COVID-19 and its impact on environment: Improved pollution levels during the lockdown period – A case from Ahmedabad, India

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ABSTRACT

The novel Coronavirus pandemic (COVID-19) hit the world severely in the first half of 2020 which forced several nations to impose severe restrictions on all sorts of activities involving human population. People were mainly advised to remain home quarantined to curb the virus spread. Industrial and vehicular movements were ceased as a result of lockdown, and therefore the rate of pollutants entering the ecosystem was also reduced in many places. Water and air pollution remained a major concern in the last few decades as these were gradually deteriorating in many spheres including the hydrosphere and atmosphere. As the nation-wide lockdown period in India completed more than two months, this study attempted to analyze the impact of lockdown on water and air quality to understand the short-term environmental changes. Using remote sensing data, this study demonstrated the improvements in ambient water quality in terms of decreased turbidity levels for a section of the Sabarmati River in the Ahmedabad region of India. The Suspended Particulate Matter (SPM) concentrations are evaluated to underline the turbidity levels in the study area before and during the lockdown period using the Landsat 8 OLI images. We noticed that the average SPM has significantly decreased by about 36.48% when compared with the pre-lockdown period; and a drop of 16.79% was observed from the previous year's average SPM. Overall, the average SPM concentration during the lockdown period (8.08 mg/l), was the lowest when compared with pre-lockdown average and long-term (2015–2019) April month average. The atmospheric pollution level (NO_2, $PM_{2.5}$, and PM_{10}) data obtained from the Central Pollution Control Board for Ahmedabad city also shows a significant improvement during the study period, implying a positive response of COVID-19 imposed lockdown on the environmental fronts.

1. Introduction

The novel Coronavirus (COVID-19) infected several thousands of people around the globe and affected the world economy severely in the first half of 2020. The worst affected countries in terms of population are the United States, Brazil, and India, altogether accounting for more than 5.5 million cases of virus infection and the graph is rising exponentially each day (worldometers.info, 2020). As of July 2020, the total number of COVID-19 cases reported by World Health Organizations (WHO) are 11.60 million, including more than 500,000 deaths globally (WHO, 2020). To curb the virus spread, WHO advised people to practice social distancing, avoid public gathering and transportation, and maintain proper hygiene.

The first case of COVID-19 was reported in India on 30th January, thereafter, a nationwide 14-h voluntary curfew was observed on 22nd march due to a jump in the number of positive cases. This curfew was extended for another 21 more days from 25th March to 14th April initially. This lockdown resulted in shutting down schools, industries, businesses, markets, religious and social gatherings, and kept people at home. It suspended all forms of travel except in case of emergencies and closed national and international boundaries. The lockdown period was further extended in many phases till June 8, 2020 and a lockdown of total 75 days completed with very strict guidelines, and the nation came to a standstill during this period (Singh, 2020). The lockdown in India has been unique and no such event has taken place over the recorded history where all the anthropogenic activities have been reduced to the

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minimum levels. This has led to a decline in emissions and restricted the production of industrial waste and other pollutants in the urban centers of India during the duration of lockdown.

The anthropogenic activities are known to be one of the primary drivers of pollution within various spheres of the environment (Akimoto, 2003; Volkamer et al., 2006; Masood et al., 2016; Schlacher et al., 2016). Since the lockdown implemented due to COVID-19 in various countries has almost seized the industrial activities and vehicle movement, a decrease in air pollution across the globe has been reported (Henriques, 2020; Stone, 2020). Several studies have conducted analysis on the short term impact of COVID-19 in the atmospheric column, including the satellite monitoring program from Sentinel 5 mission (ESA, 2020), but studies pertaining to hydrosphere are very few. Hader et al. (2020) have emphasized that the lockdown period has drastically reduced the industrial waste generation, industrial pollution, and the addition of heavy metals and plastic to hydrosphere through different sources. Thus, at the time when COVID-19 has crippled Italy, the Grand Canal in Italy became much clear and some aquatic species have reappeared (Clifford, 2020). This finding is similar to the case of river Ganges, a highly polluted river in India, which was found to be cleaner during the lockdown period in India (Mani, 2020).

The analysis of water pollution and water quality requires measurements of physical, chemical, and biological properties of water and traditionally based upon fieldwork for sample collection and then lab testing for determining the results. This manual process is not only time consuming and expensive, but also not suitable for analysis over a regional scale (Duan et al., 2013; Ritchie et al., 2003). Recently, remote sensing techniques have been widely used to undertake these studies with accuracy, and advantageous of having both cost and time over the manual approaches (Yunus et al., 2019; Avtar et al., 2019). The use of remotely sensed data helps not only to monitor and identify the water quality over large regions, but temporal changes can also be assessed regularly. (Dekker et al., 1996; Wang and Ma, 2001; Alparslan et al., 2007; Zhu and Dou, 2018; Ali et al., 2019). The remote sensing based water quality is undertaken by analyzing the spectral characteristics of water color. These spectral characteristics are the function of chemical, hydrological and biological characteristics of water (Wang and Yang, 2019).

In this study, we considered turbidity of water as a criterion of water pollution (Stumpf and Pennock, 1989). A higher level of suspended particulate matter (SPM) caused by sedimentation, sewage disposals, and other pollutants result in a high level of turbidity (Yunus et al., 2020). The remote sensing techniques have analyzed the relationship between turbidity and reflectance in water bodies (Curran et al., 1987; Novo et al., 1989; Sravanthi et al., 2013). It was observed that an increase in turbidity leads to an increase in reflectance levels in water bodies (Doxaran et al., 2002). Thus, empirically calibrated models, machine learning and artificial intelligence, etc. have been developed to fit the reflectance spectrum with in-situ profiles (Doxaran et al., 2002; Yunus et al., 2019; Davies-Colley and Smith, 2001; Luis et al., 2019). Among these, machine learning has become popular recently in many fields of satellite remote sensing and GIS analysis (Dou et al., 2020; Merghadi et al., 2020). Over the years, various satellite sensors have been widely used by scholars to map the SPM in aquatic systems. These include Sentinal-2, Landsat series, Spot series, MODIS Aqua and Terra, SeaWiFS and OceanSAT, etc. (Vanhellemont and Ruddick, 2014; Gholizadeh et al., 2016; Wei et al., 2018).

Apart from the hydrospheric component, the steep decline in social and economic activities has also reduced carbon emissions especially the combustion of fossil fuels (Dutheil et al., 2020). In many developing cities, air pollution is largely related to levels of NO_2, $PM_{2.5}$, and PM_{10} which are generated by industrial and anthropogenic activities, especially vehicular pollution (He et al., 2020a, 2020b). Guo et al. (2017) reported that more than one million people have died in India during 2015 alone due to ambient Particulate Matter (PM) pollution. In the present scenario of the lockdown, the steep decline in all types of air

Table 1
Details of the Landsat 8 OLI scenes used in this study.

Date of Acquisition	Landsat 8 Scene ID	Acquisition period
22-Apr-15	LC08_L1TP_149044_20150422_20170409_01_T1	Previous year
24-Apr-16	LC08_L1TP_149044_20160424_20170326_01_T1	Previous year
27-Apr-17	LC08_L1TP_149044_20170427_20170515_01_T1	Previous year
30-Apr-18	LC08_L1TP_149044_20180430_20180502_01_T1	Previous year
26-Apr-19	LC08_L1TP_148044_20190426_20190508_01_T1	Previous year
24-Feb-20	LC08_L1TP_148044_20200224_20200313_01_T1	Pre-lockdown
2-Mar-20	LC08_L1TP_149044_20200302_20200314_01_T1	Pre-lockdown
18-Mar-20	LC08_L1TP_149044_20200318_20200326_01_T1	Pre-lockdown
3-Apr-20	LC08_L1TP_149044_20200403_20200410_01_T1	Lockdown period
12-Apr-20	LC08_L1TP_148044_20200412_20200422_01_T1	Lockdown period
28-Apr-20	LC08_L1TP_148044_20200428_20200428_01_RT	Lockdown period
5-May-20	LC08_L1TP_149044_20200505_20200505_01_RT	Lockdown period
14-May-20	LC08_L1TP_148044_20200514_20200515_01_RT	Lockdown period

pollutants is reported from various parts of the globe (Ficetola and Rubolini, 2020; Tobias et al., 2020; Sharma et al., 2020).

The aforementioned studies reveal that there is a unique condition in various countries due to lockdown and the reduced anthropogenic activities have a direct impact on environmental pollution. Thus, there is an urgent need to study the short and long term changes caused by lockdown in our environmental system. Till date, very few studies have been undertaken to assess the changes in air and water quality during the lockdown period. As the lockdown in India has entered its 4th phase, the present study was undertaken to study the environmental impacts of COVID-19 in the Ahmadabad Metropolitan city using Landsat 8 OLI sensor data with the objective to understand the short-term changes in water and air quality.

2. Study area

We chose the Sabarmati River (Ahmedabad section) as our study area to assess its water quality. Sabarmati River is one of the longest rivers of Western India, originating in Aravalli ranges in Udaipur and after traversing about 370 km joins the Arabian Sea. Over the route, Sabarmati passes through Ahmedabad (see Fig. 1), the largest city in the state of Gujarat (India), and currently a hotspot for COVID-19 patients. The water quality of Sabarmati is graded moderate to poor and the river's self-purification capability has degraded in recent years (Haldar et al., 2014). Excessive anthropogenic activities, discharge of industrial wastage, illegal sewage release, and exposed river sites are some of the main causes of deterioration of Sabarmati water quality (Shah and Joshi, 2017). The river water near Sardar Patel Bridge in Ahmedabad has the highest amount of metal contamination, as compared to upstream, indicating high anthropogenic activities (Kumar et al., 2013).

Ahmedabad is presently the fourth most COVID-19 hit city of India and the worst hit in the state of Gujarat having a total of 38,333 positive cases as of 9th July 2020. India goes under a nationwide lockdown on March 25, 2020. However, Gujarat Government ordered the closure of much of the public activities including educational institutions, malls, and national parks from March 16, 2020 and imposed a complete lockdown from midnight of March 24, 2020. Since then all the industrial and tourism activities (e.g. burning of boat fuel at Sabarmati Riverfront) came to a halt and hence the pollutant level due to these sources declined. Therefore this is a unique opportunity to study the water quality of the Sabarmati River before and during the lockdown.
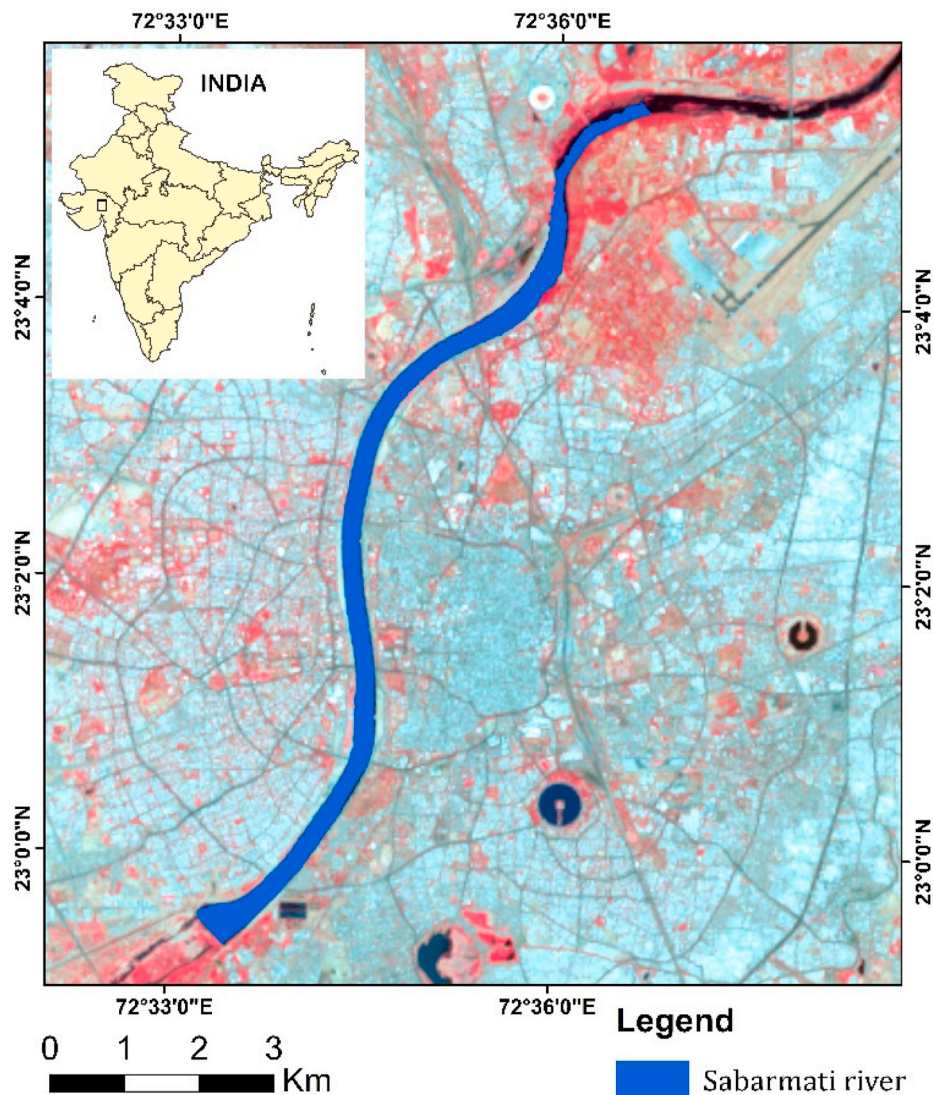
Fig. 1. Location of Sabarmati River (in the background is the Landsat 8 false color composite image of Ahmedabad). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

3. Data and methods

3.1. Landsat 8 Surface Reflectance image

For the comprehensive study of the effect of lockdown on river water quality, we downloaded thirteen LANDSAT 8 OLI Level-2 (Surface Reflectance) scenes (Table 1) from the USGS website (espa.cr.usgs.gov). The revisit interval of Landsat 8 is 16 days, however, Ahmedabad lies under two adjacent scenes (WRS path 148 and 149) and hence we were able to analyze the Sabarmati River water quality at shorter temporal resolution. All the downloaded scenes are already processed using Landsat 8 Surface Reflectance Code (LaSRC), the specialized software for atmospheric correction. Firstly, LaSRC generates the Top of Atmosphere (TOA) Reflectance using calibration parameters and then atmospheric corrections are applied to this previously generated image to generate a Surface Reflectance image.

3.2. SPM algorithm

Previously, researchers classified the water quality of the Sabarmati River as 'Medium to poor' index at data collection points within

Ahmedabad region (Shah and Joshi, 2017). Kumar et al. (2013) indicated that heavy metal concentration and water pollution gradually increased from upstream to downstream in the Sabarmati River. Haldar et al. (2014) calculated the turbidity value of 3.77 NTU at Sabarmati Narmada crossing-point, and Patel et al. (2020) assessed the in-situ water quality of Sabarmati River and evaluated that the turbidity values are below 20 NTU. Earlier studies (e.g., Mohd Hasmadi and Norsaliza, 2010 and Papoutsa et al., 2014) showed that using a single band for Turbidity estimation can provide a robust algorithm if the band is chosen appropriately. Nechad et al. (2010) proposed such a single band algorithm to precisely estimate the suspended matter concentrations, provided that the turbidity values are below 110 mg/l. The SPM is calculated for the study area using the following equation proposed by Nechad et al. (2010).

$$S = \frac{A^\rho \rho_w}{(1 - \rho_w)/C^\rho}$$

where ρ_w is the water-leaving reflectance of the red band (655 nm), A^ρ and C^ρ are the empirical coefficients .
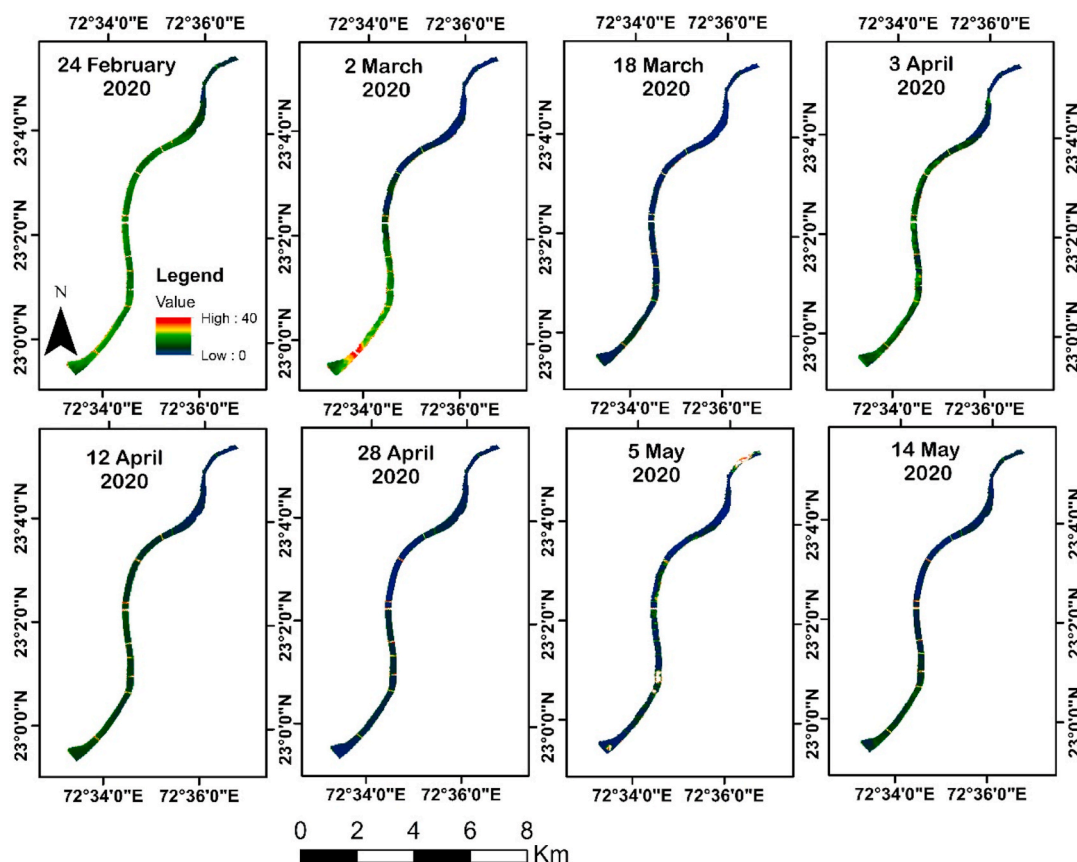
Fig. 2. Suspended Particulate Matter (SPM) concentrations of the Sabarmati River evaluated before and during the lockdown period.
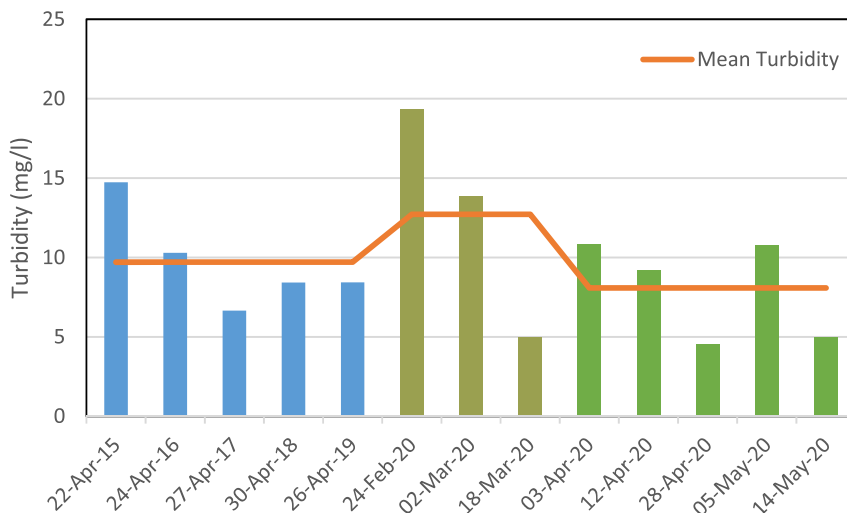

Fig. 3. SPM concentrations, mean values, and their variation over time in the Sabarmati River.

4. Results and discussion

Fig. 2–4 demonstrates the SPM concentration in the Sabarmati River; qualitative analysis suggests a decrease in the overall SPM levels during the lockdown period when compared to pre-lockdown period and previous years. Quantitative values of SPM are depicted in Table 2; the SPM concentration range observed during the lockdown period were 4.55 mg/l – 10.79 mg/l and the average SPM was found to be 8.08 mg/l. The result shows that the maximum SPM concentration for April in the last five years was observed in April 2015 (14.73 mg/l), whereas the

minimum values (6.65 mg/l) were observed in April 2017. Thus, the average SPM concentration for April 2020 (lockdown period) is second lowest in the last six years and the lowest value was found for April 2017.

To analyze the impact of lockdown on the river water quality, the SPM concentrations for the pre-lockdown period was also analyzed for the duration of about one month and it varied from 4.96 mg/l to 19.34 mg/l and the average for pre lockdown period was estimated to be 12.72 mg/l. The analysis of SPM during the lockdown was undertaken for five different days starting from 3rd April to 14th May and a gradual
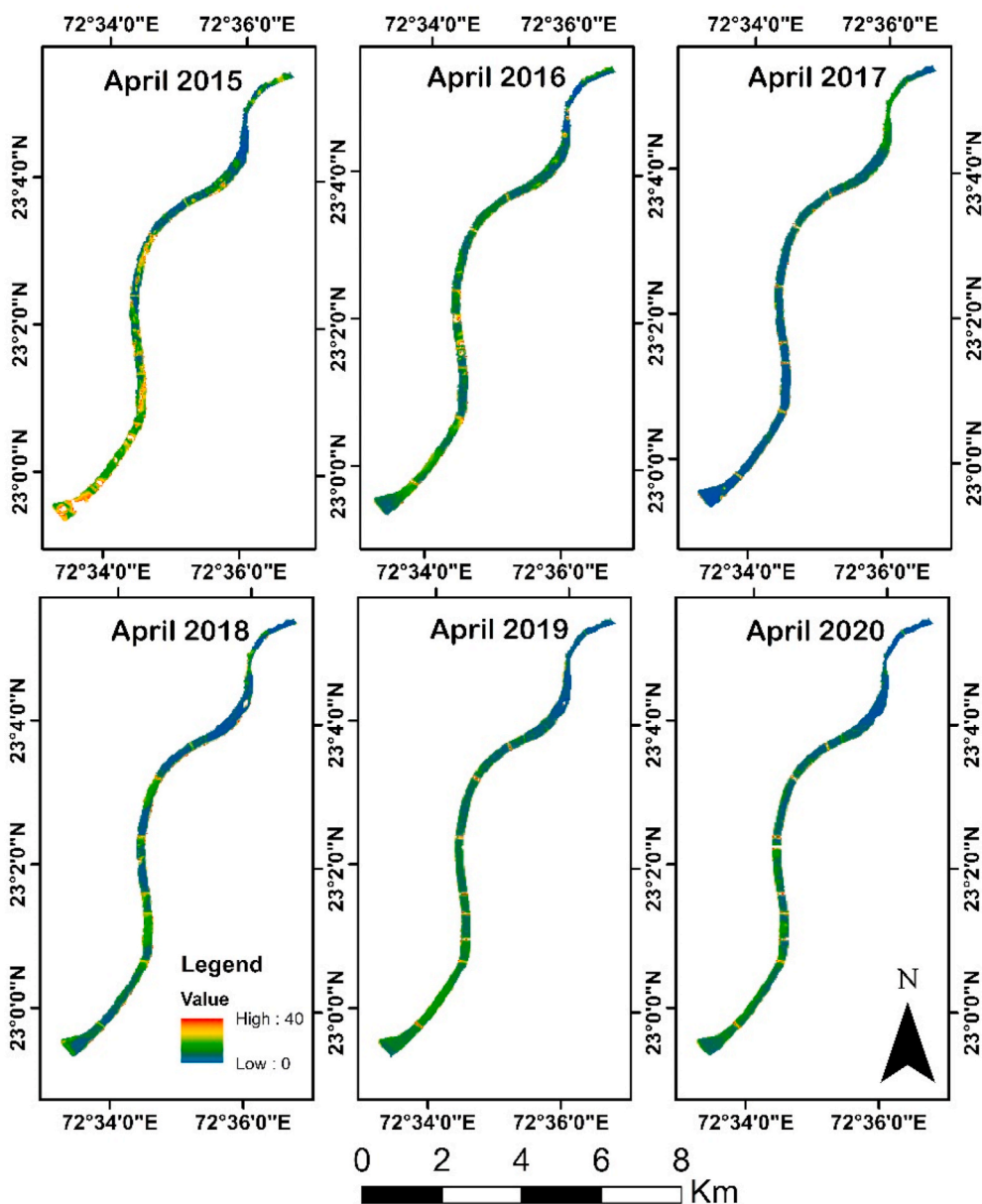
Fig. 4. SPM concentrations of the Sabarmati River evaluated for April (2015–2020).

Table 2
SPM concentrations of the Sabarmati River for different periods.

	Date of Acquisition	Turbidity (mg/l)	Mean Turbidity (mg/l)
Previous years	22-Apr-15	14.73	9.71
	24-Apr-16	10.3	
	27-Apr-17	6.65	
	30-Apr-18	8.42	
	26-Apr-19	8.43	
Pre-lockdown	24-Feb-20	19.34	12.72
	2-Mar-20	13.85	
	18-Mar-20	4.96	
During lockdown	3-Apr-20	10.85	8.08
	12-Apr-20	9.2	
	28-Apr-20	4.55	
	5-May-20	10.79	
	14-May-20	5.01	

decline with time in SPM concentrations is observed from 10.85 mg/l to 5.01 mg/l with a single upsurge on 5th May. The average SPM concentration for the lockdown period was calculated to be 8.08 mg/l, which is significantly lower than the pre-lockdown period average (12.72 mg/l), as well as the previous year average (9.71 mg/l). This suggests a substantial decrease of 36.48% in SPM concentrations during the lockdown period as compared with the pre-lockdown period, whereas a decrease of 16.79% as compared to the last five years average (Fig. 3).

Thus, the closure of anthropogenic and industrial activities has resulted in the decline of SPM concentration in the Sabarmati River. The upsurge in SPM concentration observed on May 5, 2020 may be supported by the fact that the natural river sedimentation can also alter the SPM levels in water bodies. The flow of sediments is governed by many factors such as precipitation, water and soil conservation projects, construction of reservoirs, carbonate weathering, dilution, etc. (Kumar et al., 2015; Liu et al., 2019). The upstream of Sabarmati experienced precipitation in early May 2020 (TOI, 2020) and that can be the possible source of high SPM concentrations on May 5, 2020.
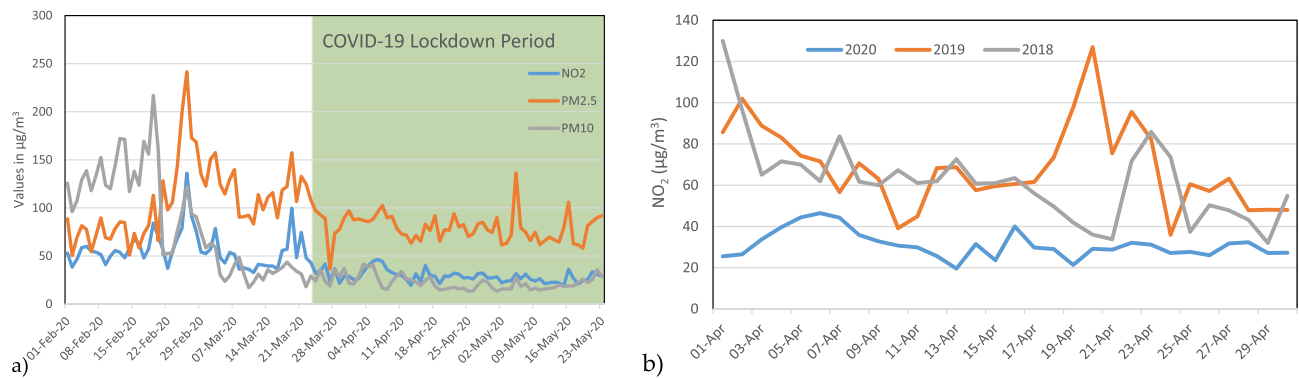
Fig. 5. Time series graph of (a) NO_2, $PM_{2.5}$, and PM_{10} concentrations for before and during lockdown period in Ahmedabad (b) NO_2 concentration for April (2018–2020).

The lockdown also made an impact on the atmosphere and the analysis of the air quality parameters (NO_2, $PM_{2.5}$, and PM_{10}) data within Ahmedabad metropolitan city obtained from the Central Pollution Control Board (CPCB), reveals a considerable improvement in the city air quality. A sharp decrease in $PM_{2.5}$ was observed at the beginning of lockdown i.e. after April 24, 2020 (Fig. 5a). Other parameters such as NO_2 and PM_{10} concentrations were also found to be much lower than the pre-lockdown period, and NO_2 concentrations in April 2020 are the minimum in the last three years (Fig. 5b) with no excessive variations observed. The NO_2 and PM_{10} values in April 2020 well were within the prescribed limit, which is 40 $\mu g/m^3$ for NO_2 and 60 $\mu g/m^3$ for PM_{10}, set by CPCB, India. The results concur with the recent studies by Mahato et al. (2020), Sharma et al. (2020), and Gautam (2020) evaluating improved air quality in different cities of India, and also worldwide (Tobias et al., 2020; Dantas et al., 2020; Isaifan, 2020; Zambrano-Monserrate et al., 2020).

5. Conclusion

The COVID-19 is a severe threat to human life and more than 500,000 deaths have been reported worldwide (as on July 9, 2020). However, with the complete restrictions on economic, social, educational, religious, and all other activities, this lockdown is turning into a "Blessing in disguise" (Muhammad et al., 2020). The authors attempted to analyze whether these restrictions have their impact on one of the severely polluted west-flowing rivers in India. The analysis revealed that the SPM concentrations in the Sabarmati River have reduced to a great extent. The changes pre and during lockdown are very significant to understand the short-term, as well as the long-term effect of anthropogenic activities on the hydrosphere. An average decrease of 36.48% is observed in SPM concentrations during lockdown compared to the pre-lockdown period albeit the domestic wastewater continues to drain into the Sabarmati River and which eventually shows the degree to which the industrial sewage discharge and other outdoor activities are deteriorating the hydrosphere and severely polluting the river water. The effect of lockdown is also clear on the air quality, as all the main parameters (NO_2, $PM_{2.5}$, and PM_{10}) have decreased to a noticeable extent from the pre-lockdown period and NO_2 concentrations are found to be minimum in last three years. However all these human activities will resume sooner or later, and since the Sabarmati River is surrounded by dense urban population, the pollutants may ultimately start deteriorating the water and air quality again and the improvement reaped during lockdown won't continue for long. Therefore, the Policymakers should take note of these improved air and water quality conditions due to the ceased anthropogenic activities and should plan the future urban dynamics accordingly. The present paper can be used for analyzing the rate of decline in SPM concentrations, NO_2, $PM_{2.5}$, and PM_{10} over the lockdown period and this could help in preparing future plan to control pollution.

CRediT authorship contribution statement

Mohammad Adil Aman: Conceptualization, Methodology, Software, Writing - original draft. **Mohd Sadiq Salman:** Writing - original draft, Visualization, Writing - review & editing. **Ali P. Yunus:** Supervision, Writing - review & editing.

Declaration of competing interest

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

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