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Covid-19 has drastically reduced air pollution in 4 metro cities of India: A comparative scholastic study before and after lockdown period

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Abstract
It is nothing to be mentioned that due to rapid urbanization in India, particularly the major metro cities induced huge environmental contamination in the environment, especially in the air with several particulate matters has posed a severe challenge to the urban population. However, owing to the pandemic situation for Corona virus concomitant lockdown in nearly all parts of the World has already started and in India also, the situation has changed significantly. All development activities were shut down. None can imagine that world is going to be at a stand-still as it is today. The present study is a time series analysis of the particulate matter in the air of 4 major metro cities of India from different corners within a specific time before lockdown, during lockdown and after lockdown, i.e. unlocks periods. Here, for study, Kolkata, Delhi, Mumbai and Chennai were considered. A significant spatial difference was observed and it was found that there was an abrupt decrease in particulate matter values during the lockdown and successive increase in 3 unlock periods. The lockdown phase associated with COVID-19 pandemic started in full swing on and from 25th March, 2020 with the aim to retard the spreading of the virus. Time period for this study was just before lockdown, on the day of lockdown, during lockdown and 3 consecutive unlock periods respectively i.e. from 10th March to 31st July. The in-depth study with the data available of the surface atmospheric level of $PM_{2.5}$, PM_{10}, CO, SO_2, NH_3, NO_2 from central pollution control board at different places of the cities before and during the lockdown phase shows a significant decrease in the levels of particulate matters in 4 major cities and after lockdown, again increased.

Keywords: corona, environment, particulate matters, air pollution, lockdown, unlock, Covid-19

1. Introduction and Background

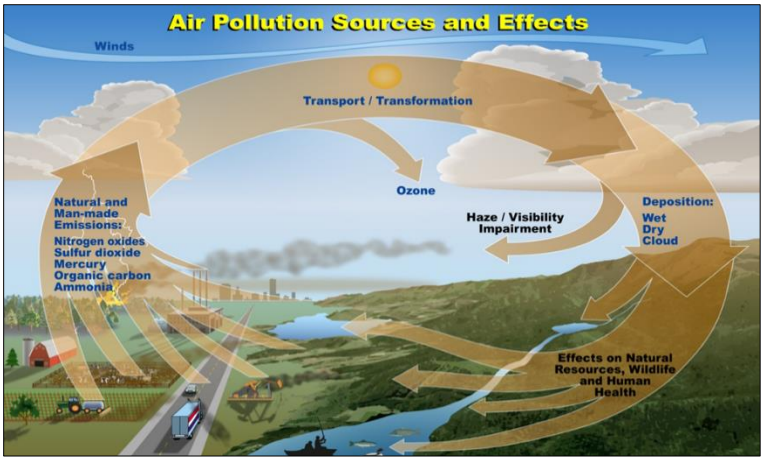

Fig 1

If timeline development of Covid-19 in India and globally is considered, it is found that, on (i) 11th March, 2020 World Health Organization (WHO) declared this epidemic as pandemic (ii) For the 1st time in Indian history, National Lockdown-1 was declared for 21 days under section 6(2) (i) of Disaster Management Act, 2005. (iii) After video conferencing and consultation with all chief ministers of every state of this country, Prime Minister declared the extension of National Lockdown-1 to National Lockdown-2, till 3rd May, 2020. (iv) Phase-2 lockdown occurred from 15th April 2020 to 3rd May, 2020 for 19 days vii) 3rd phase lockdown declared from 4th May 2020 to 17th May, 2020, for 14 days and lastly, for 4th phase, from 18th May, 2020 to 31st May 2020 i.e. for 14 days again (v) Consecutive 3 unlock period nation has faced from 1st June to 30th June, 1st July to 31st July and 1st August to 31st August 2020. Under National Disaster Management Act, during lockdown period, all the transport

system of rail-air-roadways were closed except emergency services. In fact, night curfew were started and it continued till July 2020, ie.3rd lockdown. Transportation were opened for essential goods, fire services, law, police and army, LPG and essential food products, movement of medical personnel, relief and cargo movements etc. People were more or less confined and hence a more open air started prevailing. But after unlock period started, again more vehicle movement started and due to this, more air pollution started.

Air pollution is the introduction of particulates, biological molecules, or other harmful materials into Earth's atmosphere, causing diseases, death to humans, damage to other living organisms such as animals and food crops, or the natural or built environment. According to *The Air (Prevention and Control of Pollution) Act, 1981*, "Air pollution is the presence of any solid, liquid, or gaseous substances in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment".

2. Research Methodology and Objective of the Study

The main objective of this research work is to find the air pollution level as well as the percentage of different pollution creating particulate matters of different corners of 4 major cities of India, from the 4 corners. For that reason, time period was taken from 10th March, 2020 to 30th July, 2020 and the chosen cities are Kolkata, Delhi, Mumbai and Chennai. For the primary source of information, data were taken from Central Pollution Control Board. For selection of dates, 12 days were considered for this research work like before lockdown, on the date of lockdown, during lockdown and after lockdown i.e. during consecutive 3 unlock period. 2 days, 10th March and 20th March were considered as dates before lockdown, 24th March was considered on date of lockdown, 31st March was considered just after lockdown and then 2 days in every month, till July was considered as the sample collection date. Also, the data for collection was taken as 12 noon on those selected days.

3. Different air Pollutants

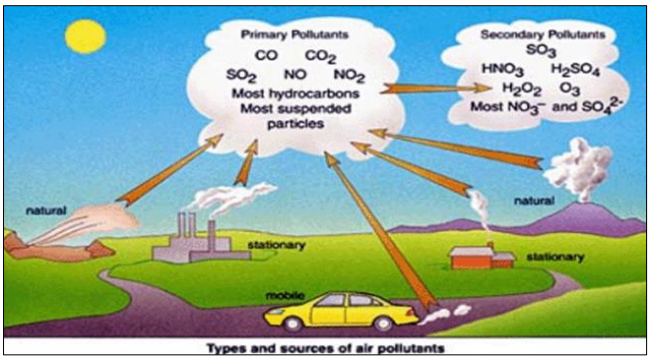

Fig 2

- **Natural air pollutants:** Natural air pollutants are emitted from natural sources such as volcanic activity, dust, sea-salt, forest fires, lightening, soil outgassing etc.
- **Anthropogenic air pollutants:** These pollutants include the emissions from stationary point sources (e.g. emission from industries), mobile sources (e.g. vehicular emission, marine vessels, airplanes etc.), waste disposal landfills, controlled burning etc.
- **Primary air pollutants:** Those pollutants which are emitted directly from any emission source in the atmosphere are termed as Primary air pollutants. E.g. Sulphur dioxide (SO_2), Carbon monoxide (CO), Lead (Pb), Ammonia (NH_3) etc.
- **Secondary air pollutants:** Secondary pollutants are formed by the reactions between primary air pollutants and normal atmospheric constituents. In some of the cases, these pollutants are formed by utilizing the solar energy. E.g. Ozone, Peroxyacetylnitrate (PAN), Nitrogen dioxide (NO_2), Smog etc.
- **Organic air pollutants:** Examples are hydrocarbons, aldehydes, ketones, amines, and alcohols etc.
- **Inorganic air pollutants:** Examples are carbon compounds (CO and carbonates), nitrogen compounds (NO_X and NH_3), sulphur compounds (H_2S, SO_2, SO_3, and H2SO4), halogen compounds (HF, HCl etc.), flyash, silica etc.
- **Gaseous air pollutants:** Pollutants which are in the form of gas are termed as gaseous air pollutants. E.g. SO_2, NO_X, O_3, CO etc.
- **Particulate air pollutants**: Particulate air pollutants or particulate matter (PM) can be defined as the microscopic solid or liquid matter suspended in the earth's atmosphere. There are various subtypes of particulate matter:
- ***Total suspended particulate matter (TSPM)***: The concentration of particulate matter which is obtained when a high volume bulk sampling is done on a filter substrate. It includes particles of all sizes.
- ***PM_{10}***: These are the particles less than 10 µm in diameter.
- ***$PM_{2.5}$***: These are the particles less than 2.5 µm in diameter.
- ***$PM_{1.0}$***: These are the particles less than 1 µm in diameter.

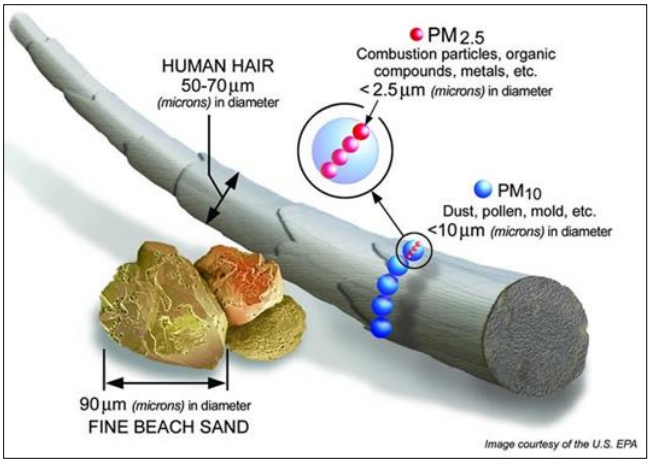

Fig 3

4. National Ambient Air Quality Standard

The National Air Quality Index (AQI) in India was launched on 17 September 2014 by the Environment Minister. The air quality index is composed of 8 pollutants (PM10, PM2.5, NO2, SO2, CO, O3, NH3, and Pb). National Air Quality Index (AQI) transforms complex air quality data of eight pollutants into a single number (index value), nomenclature and colour. National Air Quality Index (AQI) was launched on 17 October 2014 to disseminate information on air quality in an easily understandable

form for the general public. The measurement of air quality is based on eight pollutants, namely,

- Particulate Matter (size less than 10 µm) or (PM_{10}),
- Particulate Matter (size less than 2.5 µm) or ($PM_{2.5}$),
- Nitrogen Dioxide (NO_2),
- Sulphur Dioxide (SO_2),
- Carbon Monoxide (CO),
- Ozone (O_3),
- Ammonia (NH_3), and
- Lead (Pb)

For which short-term (up to 24-hourly averaging period) National Ambient Air Quality Standards are prescribed. It may be noted that ambient air quality standards are specified separately in India for around 12 pollutants including the 8 that constitute the Air Quality Index. AQI has six categories of air quality. These are: Good, Satisfactory, Moderately Polluted, Poor, Very Poor and Severe. The AQI values and corresponding ambient concentrations (health breakpoints) for the identified eight pollutants are as follows:

Table 1

AQI Category, Pollutants and Health Breakpoints (Chart-1)								
AQI Category (Range)↓	**→ Categories for the various readings of the pollutant based on the health breakpoints or health impacts**							
	PM_{10} 24-hr	**$PM_{2.5}$ 24-hr**	**NO_2 24-hr**	**O_3 8-hr**	**CO 8-hr (mg/m^3)**	**SO_2 24-hr**	**NH_3 24-hr**	**Pb 24-hr**
Good (0-50)	0-50	0-30	0-40	0-50	0-1.0	0-40	0-200	0-0.5
Satisfactory (51-100)	51-100	31-60	41-80	51-100	1.1-2.0	41-80	201-400	0.5 –1.0
Moderately polluted (101-200)	101-250	61-90	81-180	101-168	2.1- 10	81-380	401-800	1.1-2.0
Poor (201-300)	251-350	91-120	181-280	169-208	10-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17-34	801-1600	1200-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+

*One hourly monitoring (for mathematical calculations only)

Table 1: The AQI Index values and their associated health impacts are as follows

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people.
Moderately polluted (101–200)	May cause breathing discomfort to people with lung disease such as asthma, and discomfort to people with heart disease, children and older adults.
Poor (201–300)	May cause breathing discomfort to people on prolonged exposure, and discomfort to people with heart disease
Very Poor (301–400)	May cause respiratory illness to the people on prolonged exposure. Effect may be more pronounced in people with lung and heart diseases.
Severe (401-500)	May cause respiratory impact even on healthy people, and serious health impacts on people with lung/heart disease. The health impacts may be experienced even during light physical activity.

Outdoor air pollution is a major environmental health problem affecting everyone in low-, middle-, and high-income countries. Ambient (outdoor) air pollution in both cities and rural areas was estimated to cause 4.2 million premature deaths worldwide per year in 2016; this mortality is due to exposure to small particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$), which cause cardiovascular and respiratory disease, and cancers. People living in low- and middle-income countries disproportionately experience the burden of outdoor air pollution with 91% (of the 4.2 million premature deaths) occurring in low- and middle-income countries, and the greatest burden in the WHO South-East Asia and Western Pacific regions. The latest burden estimates reflect the very significant role air pollution plays in cardiovascular illness and death. More and more, evidence demonstrating the linkages between ambient air pollution and the cardiovascular disease risk is becoming available, including studies from highly polluted areas.

There are many examples of successful policies in transport, urban planning, power generation and industry that reduce air pollution:

- **for industry:** clean technologies that reduce industrial smokestack emissions; improved management of urban and agricultural waste, including capture of methane gas emitted from waste sites as an alternative to incineration (for use as biogas);
- **for energy:** ensuring access to affordable clean household energy solutions for cooking, heating and lighting;
- **for transport:** shifting to clean modes of power generation; prioritizing rapid urban transit, walking and cycling networks in cities as well as rail interurban freight and passenger travel; shifting to cleaner heavy-duty diesel vehicles and low-emissions vehicles and fuels, including fuels with reduced sulfur content;
- **for urban planning:** improving the energy efficiency of buildings and making cities more green and compact, and thus energy efficient;
- **for power generation:** increased use of low-emissions fuels and renewable combustion-free power sources (like solar, wind or hydropower); co-generation of heat and power; and distributed energy generation (e.g. mini-grids and rooftop solar power generation);
- **for municipal and agricultural waste management:** strategies for waste reduction, waste separation, recycling and reuse or waste reprocessing; as well as improved methods of biological waste management such as anaerobic waste digestion to produce biogas, are feasible, low cost alternatives to the open incineration of solid waste. Where incineration is unavoidable, then combustion technologies with strict emission controls are critical.

In addition to outdoor air pollution, indoor smoke from household air pollution is a serious health risk for some 3 billion people who cook and heat their homes with biomass fuels and coal. Some 3.8 million premature deaths were attributable to household air pollution in 2016. Almost all of the burden was in low-middle-income countries. Household air pollution is also a major source of outdoor air pollution in both urban and rural areas.

5. WHO Guidelines

WHO's work on environmental health provides the basis for global standards in environmental quality and an effective investments for public health such as air quality guidelines and drinking water quality guidelines. The "WHO air quality guidelines" provide an assessment of health effects of air pollution and thresholds for health-harmful pollution levels.

Chart 2

Pollutants	Time Weighted Average	Standard limits as per WHO guidelines (µg/m^3)
Particulate matter (PM) – 2.5	Annual mean	10
	24 hours mean	25
Particulate matter (PM) – 10	Annual mean	20
	24 hours mean	50
Ozone (O_3)	8 hour mean	100
Nitrogen dioxide (NO_2)	Annual mean	40
	1 hour mean	200
Sulphur dioxide (SO_2)	24 hours mean	20
	10 minute mean	500

References: WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide, and sulfur dioxide, Summary of risk assessment, World Health Organization, 2008.

6. Main particulates of air and adverse effect on health

$PM_{2.5}$: The term fine particles, or particulate matter 2.5 ($PM_{2.5}$), refers to tiny particles or droplets in the air that are two and one half microns or less in width. Like inches, meters and miles, a micron is a unit of measurement for distance. There are about 25,000 microns in an inch. Particles in the $PM_{2.5}$ size range are able to travel deeply into the respiratory tract, reaching the lungs. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Exposure to fine particles can also affect lung function and worsen medical conditions such as asthma and heart disease.

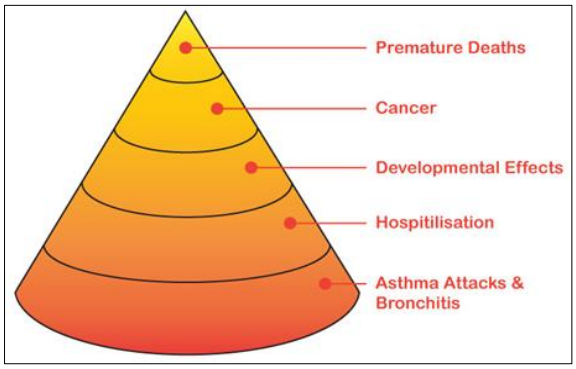

Fig 4

PM_{10}: Theses particles are so small that they effectively act as a gas. When breathed in they penetrate deep into the lungs. Exposure to high concentrations of PM10 can result in a number of health impacts ranging from coughing and wheezing to asthma attacks and bronchitis to high blood pressure, heart attack, strokes and premature death. The young and old and persons with existing medical conditions are most likely to be adversely affected by exposure to high PM10 concentrations.

NO_2: It is a gaseous air pollutant composed of nitrogen and oxygen and is one of a group of related gases called nitrogen oxides, or NOx. NO_2 forms when fossil fuels such as coal, oil, gas or diesel are burned at high temperatures. NO_2 and other nitrogen oxides in the outdoor air contribute to particle pollution and to the chemical reactions that make ozone. Nitrogen dioxide causes a range of harmful effects on the lungs, including: ●Increased inflammation of the airways ●Worsened cough and wheezing ●Reduced lung function ●Increased asthma attacks ●Greater likelihood of emergency department and hospital admissions.

Monitors show the highest concentrations of outdoor NO_2 in large urban regions. NO_2 can be a problem indoors, as well. Kerosene or gas space heaters and gas stoves also produce substantial amounts of nitrogen dioxide. If those heaters or stoves are not vented fully to the outside, levels of NO_2 can build up indoors.

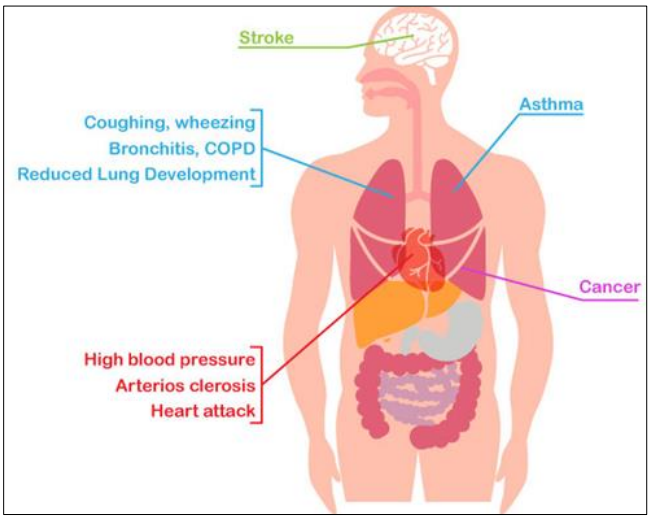

Fig 5

NH_3: It is one of the most widely produced chemicals which in pure form known as anhydrous ammonia. Ammonia is also produced in the human body and is commonly found in nature. Most people are exposed to ammonia from breathing its gas or vapors. Since ammonia exists naturally and is also present in cleaning products, exposure may occur from these sources. Ammonia is corrosive. The severity of health effects depends on the route of exposure, the dose and the duration of exposure. Exposure to high concentrations of ammonia in air causes immediate burning of the eyes, nose, throat and respiratory tract and can result in blindness, lung damage or death. Inhalation of lower concentrations can cause coughing, and nose and throat irritation. Swallowing ammonia can cause burns to the mouth, throat and stomach. Skin or eye contact with concentrated ammonia can also cause irritation and burns.

SO_2: It is a gaseous air pollutant composed of sulfur and oxygen. SO_2 forms when sulfur-containing fuel such as coal, oil, or diesel is burned. Sulfur dioxide also converts in the atmosphere to sulfates. Coal-fired power plants remain one of the biggest sources of sulfur dioxide. Ports, smelters, and other sources of sulfur dioxide also cause high concentrations of emissions nearby. Major health effect includes: Wheezing, shortness of breath and chest tightness, respiratory symptoms with asthma etc.

CO: It is an odorless, colorless, and tasteless but dangerous gas. Carbon monoxide is produced when fuels are burned such as gasoline, natural gas, oil, kerosene, wood or charcoal. Breathing CO reduces the blood's ability to carry oxygen. It can reach dangerous levels indoors or outdoors. Breathing low levels of CO can cause: Headache, Nausea, Dizziness, Weakness, Confusion, Sleepiness, Vomiting, Impaired vision, Disorientation etc.

O_3: Ozone (O_3) is a gas molecule composed of three oxygen atoms. Often called "smog," ozone is harmful to breathe. Ozone aggressively attacks lung tissue by reacting chemically with it. When ozone is present, there are other harmful pollutants created by the same processes that make ozone. Anyone who spends time outdoors where ozone pollution levels are high may be at risk. Four groups of people are especially vulnerable to the effects of breathing ozone: children and teens; anyone 65 and older; people with existing lung diseases, such as asthma and chronic obstructive pulmonary disease (also known as COPD, which includes emphysema and chronic bronchitis; and people who work or exercise outdoors. Breathing ozone can shorten life. Immediate problems—in addition to increased risk of premature death—include: shortness of breath, wheezing and coughing; asthma attacks; increased risk of respiratory infections; increased susceptibility to pulmonary inflammation; and increased need for people with lung diseases, like asthma or chronic obstructive pulmonary disease (COPD), to receive medical treatment and to go to the hospital.

Fig 6

7. Content analysis regarding air pollutants before and after lockdown

The charts and data below describes vividly the particulate matter position average of 4 metro cities in India, at the time of before lockdown and unlock period, datewise and time was taken 12 noon.

From the Delhi (Chart-3) chart, it is found that, on 10th March, 2020 PM_{10} standard was very poor and was identified in chart by red colour. Similar case on 20th March, before lockdown and on that day also, ozone standard was also moderately poor. On 24th March, after declaration of lockdown on that very day, $PM_{2.5}$ has reduced to 95, from 151, a drastic change and PM_{10} was become moderately poor. Figure will show that, on 30th May 2020, the last day of full lockdown, PM2.5 has drastically reduced to 31, which indicates very good standard of air quality. On other dates, pollutant level became satisfactory.

Delhi (Chart-3)

	PM 10	PM 2.5	CO	NO_2	O_3
10/03/20	143	172	39	47	32
20/03/20	143	151	72	60	151
24/03/20	101	95	43	41	33
31/03/20	60	52	24	12	48
14/04/20	100	70	44	32	38
30/04/20	106	81	22	17	59
15/05/20	110	74	43	26	55
30/05/20	57	31	29	23	49
15/06/20	155	97	55	42	13
30/06/20	110	45	30	30	26
15/07/20	60	14	28	22	23
30/07/20	43	43	43	46	12

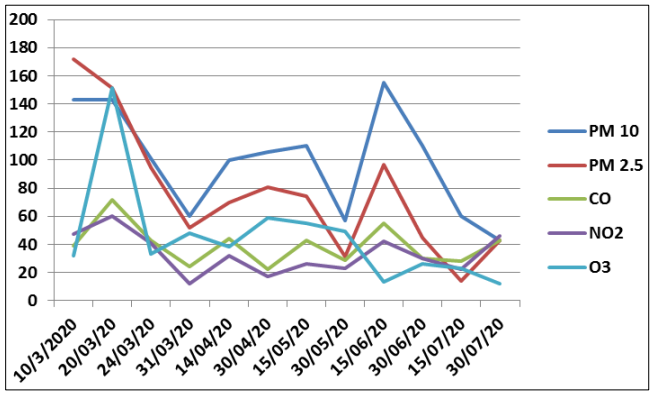

Fig 7

Fig 8

Mumbai (Chart-4)

	PM 10	PM 2.5	CO	NO_2	O_3
10/03/20	174	161	66	58	16
20/03/20	119	46	41	16	7
24/03/20	117	26	1	11	7
31/03/20	74	54	22	17	7
14/04/20	65	18	19	23	7
sss30/04/20	32	14	10	12	7
15/05/20	26	10	8	30	6
30/05/20	28	23	7	7	7
15/06/20	25	15	15	34	3
30/06/20	14	10	14	33	3
15/07/20	17	13	16	3	4
30/07/20	46	28	27	3	3

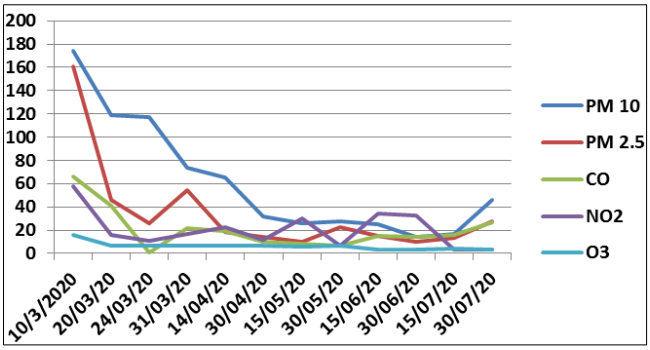

Fig 9

Fig 10

From the Mumbai (Chart-4) chart, it is found that, on 10th March, 2020 PM_{10} standard was moderately poor and was identified in chart by specified colour. Similar case on 20th March, before lockdown and on that day also, ozone standard was also moderately poor. On 24th March, after declaration of lockdown on that very day, $PM_{2.5}$ has reduced to 117, from 174, a drastic change and PM_{10} was become moderately poor. Figure will show that, on 30th March 2020, the air quality of Mumbai has become satisfactory and good and even chart will show that PM10 has already been reduced from 174 to 46, i.e. 75 percent reduction in $PM_{2.5}$, CO, NO_2, O_3 etc.

Kolkata (Chart-5)

	PM 10	PM 2.5	CO	NO_2	O_3
10/03/20	95	115	38	61	42
20/03/20	91	133	22	49	58
24/03/20	55	46	20	17	50
31/03/20	78	59	9	24	57
14/04/20	49	46	18	9	40
30/04/20	36	26	15	13	34
15/05/20	37	22	14	9	20
30/05/20	46	32	13	10	3
15/06/20	49	23	16	11	6
30/06/20	39	30	14	27	20
15/07/20	18	19	13	16	29
30/07/20	18	15	12	11	15

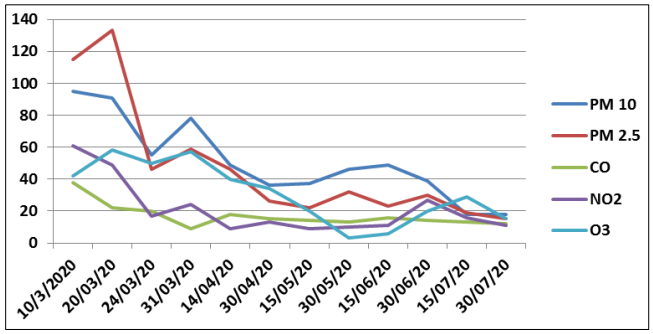

Fig 11

Fig 12

From the Kolkata (Chart-5) chart, it is found that, on 10th March, 2020 $PM_{2.5}$ standard was poor and was identified in chart by specified colour. Condition deteriated on 20th March, before lockdown and on that day standard reduced from poor to very poor. On and from 24th March, 2020, condition of PM10 was become satisfactory. It was indicated at the end of March 2020 that, air particulate matter is going better. From April 2020, PM10 percentage in air of Kolkata has gone very good quality and it was remained upto July 2020 and other particulate matters were also been reduced proportionately.

Chennai (Chart-6)

	PM 10	PM 2.5	CO	NO_2	O_3
10/03/20	86	48	36	26	22
20/03/20	122	71	45	10	2
24/03/20	81	47	32	18	6
31/03/20	65	39	18	10	11
14/04/20	51	26	18	27	13
30/04/20	34	13	22	7	12
15/05/20	29	10	28	14	18
30/05/20	56	30	32	6	14
15/06/20	59	32	27	25	16
30/06/20	48	24	26	10	23
15/07/20	61	38	30	23	27
30/07/20	53	35	24	11	26

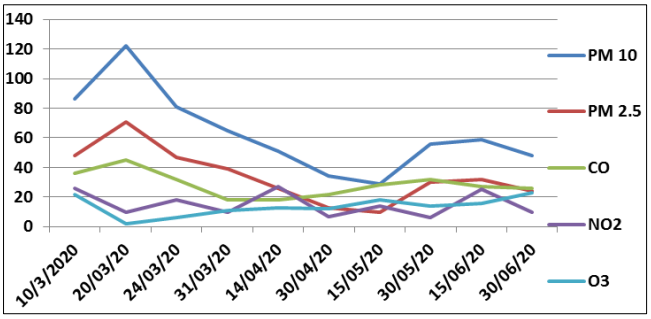

Fig 13

Fig 14

From the Chennai (Chart-6) chart, it is found that, on 10th March 2020 the overall condition of air was satisfactory and indicated by specific colour. On 20th March condition goes to moderately poor and after that air particulate matter condition was going better, till July 2020. But figure will show that, as total lockdown to unlock period goes ahead, polluted particulate matter in air going to increase.

8. Results and Discussion

From the above chart, graph and pictures it can be said that major particulate matters in air of India, before lockdown period was either moderately poor or poor or very poor. On the date of lockdown, condition was still under question and after that, till full lockdown goes on, condition became very good or satisfactory and particulate matter percentage was drastically reduced to 75 percent. After full lockdown, when unlock period started, transport going to increase again, air quality slightly deteriated and as time goes on, gradually pollution in air have started increasing.

Acknowledgement

This research data were taken from the database of Central Pollution Control Board and the author is thankful to them as the data is available in their respective websites and used as primary data.

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