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Breathing Fresh: Insights to Positive Externalities of COVID-19 Lockdown in Indian Megacities

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ABSTRACT It has been widely reported that as a consequence of nation-wide lockdown in India to control COVID-19 pandemic, the air pollution levels have significantly reduced. The near-complete shutdown of economic activities and stay-at-home instructions have tremendously helped in reducing emissions. This paper has attempted to look into the pattern of change in Air Quality Index in five megacities (Delhi, Bengaluru, Chennai, Mumbai and Kolkata) of India from pre-lockdown period to first week of lockdown and fifth week of lockdown. The paper has also discussed changes in air quality parameters at different monitoring stations in Bengaluru during the same period. A discussion on air quality, grounded on contemporary studies conducted to evaluate impact of lockdown on ambient air in different cities, has provided an overview of the changes in air quality. The results provide an understanding that the overall air quality has been improved in all the studied cities; but further comprehensive assessment, considering the factors controlling the present air quality, is suggested to identify pathways for emission reduction to maintain the air quality in business as usual situation in future.

INTRODUCTION

Severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) outbreak (WHO) in December 2019, first detected in Wuhan city of China, has been spread across countries leading to a global health crisis. It has been declared as pandemic by the World Health Organization on 30th January 2020. Countries have adopted different measures to prevent the spread of the virus, restricting their movements, closing down workplaces to contain the contagion of the virus. As a consequence of nation-wide lockdown imposed in India to control the COVID-19 pandemic, the air pollution levels have significantly reduced. Enforcement of a near-complete halt of transport sector and industrial activities reduced the emissions from man-made activities tremendously. Citizens of India, especially in the megacities, have got the first-hand experience of breathing and feeling clean air, otherwise suffocated with alarming air pollution levels. Residents of city of Jalandhar and the surrounding areas have posted photos of the peaks of the Himalayas sighted from around 250 kilometres away after about 3 decades. According to the data of Central Pollution Control Board (CPCB) on 29 March, which provides air quality index for 103 cities, show that 90 percent of the cities air quality has improved to satisfactory level. Similar improvements in air quality are also observed in Bengaluru, the Silicon Valley of India, which is also home for many heavy industries, aerospace manufacturing companies, and an important economic and cultural hub in India. The current world's most traffic-congested city, Bengaluru, is breathing well in this lockdown period meant to curb the pandemic. After the COVID-19 pandemic national lockdown the air quality is improving than never before, KPCB Air quality monitoring has recorded 64 index which is satisfactorily good air condition as on 15th April 2020, whereas, the Air Quality Index (AQI) value was recorded on an average 87 in April 2019.

The percentage of people living in cities and towns of the world has been increasing steadily and the recent increase has been more concentrated in low and middle-income countries. Among all urban agglomerations, 33 with 10 million or more inhabitants which are known as megacities, as per definition of the United Nations. These megacities in Africa, Asia, Europe,

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Latin America and Northern America accounts for 7 percent of the world's total population. Countries with high projected levels of urbanization where 90 percent of urbanization of the world will occur by 2050 belong to Asia and Africa. These cities have a major concern for sustainable urban growth while improving lives of both urban and rural population. India is one of those countries which have five megacities at present, which are Delhi, Mumbai, Kolkata, Bengaluru and Chennai, and adding Hyderabad and Ahmadabad by 2030 (UN 2018).The current population of Indian megacities is more than 90 million. The megacities have significantly contributed to an increase in human health issues worldwide where pollution is the most important environmental health risk (Marlier et al. 2016; Liu et al. 2016). When the efforts in pollution control don't match the pace of urban growth, the cities exhibit high levels of emission from housings, traffic and industries. Major emission sources of those cities include vehicles, manufacturing, electricity generation, construction, road dust, waste burning, household combustion (Guttikunda et al. 2014) and sometimes the pollution is contributed from neighbouring areas (Pommier et al. 2013; Tiwari et al. 2014; Marrapu et al. 2014) The variations in pollutant concentrations are also influenced by various factors, predominantly meteorology (Sanyal and Bhattacharyya 2009).

Urbanization in India is perceived as the force of economic development; cities being the growth engines provide economic opportunities in the form of non-agricultural livelihoods. Sanyal (2009) described this urbanization as the sociological and spatial changes that correspond to economic activities and all resulted in construction activity from rapid growth. As the large developed states in India have already faced environmental problems pertaining to urban growth, they have attracted attention for appropriate environmental planning and management; however, the attention has not been enough to deal with the growing problems of pollution.The impacts and threats to health, environment, and economy due to persistent air pollution are also extensive in urban areas. Centre for Research on Energy and Clean Air, estimated in a research publication, that in 2018, the economic costs of air pollution linked to fossil fuel accounted for almost 3.3 percent of the Global GDP (USD 2.9Trillion) and loss of 4.5 million human lives (Myllyrvirta 2020).A comprehensive report "The Global Burden of Disease- 2015" states ambient particulate matter pollution is the third largest health risk factor in India. In India, approximately 1.2 million people died every year because of problems related to air pollution and air pollution costs around 3 percent of GDP (Greenpeace 2017). The same report states that India's urban areas' air quality has deteriorated by 13 percent in 2010-15; whereas, China, US and EU have improved by 15 percent to 20 percent. Thus, to achieve the mandates of economic development in the country, it is important to tackle the problem of air pollution. Bengaluru and Delhi are the two Indian cities which have pledged to provide clean air to their citizens by 2030 by signing C40 Clean Air Cities Declaration, 2019 in Copenhagen. If all the 35 signatories reduce annual average PM2.5 levels to WHO guidelines (10 ug/m3) it could avoid 40,000 deaths each year. National Clean Air Programme is an initiative launched in 2019 with commitments to reduce air pollution in 102 most polluted cities by a maximum of 30percent by 2024. Report by IQAir AirVisual, India states that India has witnessed decrease in air pollution which can be attributed to market slowdown, favourable meteorological conditions and efforts to combat emissions. According to that report, 98 percent of the cities are improving, although five of the most polluted cities of the world are still located in India.

Study in Kolkata Municipal Corporation area shows that residential sector is responsible for 50 percent of ambient PM-2.5 concentrations, where the rest is contributed from power sector, waste and open burning, road transport (exhaust) and road transport (non-exhaust) predominantly; whereas, industrial emissions, construction and agriculture sector has minor contribution (4%, 2% and 1% respectively) (Majumdar et al. 2020). Another prediction modelling study for Delhi reveals that under business as usual scenario, the increase in coarse (PM_{10}) and fine particulate matter ($PM_{2.5}$) will be as high as 51 percent and 15 percent respectively by the year 2030 (Bhanarkar et al. 2018). Reduction in Air Quality Index values by 44 percent, 33 percent, 29 percent, 15 percent and 32 percent respectively in cities' of north, south, east, central and western India have been observed (Sharma et al. 2020). It apparently has the linkage with limiting economic activities and a sudden decrease in vehicles on road due to lockdown. This paper is a narrative of how the air quality in cities have changed during lockdown based on secondary data and literature. It has also attempted to examine the air pollution levels pre and post lockdown in Indian megacities. Bengaluru being one of the fastest-growing cities, the impact of this lockdown on levels of pollution in terms of CO, NO_x, SO_2, 03, $PM_{2.5}$ and PM_{10} across the monitoring stations has been assessed.

MATERIAL AND METHODS

Pieces of literatures regarding air quality and economic activities in cities, particularly in megacities, both in business as usual condition and lockdown led by COVID-19 have been studied to arrive at a qualitative account of the impact of lockdown. Data on individual air quality parameters and AQI for major metropolitan cities of India have been acquired from online database of Central Pollution Control Board (CPCB). List of station-wise daily AQI for before lockdown and after lockdown daily wise weekly data is obtained from different web-portals of Karnataka State Pollution Control Board, CPCB, Ministry of Environment, Forest and Climate Change. The data was converted into spatial feature using GIS tools and the graphs are presented on map for visual interpretation of AQI changes in the different cities. To perform land use and land cover change (LULC), Landsat 8 Earth observation satellite data with 30m Spatial resolution was acquired for the date 31st March 2020 form Earth explorer, USGS web portal. ArcGIS 10.3.1 and ERDAS IMAGINE geospatial platforms have been used to perform LULC of the selected Air quality monitoring stations. A circular area with a 3km radius was created using GIS tools for each of the monitoring sites to check the physical land type and landscape utilization such as development, conservations or mixed uses. Layer stacked image of multispectral bands of Landsat image is considered to obtain LULC. Supervised classification is performed to generate the image with defined classes, with the assistance of the image classification toolbar, training samples have been created for the classes which were to be extracted. Maximum Likelihood Algorithm was employed to detect the land cover types in ERDAS Imagine 14.

RESULTS AND DISCUSSION

A Qualitative Account on Lockdown and Air Quality

Restrictions on economic activities and movements have exhibited impacts on air quality in many countries which have been reported through several studies (Dantas et al. 2020; Saadat et al. 2020). Study on air pollution of Rio de Janerio, Brazil shows a significant reduction in CO and NO_2 levels during lockdown; whereas, decrease in PM concentrations was observed in the first week of lockdown (Dantas et al. 2020). Increase in ozone concentration during that period was noticed which has been linked to as a result of the reduction in NO_2 levels. Study shows that air quality improvement in China during this pandemic has the potential to prevent 24000-36000 premature death in the country (He et al. 2020). Although the outbreak of COVID-19 is unfortunate, research findings have also suggested positive impacts on human health by comparing mortality from air pollution and COVID-19 infection. Isaifan (2020) states in his research paper that air pollution is 7.6 percent mortality rate is attributed to air pollution in China which is high as compared to a lower COVID-19 mortality rate of 3.4percent as on 11th March. Another study critically discussed if the decrease in NO_2 and CO is enough for betterment of health as the SO_2 and surface level ozone decrease is not prominently seen (Almond et al. 2020), rather increase on ozone levels has been noticed in many places. Air quality in Barcelona during lockdown has shown reduction of black carbon and NO_2 by almost half, whereas 50 percent increase in ozone levels and insignificant decrease in particulate matter concentrations pose as question in this regard (Tobias et al. 2020). The improvement in air quality has been assessed in 40cities of the world (Shrestha et al. 2020) which is definitely a temporary experience, but has the potential to encourage further efforts to take action for emission reduction.

As a consequence of nation-wide lockdown imposed in India to control the Pandemic, COV-

ID-19, the air pollution levels of Indian cities have drastically reduced (Mahato et al. 2020; Ramaswamy et al. 2020; Srivastava et al. 2020). Studies in India on improvement of air quality during COVID-19 pandemic have emphasized drawing the attention of regulatory bodies in emission source control in attenuating air pollution of cities. Enforcement of a near-complete halt of transport sector and industrial activities, reduces the emissions from man-made activities tremendously. Sharma et al. (2020) testify the effectiveness of restricted emissions on pollution control. Importance has to be given to reduce secondary pollutants like ozone which have shown increased or same concentrations while other primary pollutants are decreased in concentrations during lockdown. Another study in Delhi shows that the most notable decrease (>50%) in pollutant concentrations is in terms of $PM_{2.5}$ and PM_{10} (Mahato et al. 2020). Aerosol Optical Density assessment for India shows significant decrease in the first week of lockdown and it is the lowest in last 20 years (Gautam 2020).

Megacities and Air Quality

With changing pattern of economic activities and initiatives to combat air pollution, the pattern of pollutants in megacities are also changing; where, keen concern over particulate matter, black carbon, NO_x and ozone has been observed due to their local and regional impacts including health risks and global climate change (Gurjar et al. 2016). Air pollution is in top rank among the risk factors for death in the world and population in the cities are worst affected. Estimates from past studies show that the major share of air pollution in Indian cities are 72 percent from vehicles, 20 percent from industries and the rest due to domestic sources. AQI, being a composite index maximum eight parameters indicating ranges in terms of health hazards and the health hazards risk for six categories of exposure have been described (Table 1).

Weekly averages of AQI values for three points of time, viz.- prior to lockdown, first week of lockdown and fifth week of lockdown in five megacities of India are shown in Table 2.During pre-lockdown, Chennai and Bengaluru exhibited air quality better than other three megacities, with AQI in satisfactory range. Already being in a better position, the improvement in AQI (21-23%) in these two cities was comparatively lower than the other three cities. The most polluted capital, Delhi had a weekly average of AQI 154.97 which reduced to 71.68 in the first week of lockdown. The results also show that Bengaluru, Mumbai and Kolkata have shown gradual improvement in quality of ambient air. However, a decrease in pollutant concentrations have been apparent in Delhi and Chennai in the first week of lockdown, but not noticed in the fifth week's results. Only Bengaluru and Kolkata have achieved air quality of "Good" category during fifth week, whereas the other megacities maintain their air quality as "Satisfactory". Figure 2 illustrates that the percentage decrease in AQI values with relation to vehicles registered in respective cities, where a positive correlation has been noticed between number of vehicles registered and percentage decrease in the first week of lockdown. The fifth week's decrease cannot be linked to vehicular emission, where these two parameters have shown a negative correlation (r=-0.61). Mumbai has the highest vehicular density (1900 vehicles per km) where 28 percent is private vehicles (Economic Survey 2019-20 Maharashtra as cited in ET, March 6th 2020); however, the highest improvement in air quality has been noticed in Delhi which can be linked to

Table 1: Composite AQI values and corresponding likely health impacts of exposures

AQI	*Remark*	*Possible health impacts*
0-50	Good	Minimal impact
51-100	Satisfactory	Minor breathing discomfort to sensitive people
101-200	Moderate	Breathing discomfort to the people with lungs, asthma and heart diseases
201-300	Poor	Breathing discomfort to most people on prolonged exposure
301-400	Very Poor	Respiratory illness on prolonged exposure
401-500	Severe	Affects healthy people and seriously impacts those with existing diseases

Source: https://pib.gov.in/newsite/mainpage.aspx (Retrieved on 3 May 2020)

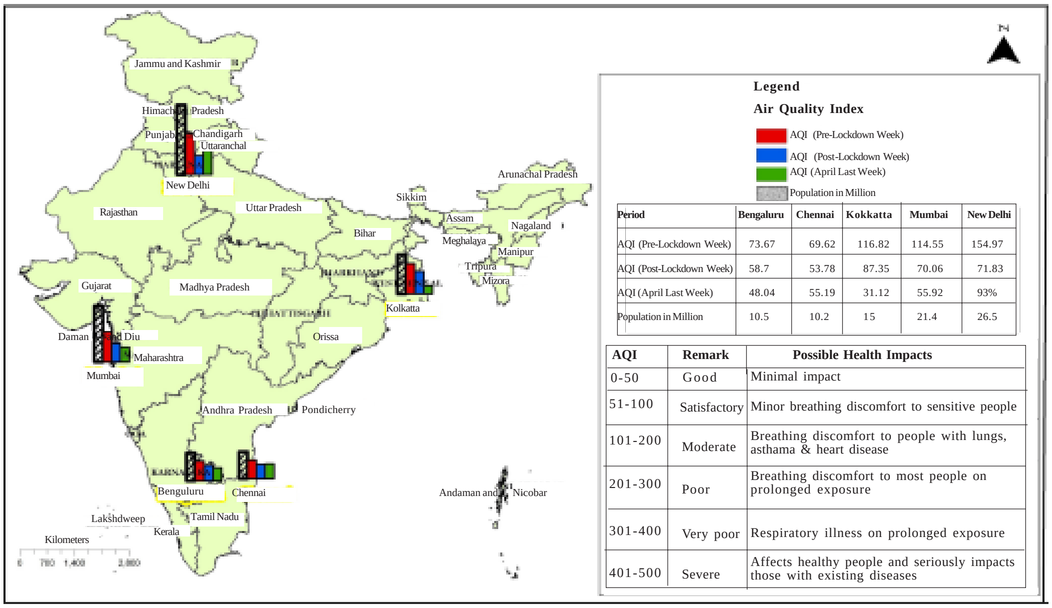

Fig. 1. Map showing population of cities, AQI in pre and post-lockdown of Indian megacities
Source: Map prepared based on the data obtained from Central Pollution Control Board (CPCB), Govt. of India

highest number of registered vehicles (more than 88 lakh in 2017) among all megacities. The partial relaxation on lockdown from 4th of May 2020 has exhibited its impact on AQI (in first day) of Bengaluru and Delhi among the megacities of India, where Bengaluru's and Delhi's AQI has increased to 80 and 111 from 48 and 93 respectively in the fifth week of lockdown.

Air Quality Parameters across Monitoring Stations of Bengaluru

The concentration of air pollutants under consideration ($PM_{2.5}$, PM_{10}, CO, Benzene, SO_2 and NO_x) aggregated over a period of seven days (8th March to 14th March) before lockdown and compared with the data recorded for the same number of days during the lockdown starting24th March (Table 3). The comparison clearly shows that other than SO_2, the concentration of other pollutants has reduced during the lockdown period. Sulphur dioxide concentrations have shown an average 2.4 percent increase across the monitoring stations of Bengaluru. Oxides of nitrogen have shown the highest decrease (average 56.1%) in concentration in all the monitoring stations which is followed by decrease in PM_{10} concentrations (37.2%). Benzene and CO

Table 2: Air Quality Index (weekly average) of megacities of India in pre and post COVID-19 Lockdown

Cities	*Delhi*	*Bengaluru*	*Chennai*	*Mumbai*	*Kolkata*
Pre-Lockdown Week	154.97	73.67	69.62	114.55	116.82
Lockdown Week-1	71.68	58.07	53.78	70.06	87.35
Lockdown Week-5	93.96	48.04	55.19	59.22	31.12
AQI Standard (Good)	50	50	50	50	50
Car density (no. of cars per km)	108	297	149	510	319
% decrease in week-1	53.75	21.18	22.75	38.84	25.23
% decrease in week-5	39.37	34.79	20.73	48.30	73.36

Source: Calculated based on the data from the Central Pollution Control Board (CPCB), Govt. of India

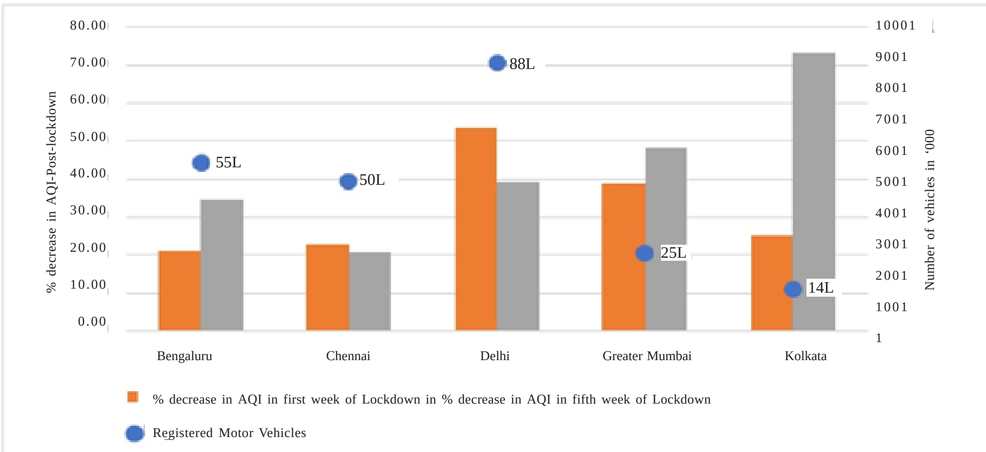

Fig. 2. Number of registered vehicles vs percentage decrease in AQI values
Source: Vehicle data: Statistical Year Book, MoSPI, India (2017)
Source: http://mospi.nic.in/statistical-year-book-india/2017/189) (Retrieved on 30 April 2020).

Table 3: Average (one-week) concentration (ppm) of air pollutants during pre and post-lockdown in Bengaluru

Pollution Monitoring Stations	*PM2.5 [µg/m3]*		*PM10 [µg/m3]*		*CO [µg/m3]*		*Benzene [µg/m3]*		*SO2 [µg/m3]*		*NOx [µg/m3]*	
	Pre-LD	*Post-LD*	*Pre-LD*	*Post-LD*	*Pre-LD*	*Post-LD*	*Pre-LD*	*Post-LD*	*Pre-LD*	*Post-LD*	*Pre-LD*	*Post-LD*
BTM Layout	26.82	24.56	DD	DD	0.99	0.87	0.0	0.0	5.28	7.17	31.38	20.71
BWSSB Kadubeesanahalli	57.00	50.45	DD	DD	0.73	1.15	0.06	0.44	7.3	8.10	48.87	15.95
Bapuji Nagar	32.29	DD	68.98	DD	0.6	DD	1.28	DD	10.53	DD	16.06	DD
Hebbal	31.86	24.83	84.43	54.51	0.74	0.62	0.27	0.17	9.78	8.03	9.90	6.34
Hombegowda Nagar	32.6	29.75	74.71	56.18	1.27	1.28	0.18	0.15	11.04	11.11	9.54	4.41
Jayanagar 5th Block	39.67	25.86	77.24	47.02	1.01	0.51	0.27	0.14	DD	DD	24.17	8.78
Peenya	43.78	36.91	DD	DD	1.00	0.79	DD	DD	3.32	3.27	17.21	8.81
Silk Board	29.23	21.27	88.82	46.61	1.13	0.86	0.61	0.42	2.62	2.67	17.30	4.45
Average Percentage Reduction In Concentration	18.2%		37.2%		6.5%		4.3%		-2.4%		56.1%	
National Ambient Air Quality Standards (24 Hours)	60.00		100.00		4.00		5		80.00		-	

DD: Data deficit
Source: CPCB [17]Pre-lockdown period: 8/3/20 -14/3/20; Post-lockdown period: 24/3/20 - 30/3/20 (https://app.cpcbccr.com/AQI_India/) (Retrieved on 1 May 2020)

have experienced the least decrease in concentration; however, these pollutants are within prescribed limits in both pre and post lockdown. Kadubeesanahalli is the only site which has witnessed increasing concentration of three air quality parameters, viz., ozone, sulphur dioxide and benzene. Before lockdown, higher levels of fine particulate matter, $PM_{2.5,}$ is recorded which is the direct result of anthropogenic activities in Peenya (industrial area) and Kadubeesanahalli (swarming construction activities in the IT belt of south-east Bengaluru). $PM_{2.5}$ can enter the respiratory system, which has adverse impacts on cardiovascular health and thereby increases the mortality risk. Carbon Monoxide has been found with no significant reduction across monitoring stations; whereas found to be increased in Kadubeesanahalli, even during lockdown which can be attributed to other micro-climatic and topographical variables. Nevertheless, all the parameters in both pre lockdown and during first week of lockdown had concentrations within the limits set by National Ambient Air Quality Standards.

Land Use Land Cover Change and Air Pollutants

The types and concentration of particulate matters in air depend on location of monitoring site, meteorological parameters and type of land use and land cover. The understanding of land use land cover patterns is essential for strategizing control measures. The conversion of natural land cover classes such as forest, grasslands and farmland to residential housing, industrial complexes and large commercial centres results in emergence of pollution sources. Figure 3 shows the distribution of air pollution mon-

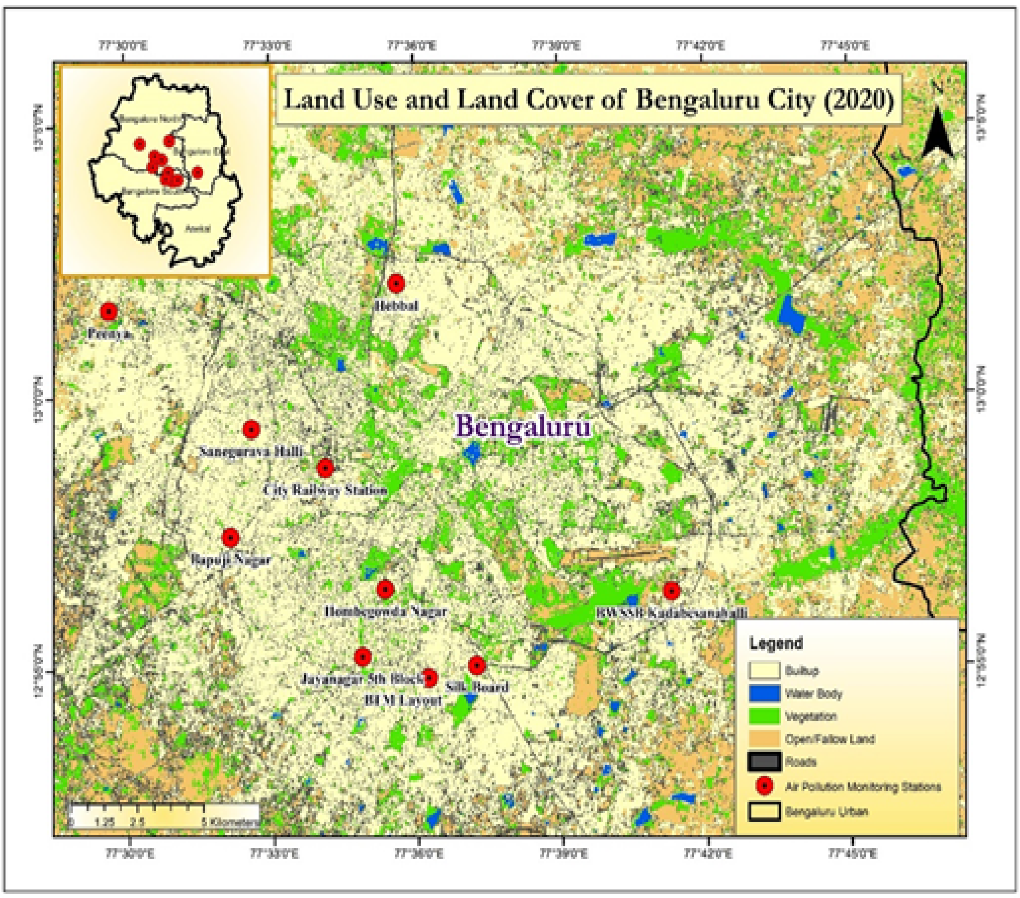

Fig. 3. Land use land cover map of Bengaluru showing air pollution monitoring stations
Source: Authors

Table 4: Percentage of area under different land use land cover types around 3km radius of monitoring stations

Pollution monitoring stations	*Built-up (%)*	*Vegetation (%)*	*Waterbody (%)*	*Open/Fallow land %)*	*Roads* (%)
Hebbal	67.5	14.17	1.48	6.07	10.79
Peenya	61.45	6.57	0.3	17.49	14.19
Bapujinagar	78.32	5.54	0.16	2.71	13.27
Silkboard	73.68	10.69	0.78	2.45	12.4
BWSSB Kadubeesanahalli	53.14	15.81	0.91	14.94	15.2

Source: Authors

itoring stations in Bengaluru and visual interpretation reveals no uniform distribution and coverage of the city area by monitoring stations.

Land use and economic activities are linked in a bi-directional loop. Extent of urban land use including built-up area (residential, commercial and industrial uses) and roads can be considered as indicator to assess urbanization and as a proxy indicator for corresponding economic activities. Previous studies show moderate to strong correlation between PM2.5 concentration and urban land (Superczynski and Christopher 2011). Table 4 presents the land use land cover pattern within a circular area of 3km radius around five monitoring stations. Among the analysed areas of monitoring stations, Bapujinagar and Silk board area exhibit the highest share of land under built-up category, 78.32 percent and 73.68 percent respectively. Bapujinagar has the lowest area under vegetation (5.54%), whereas, Kadubeesanahalli has the highest land area with vegetation cover (15.81%) among all the five sites analysed. Area under roads varies from 10.79 percent-15.2 percent among all the sites. Open and Fallow land is high in Peenya and Kadubeesanahalli. Open/fallow land and road have shown strong positive correlation with PM2.5 and NOx concentrations in monitoring stations. Larger area under open land (15.81%) and roads (15.2%) in Kadubeesanahalli may be attributed with comparatively low improvement of air pollution parameters in that area, where three of the six parameters have not improved post 23rd March 2020. The increasing concentration of Sulphur dioxide need more investigations to draw appropriate inference. In this regard, previous studies also show SO_2concentration is highly influenced by atmospheric pressure and wind (Unal et al. 2000).

Transport and dispersion of pollutants vary depending on the meteorological parameters and behaviour of pollutants in air, which determine the residence time of pollutants and removal from ambience by depositing on ground. Further assessment of behaviour and quantification of contribution from various economic activities will help to identify the possible pathways for emission reduction. This experience of lockdown has also been a lesson to improve environment-friendly behaviour without compromising the economic benefits for different industries, which will certainly help to validate the possible emission reduction opportunities.

India has plan to establish 3000 stations in class-I and class-II cities by 2022. Although the number has doubled since 2016, yet National Air Quality Monitoring Programme has only 703 stations in 2019 across 307 cities in covering the states and Union Territories of the country (Pant et al. 2019). Pollution monitoring for the purpose of emission reduction requires understanding of concentration, trend and behaviour of individual parameters. Availability of authentic data with spatially justified collection points which are representative of all the variations in landscape characteristics, is the primary requirement in this regard. Among 3400 registered industries in Bengaluru, 1600 industries are listed as Red category (Guttikunda et al. 2019), which must have in-house pollution monitoring system.The analysis of data on ambient air quality parameters across nine monitoring stations of Bengaluru to assess impact of lockdown has apparently brought in the comprehension that there is a need for extensive data from a greater number of representative sampling sites.

Opportunity for Environmental Renaissance: A Bengaluru Experience

Bengaluru is one of the megacities in India that received most benefits from economic liberalization started back in 1991. The mounting employment opportunities offered by domestic and multi-national companies, specifically from IT sector has greeted influx of migrants from all over the country. In addition to that, better educational institutes and business prospects have paved the way for people of different skill sets and economic classes to relocate in and around Bengaluru. With already having the significant share of urban population, it is projected that by 2031 Bengaluru will have 20 million residents (The Revised Master Plan of Bengaluru 2017). To accommodate the population of such a scale, Bengaluru Development Authority plans to expand city by another 80 sq km area. A haphazardly growing city contribute to environmental degradation in many forms, starting from effects of increasing energy consumption, industrial emissions, and vehicular traffic, all of which can have an adverse effect on air quality. The green patches are decreasing day by day resulting in disruption of pollution sink of the natural ecosystem.
Moreover, the individual private and public sector businesses and the town planners are neglecting the holistic inclusion of environmental aspects in urban planning, which is pushing Bengaluru, the Garden City of India, into a suffocating situation.

The effect of COVID-19 pandemic is apparent on human lives and lifestyles in almost all over the world; the world's economy has already experienced downfall, but the nature and wildlife has started to reclaim their lost spaces to humans. As a result of less vehicular traffic on the roads, Bengaluru residents spotted peacocks roaming freely in the busiest localities such as Malleswaram and Sadashivanagar. Bengaluru folks have been fortunate during this period to witness chirping and singing of birds such as cuckoo, sparrow, woodpeckers in their backyards and gardens. During this time, it is plausible to expect the attention towards the conservation of urban biodiversity in the remaining parks and small forest pockets in the city that are primarily maintained for recreational purpose.

Economic growth and rise in wealthier urban population hashuge sharein increasing number of private vehicles in Bengaluru, taking it to second highest in the country in terms of registered vehicles, which is more than 81 lakhs with a compound annual growth rate of over 10 percent. Bengaluru has one bus per 1700 persons which is much lower than both International and national standards, and it has immense scope for improvement. The largest IT park in Bengaluru, Embassy Manyata Tech Park (Hebbal) alone has more than 50 large companies occupying 1.8 million sqft of area which has approximately 35000 vehicles, of which less than a mere 150 are buses which includes both private and BMTC. In this regard, both government organizations and researchers should come forward to investigate the vehicular congestion resulting in economic loss in terms of longer commuting time, health hazards of pollution, degrading quality of life etc.Being appreciative towards the positive externalities of this lockdown, public transport can incentivized. Improved air quality, sustained in India for last few weeks due to emissions reduction also reflects the magnitude or scale of pollution contributed by vehicular emission and industrial activities. Study by Aaradhya et al. (2018) shows that the emission of greenhouse gases from transportation in Bengaluru accounts for 35 % of the total GHG emissions of the city, that is, 8521.23 Gg of CO_2e. The effect of the current situation on air pollution gives a rare glimpse of a world, if low-carbon technologies are adopted in future.

CONCLUSION

Air pollution contribute a substantial share to the health burden of a country, more specifically to respiratory illness. The current situation of pandemic led lockdown has resulted in better air quality which is realised by all and supported by this paper as well as other studies in this domain. Experts have already expressed the fear of increase in vehicular surge post-lockdown in the city because of the fear of contagion of the virus. This has to be prevented not only to protect the ambient air quality relapse to earlier situation, but also to control the severity of impacts of COVID-19, which aggravates respiratory illness. Private companies have largely adopted sustainable work style like working from home and further scope of exploration to find low emission work and lifestyle can be encouraged. Nevertheless, an unfortunate situation, yet this can be a basis for further learning to identify effective pathways for emission reduction, and an epiphany for humans at individual level to act reasonably for the improvement of environmental quality. These findings can be a learning for formulating urban policies to deal with the inevitable urbanization in India, as discussed in the introduction of this paper, to pave the way for sustainable urban growth in future.

RECOMMENDATIONS

The availability of station-wise air quality data and spatial distribution of monitoring stations in Bengaluru could be considered as an evidence to facilitate more pollution monitoring stations with justified locations for proper environmental monitoring. Discrete data series has found to be another concern to be resolved for generating useful environmental dataset. Another question emanated is the reduction of secondary pollutants (for example, surface O_3decrease was not observed) as much importance is given to particulate matter and other primary pollutants (NO_x and CO). Further indepth studies should be taken up to understand the behaviour and concentrations of air pollutants with respect to meteorological parameters under the conditions of restricted emission facilitated by this lockdown. Keeping the current environmental pollution and its severe consequences on human health and ecosystems, local authorities in Indian cities in consultation with the state government should make the provision for implementing the measures for reducing air pollution. There is a scope to mainstream the the sustainable practices people are adopting or trying to adjust in this situation of new normal. One such approach may be to instrumentalize work from home for companies belonging to ITC and similar service sectors through proper regulations. State actions based on this learning for achievable targets can help in stringent implementation of monitoring and pollution control measures for air polluting industries.

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