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AIR QUALITY ANALYSIS DURING THE FIRST LOCKDOWN OF COVID-19: A CASE STUDY OF CHENNAI METROPOLITAN AREA

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ABSTRACT

Despite the economic crisis and the loss of human life caused by COVID-19, the first complete lockdown period had shown a positive side from an environmental perspective. This lockdown has restricted the country's vehicular and industrial activities, power plants, construction activities, biomass burning, road dust resuspension, restaurants, etc., which led to a decrease in pollution levels due to reduction in pollutant sources and emissions. The study has identified significant changes in the air quality of the Chennai Metropolitan area during the first lockdown (March-May 2020). The Sentinel-5P, MODIS, and OMI/Aura satellite datasets have been used for the analysis with the help of Google Earth Engine API and NASA's GIOVANNI tool, which indicated the decreased levels of NO2, SO2, CO, and Aerosol Optical depth in various parts of the study area. The results have been acquired by carrying out change detection analysis between the satellite data of pre- lockdown and the first- lockdown phase of the year 2020, calculating per-pixel change between them. Ground-based air quality monitoring data has been used to support the trend shown by satellite data analysis. A significant decrease in the concentration level of pollutants can be seen in the industrial regions of the city. Some pockets of the city, especially the residential areas, resulted in increasing levels of pollutants with peak concentrations during April-May 2020. To validate the results, the study also analyzed the pattern of pollutant concentrations during March to May months of three consecutive years 2019,2020 and 2021, of which 2019 was taken to be a normal year, whereas 2020 and 2021 were the years with Covid-19 restrictions showing a decreasing trend of pollution. Also, the study has identified that the northern Chennai industrial regions, including Manali, Ponneri, Ennore, and the central commercial part of the city, are the significant hotspots of pollution, which need suitable air pollution control measures considering not only the COVID-19 situation but also to help in mitigation of Climate change and Global warming substantially.

Keywords: COVID-19, Air quality, Pollutant concentration, Sentinel-5P, MODIS, Google Earth Engine, GIOVANNI, Chennai

1. INTRODUCTION

The COVID-19, infection due to novel coronavirus from the Wuhan province of China, was declared a public health emergency of international concern on 30th January

2020. As of 23rd December 2021, 275,233,892 confirmed cases had been reported globally, including 5,364,996 deaths due to this infection (The Times of India, 2021; WHO, 2021). After the first case of COVID-19 reported on 30th January in India, the cases gradually increased and peaked in the following months. This has led to a nationwide public curfew on 22nd March 2020, followed by a complete lockdown (first) of the nation from 24th March 2020 (*My Gov*, 2020). This lockdown was extended until May 30th as the pandemic continued in Tamil Nadu. The first lockdown was imposed on four stages to flatten the infection curve, each with different plans, strategies, and rules (The Hindu, 2020). Chennai, at most times placed in the red category region, indicates the method devised by the Government of India to identify the pockets of severity into red, orange, and green based on the confirmed number of cases where red meant the highest severity. The rules and relaxations were based on this category (DM II, 2020). The state capital Chennai was the most affected region within Tamil Nadu by COVID-19 with 8228 confirmed cases during the first phase of lockdown (Mar-May,2020) as per the reports of 21st May 2020 (*Greater Chennai Corporation*, 2020; The Times of India, 2021)

Chennai is one of the cities highly prone to air pollution, which has recorded severe air quality crises even in the recent past. The presence of heavy industries and ports in northern Chennai served as a hotspot of pollution and has resulted in an unhealthy air quality many times in the previous years, the most recent observed during May-July, 2019 (The New Indian Express, 2020). Also, the Center for Science and Environment reported that Chennai has one of India's worst vehicular pollutions after Delhi produces 3200 tonnes of CO2 per day. PM 2.5 (Particulate Matter 2.5) concentration increase was the primary concern in the city as it has ailed the health of people living in the hotspots. The year 2018-2019 has seen a maximum PM 2.5 in the city where the peak level of PM 2.5 ever (173microgram/cubic meter) was recorded in Nungambakkam (Citizen Matters Chennai, 2019).

The study aims to identify any changes in the air quality of the study area during the first lockdown period of Covid-19 compared to the pre-lockdown and post- lockdown situations. Also, it aims to make use of the advancements in remote sensing and GIS analysis like the availability of Sentinel-5P data specially developed for monitoring real-time atmospheric trace gases and Google Earth Engine API, which makes complex geospatial workflows fast and more accessible with more readily available data.

2. STUDY AREA

Chennai is one of the four metropolitan cities of India, geographically located between 12°50'49" and 13°17'24" N latitude and 79°59'53" and 80°20'12" E longitude *(Figure 1)*. It is a port city with proximity to the Bay of Bengal that gives easy access to the markets in East Asia. The economic base of Chennai has its foundation in trade and shipping. It has many ventures of automobile industries, chemical and petrochemical enterprises, IT companies, medical care facilities, and manufacturing hubs (Urban Emissions. Info, 2017). Chennai is the administrative capital of Tamil Nadu, with people residing in the region from all over Tamil Nadu and also has a large floating population(CMDA, 2020). The Greater Chennai region has a population of 8,696,010. At the same time, Chennai alone holds a population of 67,48,026 with a population density of 37,223 persons per sq. km. It is considered one of the most densely populated cities in the world (USA Today, 2019). Nearly 820,000 people of Chennai live in slum conditions which is a matter of concern. The people in slums already live in poor environmental conditions where waste management and disposal are uncontrolled and unregulated. The proximity to the pollution hotspots increases their risk to be affected by air pollution. 13% of households own a car, and 47% own a motorcycle. (JICA, 2017)

The city can be divided into four regions: North, Central, South, and West. While the northern Chennai region serves as a manufacturing hub, the southern and western parts of the city are concentrated with Information Technology firms, financial companies, and call centres. At the same time, the central region remains a commercial hub (Statistical Handbook, 2017).

Chennai is a tropical region with a mean annual temperature of 24.3 to 32.9 °C. Late May to early June is the hottest part of the year, with maximum temperatures peaking between 35–40 °C, and January with minimum temperatures around 15–22 °C is considered the coolest part of the year. The humidity usually ranges between 65 and 84%. Prevailing winds in Chennai are generally southwesterly between April and October, and it is northeasterly during the rest of the year. The northeast monsoon brings the rains during October, November, and December, with an average annual rainfall is 1200 mm (CMDA, 2008; TNPCB, 2020)

3. MATERIALS AND METHODS

3.1 DATA

The study is based on the satellite data of the pre and post lockdown period of Chennai (Table 1 & 2) from the Sentinel 5-precursor mission, which provides near real-time global coverage data on the atmospheric concentration of NO2, SO2, O3, CO, Methane, Formaldehyde, and UV aerosol properties from TROPOMI (Tropospheric Monitoring Instrument) (van Geffen et al., 2019; Veefkind et al., 2012) and OMI/Aura NO2 Cloud-Screened Total and Tropospheric Column Level 3 data used for a total column and tropospheric column of NO2 (OMI, 2012; Earthdata, n.d.) MODIS Multi-Angle Implementation of Atmospheric Correction (MAIAC) product MCD19A2 V6 has been used for mapping Aerosol optical depth in the study area. The ground-based air quality measurements have been collected from the Continuous Ambient Air Quality Monitoring station data of TNPCB (Tamil Nadu Pollution Control Board) and CPCB (Central Pollution Control Board). The TNPCB have 4 CAAQMS in the study area that includes Kodungayyur, Koyambedu, Perungudi, and Royapuram. At the same time, the CPCB has four monitoring stations around Chennai in the places like Manali, Manali Village, Velachery Residential area, and Alandur Bus Depot. This Air quality monitoring stations measure many atmospheric parameters like PM2.5, PM10, NOx, NO2, SO2, CO, O3, etc. Combining CPCB and TNPCB stations, eight stations data around the study area limit were obtained(CPCB, 2020.; *TNPCB*, 2020).

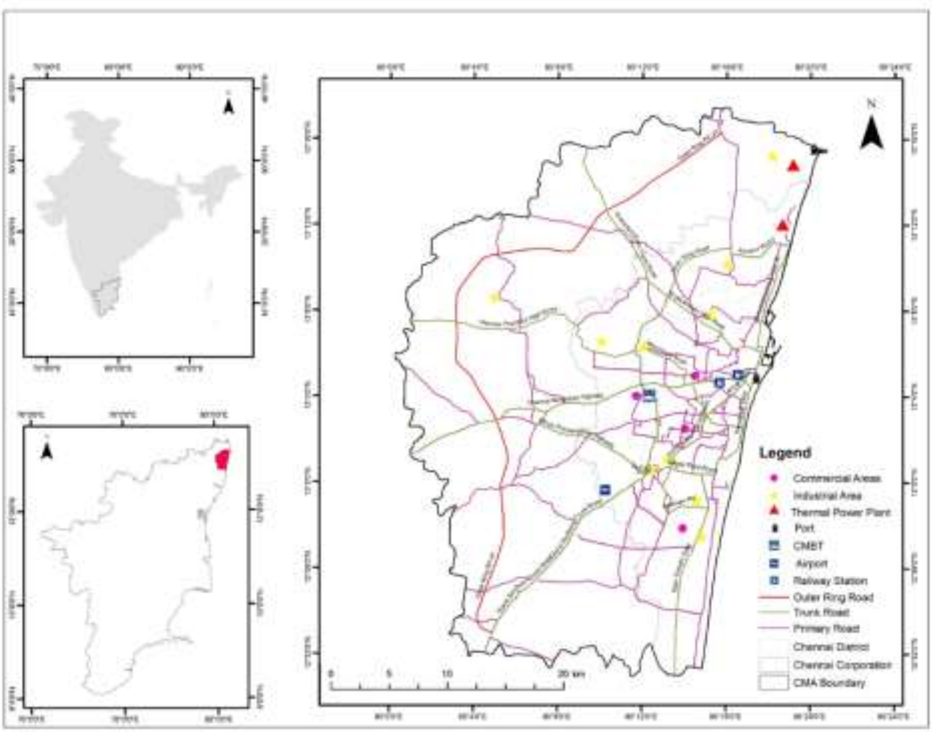


Figure 1 Location of Study Area

Table1: Data used and its sources

Pollutant	**Data**	**Band Name**	**Source**
Nitrogen Dioxide	OMNO2d	Total column NO2	Giovanni
	Sentinel 5-P NRTI/L3_NO2	NO2_column_number_density	Google Earth Engine
Sulphur Dioxide	Sentinel 5-P NRTI/L3_SO2	SO2_column_number_density	
Carbon Monoxide	Sentinel 5-P NRTI/L3_CO	CO_column_number_density	
Ozone	Sentinel 5-P NRTI/L3_O3	O3_column_number_density	
UV Aerosol Index	Sentinel 5-P NRTI/L3_AER_A	absorbing_aerosol_index	
Land Aerosol Optical Depth	MCD19A2 V6	Optical_Depth_047	

Table 2: Dates for which satellite data is acquired for all the pollutants

	Year	Date
Pre- Lockdown	2019	March 1 to May 31
	2020	January 1to March 23
Lockdown	2020	March 24to May 10
Post- Lockdown	2021	March 1 to May 31

Table3) National Air Quality Standards

Pollutant	**Concentration in µg/m³**		
	Time Weighted Average	**Industrial, Residential and Other Rural areas**	**Ecologically Sensitive Areas**
NO2	24 Hours	80	80
SO2	24 Hours	80	80
CO	24 Hours	1	1

3.2 METHODS

In this study, the Google Earth Engine, a cloud-based platform that has an analysis-ready data catalogue, was utilized to make maps on mean concentrations of NO2, SO2, CO, UV Aerosol Index, Ozone, and AOD from Sentinel 5p and MODIS imageries (Tobías et al., 2020; Veefkind et al., 2012) The platform was accessed through internet-based API and code editor by giving python or java based codes (Gorelick et al., 2017). A comparison study has been made using time-series graphs retrieved using the google earth engine for 2019, 2020, and 2021 during the intended study period (Mar-May). The GIOVANNI, a tool from NASA for accessing, visualizing, and analyzing the remote sensing data, was used to make time-series graph and time-averaged maps on NO2 concentrations using OMI/Aura Cloud-Screened Total and Tropospheric Column L3 Global Gridded data with 0.25°x 0.25° spatial resolution (OMI, 2012; Saikawa et al., 2019; Prados et al., 2010).

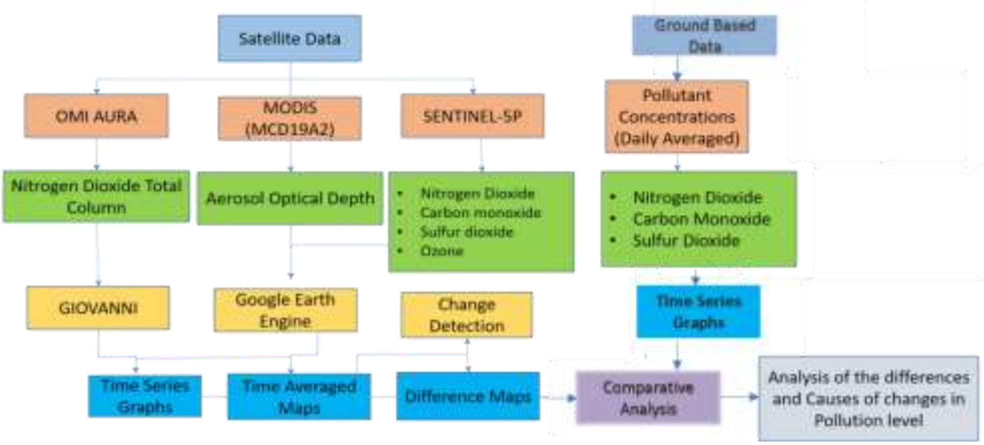


Figure 2 Methodology of the study

Further, change detection analysis was performed with ERDAS Imagine 2014 using the image difference tool. This tool calculates the change in pixel values of two raster images. The acquired time-averaged maps of NO2, SO2, and CO during the period before lockdown, which was from Feb 1st, 2020 to Mar 23rd, 2020, and the period after lockdown, which is from Mar 24th, 2020 to May 10th, 2020, had been used for difference calculation.

4. RESULTS

4.1. Nitrogen Dioxide:

The overall concentration of NO2 varies from -0.00005 to 0.0009 mol/m² during the lockdown period. From the Sentinel 5-P data, more than a 30% decrease in the concentration of NO2 *(Figure 3b & 4e)* can be noticed in the Northern and Central parts of the study area from March to May, which is the prime location for many industrial estates and commercial hubs. The MODIS data shows a similar result but with less accuracy than Sentinel 5-P *(Figure 4c & d).* The Ennore port, known for the high movement of vehicles during regular days, had the lowest concentration of NO2 during this period compared to the pre-lockdown time. April 1st to 10th of 2020 recorded low concentrations of NO2, and later on, it started increasing gradually *(Figure 3a & b)*. The Tambaram area shows a slight increase in the concentrations of NO2 during this period. From *Figure 3b,* a prominent decrease in the trend of NO2 concentration due to lockdown compared to 2019 and 2021 can be observed. It should be noted that from day 130 (May 10th) of 2021, when the 2nd phase of complete lockdown was imposed, it shows a similar decrease inNO2 concentration. The CAAQM's data also shows a similar trend of NO2 concentration for the year 2020 in line with the satellite data *(Figure 3c)*.

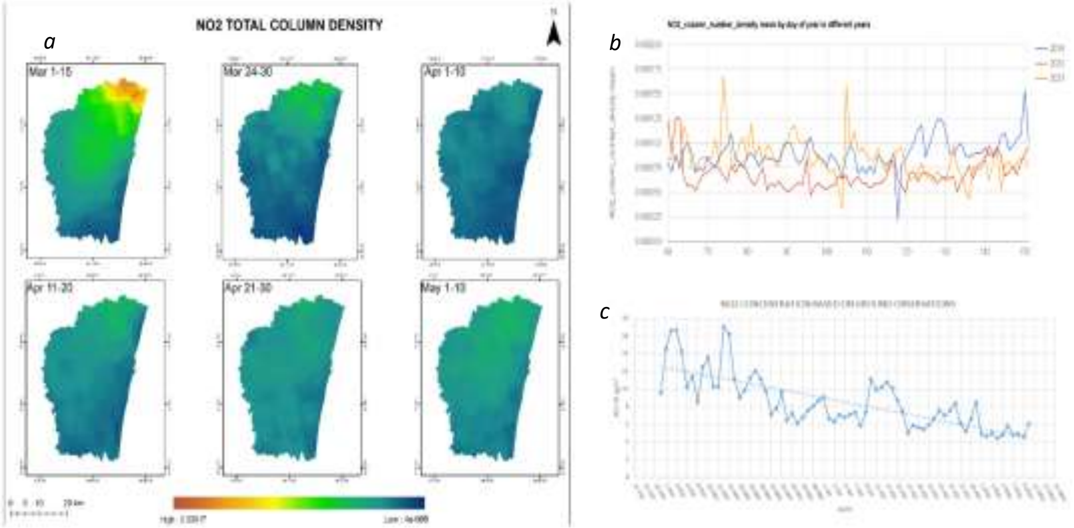


Figure 3 a) NO2 concentration weekly range from Sentinel 5P, b) Graph showing NO2 levels during 2019,2020 & 2021, c) NO2 levels of lockdown period retrieved through CAAQM's

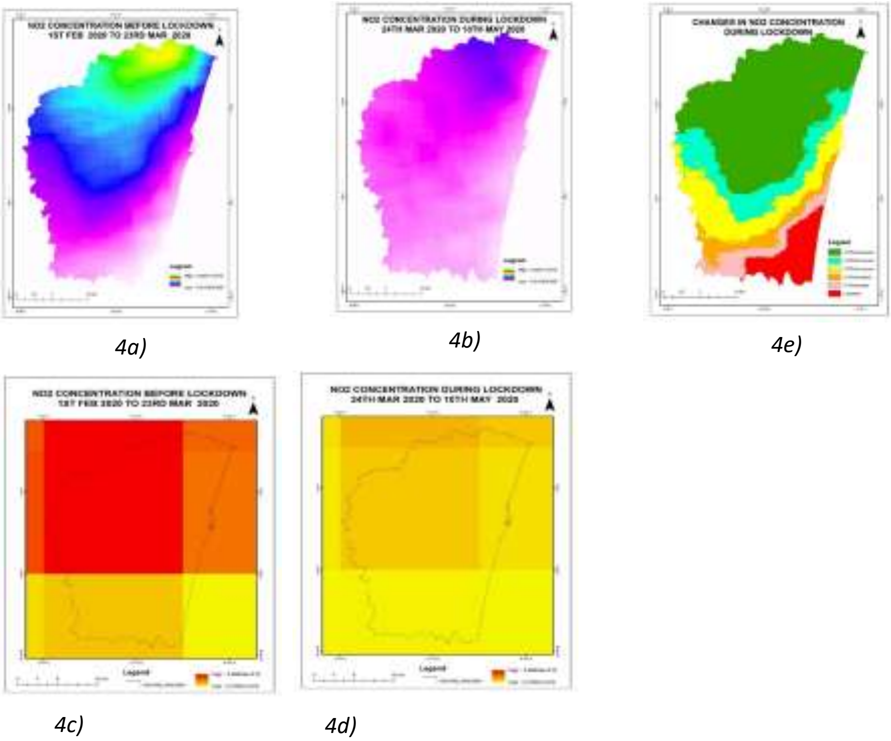


Figure 4 a) NO2 concentration before lockdown retrieved from Sentinel 5P, b) NO2 concentration during lockdown retrieved from Sentinel 5P, c) NO2 concentration before lockdown retrieved from MODIS, d) NO2 concentration during lockdown retrieved from MODIS, e) Changes in NO2 concentration in percentage

4.2. Sulphur Dioxide

In the case of SO2, there isn't an overall decrease, but a dynamic trend in the concentration can be noted during the lockdown. In some parts of the city like Ambattur, Tambaram, Chengalpattu, and Sriperumbudhur, the SO2 concentration was higher than normal days from March to May in 2020 *(Figure 5 a & 6b)*. Ambattur is an industrial area with many small-scale industries. There is a satellite earth station by Tata Consultancy situated at Redhills. Whereas Tambaram and Chengalpattu were residential areas, the anthropogenic activities didn't cease in that areas amidst lockdown. More than 30% reduction of SO2 than normal days was recorded during the 1st ten days in April 2020, which is evident in the Manali and Ennore industrial regions where the significant emitters of SO2 like the power plants, metals processing, and smelting facilities are situated *(Figure 5a & 6c).* The overall concentration of SO2 ranges from -0.0004 to 0.0005 mol/m^2 *(Figure 5b).* As observed from CAAQM's data Koyambedu region recorded 8 out of 10 highest SO2 recordings during the lockdown period. Before lockdown, in the year 2020, the SO2 concentration had reached the highest values of 60.08 µg/m^3 in the Manali area, but during the lockdown, it recorded less than ten µg/m^3 throughout. In the Velachery residential area, both the highest and lowest concentrations were recorded during the lockdown period, and the highest recordings were the consecutive days from April 11 to 14,2020. Analyzing the successive years, 2020 shows overall minimal concentrations of SO2 compared with the years 2019 and 2021 *(Figure 5b).*

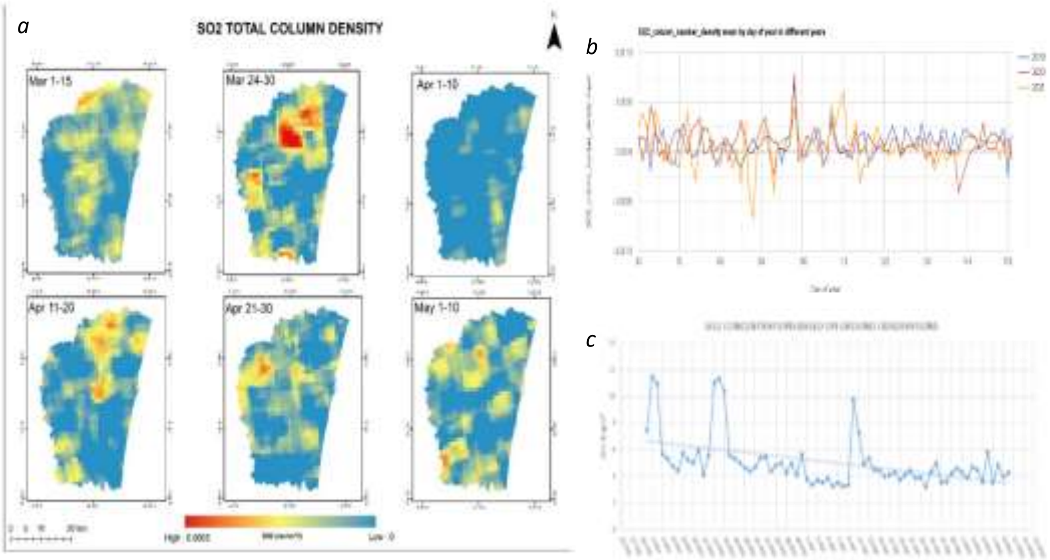
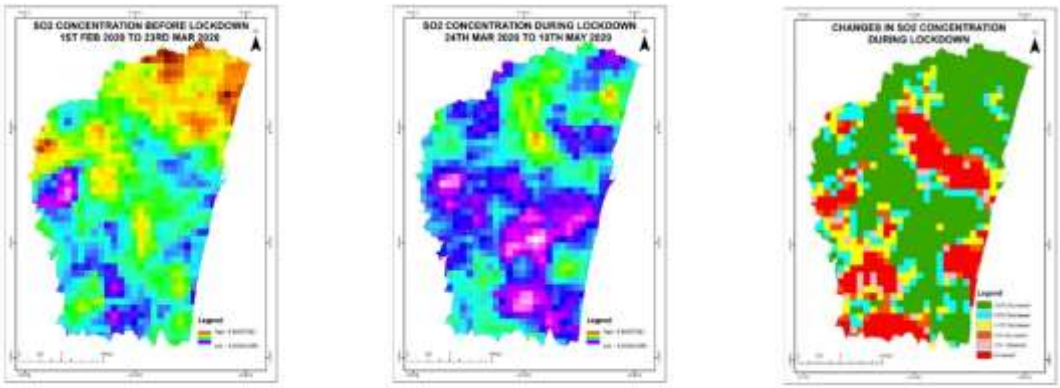


Figure 5 a) SO2 concentration weekly range from Sentinel 5P, b) Graph showing SO2 levels during 2019,2020 & 2021, c) SO2 levels of lockdown period retrieved through CAAQM's



a) *b)* *c)*

Figure 6 a) & b) Mean SO2 concentrations before and during lockdown,c) Changes in SO2 concentration mapped in percentage

4.3 Carbon Monoxide:

Comparing the pre- lockdown phase, the concentration level of CO showed a decrease in most of the places. Especially in the central parts of the study area, more than 30% decreased level of CO was recorded *(Figure 8c).* A more significant reduction in concentration was seen from March 23rd to March 31st in the year 2020*(Figure 7a).* Although recorded a traceable decrease during the lockdown period, the mean concentration of CO didn't reduce in the northern and southern regions. The concentrations increased in the Ennore industrial area and Sholinganallur but were traceable. The comparison of the concentration of CO shows a clear difference in May month *(Figure 8c & d).* From *Figure 7c*, it is seen that CO maintained a similar trend to the normal years in 2020.

According to CAAQM's data, the highest concentrations of CO were recorded in Royapuram between March and mid-April, but a significant decrease was noticed in the same area from the 2nd half of April and till May 10th in the year 2020. In Manali, an industrial area, it could be noticed that most of the days exceeded the limit set by the pollution control board before lockdown. But, it never exceeded the national standards *(Table 3)* during the first part of lockdown. In contrast, Velachery residential area recorded an increasing concentration of CO during the lockdown.

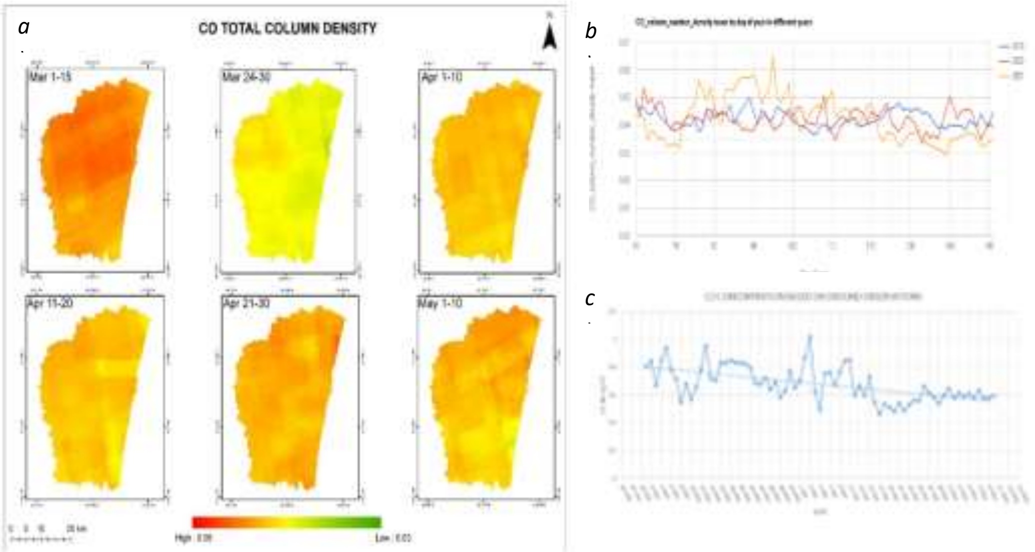


Figure 7 a) CO concentration weekly range from Sentinel 5P, b) Graph showing CO levels during 2019,2020 & 2021, c) CO levels of lockdown period retrieved through CAAQM's

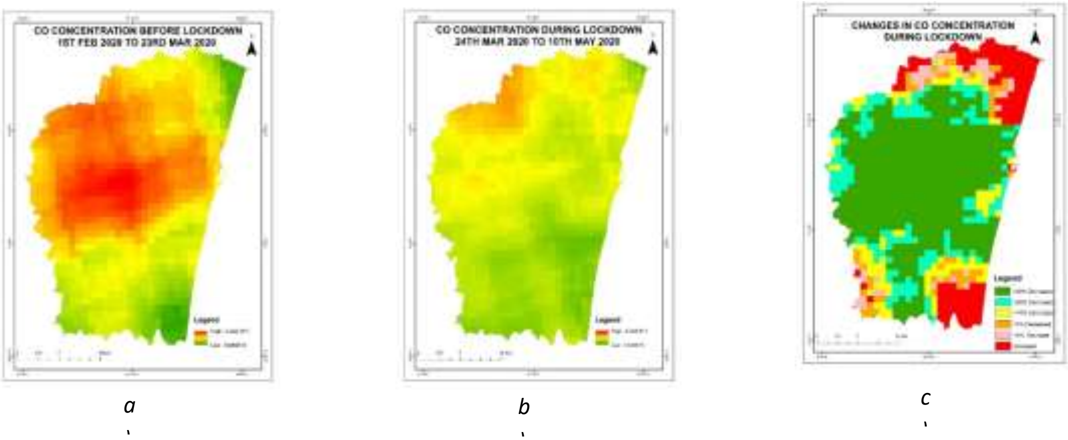


Figure 8 a) & b) Mean CO concentrations before and during lockdown,c) Changes in CO concentration mapped in percentage

4.4 Ozone:

The ozone layer shields the earth from ultraviolet radiation in the stratosphere, whereas the tropospheric ozone acts as an efficient cleansing agent. The total ozone column density, as well as the tropospheric ozone concentration, had increased. It relates to the decrease in Nitrogen Oxide in the atmosphere, resulting in the lowering of ground-level ozone consumption. (Mahato et al., 2020) The comparison analysis of the normal years showed a similar trend of increasing ozone density, but the overall concentration is significantly higher in 2020 than in 2019*(Figure 9 a&b).*

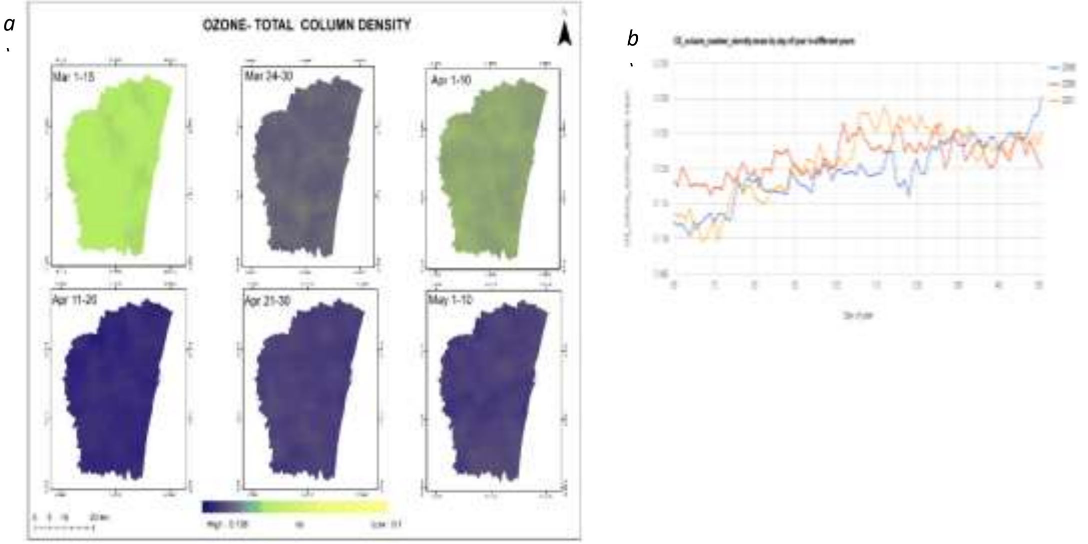


Figure 9 a) Ozone concentration weekly range from Sentinel 5P, b) Graph showing O3 levels during 2019,2020 & 2021

4.5 Aerosol Optical Depth:

The Absorbing Aerosol Index (AAI) and Aerosol Optical Depth (AOD) indicate the presence of UV absorbing aerosols in the atmosphere like dust and smoke if their values are positive. The Northwestern part of the study area, which had a very high concentration of Aerosols before lockdown, shows a significant decrease in the concentration during the lockdown. The AOD ranges from 20 to 1650 altogether, and during the lockdown, it was up to 955. Overall the year 2020 shows a decreased concentration of AAI compared to the year 2019 *(Figure 10).*

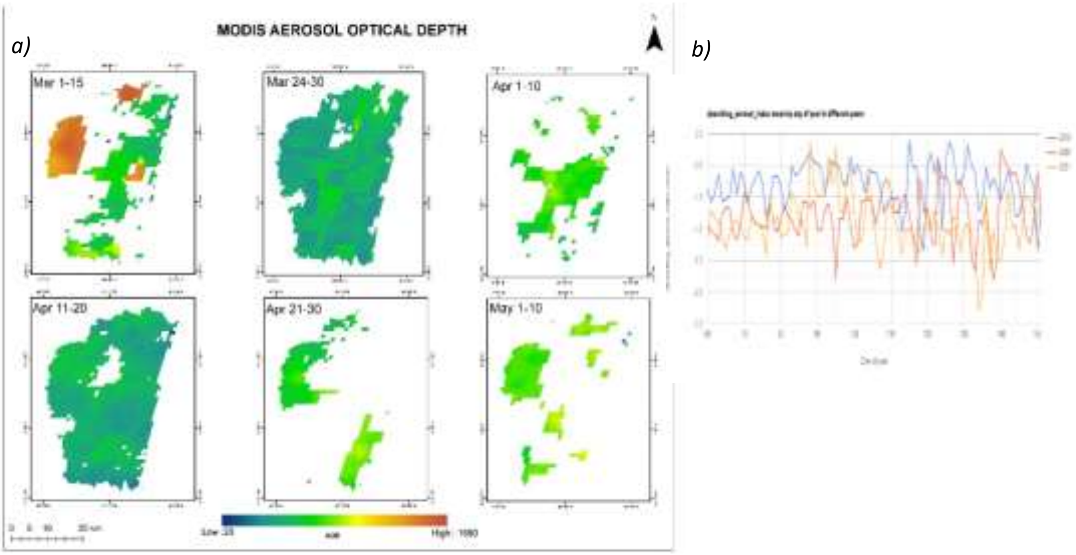


Figure 10 a) Aerosol Optical Depth retrived from MODIS, b) Graph showing Absorbing Aerosol Index during 2019,2020 & 2021 retrived from Sentinel 5P

5. DISCUSSION

The Covid-19 pandemic resulted in a series of lockdowns all over the globe. Studies have shown improved air quality in major cities of India like Delhi, Bangalore, and Mumbai. Also, the same scenario is seen in the study area where the air quality has improved during the lockdown, which started on March 24, 2020, and extended till May 3, 2020, without any relaxation to the public or business people. Whereas the essential works and services continued without any restrictions. On April 23, 2020, a relaxation was provided for heavy industries, and IT's to work with 33% of staff, but then it was taken back in the next two days due to the increase in the number of Covid-19 cases. Markets like Koyembedu continued to serve, but public entry was prohibited. Thus the movement of people has not entirely cut off in the lockdown period but has been reduced tremendously. Also, the complete closure of heavy industries was one of the main interests of the study (The Hindu, 2020b).

The primary sources of NO2 include burning fuel like coal, oil, biomass, and gas in power plants, manufacturing units, and emissions from vehicles Arora, 2019; van Geffen et al., 2019), and in the case of SO2, it is burning of coal, vehicles running with fuel containing high Sulphur content, metal extraction from an ore and some natural processes like decomposition and combustion of organic matter, spray from sea and volcanic eruptions (Dahiya & Myllyvirta, 2019; NSW.gov, 2019). For CO, the sources are residential and commercial combustion. Nearly 60% of CO emissions are due to anthropogenic activities (Kumar et al., 2013). The results also indicate that the city's industrial areas recorded a decrease in the concentration of all the pollutants during the lockdown.

In Chennai Metropolitan Area, it has been found that 48% of pollution is due to transport emission, and the industrial areas are the next source of pollution (Guttikunda et al., 2014) as the city is a base for around 30 percent of India's automobile industry and 40 percent of the auto components industry. The major automobile industries like BMW, Ford, Renault-Nissan, and related companies are in the industrial parks in the suburbs of Chennai (JICA, 2017). The Ambattur–Padi industrial zone houses many textile manufacturers, and the special economic zone (SEZ) in the city's southern suburbs contains many footwear manufacturing industries. Pharmaceuticals giant Pfizer and chemicals giant Dow Chemicals have research and development facilities in Chennai. (UrbanEmissions.Info, 2017) As of the traffic survey conducted in the city, more than 200,000 vehicles per day are passing on NH45 and Inner Ring Road, and the traffic volume in the suburbs is less than 70,000 per day. 70% of traffic on the Inner Ring Road and NH205 is due to Motorcycles. More than 3,000-4,000 container trucks go in and out of Chennai Port every day (JICA, 2017). Also, it should be noted that Chennai is one of the largest commercial and industrial hubs but has not been included under the National Clean Air Program of 2019, launched by the Ministry of Environment, Forest and Climate Change (MoEFCC).

The Northern Chennai region, especially the areas like Manali, Thiruvottriyur, Ennore, Gummidipoondi, has the highest source of pollution causing industries and has a significant movement of heavy vehicles. In southern Chennai, the movement of Individual cars and public transport is higher due to commercial, residential areas and some of the critical transport terminals (JICA, 2017). Thus, these regions can be considered the major pollution hotspots in the study area.

All the pollutant concentrations gradually increased during the last 20 days of the lockdown during the study period. The Government announced relaxations from the lockdown for various activities during this period. From April 20, relaxation from lockdown has been given to many sectors, including Industries at the outskirts, Special Economic Zones, IT companies, Vehicle repair, Brick industries, Agri Equipments, Coal and other mining, Construction based industries, Fishing, Fertilizer industries, and daily wage workers with some restrictions. This could be the reason for the gradual increase in air pollution lately.

Even though there was a reduction in pollution levels in different parts of the city during the first lockdown, it has not contributed much to the overall decrease in the pollutant concentration at a significant difference compared to the previous year. Traffic over major road junctions have been noticed like Padi flyover, Anna salai- Chinna malai road, Anna salai- Thiruvallikeni road, Aayiram Vilakku area, and Smith road, etc. which is due to the essential service and the unawareness of the general public *(Photo 1).*

During summer, the atmospheric temperature near the earth's surface is maximum, which enhances the vertical mixing height and increases the mixing layer height. As Chennai is a coastal region, the sea breeze starts to flow towards the landward side in the afternoon controlling the particulate matter's vertical mixing. An increase in temperature also elevates the ambient particulate level, usually. It also causes the pollutants to move inland, creating more pollution inland (Jayamurugan et al., 2013; Sudhakar et al., 2014). This indicates that even though a favorable situation prevails for pollution levels, the reduction in the pollution causing activities shows a noticeable change in the air quality.

Photo 1: Huge traffic on Padi Flyover amidst lockdown on1st April 2020
Source: The Times of India

6. CONCLUSION

It is evident from the study that restricted industrial and vehicular activities had a significant impact on improving the air quality. This should be taken into concern, and steps should be taken to maintain the air quality. Methods and plans to restrict the pollution caused by industries and vehicles are necessary even after the lockdown to ensure the good air quality of the human habitat, positively affecting society and the environment taking into account the lack of major air quality monitoring programs in the city. The results acquired using Google Earth Engine cloud-based API and Sentinel 5-P data which is readily available, prove it is a very efficient tool to study air pollution, especially in this lockdown period where it is challenging to collect ground-based primary data. Also, these advancements make researchers and climatologists quickly analyze real-time data of every corner of the globe to provide up-to-date information and make further plans accordingly to mitigate air pollution and build a sustainable urban environment. This study suggests using these techniques to monitor and prevent air pollution on a regional scale. It is paramount to control air pollution to improve the livable conditions of the city and the health of the citizens, especially during this pandemic.

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