Water Quality Assessment of Yamuna River for Its Impact on Durability of Concrete Structures along the Riverbed

Sameer Vyas
Central Soil and Materials Research Station, CSMRS, New Delhi , India
Samyog78@yahoo.com
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Bhanupriya Sharma
Gautam Buddha University, Greater Noida, U.P., India.

RP Pathak
Central Soil and Materials Research Station, CSMRS, New Delhi , India

US Vidyarthi
Central Soil and Materials Research Station, CSMRS, New Delhi , India

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ABSTRACT
The poor water quality of the Yamuna River may affect the durability of various existing structures adjoining the river bed like barrages, metro bridges, Delhi secretariat, akshardham temple, commonwealth game complex etc. in long term exposure. In this scenario, it is important to evaluate its water quality to envisage its effect on concrete durability. The Central Soil and Materials Research Station, CSMRS has studied the water quality of the Yamuna River and Nallahs situated in the catchment area of the river flowing in Delhi. Present study highlights the seasonal change in water quality of river and nallahs to evaluate its suitability for use in concrete making and effect on long term durability of structures. Observations were made under research schemes clearly reveals that water quality degraded over the years particularly between the Wazirabad to Okhla stretch. For comprehensive evaluation, the water quality was monitored in different season's i.e. pre-monsoon, monsoon and post monsoon period. The water samples were analysed at the site for various in-situ parameters and water samples were brought to CSMRS laboratory for detail chemical analysis after proper preservation. Water samples were analyzed as per IS: 3025 standard procedures and interpretation of results were evaluated based on IS: 456 – 2000, ICOLD Bulletin No. 71 and other relevant International/National standards. The parameters like pH varies with seasonal variations, the pH values increase with the downstream shows more alkaline nature due to increasing sewage concentration discharges from different drains. The other parameters like electrical conductivity (EC), total dissolved solids (TDS), suspended solids, chloride, sulphate, and alkalinity were shows increasing trends of concentration at downstream of Wazirabad. Water quality may cause the durability problems in existing and upcoming civil engineering structures. The Langelier Saturation Index (LSI) determines water is aggressive/corrosive in nature. Langelier Index values of the river samples were found negative in majority of river locations indicating the water is aggressive in nature. The high values of suspended solids & alkalinity in the lean and pre-monsoon seasons at majority of locations makes the water unfit for construction as per IS 456 – 2000. Presence of higher amount of sulphate, chloride, soluble salts, hardness, sodium, potassium, calcium and other ions start deteriorating reactions which ultimately damage the structures in long term exposures. The other two parameters showing the health of the river i.e. Dissolved oxygen (DO) and biochemical oxygen demand (BOD) were also presented based on literature review monitored at different locations in the year 2022. The level of DO and BOD at Jagatpur, Wazirabad and Okhla differ dramatically. River shows good health at Jagatpur village while DO level continuously decreasing down stream of Wazirabad and ended in to level zero at Okhla. The study shows that there is a need of continuous monitoring of water quality of the river and drain in different sessions for the impact assessment on the health of the existing structures. The outcome the study will help in adopting suitable remedial measures for the existing and upcoming structures for combating aggressive water quality.

1. INTRODUCTION

The Yamuna River is one of the most polluted river in the world. Due to rapid urbanization and industrialization, the discharge of untreated domestic and industrial effluents has affected the quality of Yamuna River and ruling out the possibility for underwater life and domestic supply. During the entire journey after its origin from Himalayas, Yamuna travels 48 km in Delhi, out of which 22 km stretch is severely polluted due to discharges of sewage and effluent by more than 20 drains. Delhi stretch

counts only 2% of the total length of the river however 80% of its pollution contributed by this stretch. Delhi generate more than 750 million gallons per day (MGD) sewage, out of which only 550 MGD is treated by 36 Sewage Treatment Plants (STP). Around 200 MGD untreated sewage discharges daily in to the river. According to a study made by CPCB, only 45% of sewage and 55% of industrial effluents are treated up to secondary level before discharge into the Yamuna river. Due to complex nature of sewage and industrial effluents, the chemical properties of river water, ground water, top and sub soils in the adjoining areas are severely affected and altered. Impurities in the form of sewage, dirt and other floating materials contributed in downgrading water quality. In the same time, due to infrastructure development a large number of construction projects are upcoming in the catchment area of the river. Many flyovers, bridges, buildings were constructed along the Yamuna riverbed viz. Wazirabad barrage, Signature bridge, ISBT bridge, Shastri Park Metro Bridge,Old Rail road bridge, Geeta Colony flyover, ITO bridge, Yamuna bank metro bridge, Nizamuddin Rail bridge, Barapulla flyover bridge, DND flyover etc. Photographs of some of the structures are presented in fig. Fig.1-6

Figure 1. Signature Bridge

Figure 2. Wazirabad barrage

Figure 3. ITO barrage

Figure 4. Metro bridge along Yamuna river bed

Figure 5. Akshardham Temple & Commonwealth Games Village Complex,

Figure 6. Old Iron Bridge

Structural deterioration of several concrete components due to the usage of improper quality of water are observed worldwide. Failure of many structures were also reported due to constant contact of contaminated water with the concrete structures. The water quality parameters like pH, electrical conductivity (EC), total dissolved salts, suspended solids, chloride, sulphate, acidity and alkalinity may cause durability problems in civil engineering structures at long run. The presence of higher amount of sulphate, chloride, soluble salts, pH, hardness, sodium, potassium, calcium and other ions start deteriorating reactions which ultimately damage the structures, causing development of cracks in the structures which become unsafe for human population and causes heavy economic complications.

2. EXPERIMENTAL

Present investigation work aims to cover the following aspects:

- In-situ water quality assessment of River Yamuna at different stretches w.r.t to various National and International Codes & Practices.
- To assess the effect of water quality on the long term durability of concrete.

The water samples were analysed as per analytical procedure laid down in IS: 3025-1986 "Methods of Sampling and Test (Physical and Chemical). Wherever necessary, reference has also been drawn from the procedure laid down in “Standard Methods for the Examination of Water and Waste water” published by American Public Health Association and Water Pollution Control Federation, USA, 1985.

- The health of the river was also evaluated with the determination of level of Dissolved oxygen (DO) AND Biochemical Oxygen Demand (BOD) at different locations in the year 2021.

In the study carried out in year 20218-19, The most polluted stretch of Yamuna River from Wazirabad to Okhla was selected for collection of water samples. Yamuna water samples were collected from different locations. (Table-1 & Figure-7).

Table 1. Yamuna Water Samples

Sl. No.	Sample No.	Sample Locations
1	WS 1	Wazirabad Drain (L.S)
2	WS 2	Wazirabad Drain (R.S)
3	WS 3	Jagatpur Village Ghat
4	WS 4	Nizamuddin (R.S)
5	WS 5	Nizamuddin (L.S)
6	WS 6	Okhla
7	WS 7	ITO Right Bank U/s
8	WS 8	ITO Right Bank D/s
9	WS 9	ITO Left Bank U/s

Figure 7. Photographs of different sampling locations on River Yamuna

Again, water quality testing was carried out in the year 2021 (lean period). The details of sampling locations are presented in table 2. and photographs are presented in fig. 8

Table 2. Yamuna Water Samples

Sample No.	Location
WS-1	Jagatpur Village (u/s Wizarabad) (Collected from side bank)
WS-2	Wazirabad downstream (collected from midstream mid depth)
WS-3	Bhajanpura + Najafgarh drain assimilation point
WS-5	ITO Left bank (Power house Drain)
WS-6	Tilak Bridge
WS-7	Downstream of Nizamuddin barrage - left bank

WS-8	Akshardham Nursery
WS-9	Near Akshardham Metro Bridge
WS-10	Sarai Kale Khan Farming
WS-11	Sarai Kale Khan Drain
WS-12	Batla Drain

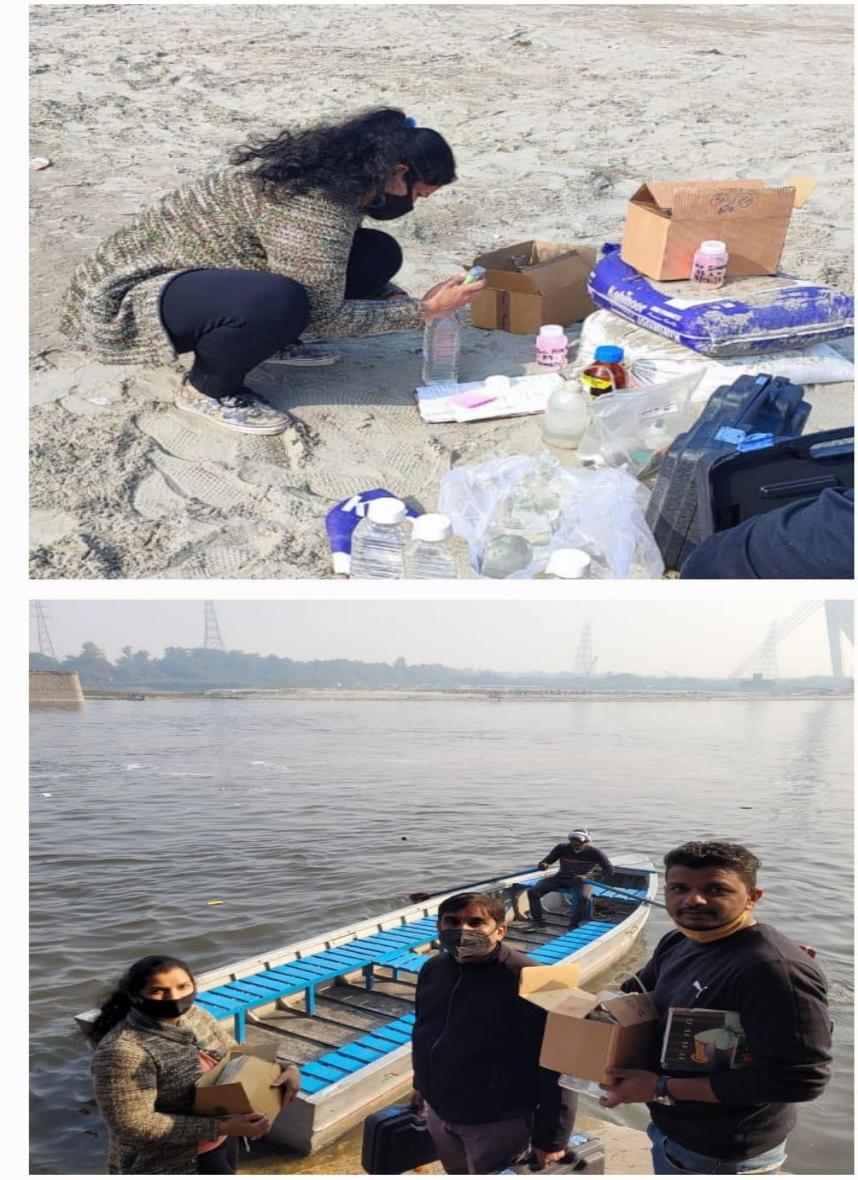

Figure 8. post monsoon sampling December 2021

3. RESULTS & DISCUSSION

The results of in- situ tests conducted at site during year 2018-19 are presented in table 3.0

Table 3. In-situ Parameters

Sl. No	Sample Location	pH	∆pH	Conductivity (µs)	Temperature ^{o}C	TDS mg/l
1	Wazirabad Drain (L.S)	7.6	0.4	908	16.3	438
2	Wazirabad Drain (R.S)	7.5	0.3	544	15.0	260
3	Jagatpur Village Ghat	7.9	0.1	529	17.5	253
4	Nizamuddin (R.S)	7.6	0.6	1342	21.1	657
5	Nizamuddin (L.S)	7.4	0.1	1531	20.9	756
6	Okhala	7.5	0.7	1273	19.3	624
7	ITO Right Bank U/s	7.8	0.3	820	20.6	396
8	ITO Right Bank D/s	7.3	0.2	795	19.9	385
9	ITO Left Bank U/s	7.5	0.1	781	18.6	379

The Interpretation of results based on national and international codes are presented in table-4

Table 4. Aggressivity of Yamuna water based on codes

Sl. No	Sample No	Conformity criteria w.r.t. CPCB Norms	USBR Classification for sulphate aggressivity	Aggressivity of water w.r.t. French National Standard p18-011, May 1985	Langelier Index Value
1	WS 1	Not Conforming	Positive (1)	A1	-0.2
2	WS 2	Conforming	Positive (1)	A2	-0.68
3	WS 3	Not Conforming	Positive (1)	A2	-0.24
4	WS 4	Not Conforming	Positive (1)	A2	-0.14
5	WS 5	Not Conforming	Positive (1)	A1	-0.41
6	WS 6	Conforming	Positive (1)	A2	-0.038
7	WS 7	Conforming	Positive (1)	A2	-0.092
8	WS 8	Conforming	Positive (1)	A2	-0.36
9	WS 9	Conforming	Positive (1)	A2	-0.042

Remarks:

- ✓ CPCB Norms: pH 6.5-8.5; Suspended Solids: not more than 100 ppm.
- ✓ A1:Slightly Aggressive; A2: Fairly Aggressive
- ✓ Positive (1): Slightly Aggressive
- ✓ Negative value of LI indicated aggresivity: All the water samples are aggressive and there is a possibility of Leaching.

The results of water quality analysis of samples collected from all locations indicated the poor water

quality as per standard codes and limits. The values of parameters observed to be higher with the downstream flow of river. The discharge of heavy sewage with the downstream flow may be possible cause of further deterioration in water quality. The results based on various indexes calculated as per table 3 indicated the aggressive nature of water towards long term durability of concrete structures.

The results of in- situ tests conducted at site during lean period year 2021 are presented in table -5.

Table 5. In-situ Parameters

Location	Temperature°C	pH	Conductivity (µS/cm)	TDS (ppm)	Salinity	$CaCO_3$ saturated pH	Qualitative observation of Ammonia
Jagatpur Village (u/s Wizarabad) (Collected from side bank)	15.8	8.03	652.3	320.3	0.363	7.99	Present
Wazirabad downstream (collected from midstream mid depth)	15.5	8.13	699.2	342.3	0.385	8.02	Present (Thick white precipitate)
Bhajanpura + Najafgarh drain assimilation point	16	7.56	155.2	761.1	0.821	7.61	Present
ITO Left bank (Power house Drain)	16.1	7.39	1308	641.4	0.693	7.63	Present
Tilak Bridge	15.9	7.42	1301	637.8	0.698	7.66	Present
Downstream of Nizamuddin barrage - left bank	16.8	7.44	1349	661.5	0.716	7.57	Present
Akshardham Nursery	15.9	7.47	1484	727.6	0.784	7.53	Present (Thick Precipitate)
Near Akshardham Metro Bridge	15.8	7.47	1535	752.6	0.810	7.50	Present
Sarai Kale Khan Farming	16.7	7.46	1547	578.1	0.816	7.54	Present
Sarai Kale Khan Drain	16.8	7.29	1039	509.5	0.557	7.53	Present (Thick Precipitate)
Batla Drain	15.7	7.44	1373	673.4	0.726	7.52	Present

The results of in-situ water quality analysis shows that the pH values falls in the slightly alkaline range due to input of heavy sewage from the different drains. The TDS values also observed to be higher near the confluence of drains in to the river. The presence of ammonia was also detected at almost all the locations. .

The Dissolved oxygen (DO) and Biochemical Oxygen Demand (BOD) values based on monitoring carried out between 2011 to 2021are presented in fig. 9 & 10. The observation between 2011-2020 was presented from the literature review however CSMRS also conducted testing in the year 2021.

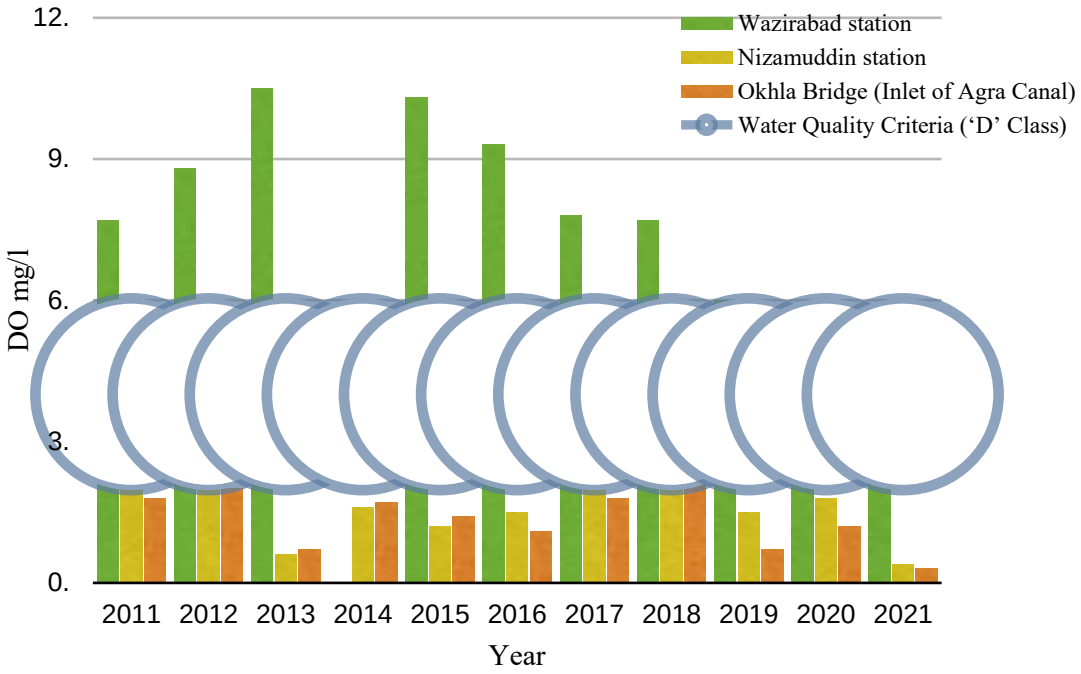

Figure 9. Concentration of DO within the Delhi Stretch of Yamuna River (2011-2021)

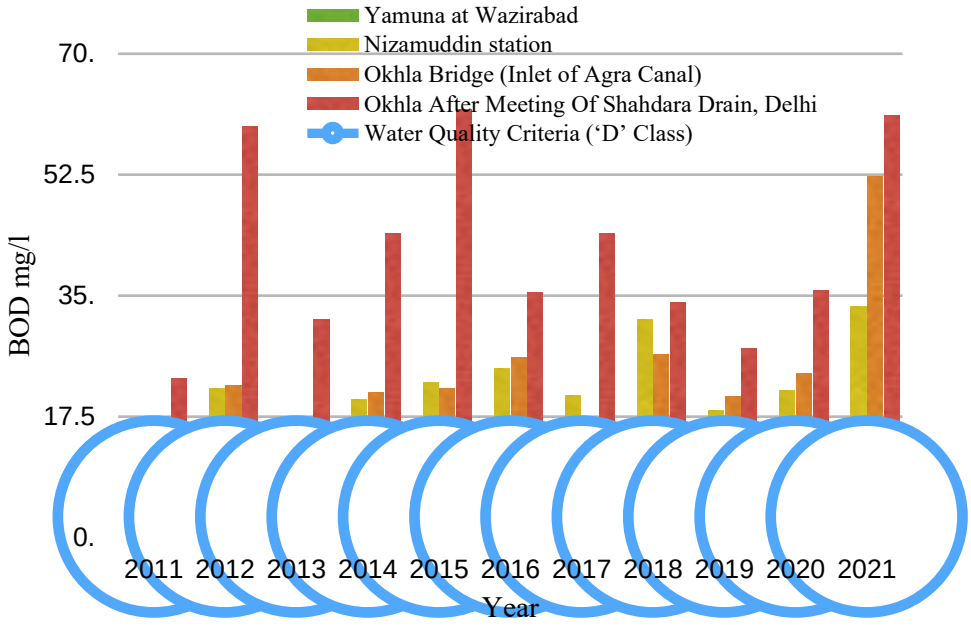

Figure 10. Concentration of BOD within the Delhi Stretch of Yamuna River (2011-2021)

Results clearly shows the level of DO is decreasing downstream while BOD level increasing as moving downwards towards okhla barrage.

4. CONCLUSION

The results of water quality analysis of samples collected from different locations indicated the aggressive water quality for concrete structures situated along the riverbed. The values of parameters observed to be higher with the downstream flow of river. The discharge of heavy sewage with the downstream flow may be possible cause of further deterioration in water quality. Very high values of BOD and very low values of DO indicating high organic pollution and poor health of the river Henceforth, there is a need for periodic comprehensive assessment of water quality of Yamuna River.

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