Impact of COVID-19 Pandemic on Air Quality Index of Hyderabad - A Review

I. Introduction

The life on earth is sustainable due to the natural resources of the earth. The Earth’s natural resources include air, water, sunlight, soil and minerals. Every living being on this planet needs these resources for their survival and growth. It is impossible for life to exist without these resources. So, preservation and conservation of these resources will benefit the human kind now and in future. Among the natural resources air is the most important thing for life but the quality of air is deteriorating due to anthropogenic activities. Human activities have a detrimental effect on the air we breathe. Although the industrial revolution was a great success in terms of technology, society, and the economy, it also introduced huge quantities of pollutants into the air that are harmful to human health (Ioannis 2020). Urbanization and industrialization are the major contributors of air pollution in urban areas. Air pollution is a global environmental problem that influences human health. Exposure to ambient air pollutants over a long period of time increases the risk of being vulnerable to respiratory and cardiovascular diseases (WHO 2009). WHO data shows that almost all of the global population (99%) breathes air that exceeds WHO guideline limits containing high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. WHO estimates that around 4.2 million people are killed worldwide every year due to ambient air pollution (WHO 2021a).

COVID-19 is an infectious disease caused by the SARS-CoV-2 virus, which was first discovered in Wuhan in Hubei Province of China in mid-December, 2019 (MoHFW 2021). The common symptoms of COVID-19 are fever, cough, general weakness/ fatigue, headache, loss of smell (anosmia) or loss of taste. The majority of the transmission of this infection is believed to occur predominantly through the airborne route. The virus can spread from an infected person’s mouth or nose in small liquid particles when they cough, sneeze, speak, sing or breathe. These particles range from larger respiratory droplets to smaller aerosols (WHO, 2021b). The easy spread of COVID-19 threatened the whole world and WHO (under International Health Regulations) has declared this outbreak as a “Public Health Emergency of International Concern” (PHEIC) on 30th January 2020. WHO subsequently declared COVID-19 a pandemic on 11th March, 2020 (WHO 2020). As of 11 October 2021, there have been 237,383,711 confirmed cases of COVID-19 globally, including 4,842,716 deaths, reported to WHO (WHO 2021b).

The best way to prevent the transmission of COVID-19 is to follow basic hygiene rules and social distancing. As the number of COVID-19 cases increased, countries have started imposing restrictions such as vacation for educational institutions, work from home, prohibition on public mass gatherings, quarantine for regions with high number of cases, etc. Physical distancing is made mandatory and people are advised to stay at home (Gope et al., 2021). As a precaution most of the countries have applied strict lockdown throughout the country to bring down the COVID-19 outbreak.

For preventing the spread of COVID-19 pandemic the Indian Government 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 to14th April (21days) which was then extended. During lockdown, all kinds of transport services (road, rail, air) were banned, except emergency services. Industrial and commercial activities have been shut down. The lockdown had negative impact on social and economic activities but it has become a reason for improved air quality in most of the cities in the world (Singh and Chakraborty 2020). A number of researchers have already studied the impacts of lockdown on air quality all over the world. This study discusses the effect of lockdown on air quality in Hyderabad city, India before and during the lockdown period. The air pollution data of the criteria pollutants (PM2.5, PM10, SO2, NO2, CO, NH3 and O3) has been collected from 6 different locations in the city. The AQI has been calculated using the collected data before and during lockdown and compared.
II. Air Quality Index

AQI is an index used by the government agencies to give information about air pollution. AQI is generally determined by calculating the degree of pollution at different monitoring stations. The Government of India launched the ‘National Air Quality Index’ (NAQI) in 2014. (MoEF&CC., 2014). The NAQI bulletin is published daily by the Central Pollution Control Board (CPCB 2021). There are two different techniques to monitor air quality; online monitoring network and manual monitoring network. The online monitoring network is more reliable as it provides data in real-time. The automatic monitoring network monitors eight major pollutants in real time, to calculate the index value (NAQI 2014). Under the NAQI, the averaging time for pollutants O₃ and CO is 1 hour and for PM₂.₅, PM₁₀, NO₂, SO₂, Pb, and NH₃ it is 24-h. All the pollutants are measured in μg/m³ whereas CO is measured in mg/m³.

The breakpoint table (Table 1) of daily NAQI provides numeric values and color codes. The color codes are dependent on the numeric values: the AQI value between 0 and 50 suggests it as good with minimal impact on health and shown by dark green color code. Values in the range of 51–100 are termed as satisfactory (light green) wherein minor breathing discomfort occurs to sensitive people, range of 101–200 is termed as moderately polluted (yellow), range of 201–300 is termed as Poor (orange), values in the range of 301–400 are termed as very poor (light red) and, values in the range of 401–500 as listed as severe (dark red). (CPCB 2021). AQI essentially translates complex data of air pollution into a single number and colour.

Table 1. Breakpoints for AQI Scale 0–500 (all pollutants are in units of μg/m³ and CO is expressed in units of mg/m³). *Hourly monitoring Source: Central Pollution Control Board (NAQI, 2014).

<table>
<thead>
<tr>
<th>AQI Category</th>
<th>AQI</th>
<th>Concentration range*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0 - 50</td>
<td>0 - 50</td>
</tr>
<tr>
<td>Satisfactory</td>
<td>51 - 100</td>
<td>31 - 80</td>
</tr>
<tr>
<td>Moderately</td>
<td>101 - 200</td>
<td>101 - 168</td>
</tr>
<tr>
<td>Poor</td>
<td>201 - 300</td>
<td>251 - 169</td>
</tr>
<tr>
<td>Very poor</td>
<td>301 - 400</td>
<td>351 - 179</td>
</tr>
<tr>
<td>Severe</td>
<td>401 - 500</td>
<td>430+ 174+</td>
</tr>
</tbody>
</table>

* CO in mg/m³ and other pollutants in μg/m³; 2h-hourly average values for PM₁₀, PM₂.₅, NO₂, SO₂, NH₃, and Pb, and 8-hourly values for CO and O₃.

Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). AQ sub-index and health breakpoints are evolved for eight pollutants (PM₂.₅, PM₁₀, CO, O₃, NO₂, SO₂, Pb, and NH₃) for which short-term National Ambient Air Quality Standards are prescribed. Based on the measured ambient concentrations of a pollutant, sub-index is calculated, which is a linear function. The sub-indices are then aggregated into a single index. The worst sub-index determines the overall AQI. AQI categories and health breakpoints for the eight pollutants are shown in Table 1. The mathematical equation for calculating sub-indices of AQI is as follows:

\[ I_p = \left[ \frac{(IHI - ILO)}{(BPHI - BPLO)} \right] \times (CP - BPLO) + ILO \]

where,

- \(I_p\) is AQI for pollutant “P” (Rounded to the nearest integer),
- \(CP\) is the actual ambient concentration of pollutant “P”,
- \(BPHI\) is the upper-end breakpoint concentration that is greater than or equal to \(CP\),
- \(BPLO\) is the lower end breakpoint concentration that is less than or equal to \(CP\),
- \(ILO\) is the sub-index or AQI value corresponding to \(BPLO\),
- \(IHI\) is the sub-index or AQI value corresponding to \(BPHI\).

III. Study area and selection of pollutants

Hyderabad is the capital city of Telangana State, India. Hyderabad is on Deccan Plateau at an average altitude of 542 m and the estimated population of the city is 10.2 million (WPR 2021). The Telangana State Pollution Control Board has been monitoring the ambient air quality in the state under National Air Quality Monitoring Program (NAMP), State Ambient Air Quality Monitoring Program (SAAQM) and Continuous Ambient Air Quality Monitoring System (CAAQMS).
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. The average concentrations of air pollutants such as PM$_{2.5}$, PM$_{10}$, Carbon monoxide (CO), Ozone (O$_3$), Nitrogen dioxide (NO$_2$) and Sulphur dioxide (SO$_2$) which is an open source data. The data was downloaded from Telangana State Pollution Control Board website (TSPCB 2021) for these six stations for 2 months pre lockdown (February and March) and during partial lockdown (April and May) 2021. The open source data from Pollution Control Board, Hyderabad, Telangana State has been taken for review analysis.

IV. Results and Discussion

The average concentration of air pollutants before and during the period of lockdown for COVID-19 at six different locations in and around Hyderabad is shown in the table 2. The effect of lockdown on air quality is discussed by considering individual pollutants.

Table 2: Mean Concentrations of individual pollutants before and during lockdown; PL- Pre-lockdown period, L- lockdown period.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Location</th>
<th>Parameters</th>
<th>SO$_2$</th>
<th>NO$_x$</th>
<th>PM$_{10}$</th>
<th>PM$_{2.5}$</th>
<th>NH$_3$</th>
<th>O$_3$</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PL</td>
<td>L</td>
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<td>PL</td>
<td>L</td>
<td>PL</td>
<td></td>
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<tr>
<td>1</td>
<td>HCU</td>
<td>3.8</td>
<td>2.7</td>
<td>5</td>
<td>42</td>
<td>33.5</td>
<td>121</td>
<td>83</td>
<td>49</td>
</tr>
<tr>
<td>2</td>
<td>Sananth Nagar</td>
<td>11.5</td>
<td>6.4</td>
<td>5</td>
<td>62.3</td>
<td>30.7</td>
<td>165.5</td>
<td>102</td>
<td>71.5</td>
</tr>
<tr>
<td>3</td>
<td>Zoopark</td>
<td>4.0</td>
<td>3.5</td>
<td>5</td>
<td>95</td>
<td>52.4</td>
<td>163.5</td>
<td>103</td>
<td>67.5</td>
</tr>
<tr>
<td>4</td>
<td>Pashamylaram</td>
<td>3.1</td>
<td>2.8</td>
<td>5</td>
<td>68.1</td>
<td>55.3</td>
<td>144.5</td>
<td>96.5</td>
<td>62.5</td>
</tr>
<tr>
<td>5</td>
<td>Bollaram, CAAQMS</td>
<td>10.3</td>
<td>9.6</td>
<td>5</td>
<td>37.7</td>
<td>25.3</td>
<td>142.5</td>
<td>100</td>
<td>66.5</td>
</tr>
<tr>
<td>6</td>
<td>ICRISAT</td>
<td>9.6</td>
<td>7.8</td>
<td>5</td>
<td>22.7</td>
<td>11</td>
<td>139</td>
<td>84.5</td>
<td>59</td>
</tr>
</tbody>
</table>

1. Particulate Matter (PM$_{10}$& PM$_{2.5}$)

The mixture of tiny solid particles and liquid droplets present in the air are referred to as PM. Some of the particles are large enough to be seen with naked eye and some are indistinguishable and can be detected using an electron microscope. The two main categories of PM are PM$_{10}$ (coarse PM) and PM$_{2.5}$ (fine PM). PM$_{10}$ are inhalable particles with a diameter of 10 microns or smaller. PM$_{2.5}$ are fine inhalable particles with a diameter of 2.5 microns or smaller. Due to its small size PM$_{2.5}$ can travel deeply into respiratory tract posing great risk to human health. It can be observed from the table that the average concentration of PM$_{10}$ decreased during lockdown. ICRISAT recorded the maximum decrease by 39.2% and Bollaram recorded minimum decrease by 29.8%. The average concentration of PM$_{2.5}$ has reduced during lockdown compared to pre lockdown conditions. Maximum reduction was seen at ICRISAT and minimum reduction was observed at HCU.

2. Ozone (O$_3$)

Ozone is the only secondary pollutant among the major pollutants considered to calculate the AQI. Ozone is produced when primary pollutants react in sunlight and air. Ground level ozone can trigger a multitude of health problems and worsen Chronic Respiratory Disorders. In 4 out of 6 locations the concentration of ground level ozone decreased whereas in two locations, Zoopark and Bollaram the concentration of ozone increased during lockdown. Bollaram is an industrial area and during the period this data was collected, the state government permitted industries to function following appropriate COVID-19 protocols. The availability of primary pollutants in combination with more sunlight and longer daylight hours may be the reason for increase in ground level ozone.

3. Nitrogen oxides (NO$_x$)

NO$_x$ is produced from reaction of Nitrogen and oxygen gases in the air during combustion, especially at high temperatures, Nitrogen oxides are emitted by automobiles, various non-road vehicles, and industrial sources in urban areas. From the table it can be observed that the average concentration of NO$_x$ before the lockdown is high compared to lockdown NO$_x$ values. The concentration of NO$_x$ dropped by 51.5%, 50.6% and 44.8% at ICRISAT, Sanathnagar and Zoopark respectively. The decrease in concentration was minimum at Pashamylaram with 18.7%.

4. Sulphur dioxide (SO$_2$)

The major source of SO$_2$ in the atmosphere is burning of fossil fuels by power plants and other industrial facilities. From the Table 1; it can be observed that there is a reduction of average concentration of SO$_2$ during the lockdown period. The maximum reduction occurred in Sanathnagar by 43.9% and minimum reduction at Bollaram by 6.7%. It can be noted that the reduction of SO$_2$ concentration is not uniform.
5. Ammonia (NH₃)

Though agriculture and NH₃ based fertilizer applications are the major sources of NH₃ emissions other sources such as industrial processes and vehicular emissions also contribute to atmospheric ammonia. In urban areas, ammonia is also emitted from NOₓ emission control equipment (Nevalainen et al., 2018; Thiruvengadam et al., 2016). In 5 out of 6 locations there is a decrease in average ammonia concentration during lockdown whereas in Bollaram the average concentration of ammonia increased by 8.6%.

6. Carbon monoxide (CO)

CO is produced by the incomplete combustion of carbon containing fuels. Transportation sources are the largest contributors of CO emissions in the urban environment. Like all the other pollutants the CO levels were decreased in the lockdown period. From the table we can notice that there is a steady decrease of CO levels in all the locations during lockdown. The concentration of CO dropped by 34.7% in ZooPark, 33.3% at HCU, 30% at both Bollaram and ICRISAT, 28.5% in Pashamylaram and 25% at Sanathnagar.

AQI was calculated using 6 major pollutants (NOₓ, SO₂, O₃, PM₁₀, PM₂.5 and CO). The AQI before and during the lockdown in Hyderabad can be seen in the Table 3.

Table 3: Pre lockdown and lockdown AQI in six locations in Hyderabad city.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Location</th>
<th>Pre-Lockdown AQI</th>
<th>AQI CATEGORY</th>
<th>Lockdown – AQI</th>
<th>AQI CATEGORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HCU</td>
<td>114</td>
<td>Moderate</td>
<td>83</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>2</td>
<td>Sanathnagar</td>
<td>144</td>
<td>Moderate</td>
<td>101</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>ZooPark</td>
<td>142</td>
<td>Moderate</td>
<td>102</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>Pashamylaram</td>
<td>130</td>
<td>Moderate</td>
<td>97</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>5</td>
<td>Bollaram, CAAQMS</td>
<td>128</td>
<td>Moderate</td>
<td>100</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>6</td>
<td>ICRISAT</td>
<td>126</td>
<td>Moderate</td>
<td>85</td>
<td>Satisfactory</td>
</tr>
</tbody>
</table>

Figure 1, 2 and 3 shows the average AQI on 25th March 2021 (pre lockdown period) in three locations in Hyderabad, particulate matter being the prominent pollutant. The air quality was poor in Sanathnagar where the prominent pollutant for calculating the AQI is PM₂.₅ and moderate in Hyderabad Central University and Pashamylaram where the prominent air pollutant is PM₁₀.

Figure 4, 5 and 6 shows the average AQI on 25th April 2021 (during lockdown) in three locations in Hyderabad with particulate matter as the prominent pollutant. The air quality in all the three locations is moderate showing that the quality of air has been improved.

Figure 1: Status of air quality in Sanathnagar, Hyderabad on 25 March 2021 (pre-lockdown period).
Figure 2: Status of air quality in Pashamylaram, Hyderabad on 25 March 2021 (pre-lockdown period).

Figure 3: Status of air quality in HCU, Hyderabad on 25 March 2021 (pre-lockdown period).

Figure 4: Status of air quality in Sanathnagar, Hyderabad on 25 April 2021 (during lockdown).
Figure 5: Status of air quality in Pashamylaram, Hyderabad on 25 April 2021 (during lockdown).

Figure 6: Status of air quality in Bollaram, Hyderabad on 25 April 2021 (during lockdown).

Table 4: Air Quality Index in Hyderabad during and before lockdown.

<table>
<thead>
<tr>
<th>Location</th>
<th>Pre-lockdown AQI</th>
<th>Lockdown AQI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICRISAT</td>
<td>85</td>
<td>126</td>
</tr>
<tr>
<td>Bollaram</td>
<td>100</td>
<td>128</td>
</tr>
<tr>
<td>Pashamylaram</td>
<td>97</td>
<td>130</td>
</tr>
<tr>
<td>Zoopark</td>
<td>102</td>
<td>142</td>
</tr>
<tr>
<td>Sanathnagar</td>
<td>101</td>
<td>144</td>
</tr>
<tr>
<td>HCU</td>
<td>83</td>
<td>114</td>
</tr>
</tbody>
</table>

AQI value of 101-200 is considered moderate air quality and before lockdown the AQI calculated using the mean concentrations of the six air pollutants ranged from 114 to 144. These values fall on the lower half of the moderate AQI values and strict measures can bring down the AQI value improving the air quality. During the lockdown period the AQI ranged from 83-102 with four locations with satisfactory and two moderate air quality category. Compared to pre lockdown period, the quality of air has been improved. In
Sanathnagar and Zoopark the AQI during lockdown is 101 and 102 respectively, these values are close to satisfactory category (51-100) implying that the air quality has improved significantly even though the AQI is considered moderate which is depicted in Table 4. The most logical reason for the improved air quality is the implementation of restrictions on vehicular movements and industrial activities during the lockdown period. It is clear that during the COVID-19 lockdown, the concentration of air pollutants is decreased and the air quality in Hyderabad has improved significantly.

In the very recent past, researchers have been studying the impact of lockdown on air quality throughout the world in major cities. Ngiam et al. (2021) presented a study on positive effects of lockdown on air quality of 2 industrial cities in Gujrat, India. The study revealed gradual to drastic reduction of pollutant concentrations (PM$_{10}$, PM$_{2.5}$, CO, SO$_2$, NO, and ozone) during lockdown. Mahato et al. (2020) studied air quality during the lockdown situation by choosing Delhi, India, as a case study location. The authors choose PM$_{2.5}$ and PM$_{10}$ for air quality assessment and observed that the values of PM$_{2.5}$ and PM$_{10}$ have reduced by 50% compared with the pre-lockdown conditions.

Liu et al. (2021) examined the environmental effect of lockdowns globally combining the daily air pollution data and weather data across 597 major cities worldwide. This study quantifies the causal impact of various lockdown measures on the air quality (measured by PM$_{2.5}$, PM$_{10}$, SO$_2$, NO, CO, and O$_3$ individual AQI) and noticed the reduction in concentrations of different pollutants. Singh and Chauhan (2020) considered SO$_2$ and PM$_{2.5}$ concentration to check the air quality in five major metropolitan cities over India in the lockdown period using satellite and ground observations and concluded that the air quality improved drastically in the lockdown. Manoh et al. (2020) assessed the impact of lockdown on the concentration of PM$_{2.5}$ (ambient aerosols) across the ten most polluted cities of Indo-Gangetic Plain of India. The researchers noted that the concentration of PM$_{2.5}$ decreased by 60% and the air quality index improved remarkably.

Sahoo et al. (2020a) evaluated the impact of lockdown on air quality and explored the association of daily COVID-19 confirmed cases with meteorological parameters and criteria pollutants in the major cities of Punjab and Chandigarh, India. Sahoo et al. (2020b) examined the changes in air quality during different phases of lockdown (pre, during and post lockdown) in the state of Maharashtra, India. It is observed that the pollutants were substantially reduced resulting in the satisfactory level of AQI. The influence of COVID-19 lockdown on the environment in India has also been studied in (Pratima et al., 2020a, b; Sharma et al., 2020; S J et al., 2020, Mishra et al., 2021, Garg et al., 2021, Mor et al., 2021, Ravindra et al., 2021).

In most of the studies criteria pollutants were considered for calculating AQI. From all these studies it is clearly evident that the quality of air is improved during the lockdown compared to pre-lockdown conditions. The improved air quality during the pandemic was also observed in several countries around the globe such as Malaysia (Abdullah et al., 2020), Rio de Janeiro of Brazil (Dantas et al., 2020), China (He et al., 2020, Filonchyk et al., 2020; Xu et al., 2020), Spain (Donzelli et al., 2021), Iran (Broomandi et al., 2020), Ecuador (Zalaikievicute et al., 2020), Italy (Donzelli et al., 2020), Mexico City (Hernández-Paniagua et al., 2021), France (Adélaïde et al., 2021), European countries (Menut et al., 2020). Several studies have investigated the relation between air quality and the lockdown in different countries around the globe (Sannigrahi et al., 2021), (Rodríguez-Urrego et al., 2020). From these studies it can be established that the environment has improved throughout the globe during the lockdown period.

Particulate Matter (PM$_{2.5}$, PM$_{10}$), Carbon monoxide (CO), ground level ozone(O$_3$) ,Nitrogen dioxide (NO$_2$) and Sulphur dioxide (SO$_2$) are the most common air pollutants observed in urban environment, arising from combustion process (vehicular emissions, household emission, industrial activities etc..) and road dust (Thorpe et al., 2008). Out of these pollutants PM$_{2.5}$ can cause hazardous health issues due to its microscopic size (Murray et al., 2019). Ground level ozone is a secondary pollutant produced when two primary pollutants (such as NO$_2$ and VOCs) react in sunlight and stagnant air. NO$_2$ is responsible for the production of secondary pollutants (O$_3$, HNO$_3$) which affect the human health. A significant decrease in air pollution has been observed all over the globe which is possible due to the lockdown in most countries (Venter et al., 2020).

V. CONCLUSION

Covid-19 is a global pandemic and a threat to humans and animals. COVID-19 forced people to stay at home in order for their safety. At the same time, the lockdown during COVID-19 has been a “blessing in disguise” for the environment where the concentrations of air pollutants were reduced and air quality was improved. The restrictions placed on industries, transport, construction, demolition and other activities during lockdown improved the air quality in Hyderabad. The reduction in mean concentrations of PM$_{10}$, PM$_{2.5}$, CO, SO$_2$ and NOx is noticeable and the air quality is evidently better. But keeping in mind the economic and social setbacks of lockdown it cannot be a long-term solution to tackle the deteriorating air quality. A few alternates to improve the air quality in metropolitan cities are:

- Reduce the use of fossil fuel-based transportation/energy.
- Promote the use of alternate energy source/ transportation(electric, CNG, solar energy, wind energy etc.).
- Improve the public transportation scenario and reduce the use of individual vehicles.
- Discourage the use of outdated vehicles and upgrade to more eco-friendly vehicles.
- Monitoring air quality data regularly and take necessary steps to ensure clean air conditions.
- Strict enforcement of existing laws and regulations relating to industries, construction activities and transportation.

Failure to take proper action will result in further decline in urban air quality, with greater health risks. We need to step up now so that the future generations can breathe.

REFERENCES


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