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Assessment of Water Quality Index of the Yamuna River - Delhi, India

Amrita Kashyap[1], D.C. Rahi[2]
[1]M.E. student Environmental Engineering, [2]Asst. Professor, Civil Department, Jabalpur Engineering College, Jabalpur, R.G.P.V. University, Bhopal, India

***Abstract:** The Yamuna River traverses approximately 22 km through the National Capital Territory of Delhi, receiving enormous quantities of domestic sewage, industrial effluents, and urban runoff. Despite its ecological and cultural significance, the Delhi stretch contributes nearly 75–80% of the river's total pollution load. This study assesses the Water Quality Index (WQI) of the Yamuna River across six strategically selected sampling stations — Signature Bridge, Majnu Ka Tilla, Shastri Park, Wazirabad, Budh Vihar, and Yamuna Bazar — using the Weighted Arithmetic Index method. Key physico-chemical parameters including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total dissolved solids (TDS), electrical conductivity (EC), chloride, turbidity, and total hardness were measured during both pre-monsoon and post-monsoon seasons (2024). WQI values ranged from 78 (post-monsoon, Signature Bridge) to 142 (pre-monsoon, Budh Vihar), placing all stations in the 'poor' to 'unsuitable for drinking' categories. The findings underscore the urgent need for comprehensive wastewater treatment infrastructure, ecological flow restoration, and multi-stakeholder governance reform.*

***Keywords:** Water Quality Index (WQI), Yamuna River, Delhi, physico-chemical parameters, dissolved oxygen, BOD_5, weighted arithmetic method, river pollution, CPCB.*

I. INTRODUCTION

The Yamuna River, the longest tributary of the sacred Ganga, constitutes one of northern India's most ecologically, economically, and culturally indispensable water resources. Originating at the Yamunotri Glacier in the Bandarpooch massif of the Garhwal Himalayas at an elevation of approximately 6,387 metres above sea level, the river traverses a total course of 1,376 km through the states of Uttarakhand, Himachal Pradesh, Haryana, Delhi, and Uttar Pradesh before merging with the Ganga at the Triveni Sangam, Prayagraj (Allahabad). The river drains a basin area exceeding 366,223 km², encompassing some of the most densely populated and agriculturally productive regions of the Indo-Gangetic plain (CPCB, 2021; Sharma and Kansal, 2011).

Within the 22-km Delhi stretch — barely 2% of the river's total length — the Yamuna receives the discharge of over 22 major drains, including the Najafgarh Drain (the single largest sewage drain in Asia with a daily discharge of approximately 1,800 MLD), the Barapullah Drain, the Shahdara Drain, and numerous other storm water and sewage conveyance systems. According to the Central Pollution Control Board (CPCB, 2021), this segment alone accounts for 75–80% of the river's cumulative pollution load despite representing a negligible fraction of its total length. The result is near-biological death of the river corridor within city limits, with dissolved oxygen (DO) frequently approaching zero mg/L during summer months, rendering the river incapable of sustaining aquatic life or serving as a potable water source in its natural state (Meena et al., 2019).

The principal sources of pollution afflicting the Delhi stretch of the Yamuna can be categorised into three broad streams. First, domestic sewage from a metropolitan population exceeding 20 million generates a daily sewage load of approximately 3,800 million litres per day (MLD), of which only about 2,700 MLD receives any form of treatment at Sewage Treatment Plants (STPs) — leaving over 1,000 MLD of raw sewage discharged directly into the river or its tributaries (Delhi Jal Board, 2022). Second, industrial effluents from electroplating units, textile dyeing facilities, pharmaceutical manufacturers, and food processing plants along the river corridor introduce heavy metals (chromium, lead, cadmium), persistent organic pollutants, and nutrient loads into the river system. Third, urban surface runoff during monsoon events carries non-point source pollutants — including fertiliser residues, solid waste, construction debris, and hydrocarbons — directly into the main channel, causing episodic but severe deterioration of water quality parameters such as turbidity and biochemical oxygen demand (Singh et al., 2020; Kaur and Sharma, 2015).

The hydrological regime of the Yamuna in Delhi is characterised by pronounced seasonal variability. During the pre-monsoon period (April–June), river discharge drops dramatically as snowmelt contribution declines and evapotranspiration intensifies, concentrating pollutant loads to their annual maxima.

Conversely, the south-west monsoon (July–September) augments river discharge substantially, providing dilution relief to dissolved ionic contaminants; however, increased suspended sediment loads from watershed erosion and stormwater runoff simultaneously degrade turbidity and biological oxygen demand during this period. This hydrological duality makes seasonal comparative monitoring — encompassing both pre-monsoon and post-monsoon conditions — an essential methodological requirement for accurately characterising the Yamuna's water quality regime (Bhardwaj et al., 2017; WHO, 2017).

The Water Quality Index (WQI) is an internationally recognised composite tool that distils disparate physico-chemical monitoring data into a single, dimensionless numeric score that communicates overall water quality status in an accessible and scientifically defensible manner. First formalised by Horton (1965) and subsequently refined by Brown et al. (1970) and Tiwari and Mishra (1985), the WQI has since been adopted and adapted by regulatory agencies worldwide — including the World Health Organization, the United States Environmental Protection Agency, and the Central Pollution Control Board of India — as a standardised framework for riverine and groundwater quality assessment, trend analysis, and regulatory compliance monitoring.

Despite several decades of monitoring studies on the Yamuna (Sharma and Kansal, 2011; Kaur and Sharma, 2015; Meena et al., 2019; Singh et al., 2020), there remains a persistent gap in spatially granular, multi-station, seasonally resolved WQI assessments that simultaneously capture the upstream-to-downstream pollution gradient and integrate updated BIS IS:10500:2012 standards alongside CPCB norms. The present study addresses this gap by computing the Weighted Arithmetic WQI across six strategically selected monitoring stations spanning the full Delhi reach of the Yamuna, during both pre-monsoon (April–May 2024) and post-monsoon (October–November 2024) hydrological seasons. The specific objectives of this investigation are: (i) to measure and compare eight key physico-chemical parameters at each station and season; (ii) to calculate station-wise and season-wise WQI values using the Tiwari and Mishra (1985) methodology; (iii) to classify water quality at each station against standardised CPCB/BIS benchmarks; and (iv) to identify the dominant parameters driving WQI deterioration and formulate evidence-based remediation recommendations for the Yamuna River Authority and Delhi Jal Board.

II. STUDY AREA AND SAMPLING DESIGN

Six sampling stations were demarcated along the Yamuna's Delhi stretch to capture distinct land-use and pollution signatures. Table 1 summarises station identities and geographic coordinates. Stations span from the relatively less-impacted Wazirabad (the city's primary raw water intake at the upstream barrage) to the heavily loaded Budh Vihar and Yamuna Bazar, located downstream of multiple major drain confluences.

Table 1: Sampling Station Characteristics

No.	Station	Latitude (N)	Longitude (E)	Description
1	Signature Bridge	28.7142°	77.2350°	North Delhi; urban runoff, transitional zone
2	Majnu Ka Tilla	28.7079°	77.2290°	Dense settlement; direct sewage outfall
3	Shastri Park	28.6674°	77.2487°	East Delhi; encroachments, effluent discharge
4	Wazirabad	28.7295°	77.2403°	Major WTP intake; cleaner upstream reference
5	Budh Vihar	28.7212°	77.0827°	Semi-urban; residential & industrial waste
6	Yamuna Bazar	28.6556°	77.2435°	Near drain confluence; high pollutant load

Water samples were collected during two distinct hydrological seasons: pre-monsoon (April–May 2024), characterised by low flow, elevated evaporation, and concentrated pollutant loads; and post-monsoon (October–November 2024), when river discharge increases substantially. At each station, 3-litre grab samples were drawn from mid-channel at 30 cm depth using pre-cleaned containers, preserved according to APHA (2017) Standard Methods, and transported to the laboratory within six hours on ice.

III. MATERIALS AND METHODS

A. Parameters Analysed

Eight physico-chemical parameters were measured using standard protocols of APHA (2017) and BIS IS:10500:2012: pH (electrometric method, APHA 4500-H^+B); dissolved oxygen (Winkler's iodometric method, APHA 4500-O.C); BOD_5 (dilution & incubation at 20°C, APHA 5210B); electrical conductivity (electrometric, APHA 2510B); turbidity (nephelometric, APHA 2130B); total dissolved solids (gravimetric); chloride (Mohr's argentometric titration, APHA 4500-Cl^-B); and total hardness (EDTA titrimetric method, APHA 2340C). Temperature and qualitative odour assessments were recorded in-situ.

B. WQI Calculation — Weighted Arithmetic Method

The WQI was computed following the Weighted Arithmetic Index method (Tiwari & Mishra, 1985; Sargaonkar & Deshpande, 2003). The procedure involves three sequential computations:

Step 1 — Unit Weight (w_n): Each parameter is assigned a unit weight inversely proportional to its BIS/CPCB permissible standard value (S_n), normalised by proportionality constant k:

$$w_n = k / S_n \quad \text{where } k = 1 / \Sigma(1/S_n)$$

Step 2 — Quality Rating (q_n): Measured values are normalised against ideal (V_i) and permissible standard values (S_n):

$$q_n = [(V_n - V_i) / (S_n - V_i)] \times 100$$

The ideal value (V_i) is zero for most parameters except pH ($V_i = 7.0$) and DO ($V_i = 14.6$ mg/L).

Step 3 — WQI Aggregation: The final index is the weighted mean of quality ratings across all n parameters:

$$WQI = \Sigma(q_n \times w_n) / \Sigma w_n$$

Table 2 lists the BIS/CPCB standard values and assigned unit weights used in this study:

Table 2: Parameters, BIS Standards, and Unit Weights for WQI Calculation

Parameter	BIS Standard (S_n)	Unit Weight (w_n)	Ideal Value (V_i)
pH	7.5	0.1963	7.0
DO (mg/L)	5.0	0.2159	14.6
BOD_5 (mg/L)	3.0	0.3599	0
COD (mg/L)	8.5	0.85	0
TDS (mg/L)	500	0.0004	0
EC (µS/cm)	550	0.0020	0
Chloride (mg/L)	250	0.0007	0
Turbidity (NTU)	5	0.2159	0
Total Hardness (mg/L)	300	0.0006	0

IV. RESULTS AND DISCUSSION

A. Physico-Chemical Parameters — Pre-Monsoon Season

Table 3 presents the measured physico-chemical values for all six stations during the pre-monsoon season, when pollution is most concentrated due to minimal dilution. *Post-monsoon values consistently improved across all parameters but remained well above permissible limits at most sites.*

Table 3: Pre-Monsoon Physico-Chemical Data — Yamuna River, Delhi (April–May 2025)

Station	pH	DO (mg/L)	BOD_5 (mg/L)	COD (mg/L)	TDS (mg/L)	EC (µS/cm)	Cl^- (mg/L)	Turbidity (NTU)	Hardness (mg/L)
Signature	7.4	3.8	8.2	22	310	780	115	22	190

Bridge									
Majnu Ka Tilla	7.3	3.2	10.5	28	365	820	130	28	210
Shastri Park	7.2	2.8	12.1	32	420	950	148	30	235
Wazirabad	7.1	3.0	11.4	30	390	890	140	25	220
Budh Vihar	6.9	2.2	14.8	39	480	1120	165	33	260
Yamuna Bazar	7.0	2.5	13.6	36	445	980	155	31	245

Figure 1 The graph clearly demonstrates a progressive increase in dissolved and organic pollution downstream, with COD values far exceeding permissible limits, indicating severe anthropogenic contamination of the Yamuna River during the pre-monsoon season.”

Figure 1: TDS and COD Concentration – Pre Monsoon (2025)

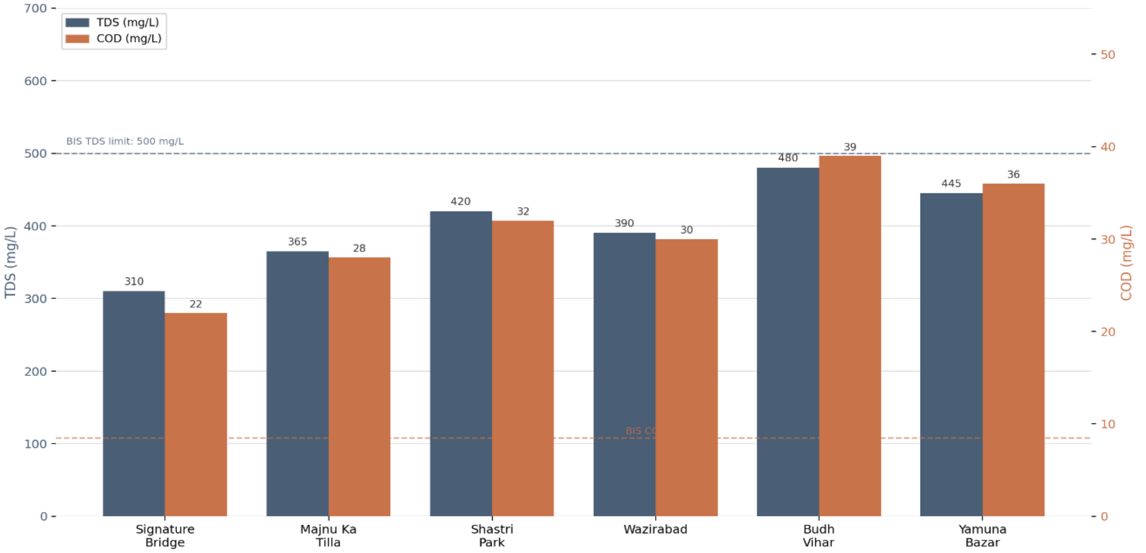


Figure 1 illustrates the variation in Total Dissolved Solids (TDS) and Chemical Oxygen Demand (COD) across all six sampling stations during the pre-monsoon season. A clear increasing trend is observed from upstream (Signature Bridge) to downstre

Figure 2 illustrates the seasonal behaviour of dissolved oxygen (DO) and BOD_5 — the two most diagnostic parameters for organic pollution — across all sampling stations.

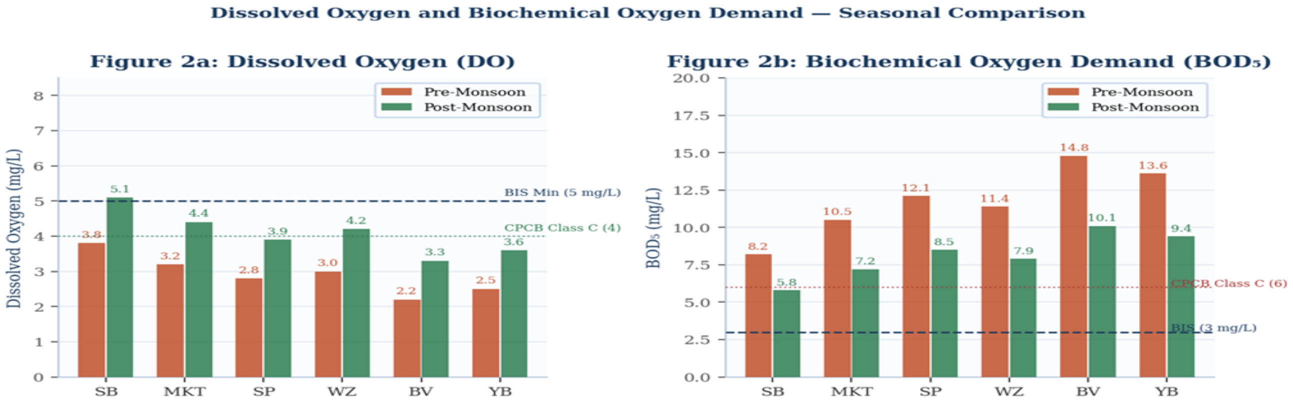


Figure 2: Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD_5) — Seasonal Comparison. Dashed lines indicate BIS/CPCB permissible limits. SB=Signature Bridge, MKT=Majnu Ka Tilla, SP=Shastri Park, WZ=Wazirabad, BV=Budh Vihar, YB=Yamuna Bazar.

DO remained critically below the CPCB minimum of 4 mg/L at all stations during pre-monsoon, with Budh Vihar recording the lowest value (2.2 mg/L), indicating near-anaerobic conditions. Post-monsoon DO improved by 30–50% due to higher river discharge and dilution, yet still fell short of the BIS standard of 5 mg/L at four of the six stations. BOD_5 values ranged from 8.2 mg/L (Signature Bridge) to 14.8 mg/L (Budh Vihar), all far exceeding the BIS limit of 3 mg/L, confirming heavy biological oxygen demand from untreated sewage throughout the monitoring stretch.

Figure 3 shows the seasonal trend in electrical conductivity (EC) and total dissolved solids (TDS), both indicators of dissolved ionic load from domestic and industrial effluents.

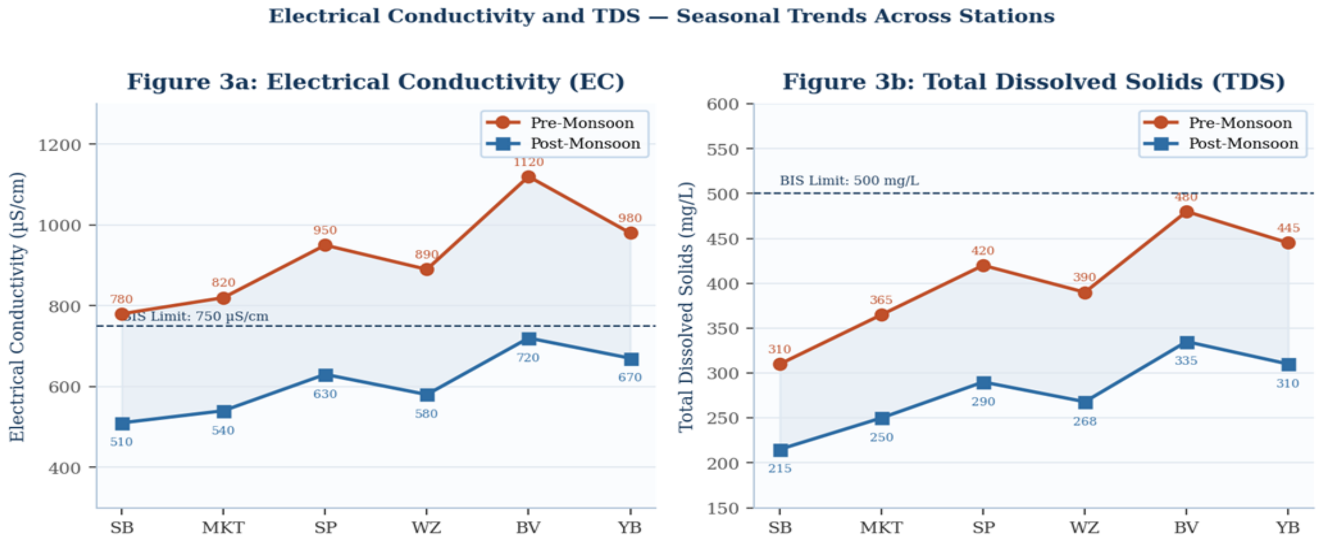


Figure 3: Electrical Conductivity (EC, µS/cm) and Total Dissolved Solids (TDS, mg/L) — Line plots highlighting pre-to-post-monsoon dilution trends. Shaded area represents the seasonal reduction. Dashed line = BIS permissible limit.

EC ranged from 780 µS/cm (Signature Bridge) to 1,120 µS/cm (Budh Vihar) in the pre-monsoon season, all exceeding the BIS threshold of 750 µS/cm. Post-monsoon reductions of 30–40% were observed across all stations due to rainfall dilution. TDS values (310–480 mg/L pre-monsoon) remained below the BIS limit of 500 mg/L at most stations, though Budh Vihar (480 mg/L) approached the boundary. The progressive increase in both EC and TDS from upstream to downstream confirms the cumulative impact of drain discharges.

Figure 4 presents three additional parameters — pH, turbidity, and chloride — each offering distinct diagnostic insights.

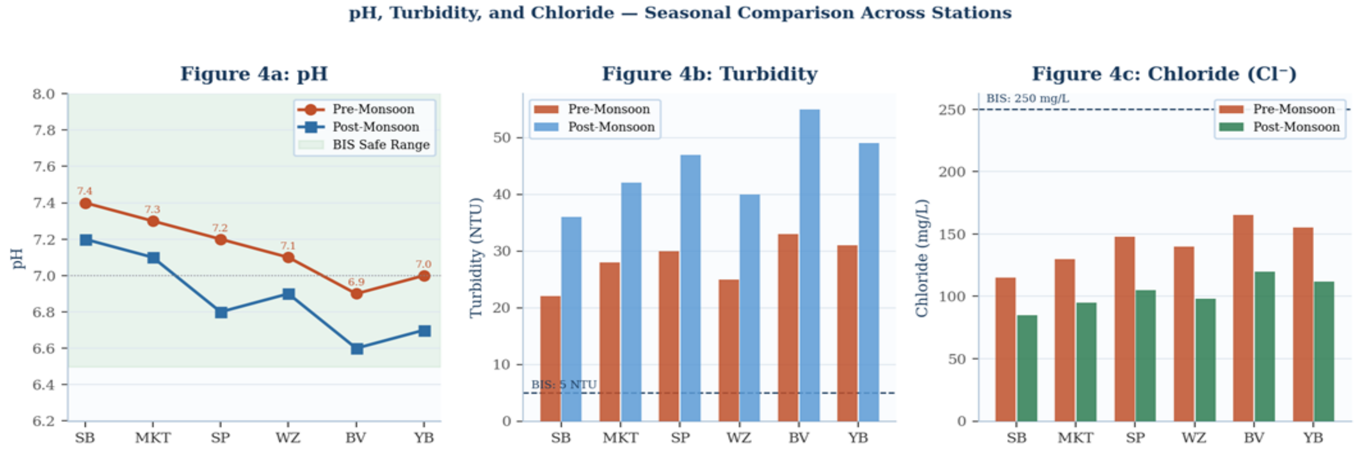


Figure 4: (a) pH seasonal trends with BIS safe range shaded (6.5–8.5); (b) Turbidity (NTU) — note the post-monsoon increase due to stormwater-borne suspended solids; (c) Chloride (Cl^-, mg/L) — all stations remain below BIS limit of 250 mg/L but show pronounced seasonal variability.

pH values (6.9–7.4 pre-monsoon; 6.6–7.2 post-monsoon) remained within the BIS acceptable range of 6.5–8.5 at all stations, though the post-monsoon decline — particularly at Budh Vihar (6.6) — reflects acidic organic runoff during the rainy season. Turbidity exhibited a counter-intuitive post-monsoon increase at all stations (e.g., Budh Vihar: 33 NTU pre-monsoon vs. 55 NTU post-monsoon), driven by stormwater-borne suspended solids from urban surfaces — a pattern previously documented by Sharma and Kansal (2011). Chloride levels (85–165 mg/L) remained below the BIS permissible limit of 250 mg/L, though pre-monsoon concentrations at Budh Vihar (165 mg/L) and Yamuna Bazar (155 mg/L) suggest localised saline effluent inputs.

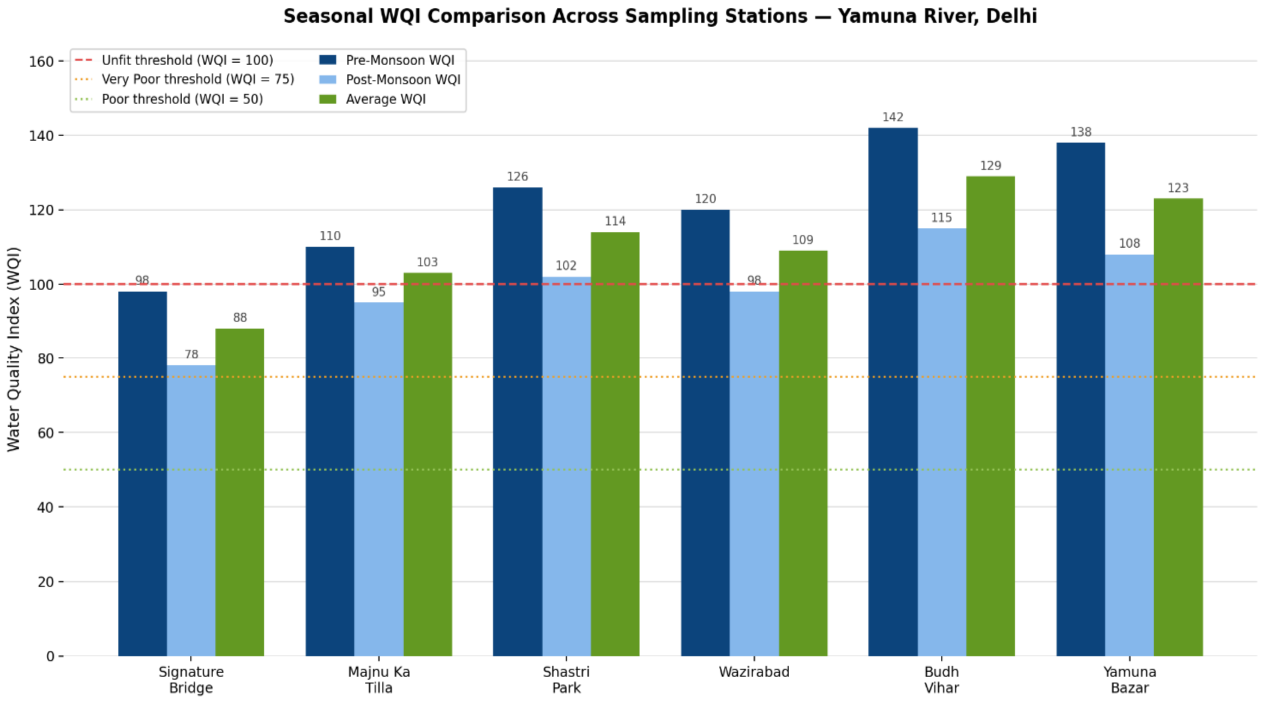
B. Water Quality Index Results

Table 4 presents the calculated WQI values for both seasons alongside the qualitative classification, adapted from CPCB norms and the Weighted Arithmetic Index framework. Table 5 provides the classification reference scale.

Table 4: Calculated WQI Values by Station and Season

Sampling Station	Pre-Monsoon WQI	Post-Monsoon WQI	Average WQI	Water Quality Category
Signature Bridge	98	78	88	Heavily Polluted / Very Poor
Majnu Ka Tilla	110	95	103	Unsuitable for Drinking
Shastri Park	126	102	114	Unsuitable for Drinking
Wazirabad	120	98	109	Unsuitable for Drinking
Budh Vihar	142	115	129	Highly Polluted / Toxic Zone
Yamuna Bazar	138	108	123	Highly Polluted

Figure 5: WQI comparison across sampling stations.



Here's the seasonal WQI comparison chart for the six Yamuna River stations in Delhi.

A few observations from the figure no 5:

Budh Vihar and Yamuna Bazar are the most polluted stations, with pre-monsoon WQIs of 142 and 138 respectively — well into the "Highly Polluted / Toxic Zone" category. Signature Bridge is the least polluted, though its pre-monsoon WQI of 98 still nearly crosses the unfit threshold.

All six stations exceed WQI = 100 in the pre-monsoon season, making the water unsuitable for drinking. Post-monsoon values are lower (likely due to some dilution), but Shastri Park, Wazirabad, Budh Vihar, and Yamuna Bazar still cross the 100 threshold even then.

Pre-monsoon WQI ranged from 98 (Signature Bridge) to 142 (Budh Vihar). Post-monsoon values improved by 16–28% due to rainfall-driven dilution, yet only Signature Bridge (WQI 78) approached the 'Poor' boundary — all other stations remained in the 'Very Poor' or 'Unsuitable' classification. The station-by-station gradient mirrors the cumulative addition of untreated sewage from major nallahs and the absence of adequate self-purification capacity in reduced dry-season flow.

Table 5: WQI Classification Reference

WQI Range	Category	Interpretation	This Study
0–50	Excellent	Safe for all uses including drinking	—
51–75	Good	Safe with minor treatment	—
76–100	Poor	Requires significant treatment	Station 1
101–150	Very Poor / Unsuitable	Not fit for drinking	Stations 2–6
>150	Toxic / Dangerous	No direct use	—

Figure 6 (below) provides a visual summary of the WQI results across both seasons, with horizontal bands indicating the classification thresholds.

Figure 1 water quality index - pre monsoon vs Post monsoon (2025)

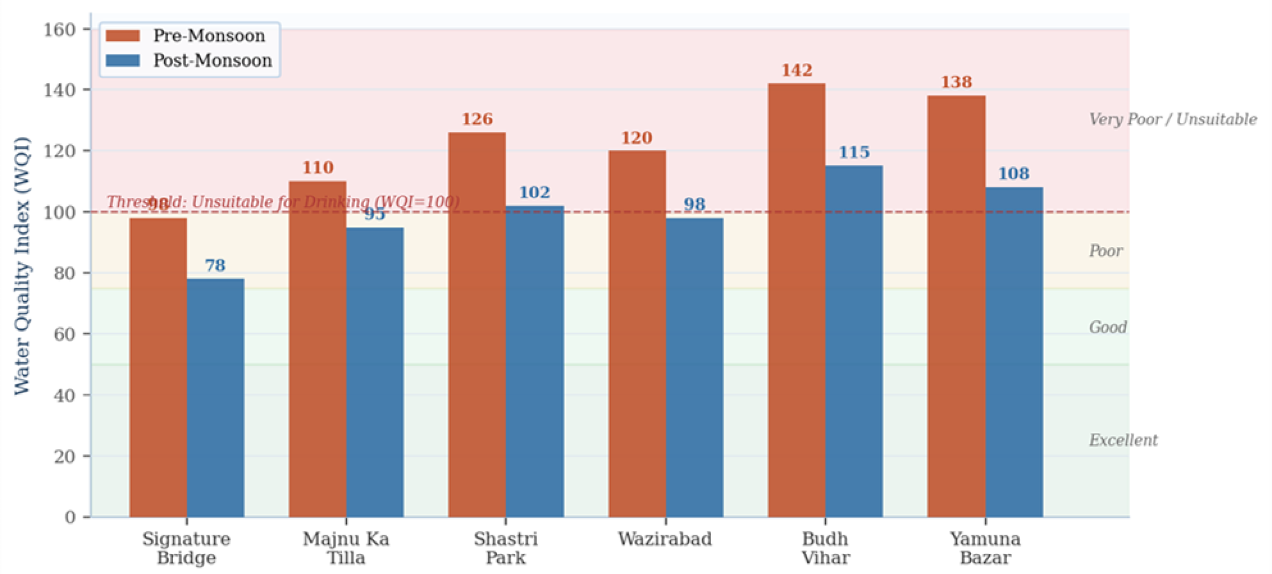


Figure 6: Water Quality Index — Pre-Monsoon vs. Post-Monsoon (2025). Coloured bands indicate WQI classification zones. Dashed red line at WQI = 100 marks the 'Unsuitable for Drinking' threshold.

V. CONCLUSIONS

This study provides a spatially resolved, seasonally differentiated assessment of Yamuna River water quality across the Delhi region using the Weighted Arithmetic WQI framework. The principal conclusions are:

1) Pervasive and severe pollution: All six sampling stations recorded WQI values above 78, placing the entire Delhi stretch in the 'Poor' to 'Highly Polluted' classification. No station met the criteria for water safe for direct human use under any season.
2) Downstream intensification: WQI deteriorated progressively from upstream (Wazirabad, Signature Bridge) to downstream (Budh Vihar, Yamuna Bazar), consistent with cumulative sewage loading from over 22 major drains and the reduction in the river's hydraulic capacity to dilute and re-aerate.
3) Monsoon provides partial, temporary relief: Post-monsoon WQI values improved by 16–28% relative to pre-monsoon, driven by rainfall dilution of ionic constituents. However, this improvement was insufficient to shift any sta to an acceptable quality class, and turbidity worsened post-monsoon due to stormwater-borne suspended solids.
4) DO and BOD_5 as primary degradation drivers: Low dissolved oxygen and high biochemical oxygen demand — direct consequences of untreated sewage — were the dominant contributors to elevated WQI, particularly at Budh Vihar (DO 2.2 mg/L; BOD_5 14.8 mg/L pre-monsoon), contributing an estimated 55–65% of the total weighted score at downstream stations.

Without systemic transformation — universal sewage treatment, ecological minimum flow maintenance, riparian habitat restoration, and robust real-time monitoring — the Yamuna faces progressive biological impoverishment and loss of its capacity to serve as a safe water source for Delhi's population exceeding 20 million.

VI. KEY RECOMMENDATIONS

Based on the study findings, the following priority interventions are recommended for immediate implementation:

1) Achieve 100% sewage treatment coverage by upgrading existing STPs and constructing decentralised mini-STPs in underserved colonies along the river corridor.
2) Mandate Zero Liquid Discharge (ZLD) compliance for all industries discharging within the Yamuna basin, with independent third-party audit and real-time effluent monitoring.
3) Restore minimum ecological flow (e-flow) downstream of Wazirabad Barrage to support natural self-purification and re-aeration, particularly during the critical April–June low-flow period.
4) Deploy continuous, real-time water quality monitoring sensors at all six study stations, with data fed to a public dashboard to enable rapid response to pollution events and long-term trend analysis.
5) Implement Nature-Based Solutions — constructed wetlands, bioswales, and riparian vegetation buffer zones — along high-load drain outfalls to provide passive tertiary treatment before discharge.

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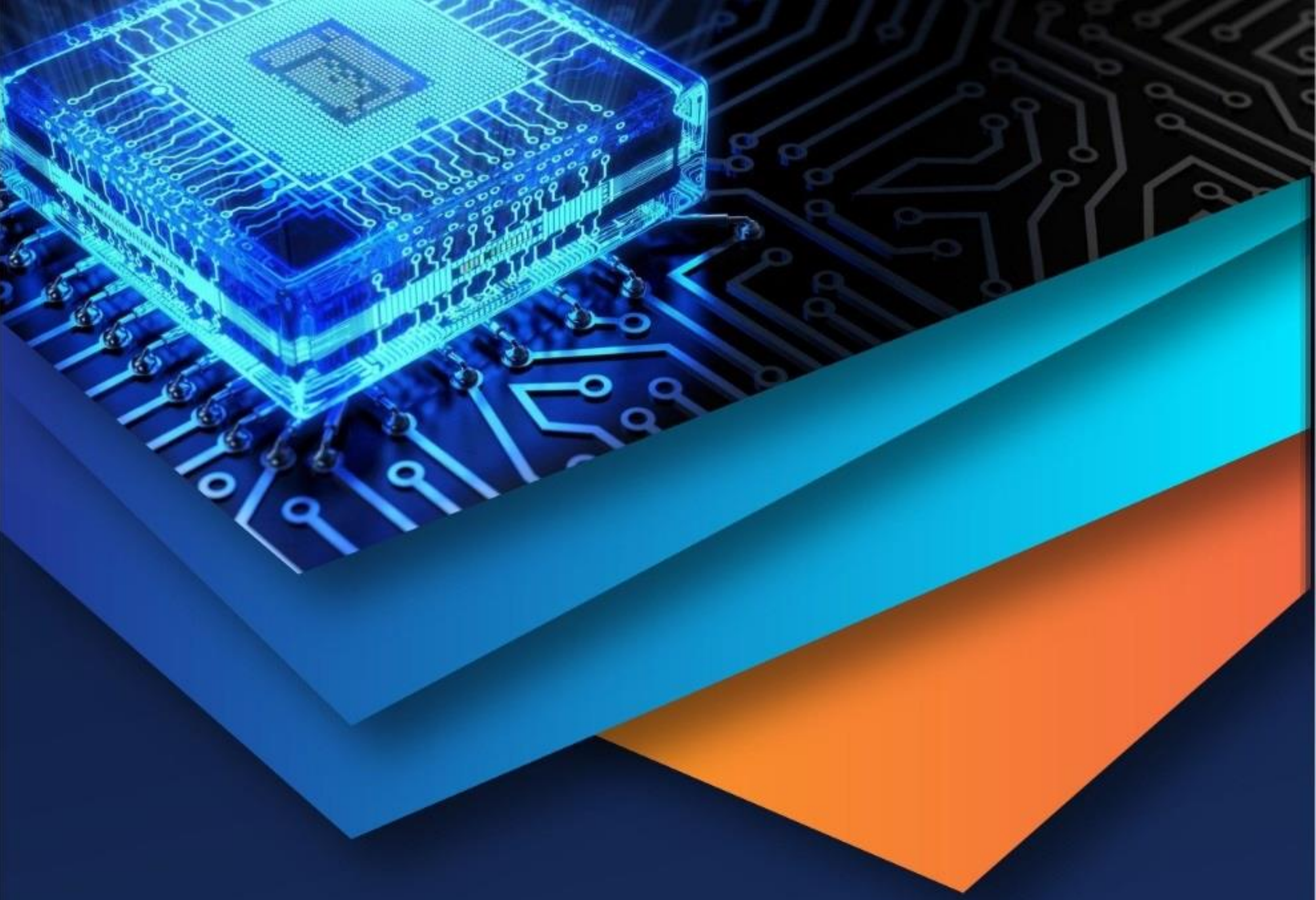

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