Impact of Covid-19 on Yamuna River water quality: Possible ways to rejuvenate the riverine ecosystem in national capital of India

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Abstract. The water quality of Yamuna River was studied for four years from 2019 until August 2022. The period witnessed the onset of COVID-19 pandemic and government-imposed complete lockdown which caused slight improvement in the water quality. Five parameters pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) and Faecal Coliform (FC) monitored by Delhi Pollution Control Committee (DPCC) were analyzed to see the changes in water quality of Yamuna River in the Delhi stretch before the onset of COVID-19 (2019), during the COVID-19 (2020 and 2021) and after the pandemic (2022). Maximum improvement in some water quality parameters were observed only during the 1st lockdown in the year 2020 when government had imposed complete restriction on the movement of people and industries were not functioning at there maximum capacity. The water quality again declined in the year 2021 and further in the year 2022. Major cause of pollution was the untreated waste reaching the river from various drains. Therefore, it is extremely important to intersect all the major and minor drains through Sewage Treatment Plants (STPs). The floodplain of the river needs to be managed to keep the pollution in control.

Keywords: Yamuna Water Quality, Delhi Stretch, Pandemic, COVID-19, BOD, STPs, IWRM.

1. Introduction

The Covid-19 pandemic hit the globe in an unprecedented way and continued raging in severe and mild manner until the beginning of 2022 (Khan et al., 2023), which even contributed to the development of digital health care (Kryvenko et al., 2023). As you know, many viruses are transmitted through water (El Morabet et al., 2023; Zahorodniuk et al., 2019). The pandemic caused damage in several spheres besides human lives. Economic activities were disrupted and many industrial activities came to a standstill. However, as a result of complete lockdown and restricted human activities, Covid-19 showed positive impact on many environmental parameters. The national capital of India was worst affected by pandemic, however studies suggested improvement in the environmental parameters. Many authors have studied the impact of lockdown on air quality of Delhi and water quality of river Yamuna in the Delhi stretch (Awasthi et al. 2021; Chaudhary et al., 2022; Mangla et al., 2021; Singh & Kumar, 2021; Singh et al., 2022). Yamuna is the second largest river in India and lifeline of National Capital Territory of Delhi. Only 2% of the Yamuna flows through Delhi yet it is responsible for 80% of the pollution downstream. The Delhi segment of 22 km that the river traverses from the Wazirabad barrage to the Okhla barrage is responsible for 80% of the pollution load of the river (Parween et al., 2017). According to a report in CBS news less than 10% of the sewage discharged into the river is treated, putting millions of people who use the water at risk of disease. This untreated toxic waste could also give rise to drug resistant bacteria according to some experts (Zagar, 2019). Several measures have been taken to improve the water quality of river Yamuna without much positive results. However, several studies suggested that the river got much respite during the COVID-19 pandemic induced lockdown. Most of the studies focussed on COVID-19 have been released and published with data from first lockdown. Therefore, it was important to see the long-term impact of government and self-imposed restricted movement on the water quality. Several authors studied the impact of COVID-19 imposed lockdown on water quality of different rivers in India (Patel, 2020; Somani et al., 2020). Some studies have also been carried out on surface water quality of coastal regions to study the COVID-19 impact (Robin et al., 2021). The water quality of Yamuna was reported to have improved in other stretches also in some studies (Sharma & Gupta, 2022). The water quality of River Damodar and River Ganga was also studied (Chakraborty S. et al., 2020; Lokhandwala & Gautam, 2020; Chakraborty B. et al., 2021). Similar studies on river water quality and surface water quality have also been carried out in other parts of the world (Yunus et al., 2020; Tokatli & Varol, 2021). This paper studies the variation in water quality before, during and after the Covid -19 waves on Yamuna -river in the Delhi region. The study has been taken with aim to find the possible reasons for water quality improvement and suggest ways to maintain the water quality and health of the river ecosystem in the long term.

2. Study area

Yamuna flows for 45 km in the National capital Region (NCR) of which 22 km flows through Delhi alone. The river enters at Palla near Wazirpur and exits Delhi around Jaitpur. The study has been taken in the Yamuna River stretch passing through Delhi city. Regular monitoring of nine locations is done by Delhi Pollution Control Committee (DPCC) and 4 locations by Central Pollution Control Board (CPCB). For the present study four-year monthly data for nine locations was obtained from DPCC (Fig. 1). Delhi has a population of 1.5 million people which primarily depend on Yamuna River water for drinking and other purposes. The Delhi Pollution Control Committee (DPCC) monitors 9 locations of Yamuna on monthly basis. These nine locations are: Palla, Surghat, Khajuri Paltoon Pool, Kudesia Ghat, ITO Bridge, Nizamuddin Bridge, Agra Canal (Okhla), After meeting Shahdra Drain (Downstream Okhla Barrage), Agra Canal (Jaitpur). The water quality data for pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO) and Faecal Coliform (FC) has been studied for the year 2019, 2020, 2021 and 2022 (up to the month of August).

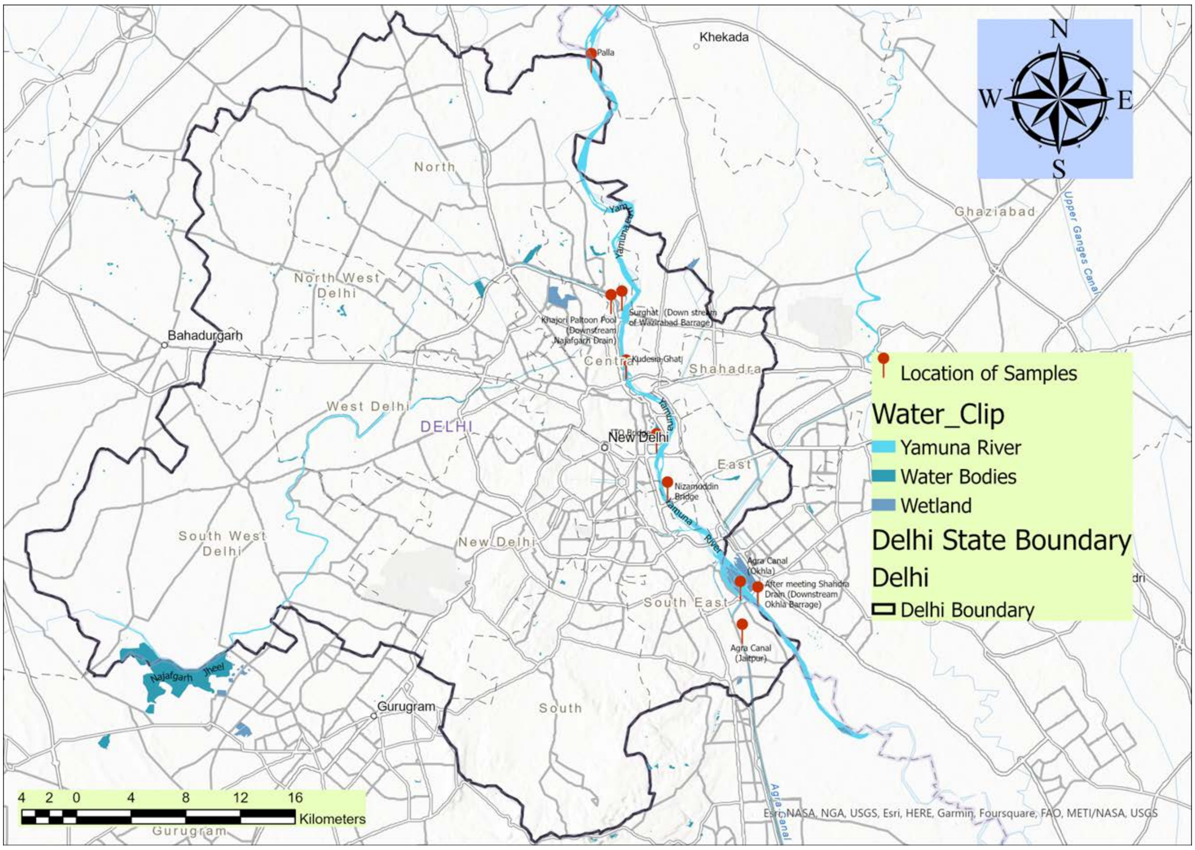

Figure 1. Yamuna stretch in Delhi with sampling locations

3. Materials and Methods

The present study includes the stretch of Yamuna River flowing through Delhi. The water quality data for 5 parameters were obtained from 9 locations on Yamuna River stretch flowing through Delhi (Fig. 1). These stations are continuously monitored on monthly basis by Delhi Pollution Control Committee (DPCC). The data for pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Faecal coliform (FC) was obtained for 4 years from 2019 – 2022 (till the month of August) from 9 locations as shown on the map of the river Yamuna (Fig. 1). The DPCC monitored only 4 parameters during the year 2019 excluding faecal coliform (FC) as the facility for monitoring of FC was not available then. According to the CPCB report during the COVID-19 induced lockdown human activities such as bathing, washing of clothes at Dhobi Ghats, religious activities, throwing of flowers, garlands and other worship materials, was not observed.

3.1 Statistical Analysis

The data was treated for t-test and ANOVA using SPSS 20 version. All statistical tests were conducted with a significance level of $p = 0.05$ and data were reported as mean ± standard error (SE). If data is normal, we use parametric test like ANOVA, regression, t-test etc. If data is not normal then we apply non-parametric test. So in our case pH, FC, BOD data follows non-normality. So, we apply Krusal-Wallis Test and Mann-Whitney U Test as required.

4. Results and Discussion

Here we discuss the water quality of Yamuna for four years 2019- 2022 (till August). The period from March 2020 to March 2022 witnessed three waves of COVID-19 and there were two periods of lockdown imposed by the Central Government in wake of the raging COVID-19 pandemic. The 1st period from 25th March 2020 to May 2020 witnessed absolute lockdown. The vehicular movement, industrial activities and human movement was almost negligible. The second period of lockdown was from April 2021 to June 2021. Various studies suggested improvement in the water quality of the river because of reduced human activities and almost absence of industrial activities (Singh et al., 2022; Yashvardhin et al., 2022). Yamuna flows for 45 km in the NCR region of which 22 km flows through Delhi alone. The study describes the results of water quality parameters of only Delhi region in the 22 km stretch where nine locations are regularly monitored by Delhi Pollution Control Committee (DPCC). Yamuna enters in Delhi at Palla near Wazirpur and exits around Jaitpur (Patel et al., 2020). At the time of sampling, no human activity such as bathing, washing of clothes at Dhobi Ghats, religious activities, throwing of flowers, garlands and other worship materials, was observed by the CPCB and DPCC monitoring teams in the vicinity of the sampling locations (CPCB, 2020).

The water quality of Yamuna was obtained for four years from 2019 to 2022. The data has been further compiled in the light of COVID-19 according to the waves of COVID-19 and the lockdown imposed by the government of India. The paper discusses the variation in water quality prior to the onset of COVID-19, during the pandemic when human activities were restricted and post pandemic months in the year 2022. The pandemic occurred in waves between 2020 to 2022. The results have been discussed in light of three major waves of COVID-19 and Government imposed lockdown. The idea of the study is to assess the impact of government-imposed lockdown leading to very restricted movement of general public and vehicles and reduced industrial activities.

According to the CPCB report, 2019 based on the assessment carried out for the year out of all the drains that flow into the river Yamuna, the drains viz., Najafgarh drain (including Supplementary drain), Delhi Gate drain, Sen Nursing Home drain, Barapulla, Tughlakabad and Shahdara drain contribute about 86% of hydraulic load (Volume of Waste Water) and 75% of organic load (BOD i.e., amount of organic matter). Main causes for pollution in river Yamuna are (i) discharge of treated or untreated sewage, (ii) discharge of treated and untreated industrial effluents, (iii) bathing by the general public, (iv) washing of clothes on the banks, (v) performing poojas, (vi) throwing of worship materials including idols made of Plaster of Paris (PoP) and decorated with toxic paints during festival season, (vii) disposal of solid waste, and (viii) Flood plain farming and other activities etc. Yamuna river water is used for multiple purposes like drinking water supply, irrigation, industrial use, bathing, and disposal of sewage and industrial effluents. Yamuna is the only natural source of water resource for drinking and other purposes in Delhi region. However, with ever increasing population and urban activities in Delhi NCR, Yamuna water quality is declining, unable to bear the tremendous demand for water (DPCC Report, 2020; Mandal, 2010). The BOD values decreased significantly during the month of April 2020 at ITO Bridge, Nizamuddin Bridge, Agra Canal, Okhla Bridge, Okhla Barrage after meeting Shahdra Drain, Agra Canal, Jaitpur (Table 1). The value of BOD increased again in the month of April 2021 and further increase was observed in April 2022. Similarly, the DO values improved from 0 mg/l to 2.3 mg/l at ITO bridge to 4.8 mg/l at Agra canal (Okhla) and 4.2 mg/l at Agra Canal at Jaitpur (Table 1). The DO values again became 0 mg/l in the years 2021 and 2022. A similar trend was observed for COD. The ANOVA results showed a similar result. There was significant decrease in BOD and COD and increase in pH and DO values at some monitoring locations. A significant decrease was only observed in April 2020 when there was complete lockdown imposed the Government of India. Delhi also witnessed more amount of rainfall in the month of April 2020 as compared to 2019, which caused dilution (CPCB, 2020). According to Times of India article dated 15th January, 2021, where the monitoring of the water quality parameters like BOD and DO was done by CPCB and DPCC, the DO almost became zero after Palla and Surghat.

The lockdown period witnessed the industrial activities to slow down. Since the industries were not operational, there was no discharge from them during the first lockdown (CPCB 2020). However, the discharge of partially treated and untreated domestic wastewater continued in the same proportion as it used to be in the usual days. Shutting down of industries resulted in reduction of only 35.9 MLD of industrial effluent. The organic and BOD load from domestic waste discharged remained the same even during the lockdown period (Patel et al., 2020). The BOD levels which remained low at Palla and Surghat had increased and much above the permissible limits at other monitoring stations (Table 1). When the water quality data is compared for the months (April, May and June) in the year 2019 (Pre-lockdown), 2020 (1st lockdown) and 2021 (2nd lockdown), a similar trend is observed (Fig. 2) where an improvement of all the parameters like pH, DO, COD and BOD is observed during the first lockdown.

ANOVA results also indicated a insignificant difference in all five parameters namely pH, BOD, COD, DO and FC at Palla and Surghat (Table 2). There is a significant difference in pH, BOD at Kudesia Ghat at Khajuri Paltoon. At the monitoring location, ITO Bridge, no significant difference in any parameter was observed whereas Nizamuddin bridge monitoring station showed a significant difference in pH and DO. Agra Canal (Okhla) showed significant difference in DO. There was insignificant difference in all the parameters at Okhla (Shahadra Drain). In the last monitoring station at Agra Canal (Jaitpur) there was a significant difference only in pH (Table 2).

Table 1. Comparison of DO, BOD and COD values for the months of April in the years 2019, 2020, 2021 and 2022.

S.No	Locations	DO (mg/l)				BOD (mg/l)				COD (mg/l)			
		2019	2020	2021	2022	2019	2020	2021	2022	2019	2020	2021	2022
1	Palla	8.5	6.9	11.2	8.1	1.7	2.8	3.1	2.5	8	12	36	37
2	Surghat	5.8	6.8	1.5	5	2.8	3.8	7.6	9	12	16	76	72
3	Khajori Paltoon Pool	0	0	NM	NM	19	33	NM	NM	64	116	NM	NM
4	Kudesia Ghat	0	0	0	NM	24	25	36	NM	76	60	88	NM
5	ITO Bridge	0	2.3	NM	0	28	22	NM	50	88	32	NM	192
6	Nizamuddin Bridge	0	2.3	0	0.4	20	16	38	57	68	42	92	160
7	Agra Canal (Okhla)	0	4.8	0	0	24	16	45	60	68	42	232	176
8	After meeting Shahdra Drain (Downstream Okhla Barrage)	0	0	0	0	28	23	54	70	96	76	268	208
9	Agra Canal (Jaitpur)	0	4.2	0	0	23	17	26	64	64	48	144	168

NM – Not Monitored

Table 2. ANOVA in the pre-lockdown and lockdown period.

	Palla		Surghat		Khajori Paltoon Pool		Kudesia Ghat		ITO Bridge		Nizamuddin Bridge		Agra Canal (Okhla)		Shahdra Drain		Agra Canal (Jaitpur)	
	Mean	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**	**Mean**	**Std. Dev**
pH																		
Non-Covid	7.78	0.17	7.80	0.40	0	0	7.62	0.49	7.78	0.31	7.72	0.194	7.85	0.10	7.78	0.16	0	0
First Wave	7.41	0.13	7.42	0.32	0	0	7.35	0.15	7.27	0.15	7.18	0.076	7.45	0.23	7.52	0.20	0	0
DO																		
Non-Covid	0	0	5.58	1.57	0	0	0	0	0	0	2.03	0.85	0	0	0	0	0	0
First Wave	0	0	6.10	1.41	0	0	0	0	0	0	2.20	1.65	0	0	0	0	0	0
BOD																		
Non-Covid	64.37	33.54	3.4	0.97	20	11.140	21.53	10.18	19.92	6.05	20.5	5.050	27.50	15.28	34.33	16.72	0	0
First Wave	68.37	33.59	3.3	1.40	31.83	10.70	28.17	16.69	23.83	11.57	23.33	10.39	20.33	10.23	36.50	23.39	0	0
COD																		
Non-Covid	19.44	10.45	14.67	4.84	69.33	35.66	73.67	35.11	62.67	13.54	64.67	9.27	86.67	44.01	0	0	76.00	27.25
First Wave	21.51	11.81	18.33	8.24	101.00	25.16	82.00	44.02	75.33	28.10	78.00	24.33	62.00	29.26	0	0	82.67	28.78

4.1. Status of Wastewater Generation and Treatment Capacity

There are 41 Sewage Treatment Plants (STPs) and out of which 33 STPs are operational and remaining 08 STPs are observed non-operational. The total installed capacity of wastewater in Delhi is 3149.3 MLD and operational capacity of 33 STPs are 2801.27 MLD and capacity of non-operational 08 STPs is 348.03 MLD. Out of 2801 MLD of operational capacity, actual treatment capacity utilization is 2254 MLD (CPCB, 2020; DPCC Report, 2020). Hence, there is a gap in the amount of sewage generated and treatment. Several drains discharge untreated waste water into river Yamuna (Fig. 3). There are 23 drains discharging wastewater in Yamuna out of which only 4 drains are intercepted by STPs adding a huge amount of waste in the river (Parween et al., 2017a; Patel et al., 2020). This is one of the main reasons for heavy pollution load in the river. The drains are the major cause of organic load in the river. Other anthropogenic activities like washing of clothes on the river bank, immersion of idols, bathing causes pollution, however untreated domestic sewage was the primary reason for pollution load inspite of no industrial discharge during the lockdown period (Patel et al., 2020). A similar finding has been observed for river Gomati all along its > 960 kms stretch. Untreated wastewater contributes to the deterioration of water quality (Khan et al., 2021).

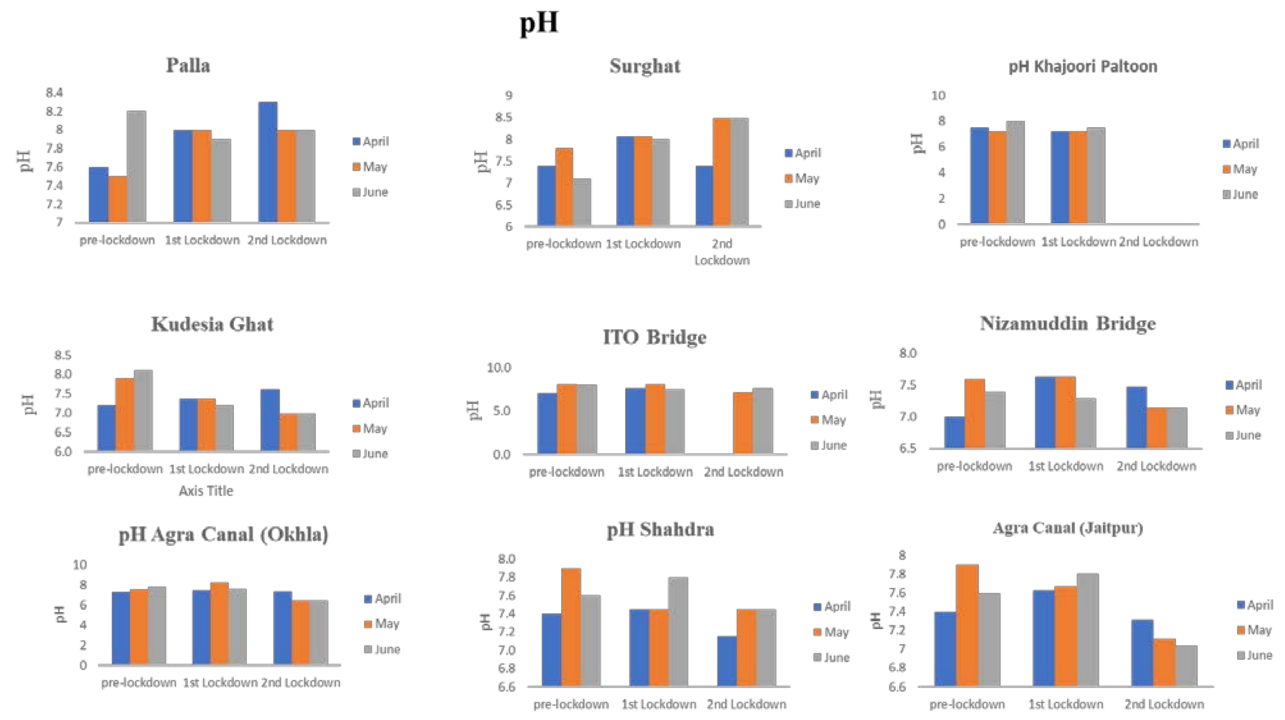

Figure 2(a). pH values of nine monitoring locations in the year 2019 (pre-lockdown), 2020 (1st lockdown) and 2021 (2nd lockdown)

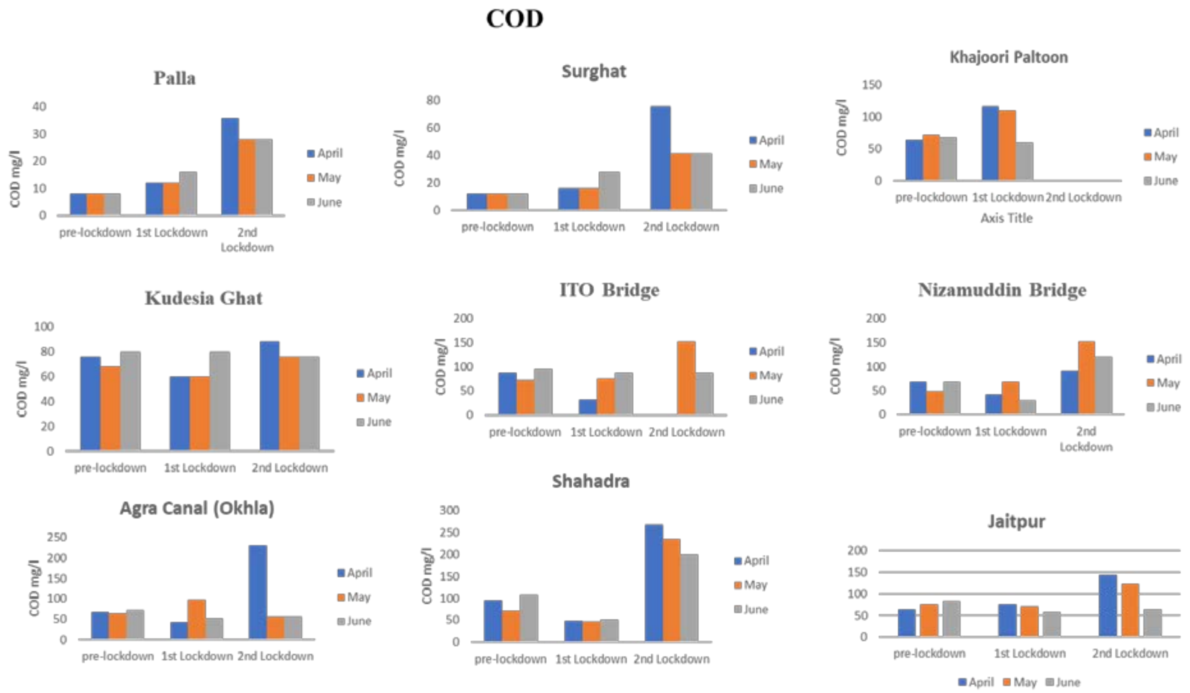

Figure 2(b). COD values of nine monitoring locations in the year 2019 (pre-lockdown), 2020 (1st lockdown) and 2021 (2nd lockdown)

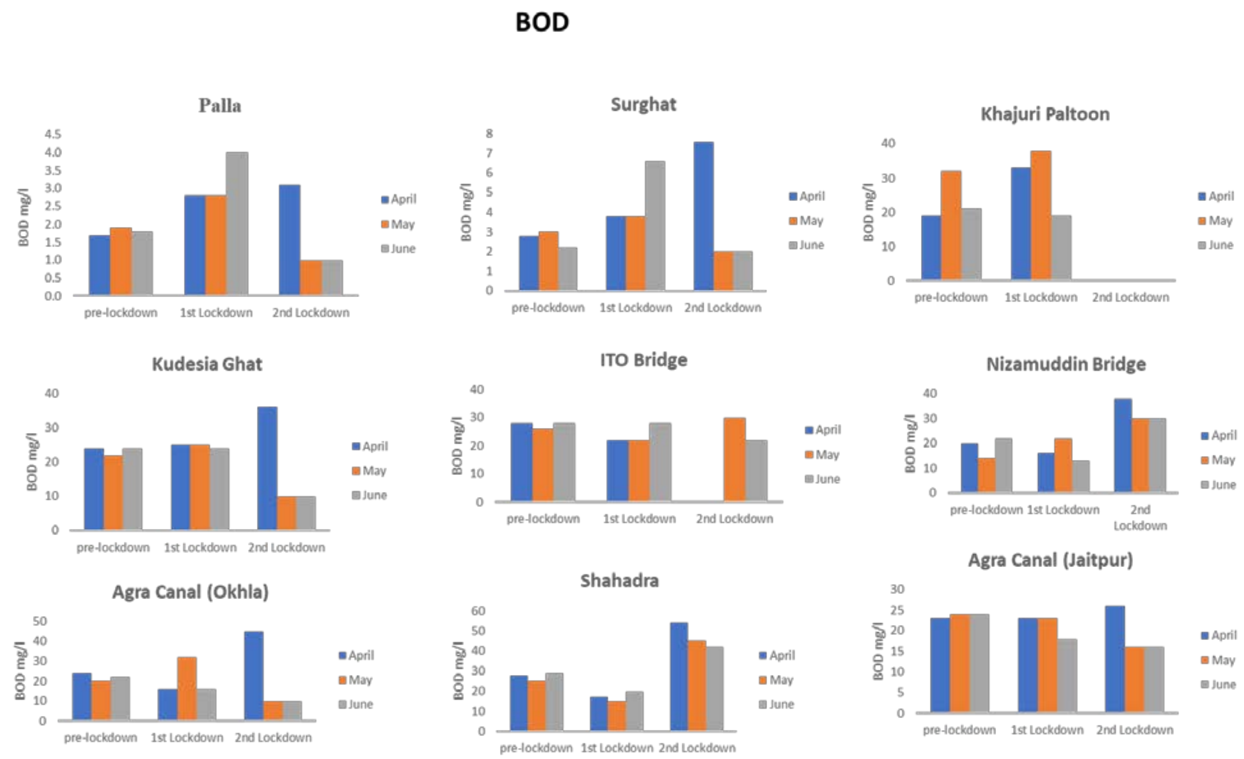

Figure 2(c). BOD values of nine monitoring locations in the year 2019 (pre-lockdown), 2020 (1st lockdown) and 2021 (2nd lockdown)

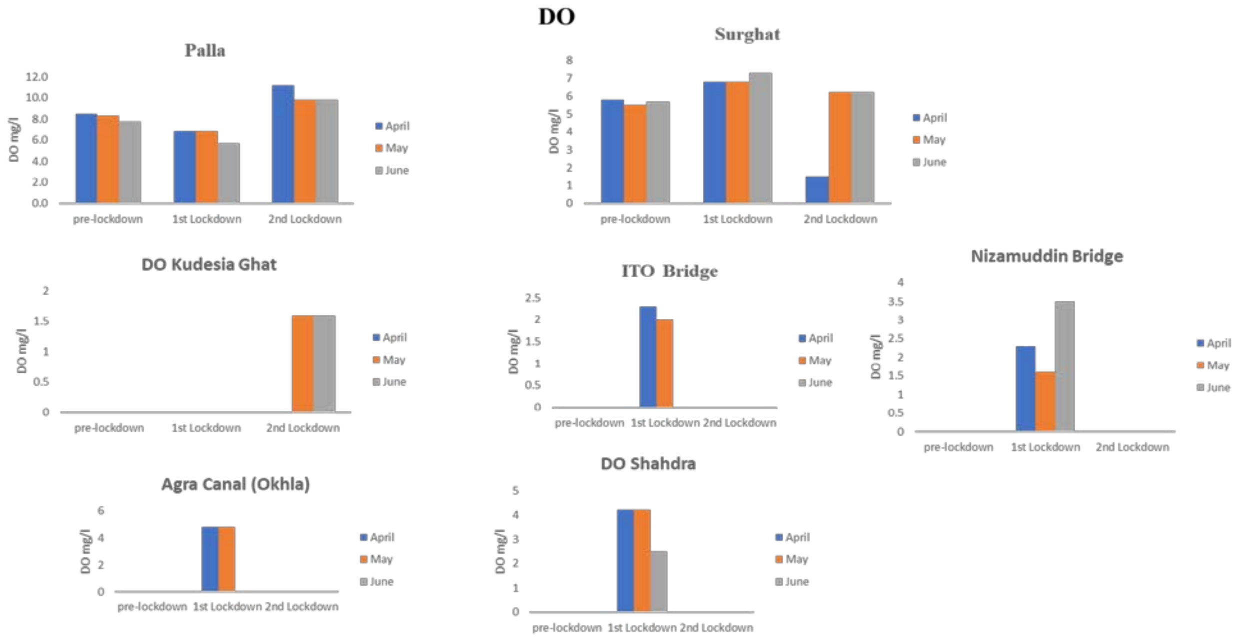

Figure 2(d). DO values from seven locations in the year 2019 (pre-lockdown), 2020 (1st lockdown) and 2021 (2nd lockdown) (the DO values at Khajoori Paltoon and Agra canal Jaitpur remained zero)

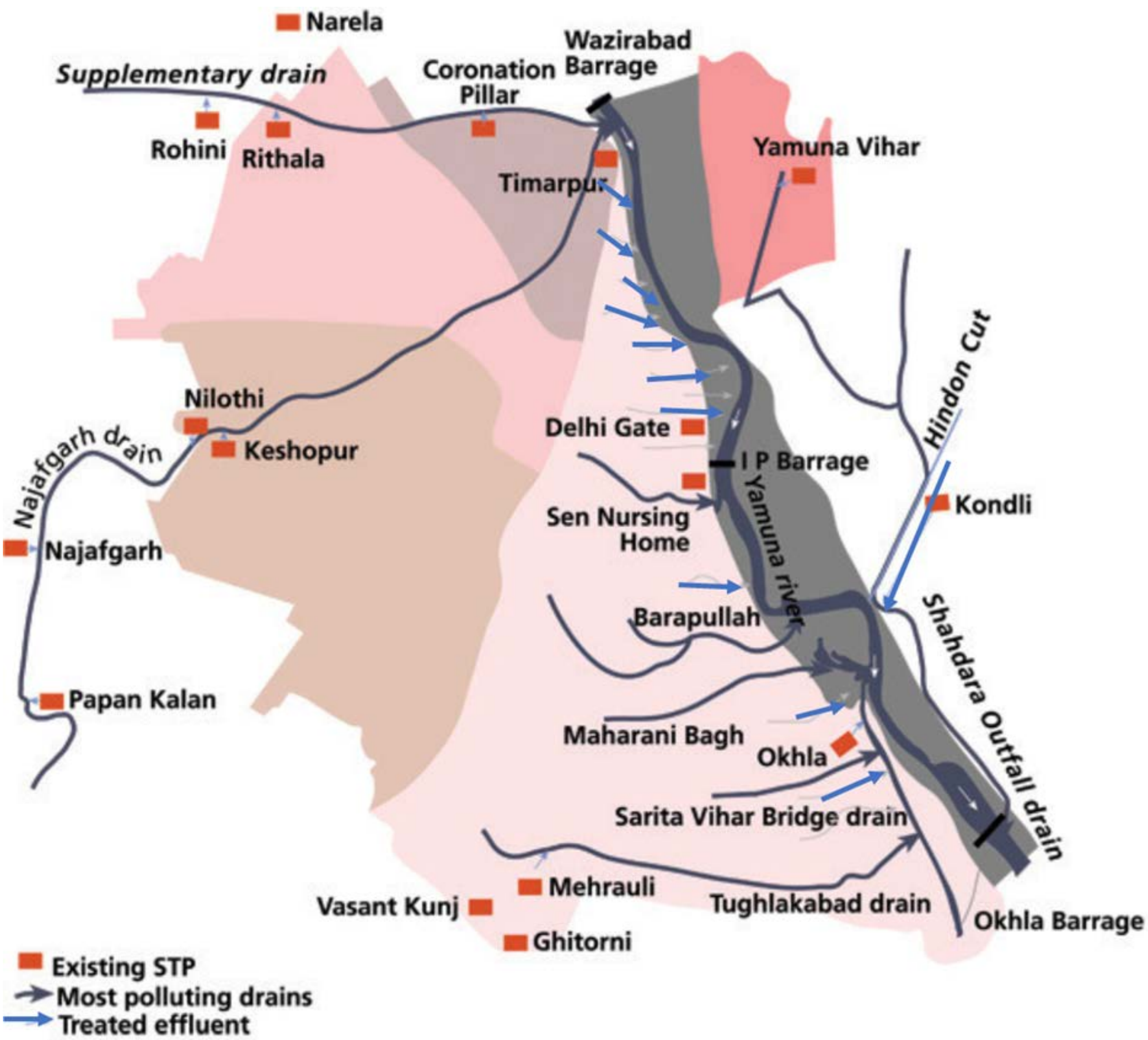

Figure 3. Most polluting drains and STPs on River Yamuna (Source: CPCB, 2020)

5. Recommendations

The water quality of river Yamuna did show an improvement at some monitoring stations when most of the activities causing water pollution were restricted. This is positive sign which gives a chance to emulate the condition with proper management of the untreated waste reaching the river. The reduction in only industrial waste discharge made a visible difference in the water quality. If all the domestic waste Integrated Water Resources Management (IWRM) is important to maintain the vital parameters of water in river Yamuna for drinking, agricultural and ecological purposes. The improvement in water quality of the most polluted river in India during the lockdown period suggests that even slight cut down in waste reaching the river can have profound impact on its water quality. Management, restoration and sustainable use of river water is possible by integrated approach of waste reduction, floodplain management, sludge processing, zero sewage discharge in the river by intercepting the waste water in STPs (Fig. 4). It is rightly said that lockdown cleaned the environment and especially major rivers passing through urban areas more than any government programmes like Ganga Action Plan, Namami

Ganga and Yamuna Action Plan. Therefore, the government can take cues from the this otherwise devasting situation of pandemic for the revival of water quality in the most polluted rivers of the country. Besides the management of domestic waste, agriculture runoff needs to be controlled. Fertilizers residues are a major source of eutrophication and lowering of DO in the river water.

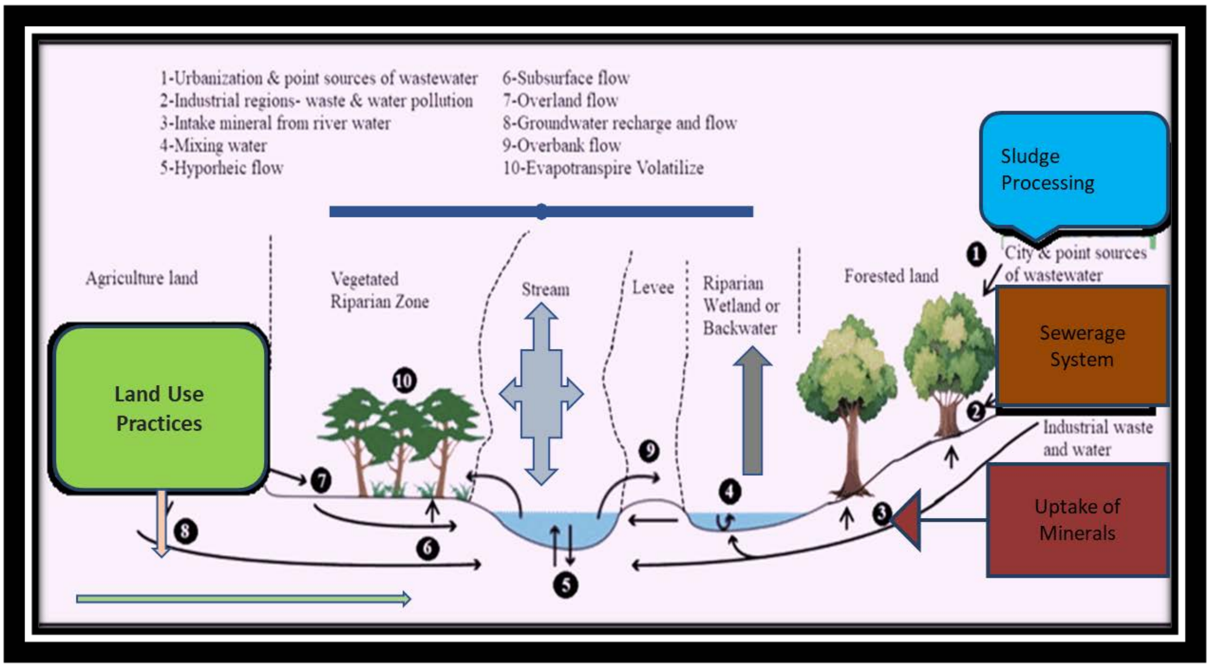

Figure 4. Schematic diagram of restoration pathways of improving water quality of river Yamuna

6. Conclusions

Improvement in water quality parameters was observed only some locations along the stretch of Yamuna. The water quality of river Yamuna did show an improvement at some monitoring stations when most of the activities causing water pollution were restricted. The overall improvement in water quality rejuvenated the ecology of the river and areas in and around the river became visibly clean. However, with the movement of vehicles and human activities during the second wave of COVID-19 brought back the pollution load which further increased in the year 2022 in spite of restricted public movement in wake of 3rd wave. Untreated sewage is the most polluting source in river Yamuna. Delhi drains discharging directly into Yamuna need to be tapped and connected to STPs. Decentralised treatment of sewage at the outfall itself can much better management the waste load reaching the river. There has to be a stringent and water tight regulation from the authorities to prevent discharge of untreated municipal and industrial waste water into the river.

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