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RESEARCH ARTICLE

ASSESSMENT OF WATER QUALITY OF RIVER YAMUNA USING POLLUTION INDICES

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Abstract

The river Yamuna is considered a crucial river in the Indo-Gangetic plain. Having 0.4 Percent of the catchment area in the National Capital Territory (NCT) of Delhi, it feeds about 70 per cent of the population of Delhi and hence, is a major source of dependency for NCT of Delhi. The water quality monitoring of River Yamuna is done by the Delhi Pollution Control Committee (DPCC), Delhi on monthly basis.The objective of the study is to investigate the water quality of the river in the Delhi stretch, for the period 2003-2021. The water quality data has been derived from experimental analysis at DPCC across seven monitoring stations and has been analysed in the present study. It has been revealed that pollutant load from urban local bodies and drains have a stronger impact on the water parameters after the Wazirabad in Delhi, resulting in deteriorated water quality and high-Water Quality Indices (WQI). Water Quality Index (WQI) for the year 2021 indicates that pollution in the river Yamuna increases during monsoon and post-monsoonperiods while during pre-monsoon it remains relatively low.The average pH of the river water ranges from 6 to 8 throughout the year. The comparative data reveals that dissolved oxygen (DO) at most of the sites (except Palla) is nil and, the values of BiochemicalOxygen Demand(BOD) and Chemical Oxygen Demand (COD) have been increasing tremendously, which is due to the unregulated discharge or dumping of sewage water from urban local bodies (ULB) in the river.

Introduction:-

Rivers have always been contemplated as an important ecological habitat for sustaining various life forms. It is an incredible ecological concern around the globe. Rapid urbanization and developing economies have increased the pollution load on rivers significantly. The river Yamuna is the largest tributary of the river Ganga and the longest tributary in India. Originating from the Yamunotri Glacier at a height of 6,387 metres (20,955 ft) on the southwestern slopes of Lower Himalaya in Uttarakhand, it travels a total length of 1,376 kilometres (855 mi) and has a drainage system of 366,223 square kilometres (141,399 sq mi), It merges with the Ganga at Triveni Sangam, Prayagraj. Yamuna being the significant source of water for the National Capital Region Delhi (NCR Delhi), is also worshipped by the people because of its spiritual values.

The water quality of the river Yamuna throughout its length, emerging from Yamunotri in the Himalayas till upstream Wazirabad in Delhi remains good (CPCB river classification)(Kumar et al., 2018; Upadhyay et al., 2011).

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It enters Delhi at 1.5 km upstream ofPalla in the north, followed by Wazirabad and leaves at Okhla in the south. This stretch of 22 km, which is less than 2% of the total length of the river, is severely polluted and is responsible for 79% of the entire pollution load in the river (CPCB, 2006). Although the Delhi stretch is the shortest among the total five major stretches – Himalayan stretch (172 km), upper stretch (224 km), mixed stretch (490 km) and diluted stretch (468 km), it contributes more than 50% of the pollutants found in the Yamuna(Sehgal et al., 2011). It has been facing challenges for its survival due to the natural processes as well as anthropogenic pressures that have contributedto the degradation of surface waters and hence, impeded the utilization of the river water for drinking, industrial and agricultural purposes. Huge amounts of domestic and industrial wastewater (approx.3296 MLD)(CPCB, 2004; Gautam et al., 2017; Paliwal et al., 2007; Upadhyay et al., 2011), or treated waste from ULB discharge directly into the river, which prompts the water system, to become highly contaminated. Due to this, there have been rising concerns over the deteriorating water quality of the river Yamuna(Babu & Seth, 2007).Despite, Delhi having the highest number of working Sewage Treatment Plants (STPs) with the highest sewage treatment capacity in India (Mutiyar et al., 2018), the treated, or partially treated sewage from these STPs is being discharged into the river(Babu & Seth, 2007). Also, due to the non-operationality of STPs because of power failures, mechanical problems or maintenance issues, the untreated sewage directly goes into the river(CPCB, 2006).

In Delhi, water quality monitoring of water bodies is being carried out by Delhi Pollution Control Committee (DPCC).DPCC monitors the water quality of river Yamuna, based on physicochemical parameters across various points viz. Palla, Wazirabad, ISBT Bridge, ITO Bridge, Nizamuddin, Agra Canal and Downstream Okhla Barrageon monthly basis. DPCC also monitors the water quality of 27 drains falling in river Yamuna, based on physicochemical parameters.Najafgarh drain (133.82 TPD) and Shahdara drain (61.44 TPD) contribute about 74% of total BOD load and 81% of the total flow in Delhi. The other drains contributing to the BOD load are Barapulla drain (10.46 TPD), Sarita Vihar drain (7.73 TPD) and Sen Nursing Home (4.69 TPD). The total BOD load from 22 drains in the year 2019 was 264.31 TPD (Chandra & B.S. Sajwan, 2020).

Some studies have additionally examined the limnological parameters, likeSarkar & Shekhar, 2018 has revealed high contamination of iron-rich minerals in groundwater and river water of Upper Yamuna Basin. Also, Sehgal et al., 2011 have shown the overall mean concentration of heavy metals in the order Fe > Cu > Zn > Ni > Cr > Pb > Cd during December 2013–August 2015. Study such as Mutiyar et al., 2018 has depicted a substantial amount of pharmaceutical residues released through STP effluents to the Yamuna River and comparably higher pharmaceutical active compounds (PhACs) contamination at downstream Wazirabad, where Najafgarh drain joins river Yamuna.

With this background, the current study aims to analyse the status of the water quality of River Yamuna at different locations over the period 2003-2021.

Methodology:-

Details of the methodology have been discussed in the following sub-sections.

Site of the Study

The sampling of the river Yamuna has been carried out by DPCC at 7 different locations (Fig. 1) from 2003 – 2021 and the analysis includes the physicochemical parameters (Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), pH).The sampling of the river Yamuna has been done on the stations listed below and the coordinates of these stationsare shown in Table 1 below.

Table 1:- Water Quality Monitoring Stations.

Stations	Coordinates	
	Latitude	Longitude
Palla	28°51'00.7"N	77°12'36.7"E
Wazirabad	28°42'47.6"N	77°13'52.6"E
ISBT Bridge	28°40'15.0"N	77°14'04.0"E
ITO Bridge	28°37'40.0"N	77°15'12.5"E
Nizamuddin	28°35'54.9"N	77°15'47.9"E
Agra Canal	28°31'55.1"N	77°18'13.8"E
Downstream Okhla Barrage	28°32'39.6"N	77°18'45.9"E

Figure 1:- Sampling sites along river Yamuna.

Data and Methods:-

To assess the water quality of the river Yamuna, data of 2003-2021 has been used for the current study.Before calculating WQI, different water quality parameters viz. BOD, DO, pH, COD have been compared at different locations throughout 2003-2021, to assess the water quality trends of river Yamuna in the Delhi region.

However, for calculating WQI, threephysico-chemical parameters of water quality have been taken into account. Table 2 below shows the details of the parameters and their standard and ideal values. All the ideal values are taken as zero for the drinking water except pH and DO.

Table 2:- Water quality parameters.

Parameters	Units	Standard Value	Ideal Value
pH	pH units	6.5-8.5	7
Biochemical Oxygen Demand (BOD)	mg/L	3	0
Dissolved Oxygen (DO)	mg/L	5	14.6

To assess the water quality of the river, Weighted Arithmetic Water Quality Index (WAWQI) methodis used. Moreover, WQI is computed for three different seasons i.e.,pre-monsoon, monsoon and post-monsoon for the year 2021. This strategy has been broadly utilized by different researchers(Chauhan & Singh, 2011; Rao & Manjula, 2010).

The WQI is calculated by the following equation:

$WQI = \frac{\sum_{i=1}^{n} WiQi}{\sum_{i=1}^{n} Wi}$……. (1)

where Qi is the sub-index of the i^{th} parameter and Wi is the unit weightage of the i^{th} parameter and n is the considered parameters in the analysis. The unit weightage (Wi) of the parameter is calculated using Eq. (2), where, Si is the maximum allowable recommended standard for the i^{th} parameter and k is the constant of proportionality.

$Wi = \frac{k}{Si}$…….. (2)

The sub-index (Qi) of the parameter is calculated using Eq. (3), where (Ii) indicates the maximum desirable/ideal value for the same parameters in drinking water and Mi is the estimated concentration of the i^{th} parameter in the analysed water.

$Qi = \sum_{i=1}^{n} \frac{Mi-Ii}{Si-Ii}$x 100……. (3)

Ii = 0, in case of pure water (except pH = 7 and DO = 14.6 mg/L).

The index produces a number which then can be compared with the categories given in Table 3. These numbers are divided into descriptive categories and transformedinto a group of water quality parameters to form a single number in accordance with a chosen method or computation model. Themain objective of the WQI system is to use it as a preliminarymeans of assessing the water quality of a water body for compliancewith standards adopted for designated classes of beneficialuses(Lohkare et al., n.d.; Tiwari et al., 2014).

Table 3:- Water Quality Index (WQI).

WQI	Rating of Water Quality	Grading
Below 50	Excellent	A
50-100	Good Water	B
100-200	Poor Water	C
200-300	Very Poor (Bad) Water	D
Above 300	Unsuitable (unfit) for Drinking	E

Results and discussion of Water quality trends of River Yamuna in Delhi:-

To assess the water quality trends of River Yamuna in Delhi, seven prominent locations have been taken into account. The analysis shows that average BOD is found to be maximum (54.1 mg/l) at Downstream Okhla Barrage in 2021 and minimum (1.8 mg/l) atPalla in 2010 and 2011. BOD fluctuates less at Palla and Wazirabad, the trend observed can be considered as a straight line. However, the average BOD shows an increase in trend from 2020 to 2021, at all the sites exceptPalla and Wazirabad. Likewise, the average COD is found maximum (223.3 mg/l) at Downstream Okhla Barrage in 2021 and minimum (7.6 mg/l) at Palla in 2018. In this case, the average COD at all sites shows an increase in trend. DO is found highest (9 mg/l) atPalla in 2016. Moreover, there have been fluctuations in average DO in the periods 2004-2007, 2011-2015 and 2019-2021. In the case of DO, the average value of DO at Palla increases whereas at Wazirabad it is shown to be decreasing.

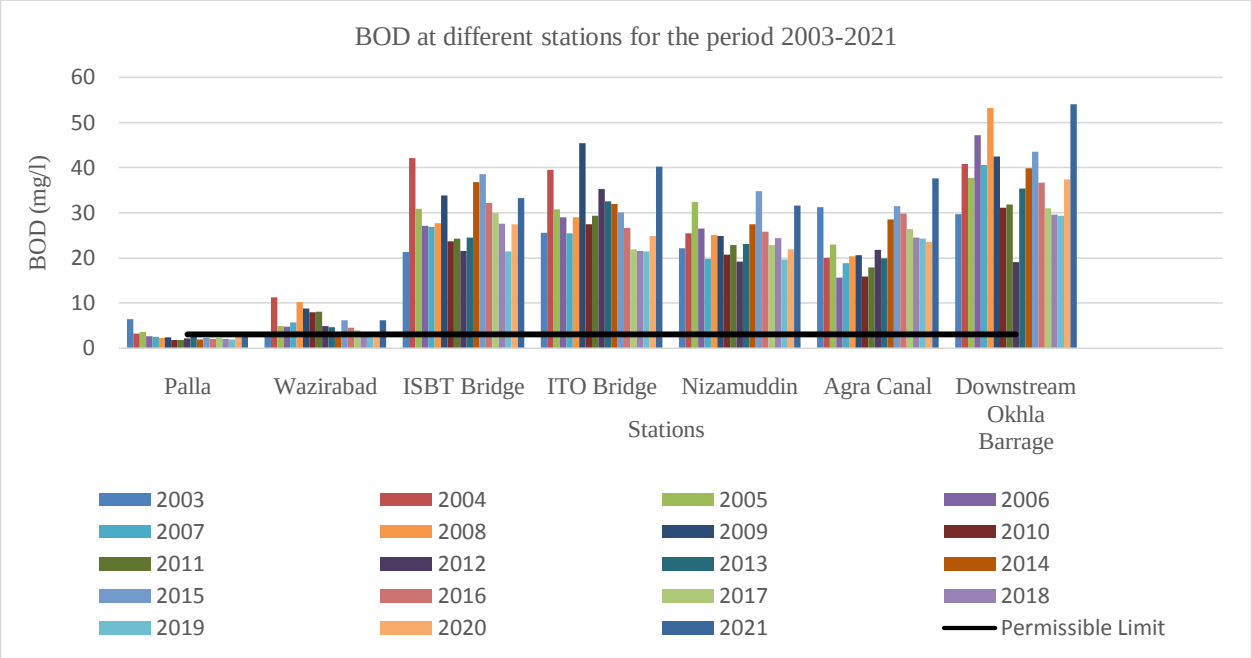

Figure 2:- Variation of Biological Oxygen Demand (2003-21) within the Delhi stretch of River Yamuna.

At Palla and Wazirabad, there is no severe degradation in water quality with respect to BOD, COD and DO as the graphs show little fluctuation in the period of 2003 to 2021 (Figs. 2-4). This is because the Najafgarh drain meets River Yamuna after Wazirabad and hence, thereafter the water quality deteriorates. After Wazirabad, the fluctuation at all five sites is severe; with DO being reportedas nil many times during the period of the study. It is noticeable that the parameters highly fluctuate at Downstream Okhla Barrage compared to other stations and the water quality at Agra Canal is better when compared to all the stations except Palla and Wazirabad.

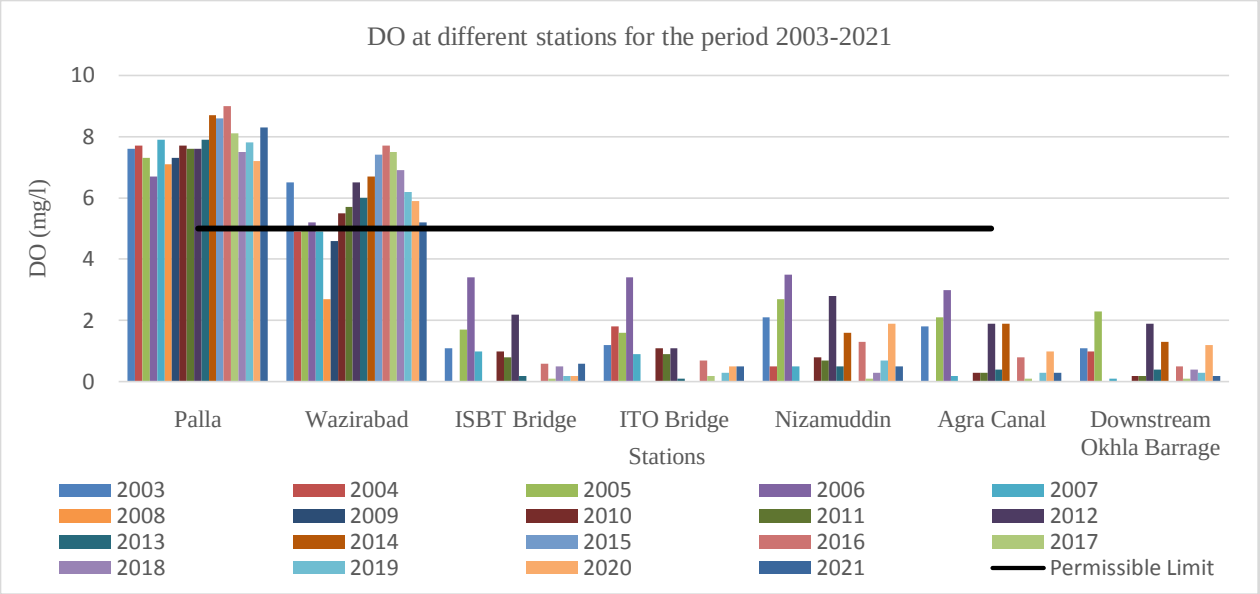

Figure 3:- Variation of Dissolved Oxygen (2003-21) within the Delhi stretch of River Yamuna.

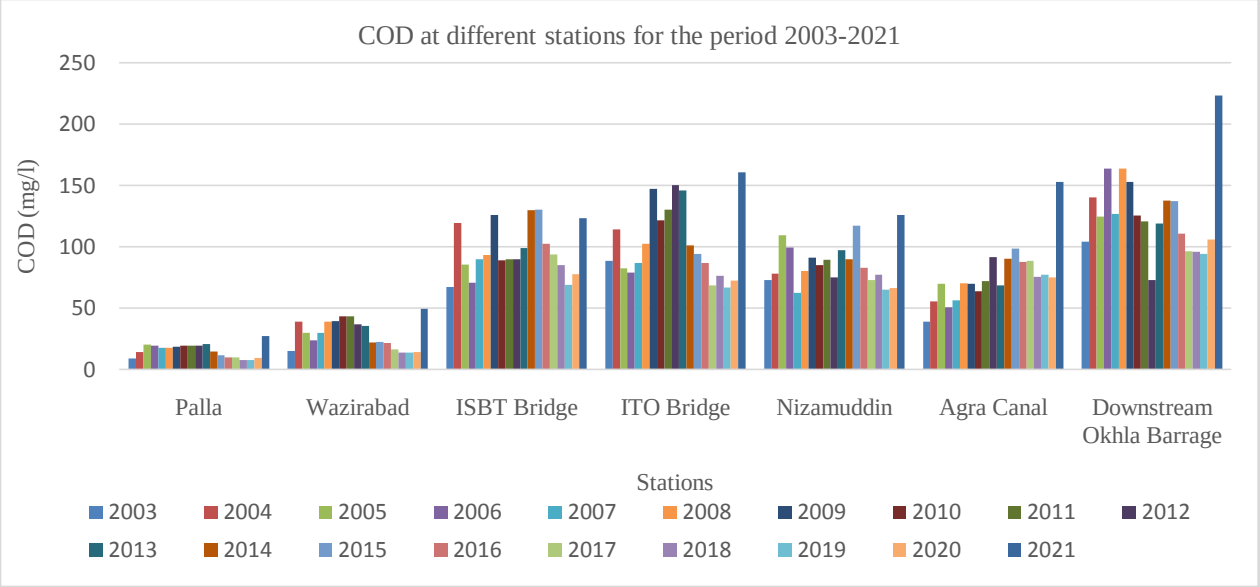

Figure 4:- Variation of Chemical Oxygen Demand (2003-21) within the Delhi stretch of River Yamuna.

To understand the overall water quality, a weighted arithmetic water quality index (WAWQI) is formulated for all the sites over the period 2003-2021,based upon three important parameters viz. pH, DO and BOD (Table 4).

Table 4:- WQI for the period of 2003-2021.

Stations / Years	Palla	Wazirabad	ISBT Bridge	ITO Bridge	Nizamuddin	Agra Canal	Downstream Okhla Barrage
2003	145	80	413	485	423	580	555
2004	89	230	767	719	485	395	745
2005	93	118	569	569	593	436	686
2006	77	116	501	529	491	309	853
2007	73	133	503	477	384	369	739
2008	76	218	523	543	477	398	955
2009	74	188	625	824	472	403	774
2010	61	171	451	516	400	310	579

2011	63	173	461	546	436	355	592
2012	71	119	413	649	372	419	370
2013	67	110	464	601	442	386	651
2014	60	91	677	595	511	530	727
2015	63	130	707	562	641	586	790
2016	58	104	596	500	486	558	674
2017	60	91	556	419	437	499	577
2018	62	88	517	416	464	467	551
2019	67	91	417	418	384	466	551
2020	76	92	517	473	417	451	687
2021	73	139	613	732	585	687	972

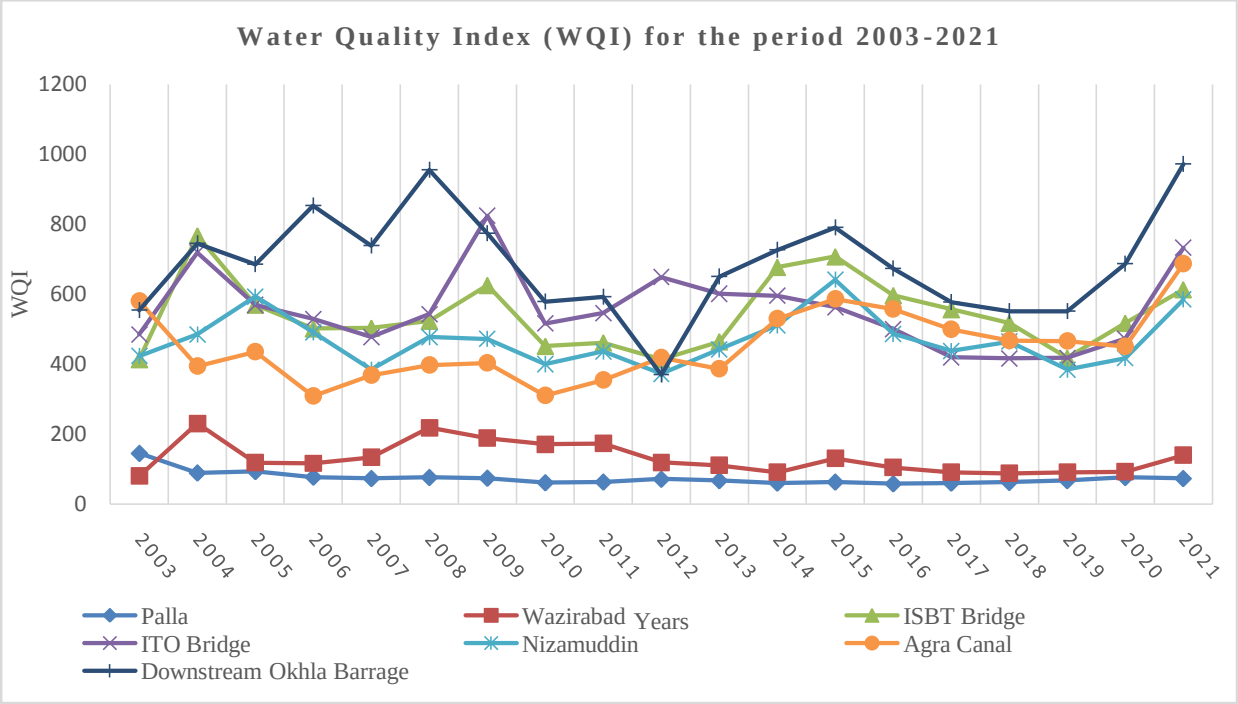

Figure 5:- Variation of WQI (2003-21) within the Delhi stretch of River Yamuna.

Table 5 depicts the values of the highest and lowest WQI and its corresponding year for each station. From the table, it can be inferred that Palla is the cleanest station, having the lowest WQI and Downstream Okhla Barrage being the most polluted station, have the highest WQI. Downstream Okhla Barrage is the last station in the Delhi stretch of River Yamuna. The WQI indicates that wastewater from various drains (trapped or un-trapped) discharging into the river, causes a percentage increase of 825% (Table 7), which is undesirable and alarming. Stagnant water or water having low flow velocity also contributes to high WQI.The average WQI (2003-2021) has been calculated and computed in Table 6 and the overall grading has been done to recount the status of the water quality for the study period.

Table 6:- Average WQI and the rating of Water Quality.

Sl. No.	Station	Average WQI (2003-2021)	Rating of Water Quality	Grading
1	Palla	74	Good Water	B
2	Wazirabad	130	Poor Water	C
3	ISBT Bridge	541	Unsuitable for Drinking	E
4	ITO Bridge	556	Unsuitable for Drinking	E
5	Nizamuddin	468	Unsuitable for Drinking	E
6	Agra Canal	452	Unsuitable for Drinking	E
7	Downstream Okhla Barrage	685	Unsuitable for Drinking	E

Table 7: Percentage variation of WQI in the river stretches.

Sl No.	Stretches of the river	Percentage Increase/Decrease between the stations	Remarks
1	Palla– Wazirabad stretch	76	WQI increases as untreated waste/sewage are discharged from urban local bodies (ULB) and unregulated drains/ activities in this stretch of the river.
2	Wazirabad – ISBT Bridge stretch	316	Result of unregulated or partially treated discharge of sewage water from Najafgarh drain, Metcalf drain, Khyber Pass drain, Sweeper Colony drain, Magazine Road drain, ISBT drain, Tonga Stand drain and Sonia Vihar drain in the river.
3	ISBT Bridge – ITO Bridge stretch	3	Marginalincrease in WQI. Minimal dumping from urban local bodies (ULB) and drains viz. Civil Mill drain, Power House drain, Kailash Nagar drain and Shastri Park drain.
4	ITO Bridge – Nizamuddin stretch	-16	Decrease in the percentage variation due to the regulated and treated discharge of sewage water by STPs in the river, resulting in dilution of River Water and upliftment of water quality.
5	Nizamuddin – Downstream Okhla Barrage stretch	46	Marginal decrease in WQI due tominimal dumping from urban local bodies (ULB) and drains viz. Barapulla drain, Maharani Bagh drain, Sahibabad drain, Old Agra Canal drain.
6	Palla – Downstream Okhla Barrage stretch	825	The overall increase of WQI in the Delhi stretch of River Yamuna.

(Note: Negative sign depicts a decrease in the percentage variation of average WQI)

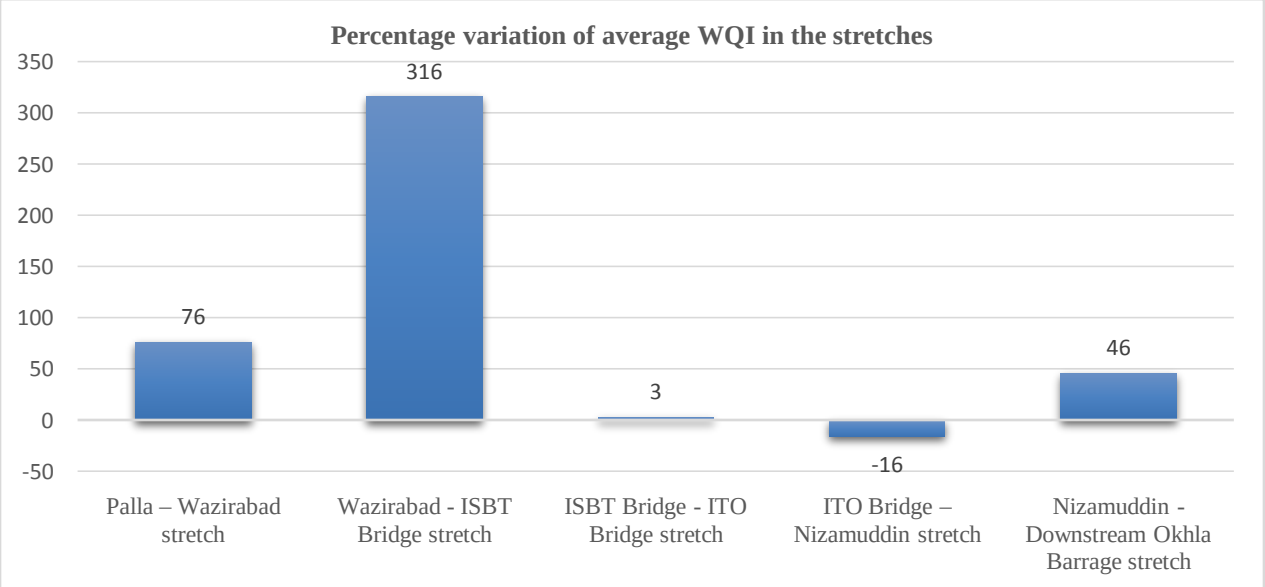

Figure 6:- Percentage variation of average WQI (2003-2021) in the river stretches.

To study the percentage increase during the course of the river, the river is divided into 5 stretches with respect to its locations (Table 7 and Fig. 6). A sharp increase is noticed in the Wazirabad - ISBT Bridge stretch. This is due to the high amount of untreated sewage from Najafgarh drain, Metcalf drain, Khyber Pass drain, Sweeper Colony drain, Magazine Road drain, ISBT drain, Tonga Stand drain and Sonia Vihar drain being discharged in this stretch. Najafgarh drain being the largest contributor with highest BOD load can be identified as a problematic or 'Action Required Zone', as this stretch is highly responsible for the deterioration of the water quality of river Yamuna.

Furthermore, the WQI has been calculated for three different seasons, for the year 2021 (Table8). The results reveal that the water quality index remains relatively lowerduring pre-monsoon and increasesin the post-monsoon season.Water quality at Palla remains relatively good compared to other sites in all three seasons. Except forPalla and Wazirabad, water quality is not meeting the primary water quality criteria ('C' class) for bathing purposes.

Table 8:- WQI for three different seasons for the year 2021.

Seasons / Stations	Pre-monsoon	Grading	Monsoon	Grading	Post-monsoon	Grading
Palla	63	B	77.75	B	82.33	B
Wazirabad	124	C	147	C	171.67	C
ISBT Bridge	573.5	E	615.25	E	671.33	E
ITO Bridge	555	E	712.5	E	933.33	E
Nizamuddin	606.5	E	540.75	E	662.33	E
Agra Canal	685	E	665.25	E	717.67	E
Downstream Okhla Barrage	654	E	1099	E	947.33	E

Conclusions:-

Water quality of the river Yamuna at seven different locations in the Delhi stretch over the period 2003-2021, which is more than a decade, shows that the water quality fluctuates across the spatial and temporal scales in the river. Water quality during post-monsoon is relatively poor compared to the pre-monsoon season. Water Quality Index (WQI) shows that Palla and Wazirabad have better water quality compared to other monitoring stations.This paper also throws light on the fluctuations of the water quality parameters due to the discharge of various drains especially the Najafgarh drain into river Yamuna.

There is a need to take up some crucial preventive and corrective policy measures to clean and maintain the good water quality of river Yamuna. Plan of Action or Graded Action Plan should be drafted by the Municipal Bodies operating in Delhi like Delhi Jal Board (Regulator of Sewage Treatment Plants in NCT of Delhi), Municipal Corporation of Delhi (Regulator of Municipal activities like sanitation etc across NCT of Delhi) and DSIDC (Regulator of Industrial Areas & CETP's in NCT of Delhi), across the Najafgarh drain. River Training Works like Bank Protection, Sediment Traps and the building of Guide Bunds are also recommended to boost up the water quality of river Yamuna by lowering the turbidity and amounts of sediments in the water, making the river a sustainable lotic ecosystem.

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