each parameter in inverse proportion to their respective permissible standard values, following Equation 2:

$$W_i = \frac{K}{S_i} \quad \dots (2)$$

Where S_i denotes the standard permissible value of the given parameter, and K is a proportionality constant set to 1 for computational simplicity. Table 1 presents the standard values, ideal concentrations, and resulting unit weights for all assessed parameters.

Parameter	Standard Value (CPCB)	Unit weight (Wi)
pH	6.5-8.5(ideal 7.0)	—
Biochemical Oxygen Demand (BOD)	3 mg/l	0.33
Dissolved oxygen (DO)	6.0 mg/l	0.16
Fecal Coliform	2500MPN/100ml	0.04

Table 1: Water Quality Parameters- Standard Values and Assigned Unit Weights

The composite WAWQI score for each year was computed as the weighted arithmetic mean of individual quality ratings:

$$WAWQI = \sum \frac{W_i \times Q_i}{W_i} \quad \dots (3)$$

The resulting WAWQI values were linearly scaled to a 1–5 Water Quality Score (WQS) to

facilitate inter-year comparisons and integration with the expenditure-based efficiency metric.

2.3.3 Efficiency Ratio (ER) and Policy Grade

To evaluate the cost-effectiveness of policy interventions, an annual Efficiency Ratio was computed as:

$$ER = \frac{WQS}{\text{Total Expenditure that Year}(\text{₹ Cr.})} \dots (4)$$

The ER values were standardised across all study years onto a 0–5 scale using percentile-based normalisation. A composite Performance Score was then calculated as:

$$\text{Final Score} = 0.6 \times WQS + 0.4ER \dots (5)$$

This weighted composite assigns greater weight to actual environmental outcomes (60%) relative to cost-efficiency (40%), reflecting the primacy of ecological recovery. Annual performance was then classified into five policy grades (A–E) using the mapping presented in Table 2.

Final Score (0.6×WQS + 0.4×ER)	Policy Grade	Interpretation
≥ 4.0	A	Excellent — Target achieved, high cost-efficiency
3.0 – 3.9	B	Good — Near-target; moderate efficiency
2.0 – 2.9	C	Fair — Partial improvement; low efficiency
1.0 – 1.9	D	Poor — Minimal improvement despite spending
< 1.0	E	Critical — No measurable progress

Table 2: Policy Performance Grade Classification

CHAPTER-3

EVOLUTION AND FRAMEWORK OF YAMUNA ACTION PLAN

The Yamuna Action Plans (YAP I–III) together represent one of India’s longest-running environmental restoration efforts, implemented under the National River Conservation Plan (NRCP) with assistance from the JICA (JICA 2019). The history of YAP interventions shows three decades of gradual shift in the application of infrastructure-intensive approaches to pollution abatement to integrated sustainable river-basin management regimes. The cumulative sewage treatment capacity is estimated at 2,893, 000 litres per day (MLD) as per the Delhi Jal Board 2025 report, and the daily sewage generation is estimated at over 3,400 MLD, which is significantly higher than the cumulative capacity, hence creating a shortfall of between 500 and 800 MLD on a daily basis. Despite this capacity expansion, river segments such as Wazirabad–Okhla remain under Priority-I pollution status (CPCB 2024). The Yamuna Action Plan (YAP) is a major bilateral project initiated in 1993 by India and Japan to reduce pollution in the Yamuna River, structured in three phases (YAP-I, II, and III). It focuses on constructing Sewage Treatment Plants (STPs), improving sewerage systems, and cleaning in Delhi, Haryana, and UP.

3.1 Yamuna Action Plan Phase I (1993–2003)

YAP I was launched in 1993 with a total cost of ₹705 crore, largely funded through a JICA soft loan of ₹500 crore (NRCD 2014). The plan targeted the high-load urban centres of Delhi, Agra, and Mathura—responsible for nearly 70 percent of total pollution entering the river. During this monitoring plan, 19 sampling locations along the main river channel were selected for analysis. Additionally, 16 drainage outfalls from Delhi—identified as significant contributors to river pollution—were included in the monitoring programme. Of these, 12 locations were designated for the assessment of water quality parameters associated with organic pollution (Lokhande and Tare, 2021).

Therefore, under YAP I, 29 sewage treatment plants (STPs) were established, adding a combined capacity of about 726 MLD (403 MLD in Uttar Pradesh, 303 MLD in Haryana, and 20 MLD in Delhi) (MoEFCC 2018). Over 1,900 km of sewers and several low-cost sanitation units were installed to prevent open defecation and direct waste discharge.

Nevertheless, there was a very significant increase in sewage generation, increasing from 2,460 MLD in 2003 to over 3,200 MLD by 2011, resulting in much greater increases in generation than the growth of treatment capacity. In approving the treatment plant performance audit on February 4, 2013, the Comptroller and Auditor General of India found that nearly 40% of STPs were not utilized at all, and substantial delays ranged from one to five years in project completion (CAG 2013). While there was little improvement in water quality as a result, YAP II provided some important lessons for policy development for the next program: funding for O&M; monitoring program capacity and performance; and validating the role of citizens as participants in planning and monitoring.

3.2 Yamuna Action Plan Phase II (2003–2015)

Recognising shortcomings of the earlier effort, YAP II was initiated in 2003 with a wider coverage of stakeholder participation and system rehabilitation (Rao & Singh 2015). The sanctioned budget under YAP-II is ₹624 crores in total. Of this amount, ₹387 crores were sanctioned to Delhi, ₹124 crores to Uttar Pradesh, and ₹63 crores to Haryana (Said and Hussain, 2019). Another ₹50 crores were sanctioned for capacity-building activities (PMC-TEC consortium, 2005). The Japanese International Cooperation Agency provided funds to the tune of ₹511 crores. Under this scheme, sewage treatment plants have been sanctioned to be set up in 15 towns of the three participating states, having a capacity of 189 MLD. Due to non-completion of the project on time, the deadline of March 2011 has been imposed for its completion.

The important works involved the construction of a 189 MLD new STP capacity and the rehabilitation of 273 MLD older systems. Institutions like the Delhi Jal Board, State Pollution Control Boards, and Central Pollution Control Board collectively monitored the outcomes.

Public awareness programs through NGOs and schools began, relating to India's first structured attempt at having community participation in river policy (MoEFCC 2018).

Yet sewage production accelerated significantly - from 2,460 MLD in 2003 to more than 3,200 MLD by 2011—that outstripped expanded treatment capacity. The performance audit from the Comptroller and Auditor General of India (CAG 2013) found that almost 40% STPs were under-performing, while project delays reached five years. Even though the color of the water received from YAP II did not lead to substantive gain in terms of water quality, YAP II provided important lessons in policy - notably in O&M funding, performance monitoring, and citizen engagement - which would be part of the next phase.

3.3 Yamuna Action Plan Phase III (2015–Present)

YAP III, under NMCG and launched in 2015, ushered in a paradigm shift toward sustainable and technology-driven wastewater management in tune with the UN Sustainable Development Goal 6 on Clean Water and Sanitation. From the research (Srivastava and Prathna, 2022), The project YAP-III comprised nine work packages which had been conceived in an attempt to upgrade the existing WWTPs in three drainage zones of Rithala, Kondli, and Okhla. Besides, the project also sought to restore the deteriorated trunk sewers, peripheral sewer networks, and rising mains at structurally vulnerable sites of the above catchments. YAP-III was distinct from its other phases as it sought to achieve some positive outcomes with respect to lowering down the pollutant loading on the river Yamuna by implementing a targeted intervention along the stretch of the city of Delhi. From a socioeconomic perspective, the project had a high potential for adding substantial value to the local communities owing to its beneficial outcomes.

Major investments include

- Okhla STP (564 MLD) has been executed through Larsen & Toubro together with Suez India, by following the DBO model.
- Kondli STP (204 MLD) - upgraded for ₹338 crore with 10 years O&M.

- Rithala STP - 182 MLD, upgraded by Sequencing Batch Reactor (SBR) and Anaerobic Digester technologies.

Together, these plants treat almost one-third of Delhi's sewage load and reuse around 15% for horticulture, cooling, and groundwater recharge.

Despite technological advancements, CPCB, 2024, classifies the Delhi reach as falling under the category of Priority-I pollution, with BOD levels recorded as greater than 40 mg/L and Dissolved Oxygen below 2 mg/L. The emerging issues relate to a high cost of O&M, lapses in coordination, and supply of power on an intermittent basis continue to persist. DPCC 2025

Nonetheless, YAP III introduced performance-based PPP models, real-time monitoring at 33 key locations, and data transparency dashboards, thus indicating a movement toward outcome-based governance.

3.4 Institutional and Financial Framework

Delhi's water governance system functions through a tiered institutional structure, with many central government organizations serving the roles of regulation and advisories. These include the Ministry of Jal Shakti, the Central Ground Water Board, the National Green Tribunal, CPHEEO, the Delhi Development Authority (DDA), and many more – each of which contributes in terms of policy, technical guidance, and environment. The funding sources of water development programs by the GNCTD include both its own resources, centrally collected funds allocated for use by it, and borrowed money from financial institutions and the corporate business sector (Kumari and Biswas, 2022).

The YAPs work under a multi-tier institutional arrangement:

- The National River Conservation Directorate, now merged into NMCG, serves as the apex coordinating body.

State Governments and Urban Local Bodies - such as DJB, Haryana Urban Development Authority (HUDA), and UP Jal Nigam - implement projects.

- CPCB and SPCBs monitor compliance.

The funding pattern follows a 70:30 cost-sharing model between the Centre and States, supplemented by loans from JICA and corporate CSR contributions.

By 2024, total cumulative investment across all YAP phases exceeded ₹5,400 crore. (MoEFCC, 2024)

The Yamuna Action Plan is an example of a collective effort that involved various government agencies under the financial assistance provided by the Japan Bank for International Cooperation, with the main goal of enhancing the poor water quality conditions of the river. However, despite spending considerable amounts on the project – which stood at about Rs. 1,187 to 1,443 crore – the results were not achieved as desired. The BOD load in the 18 drains within the NCT region experienced a dramatic increase, reaching almost double its original value – from 105 tonnes per day in 2014 to 214 tonnes per day in 2015 (Sharma et al., 2025). The challenges remain, however. The institutional fragmentation-multiple departments with overlapping mandates-continues to weaken coordination, as Rao & Singh, (2015), mention. While the investment in capital is accommodated centrally,

municipalities bear O&M, making performance variable. The absence of any Yamuna Basin Authority further weakens basin-wide integration. Recent policy dialogues under NMCG (2024) propose performance-linked disbursal and a unified Basin Data Portal—steps toward more transparent, evidence-driven governance. Further, the Evolution and Framework of the Yamuna Action Plans are tabulated in Table 3.

Table 3: Evolution and Framework of the Yamuna Action Plans

Author	Study Type	Focus	Action Plan	Findings					Challenges
				Cities covered	Timeline	BOD	Average load	MGD	
(Lokhande and Tare, 2021)	Research Study	Spatio-temporal analysis of Yamuna water quality	YAP-I	Delhi	1978 to 2015	93 mg/L	50%	Nil	This study represented only the recent water quality, thereby restricting the inferences to knowledge based on limited data.
(Said and Hussain, 2019)	Observational Study	Effects of YAP	YAP-I	Haryana, Delhi, Uttar Pradesh	1996 to 2009	23 mg/L	30%	Nil	In Delhi, the river quality was still poor and not meeting the required standards, with DO values.
(Srivastava and Prathna, 2022)	Research Study	Water quality Impact analysis	YAP-III	Delhi, Agra, Mathura	1993 to present	<10 mg/L	260 tonnes	748	The plan, however, was not targeted at other polluting activities, such as industry, agriculture, and livestock breeding.
(Kumari and Biswas, 2022)	Observational Study	Analysing Water Governance of Delhi	Nil	Haryana, Himachal Pradesh, Uttar Pradesh, Delhi	Nil	Nil	Nil	389	The situation was further complicated by the intervention of political actors, such as the local MLA in certain areas.
(Sharma et al., 2025)	Research Study	Characterization of the water quality of the Yamuna	YAP	Panipat, Mathura, Vrindhavan, Delhi, Agra	Nil	68 mg/L	85%	566.3	Installation and maintenance costs were notably high.

From the table, it was found that the research study (Lokhande and Tare, 2021) focused on Spatial-temporal analysis of Yamuna water quality and reported the highest BOD value of 93 mg/L. However, the study represented only the recent water quality, thereby restricting the inferences to knowledge based on limited data. Subsequently, the research study (Said and Hussain, 2019) reported an average load of 30%. Also, the river quality was still poor and not meeting the required standards with DO values. Nevertheless, the Installation and maintenance costs were found to be notably high (Sharma et al., 2025).

CHAPTER- 4

POLICY AND GOVERNANCE ANALYSIS

4.1 Policy Design and Objectives

The evolution of policy thinking reveals a gradual but steady broadening in scope from YAP I to YAP III. Key policy documents and technical reports concerning the socio-ecological condition of the Yamuna River have been produced by the Central Pollution Control Board (CPCB), the Delhi Development Authority (DDA), and the Yamuna Monitoring Committee. (Singhal and Gupta, 2024).

- YAP I (1993–2003): project-oriented, an end-of-pipe model focused on sewage-treatment infrastructure and pollution-load reduction (NRCD 2014)
- YAP II 2003 – 2015: introduced public awareness, solid-waste management, and non-point-source controls. There is recognition that technical solutions cannot reverse ecological decline (Rao & Singh 2015).
- YAP III (2015-present): Re-framed in the lens of NMCG and SDG 6 - as part of Integrated River Basin Management; with growing attention to re-use, efficiency, etc. Despite the maturity of this concept, policy fragmentation continues. For example, pollution abatement in Delhi is also undermined by untreated discharges from upstream industrial clusters in Haryana (DPCC 2025). The absence of a basin-wide coordination mechanism makes policies state-centric rather than ecosystem-centric.

The funding is erratic. For example, it was approximately 5 crore in 2019 and nearly ₹400 crore in 2021, which is impacting the continuity of project works (DJB 2024). The latest reforms include online dashboards of progress and third-party audits to enhance transparency. Nevertheless, the monitoring is still based on outputs - e.g., number of STPs built - rather than outcomes - actual improvement in water quality. Number of STPs built, rather than outcome-based, actual improvement in water quality. It was also found that the water quality of the river Yamuna was affected by agriculture as well as the discharge of various untreated water from sewage and industrial waste (Sharma et al., 2021).

4.2 Institutional Coordination and Administrative Mechanisms

The mandate for implementation is fragmented among several agencies: NMCG for planning, CPCB/SPCBs for regulation, and ULBs for operations. This sounds comprehensive on paper, but it actually brings about duplication and blurred accountability.

For instance, sewer infrastructure in Delhi comes under the purview of both DJB and PWD; this leads to a web of overlapping contracts with ensuing delays. CPCB and SPCBs sometimes release conflicting data on water quality because sampling protocols are not standardized. Regulating bodies like the CPCB and DPCC should regularly monitor river water quality and disseminate directives to relevant authorities. While this approach can be replicated globally, interceptor sewer success ultimately depends on effective coordination and cooperation among all stakeholders (Tyagia et al., 2024). Though YAP III instituted PMUs at the national and state levels, there are still problems of coordination. Disbursal of funds is the policy and governance framework of the Yamuna Action Plans, which epitomizes how ambitious environmental programs go astray when institutional coordination and enforcement lag behind investment in infrastructure. Whereas major engineering milestones have been achieved under the YAPs, weak governance and fragmented accountability persist as binding constraints to outcomes (Singh & Kansal 2018; CPCB 2024).

4.3 Legislative and Regulatory Framework

The implementation of the Yamuna Action Plans (YAPs) is supported by the statutory framework established under the Water (Prevention and Control of Pollution) Act, 1974, and the Environment (Protection) Act, 1986. These empower CPCB / SPCBs to set standards and prosecute non-compliance. The legislative frameworks included the implementation of sewage control laws, prohibiting sewage disposal in the sewerage, and the use of surveillance and sanctions. Despite the legislative framework and available technical facilities, water was still not provided to everyone in the city (Patel and Gautam, 2025). The NGT has ensured better enforcement since 2010 through 100 percent sewage treatment and effluent reuse orders. In 2023, the NGT directed that Okhla STP's treated water be used for horticulture and flow maintenance. (NMCG 2024). However, urges are fickle; only a small percentage are penalized for non-compliance, while litigations seem to stalemate compliance. There is a Ganga River Basin Authority, but there is no Yamuna River Basin Authority. No single body has been empowered so as to integrate land-use, industrial, and water-management decisions across the basin. The CPCB 2024 report shows that 23 of the 33 monitoring stations still fall under priority I–II with BOD > 40 mg/l. It is evident that the policy and legal measures are yet to show any tangible ecological recovery (CPCB 2024).

4.4 Governance Challenges and Accountability Gaps

The governance of water reuse is a key part of the discussion on water management globally. India's national water policies now reflect recent global trends in water governance, especially Integrated Water Resources Management (IWRM), river basin approaches and participatory inclusion (Chattopadhyay, 2018). Yamuna is still polluted after spending more than ₹5,000 crores (DPCC 2025). The main structural governance issues are.

1. Fragmented responsibility – different agencies for design, implementation, and monitoring cause weak ownership.
2. Financial discontinuity – O&M budgets left to under-funded municipalities reduce plant efficiency (Singh & Sharma 2016).
3. Low public engagement – awareness drives are sporadic; citizen participation in monitoring is minimal (MoEFCC 2018).
4. Upstream–downstream disconnect – untreated effluents from Haryana and Uttar Pradesh undermine Delhi's investments (CPCB 2024).

Experts are now telling us that basin governance should be integrated, and ring-fenced O&M financing should be provided to remedy this ongoing accountability gap. Further, the Policy and Governance Analysis related to the YAP is tabulated in Table 4

Table 4: Policy and Governance Analysis related to the YAP

Author	Duration/ Timeline	Policies	Governance	Findings					Challenges
				Regions Covered	BOD	Drains analysed	Coliform	Area	
(Singhal and Gupta, 2024)	5 Years	Water Policy, Rezoning Policy, Spatial Policy	National Institute of Urban Affairs, the Delhi Jal Board, and CPCB	Delhi	Nil	Nil	Nil	7.42%	DDA acquired large agricultural lands and the commons and “modernized” them.
(Sharma et al., 2021)	1999 to 2010	Climate Change Mitigation Policy	CPCB, CCME	Delhi	2.65 mg/L	22	Nil	3.25%	No standard frequency level.
(Tyagia et al., 2024)	2006 to 2021	Nil	CPCB, DPCC	Uttar Pradesh, Haryana, Madhya Pradesh	32 ppm to 11 ppm	45 to 50	2.4 107	8%	No adequate freshwater was left to maintain the ecological flow.
(Patel and Gautam, 2025)	2018 to 2024	Nil	CPCB, NGT	Haryana, Agra, Delhi	16mg/L	24	40 to 100 MPN/100 mL	Nil	Limited improvements were measurable through years of sustained improvements.
(Chattopadhyay, 2018)	1995 to 2011	UNICEF, NWP, CWFL	CPCB	Delhi	Nil	Nil	Nil	7%	Emissions from the diffuse sources could not be mentioned directly.
(Rao and Singh, 2015)	1990	National River Conservation Plan (NRCP)	CPCB	Haryana, Uttar Pradesh	3mg/L	Nil	550 MPN/100ml	7%	High water tariffs
(Singh and Kansal, 2018)	1985-1993	NCRP, GAP	YAP	Bihar, West Bengal, Delhi	20 mg/L	Kanpur, Varanasi (major sewages)	100MPN/100ml	6%	Insufficient data for analysis
(Singh and Sharma, 2018)	1993	Sewage Treatment Plants (STP)	Delhi Jal Board	Delhi, Agra, Haryana	Nil	43	Nil	8.7%	Limited focus on sector reforms

From the above table, it was found that governance and policies were involved in the water quality analysis and YAP. The research study (Tyagia et al., 2024) reported the highest BOD of 32 ppm to 11 ppm. Subsequently, the research study (Patel and Gautam, 2025) reported the BOD value of 16mg/L. However, the limited improvements were measurable through years of sustained improvement. Subsequently, in the research study (Sharma et al., 2021), the policies like CPCME and CCME were analysed. The results showed that it had a lower BOD with no standard frequency level.

4.5 Expenditure Spent for Yamuna Rejuvenation-

Financial Year	Total Spent in YAP (approx.)	Infrastructure (STP, Drains, Interceptors)	Awareness (Outreach, Public camps)	Operation and maintenance
2017-18	~15.93 (DJB under YAP-III)	Major STP- and sewer-network work	Bigger IEC campaigns as part of YAP-III	Some drain-cleaning and dredging
2018-19	~113.74 (DJB under YAP-III)	Large STP and interceptor-drain projects	Awareness tied to YAP-III public-outreach	Mechanised cleaning, dredging under YAP-III
2019-20	~219.49 (DJB under YAP-III)	Continued STP and sewer expansion	Awareness linked to NGT / DJB monitoring	Drain-cleaning, foam-control, mechanised equipment
2020-21	~299.91 (DJB under YAP-III)	Big STP and CETP-related works	Public-awareness on Yamuna-clean-up	Foam-control machines, cleaning equipment, foamed-drain removal
2021-22	~233.21 (DJB under YAP-III)	Major STP and sewer-network completion	Awareness campaigns on Yamuna-health	Mechanised cleaning, sludge-handling, logistics
2022-23	~124.60 (DJB under YAP-III)	Last-mile STP and drain-related works	Smaller IEC around river-health	Foam-control and cleaning operations
2023-24	Delhi Govt. states ~₹5,536 crore spent on Yamuna-clean-up	Bulk of this head (STPs, CETPs, interceptors)	Smaller fraction for awareness / IEC	Logistics for cleaning, mechanised waste removal
2024-25	~₹5,536 crore spent on Yamuna-clean-up	Most going to sewage treatment and related works.	Smaller fraction for awareness / IEC	Logistics for cleaning, mechanised waste removal
2025-26	Part of a ₹9,000-crore Delhi Yamuna-clean-up mission and 2026-27 Green Budget; ₹6,485 crore to DJB alone for Yamuna sewage treatment and clean-up.	Majority spent on STPs, decentralised STPs, CETPs, drain-taps	Budget embedded in “public awareness” and “environment education” components of the 45-point plan	Drain-cleaning machines, foam-control, mechanised waste-removal, dredging equipment

2026-27	Part of the same ₹9,000-crore Yamuna-mission envelope; ₹6,485 crore to DJB for Yamuna-related sewage treatment and clean-up is allocated	Same as above (STPs, CETPs, decentralised STPs, interceptors	Awareness campaigns under Delhi-Govt “green budget” framework	Logistics for continuous cleaning, foam-control, and equipment
----------------	---	--	---	--

Table 5: Funds Spent each Financial Year

From the table above we observe that public expenditure for rejuvenation of the Yamuna grew from ₹16 crore during YAP-III in 2017-18 to a ₹9,000 crore budget for 2025-26. While the large financial commitment certainly reflects a political commitment towards betterment, a look at the pattern of spending sheds light on a larger structural problem. Money has always been spent after a problem emerges rather than preempting it.

During the initial years (2017-18 to 2022-23), the focus had been on constructing plants and interceptors, but there was a lack of spending on awareness and operations and maintenance. Although essential steps, they came at the wrong time. This is observed as plants without adequate operational funds and cleaning drains without reducing upstream discharge, which ultimately led to little ecological restoration despite large financial outlays. Looking forward for the successful restoration of the Yamuna will depend on a rebalance, involving steady funding for operations and maintenance, audit of expenditure, decentralized management of drainage, and time limits for making STPs operational. Otherwise, higher budgets will simply yield decreasing returns on investment, leaving the Yamuna a testament to failed policies masquerading as grand visions.

CHAPTER-5

PUBLIC-PRIVATE PARTNERSHIP

The degradation of river water quality can be attributed to multiple point and non-point sources of pollution, including soil erosion, the release of untreated effluents, surface runoff, and anthropogenic activities associated with agriculture and industry. These pollution sources have emerged due to the rapid economic development, increasing population, and urbanization (Samui et al., 2025). Such multi-source pollution challenges in river water highlight the failure of the existing regulatory approaches and necessitate the need for a collaborative governance mechanism with PPP and stakeholder participation. PPP and stakeholder participation have increasingly been promoted as means to address capacity and accountability gaps in India's environmental governance (Singh & Kansal 2018), thereby preventing pollution and improving the Yamuna action plans. In the frame of the Yamuna Action Plans, the instruments like advanced sewage treatment technologies, community participation programs, etc., are successively introduced in order to enhance project financing, technological efficiency, and community involvement. Ultimately, this shift from government-dominated implementation to collaborative models reflects the wider transition in India toward participatory water governance. (NMCG 2024). Based on the evaluation, these alternatives were shortlisted for the implementation of works under the Public–Private Partnership (PPP) model.

5.1 Evolution of PPPs in River Management

In Yamuna River management, the involvement of the simple and construction-based infrastructure of PPP evolved into a complex and performance driven models. This evolution of PPP was due to the introduction of the “Namami Gange” framework. Due to this framework, the focus was shifted to building Sewage Treatment Plants (STPs) for ensuring the long-term functionality, operation, and maintenance. For the process of operation and maintenance, the YAP I was introduced. In YAP I (1993–2003), the implementation of the project was based on the public agencies, Delhi Jal Board (DJB), and the State Pollution Control Board. However, limited technological flexibility and high O&M costs revealed the need for private-sector expertise (Rao & Singh 2015). By YAP II (2003–2015), the Government of India, supported by JICA, experimented with engineering, procurement, and construction (EPC) contracts that improved completion rates but failed at ensuring sustainable operations (MoEFCC 2018).

With YAP III, from 2015 to the present, PPPs reached maturity in the forms of DBO and HAM models, which integrate private capital with public oversight. The NMCG guidelines of 2024 clearly link private payments to environmental performance as reflected in the biochemical oxygen demand and total suspended solids compliance.

5.2 Major PPP Initiatives under YAP III

The YAP had contemplated the implementation of projects through public-private partnership (PPP) model. This approach called for significant private sector involvement in river management, both in technical and managerial investment, in order to engage a broad range of private sector actors in all YAP components. (Kumar et al., 2017).

The flagship projects under YAP III include the Okhla (564 MLD), Kondli (204 MLD), and Rithala (182 MLD) sewage treatment plants, developed under DBO contracts involving private operators such as Larsen & Toubro and Suez India.

These plants are fitted with modern treatment systems, such as SBRs, MBRs, and anaerobic digesters. These systems bring down the energy consumption by almost 25% compared to previous systems. The Okhla STP itself treats one-third of Delhi's wastewater and re-supplies 50 MLD of reclaimed water for horticulture and industrial cooling (NMCG 2024).

Beyond Delhi, PPP-based plants at Agra (60 MLD) and Vrindavan (62 MLD) under HAM contracts reflect a decentralized approach to wastewater management. The introduction of Viability Gap Funding has also inspired private sector participation in cities with smaller revenue bases.

These advances notwithstanding, the recent audits reveal operational inconsistencies and underperformance because of delayed payments and inadequate long-term accountability provisions. While the PPPs have managed to improve efficiency, many still focus on short-term engineering outputs rather than sustained environmental outcomes (Singh & Sharma 2016).

5.3 Stakeholder Participation and Community Engagement

While the participation of stakeholders is increasingly being regarded as the social foundation of sustainable river rejuvenation, YAP II initiated partnerships with more than 200 NGOs and schools for awareness campaigns and community clean-up drives in Delhi, Agra, and Mathura (MoEFCC 2018). However, many of these initiatives lacked continuity and institutional anchoring.

Under YAP III, participation has been extended through the Namami Gange–Yamuna framework that mobilises local communities and faith-based groups, in addition to youth volunteers. Programs like “Yamuna Mitra” encourage citizens to report drain pollution and monitor local water bodies (DPCC 2025). Conceptually, the Yamuna Action Plan was well in sync with the principles of Dublin, particularly those related to integrated planning at the level of the river basin, environmental conservation, and stakeholder participation. The decentralized structure adopted by the plan, where participation from all institutions, including Panchayati Raj Institutions, NGOs, communities, and governments, was encouraged, is a modern approach even in the context of today's times.

Since the Yamuna is an essential source of drinking water for several millions of people in its basin, it made sense for pollution prevention to be prioritized at its source itself, instead of depending merely on treatment downriver. (Sharma et al., 2025a).

Organizations such as INTACH and the Chintan Environmental Research and Action Group have been collaborating with local municipal bodies on waste segregation, reuse of sludge, and riparian restoration projects. These initiatives are a step in the right direction despite their limited reach. The DPCC found that in 2025, almost 70% of respondents in Delhi had no idea what their local STPs were or what the goals of the YAP were. The outreach to the public has been largely symbolic and needs to be put into institutions through ward-level monitoring committees, school curriculum, and citizen science. Despite the possibility of sustainable development alongside water resource conservation, an unhealthy bias continues to influence the perceptions of stakeholders.

5.4 Evaluation of PPP and Participation Outcomes

Environmental goods such as rivers are naturally common resources, meaning they cannot be privatized or expropriated by anybody; hence, there is a potential for overuse and degradation as a result of uncontrolled negative externalities in such markets. Such market inefficiencies lead to governance problems requiring the need for governmental regulation. Considering the public investment required in projects such as the Yamuna Action Plan, evaluation of the efficacy of such interventions in relation to expenditures becomes crucial. Benefit-cost analysis remains one of the most utilized means of evaluating such environmental interventions (Kandula, 2018). Recent reviews suggest that the PPP-led projects have better technical efficiency, mainly when O&M contracts are for more than ten years (NMCG 2024; JICA 2024). Plants operated under the HAM, which are linked to performance-based payment, demonstrate higher compliance with discharge norms.

Most contracts do not contain citizen oversight or grievance mechanisms. If inclusive monitoring mechanisms are not established, there is a risk that PPPs will entrench the top-down structures they are intended to replace. Global experience, for instance, Thames Restoration in the UK to the Cheonggyecheon Stream in South Korea, has shown that infrastructure, policy coherence, and local citizens' and other stakeholders' ongoing participation are components of successful urban river restoration efforts (Rani & Kumar 2020). Regarding Yamuna specifically, institutionalizing stakeholder engagement is important in ensuring long-term ecological recovery.

CHAPTER- 6

RESULT AND DISCUSSIONS

The Yamuna Action Plans (YAPs) span over a period of over three decades and are the longest and most active river restoration programme in India. The YAPs have achieved high infrastructural and institutional milestones with the support of the Japan International Cooperation Agency (JICA), coordinated by the National Mission for Clean Ganga (NMCG). Despite such funding, Yamuna is still one of the most contaminated rivers in India, especially in the Delhi section (CPCB 2024) (DPCC 2025).

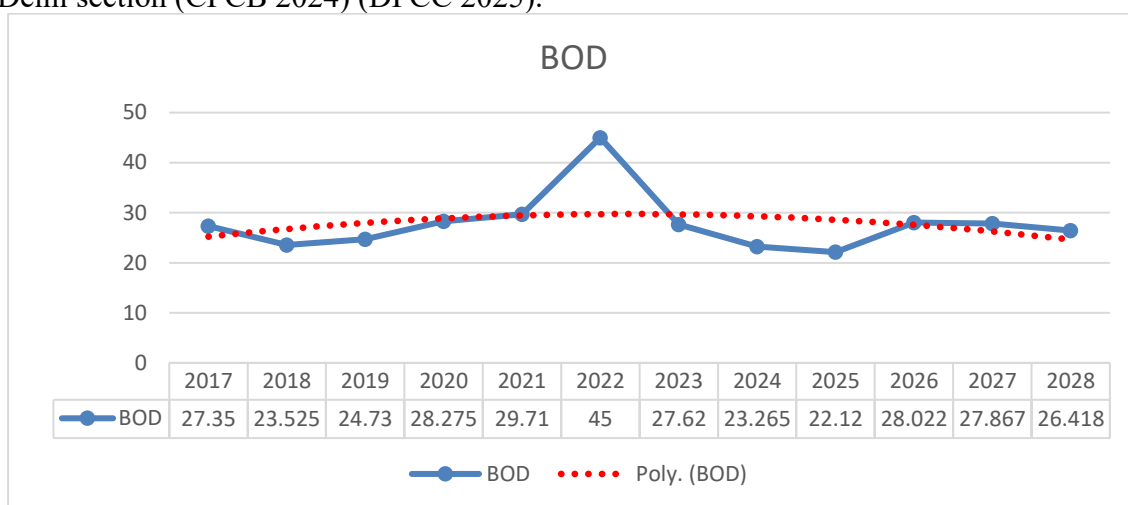


Figure 3: BOD Prediction using R-studio

As seen from the data collected within the early years of the project (2017-2019), BOD was consistently between 24 and 27 mg/L, indicating that organic contamination had been extremely high. The worst case was seen in 2022, when the indicator climbed up to an impressive 45 mg/L, which is the maximum level ever recorded. It may be concluded that this situation probably occurred due to the inability of local wastewater purification stations to handle the quantity of organic pollution. As of 2023, there seems to have been some improvement, with BOD falling down to a mere 22 mg/L in 2025. While it looks like this is some positive development, it can hardly be regarded as satisfactory since the indicator remains much too high.

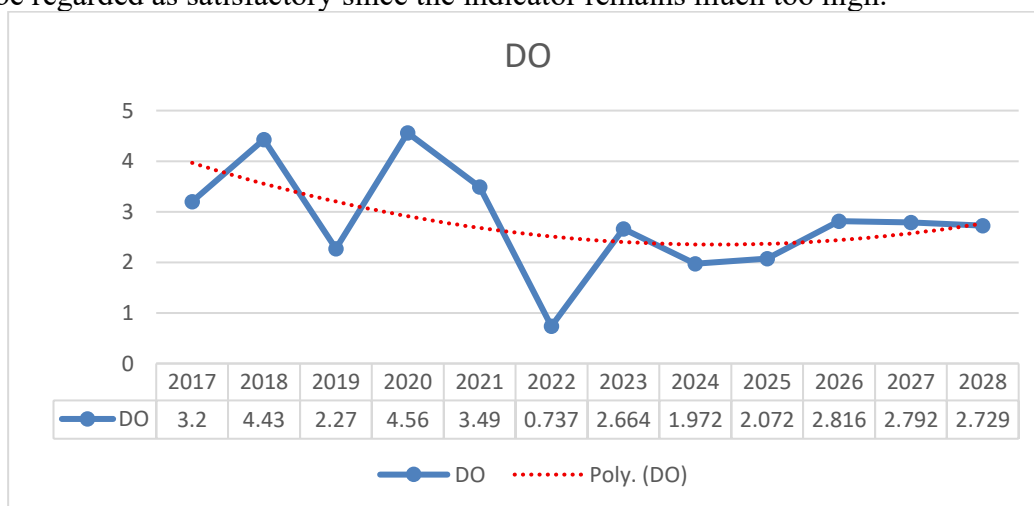


Figure 4: DO Prediction using R-studio

The dissolved oxygen is possibly the best indicator of the current ecological state of the river. During the period of 2017-2018, the levels were relatively healthy at 3-4.5 mg/L; however, the following course of events has been characterized by their steady decrease. Thus, in 2022, which saw an all-time high in the levels of BOD, the levels of DO have dropped drastically to about 0.7 mg/L. Notably, this is the threshold where almost no aquatic organisms can survive. This pattern is due to the fact that with the increase in the organic matter in the water, the decomposition process has been faster than oxygen production. Currently, the levels have slightly recovered to 2.0-2.7 mg/L.

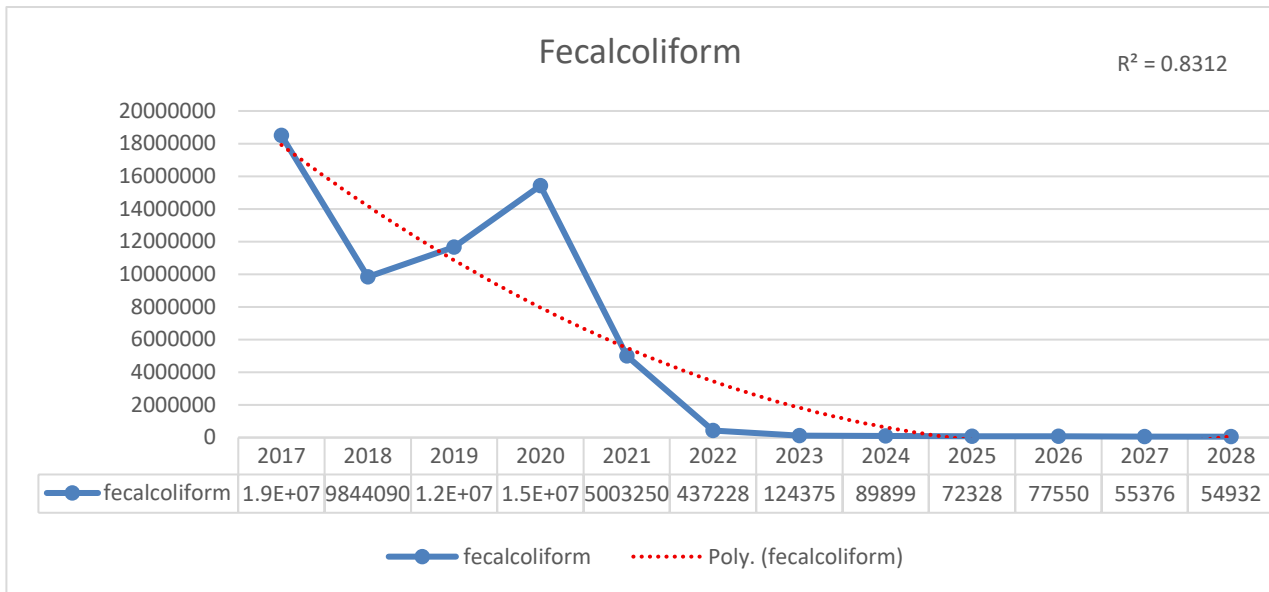


Figure 5: Fecal Coliform Prediction using R-studio

Among the three indicators being looked at, fecal coliform shows where there has truly been some improvement. The number of contaminations went from a shocking 18.5 million MPN/100 mL in 2017 to about 5 million in 2021, and further reduced to about 70,000 MPN/100 mL in 2025. Based on this continuous improvement, with an excellent trendline correlation of $R^2 \approx 0.83$, it can be observed that measures taken such as the implementation of sewage interception and drain management programs have indeed yielded concrete results. However, with even 70,000 MPN/100 mL still far from the ideal level, it can be seen that the health risks posed have only been partially alleviated and not completely eradicated.

6.1 Environmental and Technical Outcomes

Started with YAP I in 1993, sewage treatment capacity in the Yamuna basin grew to around 1,900MLD by 2024, as compared to its initial state of less than 300MLD. The refurbishment of large plants at Okhla, Kondli, and Rithala with 564MLD, 204MLD, and 182MLD capacities, respectively, using technology of Sequencing Batch Reactor (SBR) and Membrane Bioreactor (MBR), was undertaken by YAP alone and improved the treatment process and energy savings. Parameters were monitored in real-time by means of real-time monitoring systems installed at 33 locations on the river track and included Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), and Total Coliform. In spite of this advancement, the CPCB report in 2024 shows that BOD in the Yamuna segment in Delhi ranges between 3050mg L⁻¹ and DO is more often under 2mg L⁻¹, implying minimal biological activity. Therefore, grappling with substantial environmental challenges, paradoxically, witnesses an exacerbation of drainage and wastewater treatment issues alongside the rise in water supply and water-borne sanitation facilities.

There has been significant evidence that decentralized systems are feasible on many fronts, encompassing socioeconomic, administrative, planning, technological, and environmental aspects, provided that shortcomings are diligently monitored (Ramadhan et al., 2024).

About 70-80 percent of the pollution load is taken up in the Wazirabad-Okhla stretch that covers about 2 percent of the river length. The report has put this burden on untreated domestic wastewater. The city produces 3,400ml of sewage, with approximately 800-1000ml going untreated through incomplete sewer systems and poor performing STPs (DPCC 2025). Although the use of modern technologies and the provision of high-level monitoring have been implemented, the gap between the amount of sewage discharge and the treatment process is a fundamental ecological limitation. Periodic power cuts, poor maintenance, and uneven financing remain a hindrance to performance (Rani and Kumar 2020). Wastewater management techniques that can help protect the Yamuna River from pollution include the use of wastewater for agricultural purposes only when it undergoes tertiary treatment, and the creation of a strategy to deal with pollutants, both soluble and insoluble. (Parween et al., 2017)

6.2 Institutional and Policy Outcomes

At an institutional level, the YAPs transformed the river-management system in India, which encouraged inter-agency cooperation between NRCD, the SPCBs, Urban Local Bodies (ULBs), and international collaborators. Project Management Units (PMUs) under YAP III professionalised the delivery of projects and facilitated the oversight by data (NMCG 2024). The adoption of Hybrid Annuity Models (HAM) and Public-Private Partnerships (PPP) also updated the wastewater governance. The performance-based contracts in the Okhla and Kondli STPs are currently based on payments that rely on effluent-quality standards (CPCB 2024). Furthermore, the YAPs have shaped national programmes, including Namami Gange (2014) and Swachh Bharat Mission (2015), hence enhancing the linkage of sanitation and river restoration (MoEFCC 2024). Nevertheless, amidst such policy benefits, it lacks a Yamuna Basin Authority to facilitate basin-wide coordination. Industrial effluents in Panipat and Sonipat (Haryana) and urban effluents in Mathura -Vrindavan (Uttar Pradesh) continue to affect the downstream water quality (DPCC 2025). So, emphasis has also been placed on strengthening institutional and organizational capacity for executing cost-effective capital works and operation and maintenance (O&M) activities (Deepika et al., 2017).

6.3 Socio-Economic and Community-Level Outcomes

The research study (Kumar, 2023) reported that the experiences of toxicity were embedded in the social, political, and economic context of the urban ecology of the Yamuna khaddar, such as the social relationships with the landowners, river, soil, and the city. This influences the social ecology of this space and vice versa in YAP. The YAPs also created job opportunities in the building and running of plants and community participation in sanitation efforts. The cheap toilets and sanitation units developed with YAP I and II enhanced hygiene in the informal settlements (NRCD 2014). YAP III reuse of treated water in industries and horticulture generated small-scale opportunities for a circular economy (NMCG 2024). However, there is a peripheral community involvement. According to the survey conducted in the city in 2025 by DPCC, 70 per cent of the residents of Delhi did not know anything about the goals of YAP, nor where the treatment plants are located. Projects like Yamuna Mitra, in collaboration with NGOs like INTACH, have raised awareness of the locals, but these efforts are not large-scale (MoEFCC 2024). Failure to engage citizens on a continuous basis simply means that the environmental awareness efforts rarely result in behavioural change. As an example, solid waste and domestic effluent are illegally dumped along drains, including Najafgarh and Shahdara (DPCC 2025). This

resulted in the negative correlation of DO with other parameters when there was an increase in the pollution (Kaur et al., 2021).

6.4 Policy Score-

Comparison is done between yearly expenditure for cleaning the Yamuna and improvement in the quality of water between 2017 and 2025. The overall analysis suggests that while there has been a substantial increase in terms of monetary allocation, the environmental outcome does not seem to match the same level.

Year	Expenditure by End of Financial Year (₹ Cr.)	BOD (mg/L)	DO (mg/L)	Fecal coliform (MPN/100ml)	WQS	ER	Policy score	Policy Grade
2017	16	27.35	3.2	18500000	0.55	1.46	3.40	B
2018	114	23.525	4.43	9844090	0.71	1.08	3.07	B
2019	219	24.73	2.27	11663000	0.31	1.02	2.67	C
2020	300	28.275	4.56	15429384	0.73	1.03	3.02	B
2021	233	29.71	3.49	5003250	0.61	1.03	2.93	C
2022	125	45	0.737	437228	0.42	0.85	1.08	D
2023	5,536	27.62	2.664	124375	0.43	1.00	2.75	C
2024	5,536	23.265	1.972	89899	0.17	1.00	2.54	C
2025	6,485	22.12	2.072	72328	0.21	1.00	2.57	C

Table 6: Policy score and Grade calculation

- **Expenditure-** There has definitely been an increase in terms of amount of money spent. A marked increase is observed post-2022, as the allocation of funds increased from around ₹125 crore to more than ₹5,536 crore in 2023-24 and to ₹6,485 crore in 2025. But in comparison there has not been a similar improvement in the quality of water.
- **BOD and DO level-** However, the Biochemical Oxygen Demand (BOD) did not fall significantly within the period under discussion. It remained relatively stable in the range of 23-29 mg/L between 2017 and 2021, after which it skyrocketed to 45 mg/L in 2022 and started falling gradually to 22.12 mg/L in 2025. Although such an improvement is notable, the figures are still quite unsatisfactory since they do not signify any good water quality.

Dissolved Oxygen (DO) experienced a reverse trend while remaining relatively low during the observation period. DO was at the lowest point of 0.737 mg/L in 2022 before starting to rise and stabilizing at 2.07 mg/L in 2025. The recovery rate indicates that the river cannot rejuvenate by itself effectively.

- **Fecal contamination-** The amount of fecal coliforms significantly decreased during the observation period. Specifically, it declined from 18.5 million MPN/100 ml in 2017 to 72,328 MPN/100 ml in 2025. Such a reduction could be observed due to some of the interventions' effects.
- **Composite indicators-** The WQS was erratic; it experienced some positive changes in the initial period when, for example, the indicator was recorded at a value of 0.71 in 2018, but soon afterward, it declined drastically and reached 0.17 in 2024. Such an irregular trend shows that overall water quality was unstable even despite higher funding. The indicator of Ecological Risk decreased gradually from 1.46 in 2017 to nearly 1.00 in 2023–2025. These findings reveal that while the river ecosystem was under lesser stress, the values do not demonstrate improvement beyond the threshold above which environmental conditions were relatively healthy. In other words, it can be said that the river ecosystem was less stressed than before but still had much room for improvement.
- **Policy performance-** Policy effectiveness is reflected by the mixed values of the scores and grades. The majority of the analyzed years scored within Grade B and Grade C; however, the lowest value, i.e., Grade D, was recorded in 2022. It reflects the worst environmental situation among all years in terms of pollution. Following this year, there was gradual recovery of the scores, but their values remained steady at Grade C level.

All things considered, it is clear that there is a weak relationship between expenditures and improvements in environmental quality. The high jump in expenditure does not correspond to an equivalent jump in water quality, perhaps because of a lag between policies being implemented, misuse of funds, or a lack of coordination among the different authorities involved. On the other hand, the consistent decrease in fecal coliform is proof that measures taken concerning sewage have worked.

2022 marks the lowest point in both aspects, with poor water quality and a very low policy performance. Thereafter, there has been slight improvement in conditions, although it has been rather slow. This indicates that for future attempts, less reliance on purely infrastructural solutions might be required.

6.5 Challenges

In spite of infrastructure and institutional improvement, there are still some challenges that persist:

1. **Infrastructure-Operation Gap:** Sewage treatment plants are less efficient due to a lack of a complete sewerage network and inadequate operation and maintenance budgets, which leads to most of the units operating below 70 per cent (CAG 2013; DJB 2024).
2. **Financial Shortfalls:** The Drainage system of Delhi empties its waste into the Yamuna via a total of 23 drains in various stretches of the river. The most important among these are the 16 drains that empty waste in the stretch of the river located between Wazirabad and Okhla Barrages—the most contaminated stretch of the Yamuna. Four more drains drain their waste in the Yamuna in the stretch below the Okhla Barrage. The rest of the three drains do not drain into the river but into the Agra and Gurgaon canals instead (Arif et al., 2020). So, while total investment exceeds 5,400 crore for analysing these drains, municipal authorities are faced with the problems of covering operation and maintenance, which is limiting the efficiency of the systems.
3. **Fragmented Governance:** PCB, SPCBs, and local authorities have overlaps that hinder coordinated execution and create a lack of accountability (Rao & Singh 2015).
4. **Weak Enforcement:** There are regulatory measures, but they are not enforced regularly, and penalties are seldom imposed, resulting in inconsistent compliance (NGT 2017). The research study (Karvouni, 2025) indicated that the pollution in the river was not managed properly due to weak law enforcement, a lack of environmental regulations, and the failure of the responsible authorities to locate specific polluting industries.
5. **Upstream-Downstream Disconnect:** Haryana and Uttar Pradesh contribute to the pollution of the inflows to Delhi by undermining the investment made in water purification in Delhi (CPCB 2024).
6. **Limited Public Awareness:** Even though various missions and NGO's initiative the awareness is still not as widespread among the population.
7. **Ecological Imbalance:** Overuse of water in irrigation dampens ecological flows, which prolongs foaming and eutrophication (Rani & Kumar 2020). Also, from the research study Bhutiani et al. (2019) found that the unrestricted release of industrial wastewater, domestic sewage, and agricultural waste was the main reason for ecological damage in rivers, having significant effects on biological life as well as human health. Such a conclusion highlights a wider need; that tackling water pollution is not just an environmental challenge but also an economic issue and, of course, a human one. Since the Yamuna acts both as an ecosystem and as a source of water, it becomes imperative to take pollution control measures urgently and systematically.

Recent government initiative (NMCG 2025) emphasises the need for an Integrated Basin Management Strategy that combines governance reforms, technology upgrades, and community participation to overcome these challenges.

CHAPTER- 7

CONCLUSION AND POLICY RECOMMENDATIONS

7.1 Conclusion

One of the biggest and most ambitious projects in the area of environmental governance and international cooperation in India is the Yamuna Action Plans (YAP I, II, and III). As a conceptualization of the National River Conservation Plan and with financial assistance from the Japan International Cooperation Agency, the YAPs have produced significant wastewater infrastructural advancements, policy learning, and governance capacity. Starting with a treatment capacity of less than 300MLD in 1993, the total capacity has since reached over 1,900 MLD (NMCG 2024). The Okhla (564-MLD) and Kondli (204-MLD) sewage treatment installations use the modern technologies of the Sequencing Batch Reactor (SBR) and Anaerobic Digester (DJB 2024). However, in the presence of these technological and institutional improvements, the Yamuna still records high levels of critical pollution, especially the 22-km stretch of the Yamuna in Delhi, where almost 80 percent of the total pollution is recorded (CPCB 2024).

7.2 Policy Recommendations

Based on the three decades of operation, the following strategies are put forward in an effort to realize true and long-term rejuvenation of the rivers:

1. **Establish a Statutory Authority:** A legally mandated body should be appointed under the Ministry of Jal Shakti for the Yamuna basin to provide a legally binding framework to manage the critical water issues. This authority incorporates various schemes like basin-wide planning, equitable water allocation, and water pollution control schemes. These schemes can establish a transparent repository of flow and quality metrics, enabling evidence-based decisions. Hence, these policy harmonisations under the Ministry of Jal Shakti coordinate interstate planning and data sharing across the Yamuna basin (NMCG 2025).
2. **Adopt Basin-Scale Integrated Management:** The present geomorphology of the Yamuna River Basin of the Garhwal Himalayas is a consequence of geological forces that have operated in the past and continue to operate today, dominated mainly by tectonic deformations along with erosion and sedimentation. This basin is located in a geologically active region where the tectonic activities operating at depth have played a key part in shaping the topography as well as the hydrography of the area (Gahlaut et al., 2021). So, an integrated basin management approach is essential to address the impacts of urban sewage, industrial effluents, and agricultural runoffs.
3. **Ensure Sustainable Financing and O&M Support:** A performance-linked funding model should be introduced to deliver substantial outcomes rather than just the infrastructure, where the central grants are tied to water-quality outcomes. These approaches enhance accountability and ensure long-term effectiveness. Additionally, prompting the treated-water reuse markets can generate a revenue system to cover O&M costs. In conclusion, these measures promote efficiency, resilience, and self-resilience in the basin management (DJB 2024).

4. **Expand Long-Term PPP Frameworks:** The long term PPP frameworks can be expanded through the standardized Hybrid Annuity Model (HAM) contracts to transform the Yamuna basin management. In Yamuna basin management, HAM combines government support with private investments, ensuring risk-sharing and financial sustainability. These mandatory transparency audits strengthen accountability, public trust, and the prevention of fund misuse. This enhances development impacts through wide-ranging partnerships and co-creation with development partners through the promotion of the JICA Global Agenda (JICA 2024).
5. **Institutionalise Community Monitoring:** Establishing the ward-level watch communities empowers local residents to track pollution sources, report violations, and participate in the conservation efforts. This decentralised model builds accountability, which ensures community-driven interventions. Integrating this environmental education into the school syllabus promotes awareness among the younger generations, thereby improving the sense of ownership and responsibility towards the river's health (DPCC 2025).
6. **Incorporate Nature-Based Solutions (NBS):** Engineer interventions on constructed wetlands, restoration of riparian vegetation, and bio-remediation to improve the self-purification of the river (Rani and Kumar 2020). Nature-Based Solutions (NbS) provide a way forward for the integration of decentralized and on-site systems for wastewater treatment. This method would help reduce the gap between wastewater production and wastewater treatment capacity while promoting urban agriculture in areas adjoining rivers (Srivastava et al., 2023). The DRRWG recognizes the worth of NbS and ecosystem-based solutions in terms of disaster risk reduction. It aims to establish an evidentiary base, including cost-benefit analysis, that will facilitate implementation (Satsangi, 2024).
7. **Strengthen Legal and Regulatory Oversight:** The implementation of compliance regarding the Yamuna water management follows the Water Act (1974) and the Environment Protection Act (1986). The CPCB informs that the damage assessment due to non-compliance with the directions of the tribunal is being done in consultation with all the stakeholders after assessing the level of non-compliance and the continuing pollution of the Yamuna River through the obedience of the National Green Tribunal (NGT) (NGT 2017).
8. **Adopt Global Best Practices:** Adopt lessons learned with the Thames (UK), Rhine (Europe), and Cheonggyecheon (South Korea) rivers restorations that show how adaptive governance, cross-sectoral integration, and inclusion of the general population work (Singh and Kansal 2018). Sectoral integration and mass participation are necessary and with such efforts, the government is able to motivate locals, NGOs, business organizations, and consumers to work towards developing their social surroundings. This would help bring about constructive changes in society (Mulloth & Rao, 2018).

In conclusion, the future of rejuvenation of the Yamuna lies in technological innovation in a system along with support in governance, economic sustainability, and civic accountability. The restoration of the river is not just an environmental project but also a challenge to India to put sustainable development into practice.

REFERENCES-

1. Arif, M., Kumar, R., & Parveen, S. (2020). Reduction in Water Pollution in Yamuna River Due to Lockdown Under COVID-19 Pandemic. *International Journal of Chemical Studies*, 1–15. <https://doi.org/10.26434/chemrxiv.12440525.v1>
2. Bhutiani, R., Khanna, D. R., Kumar, R., Ram, K., Ahamad, F., Science, E., & Vishwavidyalaya, K. (2019). Impact Assessment of Sewage Treatment Plants ' Effluent Discharge on The Quality of Ganga River at Haridwar, Uttarakhand. *Journal of Mountain Research*, 14(2), 77–83. <https://rakeshbhutiani.in/wp-content/uploads/NationalPublications/Publications/1.pdf>
3. Central Pollution Control Board (CPCB). (2024). Status of Water Quality in India: Monitoring Results of Yamuna River (2023–2024). *Ministry of Environment, Forest and Climate Change, Government of India*.
4. Chattopadhyay, S. (2018). Challenges of water governance in the context of water quality problem : Comparative study of India, Indonesia and Germany. *Transactions*, 40(2), 171–183. https://iigeo.org/IIG_journals_Vol_36_year_2014_to_46_year_2024/vol_40-2/2-Challenges-of-water-governance-in-the-context-of-water-quality-problem-Comparative-study-of-India-Indonesia-and-Germany.pdf
5. Comptroller and Auditor General of India (CAG). (2013). Performance Audit on Conservation of Rivers (Including Yamuna, Ganga, and Others): *Report No. 21 of 2013. Government of India, New Delhi*.
6. Deepika, Kumar, R., & McMasters, F. (2017). Planning and Design of Sewerage Infrastructure for a Congested Area in Delhi: A Case Study Towards Pollution Abatement in River Yamuna. *Pipelines*, 249–260. <https://ascelibrary.org/doi/abs/10.1061/9780784480878.024>
7. Delhi Jal Board (DJB). (2024). Budget and Annual Reports: Water and Sewage Treatment Performance 2023–24. *Government of NCT of Delhi*.
8. Delhi Pollution Control Committee (DPCC). (2025). Annual Report on Water Quality Monitoring of River Yamuna (2024–2025). *Government of NCT of Delhi*.
9. Gahlaut, P., Patel, R. C., Ayyamperumal, R., Sati, M., & Nainwal, D. C. (2021). Assessment of Recent Tectonic Activity along the Yamuna Basin , Garhwal Region , NW-Himalaya , India : Based on Morphotectonic Analysis. *Open Journal of Geology*, 11, 734–755. <https://doi.org/10.4236/ojg.2021.1112036>
10. Gosain, A. K., & Sharma, D. (2008). Development of River Water Quality Management Plan Using Qual2E Simulation Model: Yamuna River, India. *Environmental Monitoring and Assessment*, 144(1–3), 143–154.
11. India–Japan Cooperation Office (JICA). (2019). Yamuna Action Plan Phase III: Progress and Impact Evaluation Report. *Japan International Cooperation Agency, New Delhi*.
12. Jaiswal, M., Hussain, J., Gupta, S. K., Nasr, M., & Nema, A. K. (2019). Comprehensive evaluation of water quality status for entire stretch of Yamuna River , India. *Environmental Monitoring and Assessment*, 191, 1–17. <https://doi.org/10.1007/s10661-019-7312-8>

13. Japan International Cooperation Agency (JICA). (2024). Urban Water Reuse and Sewage Management in Delhi: YAP III Technical Evaluation Update. *Tokyo: JICA Research Department*.
14. Kandula, S. N. (2018). Journal of Governance & Public Policy. *Institute of Public Enterprise*, 8(2), 1–120. https://www.researchgate.net/publication/353417136_A_Study_on_Growth_of_Capital_Adequacy_Profitability_and_Liquidity_Analysis_of_Indian_Public_and_Private_Sector_Banks_in_the_Post_Financial_Crises_Period
15. Karvouni, R. (2025). Limiting the Consequences of the Recovery of Polluted Rivers in Megacities. *The American College of Greece Model United Nations*, 1–26. https://www.acgmun.gr/wp-content/uploads/2025/03/EC.1.RK_.pdf
16. Kaur, H., Shashi, Warren, A., & Kamra, K. (2021). Spatial variation in ciliate communities with respect to water quality in the Delhi NCR stretch of River Yamuna , India. *European Journal of Protistology*, 79, 125793. <https://doi.org/10.1016/j.ejop.2021.125793>
17. Kumar, R. (2023). Political Ecology of Urban Agricultural Pollution: Cultivating the Yamuna Floodplains in Delhi. *Ecology, Economy, and Society—the INSEE Journal*, 6(2), 237–252. <https://doi.org/10.37773/ees.v6i2.1052>
18. Kumar, R., Deepika, & McMasters, F. (2017). River Rejuvenation along Heritage Site: Drainage and Sewerage Infrastructure Condition Assessment, Planning, Design, and Upgradation. *Pipelines*, 213–225. <https://ascelibrary.org/doi/abs/10.1061/9780784480885.021>
19. Kumari, S., & Biswas, R. (2022). Decoding Delhi ’ s water governance through multi-level governance approach. *H2Open Journal*, 5(4), 1–13. <https://doi.org/10.2166/h2oj.2022.048>
20. Lokhande, S., & Tare, V. (2021). Spatio-temporal trends in the flow and water quality : response of river Yamuna to urbanization. *Environmental Monitoring and Assessment*, 193, 1–14. <https://doi.org/10.1007/s10661-021-08873-x>
21. Ministry of Environment, Forest and Climate Change (MoEFCC). (2018). Compendium of River Cleaning Projects in India: Lessons from Yamuna and Ganga Action Plans. *Government of India*.
22. Ministry of Environment, Forest and Climate Change (MoEFCC). (2024). National River Conservation Plan Progress Report 2023–24. *Government of India, New Delhi*.
23. Ministry of Jal Shakti. (2024). National Mission for Clean Ganga (NMCG): Monthly Progress Report (Delhi – May 2024). *Government of India*.
24. Mulloth, B., & Rao, B. (2018). Revitalizing the Yamuna River : Social Entrepreneurship Approaches. *2018 Proceedings of PICMET '18: Technology Management for Interconnected World*, 1–9. <https://doi.org/10.23919/PICMET.2018.8481862>
25. National Green Tribunal (NGT). (2017). Order in O.A. No. 6/2012: Manoj Mishra v. Union of India & Ors. (Yamuna Pollution Case). *National Green Tribunal, New Delhi*.
26. National Mission for Clean Ganga (NMCG). (2024). Delhi Sewerage and Yamuna River Rejuvenation: Project Status and Data Dashboard. *Ministry of Jal Shakti, Government of India*.

27. National Mission for Clean Ganga (NMCG). (2025). Integrated Basin Management Policy Proposal for the Yamuna River. *Ministry of Jal Shakti, New Delhi*.
28. National River Conservation Directorate (NRCD). (2014). Achievements and Challenges under Yamuna Action Plan Phases I & II. *Ministry of Environment and Forests, Government of India*.
29. Nehra, V., & Singh, S. K. (2020). Assessment of water quality of Najafgarh drain and its impact on river Yamuna. *International Conference of Advance Research and Innovation (ICARI)*, 1–4. <https://dx.doi.org/10.2139/ssrn.3577270>
30. Pandey, J., & Pandey, R. (2013). Impact of Urbanization and Industrialization on River Yamuna Water Quality in Delhi, India. *Journal of Environmental Sciences*, 25(3), 575–586.
31. Parween, M., Ramanathan, A. L., & Raju, N. J. (2017). Waste water management and water quality of river Yamuna in the megacity of Delhi. *International Journal of Environmental Science and Technology*, 1-16. <https://doi.org/10.1007/s13762-017-1280-8>
32. Patel, S., & Gautam, B. (2025). Urbanisation and Environmental Degradation: A Geographical Perspective on Yamuna River Pollution in NCT Delhi. *International Journal of Leading Research Publication (IJLRP)*, 6(11), 1–6. <https://www.ijlrp.com/papers/2025/11/1846.pdf>
33. Ramadhan, A. J., Yadav, S., Anand, S., Singh, A. P., Atta, K., Abotaleb, M., Alkattan, H., & Albadran, Z. (2024). Assessment of Municipal and Industrial Wastewater Impact on Yamuna River Water Quality in Delhi. *BIO Web of Conferences*, 97, 1–14. <https://doi.org/10.1051/bioconf/20249700124>
34. Rani, M., & Kumar, R. (2020). Assessment of Spatio-Temporal Variations in Water Quality of River Yamuna Using Multivariate Analysis. *Environmental Monitoring and Assessment*, 192(2), 125.
35. Rao, P. G., & Singh, S. (2015). Governance and Institutional Challenges in India's River Rejuvenation Programmes: The Case of the Yamuna Action Plan. *International Journal of Water Resources Development*, 31(4), 687–702.
36. Said, S., & Hussain, A. (2019). Pollution mapping of Yamuna River segment passing through Delhi using high-resolution GeoEye-2 imagery. *Applied Water Science*, 9(3), 1-8. <https://doi.org/10.1007/s13201-019-0923-y>
37. Samui, S., Mallik, A., Kumar, D., Rao, S., Dhanya, C. T., & Gosain, A. K. (2025). Identifying the pollution sources of River Yamuna through B eld observations and participatory approach. *Journal of Earth System Science*, 134, 1–15. <https://doi.org/10.1007/s12040-024-02498-7>
38. Satsangi, P. S. (2024). Restoration/Rejuvenation of ater in the River Yamuna, Agra. *Journal of Systems Science and Engineering*, 28(1), 1–94. https://www.dei.ac.in/dei/edei/files/2024/Paritantra Jan 2024 V3_1.pdf
39. Sharma, B., Ram, S., & Vyas, S. (2025). Characterization of Yamuna River water quality and its remediation by Phytoremediation technique. *South African Journal of Chemical Engineering*, 53, 49–59. <https://doi.org/10.1016/j.sajce.2025.04.006>
40. Sharma, B., Ram, S., & Vyas, S. (2025a). Evaluation of water quality of Yamuna River: A study conducted on Delhi Stretch using CCME WQI and HACA methods. *IOP Conf. Series:*

Earth and Environmental Science, 1489. <https://doi.org/10.1088/1755-1315/1489/1/012008>

41. Sharma, V. R., Bisht, K., Sanu, S. K., Arora, K., & Rajput, S. (2021). Appraisal of Urban Growth Dynamics and Water Quality Assessment along River Yamuna in Delhi , India. *Journal of Indian Water Works Association*, 1–10. https://www.researchgate.net/profile/Shubham-Sanu/publication/357419885_Appraisal_of_Urban_Growth_Dynamics_and_Water_Quality_Assessment_along_River_Yamuna_in_Delhi_India/links/61cd791ed450060816789528/Appraisal-of-Urban-Growth-Dynamics-and-Water-Quality-Assessment-along-River-Yamuna-in-Delhi-India.pdf?_sg%5B0%5D=started_experiment_milestone&origin=journalDetail&_rtd=e30%3D
42. Singh, G., & Kansal, M. L. (2018). Comparative Evaluation of River Action Plans in India: A Case Study of Yamuna and Ganga. *Water Policy*, 20(3), 479–494.
43. Singh, R. P., & Sharma, M. (2016). Urban Wastewater Management and River Pollution in Delhi: Evaluating Yamuna Action Plan Outcomes. *Environmental Policy and Governance*, 26(5), 432–445.
44. Singhal, S., & Gupta, M. (2024). Critically analyzing nature-based solutions : A political ecology framework of planning for the Yamuna River floodplains , Delhi. *Journal of Urban Affairs*, 1–21. <https://doi.org/10.1080/07352166.2024.2413587>
45. Srivastava, A., & Prathna, T. C. (2022). Yamuna Action Plan-III : Impact on Water Quality of River Yamuna ,. *Fine Chemical Engineering*, 3(1), 1–10. <https://wisepub.com/uploads/1/20211112/a8558b4d143bb818037e2c56335a3ad3.pdf>
46. Srivastava, R., Malhotra, R., & Sachdeva, R. (2023). Wastewater Pollution , Declining River Water Quality , and Its Socio-Economic Impact in NCT of Delhi. *Urban India*, 43, 179–204. https://gyanganga.ai/admin/fileupload/STC/RUPAL_SRIVASTAVA_Declining_River_water_quality,_NCT_DELHI.pdf
47. The Indian Express. (2025). Yamuna Pollution Worsens: Bacteria Levels and BOD Fluctuations Raise Alarm. *The Indian Express*
48. Times of India. (2025, April 12). Delhi Spent Over Rs 1,500 Crore on Yamuna Cleaning, But Water Still Toxic. *Times News Network*.
49. Tyagia, R. S., Singha, S. K., & Goyal, P. K. (2024). Interceptor sewer for abatement of pollution in surface water. *Water Practice & Technology*, 19(2), 532–545. <https://doi.org/10.2166/wpt.2024.005>
50. Yamuna Monitoring Committee (YMC). (2022). Report on Implementation of NGT Directives for Rejuvenation of River Yamuna. National Green Tribunal, New Delhi. *Yamuna Monitoring Committee (YMC)*

ANNEXURE A – Dataset Summary for R Analysis

This annexure presents a structured summary of the dataset employed for future trend analysis of water quality along the studied stretch of the Yamuna River. The dataset has been compiled from field monitoring records and official databases, and subsequently processed using the R statistical computing environment to facilitate systematic temporal and seasonal analyses. The period of analysis spans the years 2027 to 2028, representing a near-future projection window derived from established historical baselines. Yearly monitoring data form the primary basis of the dataset, providing a consistent temporal resolution suitable for trend detection and predictive modelling.

All statistical analyses, including temporal trend detection, seasonal decomposition, and predictive modelling, have been performed using R (Version 4.5.2) — a widely adopted, open-source statistical computing environment endorsed in environmental and hydrological research for its flexibility, reproducibility, and extensive library ecosystem. The use of a consistent, version-controlled software platform ensures that the analytical procedures are transparent and fully reproducible.

Attribute	Details
Attribute	Future Trend Analysis
Study Stretch	Palla → Okhla Barrage
Monitoring Stations	8 Stations (as per CPCB 2024; DPCC 2025)
Period of Analysis	2027–2028
Water Quality Parameters	Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Fecal Coliform (FC)
Data Type	Yearly Monitoring Data
Seasonal Aggregation	Pre-Monsoon, Monsoon, Post-Monsoon
Statistical Software	R (Version 4.5.2)

The dataset described above constitutes the empirical foundation upon which the future trend analyses presented in the main body of this thesis are built. The selection of parameters, spatial coverage, temporal resolution, and seasonal stratification has been guided by both scientific relevance and data availability, ensuring that the analysis is robust, replicable, and contextually meaningful within the broader framework of urban river water quality assessment.

ANNEXURE B – Full R Code Used in the Report

```

17 library(readxl)
18 library(dplyr)
19 library(tidyr)
20 library(ggplot2)
21 library(openxlsx)
22
23
24 df <- read_excel("C:/Users/User/OneDrive/Desktop/Projects/Data.xlsx")
25 df <- df %>%
26   mutate(FC = `Fecal cloiform`)
27 seasons <- c("Pre-Monsoon", "Monsoon", "Post-monsoon")
28
29 df2 <- df %>%
30   filter(Season %in% seasons)
31
32 params <- c("pH", "BOD", "COD", "DO", "FC")
33
34 hist_long <- df2 %>%
35   select(Year, Station, Season, pH, BOD, COD, DO, FC) %>%
36   pivot_longer(cols = all_of(params),
37     names_to = "Parameter",
38     values_to = "Value") %>%
39   mutate(Type = "Observed")
40
41 future_years <- 2026:2028
42 future_rows <- list()
43
44 for (st in unique(df2$Station)) {
45   for (se in seasons) {

```

```

45 for (se in seasons) {
46   sub <- df2 %>%
47     filter(Station == st, Season == se)
48
49   if (nrow(sub) == 0) next # no data for this station-season
50
51   for (param in params) {
52     y_hist <- sub[[param]]
53     years_hist <- sub$Year
54     valid <- !is.na(y_hist) & !is.na(years_hist)
55     y_hist <- y_hist[valid]
56     years_hist <- years_hist[valid]
57     if (length(y_hist) == 0) next
58     if (length(y_hist) >= 2) {
59       fit <- lm(y_hist ~ years_hist)
60       pred <- predict(fit,
61         newdata = data.frame(years_hist = future_years))
62     } else {
63       last_val <- tail(y_hist, 1)
64       pred <- rep(last_val, length(future_years))
65     }
66
67     future_rows[[length(future_rows) + 1]] <- data.frame(
68       Year = future_years,
69       Station = st,
70       Season = se,
71       Parameter = param,
72       Value = as.numeric(pred),
73       Type = "Predicted"

```

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function Addins

Project: (None)

Environment History Connections Tutorial

R Global Environment

Data

Object	Details
all_long	600 obs. of 6 variables
all_wide	120 obs. of 9 variables
df	64 obs. of 9 variables
df2	48 obs. of 9 variables
fit	List of 12
future_lo...	360 obs. of 6 variables

Files Plots Packages Help Viewer Pres

Home

Name	Size
.RData	441.9 KB
.Rhistory	16.7 KB
Book.xlsx	8.7 KB
Certificate of Completion.docx	12.8 KB
Custom Office Templates	
desktop.ini	418 B
Experience certificate.docx	13.2 KB
Impacts.docx	12.9 KB
Internship Report.docx	170.9 KB
Krish_Shokeen_CV.docx	34.5 KB
Offer letter.docx	13 KB
Office Lens	

```

73   type = Predicted
74   }
75 }
76 }
77 }
78
79 future_long <- bind_rows(future_rows)
80 all_long <- bind_rows(hist_long, future_long) %>%
81   arrange(Station, Season, Parameter, Year, Type)
82 all_wide <- all_long %>%
83   select(Year, Station, Season, Parameter, Value, Type) %>%
84   pivot_wider(names_from = Parameter, values_from = Value)
85
86 out_path <- "C:/Users/User/OneDrive/Desktop/Projects/Yamuna_Predictions_By_Station.xlsx"
87
88 wb <- createWorkbook()
89 addWorksheet(wb, "All_Data_Long")
90 writeData(wb, "All_Data_Long", all_long)
91
92 addWorksheet(wb, "All_Data_Wide")
93 writeData(wb, "All_Data_Wide", all_wide)
94
95 saveWorkbook(wb, out_path, overwrite = TRUE)
96
97 cat("Excel file saved to:\n", out_path, "\n")
98
99 clean_name <- function(x) {
100   gsub("[A-Za-z0-9]+", "_", x)
101 }
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

```

Console

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function Addins

Project: (None)

Environment History Connections Tutorial

R Global Environment

Data

Object	Details
all_long	600 obs. of 6 variables
all_wide	120 obs. of 9 variables
df	64 obs. of 9 variables
df2	48 obs. of 9 variables
fit	List of 12
future_lo...	360 obs. of 6 variables

Files Plots Packages Help Viewer Pres

Home

Name	Size
.RData	441.9 KB
.Rhistory	16.7 KB
Book.xlsx	8.7 KB
Certificate of Completion.docx	12.8 KB
Custom Office Templates	
desktop.ini	418 B
Experience certificate.docx	13.2 KB
Impacts.docx	12.9 KB
Internship Report.docx	170.9 KB
Krish_Shokeen_CV.docx	34.5 KB
Offer letter.docx	13 KB
Office Lens	

```

102
103 plots_folder <- "C:/Users/User/OneDrive/Desktop/Projects/Yamuna_Plots"
104 if (!dir.exists(plots_folder)) dir.create(plots_folder)
105
106 for (st in unique(all_long$Station)) {
107   for (param in params) {
108     plot_data <- all_long %>%
109       filter(Station == st, Parameter == param)
110
111     if (nrow(plot_data) == 0) next
112
113     p <- ggplot(plot_data,
114               aes(x = Year, y = Value,
115                 color = Season,
116                 linetype = Type, group = interaction(Season, Type))) +
117       geom_point(size = 2) +
118       geom_line(linewidth = 1) +
119       ggtitle(paste(st, "-", param, "Trend & Forecast (2024-2028)")) +
120       theme_minimal() +
121       theme(plot.title = element_text(size = 12, face = "bold"),
122             axis.text.x = element_text(angle = 45, hjust = 1))
123
124     print(p) |
125     file_name <- paste0("Plot_",
126                       clean_name(st), "_",
127                       param, ".png")
128     ggsave(filename = file.path(plots_folder, file_name),
129           plot = p, width = 7, height = 5, dpi = 300)
130   }
131 }
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

```

Console

RStudio

File Edit Code View Plots Session Build Debug Profile Tools Help

Go to file/function Addins

Project (None)

Environment History Connections Tutorial

R Global Environment

253 MiB

List

Source Visual

Outline

```

126         clean_name(st, "-",
127                     param, ".png")
128     ggsave(filename = file.path(plots_folder, file_name),
129           plot = p, width = 7, height = 5, dpi = 300)
130 }
131 }
132
133 cat("Plots saved in folder:\n", plots_folder, "\n")
134
135
136

```

Visual

R Console

124:15 Chunk 2

R Markdown

Console

Data

Object	Description
all_long	600 obs. of 6 variables
all_wide	120 obs. of 9 variables
df	64 obs. of 9 variables
df2	48 obs. of 9 variables
fit	List of 12
future_lo...	360 obs. of 6 variables

Files Plots Packages Help Viewer Presentations

Home

Name	Size
.RData	441.9 KB
.Rhistory	16.7 KB
Book.xlsx	8.7 KB
Certificate of Completion.docx	12.8 KB
Custom Office Templates	
desktop.ini	418 B
Experience certificate.docx	13.2 KB
Impacts.docx	12.9 KB
Internship Report.docx	170.9 KB
Krish_Shokeen_CV.docx	34.5 KB
Offer letter.docx	13 KB
Office Lens	



DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-42

CERTIFICATE OF THESIS SUBMISSION FOR EVALUATION

1. Name:.....
2. Roll No.:.....
3. Thesis title:.....
.....
.....
4. Degree for which the thesis is submitted:.....
5. Faculty of the University to which the thesis is submitted:
.....
6. Thesis Preparation Guide was referred to for preparing the thesis. YES ☐ NO ☐
7. Specifications regarding thesis format have been closely followed. YES ☐ NO ☐
8. The contents of the thesis have been organized based on the guidelines. YES ☐ NO ☐
9. The thesis has been prepared without resorting to plagiarism. YES ☐ NO ☐
10. All sources used have been cited appropriately. YES ☐ NO ☐
11. The thesis has not been submitted elsewhere for a degree. YES ☐ NO ☐
12. Submitted 2 spiral bound copies. YES ☐ NO ☐

(Signature of Candidate)

Name:.....

Roll No.:.....



DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-42

CERTIFICATE OF FINAL THESIS SUBMISSION

13. Name:.....

14. Roll No.:.....

15. Thesis title:.....

.....

16. Degree for which the thesis is submitted:.....

17. Faculty of the University to which the thesis is submitted:

.....

18. Thesis Preparation Guide was referred to for preparing the thesis. YES ☐ NO ☐

19. Specifications regarding thesis format have been closely followed. YES ☐ NO ☐

20. The contents of the thesis have been organized based on the guidelines. YES ☐ NO ☐

21. The thesis has been prepared without resorting to plagiarism. YES ☐ NO ☐

22. All sources used have been cited appropriately. YES ☐ NO ☐

23. The thesis has not been submitted elsewhere for a degree. YES ☐ NO ☐

24. Submitted 2 spiral bound copies. YES ☐ NO ☐

(Signature of the Supervisor)

(Signature of Candidate)

Name:.....

Name:.....

Roll No.:.....



DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Bawana Road, Delhi-42

PLAGIARISM VERIFICATION

Title of the Thesis _____

Total Pages _____ Name of the Scholar _____

Supervisor(s)

(1) _____

(2) _____

(3) _____

Department _____

This is to report that the above thesis was scanned for similarity detection. Process and outcome is given below:

Software used: _____ Similarity Index: _____, Total Word Count: _____

Date: _____



CERTIFICATE OF PRESENTATION



**International Conference on River Basin Hydrology and Water Resource Sustainability
(ICRBHWS-26)**

12th April 2026 | Mumbai - India

This is to certify that.....**Krish Shokeen**.....affiliated with
.....Delhi Technological University, New Delhi, Delhi, India.....has presented a paper titled

.....Governance, Policy and Sustainability Evaluation of Yamuna Action Plan.....

.....at the conference organized by the National Institute For Engineering And Research (NIER) held on
12th April 2026 at Mumbai - India.




Dr. Tara Srivastava
Director, NIER




Raj Kumar
Co-ordinator, NIER

DOAJ DIRECTORY OF
OPEN ACCESS
JOURNALS



Acceptance Letter

Dear Author(s): Krish Shokeen, Dr. Anil Kumar Haritash

Paper ID	NIER_76824
Paper Title	Governance, Policy and Sustainability Evaluation of Yamuna Action Plan

This is to enlighten you that above manuscript reviewed and appraised by the review committee members of **NIER** and it is accepted for the purpose of publication in the “**The Journal of Harbin Engineering University (JHEU)**” with ISSN: **1006-7043 (Online)** that will be available at <https://harbinengineeringjournal.com/index.php/journal>

Note: Please read carefully

1. **The Journal of Harbin Engineering University (JHEU)** Journal is a Scopus Journal.
2. Author(s) will receive Publication information and Published Paper link through **NIER**.
3. You may see more about the journal at: <https://harbinengineeringjournal.com/index.php/journal>
4. You will receive Volume/ Issue information of your paper very soon.

Sincerely,



Dr. Tara Srivastava

Director

National Institute For Engineering And Research (NIER)

Advanced Research Society for Science and Sociology



INTERNATIONAL CONFERENCE ON
Environmental Science and Green Energy

Certificate OF PRESENTATION

This is to certify that

Krish Shokeen

has presented a research paper entitled “Yamuna Action Plans and Sustainable River Pollution Control: A Policy and Governance Review” at the International Conference on Environmental Science and Green Energy (ICESGE) held in Pune, India during 19th April, 2026.



[Signature]
CONFERENCE COORDINATOR
ADVANCED RESEARCH SOCIETY FOR
SCIENCE AND SOCIOLOGY
(ARSSS)



[Signature]
MANAGING DIRECTOR
ADVANCED RESEARCH SOCIETY FOR
SCIENCE AND SOCIOLOGY
(ARSSS)

PAPER ID

AR-ESGE-PUNE-190426-16637

WWW.ARSSS.ORG