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Positive impact of COVID-19 induced lockdown on the environment of India's national capital, Delhi

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Abstract The rapid emergence of novel coronavirus disease has shown some positive impact on the health of natural environment. Present study was aimed to assess the impact of COVID-19 induced lockdown on the water quality of Yamuna River and air quality of national capital territory, Delhi. Significant decline in air quality pollutants like NH_3, SO_2, CO, $PM_{2.5}$, NO_2 were observed. The major decline was found in the levels of $PM_{2.5}$, SO_2, NO_2 and NH_3. The less significant decline was seen in the CO level during the lockdown period. Furthermore, the overall decline in the concentrations of BOD, COD and increase in pH suggesting an improvement in Yamuna water during the lockdown. However, the concentration of DO was found insignificant during the lockdown period. Additionally, comparative analysis of morbidity, mortality as well causalities during this period has also been recorded to establish correlation of pre and post COVID-19 situations. Altogether, present study is found to be a useful supplement for policymakers because marked improvements in the water and air quality indices have been observed after enforcement of lockdown leading to control of the various pollution sources. Therefore, periodical lockdown can be utilized as an effective mitigation measures for natures' restoration.

Keyword COVID-19 · Lockdown · Water quality index · Air quality index · Delhi national capital territory · Yamuna river

1 Introduction

SARS-CoV-2 is an etiolating agent of current novel human coronavirus disease (COVID-19) reported from wet sea food market of Wuhan city (Hubei province), China, in December 2019 [1, 2]. COVID-19 is a highly contagious disease that induces mild to severe respiratory illness in infected individuals [3]. Due to its rapid spread, coronavirus outbreak has been declared as public health emergency of international concern by the World Health Organization (WHO) on 30th January 2020 [4]. As of June 1st, 2021, worldwide 170,812,850 confirmed cases of COVID-19 have been reported to WHO including 3,557,586 casualties (WHO COVID-19 Dashboard).

The devastations caused by COVID-19 pandemic has adversely affected almost all aspects of human life as well as economic development of twenty-first century globally. Due to its ability to cause rapid infection and mortality, many countries around the world have adopted several precautionary measures, such as massive testing, social distancing, sanitization of hands at regular intervals and quarantine etc. to contain the transmissibility of this highly contagious viral disease [5–7]. Similarly, the Government of India had declared a lockdown since the midnight of 24th March 2020, to break the chains of coronavirus spread. With work halting, industries become non-functional and vehicular transportation systems including

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railways and public transport almost remained standstill, leading to the improvement in the parameters of air quality across India's big cities [8, 9]. Simultaneously, the water quality indices of many rivers across the country including Yamuna River were found improving [10–12].

In the present study, an attempt was made to analyze the positive impact of lockdown on the environmental parameters like air quality index of Delhi region and water quality of river Yamuna (Delhi). Previously, numerous studies have been carried out on the assessment of water quality and health of the river. Upadhyay et al. (2011) [13] have reported that Yamuna is one of the worst polluted rivers in India, mainly in, Delhi. Therefore, it is highly pertinent to evaluate the water quality of Yamuna River during the period of lockdown as well as air quality of densely populated city like Delhi for the assessment of natural recovery of the environments. The data of our study revealed that environmental parameters including water quality index (like pH, DO, BOD, COD) and air quality index (NH_3, SO_2, CO, $PM_{2.5}$, NO_2) have appeared to be giving positive sign towards restoring nature. This showed eco-restoration of nature leading to improvements in the environmental parameters during COVID-19 induced lockdown which will open new horizons for the environmental sustainability and will also help policymakers to amend policy for sustainable development. Furthermore, comparative analysis of morbidity, mortality and recovery during this period has also been recorded to establish correlation between pre and post COVID-19 situations.

2 Methods

2.1 Study area

The present work involves the study area as Delhi, the capital of India, situated on the western bank of the Yamuna River in the north-central part of the country. Delhi being the largest city in the country is one of the overcrowded cities amongst the world. The location of Delhi lies between 28.7041° North latitude and 77.1025° East latitude. The population of Delhi as per census 2011 was 1.42 lakhs inhabitants with a population growth rate of 1.39% per year. Delhi covers a land area of 1484 km^2 with 4057 individual per km^2.

2.2 Data collection

Total number of COVID-19 confirmed cases, number of cured cases and death occurred due coronavirus infections were recorded from the website (https://www.kaggle.com) [14]. The parameters of Air Quality Index (AQI) [15] like $PM_{2.5}$, NH_3, SO_2, NO_2, and CO were extracted from (https://app.cpcbccr.com) Central Pollution Control Board (CPCB) website. To detect the actual impact of lockdown on the AQI of Delhi, the National Air Quality Index (NAQI) website was used as the data source. The parameters of Water Quality Index (WQI) [16] like DO (Dissolved Oxygen), pH, BOD (Biological Oxygen Demand) and COD (Chemical Oxygen Demand) were collected from the Delhi Pollution Control Committee (DPCC) (https://www.dpcc.delhigovt.nic.in) [17]. In the present study, three sites were selected for the analysis of WQI of river Yamuna viz. Palla, Nizamuddin Bridge and Agra canal (Jaitpur) stations from January 2020 to March 2021. This period was divided into pre-lockdown phase (January–March, 2020), lockdown phase (April and May, 2020) and post-lockdown phase (June 2020–March 2021).

2.3 Statistical analysis

To investigate the impact of the lockdown on Delhi's air and water quality, three sets of data were collected from the above-mentioned sources at 10-days intervals for air quality and per-month data for water quality from January 2020 to March 2021. One way ANOVA test was performed with a hypothesis for all different AQI and WQI parameters that mean pollutant concentration has no effect of lockdown. For all the parameters the p value < 0.05, leading to rejection of null hypothesis implying that lockdown had significant impact on concentration of most of the parameters including $PM_{2.5}$, NH_3, SO_2, NO_2, and CO and also on pH, DO, BOD and COD values.

3 Results

3.1 Effect of lockdown on air quality index

For the study of the impact of lockdown on air quality of India's capital (Delhi), data was collected on 10 days intervals for five major pollutants $PM_{2.5}$, SO_2, NO_2, CO and NH_3 from CPCB website for further analysis. Our study involved the time period pre-lockdown as January-March 2020, during lockdown as April and May 2020, whereas post-lockdown as June 2020-March 2021. The average concentration of different pollutants before the lockdown (From January to March 2020) was $PM_{2.5}$ (188.77 ± 82.17 $\mu g/m^3$), NO_2 (52.77 ± 14.68 $\mu g/m^3$), NH_3 (6.66 ± 2.17 $\mu g/m^3$) SO_2 (20.55 ± 10.12 $\mu g/m^3$) and CO (36.88 ± 10.12 mg/m^3) as shown in Table 1 [18]. The nationwide lockdown was imposed on 24th March 2020 due to the COVID-19 pandemic. Due to this lockdown, the major sources of air pollution like vehicles, power plants, industries were halted and hence its impact was seen on air quality of Delhi, which is a pollution hub of the country.

Table 1 Showing air quality index parameters during pre, during and post lockdown period of COVID-19

	$PM_{2.5}$	NO_2	NH_3	SO_2	CO
Pre-lockdown	188.77 ± 82.17	52.77 ± 14.687	6.667 ± 2.179	20.556 ± 10.126	36.889 ± 12.150
Lockdown	65.16 ± 51.32	33.66 ± 12.56	4.83 ± 1.47	10.500 ± 4.929503	35.500 ± 23.96
Post-lockdown	178.18 ± 109.20	66.78 ± 37.76	13.63 ± 7.32	13.87 ± 7.82	44.06 ± 19.46
% Inc. or dec	65.48%	36.21%	27.55%	48.92%	3.76%
	Decrease	Decrease	Decrease	Decrease	Decrease

The Air Quality Index (AQI) became moderate during the lockdown period as compared to pre-lockdown and again worsened from October 2020 onwards (Fig. 1a). During the lockdown period i.e., from 1st April 2020 till 31st May 2020, the pollution parameters showed significant reduction to $PM_{2.5}$ (65.16 ± 51.32 μg/m^3), NO_2 (33.66 ± 12.56 μg/m^3), NH_3 (4.83 ± 1.47 μg/m^3), SO_2 (10.50 ± 4.92 μg/m^3) and CO (35.50 ± 23.96 mg/m^3) as

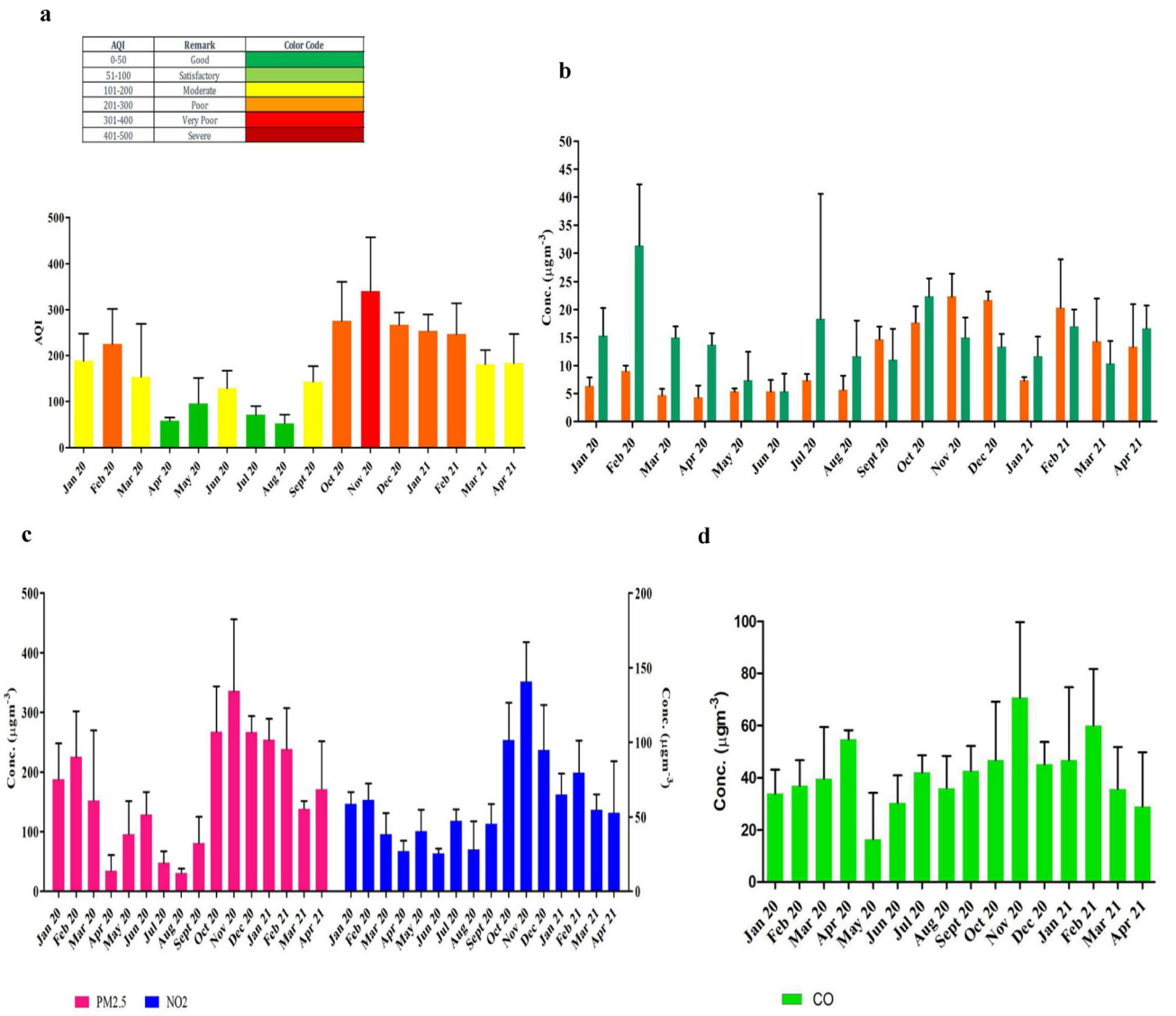

Fig. 1 Monthly variation of air pollutants in Delhi, India during the period of pre-lockdown, during lockdown and post-lockdown. **a**. Air quality index (AQI), **b**. NH_3 and SO_2, **c**. $PM_{2.5}$ and NO_2, **d**. Carbon monoxide

shown in Table 1 (Fig. 1b, c, d). The pollutant level again showed a significant rise as soon as the lockdown period was over as denoted by the different pollutants. The pollutant level $PM_{2.5}$ reached 178.18 ± 109.20 μg/m^3, NO_2 66.78 ± 37.76 μg/m^3, NH_3 13.63 ± 7.32 μg/m^3, SO_2 13.87 ± 7.82 μg/m^3 and CO 44.06 ± 19.46 mg/m^3, during the post lockdown period as shown in Table 1. The AQI scale used by CPCB to monitor the pollutant level is shown in Table 2 (Fig. 1). NAQI provides a numerical value as well as color codes in which the values between 0 and 50 denote the air quality as good and hence will have minimal impact on health (shown by green color). Similarly, the values in the range 51–100 are considered as satisfactory shown by light green color, whereas the value in the range 101–200 is termed as moderately polluted (shown by yellow color), the situation where breathing discomforts start in sensitive people. The range 201–300 is termed as poor quality air (orange color), followed by 301–400 (light red) which is very poor and 401–500 (dark red) as the most severe ones. As per the NAQI standards, the level of pollutant $PM_{2.5}$ reached moderate from very poor due to the lockdown imposed due to COVID-19, whereas the pollutant NO_2 reached the status good from satisfactory. The effect of lockdown on SO_2 pollutant resulted in nearly half the emission whereas the pollutant NH_3 and CO did not show much decline due to lockdown as the carbon monoxide emission was still severe. The level of these pollutants again becomes moderate for $PM_{2.5}$ and NO_2, satisfactory for SO_2, whereas remained good for NH_3 and severe for CO.

3.2 Statistical analysis of air quality parameters

A one-way ANOVA test was used to examine the data in order to get a compelling conclusion on the "impact of lockdown on pollutant concentration," with the premise that mean pollutant concentration had no influence on lockdown. Table 3 describe the ANOVA findings for several parameters such as $PM_{2.5}$, NO_2, NH_3, CO, and SO_2. The p value for all other parameters was less than 0.05, indicating that lockdown had a substantial influence on the concentrations of most of the metrics, including $PM_{2.5}$, NO_2, NH_3, CO, and SO_2. The ANOVA results of Air Quality parameters are shown in Table 3 which indicates that the parameters $PM_{2.5}$, NO_2, NH_3, CO, and SO_2 were affected by the COVID-19 induced lockdown.

3.3 Effect of lockdown on water quality index

The impact of lockdown on the level of water pollution of Yamuna River was studied (map shown in Fig. 2), as the major sources of water pollution like industries, transportation, different power plants and other construction activities were stopped. This resulted in improvement of all river bodies in the country including the Yamuna River in Delhi. So, in this study we have analyzed the water quality in the form of pH, DO (Dissolved Oxygen), COD (Chemical Oxygen Demand) and BOD (Biological Oxygen Demand) before, during and after the lockdown period (Table 4).

3.4 Impact of lockdown on the pH of Yamuna river

The impact of lockdown in this study was analysed during the pre, during and post-lockdown period. The average pH of Yamuna River was found to be alkaline with a pH of 7.3. During the pre-lockdown period the pH at village Palla and Nizamuddin Bridge was nearly 7.6 whereas that of Agra canal was 7.63 with a mean value of 7.57 (Fig. 3a). When the lockdown was imposed there was a slight increase in alkalinity of Yamuna River at village Palla with a pH of 8.0, whereas that of Nizamuddin Bridge and Agra canal was 7.64 and 7.45 respectively with a mean value of 7.69. After the lockdown, the pH at all these places decreased again and found similar to the pre-lockdown phase with a mean value of 7.36. The pH level was nearly in the threshold limit of 6.6–8.5, which is optimum for aquatic life and village Palla which is the entry point of Yamuna River recorded the highest pH of 8.0 during the lockdown period. The rise in the level of pH during the lockdown periods is probably due to the entry of organic waste products from anthropogenic sources into the water of river Yamuna in the urban areas. Therefore an alkaline pH was observed during the lockdown period. It is presumed that the industrial wastes composed of various ingredients which promote acidity.

3.5 Chemical oxygen demand (COD) level in Yamuna river

Chemical Oxygen Demand (COD) indicates the amount of dissolved susceptible matter and is an indicator of water pollution. The major sources which contribute to rise in COD values include effluents from industries and wastewater treatment plants which were on halt during the lockdown period. An increase in COD not only indicates pollution, but also severely affects the dissolved oxygen, ultimately affecting the aquatic life. During the pre-lockdown phase, the COD value ranged from 9 to 102.66 mg/l with a mean value of 62 mg/l. The highest COD of 102.66 mg/l was recorded at Agra Canal and lowest at village Palla (9 mg/l) during the pre-lockdown phase as shown in Table 4 (Fig. 3b). However, there was significant reduction in the COD values during the lockdown period at all locations as it was observed between 12 to 48 mg/l with a mean value of 34 mg/l. The maximum reduction in COD

Table 2 National AQI and concentration ranges of the pollutants

AQI Category		Concentration range*				
	AQI	$PM_{2.5}$	NO_2	NH_3	SO_2	CO
Good	0 – 50	0 -30	0 – 40	0-200	0-40	0-1.0
Satisfactory	51 – 100	31 – 60	41 – 80	201-400	41-80	1.1-2.0
Moderate	101 – 200	61 – 90	81 – 180	401-800	81-380	2.1-10
Poor	201 – 300	91 – 120	181 - 280	801-1200	381-800	10-17
Very Poor	301 – 400	121 – 250	281 – 400	1200-1800	801-1600	17-34
Severe	401 - 500	250+	400+	1800+	1600+	34+

*CO in mg/m^3 and other pollutant in µg/m3; 24-hourly average values for $PM_{2.5}$, NO_2, NH_3, and SO_2, and 8 hourly values for CO

was found at Agra canal during the lockdown phase followed by Nizamuddin Bridge. During the post-lockdown phase, there was slight increase in COD values of village Palla (12.4 mg/l), whereas the COD values at Nizamuddin Bridge and Agra Canal nearly doubled with respect to the lockdown period. During the post-lockdown phase, the COD value ranges from 12.4 to 92.4 mg/l with a mean value of 62 mg/l.

3.6 Dissolved oxygen level in Yamuna river

Dissolved Oxygen (DO), an important indicator of water pollution is an important parameter as it severely affects aquatic life. The highest DO (8.1 mg/l) was recorded at Palla and lowest (0 mg/l) at Agra Canal (Jaitpur) during the pre-lockdown phase (Fig. 3c). During the pre-lockdown phase, the DO value ranges from 0 to 8.1 mg/l with a mean value of 3.2 mg/l. Overall, the DO value ranges from 2.3 to 6.9 mg/l with a mean value of 4.46 mg/l during the lockdown period. During the lockdown period, there was an improvement in the DO levels of all the regions due to the halt in industrial and other pollution activities. As the lockdown period was over, the DO levels again declined except for village Palla which showed DO level of 7.0 mg/l. So, overall lockdown helped the aquatic life as the DO values showed a significant rise in level (except for Palla region). During the post-lockdown phase, the DO value ranges from 0.3 to 7.0 mg/l with a mean value of 2.89 mg/l.

3.7 Biological oxygen demand (BOD) of Yamuna river

Biological Oxygen Demand (BOD) is an important indicator of water pollution as more the BOD value, high is level of water pollution, as more oxygen is required to oxidize the organic wastes in water. The major contributors of BOD in Yamuna River include dead plant and animals as well as effluents from industries and power plants. BOD value varied from 2.7 to 34.66 mg/l with a mean value of 21.78 mg/l during the pre-lockdown phase while it observed between 2.8 and 17 mg/l with a mean value of 11.93 mg/l during the lockdown phase as shown in Fig. 3d. The highest BOD (34.66 mg/l) was recorded at Agra Canal (Jaitpur) and lowest (2.7 mg/l) at village Palla during the pre-lockdown phase which showed significant decline during the lockdown phase due to the decrease in industrial activities as well as the prevailing weather conditions (Table 3). The BOD value again showed an increment during the post-lockdown phase where the BOD varied from 2.07 to 29.8 mg/l with a mean value of 18.19 mg/l. Overall, the BOD ranges were quite higher than the threshold limit (3 mg/l) during the pre-lockdown phase, which has hazardous impact on all biological processes in water and ultimately affects aquatic life.

3.8 Statistical analysis of water quality parameters

A one-way ANOVA test was used to examine the data in order to get a compelling conclusion on the "impact of lockdown on pollutant concentration," with the premise that mean pollutant concentration had no influence on lockdown. Table 5 describes the ANOVA findings for several parameters such as pH, BOD, COD and DO. The p value for all other parameters was less than 0.05, indicating that lockdown had a substantial influence on the concentrations of most of the metrics, including pH, BOD, COD and DO. The ANOVA results of Water Quality parameters are shown in Table 5 which indicates that the parameters pH, BOD, COD and DO were affected by the COVID-19 induced lockdown.

Table 3 Analysis of variance for AQI, $PM_{2.5}$, SO_2, NO_2, NH_3 and CO

		Sum of squares	df	Mean square	*F*	Sig
AQI	Between groups	3827	2	1913	0.1928	0.000
	Within groups	446,548	45	9923		
	Total	450,375	47			
$PM_{2.5}$	Between groups	4285	2	2143	0.1872	0.000
	Within groups	515,131	45	11,447		
	Total	519,416	47			
SO_2	Between groups	73.17	2	36.58	0.5042	0.000
	Within groups	3265	45	72.55		
	Total	3338	47			
NO_2	Between groups	1037	2	518.6	0.4381	0.000
	Within groups	53,272	45	1184		
	Total	54,309	47			
NH_3	Between groups	37.04	2	18.52	0.3544	0.000
	Within groups	2351	45	52.25		
	Total	2388	47			
CO	Between groups	10.04	2	5.021	0.01346	0.000
	Within groups	16,785	45	373.0		
	Total	16,795	47			

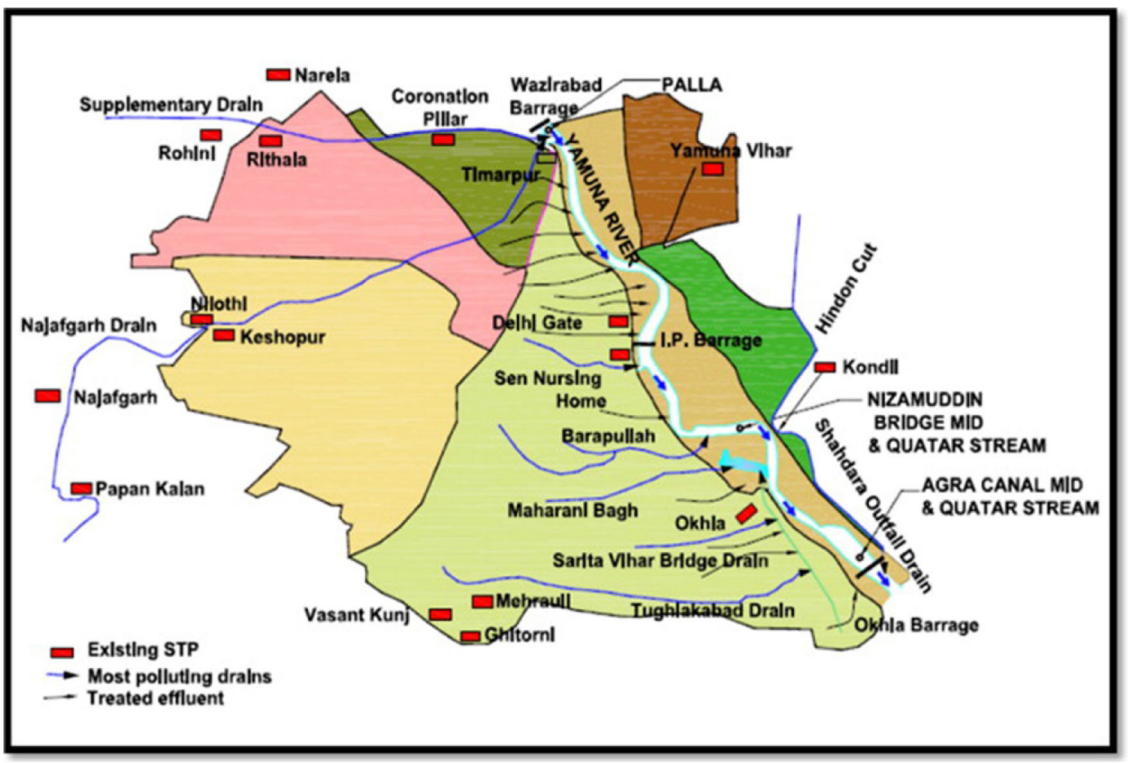

Fig. 2 Showing different pollution sources of Yamuna River, and their locations (*Source*: CPCB, 2020)

3.9 Impact of lockdown on COVID-19 cases as well as deaths

To study the affect of pandemic induced lockdown on the confirmed and cured cases of COVID-19 disease in Delhi, the data for total number of confirmed cases, number of deaths as well as cured cases before, during and post-lockdown was gathered from website (https://www.kaggle.com). During the pre-lockdown phase the cases as well as deaths were low as the disease has just arrived India, but

Table 4 Comparative analysis of various water quality index parameters during pre-lockdown, lockdown and Post lockdown phases and their change at different hotspot locations of Yamuna River in Delhi

Location	Phase	pH (Mean + SD)	COD (Mean + SD)	BOD (Mean + SD)	DO (Mean + SD)
Palla	Pre-lockdown	7.60 ± 0.20	9.00 ± 1.00	2.70 ± 0.26	8.13 ± 0.73
	Lockdown	8.00 ± 0.20	12.00 ± 1.50	2.80 ± 0.15	6.90 ± 0.23
	Post-lockdown	7.62 ± 0.41	12.40 ± 6.31	2.07 ± 0.98	7.00 ± 1.74
	% Inc. or dec	5.26%	33.33%	3.70%	15.12%
		Increase	Increase	Increase	Decrease
Nizamudin bridge	Pre-lockdown	7.63 ± 0.11	77.33 ± 2.30	28.00 ± 4.00	1.53 ± 0.63
	Lockdown	7.64 ± 0.35	42.00 ± 0.80	16.00 ± 0.30	2.30 ± 0.38
	Post-lockdown	7.20 ± 0.32	81.40 ± 32.51	22.70 ± 8.60	1.39 ± 1.60
	% Inc. or dec	0.13%	45.68%	42.85%	50.32%
		Increase	Decrease	Decrease	Increase
Agra canal (Jaitpur)	Pre-lockdown	7.50 ± 0.45	102.66 ± 37.16	34.66 ± 13.20	0.00 ± 0.00
	Lockdown	7.45 ± 0.60	48.00 ± 0.75	17.00 ± 0.60	4.20 ± 0.59
	Post-lockdown	7.32 ± 0.36	92.40 ± 34.40	29.80 ± 14.25	0.30 ± 0.63
	% Inc. or dec	0.66%	53.24%	50.95%	

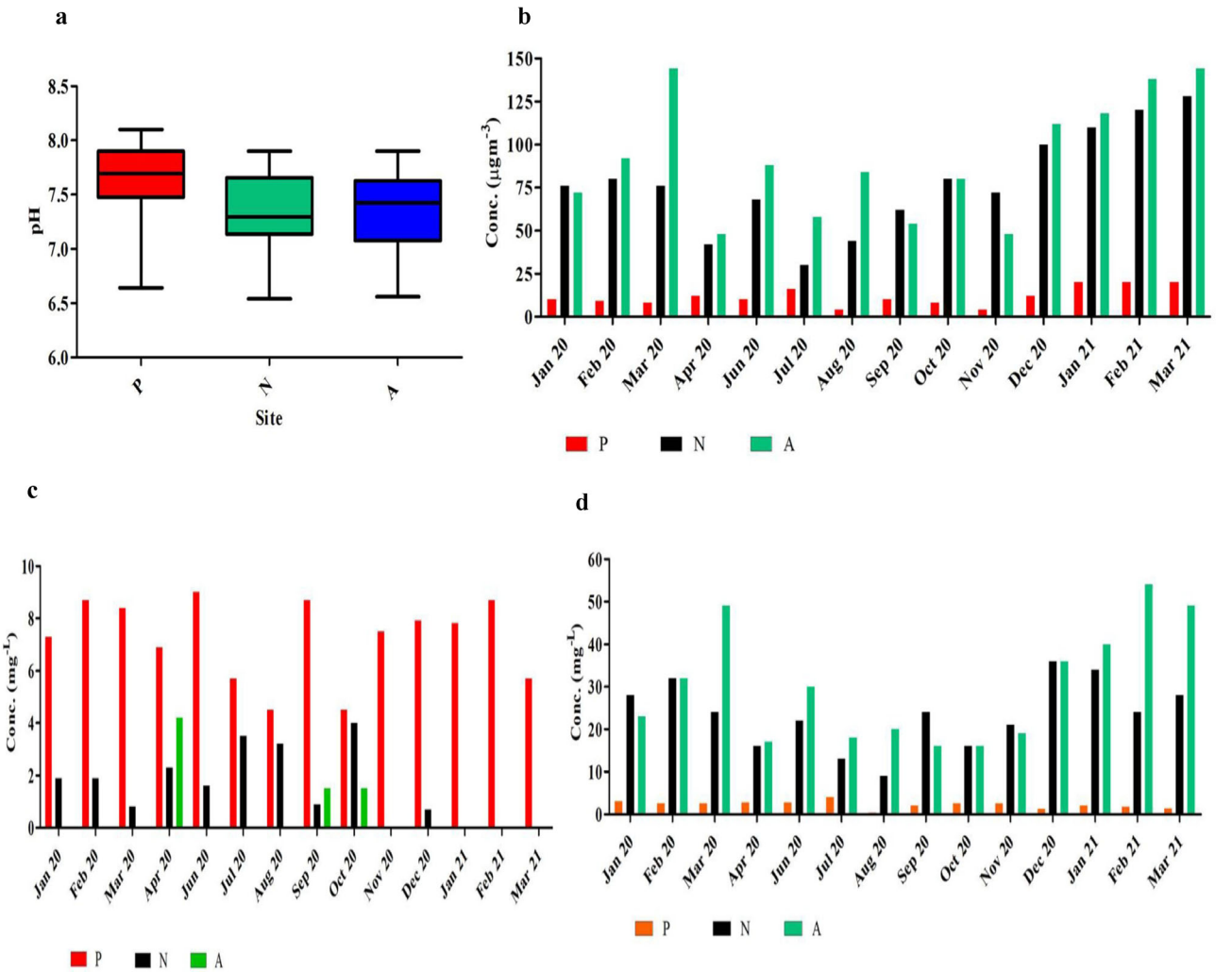

Fig. 3 Monthly variation of water pollutants in Yamuna River, Delhi, India during the period of pre-lockdown, during lockdown and post-lockdown. **a**. pH, **b**. COD, **c**. DO, **d**. BOD where, P stands for village Palla, N for Nizamuddin bridge and A for Agra canal

post-lockdown the cases increased at much higher rates with increased fatality. The lockdown had positive impact as the number of cases as well as death rate was quite low as compared to post-lockdown period as shown in Fig. 4. After the post-lockdown period the country witnessed a second wave of COVID-19 pandemic where the cases and deaths reached an uncontrolled limit.

4 Discussion

Due to rapid urbanization, industrialization and reckless use of natural resources by anthropogenic activities, environmental pollution have become major challenges all over the world. Degradation of air and water quality, especially in urban areas is the result of improper or haphazard developments. Continuous decline in the quality of air especially in the megacities across the nation has led to the eruption of several severe respiratory disorders. The main reason behind the abrupt rise in the air pollution is the incomplete or partial combustion of fossil fuels by vehicular transportation, industrial operations as well as generation of huge amount of domestic or anthropogenic waste products [19]. In the Mid-March of 2020, Indian Government has imposed nationwide lockdown to curb the rapid spread of COVID-19 pandemic. Although, it seems that COVID-19 induced lockdown has shown its devastating effects on global economy, however, environments rejuvenate itself in this short span of time temporarily from the excessive exploitation by humans [20].

Recent studies have shown that significant reduction in many pollutants has been recorded almost every regions of India during the period of lockdown. Das et al. (2020) [21] have reported that significant decline (35%) in the concentration of $PM_{2.5}$ was observed in the cities located in the Indo-Gangetic Plain after declaration of lockdown. Levels of pollutants in Delhi during the lockdown periods were recorded minimum of last 5 years level [22]. The data of our study showed similar results where we observed the concentration (average) of different pollutants before the lockdown (From January to March 2020) was $PM_{2.5}$ (188.77 ± 82.17 $\mu g/m^3$), NO_2 (52.77 ± 14.68 $\mu g/m^3$), NH_3 (6.66 ± 2.17 $\mu g/m^3$) SO_2 (20.55 ± 10.12 $\mu g/m^3$) and CO (36.88 ± 10.12 mg/m^3) as shown in (Table 1). During the lockdown period (from 1st April 2020 till 31st May 2020), the concentration of different air quality pollutant parameters showed significant reduction in $PM_{2.5}$ (65.16 ± 51.32 $\mu g/m^3$), NO_2 (33.66 ± 12.56 $\mu g/m^3$), NH_3 (4.83 ± 1.47 $\mu g/m^3$), SO_2 (10.50 ± 4.92 $\mu g/m^3$) and CO (35.50 ± 23.96 mg/m^3) as shown in Table 1 (Fig. 2b–d). The Air Quality parameters improves during the lockdown period and hence became moderate as compared to pre-lockdown and again worsened from October 2020 onwards (Fig. 2a).

The pH of water is an important indicator of water quality. It represents concentration of hydrogen ion in the water. The BIS (Bureau of Indian Standard) standard limit of pH for drinking water as well as for aquatic life is 6.5. Before lockdown, ranges of pH were recorded from 7.5 to 7.63 with mean value of 7.57. Whereas during the lockdown period, the pH level ranges from 7.45 to 8 with an average of 7.69. After completion of lockdown the pH was recorded 7.3–7.6 with mean value of 7.36. Due to less mixing of industrial effluents, pH in the unlock period was recorded alkaline. Similar results have also been documented previously by Peter (2009) [23] and Mocellin and Magro (2011) [24].

Chemical oxygen demand (COD) is the estimate of O_2 needed for the part of organic matter in polluted water which is subjected to oxidation. COD indicates water quality, used to determine the actual amount of biologically active matters in water. High COD concentration is responsible for fast degradation of O_2 in water bodies and decreases oxygen availability for aquatic life forms. BIS desirable limit of COD for aquatic life as well as drinking water is 120 mg/l. In the pre-lockdown COD ranged from 9 to 102 mg/l with a mean value of 62 mg/l. During the lockdown period, less mixing of organic chemicals helped in decreasing BOD level in Yamuna river water and recorded as 12–48 mg/l with an average value of 34. While post lockdown period recorded 12.4–92.4 mg/l of BOD with average of 62 in river water.

Dissolve oxygen indicates oxygen availability in water. Good quality of water contains higher rate of DO. BIS permissible limit of DO for aquatic life as well as drinking water is above 6 mg/l. In the pre-lockdown DO ranged from 0 to 8.1 mg/l with a mean value of 3.2 mg/l. During the lockdown period, as a consequence of less amount of mixing of organic chemicals, decreasing DO level in Yamuna river water and recorded as 2.3–6.9 mg/l with an average value of 4.46. In contrast, during the post lockdown period the concentration of DO was recorded 0.34–7 mg/l with average of 2.89 in river water.

Biological oxygen demand (BOD) is considered as a crucial water quality parameter. Greater level of BOD indicates very poor water quality. BIS recommended value of BOD for aquatic life as well as drinking water is 5 mg/l. Increased level of BOD indicates the river water is highly polluted. In the pre-lockdown BOD ranged from 2.7 to 34.66 mg/l with a mean value of 21.78 mg/l. During the lockdown period, less mixing of organic chemicals helped in decreasing BOD level in Yamuna river water and recorded as 2.8–17 mg/l with an average value of 11.93. While post lockdown period recorded 2.07–29.8 mg/l of BOD with average of 18.19 in river water.

Table 5 Analysis of variance for BOD, COD, DO and pH

		Sum of squares	df	Mean square	*F*	Sig
BOD	Between groups	5852	2	2926	35.18	< 0.0001
	Within groups	3244	39	83.19		
	Total	9097	41			
COD	Between groups	50,957	2	25,478	36.78	< 0.0001
	Within groups	27,013	39	692.7		
	Total	77,970	41			
DO	Between groups	369.5	2	184.8	96.63	< 0.0001
	Within groups	74.57	39	1.912		
	Total	444.1	41			
pH	Between groups	0.8188	2	0.4094	3.212	0.000
	Within groups	4.971	39	0.1275		
	Total	5.790	41			

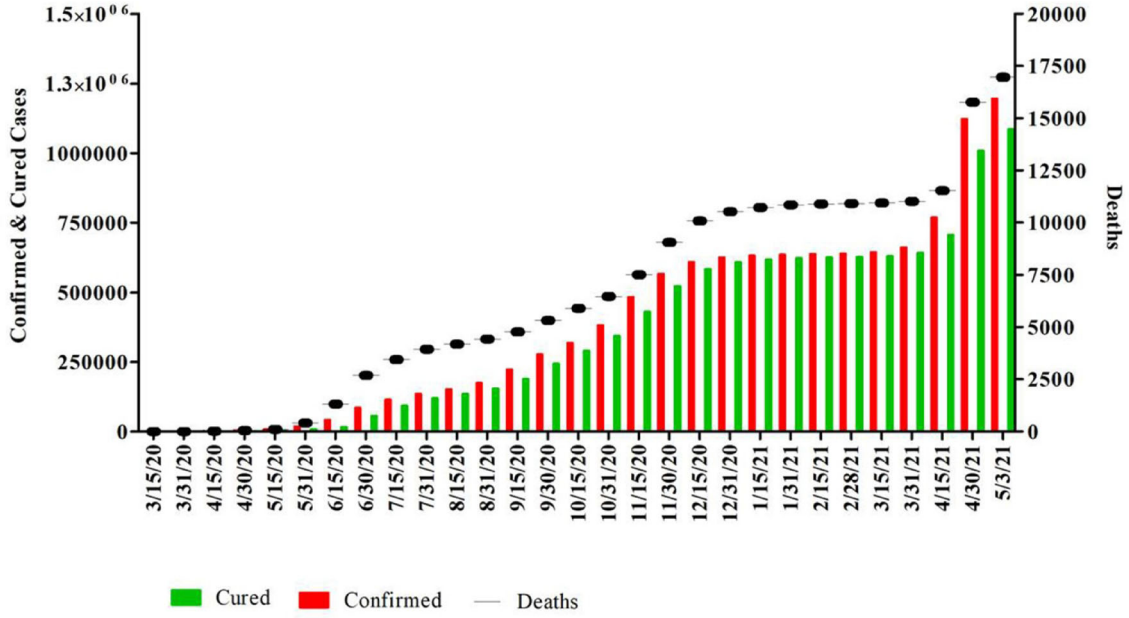

Fig. 4 Monthly variation in the number of confirmed COVID-19 cases, cured cases as well as deaths in Delhi, India during the period of pre-lockdown, during lockdown and post-lockdown. A dark line indicates the pre and post lockdown phase of COVID-19 pandemic

The findings of present work showing the impact of lockdown on the water quality parameters of river Yamuna in Delhi national capital territory. Zargar (2019) [25] has reported that the conditions of Yamuna's water quality amid lockdown was appeared much better than its earlier toxic status where the foam was found all around the channel. It was quite evident from the results of our study that there is a significant improvement in the Yamuna WQI, like pH, DO, BOD, COD, when compared with the pre-lockdown conditions and found consistent with the reports of Jha D. (2020a) [26]. Yamuna river is known to be the highly polluted rivers in India, mainly in Delhi region [13]. The recent analysis reflected that the considerable decline in the water pollution of Yamuna River has been observed during the lockdown phase.

COVID-19 brought a lot of negative impacts on millions of lives, however, it has a significant positive effect on nature and the environment [27]. The declaration of SARS-CoV-2 induced lockdown improves the quality of air and water in a short time interval because of temporary suspension of industries, factories, transportation and human activities which are the major cause of pollution [28, 29]. Enforcement of lockdown in countries like France, Germany, Spain, Italy, China, India led to temporary closure of industries and transportation as a result of which concentration of green house gases, nitrogen dioxide, $PM_{2.5}$, PM_{10} and CO decreased drastically [30]. The lockdown brought

good signs for the deadly global environment and the absence of human imparted positive effects [31]. Back before COVID-19, the biggest concern was pollution and various agencies worked all over the world to reduce pollution levels especially urban pollution in the form of carbon dioxide, nitrogen dioxide, sulphur dioxide and particulate matter [32]. According to the report of WHO, 2016 almost 8% of total deaths in the world occurred due to air pollution. Zambrano-Monserrateet et al. (2020) [33] have reported that AQI (Air Quality Index) in North, South, East, Central and Western part of India dipped by 44%, 33%, 29%, 15% and 32% respectively. The capital of India, Delhi recorded the reduction of almost 70% in the levels of nitrogen dioxide and $PM_{2.5}$ [34]. Rivers mainly Ganga and Yamuna in India were seen clearer and significant reduction in water pollution [35] was observed.

Similarly, during the pre-lockdown phase the COVID-19 positive cases and causalities were recorded low because the disease has just came India, while during the post-lockdown period the cases increased at much higher rates with increased mortality. It is clearly evident from the data of our study that lockdown had positive impact, as the number of cases as well as death rate was recorded low after implementation of lockdown as compared to post-lockdown period. After the post-lockdown period the country witnessed the emergence of second wave of COVID-19 pandemic where the cases and deaths reached an uncontrolled limit.

In summary, the marked improvements in the water and air quality indices are the positive outcomes of the COVID-19 induced lockdown. This lockdown exhibited the solutions for the natures' rejuvenation by means of natural resource preservation as well as sustainable development. Thus, present investigation will draw the attention of the policymakers to introduce strict integrative plans to minimize the water as well as air pollution together using better regulatory and robust technological interventions.

5 Conclusion

Overall, the present study revealed that the implementation of lockdown appears to show pronounced improvement in the air quality indices in the densely populated metropolitan city such as New Delhi (India). Our study also highlighted the water quality parameters which were found beyond the permissible range during the pre and post lockdown periods that were significantly improved during the lockdown period. Therefore, it may be concluded that lockdown imposed due to COVID-19 has brought noticeable transformation for Yamuna River, and it has appeared to be a positive sign for nature's rejuvenation. Similarly, lockdown has also improved the recovery rate of patients and, therefore, helped in breaking the chain of COVID-19. The findings of this study will assist the regulatory bodies to devise a pathway on how to strictly minimize vehicular and industrial pollution adequately in several big cities to improve air and water quality that in turn help to sustain better public health around the world.

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Declarations

Conflict of interest All the authors declare they have no conflict of interest.

Ethical statement The study presented here does not involve any work on animals or human.

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