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Significant Changes in Urban Air Quality during Covid-19 Pandemic Lockdown in Rohtak City, India

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The global spread of Covid-19 brought a dramatic decrease in vehicular activities, industrial activities and tourism for a limited period of time during the lockdown phase (Year 2020). The variations in ambient air quality were studied in Maharshi Dayanand University, Rohtak city (Haryana state, India) during the lockdown period and pollutants data were gathered from Haryana State Pollution Control Board (HSPCB). The study was conducted for 186 days in three periods; first pre-lockdown, second during the lockdown and third during post-lockdown phase (62 days each). The results showed a significantly decreased the levels of air pollutants through the lockdown season in comparison to pre and post-lockdown concentrations of air pollutants. Mean $PM_{2.5}$ concentration was found to be higher than their standard limit for the episode of pre and post-lockdown and the mean value of $PM_{2.5}$ was 2.3 and 2.8 times higher in pre and post-lockdown compared to during the lockdown period. The average air quality index (AQI) during lockdown has shown a 64.1% decrease as compared to pre-lockdown data and a 69.3% reduction from post-lockdown period. Based on one way Analysis of variance (ANOVA) results show ozone accepts the null hypothesis that lockdown had no effect on the atmospheric pollutant concentration due to the increasing pattern of ozone concentration because of a decrease in the concentration of NOx, which breakdown ozone.

Keywords: Pollution, COVID-19, Lockdown, Haryana State Pollution Control Board, Atmosphere, Air pollutants.

INTRODUCTION

The world economy, health and the environment are being extremely affected due to the widespread COVID-19 pandemic in different ways. The virus is a single-stranded RNA virus with a diameter of 65-125 nm [1]. Causes that concern the most in this pandemic are its pace of being transmitted globally, its repeated emergence, the infection and death rate and the multiplicative effect in susceptible groups [2]. Also, like any other virus, this one too mutates as it replicates inside the body of the host and, as a result, new strains are formed, which are generally more contagious than the former strain. Particularly in India, till the second wave over 24000 mutations have resulted in a total of around 7000 variants of SARS-CoV-2, which are circulating in the country as per reports from diagnostic laboratories in February 2021 [3]. The human-to-human transmission of this virus through respiratory droplets was confirmed by WHO in January 2020 [4,5]. In India, the first corona infection case confirmed on January 30, 2020 in a student of Wuhan university natively from Thrissur district, India [6].

Soon, by the end of March 2020, the entire world entered in a lockdown phase at various levels as the epidemic had taken the form of a pandemic [7,8]. In India, due to the elevating rate of reported cases per day and the foreseeable looming crisis on the country, on 24th March 2020, India has announced a whole nationwide lockdown for a period of 21 days and was more extended on 14th April for 19 days in the second phase of lockdown followed by 14 days till 17th May 2020 in the third phase followed by 14 days more in fourth phase along with the districts being classified into three severity zones namely red, orange and green. This was followed by unlocking in six steps till November 2020. This nationwide lockdown during the pandemic created an unprecedented scope in research towards this direction and suggested formulation of policy measures for future in order to control air pollution of cities having poor air quality.

These containment measures, through government-laid restrictions on the commute of public along with the suspension of industrial activities, led to a steep decline in social and industrialized actions [9,10]. As a result of low fossil fuel combustion, less emission of greenhouse gases and an overall fall in energy consumption, pollution levels decreased drastically, whether it's air or water [4,9] decreasing harmful effects on the climate such as ozone layer depletion and greenhouse effect. This was a pleasant and much-needed change as increasing population growth coupled with unprecedented urban growth, which leads to intense industrialization, has made a disastrous impact on the environment. According to WHO report in 2018, every year, due to exposure to fine particles in polluted air average of 7 million people die [11]. Around 12.5% of total death in India caused because of air pollution only [12]. The foremost are cause of pollution is emission due to transportation, agriculture waste and biomass burning, construction activities and urbanization. Major anthropogenic source of particulate matter is industrialization and urbanization, use of sulfur containing fuel in various industrial sectors and thermal power plant release oxides of sulfur, oxides of nitrogen released mainly due to vehicular emission, industrial sector and thermal power plant [13]. Among the major cities in India with a population of over a million, the atmospheric air pollution levels surpass the WHO standards [14]. The decline in pollution level, which seemed farfetched throughout the last decade despite efforts by the Government's environmental policies and ecofriendly technologies, was achieved during the lockdown period.

Climatic factors such as humidity, temperature, rainfall, wind speed, due point are found to be correlated with COVID-19 transmissions and death in patients [15-19]. Recent studies reported in New York, Singapore, Norway, Indonesia and Turkey that temperature had strong positive correlation with COVID-19 pandemic and negative correlation reported in Mexico and China had no correlation with temperature [20]. Short-term variations in meteorological parameters during lockdown period have a positive effect on ambient air quality [13,21]. In this work, a trend in air pollution levels is analyzed by checking and observing the changes in ground level ozone, nitric oxide, nitrogen dioxide, particulate matter ($PM_{2.5}$), carbon monoxide, benzene, sulphur dioxide, along with important meteorological parameters such as temperature, humidity, wind speed, solar radiation, *etc*. within the phase of pre-lockdown, through lockdown and post-lockdown during the days mentioned in this study.

Different studies reported on short period exposure of COVID-19 with atmospheric pollution and found a significant positive relation between them. A study was performed in Malaysia and China found a strong positive relation between particulate matters, carbon monoxide, nitrogen dioxide, sulfur dioxide with COVID-19 [19,22]. The environment underwent some positive changes and improved a lot but degradation continues in the same ways like before all this happened, hence cannot be seen as a long-lasting pollution control, but these conditions have given us enough insight to develop effective environmental policies to avoid rapid increase of pollution in the future. Relevant knowledge can be formulated from reviews like this and can be implemented anywhere in the world to further research about the alterations in the environment due to COVID-19 [2]. In this article, information have been gathered from different agencies and analyzed to understand the air quality of Maharshi Dayanand University, Rohtak city, India during lockdown. The parameters of below-mentioned pollutants were taken from credible sources and the dependence of their concentration on meteorological parameters like rainfall, relative humidity, temperature and wind speed was also observed. Different statistical tools have been used for analysis of air pollutants during a pandemic period, such as Air Quality Index (AQI), Analysis of variance (ANOVA), SPSS software 22 and satellite image to analyze how the mentioned pandemic changed the environment.

EXPERIMENTAL

Rohtak city is spread over an area of 139.4 km^2. According to the census 2011, Rohtak had population of 940,128 with 509,038 males and 431,090 females. Rohtak being a part of education hub and the national capital region, the number of vehicles and population growth is increasing at a fast rate and the pollution levels have been high for the same reasons. A load of traffic is higher due to local transportation and vehicles passing through from other cities and movement of farm tractors and other heavy vehicles owing to prevalent agricultural practices in nearby rural areas.

The data of air pollutant concentration were gathered for selected parameters from M.D. University, Rohtak; an air quality monitoring station governed by Haryana State Pollution Control Board (HSPCB) [23]. The data collected [24] for three phases or periods, which were pre lockdown (1st Dec 2019 to 31st Jan 2020), during lockdown (26th March 2020 to 26th May 2020) and post-lockdown (1st Jan2021 to 3rd March 2021). Microsoft office excel 2007, SPSS 22 software and satellite images were used to compile the data. Air quality index (AQI) was calculated as per CPCB' recommendations [23,24] (Table-1).

$$AQI_j = \left(\frac{(IHI - ILO)}{(BHI - BLO)} \times (C_j - BLO) \right) + ILO$$

where C_j is a concentration of jth parameter, IHI and ILO corresponding AQI range, BHI and BLO is the breakpoints greater than and less than the concentration of jth pollutant (C_j).

RESULTS AND DISCUSSION

Effect of lockdown period on environment in Rohtak city: In order to study the significant effect of lockdown period on the atmospheric air quality of Rohtak city, 24 h of mean concentration of $PM_{2.5}$, SO_2, NO_2 and 8 h for CO and ozone air pollutants were taken from 1st December 2019 to 31st January 2020 (pre lockdown), 26th March 2020 to 26th May 2020 (during lockdown) and 1st January to 3rd March 2021 (post-lockdown) from M.D. University Rohtak, HSPCB and the result are compiled in Fig. 1a-f. These data were taken during lockdown, pre and post-lockdown and compared for different parameters in Fig. 1a-f, which correspond to $PM_{2.5}$, SO_2, NO_2,

TABLE-1
AIR QUALITY INDEX CATEGORIES ALONG WITH POLLUTANTS AND HEALTH BREAKPOINTS (CPCB)

AQI category (range)	$PM_{2.5}$ (24 h)	NO_2 (24 h)	SO_2 (24 h)	O_3 (8 h)	CO (8 h)
Good (0-50)	0-50	0-40	0-40	0-50	0-1
Satisfactory (51-100)	51-100	41-80	41-80	51-100	1.1-2
Moderately (101-200)	101-250	81-180	81-380	101-168	2.1-10
Poor (201-300)	251-350	181-280	381-800	169-208	1-17
Very poor (301-400)	351-430	281-400	801-1600	208-748	17-34
Severe (401-500)	430+	400+	1600+	748+	34+

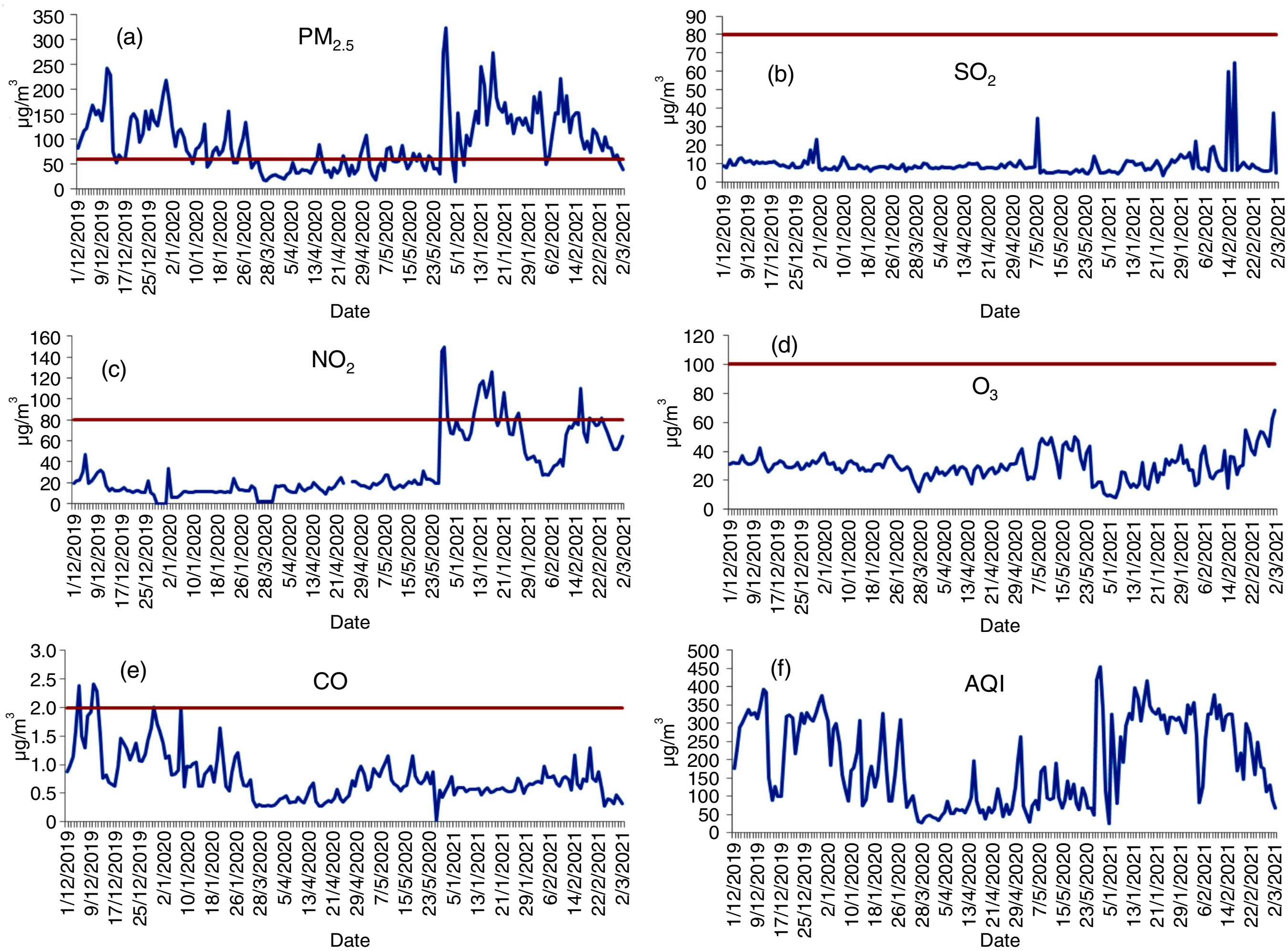

Fig. 1. Trends of air pollutant concentration in Rohtak city

ozone, CO and AQI. The graph plotted in Fig. 1a-f evidently indicates that due to COVID-19 lockdown episode (26th March to 26th May 2020), restriction on human activities such as transportation and closure of industries had a significant reduction in pollutant concentration at the time of lockdown period in comparison to pre and post-lockdown concentration of those air pollutants [25,26]. The mean concentration of $PM_{2.5}$ was 110.53 µg/m^3 before lockdown, 46.17 µg/m^3 during lockdown and 132.03 µg/m^3 after lockdown period showing that there was a significant decrease in the concentration of $PM_{2.5}$ during the lockdown period and met the national ambient air quality standard (24 h average 60 µg/m^3); which improved the overall Rohtak city atmospheric air quality by reducing the air pollution during lockdown period as the major cause of $PM_{2.5}$ pollutant reduction was restriction on vehicular movement and industrial activities. Significant fall in the $PM_{2.5}$ concentration was observed in different metropolitan cities, such as 62% in Kolkata, 53% in Kollam, 49% in Mumbai, 34% in Chennai and a 26% reduction in New Delhi during lockdown period [24,27]. The concentration of $PM_{2.5}$ was reduced 28% in a megacity, 33% in large, 16% in small cities and 23% in medium town [28]. The average AQI value during lockdown has a 64.1% reduction as compared to Dec 2019-Jan 2020 (pre lockdown) data and a 69.3% reduction from Jan-Mar 2021 (post-lockdown).

As seen in Table-2, a descriptive statistical study was done for atmospheric air pollutants using SPSS 22 software during lockdown (26th March 2020 to 26th May 2020), pre lockdown (1st Dec 2019 to 31st Jan 2020) and post-lockdown (1st Jan to

TABLE-2
STATISTICS OF VARIOUS ATMOSPHERIC POLLUTANTS IN ROHTAK CITY

Pollutant	Limit	Period	Minimum	Maximum	Mean	Standard deviation	Variance	Skewness	Kurtosis
$PM_{2.5}$ (µg/m^3)	60	Pre-lockdown	42.27	241.81	110.53	47.33	2241.038	0.731	0.126
		During lockdown	16.01	108.98	46.17	20.17	406.95	0.973	0.706
		Post-lockdown	14.68	323.15	132.03	58.98	3478.65	0.835	1.292
NO_2 (µg/m^3)	80	Pre-lockdown	5.97	46.78	15.42	7.86	61.884	1.833	3.785
		During lockdown	1.78	31.32	16.37	6.36	40.45	-0.711	0.97
		Post-lockdown	27.28	149.52	71.37	26.9	724.03	0.725	0.813
SO_2 (µg/m^3)	80	Pre-lockdown	6.15	23.4	9.57	2.734	7.48	2.579	10.462
		During lockdown	4.65	34.81	8.22	3.82	14.65	5.605	39.08
		Post-lockdown	3.85	64.69	11.34	10.69	114.38	3..91	816.46
CO (mg/m^3)	2	Pre-lockdown	0.54	2.41	1.16	0.463	0.215	0.959	0.433
		During lockdown	0.03	1.16	0.555	0.252	0.64	0.508	-0.483
		Post-lockdown	0.28	1.29	0.623	0.176	0.031	1.22	3.481
Ozone (µg/m^3)	100	Pre-lockdown	25.45	42.41	31.13	3.34	11.169	0.840	1.232
		During lockdown	12.39	49.8	30.34	9.45	89.347	0.545	-0.582
		Post-lockdown	8.15	68.52	29.15	13.64	186.17	0.711	0.215
AQI		Pre-lockdown	70.75	393.7	231.14	97.43	9493.18	-0.185	-1.39
		During lockdown	26.68	263.27	83.05	47.47	2253.44	1.76	3.29
		Post-lockdown	24.47	456.27	269.81	97.08	9426.05	-0.724	-0.166

3rd March 2021) data in Rohtak city, Haryana. The average concentration of gaseous pollutants, including NO_2, SO_2, CO_2 and ozone were found within standard limit given by NAAQS, CPCB 2009. In some cases after lockdown, the concentration of NO_2 crosses the standard limit 80 µg/m^3 and in pre lockdown period CO crosses the standard limit of 2 mg/m^3 as per obtained maximum value. During lockdown all given gaseous air pollutants were within the limit due to the closure of university campus, industries and vehicular transport activities. During lockdown, the concentration of NO_2, SO_2 and CO pollutants was 77.1%, 27.6% and11.3% less than the post-lockdown concentration. Similarly, the concentration of $PM_{2.5}$, PM_{10}, NO_2 and CO in megacity Delhi has shown a declining trend during lockdown [23]. Carbon monoxide and sulfur dioxide decreased by 67% and 62% and an increasing tread of ozone was observed during lockdown in Kollam [24]. The concentration of $PM_{2.5}$ was found to be higher in comparison to their standard limit and the mean value of $PM_{2.5}$ was 2.3 and 2.8 times higher in pre and post-lockdown period as compared to during lockdown period due to industrial emission, vehicular exhaust emission, construction, agricultural practices and re-suspended dust on highway due to traffic. During the lockdown period due to closure of all these sectors resulted in a decrease in air pollutants in the ambient environment [23].

Gradual decreasing trend of air pollutant concentrations, particularly $PM_{2.5}$ and PM_{10} were found associated to human mobility in Singapore during Covid-19 lockdown period [26]. During lockdown, in some cases, concentration of $PM_{2.5}$ was found to be higher than the limit as per maximum concentration (108.98 µg/m^3) due to dust storms, stubble burning and agriculture activities in nearby rural areas [13]. The mean AQI value in pre lockdown was 231.14 and 269.81 post-lockdown, depicting the worsened air quality condition unhealthy for human beings, which falls under poor category AQI. During lockdown period, AQI reduced by 64.1% from pre lockdown AQI value and post-lockdown the AQI value increased by 69.3% of lockdown period due to continuous service of the vehicles and industrial processes. The complete lockdown condition had a positive environmental impact on overall atmospheric conditions and the overall air quality improved during lockdown period [29]. High rate of air pollutants decreased with a strong outbreak of Covid-19 pandemic in major cities worldwide [30].

Impact of meteorological parameters: The intensity of rain is directly proportional to the air pollutant removal rate and rain scavenging is vital phenomenon for air pollutants removals such as $PM_{2.5}$, NO_2, SO_2, CO and ozone [25,31]. In the lockdown study period, there was no rainfall event or negligible rainfall. Dispersion of air pollutants mainly depends on ambient temperature and wind speed. As the summer season comes during lockdown season, the temperature increases and atmospheric stability decreases, as a result, mixing height increases and cause vertical mixing of air pollutant in the troposphere [32]. As the summer season comes, solar radiation enhances and causes a rise in temperature, leading to photochemical reaction in lower atmosphere. As shown in Table-3, the average temperature during lockdown increase by 2 times (13.5 ºC) than pre lockdown period and 1.3 times (6.8 ºC) higher than the post-lockdown period. The overall rise in temperature and intense solar radiation results in ground-level ozone formation, which ultimately reduces the other pollutants concentration by photochemical reaction. A study in Chandigarh city showed an increase in the concentration of ground-level ozone due to intense solar radiation at a higher temperatures during lockdown period due to photochemical reactions [25]. Higher wind speed during lockdown period resulted in a decrease in atmospheric pollutant concentration due to dispersion of pollutants [13]. Lower relative humidity causes the accrual rate of pollutants to increase, including $PM_{2.5}$, NO_2 and SO_2, during lockdown period as compared to others [33,34]. In present study, the relative humidity remained favourable for $PM_{2.5}$ accumulation during lockdown period and showed little fluctuation throughout the study period.

TABLE-3
MEAN VALUE OF METEOROLOGICAL PARAMETERS FOR DIFFERENT TIME PERIODS IN ROHTAK CITY

Study period	Temp. (°C)	WS (m/s)	RH (%)	WD (degree)	SR (W/m^2)
Pre-lockdown	12.28	0.73	61.21	99.24	94.89
During lockdown	25.77	0.86	54.26	111.14	209.36
Post-lockdown	18.98	1.23	49.35	133.62	122.74

Statistical analysis for various atmospheric parameters: In order to find out the outcome of lockdown on ambient air quality statistically, daily average data of around six months of Rohtak city, in which months from 1st December 2019 to 31st January 2020 (pre lockdown) were with a normal situation, two lockdown months 26th March 2020 to 26th May 2020 and then again two months post-lockdown from 1st January to 3rd March 2021were considered. Analysis of variance (ANOVA) one-way test was carried out for the analysis of data using excel, through a hypothesis that average pollutant concentration has no effect of lockdown. Table-4 summarized the result of one-way ANOVA for various parameters such as $PM_{2.5}$, NO_2, SO_2, CO, O_3 and benzene. The results show that the p-value of ozone is more significant than 0.05, which accepts the null hypothesis that lockdown has no effect on the concentration ozone pollutant. This is because of atmospheric chemistry, since NO_x consists of NO_2 and NO where NO_2 helps in formation of ozone by photochemical reaction and NO breakdown ozone. Vehicular or transport sector is responsible for almost 50% of NO_x emission in urban areas. So a reduction in vehicular emission during covid-19 lockdown eliminates NO_x emission and causes accumulation of ozone [29]. All other parameters reject the null hypothesis and have *p*-value less than 0.05, which indicates that lockdown has a significant effect on pollutants concentration such as $PM_{2.5}$, SO_2, NO_2, CO and benzene. In China NO_2 and CO were reduced by about 30 and 25% during Covid-19 lockdown [35,36]. Lockdown causes control on industries and transport sectors, which lead to a reduction in overall pollutant load in atmosphere [2].

A correlation study was performed for air pollutants, including $PM_{2.5}$, SO_2, NO_2, NO_x, NO, CO, O_3 and benzene, using SPSS 22 software at Rohtak city for six months (*i.e.* two months before lockdown, two during and two after lockdown months) (Table-5). $PM_{2.5}$ has a positive correlation with NO_2, NO_x, benzene and NO_2 has a positive correlation with benzene. A strong positive correlation of $PM_{2.5}$ was found with NO_2, NO,

TABLE-4
ANALYSIS OF VARIANCE (ONE WAY) FOR DIFFERENT AIR POLLUTANTS

Source of variation	SS	DF	MS	F	P-value	F crit	SS	DF	MS	F	P-value	F crit
	ANOVA $PM_{2.5}$						**ANOVA SO_2**					
Between groups	247518.7	2	123759.3	60.60051	0.00000	3.0453	304.1083	2	152.0541	3.341	0.0375	3.045312
Within groups	373725.5	183	2042.216				8327.321	183	45.50448			
Total	621244.2	185					8631.429	185				
	ANOVA NO_2						**ANOVA CO**					
Between groups	124667.020	2.000	62333.510	219.332	0.000	3.047	13.83	2.00	6.91917	66.91669	0.00000	3.04531
Within groups	50018.616	176.000	284.197				18.92	183.00	0.10340			
Total	174685.637	178.000					32.76	185.00				
	ANOVA O_3						**ANOVA benzene**					
Between groups	123.2362	2	61.61812	0.644793	0.525959	3.045312	360.1362	2	180.0681	93.64598	0.00000	3.045312
Within groups	17487.98	183	95.56271				351.8834	183	1.92286			
Total	17611.21	185					712.0196	185				

TABLE-5
CORRELATION MATRIX FOR VARIOUS AIR POLLUTANTS

		$PM_{2.5}$	NO	NO_2	NO_x	SO_2	CO	O_3	Benzene
Correlation	$PM_{2.5}$	1.000	.222	.596	.593	.159	.368	-.098	.511
	NO	.222	1.000	.148	.396	.108	.181	.002	.034
	NO_2	.596	.148	1.000	.902	.198	-.175	-.121	.618
	NO_x	.593	.396	.902	1.000	.210	-.062	-.133	.483
	SO_2	.159	.108	.198	.210	1.000	.064	.005	.040
	CO	.368	.181	-.175	-.062	.064	1.000	.163	-.177
	O_3	-.098	.002	-.121	-.133	.005	.163	1.000	-.420
	Benzene	.511	.034	.618	.483	.040	-.177	-.420	1.000
Sig. (1-tailed)	$PM_{2.5}$		.001	.000	.000	.017	.000	.095	.000
	NO	.001		.024	.000	.075	.008	.490	.326
	NO_2	.000	.024		.000	.004	.009	.053	.000
	NO_x	.000	.000	.000		.002	.206	.038	.000
	SO_2	.017	.075	.004	.002		.196	.473	.299
	CO	.000	.008	.009	.206	.196		.015	.009
	O_3	.095	.490	.053	.038	.473	.015		.000
	Benzene	.000	.326	.000	.000	.299	.009	.000	

NH_3 and benzene at the Ghaziabad location during a lockdown [2].

Principle component analysis: SPSS 22 software was used to recognize the sources of atmospheric pollutants [37]. In case of pre-lockdown period, factor analysis represents the cumulative variance of 82.47%, with four factors showing maximum variance as shown in Table-6. Factor 1 showed 35.04% variance with significant factor loading for $PM_{2.5}$, CO and ozone. Factor 2 showed 20.15% of variances with factor loading for NO_x and NO. Burning of fossil fuels and excessive use of vehicles are the primary sources of air pollutants such as $PM_{2.5}$, NO, NO_x and CO. Hence, it was found that the significant source of pollution is vehicular emission [28,38]. Factor 3 and factor 4 showed the factor loading of 13.9% and 13.3% for benzene and NO_2. Emission of benzene could be associated with residential and industrial exhaust.

During the lockdown periods the factor loading showed the maximum variance cumulative variance of 81.04% and factor 1 showed 40.85%, with factor loading for $PM_{2.5}$, NO, NO_2, CO and ozone showing the major source of pollutants is regional vehicular emission, dust storm, stubble burning and agricultural activities. Factor 2, factor 3 and factor 4 has 13.9%, 13.2% and 13% variance, respectively showed considerable factor loading for benzene, NO_x and SO_2. The source for SO_2 and benzene might be regional transport from a thermal power plants [39].

During the post-lockdown period, the factor analysis repre-sents three factors of maximum variance with a cumulative variance of 76.02%. Factor 1 represents 35.17% of variance for significant component loading for $PM_{2.5}$, NO, NO_x and NO_2. The major source is vehicular emission at large scale, industrial emission and wood or stubble and fuel burning for keeping warm during winter season [40]. Factor 2 and factor 3 represent 24.14% and 16.705% of variance for factor loading of ozone and SO_2 and CO due to emission from coal-burning power plants.

Air quality study using satellite images: The overall air quality is indicated by particulate matter, including $PM_{2.5}$ and PM_{10}; the emission of these pollutants is from different sources like fossil fuel burning, thermal power plants, other industries, road re-suspended dust particles and refuge from burning fuel and materials. Restrictions on all the activities in the entire country due to lockdown COVID-19 situation cause a significant reduction in the quantity of particulate matter. $PM_{2.5}$ and PM_{10} satellite image was observed to analyze the changes in the concentration of particulate matter in Fig. 2. The satellite image was taken on 10th April 2019 (pre-lockdown), 10th April 2020 (during lockdown) and 10th April 2021 (post-lockdown). The satellite images clearly show the concentration of $PM_{2.5}$ and PM_{10} has decreased during lockdown on 10th April 2020. And particulate matter load was higher on 10th April 2019 and 2021 all over India. Higher amount of particulate matter have an effect on human health by degrading atmospheric quality, which leads to cardiopulmonary disease, lung cancer and premature death [41]. A significant amount of particulate matter decreases in the Delhi NCR region, which is the hotspot of air pollution [2].

Conclusion

The present study exposed substantial decrease in the concentration of atmospheric pollutants over the area of Rohtak city, during the lockdown which was imposed in India due to the pandemic Covid-19. The mean concentration of air pollutants that were found, such as $PM_{2.5}$ 46.17 µg/m^3, NO_2 16.37 µg/m^3, SO_2 8.22 µg/m^3, CO 0.55 mg/m^3 showed a significant reduction during lockdown due to limitation on vehicle transport, industrial activities imposed by the government to manage and stop the spread of a pandemic. Meteorological parameters indicated an important function is reducing of atmospheric pollutants but the rainfall was minimum and had no significant impact on air pollutants. The AQI analysis concluded that the atmospheric quality improved significantly during lockdown period. The mean value of AQI was 83.05, which falls under the category of satisfactory atmospheric air quality. The lockdown restricted the spread of infection and also improved the atmospheric condition and restored the quality environment for living beings. Principle component analysis showed that the major source of pollution was stubble burning, agricultural residue, dust storms and local vehicular transport during lockdown period. Satellite images reflect the reducing trend of $PM_{2.5}$ and PM_{10} in the Indian atmosphere during lockdown period compared to other time period. The present study may help in thinking about how far we are responsible for degradation of the atmosphere and overall environment by looking

TABLE-6
PRINCIPLE COMPONENT ANALYSIS FOR WHOLE STUDY PERIOD IN ROHTAK CITY

Parameter	Before lockdown				During lockdown				After lockdown		
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3	Factor 4	Factor 1	Factor 2	Factor 3
$PM_{2.5}$	.790	-.385	.214	-.054	.720	.228	-.283	.235	.648	-.428	-.138
NO	.288	.652	.374	-.531	.838	-.161	.178	-.207	.690	.499	.235
NO_2	.580	.417	-.339	.557	.801	-.248	.010	.144	.900	.054	-.186
NOx	.553	.772	-.060	-.086	.245	-.495	.727	.175	.929	.291	-.042
SO_2	.505	-.410	-.147	-.538	-.010	.491	.272	.794	.153	.273	.639
CO	.817	-.257	.144	.084	.876	.130	-.011	-.005	-.118	-.112	.849
Ozone	.716	-.186	.045	.235	.760	.222	-.173	-.173	-.430	.708	-.309
Benzene	-.138	.013	.876	.334	.020	.648	.558	-.486	.150	-.907	.016
Eigenvalue	2.804	1.613	1.116	1.065	3.269	1.112	1.057	1.046	2.814	1.931	1.336
Variance (%)	35.049	20.156	13.954	13.315	40.858	13.906	13.211	13.073	35.178	24.141	16.703
Cumulative (%)	35.049	55.205	69.159	82.474	40.858	54.763	67.974	81.047	35.178	59.319	76.022

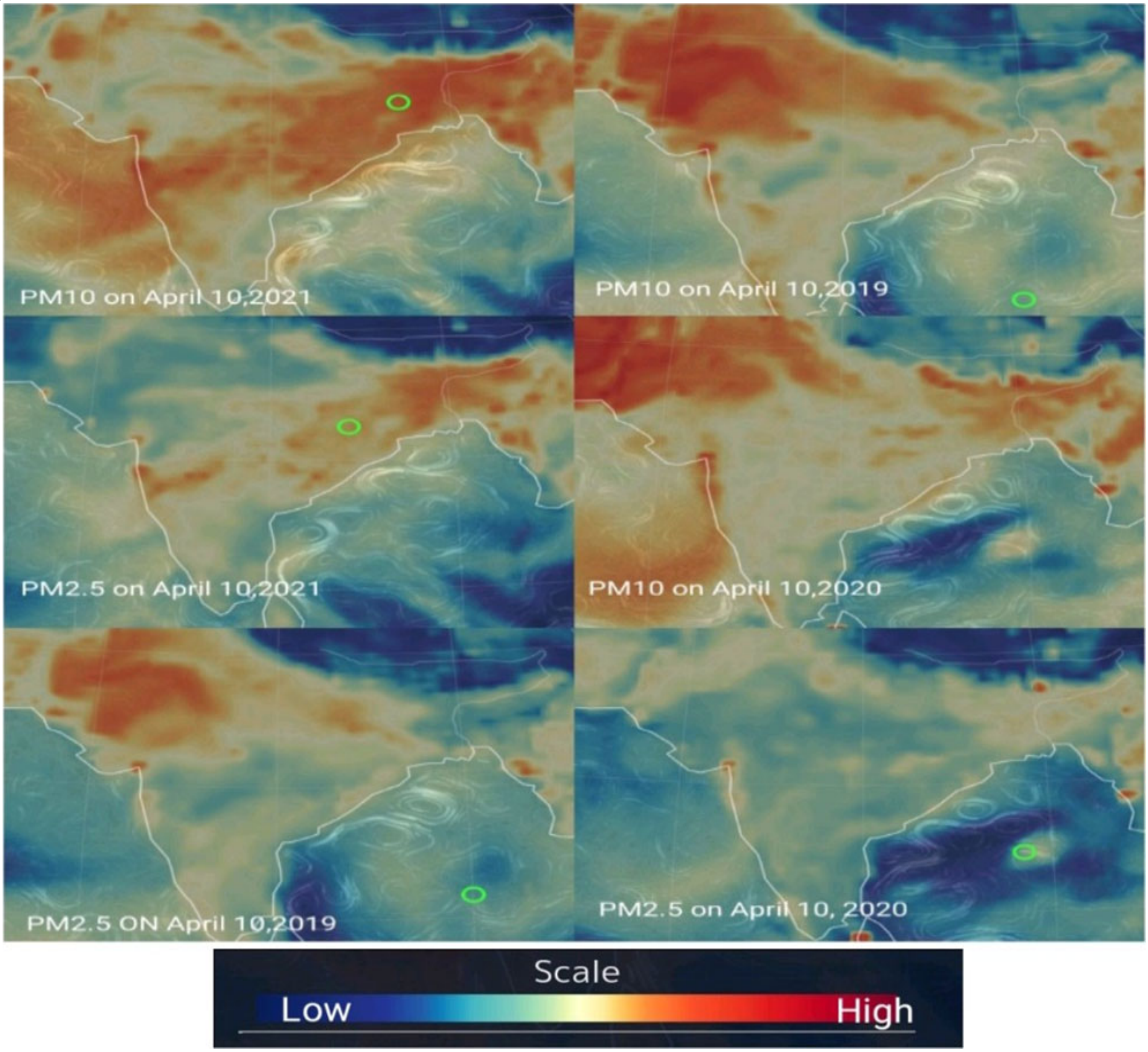

Fig. 2. Satellite image of levels of $PM_{2.5}$ and PM_{10} in Indian atmosphere (nullearth.com)

at the drastic fall and rise in the concentrations of mentioned pollutants due to the Government's strict control of the major anthropogenic activities, which are generally considered polluting for the climate. The effects were so profound due to the imposition of lockdown throughout the world simultaneously, which teaches us that the improved quality of the environment can be maintained to an extent if unified efforts are made.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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