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Effect of Covid-19 on air quality in Visakhapatnam-A comparative study

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Abstract
Data on air pollutants NO_2, SO_2, NH_3, $PM_{2.5,}$ and PM_{10} collected from January 2018-December 2020 for nine monitoring stations in Visakhapatnam, Andhra Pradesh were assessed for the air pollution status during the COVID-19 lockdown period in comparison to the air pollution status before COVID-19. The study indicated that these air pollutants did not show any strong sign of air pollution. $NO_2$and SO_2 levels fall within the range of 0-40 µg/m^3, NH_3 levels within the range of 0-200 µg/m^3, the minimum $PM_{2.5}$ levels within the range of 0-30 µg/m^3 in 2019 and 2020 and the minimum PM_{10} levels within the range of 0-50 µg/m^3 in 2019 and 2020 indicating the air pollution status as Good according AQI. But, the maximum $PM_{2.5}$ levels fall within the range of 61-90 µg/m^3 and the maximum PM_{10} within the range of 101-250 µg/m^3 in 2019 and 2020 indicating the air pollution status as Moderately Polluted according to AQI. Among these three parameters, NH_3 recorded the highest values followed by SO_2 and NO_2 in all three years of the study.

Keywords: pollutants, lockdown, COVID-19, air quality

Introduction
At the dawn of the 21st century, industrialization and modernization are at their peak across the globe, which is continuously increasing the catastrophic levels of air pollution. Atmospheric pollution is a major environmental issue that affects humans and biodiversity in developed and developing countries alike. The particulate matter (PM_{10} and PM_{25}), oxides of Nitrogen (NO and NO_2), Sulfur dioxide (SO_2), Ozone (O_3), Carbon monoxide (CO), Volatile compounds (VOC'S) and NH_3 are the most common atmospheric air pollutants encountered in our daily life (Chen & Kan, 2008; Guo *et al*., 2019) [2, 5]. The major anthropogenic sources of this particulate matter are vehicular emissions, industry, burning of fossil fuel, and power plants.

Sulfur dioxide is released into the atmosphere through both natural and anthropogenic emissions. Natural sources are mainly by volcanic eruptions while anthropogenic sources include the combustion of all sulfur-containing fuels like oil, coal, and diesel used for the power generation for industrial activities (Malik and Lal, 2014; Zhang *et al*., 2017) [11, 16]. Air pollution has adverse effects on all livelihoods on earth. The poor air quality has become a matter of global concern. According to a report, every year around 4.2 million people die prematurely due to exposure to poor air quality, which causes lung cancer, heart disease, asthma, and other chronic respiratory disorders (Gupta *et al*., 2020) [6]. Along with health, air pollution also shows an adverse impact on the environment, climate, vegetation, and economy.

The current COVID-19outbreak has been reported to have a positive impact on the environment. Different workers reported that COVID-19 lockdown showed a significant decrease in the concentrations of SO_2 (6.76%), NO_2 (5.93%), $PM_{2.5}$ (13.66%) and PM_{10} (24.67%) over 44 cities in Northern China (Dutheli *et al*., 2020; Muhammad *et al*., 2020; Wang & Su, 2020) [3, 12, 15]. In urban regions of Malaysia, the COVID-19 lockdown has shown a reduction in NO_2 and SO_2, $PM_{2.5}$, PM_{10} concentrations (Kannaiah *et al*. 2020) [7]. Air pollution was significantly reduced in Barcelona, Spain due to COVID-19 lockdown (Tobias *et al*. 2020) [14]. Air pollution levels have dropped significantly in India due to a massive dip in vehicular movement and industrial activity which resulted in clean and fresh air (Gautam, 2020; Mahato & Ghosh, 2020) [9, 10]. The COVID-19 lockdown has been reported to improve the air quality in 22 Indian cities by (Sharma and Balyan, 2020) [13]. The influence of COVID-19 lockdown measures on air pollution levels have been analyzed in six mega cities of India and China and the analysis indicated a drastic reduction in air pollution (Agarwal *et al*. 2020) [1]. With this backdrop, the present study was contemplated to evaluate the influence of COVID-19 lockdown in 2020 on the concentrations of air pollutants NO_2, SO_2, NH_3, $PM_{2.5,}$ and PM_{10} in the selected locations of Visakhapatnam city, Andhra Pradesh. The values of these parameters were compared with the same parameters obtained at the same locations of the city in 2018 and 2019 in order to record the effect of lockdown on the evaluated parameters.

Study Area
Visakhapatnam is a city situated on the East Coast of India. It is one of the fast-growing cities in the state of Andhra Pradesh. It is an urban and industrial hub with continuously increasing population and daily traffic. Huge construction activities are the order of the day and these activities are contributing to a large amount of air pollution. Further, air travel and shipping activities release enormous amounts of air pollutants in to the environment. All these activities are posing a major threat to the livelihoods and this present situation warrants for taking proper measures.

Methodology
Monthly and annual average values of $NO_{2,}$ $SO_{2,}$ NH_3, PM_{10} and $PM_{2.5}$ for the period from January 2018 to December 2020 at nine

monitoring stations, namely Minidi (S1), Industrial Estate (S2), Police Barracks (S3), ESI-Hospital (S4), Seethammadhara (S5), Gnanapuram (S6), Pedagantyada (S7), Ramky Pharmaracity (S8), M.V.P Colony Rythubazar (S9) in Visakhapatnam collected from the State Pollution Control Board were used in this study. This data were evaluated to record an increase or decline in the levels of these air pollutants during COVID-19 lockdown period. Further, the data were also used to compare against Indian Air Quality Index.

Table 1: Proposed sub-index and breakpoint pollutant concentrations for Indian Air Quality Index

AQI	Category	24 hr. average (µgm/m^3)				
		SO_2	NO_2	NH_3	PM_{10}	$PM_{2.5}$
0-50	Good	0-40	0-40	0-200	0-50	0-30
51-100	Satisfactory	41-80	41-80	201-400	51-100	31-60
101-200	Moderate	81-380	81-180	401-800	101-250	61-90
201-300	Poor	381-800	181-280	801-1200	251-350	90-120
301-400	Very poor	801-1600	281-400	1201-1800	351-430	121-250
401-500	Severe	1600+	400+	1800+	430+	250+

Results and Discussion

NO2 levels: In the year 2018, the minimum value of 14.6 µg/m^3 was recorded at S7 and maximum value of 30.4 µg/m^3 at S3. In 2019, the minimum value of 15.0 µg/m^3 was recorded at S1, S4, S5, and S9 and the maximum of 26.0 µg/m^3 at S6. In 2020, the minimum value of 15.0 µg/m^3 was recorded at S5, S7, and S9 and the maximum value of 24.0 µg/m^3 at ^{S2}. According to the Indian AQI outlined in Table 1, the minimum and maximum values of NO_2 lie within the range of 0-40 µg/m^3 indicating that the pollution status was good at all the monitoring stations in all the three years of the study period. The data presented in Table 2 shows that there was a slight decrease in NO_2 in 2018 compared to the levels of NO_2 in 2019 and 2020 indicating that the lockdown did not have any impact on the sources of NO_2 at the monitoring stations. Among all the monitoring stations, ESI-Hospital recorded a higher value in 2020 compared to NO_2 in 2018 and 2019 indicating that COVID-lockdown period contributed to an increase in NO_2 levels.

SO_2 levels: In the year 2018, the minimum value of 7.0 µg/m^3 was recorded at S4 and the maximum value of 14.9 µg/m^3 at S6. In 2019, the minimum value of 6.0 µg/m^3 was recorded at S5 and the maximum values of 11.0 µg/m^3 at S3, S6 and S8. In 2020, the minimum value of 6.0 µg/m^3 was recorded at S7 and the maximum value of 12.0 µg/m^3 at S2. According to the Indian AQI, the minimum and maximum values of SO_2 lie within the range of 0-40 µg/m^3 indicating that the pollution status was good at all monitoring stations in all three years of the study period. The data presented in Table 2 shows that there was a slight decrease of SO_2 in 2018 compared to its values recorded in 2019 and 2020 indicating that the lockdown did not have any impact on the sources of SO_2. Further, Police Barracks station (S3) recorded the highest value in 2018 among all monitoring stations but in 2019 and 2020 Gnanapuram Area station (S6) recorded the highest values. Kumari and Toshniwal (2020) [8] reported that there was no reduction in SO_2 concentrations during the lockdown period in some cities. These authors attributed the lack of lockdown effect on SO_2 concentrations to the operation of coal-based power plants in those cities. Lokhandwala and Gautam (2020) [9] noted that the local meteorological conditions such as temperature, rainfall, wind speed and solar radiation could contribute to the recorded levels of SO_2 concentrations during lockdown period. Therefore, the SO_2 levels recorded at all monitoring stations in the present study could be attributed to the local meteorological factors as well as to local factors in operation during lockdown period.

NH_3 levels: In 2018, the minimum value of 60.7 µg/m^3 was recorded at S4 and the maximum of 91.4µg/m^3 at S3. In 2019, minimum value of 25.0µg/m^3 was recorded at S4, S5, and S9 while the maximum of 90µg/m^3 at S6. In 2020, the minimum value of 23.0 µg/m^3 was recorded at S9 and the maximum value of 32.0 µg/m^3 at S8. According to the Indian AQI, the minimum and maximum values of NH_3 during the study period lie within the range of 0-200 µg/m^3 indicating that the pollution status was good in all the three years of the study. Further, there was a significant decrease in NH_3 concentration in the year 2020 when compared to 2018 and 2018 years and this decrease is attributable to restricted movement of people during lockdown period.
Among No_2, SO_2 and NH_3 parameters, the last parameter recorded the highest values followed by SO_2 and lastly NO_2 in all the three years of the study.

$PM_{2.5}$ levels: In the year 2020, all stations recorded lower values of $PM_{2.5}$ as opposed to 2019 except ESI-Hospital station which recorded a high value in 2020 as compared to 2019. In 2019, the minimum value of 11.0 µg/m^3 was recorded at S4 and the maximum value of 77.6 µg/m^3 at S6. In 2020, the minimum value of 8.0 µg/m^3 was recorded at S9 and the maximum value of 59.8 µg/m^3 at S6. In 2019, the minimum of $PM_{2.5}$ lies within the range of 0-30 µg/m^3 indicating that pollution status was good and maximum value within the range of 61-90 µg/m^3 indicating that the air quality was moderately polluted according to the Indian AQI. In 2020, the minimum of $PM_{2.5}$ lies within the range of 0-30 µg/m^3 indicating that the pollution status was good and the maximum value lies within the range of 31-60 µg/m^3 indicating that the air quality was satisfactory according to the Indian AQI. The values of $PM_{2.5}$ recorded in this study are in agreement with the results of Kumari and Toshniwal (2020) [8] who reported that there was a notable reduction in $PM_{2.5}$ concentration levels in many cities of the study. The present study suggests that the sources of $PM_{2.5}$ were much affected by the lockdown except at the ESI-Hospital station (S4).

Table 2: The annual averages, minimum and maximum values of the NO_2, SO_2, NH_3 and PM_{10} and $PM_{2.5}$

2018															
Station	NO2			SO2			NH3			PM 2.5			PM 10		
	Min	Max	Ann. Avg.	Min	Max	Ann. Avg.	Min	Max	Ann. Avg.	Min	Max	Ann. Avg.	Min	Max	Ann. Avg.
S1	15.8	23.0	19.6	8.0	11.0	9.5	65.9	78.1	70.1	-	-	-	-	-	-
S2	16.8	24.9	19.6	8.0	11.3	9.4	64.9	79.9	72.7	-	-	-	-	-	-
S3	22.7	30.4	25.1	10.0	13.8	11.7	77.9	91.4	84.7	-	-	-	-	-	-
S4	15.7	20.0	16.7	7.0	10.0	8.4	60.7	77.0	64.9	-	-	-	-	-	-
S5	16.2	24.7	18.7	8.0	12.6	9.1	65.8	75.0	70.1	-	-	-	-	-	-
S6	19.4	29.5	24.7	11.0	14.9	11.5	78.8	89.7	86.1	-	-	-	-	-	-
S7	13.3	22.9	17.8	8.0	10.0	8.6	60.8	76.0	67.2	-	-	-	-	-	-
S8	14.6	25.0	19.6	8.0	11.0	9.5	71.3	86.4	79.2	-	-	-	-	-	-
S9	20.1	22.2	21.3	9.0	11.0	9.8	70.3	77.0	73.6	-	-	-	-	-	-
2019															
S1	15.0	20.0	17.9	7.0	9.0	7.8	26.0	73.0	50.7	19.3	68.3	33.5	47.0	126.0	71.4
S2	18.0	23.0	20.9	8.0	10.0	9.0	27.0	79.0	55.2	17.2	66.8	39.8	60.0	134.0	85.9
S3	18.0	25.0	21.7	8.0	11.0	9.3	27.0	87.0	57.4	21.0	61.4	39.4	53.0	122.0	86.6
S4	15.0	21.0	17.3	7.0	9.0	7.4	25.0	72.0	49.7	11.0	57.6	30.4	46.0	121.0	79.0
S5	15.0	21.0	18.5	6.0	9.0	7.8	25.0	77.0	52.9	19.3	55.1	31.8	46.0	88.0	63.4
S6	17.0	26.0	22.1	8.0	11.0	9.5	28.0	90.0	58.4	24.3	77.3	43.8	52.0	131.0	91.3
S7	16.0	19.0	18.0	7.0	8.0	7.8	26.0	76.0	51.8	16.2	55.9	36.0	53.0	112.0	73.3
S8	16.0	25.0	20.5	7.0	11.0	8.8	26.0	84.0	56.0	19.5	60.0	34.0	44.0	116.0	68.9
S9	15.0	21.0	17.3	7.0	9.0	7.4	25.0	79.0	51.5	32.3	49.0	32.3	45.0	95.0	64.0
2020															
S1	16.0	21.0	18.1	7.0	9.0	7.7	24.2	28.0	25.6	12.0	57.3	28.3	38.0	130.0	74.8
S2	17.0	24.0	20.3	7.0	12.0	9.0	25.0	30.0	26.8	20.9	54.4	35.0	55.0	143.0	89.1
S3	18.0	21.0	19.7	8.0	10.0	8.6	24.0	28.0	26.1	16.3	57.1	30.9	48.0	118.0	74.9
S4	19.0	21.0	20.0	8.0	9.0	8.7	25.0	27.0	26.3	40.3	50.2	43.9	83.0	132.0	103.3
S5	15.0	20.0	17.4	7.0	9.0	7.3	24.0	28.0	25.3	11.7	35.1	22.7	35.0	81.0	56.1
S6	18.0	23.0	20.4	8.0	10.0	8.8	25.0	29.0	26.6	27.9	59.8	37.8	68.0	136.0	90.5
S7	15.0	19.0	17.5	6.0	9.0	7.4	24.0	27.0	25.6	18.3	48.1	28.4	47.0	122.0	74.1
S8	16.0	23.0	19.4	7.0	11.0	8.5	24.0	32.0	26.1	13.0	65.2	31.5	44.0	143.0	75.9
S9	15.0	19.0	17.0	7.0	8.0	7.3	23.0	26.0	24.5	8.0	36.2	23.6	40.0	92.0	60.0

PM_{10} levels: In the year 2020, all stations recorded highest PM10 values compared to 2019 except for S3, S5, and S9 which recorded the lowest values as compared to 2019. In 2019, the minimum value of 44.0 µg/m^3 was recorded at S8 and the maximum value of 134.0 µg/m^3 at S2. In 2020, the minimum value of 35.0 µg/m^3 was recorded at S5 and the maximum 143.0 µg/m^3 at S2 and S8. The minimum of PM_{10} lies within the range of 0-50 µg/m^3 in 2019 and 2020 indicating that the pollution status was good and the maximum value lies within the range of 101-250 µg/m^3 in 2019 and 2020 indicating that the air quality was moderately polluted according to the Indian AQI. The PM_{10} values in this study for the stations S3, S5, and S9 tally with the results of Kumari and Toshniwal (2020) [8] reported a significant decline in PM_{10} concentration levels in March 2020 as compared to March 2019. The present study suggests that the sources of PM_{10} were not affected by the lockdown but except in case of three stations S3, S5, and S9, the lower values PM_{10} recorded during 2020 could be a result of the lockdown.

Conclusions

The study found that there is no significant decline in the concentration levels of the NH3, $PM_{2.5}$ and PM_{10} during lockdown period which could be due to the sources of these parameters unaffected by the COVID-19 lockdown. The air quality in the years of the study showed that the air quality in all monitoring stations were within the permissible limits. Among the parameters studied, NH_3 is the only parameter that recorded the decline in all monitoring stations from 2018 to 2020 indicating that there was a positive response to the COVID-19 lockdown. In general, COVID-19 lockdown had a positive response in improving the air quality. The study might assist the environmentalists and policy makers to curb down the air pollution in future by implementing the strategic lockdowns at the pollution hotspots with minimal economic loss.

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