INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Effect of lockdown on air pollutants during COVID – 19 over Hyderabad

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OPEN ACCESS

Received: 14-08-2020
Accepted: 19-08-2020
Published: 02-09-2020

Editor: Dr. Natarajan Gajendran

Citation: Polisetty VR, Ajay Kumar MC, Vinay Kumar P (2020) Effect of lockdown on air pollutants during COVID – 19 over Hyderabad. Indian Journal of Science and Technology 13(32): 3339-3348. https://doi.org/10.17485/IJST/v13i32.1411

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objective: To understand the temporal characteristics of air pollutants during lockdown and to assess the impact of them on air quality. **Method**: We have analyzed the ambient monitoring data, from Central Pollution Control Board (CPCB), of air pollutants from 27th January to 12th July 2020 to compare pre-lockdown (27th Jan to 22nd March), during lockdown (23rd March to 17th May) and post lockdown (18th May to 12th July) effects over six stations in Hyderabad. Further, to understand the significant differences in PM concentrations we have evaluated rate of change (ROC) over a defined period of time. Pearson correlation analysis was used as an indicator of the relation between $PM_{2.5}$ and PM_{10} for the study period. **Findings**: Our results show a significant decline in $PM_{2.5}$ (27%) and PM_{10} (34%) concentrations during lockdown. This indicates positive effect of lockdown on air quality over Hyderabad. The contribution of $PM_{2.5}$ in PM_{10} (46%) during lockdown remains same when compared to previous years though the concentrations have decreased. The $PM_{2.5}$ was highly correlated with PM_{10} over all the stations. A substantial decrease in $PM_{2.5}$ (27%) and PM10(39%) compared to the same period of previous years were observed. Apart of particulate matter the concentration of NO_2 decreased by 33% during lockdown. Another noticeable point observed is that the concentrations of CO and SO_2 showed a marginal decrease and they remained below permissible limits (NAAQS) during study period. **Novelty / Recommendations**: Overall, this study may be helpful to understand how air pollution is affected during COVID – 19 pandemic and provide important signs regarding the control of emissions by subsequently implementing stringent rules, like complete lockdown at least one day per week, imposing traffic rules, encouraging online teaching, digital shopping etc., to heal and save the environment.

Keywords: Covid-19; lockdown; air pollutants; particulate matter; air quality

1 Introduction

The rapid spread of coronavirus disease (COVID-19) was first identified in Wuhan, China. Within a few months, more than one million cases were recorded worldwide. Under these circumstances World Health Organization (WHO) has declared this disease as a global pandemic. The Indian authorities, for preventing the spread of the disease and securing the health and safety of Indian citizens, have decided to implement the first nationwide lockdown (Janata Curfew) for 14 hrs on 22nd March, followed by first phase of lockdown form 24th March to 14th April (21 days). Such lockdown was unique in India where all air and road transport was banned. During this lockdown, roads were deserted without any vehicle except the emergency services. It has enforced the human activities (industrial and commercial) to shut down forcibly within the cities and has shown some positive effect on natural environment. As a result, it has major impact on the improvement of the air quality due to the changes in the air pollution because of reduced emissions from the transportation and industries. Up to date there are many studies throughout the world focused on the effect of lockdown on air quality. These studies reported a drastic reduction in anthropogenic activities which results a decline in air pollution which influence the total ambient air quality during Covid-19 outbreak[1–4]. Later, Government of India further extended the lockdown (second phase) upto 3rd May 2020 with slight relaxations in agricultural sector. In view of rising cases of COVID -19, Indian Government classified all districts in the country into RED, ORANGE and GREEN zones. These zones have varying levels of restrictions with maximum in RED zone. Hyderabad falls in RED zone and the lockdown was extended till 17th May 2020.

Particulate Matter ($PM_{2.5}$, PM_{10}), Carbon monoxide (CO), Ozone (O_3), Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) are common air pollutants, observed in urban environment, arising from combustion process (vehicular emissions, house hold emission, industrial activities etc.,) and road dust[5,6].

In the last few years air pollutants in many urban cities of India are exceeding the ambient air quality standard recommended by World Health Organization (WHO) and National Ambient Air Quality (NAAQ) standards[7–9]. Hyderabad, capital city of Telangana State, is one among such cities where the air pollutants exceed the standard values due to its vast urbanization. The city is having a wide spread Industrial Development Areas (IDA) and a vast growth in population ~10 million, contributing to the anthropogenic activities which seriously play an important role in air pollution.

In this context, the main objective of the present study is to assess the variations of $PM_{2.5}$, PM_{10}, CO, O_3, NO_2 and SO_2 concentrations in the ambient air of Hyderabad city for pre, during and post lockdown periods and to quantify the effect of lockdown on air pollution.

2 Data details

The Telangana State Pollution Control Board (TSPCB) is operating six Continuous Ambient Air Quality Monitoring Stations (CAAQMS) [IDA Bollaram (BLM); Hyderabad Central University (HCU); ICRISAT Patancheru (PTC); IDA Pashamylaram (PSM); Zoo Park (ZOO); Sanathnagar (SNN)] over Hyderabad. An hourly data of air pollutants such as $PM_{2.5}$, PM_{10}, Carbon monoxide (CO), Ozone (O_3), Nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) were downloaded from CAAQMS website (https://cpcb.nic.in/automatic-monitoring-data/) for these six stations from 27thJan to July 12th 2020 and it was used in our present study. It provides instant data generation, online data dissemination using sophisticated analyzers for various parameters which include particulate matter of size less than 2.5 μm ($PM_{2.5}$) and 10 μm (PM_{10}) and pollutant gases like NO_2; SO_2; CO and O_3.

Table 1. Details of the stations

S. No	Name of the station	Significance of station	Latitude (°N)	Longitude (°E)
1	Bollaram Industrial Area, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.54	78.34
2	Central University, Hyderabad – TSPCB	Downstream of industrial area and sensitive zone	17.45	78.32
3	ICRISAT Patancheru, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.51	78.27
4	IDA Pashamylaram, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.53	78.43
5	Zoo Park, Hyderabad – TSPCB	Industrial Residential Rural and Other Area	17.34	78.45
6	Sanathnagar, Hyderabad – TSPCB	Centre of the city and Balanagar IDA	17.45	78.47

To assess the impact of lockdown on air quality status over Hyderabad, we divided the total data into three equal windows namely: pre-lockdown (27th Jan to 22nd March), during lockdown (23rd March to 17th May) and post lockdown (18th May to 12th July). The PM10 concentration is not available for Sanathnagar station during the study period. In addition, to study the annual variation, we also considered two more years of data (2018 and 2019) for the same period. The details of the stations and their significance are given in the Table 1.

3 Literature survey

A gradual deterioration of air quality across the country has been observed since 2018 and at the same time the economic lockdown under COVID – 19 also brought unexpected relief to the poor air quality[10]. Many efforts have been carried out by environmental experts and researchers to contend the air pollution. Numerous studies (both national and global levels) are carried out to study the effect of lockdown on air pollutants and showed an improvement in the air quality and declination of air pollution during lockdown.

In comparison, the reduction in air pollutants have been reported across the countries specially comparing between the urban areas of ground based air pollutant concentrations. Many recent studies have investigated the variation of air pollutants during COVID – 19 lockdown in different countries and regions. The short- term impacts of lockdown on urban air pollution over China were studied and found a sizeable improvement in air quality[11]. The Satellite and ground based observations showed unexpected reduction in particulate matter levels over North China during lockdown[12]. Sicard et al. [13] observed a significant reduction in NO_2 during lockdown, in four southern European cities and compared to the same period 2017-2019. Li et al. [14] WRF- CAMX modelling system together with monitoring data was used to investigate the impact of human activity pattern changes on air quality over China and found the concentrations of $PM_{2.5}$, NO_2 and SO_2 reduced by 31.8%, 45.1% and 20.4% respectively during the level I of lockdown. The impact of lockdown on air pollutants showed a significant reduction in CO, NO_2 and PM_{10} during first week of lockdown in the Rio de Janerio city, Brazil[15].

A comprehensive study on air pollutants across India during the lockdown period was made using the observations from 134 real- time monitoring sites of Central Pollution Control Board (CPCB)[16]. The concentration of air pollutants has shown a significant decrease in all the regions during the lockdown and a mixed variation, with a mild increase in O_3 in Indo Gangetic Plane (IGP) and a decrease in South India. Singh & Chauhan[17] studied variations in two primary pollutants $PM_{2.5}$ and NO_2 over five metropolitan cities using Environmental Protection Agency EPA online data located in US embassies across India and found a pronounced decline in pollutants during lockdown period. Sharma et al.[18]analysed a 24-hour daily average data of five pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2 and O_3) over seven cities in Rajasthan and showed a trend of decrease in all pollutants except ozone. A significant decrease in air pollutants during lockdown over Kolkata was observed[19]. Dhaka et al. [20] analysed variations in the fine particulate matter ($PM_{2.5}$) over the Delhi-National Capital Region and their measurements revealed large reductions (by 40-70%) in $PM_{2.5}$ during the first week of lockdown (25-31 March 2020) as compared to the pre-lockdown conditions. Such comparisons are important to quantify and assess the effect of lockdown period on air pollution. Thus, in this study we have examined the variations of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, CO and O_3) and their trends during the COVID – 19 lockdown period over Hyderabad.

4 Results and Discussion

4.1. Effect of lockdown on air pollutants

In order to assess and quantify the impact of lockdown on air pollution over Hyderabad, we have studied the variations of air pollutants ($PM_{2.5}$, PM_{10} NO_2, SO_2, O_3 and CO) in this paper.

4.1.1 Temporal Variations of $PM_{2.5}$ and PM_{10}

The percentage days of particulate matter concentrations (lower panel for PM_{10} and upper panel for $PM_{2.5}$) for all stations during the study period is depicted in Figure 1. During and post lockdowns the daily concentration of $PM_{2.5}$ mainly fell in the range 20 – 35 $\mu g/m^3$ and 35 – 50 $\mu g/m^3$ respectively, whereas, during pre-lockdown it falls in the range 20 - 75 $\mu g/m^3$. In general across the stations, $PM_{2.5}$ concentration remained below the NAAQ standard value during lockdown period. In case of Zoo Park, during pre-lockdown around 70% of days are exceeding the standard value whereas it has reduced to 20% during lockdown.

The percentage day concentrations of PM_{10} fall within the range 35 - 100 $\mu g/m^3$ during lockdown whereas it exceeds standard value of NAAQ (100 $\mu g/m^3$) in pre and post lockdowns. It clearly indicates that the number of days with concentration greater than100 $\mu g/m^3$ is reduced by 40% during lockdown when compared with pre-lockdown. Further in post lockdown

period the number of days above standard values increased by 15% except at Zoo Park where it is raised by 50%. Lockdown period has proved beneficial for the breathable air in the city, with considerable reduction in the particulate matter. In case of Zoo Park, the fraction of days exceeding the standard values remained unchanged for both pre and post lockdowns, suggesting continued emissions of PM pollutants during these periods.

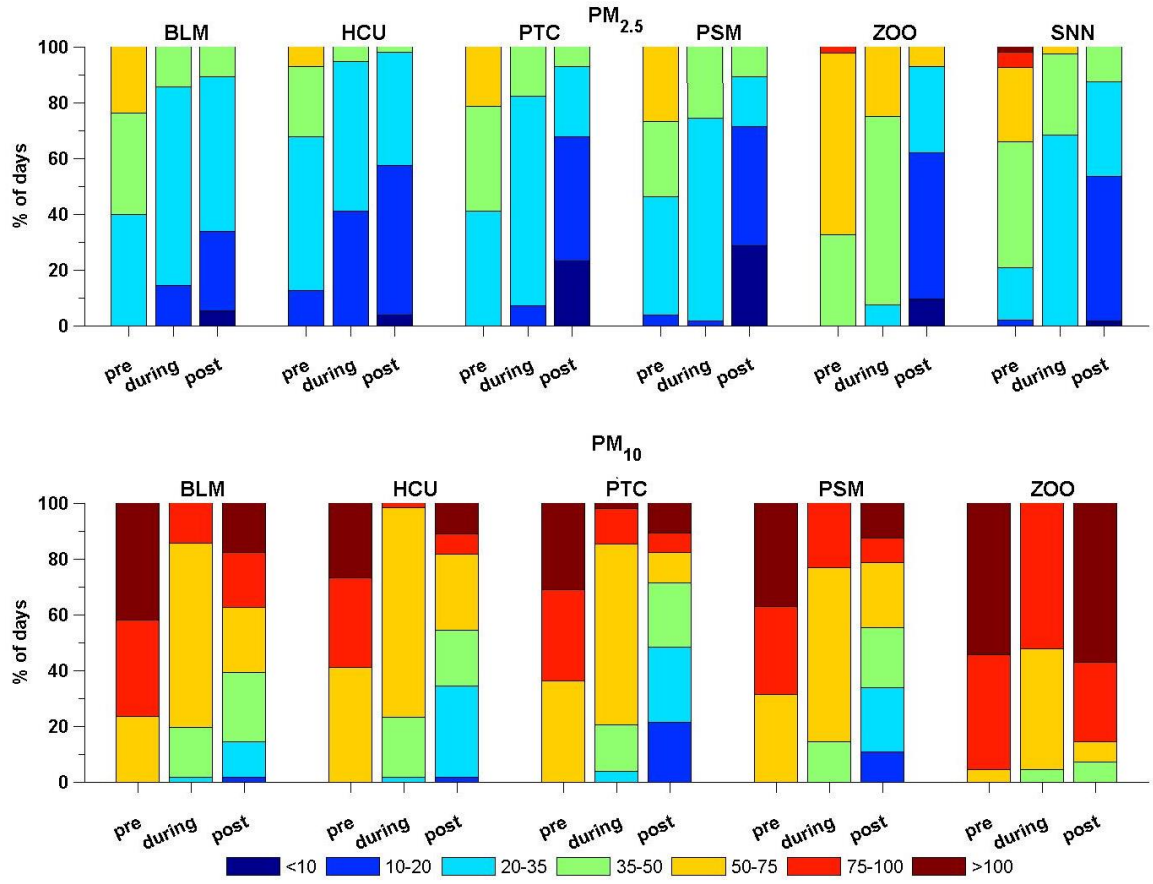

Fig 1. The percentage days of PM_{10} (lower panel)and $PM_{2.5}$ (upper panel) concentrations for all stations.

The hourly values of PM concentrations are averaged initially day-wise and subsequently averaged over a week for all six stations. Mean values are plotted, from 27th Jan to 12th July 2020 in three different windows: pre lockdown (27th January – 23rd March), during lockdown (24th March –17th May) and post lockdown (18th May – 12th July) for all stations in Figure 2 (a, b) along with average PM concentrations (thick red). The PM concentration indicates a clear decline during the lockdown period and the trend of declination throughout the study period for all stations was observed to be same except for Zoo Park.

The average concentrations of PM2.5 and PM10 for pre, during and post lockdown for all stations were depicted in Figure 2(c, d). The figure clearly shows a considerable fall in concentrations during lockdown when compared with pre lockdown. The PM2.5 concentrations during lockdown (pre-lockdown) were varied across the stations from 22.9 μg/m (31.4 μg/m) to 45.8 μg/m (56.6 μg/m) and for PM10 concentration it is varied between 56.9 μg/m (88.0 μg/m) and 73.6 μg/m (110.0 μg/m). The variation of concentration across the station is less during lockdown compared to pre lockdown period. The mean concentrations of PM2.5 (PM10) during the lockdown period were found to be 31.2 μg/m (63.52 μg/m), indicating a reduction of PM concentrations by 27 % (34%) when compared to pre-lockdown values 42.85 μg/m^3 (96.78 μg/m^3) respectively. The higher decrease in PM10 compared to PM2.5 during study period may be due to its greater contribution from anthropogenic sources[21]. With reference to Table 1, the mentioned stations are categorized into three different types namely Industrial,

Residential Rural areas (BLM, PTC, PSM and ZOO); Industrial, Residential Urban area (SNN) and Residential Urban area (HCU). The PM concentrations during lockdown across the stations are found to decline accordingly with maximum at Industrial, Residential Urban area when compared to Industrial, Residential Rural areas. Minimum declination was observed in Residential Urban area.

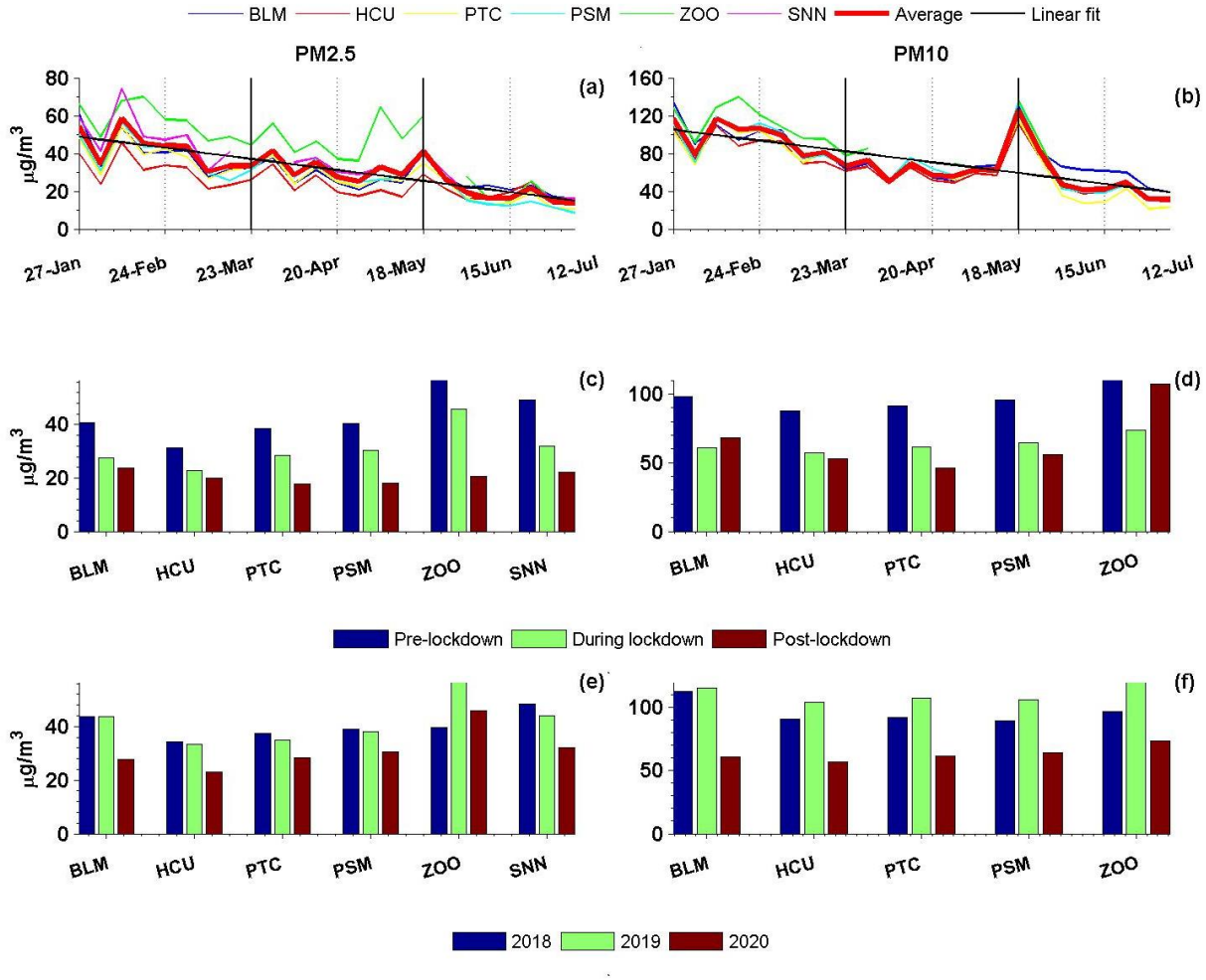

Fig 2. Upper panel: Variation of mean concentrations (a) $PM_{2.5}$ and (b) PM_{10} between 27th Jan and 12th July 2020 for all stations along with average concentration (thick red). Middle panel: Mean concentrations of (c) $PM_{2.5}$ and (d) PM_{10} for pre, during and post lockdowns for different stations. Lower panel: Mean concentrations of (e) $PM_{2.5}$ and (f) PM_{10} during the study of corresponding period of lockdown (23rd March – 17th May) of 2018, 2019 and 2020.

To supplement the effect of lockdown on air pollution, we have also tried to find out the annual variation of pollutants, for the last two preceding years for the identical window lockdown period. Comparison of the mean PM concentrations ($PM_{2.5}$ and PM_{10}), during the study of corresponding period of lockdown (23rd March – 17th May) of 2018, 2019 and 2020 for different stations was depicted in Figure 2(e, f). Overall a significant decrease in concentrations of $PM_{2.5}$ and PM_{10} was observed in 2020 i.e., during lockdown when compared to other years for all stations. This decrease in concentrations may be attributed to exclusion of industrial and traffic emission with their varying contributions to the spatial locations.

From Table 2, the percentage contribution of $PM_{2.5}$ in PM_{10} during lockdown period indicates that there is no change in concentration of $PM_{2.5}$ in PM_{10} when compared with average contributions of previous two years (2018 and 2019) except in case Zoo Park, though the concentrations have decreased. Further the major sources of $PM_{2.5}$ are vehicular emissions due to transportation. But during lockdown even in the absence of transportation sectors the emissions remained same in the atmosphere which contributes more towards the $PM_{2.5}$. In addition, the $PM_{2.5}$ is highly correlated with PM_{10} over all the

stations with coefficients for pre (0.875), during (0.775) and post lockdowns (0.874).

Table 2. Contribution of $PM_{2.5}$ in PM_{10} during the study period

	2018-2019			2020		
Station	**PM2.5**	**PM10**	**PM2.5/PM10 (%)**	**PM2.5**	**PM10**	**PM2.5/PM10 (%)**
BLM	43.71	113.82	38.40	27.69	60.97	45.42
HCU	33.85	97.50	34.72	22.89	56.92	40.21
PTC	36.10	99.53	36.27	22.38	61.77	36.23
PSM	38.63	97.74	39.52	30.38	64.27	47.27
ZOO	48.05	108.20	44.40	45.75	73.57	62.19
Average	40.07	103.36	38.77	29.82	63.50	46.96

Rate of change (ROC) was used to describe mathematically the percentage change in $PM_{2.5}$ and PM_{10} concentrations over a defined period of time

$$ROC\ (\%)\ =\ [(X-Y)/Y]\ *\ 100$$

where Y and X represents the previous and current values respectively.

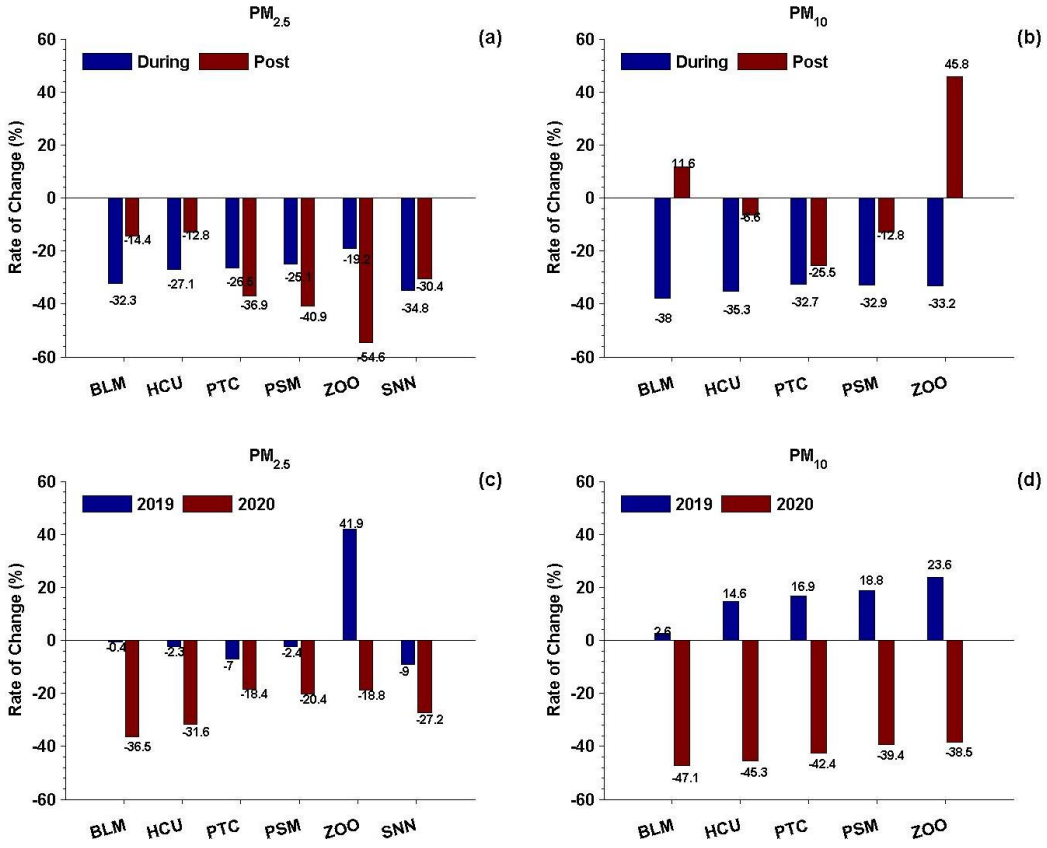

Fig 3. Upper panel: Rate of change of PM and PM from pre lockdown through the subsequent windows for all stations. Lower Panel: Similarly from 2018 through the subsequent year

Figure 3 shows ROC (%) in PM concentrations for three windows following pre-lockdown (upper panel) and for three years (averaged over lockdown period) following 2018 (lower panel). The results show significant differences across the stations

over Hyderabad. The overall PM concentrations in all six stations were seemed to be declined by 27% during lockdown when compared with pre lockdown period. Similar downfall was observed with significant differences across the stations for post lockdown period. The concentration of PM_{10} at Bollaram and Zoo Park are found to be increased by 10% and 40% respectively during post lockdown period. The $PM_{2.5}$ concentration shows a significant decrease in every year, but a sharp increase of 42% in 2019 was observed for Zoo Park. The average PM_{10} concentration sharply decreased across all the stations in 2020 and a gradual increase was observed from Bollaram to Zoo Park in 2019.

The levels of PM concentration for different stations during study period are shown in Figure 4. The central box comprises values of 25 and 75 percentiles, and whiskers show the range of values falling within 1.5 times the inter-quartile range beyond the box. The solid lines within the box represent the median values. The outliers, defined as data points beyond the inner fence are represented with '+' symbols. A remarkable decrease of concentration was observed across all the stations during lockdown period. Further during post – lockdown the declination in the concentrations was mainly due to short term meteorological conditions and monsoon seasonal effect. In addition to this, the actions and guidelines given by state government during post lockdown with restricted relaxations on industries, public transportation, institutions and offices may also attribute for further declination of PM concentration.

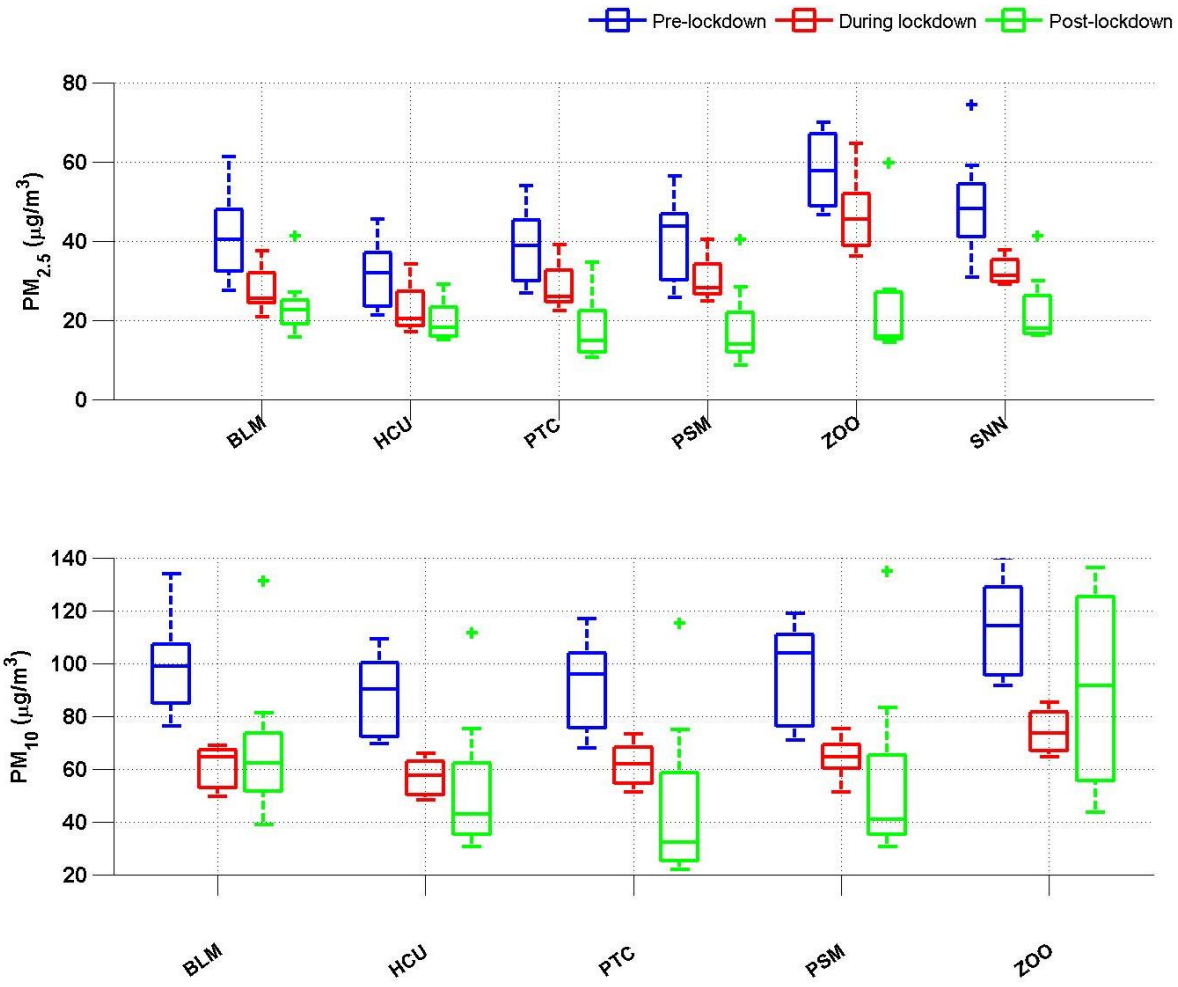

Fig 4. The levels of PM concentration for different stations during study period with median values(solid line within box), 25 and 75 percentiles and whiskers. The outliers are represented with '+'symbols.

4.1.2 Temporal variations in CO, O_3, NO_2 and SO_2 during the study period

The temporal changes in the average concentrations of pollutants for all stations during the study period were depicted in Figure 5 (a – d) along with bar graph (e – h). The mean concentration of air pollutants for pre and during lockdown periods are depicted in Table 3. Overall, around 12%, 3%, 17% and 33% decrease in CO, O_3, SO_2 and NO_2 were observed during lockdown period when compared to pre lockdown.

Table 3. Mean concentrations of air pollutants during study period

Air Pollutants	**NAAQ standard value** ($\mu g/m^3$)	**Pre Lockdown** ($\mu g/m^3$)	**During Lockdown** ($\mu g/m^3$)	**ROC** (%)
CO	2 (8 Hrs average)	0.75	0.66	-12
O_3	100 (8 Hrs average)	41.03	40.00	-3
SO_2	80 (24 Hrs average)	6.83	5.67	-17
NO_2	80 (24 Hrs average)	32.93	22.05	-33
$PM_{2.5}$	60 (24 Hrs average)	42.85	31.20	-27
PM_{10}	100 (24 Hrs average)	96.78	63.52	-34

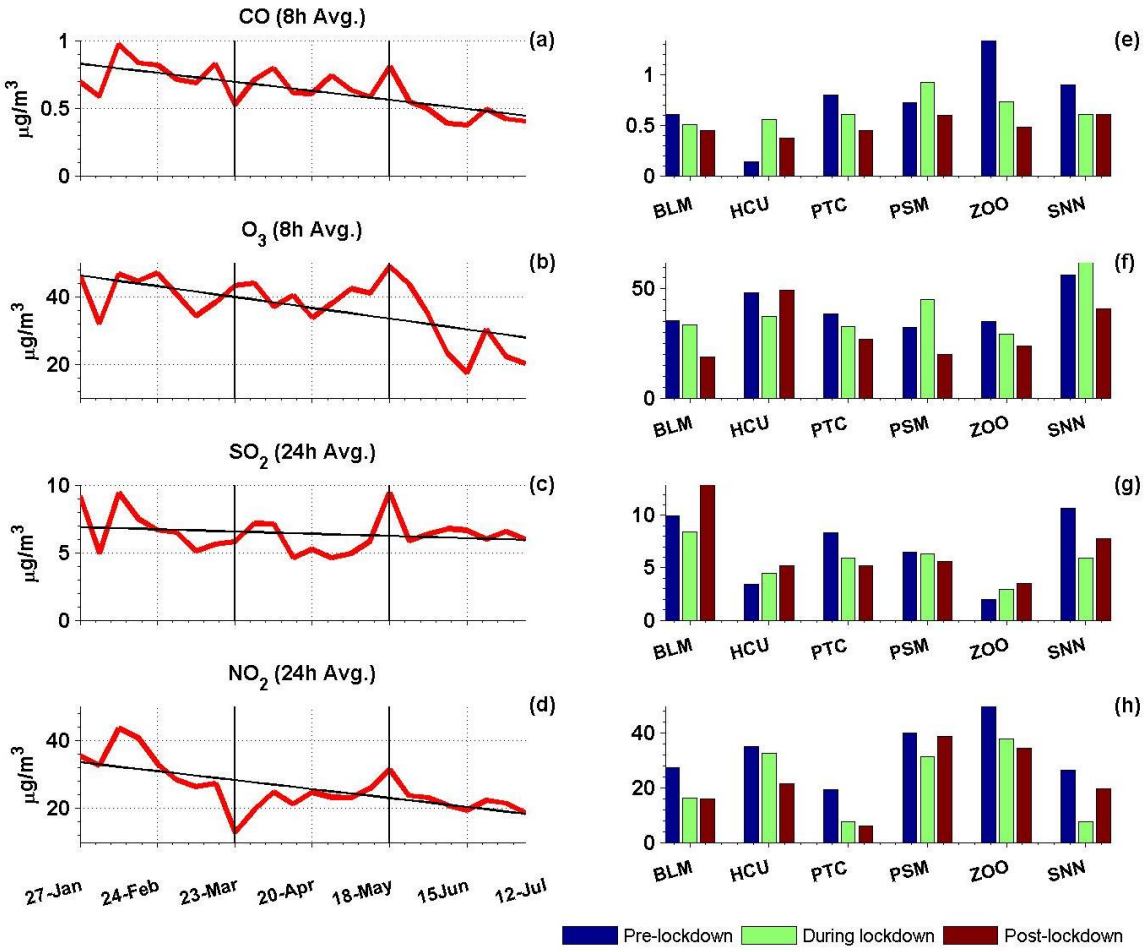

Fig 5. The mean temporal change in concentrations of pollutants averaged over all stations during the study period (a – d) with corresponding mean values for each station (e – h).

The variations in 8 hour average daily maximum of CO concentration across all stations did not appreciably decrease during lockdown when compared to pre lockdown or post lockdown. The most significant declination was observed in NO_2 (33%)

which is a common tracer of urban air pollution / industrial and transportation activity. This could be explained by the fact that the restrictions imposed by authorities during lockdown on industrial and transport activities resulted in the consequence of declination in NO_2 emission. Berman & Ebisureported that the urban countries show larger percent reductions in NO_2 concentrations [22]. An 8 hour average daily maximum concentration of O_3 in the lockdown period shows a negligible decrease (3%) and it is due to large spatial difference varying between -23 % to +39% across all the stations. In PSM and SNN stations there was an increase of 39% and 10% of O_3 concentrations respectively during lockdown when compared to pre lockdown. This increase may be due to fall of NO_2 which leads to low consumption of O_3 (titration, $NO + O_3 = NO_2 + O_2$), resulting an increase of O_3 concentrations and can also be attributed to more sunlight through the atmosphere encouraging more photochemical activities resulting in higher production of O_3. This increase in O_3 concentration could be due to significance of the location such as industrial, residential areas as mentioned Table 1. Mahnto et al. [4,23] also found similar observation over Delhi, another metropolitan city in India. A marginal decrease of SO_2 concentration was observed in the lockdown. Although, all pollutant levels did not exceed the NAAQ standard values during the study period. Further, a declination in air pollutants was observed during post lockdown which may be due to seasonal effect of monsoon.

During second and third phases of lockdown certain relaxations have been given for agricultural sector, restricted public transportation, controlled industrial activity which may also have an effect on concentration of pollutants during partial lockdown. Overall, the air quality has enhanced at all stations which clearly show positive impact of lockdown on air pollution when compared to non-lockdown period.

5 Conclusions

The enforcement of lockdown due to the COVID – 19 pandemic led to big change in life style and habits. On positive side, it led to a large improvement in the air quality and decline of air pollution. The benefit of this outbreak is that it showed a better future that we all want to accept. The changes that become part of our lives during this pandemic situation are – hygienic and health consciousness, work from home, online teaching, digital shopping and societal changes which may help the regulatory bodies and policy-makers to impose stringent rules to continue these changes at least partially so that the human activities have less effect on air pollution.

From these studies, we could note the government decisions in response to COVID – 19 have impact on air quality over Hyderabad. We observed an overall decline in $PM_{2.5}$ (27%) and PM_{10} (34%) during lockdown when compared to pre-lockdown. The restrictions imposed by government during lockdown on transportation, industrial and construction activities results a significant decrease of PM concentrations. COVID 19 epidemic control measures showed a significant reduction in PM concentration in 2020 when compared with the same period in 2018 and 2019. The contribution of $PM_{2.5}$ in PM_{10} (46%) during lockdown remains same when compared to previous years though the concentrations have decreased. Apart from particulate matter a significant declination (33%) observed in NO_2, could be due to cessation of transport and industrial activities which limits NO_2 emission during lockdown. Another noticeable point observed is that the mean concentration of other air pollutants showed a marginal decrease and remained below permissible limits (NAAQS) during study period. The present results give confidence to the authorities that the significant improvement in air quality could be expected if strict execution in implementing the air quality control plans is ensured.

Acknowledgment

The authors acknowledge Telangana State Pollution Control Board for making the data available to users. The authors would like to thank the management of Vasavi College of Engineering, Hyderabad, India and Aurora's Technological and Research Institute, Hyderabad, India for their active support and encouragement.

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