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MUTUAL IMPACT OF COVID 19 AND POLLUTION

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ABSTRACT

COVID 19 is a viral infection that originated from Wuhan province of China. The first case of COVID 19 in India was reported on 31st January 2020. Till now more than 11 million cases and more than 0.16 million deaths have been reported in India. The pandemic has played a major role in impacting the environment due to subsequent lockdowns in many countries all over the world. The Indian environment had also changed and pollution levels greatly affected by the lockdown imposed due to the ongoing pandemic. The virus spreads mainly through human to human contact but there have been certain studies suggesting its spread through air and aerosols. It is observed in many studies that pollution can also impact the spread of the virus SARS CoV2. In this review we aim at exploring the various mutual impacts of Covid 19 on pollution and the severity of the disease due to air pollution. An in-depth report of various transmission ways of the SARS CoV2 and the impact of the pandemic on Indian environment including air, water and is also highlighted.

KEY WORDS : COVID, Air pollution, AQI, Lockdown

AIR POLLUTION

Human lives have been majorly impacted in every aspect by COVID19 which has taken a number of lives till now, but the situation is getting better and hopes are on the ongoing vaccination across many nations. The situation initially had been very threatening. There are a number of reasons that have led to the 'super spread' of this virus affecting different socio economic groups in different ways. One of these factors included air pollution and its fluctuating parameters. Toxic gases released from industries, vehicles and global warming gases like NO_2 have shown to increase the fatality rate in areas of the world due to COVID19 infection. Long term exposure to NO_2 can lead to heart and lung disorders, diabetes, along with cytokine storms in the body emerging due to severe immune reactions. As per a study, 38% of India's disease burden is contributed by cardiovascular disease and diabetes caused as a result of air pollution (Balakrishnan, K. *et al.*, 2019) Another study emphasizes the fact that COPD was responsible for around 76% of chronic respiratory diseases in India (as per 2016 data), which increases the prevalence of lung disorders making individuals more prone to air borne infections (Salvi *et al*., 2018). According to some studies, in normal conditions the body produces small amounts of nitrogen oxides that prevents the duplication of Respiratory Syncytial Virus (RSV) in lungs. But when environmental NO_x levels rise, endogenous nitrogen oxide formation is hampered, thus making lungs prone to infection (Daraei *et al*., 2020).

According to the world air quality report 2020 published by IQ AIR visuals, out of the 10 most polluted cities of the world, 9 were from India. The top 50 most polluted cities had 35 Indian cities (based on $PM_{2.5}$ levels). The air quality of $PM_{2.5}$ is highly dangerous amongst the other pollutants in

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India (https://www.iqair.com/us/). In India nationwide lockdown, the pandemic which started from 24th March 2020, had contributed to a reduction in the number of vehicles on roads, industries getting shut and people being inside their houses. This was a big reason which helped in restoration of good air quality and reduction in levels of $PM_{2.5.}$ Also positive impact on the environment was observed with reference to reduction in Air Quality Index (AQI) by 44%, 33%, 29%, 32% and 15% in north, south, east, west and central parts of India respectively (Sharma *et al*., 2020). The main risk of particulate matter (PM) reduced by 52%. Delhi, the national capital of India, observed a 49% reduction in AQI during the lockdown period which is a big achievement keeping in mind that it is the second leading megacity in the world with a population density of 11,297 person/km^2 (Sharma *et al*., 2020; Mahato *et al*., 2020).

The 2019 report had air quality of most cities as moderate to unhealthy but this situation has changed in 2020 after the COVID19 pandemic hit the world. The AQI was observed to be fairly good in most cities. The below table records the average air quality index for $PM_{2.5}$ from January 2020 (before lockdown) till February 2021 (after lockdown) (https://app.cpcbccr.com/AQI_India/). The data are taken for $PM_{2.5}$ as it is the most harmful air pollutant for human health and has a size of 2.5 microns (even smaller than human hair follicles). These small sized particulate matter tend to go to the bloodstream through the respiratory tract and cause many severe diseases like heart diseases, lung cancers and asthma. According to the US AQI, a $PM_{2.5}$ level of less than 12 μg/m^3 is considered to be good. According to the 2020 report, India was placed at 3rd position in the global pollution country wise rankings. This means that India has to fight the pollution problem as well in order to contain the COVID19 infection (https://www.iqair.com/us/).

The below graph shows the comparison between the AQI data of January 2020 when there was no lockdown, April 2020 when there had been strict implementation of lockdown, July 2020 and October 2020, when process of unlock was being conducted gradually by the Government of India and India was trying to control and manage the spread of the SARS-CoV2 viral disease, and that of February 2021 when unlock had been done in almost all cities in the country and vaccine has been approved and is being provided in parts of the country. The graph clearly depicts a significant reduction in AQI of $PM_{2.5}$ during lockdown in below mentioned Indian cities in the month of April as compared to the earlier situation in January 2020. On comparing the data of the below graph, we can observe that the maximum reduction in pollution from January to April was seen in Ghaziabad (236.31) followed by Delhi (230.97), Greater Noida (216.52), Noida (210.28), Bhiwadi (165.2) Bulandshahr (163.08) and the least reduction seen for the city of Meerut (134.17).

Delhi and Ghaziabad are situated in a high and low per-capita income state respectively and major development is in their secondary and tertiary sector, though the motorized vehicles are lesser in Ghaziabad. High pollutant levels in Ghaziabad are mainly due to the use of thermal energy for most of its power supply. Alongside, the dust from the construction site had been the major source of pollution in the city all of which decreased during lockdown (Dasgupta and Srikanth, 2020).

After Unlock 1 was implemented on 1st June in a restricted pattern, data for AQI was taken into account for months of July 2020 and October, 2020. It can be seen in the below graph that there is no rise in pollution levels depicted by decreased $PM_{2.5}$ AQI levels in July but a significantly higher rise is seen in the month of October. A rapid high rise is seen for the $PM_{2.5}$ levels from July to October for the cities with highest rise in Bulandshahr (225.76) followed

Table 1. The monthly data for $PM_{2.5}$ AQI levels for 7 polluted Indian cities from Jan 2020 to Feb 2021.

	AVERAGE PM2.5 AQI (μg/m^3)													
CITIES	**JAN'20**	**FEB'20**	**MAR'20**	**APR'20**	**MAY'20**	**JUN'20**	**JUL'20**	**AUG'20**	**SEPT'20**	**OCT'20**	**NOV'20**	**DEC'20**	**JAN'21**	**FEB'21**
GHAZIABAD	314.34	249.69	121.56	78.03	97.19	67.2	51.5	32.61	82.8	259.6	349.31	364.29	368.36	285.57
DELHI	320.89	251.54	124.57	89.92	151.91	130	71.08	50.48	88.2	270.19	353.53	359.57	348.19	326.88
NOIDA	287.68	228.93	105.52	77.4	88.59	119.78	61.67	33	89.26	175.92	309.67	337.38	326.09	267.36
GREATER- NOIDA	301.38	230.85	109.43	84.86	80.8	79.89	46.13	36.43	94.38	257.48	322.62	357.03	337.52	249.67
BHIWADI	246.6	250.62	146.39	81.4	139.68	113.24	84.55	57.62	157.37	303.93	319.6	317.06	295.53	268.21
BULANDSHAHAR	281.77	246.73	119.29	118.69	115.4	83.14	49.57	32.45	97.33	275.33	335.83	364.77	329.25	279.39
MEERUT	252	221.7	113.92	117.83	128.44	80.89	49.42	39.14	97.76	268.28	303.92	311.57	259.18	284.35

by Bhiwadi (219.38), Meerut (218.86), Greater Noida (211.35), Ghaziabad (208.1), Delhi (199.11) and least rise in Noida(114.25).

The patterns of pollution levels in February 2021 from October 2020 can be seen fluctuating. In cities like Greater Noida and Bhiwadi the levels of $PM_{2.5}$ were observed to decrease while in cities like Delhi, Ghaziabad, Noida, Bulandshahr and Meerut a rise in pollution was seen.

Based on the data from above table, the below graph is plotted to compare the PM_{10} AQI levels in the months of January 2020 (before lockdown), April 2020 (during lockdown), July 2020 (start of lockdown release), October 2020 (after moderate lockdown release) and February 2021 (long after the unlock implementation). All these months represent various phases of COVID19 lockdown implementation and release by the Government of India.

The PM_{10} levels can be seen high during the start of the year 2020 in the month of January represented by the blue bars in the bar graph. The implementation of lockdown phase 1 during March caused a significant reduction in the PM_{10} levels during April in all the 7 cities without an exception. The least fall was seen in Meerut (34.99) followed by Bulandshahr (37.26), Noida (106.45), Bhiwadi (109.7) Greater Noida (115.4), Ghaziabad (129.37) and biggest fall in Delhi (148.29).

A further downfall in PM_{10} levels is seen in the month of July (represented by pink bars) as compared to the levels seen in April with an exception of Bhiwadi where a little rise was observed. The average AQI increased in the month of October when lockdown was being released in phases (not entirely) and life started to come back to normal, leading to an increase in anthropogenic activities as seen by the high rise of the yellow bars

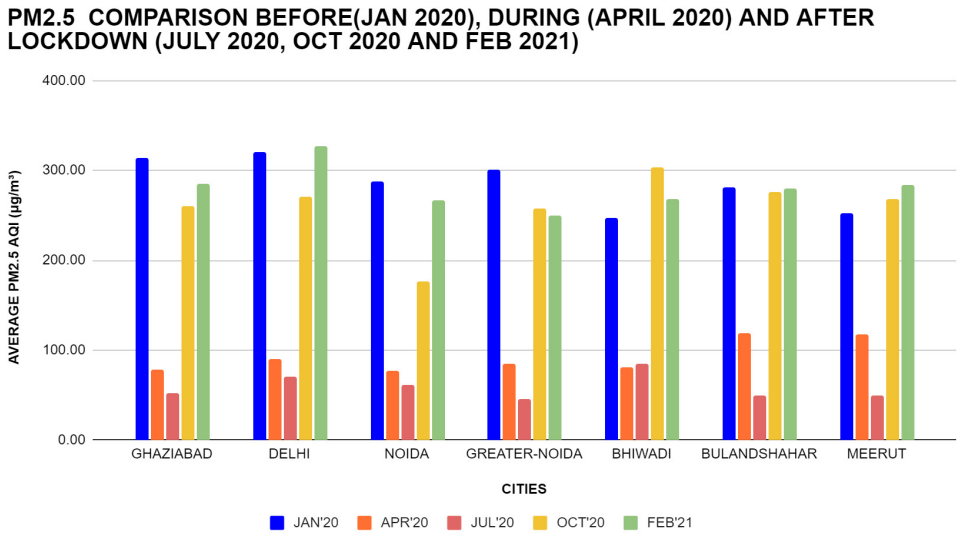

Fig. 1. Comparison of $PM_{2.5}$ levels of 7 most polluted Indian cities for the month of Jan 2020 (Before lockdown), April 2020 (During lockdown), Jul 2020, Oct 2020 and Feb 2021 (After lockdown).

Table 2. The monthly data for PM_{10} AQI levels for 7 polluted Indian cities from Jan 2020 to Feb 2021.

	AVERAGE PM10 AQI (µg/m^3)													
CITIES	**JAN'20**	**FEB'20**	**MAR'20**	**APR'20**	**MAY'20**	**JUN'20**	**JUL'20**	**AUG'20**	**SEPT'20**	**OCT'20**	**NOV'20**	**DEC'20**	**JAN'21**	**FEB'21**
GHAZIABAD	226.37	193.59	121.37	97	122.77	116.9	79.68	55.07	116.77	254.1	288.07	299.17	261.43	284.41
DELHI	241.62	228.58	131.29	93.33	109.91	102.36	68.46	53.96	111.75	280.97	324.93	277.47	258.14	282.24
NOIDA	207.9	188.22	115.07	101.45	131.78	115.67	75.38	46.25	118.84	193.77	256	268.34	255.87	235.23
GREATER-NOIDA	219.4	181.48	105.65	104	114.23	105.39	68.58	46.93	110.9	246.81	273.31	287.4	233.31	242.22
BHIWADI	197.57	187.66	121.84	87.87	130.26	118.03	91.83	68.61	148.63	280.71	284.24	259.65	226.26	255.88
BULANDSHAHAR	173.81	178.81	113.19	136.55	147.97	125.32	80.93	55.35	120.07	261.73	290.73	287.74	230.11	226.61
MEERUT	179.65	188.05	126.2	144.66	135.52	106.42	77.53	45.68	128.04	274.58	298.5	290.7	230.21	272.46

in comparison to the pink bars. The highest rise was seen in the city of Delhi (212.51) followed by Meerut (197.05), Bhiwadi (188.88), Bulandshahr (180.8), Greater Noida (178.23), Ghaziabad (174.42), and the least rise seen in Noida (118.39).

PM_{10} levels for February 2021 were seen to increase from October 2020 for some cities like Ghaziabad and Noida and a very less increase in case of Delhi whereas for cities like Greater Noida, Bhiwadi, Bulandshar and Meerut (very less difference) the PM_{10} levels decreased.

Below is a table recording the average reduction in the different types of pollutants in India after three weeks of imposing the lockdown by the Indian government on March 24th, 2020. It can be seen that there has been a huge drop in the levels of pollutants like PM_{10}, $PM_{2.5}$, NO_2 and CO in air as compared to the earlier scenario. Although for SO_2, O_3 and NH_3 there has not been a very significant fall (Arora *et al.*, 2020).

Table 3. Level of different pollutants in India before and after three weeks of imposing lockdown

Pollutant	Before Lockdown ($\mu g/m^3$)	After Lockdown ($\mu g/m^3$)
PM_{10}	176.07	84.79
$PM_{2.5}$	80.51	37.75
SO_2	16.08	13.19
NO_2	42.59	20.16
CO	1.03	0.72
O_3	34.05	34.32
NH_3	33.93	29.75

As mentioned earlier the effects of $PM_{2.5}$ and PM_{10} can cause many heart diseases and lung disorders. Thus, it can be seen as a sign of relief that levels of both these pollutants went down during lockdown by 91.28 $\mu g/m^3$ and 42.76 $\mu g/m^3$ respectively for PM_{10} and $PM_{2.5}$ (Arora *et al.*, 2020).

But since lockdown has come to an end and life came back to its pace, all the anthropogenic activities have risen again, traffic on roads has increased and industries have opened up, etc. This has caused a definite increase in the pollutant levels in the big cities. Not just in India, but in China from where this pandemic began, has reported a rise in the number of daily reported cases by 2.24, 1.76, 6.94 and 4.76% for every 10 $\mu g/m^3$ increase in $PM_{2.5}$, PM_{10}, NO_2 and O_3 levels (Ali, N and Islam, 2020). The $PM_{2.5}$ and PM_{10} levels have increased especially during the rainy season. Though the increase has not been too much initially but due to low air pressure in the coastal areas in Bay of Bengal the air didn't flow from south to north India increasing the concentration of pollutants in the air. Delhi, as compared to 2019, saw an increase in the AQI levels. The average O_3, SO_2, CO levels remained almost the same for both the years (2019 and 2020) as per the Air pollution control board. But as winters approached, the rising PM levels increased the

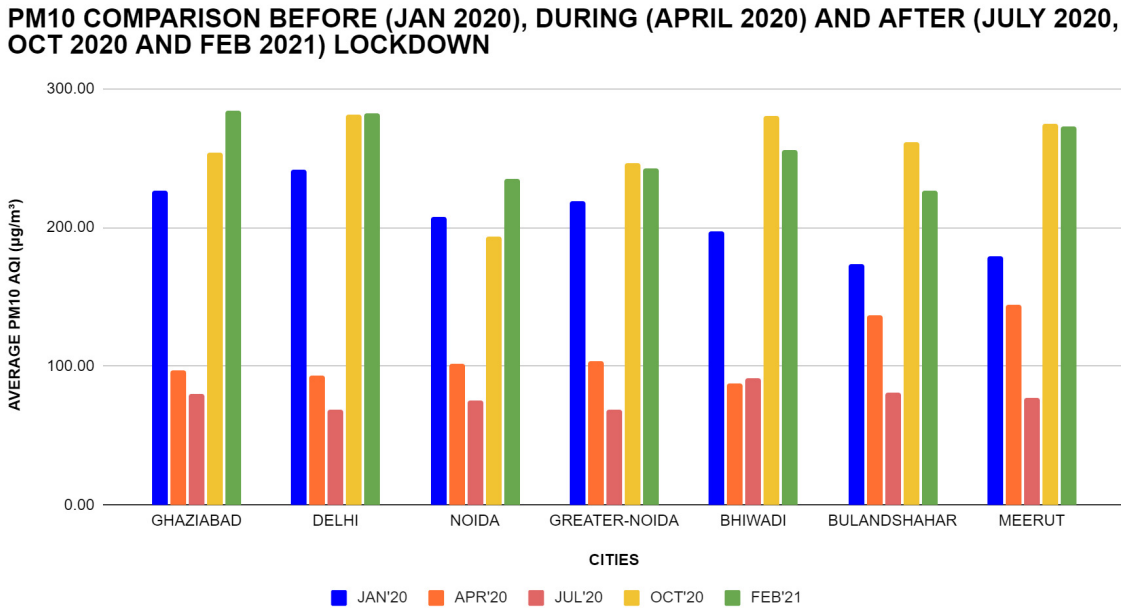

Fig. 2. Comparison of PM_{10} levels of 7 most polluted Indian cities for the month of Jan 2020 (Before lockdown), April 2020 (During lockdown), Jul 2020, Oct 2020 and Feb 2021 (After Lockdown).

threat of another wave of COVID spread and it was clearly seen from the increase in number of cases. The cases started increasing worldwide after September 2020 and rose to 842,163 total cases by 20th December 2020 (https://covid19.who.int/). The trend however, was somewhat different in India as cases saw a fall after September 2020.

But as was speculated, cold weather worsened the scenario. As temperature fell in Northern Hemispheric countries like India where unlock phases had begun and more people were stepping outdoors another wave of cases hit the nation. With decreasing temperature, the interaction of people was limited to indoor spaces with poor ventilation that increased the risk of transmission (Mallapaty, 2020). Virus has been argued to be highly stable at 4 °C with just 0.7 log unit reduction in its titre after 14 days but is sensitive to higher temperatures. Some studies have depicted that temperature has a positive linear association with COVID 19 cases when temperature is lower than 3 °C. Another study found that a 1 °C increase in temperature reduces the daily transmission of virus by 4.9% if temperature was lower than 25.8 °C, although no decrease in cases was seen if temperature was more than 25.8°C (Shakil *et al.*, 2020).

In a study it was seen that high levels of NO_2 in polluted air has a 60% correlation with adolescent psychotic behavior, due to neurodegeneration and neuro-inflammation affecting the frontal cortex. For India, a country with one of the highest youth populations in the world, this is an alarming finding as it directly affects the future generations of this country and thus the future of the country itself. The reduced NO_2 levels during lockdown therefore become a sign of positivity in this direction (Newbury *et al.*, 2019). SO_2 can cause increased oxidative stress and mitochondrial dysfunction in neurons. In women, it can affect the luteal phase of the menstrual cycle and reduce its duration. In a study, it was observed that an exposure to a 1 $\mu g/m^3$ increase in level of SO_2 reduced the luteal phase by 0.1 day. Indian population is the second highest in the world and women being part of it are at high risk of menstrual fluctuations and related problems by SO_2 pollution (Merklinger-Gruchala *et al.*, 2017). The levels of SO_2 are seen to have reduced a little during lockdown by 2.89 $\mu g/m^3$ on an average.

It is necessary to see, in Indian context, the effects of the above mentioned pollutants. India, a nation highly dependent on its agriculture, can have huge problems due to reduced crop productivity which is a major effect of high ozone levels in the atmosphere. Reduced crop productivity can cause great economic damage to India and thus rising ozone levels are a concern that should be addressed at the earliest. It can also be noted that lockdown did not have any significant reduction in ozone levels (Singh and Agrawal, 2017). The levels of greenhouse gas such as NH_3 went down by 4.18 $\mu g/m^3$ and that of carbon monoxide, which aids in the abundance of greenhouse gases, also reduced by 0.31 $\mu g/m^3$. Together all these pollutants degrade the quality of air and presently are contributing to the viral spread of the COVID19 infection as well. Reduction in levels of all these pollutants was a positive sign for COVID19 containment but the cases anyhow increased as lockdown was lifted, season changed and so did the pollutant levels. The cases increased in the rainy season though approaching winters lessened the cases, the threat is still maintained as the virus is evolving at a very fast rate, increasing the chances of another wave of pandemic. The vaccine has however, brought a ray of hope.

Air pollution's contribution to viral spread is huge but there are other factors that contribute to the spread of COVID19 infection and become easy routes for viral transmission in healthy populations and further contributing to environmental degradation. The following are explained below:

Decrease in overall pollution levels during lockdown

According to WHO report (2018), 7 million people die every year of breathing fine particles in polluted air (https://www.who.int/news-room/detail/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action). 12.5% deaths in India occur due to air pollution. The air quality index (AQI) of the metropolis cities in India has been worse, with not even breathable levels from past many years. But this pandemic situation has brought everything to halt. All the industries were shut down across the world, there were really few vehicles on the roads, all the constructions stopped suddenly. This not only gave humans and animals time to rejuvenate but also time for the environment to heal itself. Air quality index improved, water bodies became crystal clear, endangered species started to show up on roads and all the other species on earth healed.

In parts of eastern India, the levels of PM_{10} decreased from 189-278 mcg/m^3 to 50-60 mcg/m^3 within 18 days of lockdown (Lokhandwala and

Gautam, 2020). A large reduction in concentration of four major pollutants- PM_{10}, $PM_{2.5}$, NO_2, and SO_2 could be achieved due to lockdown. The pollution levels which seemed uncontrollable by various strategies came down in their range.

Using methods like Air quality index (AQI) and Aerosol optical density (AOD) - using satellites, pollution levels were checked at different time intervals during lockdown and compared with pre-lockdown period and an environment with optical density of less than 0.1 is considered to be clean. A drop of 85% was seen in $PM_{2.5}$ levels and of 40-50% in NO_2 levels (Lokhandwala and Gautam, 2020). But O_3 (a secondary pollutant) levels have increased by 37.35% in post lockdown period due to two reasons: first, because the emission of O_3 precursors (NO_x and Volatile organic compounds) decreased and second, because of decrease in ozone degrading compound (NO levels) reducing ozone consumption (Kumari and Toshniwal, 2020; Dasgupta and Srikanth, 2020).

Along with air quality, water bodies have also shown positive signs of condition, revealing that the quality of rivers like Ganga, Yamuna, Cauvery, Sutlej etc. has improved. Due to a decrease in primary effluent levels from the industries during the lockdown, the BOD levels decreased from 6.5 to 3ppm for Ganga since 2019 (Lokhandwala and Gautam, 2020). Other factors responsible for this are reduction in irrigation water demand, reduction of religious and cultural activities and above average rainfall. The water became so clean that it was declared fit for animal and human consumption. The organic load gets diluted in the river but industrial effluents hamper the self-cleansing property of the rivers.

Since lockdown-like conditions can't be imposed forever, strict and balanced measures can be taken up by the government and environmentalists to adopt better patterns.

Wildlife also got affected in a positive way. Since fishing declined, fish biomass increased. Additionally many animals were seen moving freely across towns. Even turtles returned to the places where they preferred not laying eggs due to human interference.

Adverse impact of lockdowns on the environment

Where on one side lockdowns helped in curtailing the pollution there were also some serious adverse effects causing a great deal of damage to the environment. This adverse impact originated from events like a number of industrial catastrophes (for e.g. the gas leak in a polymer plant in Andhra Pradesh, a boiler explosion in a thermal power plant and a steel factory and chemical plant in Tamil Nadu and Gujarat and a fire in the biodiversity rich landscape situated in Assam caused due to extraction of natural gas) triggered not only due to negligence and poor maintenance during pandemic and lockdowns but also due to noncompliance of environmental norms and foul practices in safety measures. This undoubtedly resulted in loss of few lives and serious contamination and destruction of the environment thereby escalating health woes for the inhabitants which could even last longer than the pandemic's impact. This has further exposed the gaps between the safety norms and thereby its adherence by the stakeholders in our country and is now getting attention of various authorities to implement more stringent laws and ensure its compliance.

It is also noticeable that there is a sudden spurt in cases after the last phase of unlocking and lowering of the temperature especially in Delhi and its surroundings as well as pollution caused by stubble burning and low air speed seems to further deteriorate the environment. This is another feature of the environmental destruction which has adversely impacted the severity of the disease. As gradually over the past few months, there were lifting of restrictions and the resumption of economic and office activity and a steady increase in road traffic, the AQI index has touched new heights surpassing 250 in some areas. With the Covid-19 virus still looming in the air, the current climatic conditions and sudden spike in pollution has largely escalated not only the number of cases but has also added to the severity of the disease because of the basic fact that Covid 19 is a respiratory disease and primarily affects the lungs and breathing activity in humans and the dangerous levels in air quality is bound to aggravate this problem largely. It has been estimated that an increase of one microgram/cubic metre (1 $\mu g/m^3$) of PM particles in the air may increase COVID-related deaths by fifteen per cent (Daraei *et al*., 2020).

DISCUSSION

The COVID 19 pandemic's rapid spread caused many countries to impose strict lockdowns and reduced the growth of major economies around the globe. More than 188 countries were affected by this

pandemic. The viral spread was earlier only believed to be from human to human contact and surface transmission. But with new studies coming forward, there came evidence of viral transmission through air. The other negative impacts of the pandemic include malpractices in safety measures in the industrial sector due to continuous lockdowns that led to some huge environmental hazards and innocent lives of the workforce were lost. A state of tension and chaos worsened the situation.

While most of the pandemics effects were negative, one positive aspect of the pandemic was seen as nature reviving itself as a halt in anthropogenic activities leading to reduction in air pollution levels especially reducing major pollutants like $PM_{2.5}$ and PM_{10}. Initially the $PM_{2.5}$ and PM_{10} levels were high in 2020, but reduced significantly during lockdown. The reduction in weather extremity, temperature fluctuations and a decrease in water pollution and the cleaning of water bodies are an outcome of this positive impact. The aquatic flora and fauna were seen to have gotten better in many places around the world including Indian cities. Many endangered species of animals were seen roaming around the cities due to highly restricted human movement.

Although there was a reduction in pollution, the situation worsened after the lockdown was called off completely and sudden increase in pollution levels of both PM_{10} and $PM_{2.5}$ along with other pollutants led to an increase in breathing and lung disorders among people, exposing them vulnerable to viral infection. It has been observed that stricter safety norms and severe vigilance are essential to ensure compliance during industrial and agricultural activities. The pre-existing vulnerability of humans exposed to air pollution has already been witnessed in the common prevalence of pollution related diseases including cardio-vascular disease, ischemic heart disease, chronic obstructive pulmonary disorders and infection of the lower respiratory tract. The endemic already present in the coexistence of hypertension and diabetes which are also due to air pollution, leaves an enhanced burden of fighting the pandemic making it tougher to fight the virus. Now since many countries have given approval to various vaccines and vaccination drives have started for the vulnerable strata there are better chances expected that we might be able to control the spread of COVID19 completely in upcoming times. But alongside, measures to ensure the control of pollution and saving the environment have to be taken up without any delays.

Controlling air pollution post lockdown is becoming a daunting task as is evident from the re-rise in pollution levels and thus the situation needs to be addressed on a war footage. With COVID19 still around, deterioration of the air quality is unaffordable and needs stringent measures and stricter guidelines to be controlled. The country surely requires a clean and sustainable environment along with efficient health care services for pandemic control and preservation of the economy and social justice.

It is in human hands to be well prepared for the forthcoming times by increasing our realisation on the fact that long term sustained measures are necessary and reduction in air pollution and health risk is non negotiable. Therefore, it is a public health emergency and inevitably requires drastic long term curtailing norms with both community and political support.

This is an appropriate time for a crisis-led change to occur in the country and around the world. But this experience with worldwide lockdown of such long duration for the first time and collective action of different communities to fight the virus has proven once again the importance of deepening public awareness over health risks to find solutions and the mutual dependence of human activities on nature.

Building public support and finding long-term solutions that otherwise seem politically and socially unrealistic and difficult to implement are advisable. Although the nation-wide collective lifestyle adjustment that we have seen so far is a powerful message, it is in human hands to prevent future pandemics by respecting nature and giving it the space it deserves.

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