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A comparative study of air quality assessment before and during lockdown among Metro Cities of India

Chaturvedi P.[1], Rathore K. S. [2], Chaturvedi M.[3] and Singh S.[1]✉

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Abstract

The aim of present study was to compare the air quality before and during lockdown due to COVID-19 pandemic at selected metro cities of India (Delhi, Kolkata, Bangalore, and Mumbai). The data of the selected parameters (Particulate Matter having diameter equal to or less than 2.5micron ($PM_{2.5}$), Particulate Matter having diameter equal to or less than 10micron (PM_{10}), Nitrogen oxides (NO_2), Ammonia (NH_3), Sulphur oxides (SO_2) Carbon monoxides (CO), and Ozone (O_3) for the present study was collected from the official website of Central pollution Control Board (CPCB) and analyzed by calculating mean, standard deviation, total variance, and correlation coefficient. Dendrogram analysis was also performed site wise. The concentration of all the parameters except ozone was found highest at Delhi among all the sites. Ozone values were found highest at Bangalore. A strong correlation was observed between PM_{10} and $PM_{2.5}$ at all the sites during the study period. A great change in the values of all the studied parameters was observed before and during the lockdown periods. In metro cities values of $PM_{2.5}$ was found higher than PM_{10} except at Bangalore where values of $PM_{2.5}$ was found lower than PM_{10}. Among all the studied metro cities, Delhi was found highly polluted before and during the lockdown period while Bangalore was found least polluted.

Key Words: ***Air Pollution, Covid-19, CPCB, Lockdown, Pollutant***

Introduction

First lockdown during COVID-19 pandemic was declared by Government of India on March 22nd 2020 and was continued in three regular phases up to 31st May 2020. In India the first case of COVID-19 was observed in Kerala on 30th January 2020 and number increased to three by 3rd February 2020; all passengers came from Wuhan, China, but there is no further rise in cases during the month of February 2020. On 4th March 2020, 22 new patients came into highlight. These people were the members of a tourist group return back from Italy. The government of India followed lockdowns in whole country on 24th March 2020 for 21 days and continued further for 3 more phases of 19,14 and 14 days respectively which ends on 31st May 2020. During the 3rd and 4th phase of lockdown some relaxations was given by Government of India, so that the financial activities were started with the opening of market and highways to maintain the supply of food and daily needs and to maintain the economy of country and livelihood of the citizens. With the huge crowd of population of around 1.3 billion Indian has paid their responsibility towards the COVID-19. The WHO (World health organisation) and most of the countries continuously appreciates the strategy of Indian Government during this pandemic situation to break the chain of corona virus and to stop community transmission. During the initial phase of lockdown period, transportation and out-going of the peoples were strictly prohibited. The immediate effect of this action, downfall in air pollutant gases was noticed. Such gases directly affect the human health. It decreases the total lung capacity by chocking the alveoli of lungs, various gases are carcinogenic and toxic in nature. A study on SARS showed positive response of pollutant on long term exposure to pollution based on 2002/03 (Cui *et al.*, 2003). These gases also disrupt agricultural practices, wild life and whole of the ecosystem directly hampered due to these pollutants. One of every eight death is directly related to the cause of air pollution. This situation is more dangerous in metro cities of India due to high level of air

Author's Address
[1]Department of Environmental Sciences, School of Sciences, ITM University, Gwalior (M.P.) India
[2]Department of Biotechnology, K. R. G. (Auto) P. G. College, Gwalior (M.P.) India
[3]School of Agriculture, ITM University, Gwalior (M.P.) India
E-mail.: *shivomsingh101@gmail.com*

pollution especially in New Delhi, Mumbai, Bengaluru and Kolkata. Present study provides us a clear picture of air quality index of above-mentioned cities under lockdown period and help strategy planners for future betterment.

Material and Methods

In present set of investigation, we analyzed data of initial 2020 up to lockdown period which is analyzed from National Air Quality Index (NAQI) of Central Pollution Control Board (CPCB) from 1st January to 31st May 2020. Data includes first two months of normal pollution trend of studied cities and the 3rd month that is March under partial lockdown whereas April follows the strict implementation of lockdown. From May 2020 the opening of lockdown was considered and all the conditions were regularly monitored during this period. Data were collected from the official website https://app.cpcbccr.com/AQI_India of Central pollution Control Board (CPCB) and analyzed. All the data presenting here is the mean of a complete month with standard error value. Statistical analysis is done with the help of Minitab 18 software.

Results and Discussion

The results of all the studied sites (Delhi, Bangalore, Kolkata, and Mumbai) of all the studied parameters (PM_{10}, $PM_{2.5}$, NO_2, SO_2, NH_3, O_3 and CO) were given in table 1 to 10d and figure 1-8d.

During and after lockdown period it was observed that the concentration of all the pollutants were decreased, only New Delhi and Mumbai showed increased concentration of SO_2. The significant decrease in concentration of $PM_{2.5}$ was observed during lockdown period i.e., March-June over January and February (Table1-4). Similar trends were observed in PM_{10}, NO_2, NH_3 and CO. The concentration of O_3 and SO_2 increased during lockdown phase because of powerplant and coal burning was allowed during this period. The OH radicle removed due to increase in atmospheric temperature and sunlight. Above mention line is responsible for high concentration of O_3. This reaction is speeded up in warmer conditions and with more UV-light. Major photochemical paths for O_3 sink are photolysis followed by the reaction of O (1D) with water vapor and via its reaction with hydrogen oxide radicals (HOx) (Monks, 2005; Wayne, 2000).Central Pollution Control Board (CPCB) of India reported that Air Quality assessment improved during lockdown period and the concentration of pollutant gases decreased up to a certain level. Similar to Mumbai, In New Delhi AQI improved during lockdown period. The Mumbai city was less pollutant in compared to the New Delhi city because of three side sea surrounding and movement of air towards the sea breeze. The comparatively similar association between SO_2, NOx, and CO and meteorological parameters (temperature and relative humidity) was also found at another urban site (Kumari and Toshniwal, 2020). In figure-1 the trend of concentration of $PM_{2.5}$ was found in order of, New Delhi> Kolkata> Mumbai> Bangalore. The maximum concentration of $PM_{2.5}$ recorded in New Delhi in month of January due to burning of agriculture waste. The emission of these pollutants increases the overall toxic burden of the environment, as well as deteriorate the ambient air quality (Ibe *et al.,* 2017: Njoku and Ibe, 2009). Similarly decreasing trend was seen in the month of February and March and minimum in April and May. In Figure-2 the concentration of PM_{10} was observed as, New Delhi > Kolkata > Mumbai > Bangalore. The elevated mean concentrations of PM_{10} across the locations could be attributed to the tendency of PM_{10} to be transported over short and long distances as a result of its particle size (Prospero *et al.,* 1981). During the lockdown PM_{10} concentration decreases in New Delhi over other months due to decrease in the construction of roads, industrial work and other activity in NCR region. Figure-3 indicates different trend in concentration of NO_2, the obseved concentration was in order Kolkata>New Delhi>Mumbai>Bangalore. Sources of NO_2 are wood burning in rural areas and fuel burning by automobiles. The lifetime of NO_2 can vary with the photochemical environment, but is typically on the order of hours to a day (Seinfeld and Pandis, 1998) which further oxidizes into HNO_3 and peroxyacetyl nitrate (PAN) (Sun *et al.,* 2011). Highest concentration was observed in New Delhi and Kolkata during January and February due to heavy automobile load and industrial activity, however, gradually decline was found during lockdown period due to decrease in mentioned activities.

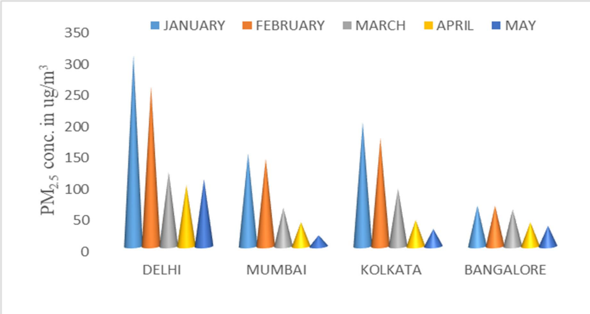

Figure 1. PM $_{2.5}$ concentration at the different metro cities

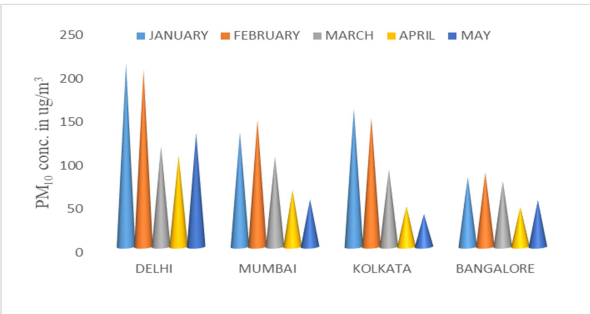

Figure 2. PM_{10} concentration at the different metro cities

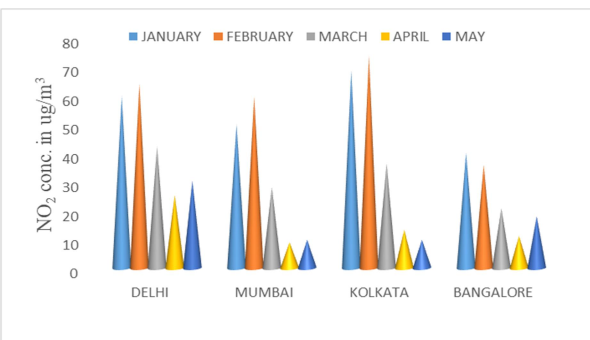

Figure 3. NO_2 concentration at the different metro cities

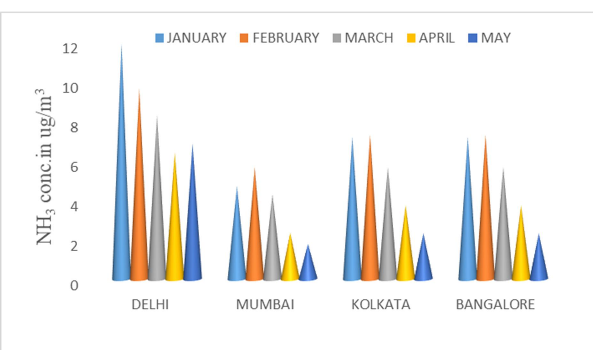

Figure 4. NH_3 concentration at the different metro cities

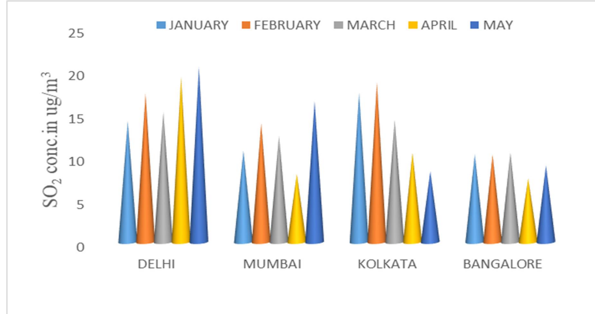

Figure 5. SO_2 concentration at the different metro cities

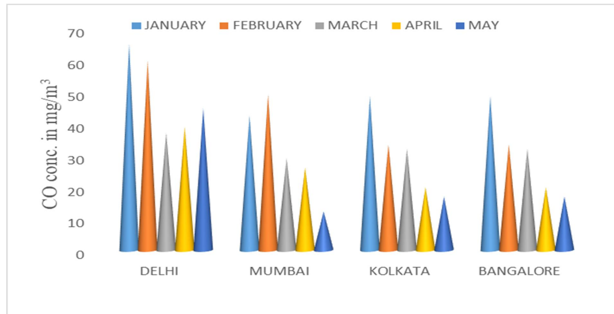

Figure 6. CO concentration at the different metro cities

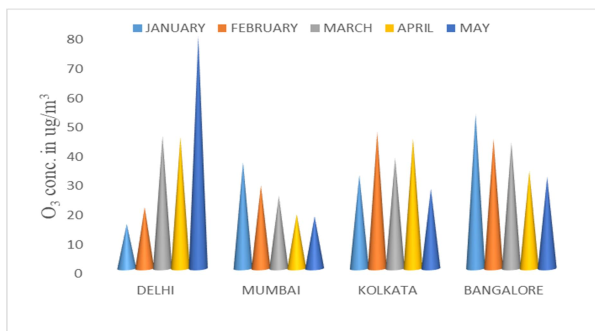

Figure 7. O_3 concentration at the different metro cities

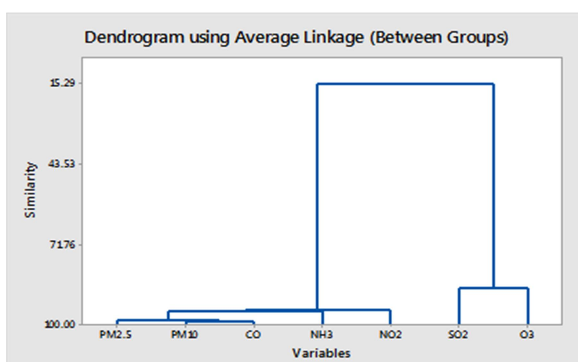

Figure 8a. The hierarchal cluster analysis of New Delhi city

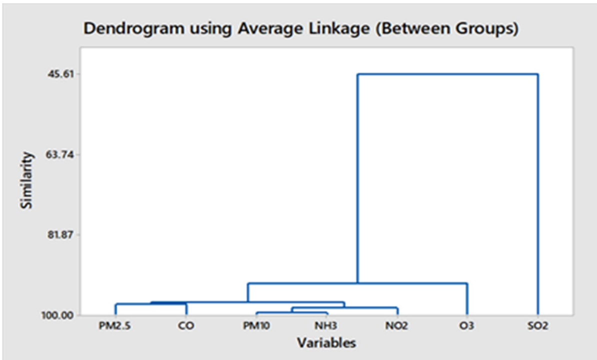

Figure 8b. The hierarchal cluster analysis of Mumbai city

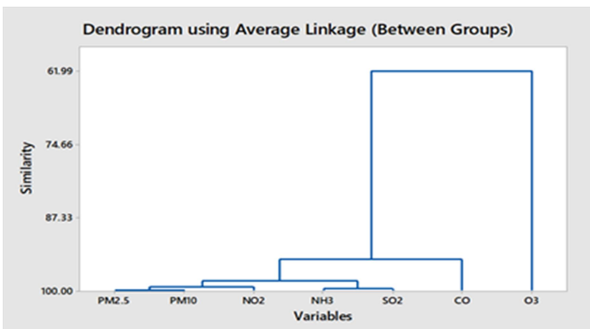

Figure 8c. The hierarchal cluster analysis of Kolkata city

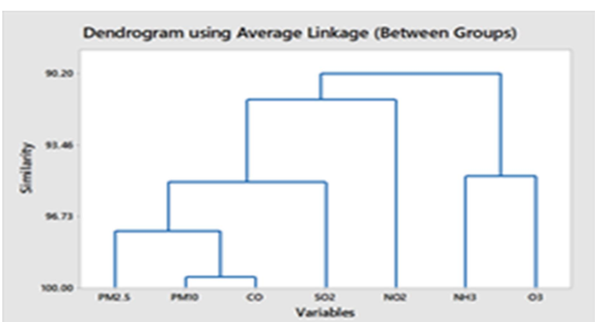

Figure 8d. The hierarchal cluster analysis of Bangalore

Furthermore, figure-4 shows maximum concentration of NH_3 is New Delhi and minimum in Mumbai. NH_3 has a residence time in the atmosphere of only a day or less, it contributes to the formation of atmosphere aerosols that reside in the atmosphere for several days to a week (Galperin and Sofiey, 1998).
The concentration of SO_2 showed different trend at different places (figure-5). In India, about 60 % of SO_2 emissions may be due to the consumption of coal and oil products, mainly from industry (36 %) and transport (7.8 %), and others include biomass and non-energy consumption (Garg *et al.,* 2001). Figure-6 indicates the trends of the CO concentration in order New Delhi> Mumbai> Kolkata> Bangalore. The maximum concentration of CO was in New Delhi because of the major sources of CO are emission from fossil- and biofuel combustion, biomass burning, and oxidation of methane (CH_4) and non-methane hydrocarbon (NMHC) (Logan *et al.,* 1981; Crutzen and Andreae 1990). Decrease in concentration was observed during the lockdown period due to decrease in above mentioned activities. The trends of pollutant gas O_3 was found maximum in Bangalore and minimum in Mumbai. The high solar radiation intensity (i.e., temperature) has a direct influence on chemical kinetics and rates and the mechanism pathways for the O_3 production (Pudasainee *et al.,* 2006; Han *et al.,* 2011). Other major factor in New Delhi is landlock condition by nearby NCR region. However, this study suggested that the negative O_3-relative humidity correlation attributed to several other meteorological factors directly influencing O_3 production (Tawfik and Steiner, 2013).
Figure-8a to figure-8d indicated the hierarchical cluster analysis (HCA) and was carried out to show the similarities and dissimilarities between the source and occurrence of the atmospheric pollutants. The result obtain from cluster analysis are represented as dendrogram. In figure 8a pollutants of New Delhi region ($PM_{2.5}$, PM_{10}, NO_2, NH_3, $SO_{2)}$ show high similarity in cluster 1 where as it does not have any association with CO and O_3. In Fig. 8b Mumbai city dendrogram shows cluster 1 as SO_2 and does not have any similarity with other pollutants. In addition, in cluster 2 $PM_{2.5}$, PM_{10}, CO, NH_3, NO_2 and O_3 depicts similarity with each other in a tree. In Figure 8c Kolkata dendrogram shows cluster 1 of O_3 and does not have any association with other pollutants, whereas, rest all the pollutants in cluster 2 shows similarity with each other. Figure-8d depicts dendrogram of Bangalore city where all the pollutants in cluster 1 and 2 not form any association with each other hence all the pollutant show dissimilarity with each other. Table 5 and 6 are the total variance of the air pollutants and rotated component matrix of the atmospheric pollutants. Table 5 indicates that there are two components with initial Eigen value more than 1.00. The result revealed that PC1 & PC2

Table 1. Concentration of various pollutants in Delhi city before and during lockdown period

Months	Air Quality Index Parameters						
	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	NO_2 (µg/m^3)	NH_3 (µg/m^3)	SO_2 (µg/m^3)	CO (mg/m^3)	O_3 (µg/m^3)
January	305.300^{a} ±14.315	210.373^{a} ±11.103	59.576^{ab} ±3.056	11.900^{a} ±0.377	14.066^{c} ±0.419	65.146^{a} ±4.191	15.200^{b} ±1.086
February	254.446^{a} ±29.478	203.500^{a} ±22.866	63.940^{a} ±5.852	9.630^{ab} ±0.351	17.290^{abc} ±2.217	59.666^{ab} ±7.070	20.953^{b} ±2.930
March	118.610^{b} ±13.434	115.526^{b} ±16.129	42.176^{bc} ±6.074	8.300^{b} ±0.799	15.130^{bc} ±1.265	37.053^{c} ±1.699	45.160^{ab} ±10.014
April	107.103^{b} ±3.545	104.950^{b} ±11.281	25.313^{c} ±1.024	6.413^{b} ±1.000	19.183^{ab} ±1.529	38.890^{c} ±0.735	44.856^{ab} ±4.101
May	97.593^{b} ±6.628	107.14^{b} ±6.962	30.323^{c} ±4.455	6.846^{b} ±0.290	20.373^{a} ±2.095	44.753^{bc} ±1.938	79.113^{a} ±17.414

Table 2. Concentration of various pollutants in Mumbai city before and during lockdown period

Months	Air Quality Index Parameters						
	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	NO_2 (µg/m^3)	NH_3 (µg/m^3)	SO_2 (µg/m^3)	CO (mg/m^3)	O_3 (µg/m^3)
January	147.670^{a} ±15.254	131.700^{a} ±2.981	49.786^{ab} ±0.477	4.700^{a} ±0.310	10.620^{a} ±0.909	42.386^{ab} ±3.755	36.313^{a} ±6.444
February	139.693^{a} ±9.816	146.053^{a} ±7.395	59.370^{a} ±4.373	5.666^{a} ±0.235	13.850^{a} ±2.457	49.046^{a} ±3.558	28.323^{a} ±3.437
March	61.450^{b} ±8.910	104.150^{ab} ±17.821	28.013^{bc} ±8.901	4.290^{a} ±0.395	12.340^{a} ±1.712	28.963^{bc} ±4.561	24.670^{a} ±2.784
April	38.440^{b} ±4.935	65.336^{bc} ±7.269	8.926^{c} ±1.036	2.343^{b} ±0.130	7.943^{a} ±1.269	26.050^{bc} ±6.777	18.520^{a} ±1.893
May	17.696^{b} ±2.228	54.676^{c} ±7.629	9.796^{c} ±1.243	1.773^{b} ±0.259	16.426^{a} ±4.707	12.203^{c} ±0.579	17.796^{a} ±3.299

Table 3. Concentration of various pollutants in Kolkata City before and during lockdown period

Months	Air Quality Index Parameters						
	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	NO_2 (µg/m^3)	NH_3 (µg/m^3)	SO_2 (µg/m^3)	CO (mg/m^3)	O_3 (µg/m^3)
January	197.853^{a} ±8.701	158.613^{a} ±7.823	68.413^{a} ±4.857	7.196^{a} ±0.413	17.390^{a} ±0.947	48.520^{a} ±3.829	31.890^{a} ±7.661
February	172.173^{a} ±10.375	148.040^{a} ±7.729	73.530^{a} ±4.584	7.306^{a} ±0.443	18.566^{a} ±1.346	33.296^{b} ±2.066	46.480^{a} ±5.171
March	92.333^{b} ±13.305	89.036^{b} ±12.298	36.320^{b} ±7.839	5.680^{a} ±0.416	14.210^{ab} ±1.150	31.930^{b} ±3.677	37.683^{a} ±8.808
April	41.896^{c} ±13.017	46.763c ±11.263	13.263^{c} ±1.960	3.733^{b} ±0.400	10.396^{bc} ±1.276	19.826^{c} ±1.954	44.270^{a} ±6.172
May	27.706^{c} ±1.236	37.726^{c} ±2.293	9.813^{c} ±1.706	2.310^{b} ±0.489	8.256^{c} ±1.095	16.906^{c} ±0.978	27.173^{a} ±2.031

Table 4. Concentration of various pollutants in Bengalore City before and during lockdown period

Months	Air Quality Index Parameters						
	$PM_{2.5}$ (µg/m^3)	PM_{10} (µg/m^3)	NO_2 (µg/m^3)	NH_3 (µg/m^3)	SO_2 (µg/m^3)	CO (mg/m^3)	O_3 (µg/m^3)
January	65.000^{a} ±4.380	80.226^{ab} ±4.833	39.943^{a} ±1.828	3.393^{a} ±0.232	10.226^{a} ±0.549	48.446^{a} ±2.305	52.663^{a} ±6.914
February	64.853^{a} ±3.110	85.326^{a} ±1.558	35.730^{ab} ±8.124	3.203^{a} ±0.151	10.173^{a} ±1.668	48.756^{a} ±2.191	44.103^{ab} ±3.517
March	59.080^{ab} ±10.262	75.706^{ab} ±10.356	20.793^{abc} ±4.689	3.080^{a} ±0.147	10.433^{a} ±0.334	47.190^{a} ±0.776	43.013^{ab} ±0.916
April	38.496^{ab} ±4.812	45.580^{c} ±3.520	17.976^{bc} ±0.335	2.776^{a} ±0.205	7.423^{a} ±0.556	29.343^{b} ±2.399	33.220^{b} ±1.172
May	32.853^{b} ±3.974	53.710^{bc} ±2.522	11.106^{c} ±1.073	2.106^{b} ±0.212	8.926^{a} ±0.296	34.116^{b} ±2.283	31.22^{b} ±2.665

Values are represented as mean ± SE

*Levels not connected by the same letters in horizontal row are monthly significantly different.

Table 5. Total variance of air pollutants concentration for Delhi city

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variances	Cumulative	Total	% of variances	Cumulative	Total	% of variances	Cumulative
1	5.185	74.100	74.100	5.185	74.100	74.100	4.015	57.400	57.400
2	1.195	17.100	91.100	1.195	17.100	91.100	1.410	20.100	77.500
3	0.279	4.000	95.100						
4	0.168	2.400	97.500						
5	0.115	1.600	99.200						
6	0.044	0.600	99.800						
7	0.014	0.200	100.000						

Table 6. Total variance of air pollutants concentration for Mumbai city

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variances	Cumulative		Total	% of variances	Cumulative		Total
1	5.028	71.800	71.800	5.028	71.800	71.800	4.319	61.700	61.700
2	1.119	16.000	87.800	1.119	16.000	87.800	1.288	18.400	80.100
3	0.556	7.900	95.800						
4	0.181	2.600	98.300						
5	0.063	0.900	99.300						
6	0.034	0.500	99.700						
7	0.018	0.300	100.000						

Table 7. Total variance of air pollutants concentration for Kolkata city

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variances	Cumulative		Total	% of variances	Cumulative		Total
1	5.622	80.300	80.300	5.622	80.300	80.300	5.372	76.700	76.700
2	1.052	15.000	95.300	1.052	15.000	95.300	1.088	15.600	92.300
3	0.131	1.900	97.200						
4	0.091	1.300	98.500						
5	0.087	1.200	99.700						
6	0.014	0.200	99.900						
7	0.004	0.001	100.000						

Table 8. Total variance of air pollutants concentration for Banglore city

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of variances	Cumulative		Total	% of variances	Cumulative		Total
1	5.062	72.300	72.300	5.062	72.300	72.300	1.366	19.500	19.500
2	0.803	11.500	83.800	0.803	11.500	83.800	1.344	19.200	38.700
3	0.447	6.400	90.200						
4	0.258	3.700	93.900						
5	0.233	3.300	97.200						
6	0.202	2.600	99.800						
7	0.012	0.200	100.000						

Table 9. Rotated Component matrix

Variable	Delhi		Mumbai		Kolkata		Banglore	
	1	2	1	2	1	2	1	2
PM 2.5	0.919	-0.191	0.890	0.389	0.988	-0.053	0.481	0.312
PM 10	0.953	-0.005	0.924	0.297	0.990	-0.062	0.269	0.362
NO_2	0.828	-0.179	0.923	0.299	0.989	-0.092	0.263	0.310
NH_3	0.718	-0.448	0.876	0.266	0.918	-0.129	0.878	0.160
SO_2	-0.070	0.968	0.030	0.092	0.901	-0.217	0.151	0.927
CO	0.953	-0.113	0.967	0.128	0.882	-0.124	0.383	0.366
O_3	-0.385	0.438	0.344	0.930	0.070	-0.997	0.481	0.312

Table 10a. Correlation analysis of atmospheric pollutants of New Delhi city

Parameters	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1						
PM_{10}	0.975	1					
NO_2	0.921	0.920	1				
NH_3	0.951	0.886	0.896	1			
SO_2	-0.640	-0.495	-0.679	-0.826	1		
CO	0.966	0.985	0.845	0.864	-0.436	1	
O_3	-0.830	-0.725	-0.808	-0.809	0.742	-0.690	1

Table 10b. Correlation analysis of atmospheric pollutants of Mumbai city

Parameters	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1						
PM_{10}	0.956	1					
NO_2	0.965	0.985	1				
NH_3	0.899	0.987	0.954	1			
SO_2	-0.127	-0.033	0.072	-0.029	1		
CO	0.950	0.954	0.935	0.932	-0.252	1	
O_3	0.931	0.869	0.862	0.805	-0.155	0.808	1

Table 10c. Correlation analysis of atmospheric pollutants of Kolkata city

Parameters	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1						
PM_{10}	0.950	1					
NO_2	0.835	0.876	1				
NH_3	0.926	0.764	0.696	1			
SO_2	0.820	0.930	0.755	0.567	1		
CO	0.945	0.990	0.844	0.761	0.960	1	
O_3	0.932	0.862	0.878	0.897	0.767	0.879	1

Table 10d. Correlation analysis of atmospheric pollutants of Bangalore city

Parameters	$PM_{2.5}$	PM_{10}	NO_2	NH_3	SO_2	CO	O_3
$PM_{2.5}$	1						
PM_{10}	0.998	1					
NO_2	0.983	0.991	1				
NH_3	0.953	0.964	0.963	1			
SO_2	0.959	0.972	0.982	0.993	1		
CO	0.931	0.918	0.862	0.886	0.856	1	
O_3	0.181	0.210	0.279	0.389	0.395	-0.018	1

accounts for 57.400% and 20.100% of the variance respectively. Result obtained from table 6 suggested that while PM $_{2.5}$, PM $_{10}$, NO_2, NH_3, and CO have positive loading in PC1 with correlation coefficient value of 0.919, 0.953, 0.823, and 0.718 respectively. Similarly, SO_2 has a high loading in PC2 with correlation coefficient of 0.968. It should be noted that all the pollutants are not correlated.

Table 11 and 12 are the total variance of the air pollutants and rotated component matrix of the atmospheric pollutants ($PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO, O_3) at Bangalore city at the normal and lockdown phase. The table 11 indicates that there is one component with initial Eigen value greater than 1.0. The result revealed that PC1 and PC2 accounted for 19.500% and 19.200% of the variance respectively. Result obtained from table suggested that $PM_{2.5}$, PM_{10}, NO_2, NH_3, SO_2, CO, and O_3 have positive loading with values in PC1 and PC2 with correlation coefficient. Correlation analysis of New Delhi city during the normal and lockdown is presented in table 10a. The result revealed a strong positive correlation between $PM_{2.5}$ and PM_{10} (r = 0.975), $PM_{2.5}$ and NO_2 (r = 0.921), $PM_{2.5}$ and NH_3 (r= 0.951) and $PM_{2.5}$ and CO (r= 0.966). similarly, PM_{10} and NO_2 (r= 0.920), PM_{10} and NH_3 (r= 0.886), PM_{10} and CO (r = 0.985), NH_3 and NO_2 (r = 0.896) a moderate positive correlation is observed between O_3 and SO_2, where as a negative correlation observed which are not statistically significant. Correlation analysis of the Mumbai city during the normal and lockdown phase is presented in the table 10b. The strong positive correlation is observed between $PM_{2.5}$ and PM_{10} (r= 0.956), $PM_{2.5}$ and NO_2 (r= 0.965), $PM_{2.5}$ and NH_3 (r = 0.899), $PM_{2.5}$ and CO (r= 0.950), $PM_{2.5}$ and O_3 (r = 0.931). Similarly, most of the correlations are strongly positive but few relations are partially negative correlated. Correlation analysis of the Kolkata city during the normal and lockdown phase is presented in the table 10c. Mostly strong positive correlation was observed between the parameters but a week correlation was also seen between $PM_{2.5}$ and O_3 (r= 0.181), PM_{10} and O_3(r= 0.210), NO_2 and O_3 (r= 0.279) NH_3 and O_3 (r=0.389) and SO_2 and O_3 (r = 0.395). In addition, a very week correlation is observed between CO and O_3(r=0.018). Correlation analysis of the Bangalore city during the normal and lockdown phase is presented in the table 10b. There is strong positive correlation between most of the pollutants. similarly, a moderate positive correlation is observed between NH_3 and NO_2 (r =0.696), NH_3 and SO_2(r =0.567), NH_3 and CO (r =0.761), SO_2 and O_3(r =0.767).

Conclusion

It should be eminent that scientific fact provides a clear picture in policy making for the future prospects and making the guideline for hence Lockdown phase of COVID-19 pandemic is a great boon to environment and wild life. While all the anthropogenic activities caused reduction in pollutant level of various gases measured by CPCB. AAQR provides a clear view of reduction in pollutant level in major cities viz., Mumbai, Kolkata, New Delhi and Bengaluru. Lockdown period provides a devastating fact about reduction in air pollution level in major cities and also provide an ideology for its cause and control efforts. The efforts should be nature friendly which include alternate source of energy to reduce the pollution level and technological measures for reduction in emission level so that air quality standard should be maintained for nature friendly future. The concentration of all the parameters except ozone was found highest at Delhi among all the sites. Order of the studied metro cities was found as Delhi>Mumbai>Kolkata>Bangalore.

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