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Reduction in water pollution in Yamuna River due to lockdown under COVID-19 Pandemic

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Abstract
The epidemic of Novel COVID-19 was reported in India in January 2020 and increased day by day due to the movement of people from abroad to India and then to the different parts of the country. The COVID-19 has been declared as pandemic because of its high transmission rate and coved more than 2010 countries of the world. Under this scenario when there is no medicine for its treatment, the only solution to this problem is to break the chain of transmission and restrict the count of infected people. To contain a coronavirus (COVID-19) outbreak, the Government of India announced the nationwide lockdown with effect from the midnight of 24th March 2020 followed by the extension of the lockdown periods and presently it is in its 4th phase. The various provisions were made under lockdown for closing the industries, transportation, etc. except the essential services. It has been very interesting to note that the behavioural changes in nature are highly positive and atmosphere, hydrosphere, and biosphere are rejuvenating and it gives an appearance that the earth is under lockdown for its repairing work. Under this natural recovery, we tried to look at the improvement in the water quality of the Yamuna River in Delhi, which has been one of the burst polluted rivers. To study this river, the concentrations of pH, EC, DO, BOD, and COD have been measured which showed a reduction by 1-10%, 33-66%, 51%, 45-90%, and 33-82% respectively during the lockdown phase in comparison to the pre-lockdown phase. The Nizamuddin Bridge, Okhla U/s, Najafgarh Drain and Shahdara Drain were the major hotspots responsible for the deterioration of the water quality of Yamuna River while passing by Delhi region. Five major locations of Yamuna River have been analysed in this paper that showed a very impressive recovery of the water quality during the lockdown phase as compared to the pre-lockdown status of water quality.

Keywords: Water quality, COVID-19, lockdown, industries, CPCB, DO, BOD

1. Introduction
The origin of the deadly pandemics coronavirus (COVID-19) has been in December 2019 from the City of Wuhan, China [1, 2, 3] and spread to the almost entire globe. The source of COVID-19 is reported from the novel coronavirus (SARS-CoV-2) and would have been produced from other mammals [1]. The World Health Organisation (WHO) in his report updated on 23 May 2020 at 05:30 GMT said that there are confirmed cases of infection by COVID-19 to 5,206,614 people while 337,736 has lost their life from 216 countries [4].
Recognizing the rate of spread of this virus with the personal contacts, various countries have imposed complete lockdown in order to maintain forced social distancing and break the chain of the spread of coronavirus. Still if there are some urgent requirements of movement of people, they were asked to under quarantine for 14 days considering the appearance of the symptoms that take about 14 days. The Govt. of India, taking note of the activities adopted by the COVID-19 affected countries, first requested the countrymen to be at home for the entire day and Prime Minister of India gave this a name as Janata (People's) Curfew, which was observed on 22nd March 2020. On this day of Janta Curfew all flights, trains, bus services, industrial and commercial activities were closed. After its success, an absolute lockdown was imposed on 25th March 2020 for 21 days to break the chain of COVID-19 [5]. Further, the lockdown has been extended in phases 2, 3, and 4 till May 31, 2020 to control the spread of infection through a complete halt on the movement. The total lockdown has elevated pandemonium among people but helped in reducing the pace of spreading the virus among society. However, under this lockdown period, Nature started to respond very positively and started giving several signals of improvement to natural parameters of the atmosphere, hydrosphere, and biosphere. It appears that the earth is rejuvenating under the lockdown period and it's a closure for the repairing of earth.

With the understanding of this natural recovery, we tried to look at the water quality status and improvement, if any, for the Yamuna River in Delhi, which has been famous for its high pollution level in Delhi. The concentrations of pH, EC, DO, BOD and COD have been measured at various hot spots for the pollutions on the bank of river Yamuna. The water quality parameters were compared between the lockdown phase and the pre-lockdown phase. Five major locations of Yamuna River have been analysed in this paper that showed a very impressive recovery of the water quality during the lockdown phase as compared to the pre-lockdown status of water quality. This showed that Nature is flourishing during the coronavirus pandemic followed by the lockdown in the larger part of the world forcing the closure of the sources of anthropogenic pollution. Yamuna river is one of the highly polluted rivers in India, especially in Delhi [6] where the recent observations reflected that the water pollution has reduced across the Yamuna River channel during the lockdown phase. Hence to quantify the status of water pollution in one of the highly polluted locations of Yamuna river, we have carried out an analysis of pH, Conductivity (EC), DO, BOD and COD at various locations of the Yamuna River, where complete lockdown has been imposed.

2. Study Area and Methodology

The Yamuna River is the second-largest and longest tributary of Ganga which enters Delhi at village Palla. It traverses 22 km to Wazirabad barrage where entire water is impounded to meet the drinking water requirement of Delhi. River Yamuna ceases to exist downstream of Wazirabad Barrage in most of the periods of the year and receives its flow from the Najafgarh drain at Wazirabad downstream. No major fresh water is allowed to flow downstream of Wazirabad barrage except during the monsoon season (Fig. 1). As the river traverses further downstream the flow is blocked by a barrage at Okhla.

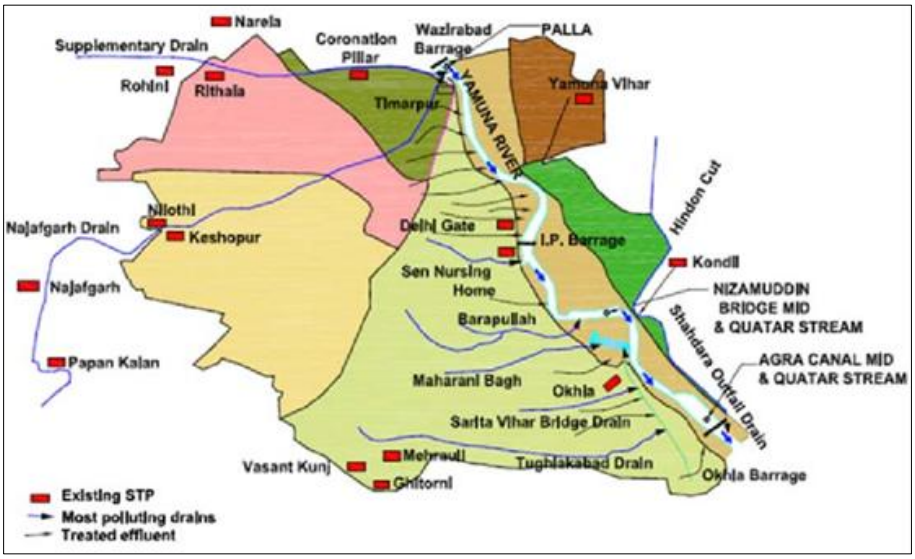

Fig 1: Yamuna River, showing various Pollution Sources and location of Barrage [7]

There are a total of 23 drains discharging wastewater in the river Yamuna. Out of 23, a total of 16 drains are discharging wastewater in river Yamuna between Wazirabad downstream to Okhla upstream and 04 drains meet the Yamuna in downstream of Okhla Barrage and 03 remaining drains discharge their wastewater further down at Agra Canal and Gurgaon Canal. There are 05 drains having interception and diversion provision of sewage to the nearby STPs for ensuring further treatment. During the year 2019, the total flow of wastewater was estimated as 3026.24 MLD and BOD load was estimated as 0.10-61.44 TPD [7]. The water quality data of various pollutants were collected from the Central Pollution Control Board (CPCB). The data were analyzed for the Yamuna at 5 monitoring stations i.e. Palla, Nizamuddin Bridge, Okhla (U/S), Najafgarh Drain and Shahdara Drain for the period from 1st March to 7 April 2020 which have been studied in two phases as pre-lockdown phase (11-23 March, 2020) and lockdown phase (24 March - 7 April, 2020).

3. Results and Discussion

3.1 Effect of lockdown on Yamuna River water quality

The nationwide lockdown has come in effect since the midnight of March 24 because of the COVID-19 pandemic. Under the lockdown, the major sectors responsible for water pollution like industries, power plants, construction activities, transportation, etc. were put on halt. The academic institutions and hospitality services were also adjourned. Under these circumstances, the improvement in water quality was noticed in the river system of the country. Delhi, which is the hub of air pollution and being counted as number one for most of the time has resulted in a noticeable improvement in the water quality of Yamuna during the lockdown period of the country. Scattered rains in Delhi on 27th March and during March 28-29, 2020 further helped in improving the water quality of Yamuna River during the lockdown phase. This result has been substantiated while analyzing the data of water pollution and water quality before and after the imposition of lockdown. The similar results were also reported in Ganga River and lack during the lockdown period [9, 10, 11].

3.1.1 pH level in Yamuna River, Delhi

The pH of the Yamuna River observed alkaline in nature which varies from 7.1 to 8.7 with a mean value of 7.6 during the pre-lockdown phase (Fig. 2) while it has been observed between 7.1-7.4 in Najafgarh and Shahdara drain during the pre-lockdown phase. However, pH varies from 7.1 to 7.8 with a mean value of 7.3 in the Yamuna during the lockdown phase. The highest pH (8.7) was recorded at village Palla (entry point of Yamuna in Delhi) and lowest (7.1) at Shahdara drain during the pre-lockdown phase. During the lockdown

phase, a slight reduction in pH has been observed due to the reduction of industrial activities, the nonfunctioning of essential commercial units, and prevailing weather conditions. The maximum reduction (10%) of pH has been observed at Village Palla during the lockdown phase. The concentration of pH was also correlated with the primary water quality criteria for a bathing water and designated best usable water quality criteria of India (https://cpcb.nic.in/wqm/Primary_Water_Quality_Criteria.pd) [8]. These exercises helped in understanding that the concentrations were greater than the threshold limit of pH (6.5-8.5) daily at the village Palla which is vulnerable to the health problem. During the pre-lockdown phase, the pH levels were lower than the threshold limit (6.5-8.5) except at village Palla while it became much lower during the lockdown phase at all locations. The pH drives most of the chemical and biological changes in water. It acts as the driving force in controlling species distributions in aquatic habitats. The varying pH values provides space to different species to flourish within however the optimum pH range is 6.5-8.0 for most of the aquatic organisms. The variability of pH outside this range physiologically put stress on numerous species and may affect decreased reproduction and growth, attack of disease, or even death. Hence beyond the optimum value of pH can adversely affect the biological diversity in water bodies.

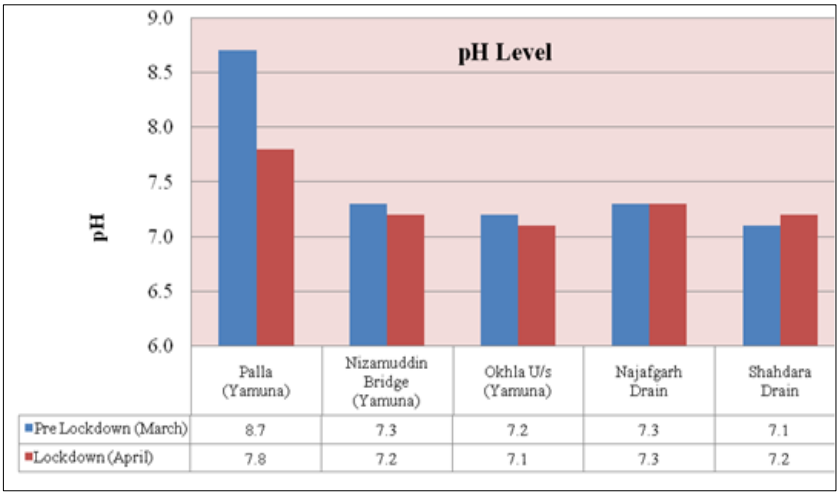

Fig 2: average pH level in the Yamuna River at Palla, Nizamuddin, Okhla U/S, Najafgarh and Shahdara drain during pre-lockdown (March 11-24, 2020) and lockdown (March 25-April 7, 2020)

3.1.2 Conductivity level in Yamuna River, Delhi

In the Yamuna, conductivity varies from 688 to 2485 µS/cm with a mean value of 1526 µS/cm during the pre-lockdown phase (Fig. 3) while it observed between 273-1657 µS/cm during the lockdown phase. The highest conductivity (2485 µS/cm) was recorded at Shadra Drain and lowest (688 µS/cm) at village Palla during the pre-lockdown phase. During the lockdown phase, a slight reduction in conductivity has been observed due to the reduction of industrial activities, the nonfunctioning of essential commercial units, and prevailing weather conditions.

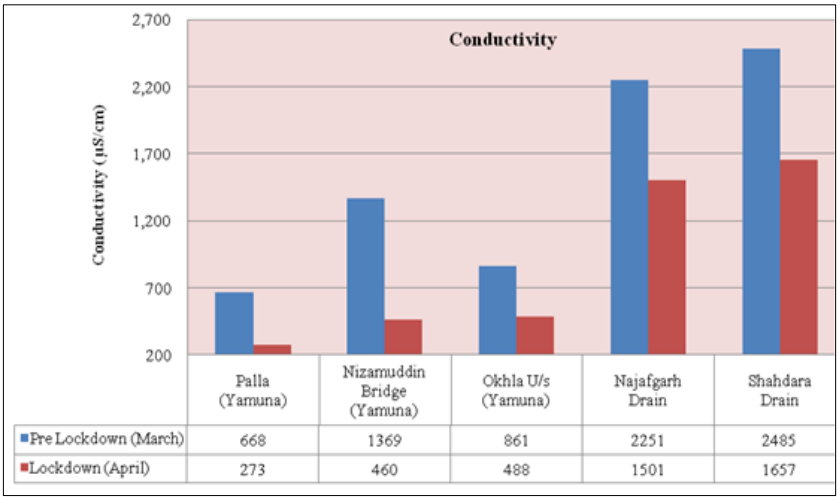

Fig 3: average conductivity level in the Yamuna River at Palla, Nizamuddin, Okhla U/S, Najafgarh and Shahdara drain during pre-lockdown (March 11-24, 2020) and lockdown (March 25-April 7, 2020)

The maximum reduction (66%) of conductivity has been observed at the Nizamuddin bridge followed by village Palla (59%), Okhla U/s (43%), and Nazafgarh/Shadra drain (33%) during the lockdown phase (Table 1).

Table 1: Comparative analysis of various water parameters during pre-lockdown and lockdown phases and their change in percentage (-ve values shows reduction and +ve shows increase) at different hotspot locations of Yamuna River in Delhi

Locations	Phase	pH	EC	DO	BOD	COD
Palla (Yamuna)	Pre-Lockdown	8.7	668	17.1	7.9	28
	Lockdown	7.8	273	8.3	2	6
	%Decrease (-ve)/Increase (+ve)	-10	-59	-51	-75	-79
Nizamuddin Bridge (Yamuna)	Pre-Lockdown	7.3	1369	ND	57	90
	Lockdown	7.2	460	2.4	5.6	16
	%Decrease (-ve)/Increase (+ve)	-1	-66	NA	-90	-82
Okhla U/s (Yamuna)	Pre-Lockdown	7.2	861	ND	27	95
	Lockdown	7.1	488	1.2	6.1	18
	%Decrease (-ve)/Increase (+ve)	-1	-43	NA	-77	-81
Najafgarh Drain	Pre-Lockdown	7.3	2251	NA	78	271
	Lockdown	7.3	1501	NA	55	150
	%Decrease (-ve)/Increase (+ve)	0	-33	NA	-29	-45
Shahdara Drain	Pre-Lockdown	7.1	2485	NA	163	574
	Lockdown	7.2	1657	NA	89	383
	%Decrease (-ve)/Increase (+ve)	+1.41	-33	NA	-45	-33

Note: ND: Not Detected; NA: Data not Available

Discharges into the streams are capable of changing the conductivity depending on their makeup. A failing sewage system raises the conductivity because of the higher presence of chloride, phosphate, and nitrate. It may be noted that 16 drains are discharging wastewater in river Yamuna which are influencing the conductivity of the Yamuna River.

3.1.3 Dissolved Oxygen level in Yamuna River, Delhi

Dissolved oxygen (DO) is one of the most important indicators of water quality on which the survival of aquatic life depends. When DO becomes too low, fish and other aquatic organisms cannot survive. The data for DO was not available at Nizamuddin Bridge and Okhla U/s location during the pre-lockdown phase while it was 17.01 mg/l at village Palla in the same period (Fig. 4). However, DO vary from 1.2 to 8.3 mg/l with a mean value of 3.9 mg/l in the Delhi region of Yamuna during the lockdown phase. During the lockdown phase, improvement in DO has been observed at both the Nizamuddin Bridge and Okhla U/s due to the reduction of industrial activities and rainfall in Delhi. It may be noted that DO was not detected at both Nizamuddin Bridge and Okhla U/s during the pre-lockdown phase due discharge of huge amount of industrial and domestic wastewater. The comparative analysis is given in Table 1. The concentration of DO was also correlated with the Primary Water Quality Criteria for bathing water and designated best use water quality criteria of India. The DO levels were lower than the threshold limit (5 mg/l) except at village Palla during both pre- lockdown and lockdown phase at all locations. Low DO affects most biological processes in water and responsible for lower biological diversity in water bodies.

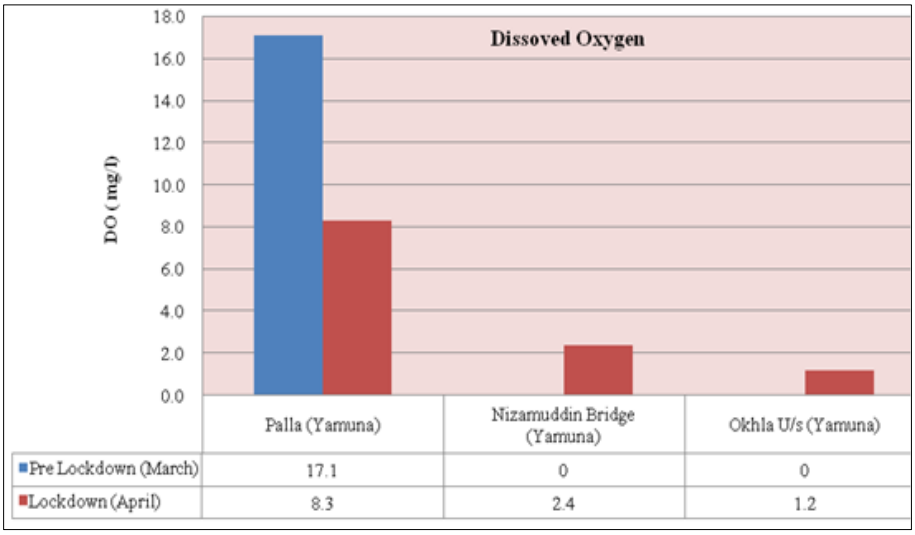

Fig 4: average dissolve Oxygen level in the Yamuna River at Palla, Nizamuddin, Okhla U/S, Najafgarh and Shahdara drain during pre-lockdown (March 11-24, 2020) and lockdown (March 25-April 7, 2020)

3.1.4 Biological Oxygen Demand level in Yamuna River, Delhi

Biological Oxygen Demand (BOD) is one of the most important indicators of water quality. BOD directly affects the amount of dissolved oxygen in water bodies. The greater demand for BOD more rapidly depletes the oxygen in the water bodies making lesser availability of oxygen for higher forms of aquatic life. The consequences of the high BOD are similar to the effect of less oxygen availability putting aquatic life under stress, suffocation and could be lethal. The major sources of increase of BOD in the Yamuna river include dead plants and animals; animal manure; industrial/domestic effluents, wastewater treatment plants, failing septic systems; and urban storm water runoff.

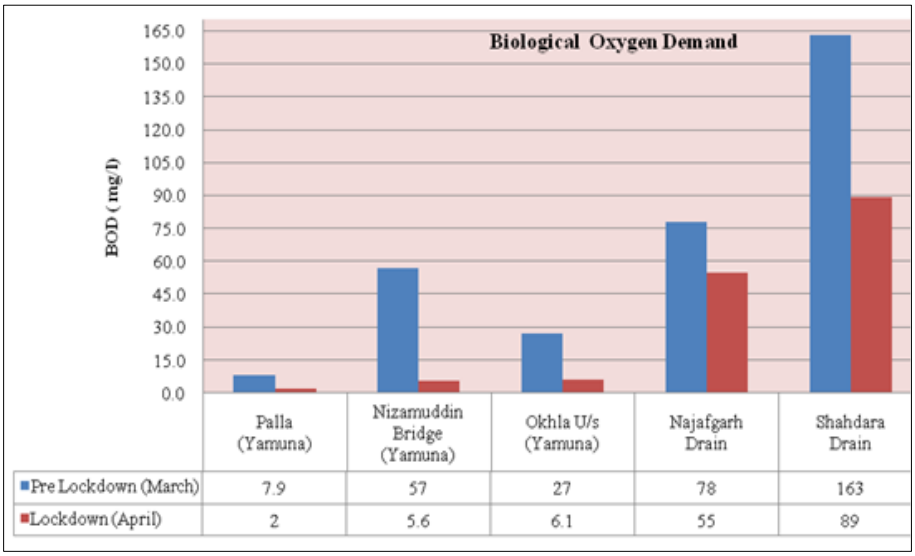

Fig 5: average biological oxygen demand in the Yamuna River at Palla, Nizamuddin, Okhla U/S, Najafgarh and Shahdara drain during pre-lockdown (March 11-24, 2020) and lockdown (March 25-April 7, 2020)

BOD vary from 7.9 to 163 mg/l with a mean value of 66.58 mg/l during the pre-lockdown phase (Fig. 5) while it observed between 2-89 mg/l during the lockdown phase. The highest BOD (163 mg/l) was recorded at Shahdara Drain and lowest (7.9 mg/l) at village Palla during the pre-lockdown phase. However, improvement in BOD (i.e. the reduced demand) has been observed at all locations in the lockdown phase due to the reduction of industrial activities and prevailing weather conditions. The maximum reduction (90%) of the BOD level has been observed at the Nizamuddin Bridge during the lockdown phase followed by Okhla U/s (77%), village Palla (75%), Shahdara drain (45%) and Najafgarh drain (29%). The comparative analysis is given in Table 1. The concentration of BOD was also correlated with the primary water quality criteria for bathing water and designated best use water quality criteria of India. The BOD levels were much higher than the threshold limit (3 mg/l) at all locations during the pre-lockdown phase. A similar trend was also observed during the lockdown phase except for village Palla. Higher BOD affects most biological processes in water and can ultimately lead to reduced biological diversity in streams.

3.1.5 Chemical Oxygen Demand level in Yamuna River, Delhi

Chemical oxygen demand (COD) is an indicator of contamination that shows the amount of dissolved matter in water susceptible to being oxidized. COD is responsible for the reduction of DO in water bodies. Higher concentration of COD is responsible for quick deterioration of oxygen in water bodies and reduces oxygen availability for higher forms of aquatic life. The major sources that increases the COD in the Yamuna River are industrial/domestic effluents, wastewater treatment plants, failing septic systems; and urban stormwater runoff.

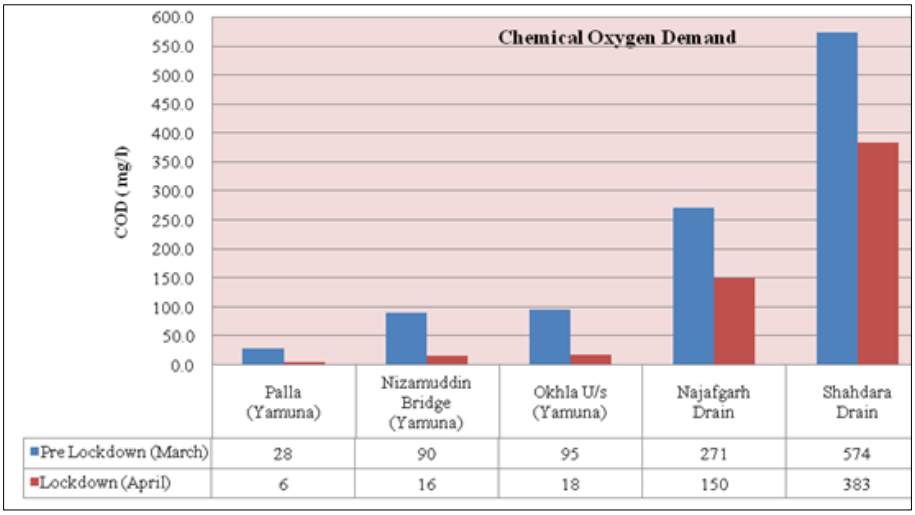

Fig 6: Average chemical oxygen demand in the Yamuna River at Palla, Nizamuddin, Okhla U/S, Najafgarh and Shahdara drain during pre-lockdown (March 11-24, 2020) and lockdown (March 25-April 7, 2020)

COD varies from 28 to 574 mg/l with a mean value of 211.6 mg/l during the pre-lockdown phase (Fig. 6) while it observed between 6 to 383 mg/l during the lockdown phase. The highest COD (574 mg/l) was recorded at Shahdara drain and lowest (28 mg/l) at village Palla during the pre-lockdown phase. However, improvement in COD has been observed at all locations in the lockdown phase due to the reduction of industrial activities, rainfall, and prevailing weather conditions. The maximum reduction (82%) of the COD level has been observed at the Nizamuddin Bridge during the

lockdown phase followed by Okhla U/s (81%), village Palla (79%), Najafgarh drain (45%) and Shahdara drain (33%). The comparative analysis is given in Table 1.

3.2 Major Pollution hotspots in the Yamuna

During the pre-lockdown period at Nizamuddin Bridge, the results showed pH (7.3), EC (1369 µs/cm), BOD (57 mg/L), DO (not detected), and COD (90 mg/L) whereas in the lockdown period pH (7.2), EC (460 µs/cm), BOD (5.6 mg/L), DO (2.4 mg/L) and COD (16 mg/L) were observed and not complying to the primary water quality criteria for outdoor bathing w.r.t analyzed parameters of DO and BOD which can be attributed to the contribution from mainly 14 drains discharging both treated and untreated sewage, no industrial effluent discharges from the industrial areas or no other human activities such as bathing, throwing of worship materials or solid waste and freshwater discharges from U/s of river Yamuna. A similar trend was also at Okhla U/s where the analysis showed pH (7.2), EC (861 µs/cm), BOD (27 mg/L), DO (not detected), and COD (95 mg/L) during pre-lockdown phase whereas pH (7.1), EC (488 µs/cm), BOD (6.1 mg/L), DO (1.2 mg/L) and COD (18 mg/L) were observed during the lockdown phase and not complying to the primary water quality criteria for outdoor bathing w.r.t analyzed parameters such as DO and BOD which can be attributed to contribution only from two drains carrying both treated or untreated sewage, no industrial effluent discharges and there is a river Yamuna stretch of about 7.5 km (after Nizamuddin Bridge) and might be helping in self-purification of river Yamuna. The Najafgarh Drain discharges 1938 MLD of wastewater into river Yamuna. During the pre-lockdown period at Najafgarh Drain, the analysis showed pH (7.3), SS (152 mg/L), BOD (78 mg/L), COD (271 mg/L) whereas the analysis showed pH (7.3), EC (1501 µs/cm), BOD (55 mg/L), and COD (150 mg/L) during the lockdown period. While at Shahdara Drain, the results showed pH (7.1), BOD (163 mg/L), COD (574 mg/L) during pre-lockdown period whereas pH (7.2), EC (1657 µs/cm), BOD (89 mg/L) and COD (303 mg/L) were observed in lockdown phase. The comparative analysis is given in Table 1. Betterment in the water parameters of the Yamuna in Delhi during the lockdown phase is due to no contribution of effluent from all the 23 sources.

4. Data statement

The data utilesd in this study has been acquired from the freely available source and based on the requirement it can be shared to the interested person.

5. Declaration of competing for interest

The authors declare that they have no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6. Acknowledgments

The authors are grateful to CPCB for making available the data at the various locations of Delhi-NCR, which prompted us to work on this problem to see the differential status of the water quality of river Yamuna in Delhi during this lockdown period. The authors are also thankful to unanimous reviewers.

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