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AMBIENT AIR POLLUTION BY PARTICULATE MATTER$_{2.5}$ AND ITS IMPACT IN METROPOLITAN CITIES IN INDIA

[1]Samiran Sarkar,

[1]Assistant Professor,

[1]Department of Geography,

[1]Netaji Satabarshiki Mahavidyalaya, Ashokenagar, India

Abstract: Recently, air pollution has become more prominent among environmental issues in Asia than elsewhere in the world. This study is initiated to assess particulate matter (mainly $PM_{2.5}$) in the outdoor air. The $PM_{2.5}$ is mainly of anthropogenic origin and the main source is transportation sector. As a result of high concentration of PM compared to the recommended permissible levels for residential areas in India, the city dwellers suffer from its adverse effects. Annual mean PM concentration data from CPCB and other sources are analyzed here. Besides, spatiotemporal variations of PM, urban environment and its associated toxicity, public health issues, socio-economic effects, trans-boundary pollution are considered in this study. The findings of the study will help researchers and policy makers to understand to what extent city dwellers are affected by ambient air pollution and what action is still necessary.

Index Terms **-** Ambient Air Pollution, Particulate Matter, Seasonal Variation, Spatial distribution, Public Health, Transboundary Pollution

1. INTRODUCTION

Now a days, air pollution has become more prominent among environmental issues in Asia than elsewhere in the world. Air pollution is the pollution of the atmosphere by harmful and toxic substances caused by natural or human activities. The harmful effects of pollution can be easily identified as the number of harmful substances released into the air is higher than in other places in an area with air pollution. Air pollution also has negative effects on humans, flora, fauna, and aquatic ecosystems.

According to World Health Organization in 2019, 99% of the world's population was living in places where the WHO air quality guidelines levels were not met (WHO, 2022). People living in low and middle-income countries (mostly South-East Asia and Western Pacific Regions) disproportionately experience the adverse effect of air pollution with 89% of the 4.2 million premature deaths (WHO, 2022). To reduce the particulate matter in outdoor air the United Nations World Health Organization has set the annual interim target of $PM_{2.5}$ (μm^3) which is divided into four sub-targets (1, 2, 3, 4) i.e., 35 μm^3, 25 μm^3, 15 μm^3, and 10 μm^3 respectively.

Particulate mass concentration for particle diameter less than 2.5 micro metre ($PM_{2.5}$) is the biggest air quality threat worldwide (Kanawade et al., 2020). Motorized vehicles and industrial factories are the main sources of particulate matter (PM_{10} and $PM_{2.5}$). Particulate Matter (PM) is a common indicator of air pollution and there is strong evidence for the negative health impacts associated with exposure to this pollutant (WHO, 2022). The impact of air pollution can be seen on vulnerable individuals with greater exposure levels and susceptible individuals with chronic conditions (such as asthma, COPD, diabetes, heart failure, and IHD), as well as children and pregnant women (WHO, 2021).

According to WHO, health equity is "the absence of unfair and avoidable or remediable differences in health among population groups defined socially, economically, demographically or geographically" (WHO, 2021). Almost every living organism and human community living in the present world is experiencing or is going to experience a serious and harmful effect of air pollution. About six hundred thousand people in India succumb to premature deaths annually because of outdoor air pollution (Kanawade et al., 2020).

It has been well documented that both long-term and short-term exposure to particles was associated with poorer lung function in children (Zhang et al., 2022). Over the past two decades, although the global number of newborn deaths declined from 3.8 million in 2000 to 2.4 million in 2019, the first 28 days of life remain the most vulnerable period for newborns' survival (Paulson et al., 2021). During this period, ambient air pollution might induce higher risks for neonatal morbidity and mortality (Lin et al., 2023). Exposure to fine particulate matter (PM2.5) is a leading cause of mortalities worldwide and PM2.5 inflicted about 4.2 million deaths annually in 2015 worldwide, with most of these occurring in Asian countries, especially in Pakistan, India, and China (Anwar et al., 2021).

Reviewing the above, it can be said that this paper mainly discusses the source, concentration, and harmful effects of particulate matter 2.5 as one of the major air pollutants. A clear outline of what policies have been or could be adopted in developing countries especially in India to control the sources of PM2.5 or to reduce its amount in the air. All possible and appropriate solutions that can be used or implemented to overcome this problem are also discussed in this paper in various aspects.

2. Material and Methods

2.1 Study Area

According to the World Air Quality Report, 2022, 12 out of the 15 most polluted cities in the world are in India. These cities are facing a major public health crisis due to air pollution. The study of ambient air pollution in major metropolitan cities in India are a good place to start. There is a lot of research being done in these cities, and there is a lot of data available. Ten (10) highly populated cities (2016) have been selected to perform this study. Alphabetically these cities are Ahmedabad, Bengaluru, Chennai, Delhi (NCT), Hyderabad, Jaipur, Kanpur, Kolkata, Mumbai and Pune.

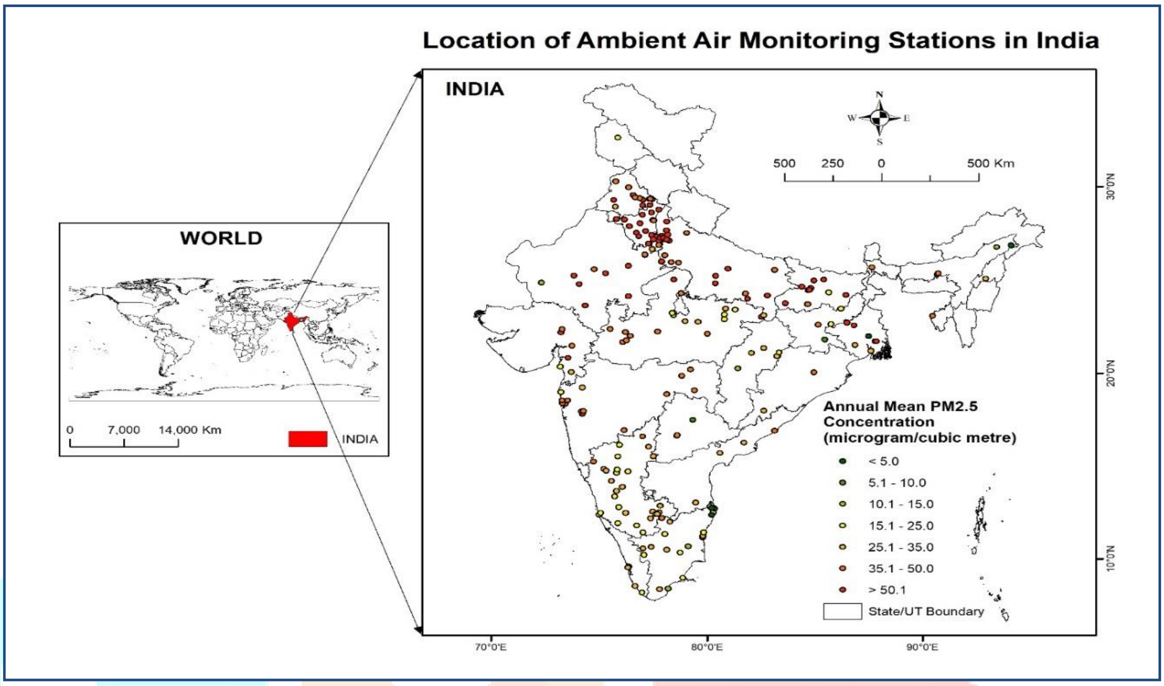

Figure 1 location of ambient air monitoring stations of India showing $pm_{2.5}$ concentration 2022

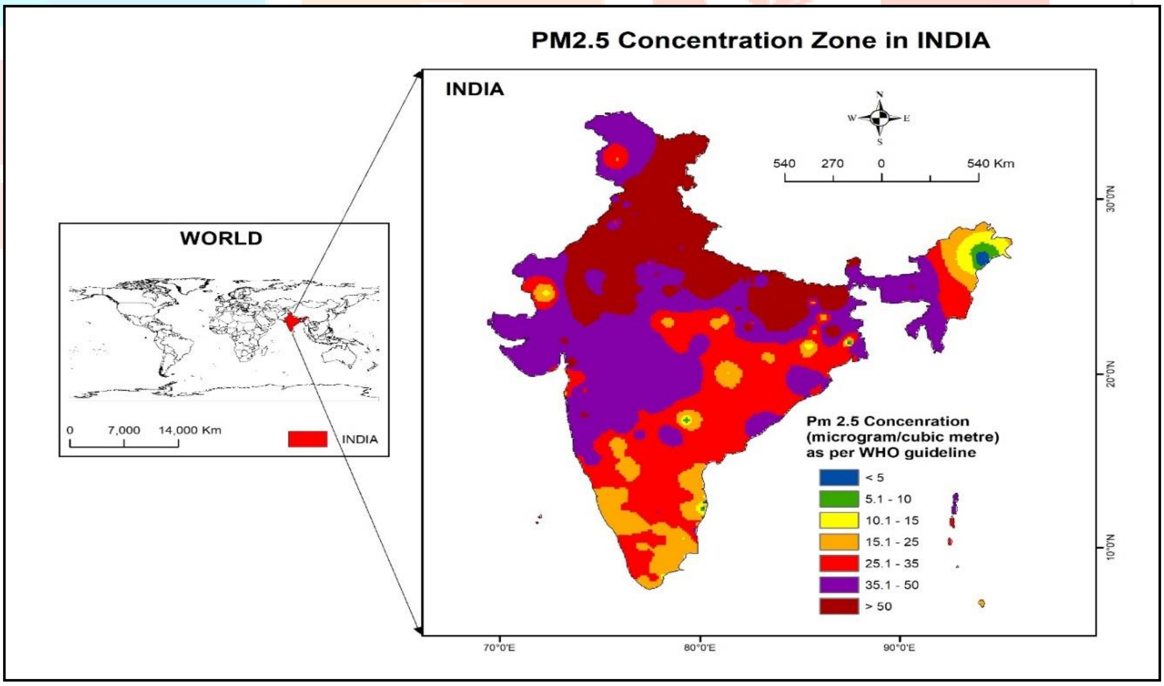

Figure 2 spatial pattern of $pm_{2.5}$ concentration in India 2022

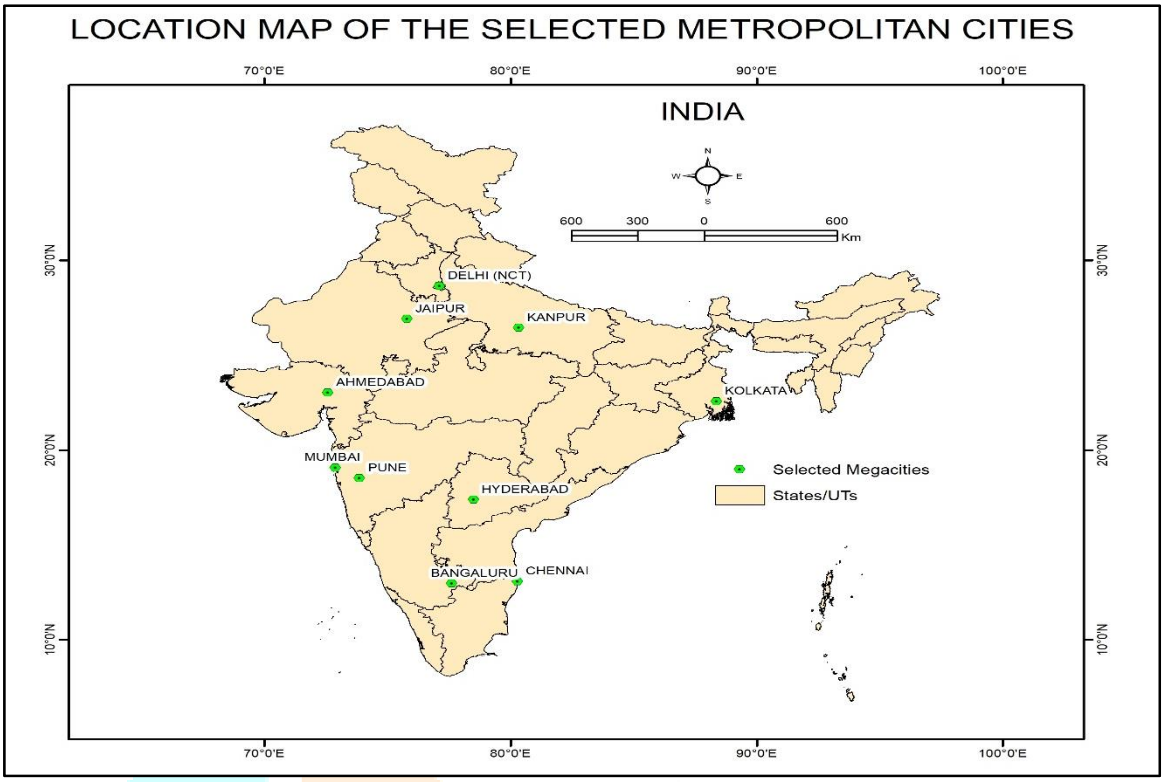

Figure 3 location of the selected metropolitan cities in India

2.2 Data sources

All the required data have been collected from different website through internet. The anomalies found in data because of regulatory-based air quality monitors and low-cost sensors. The historically sourced data and real-time PM 2.5 measurements were not integrated in this study.

- Initially data from 202 different air quality monitoring stations (AQMs) has been collected from *IQAir* website a cloud-based data platform (https://www.iqair.com/in-en/world-most-polluted-cities) -PM2.5 annual mean concentration and other data.
- Central Pollution Control Board (CPBC) (https://cpcb.nic.in/) -Air pollution related document and data.
- Air Quality Historical Data Platform (https://aqicn.org/data-platform/register/) -Past five year's air pollution data.
- Our World in Data (https://ourworldindata.org/) -Different type of maps and especially PM related data.
- The Institute for Health Metrics and Evaluation (IHEM) (https://vizhub.healthdata.org/gbd-compare/) -Health related data.
- NASA (POWER-Data Access Viewer) (https://power.larc.nasa.gov/data-access-viewer/) -Weather related data, mainly Precipitation data.

2.3 Methods

The study was performed by collecting $PM_{2.5}$ data from ambient air monitoring stations (202) across the country. In ArcGIS software, interpolation techniques (IDW) have been used to determine particulate matter concentration zone. Location of the stations was marked in Google Earth as KML file and thereafter it was processed in ArcGIS to locate the actual geographical site. As per WHO guideline on $PM_{2.5}$ concentration, the collected data were classified into seven groups and each group assigned a colour code. Annual mean precipitation and annual mean $PM_{2.5}$ concentration were prepared to represent spatio-temporal variation. Besides, different sources of PM in air have been discussed. The present scenario related to health impact have been discussed with example to the past data.

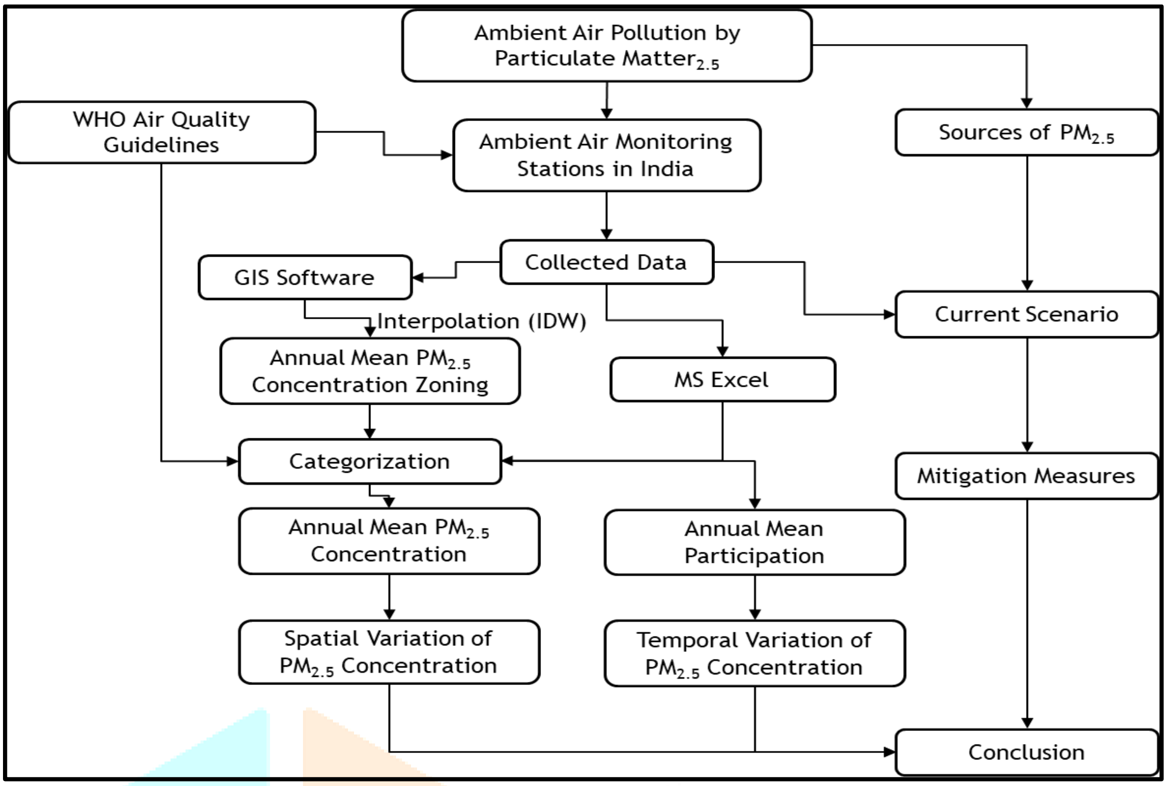

Figure 4 methodology

3. SOURCES OF $PM_{2.5}$

3.1 Vehicular emissions

The rapid increase of the number of vehicles in India leads to excessive emission to the air. Most of the cities in India are suffering from it. These pollutants can have a number of harmful health effects, including respiratory problems, such as asthma and bronchitis, heart disease, cancer, premature death etc. In addition to the health impacts, vehicular emissions also contribute to climate change.

3.2 Trans-boundary pollutants

Trans-boundary pollution occurs when air pollutants emitted in one country travel to another country and cause environmental or health problems. Aircraft emissions are a major source of trans-boundary pollution, as they can travel long distances and affect air quality in countries far from the source of the emissions.

3.3 Deforestation

Yes, deforestation leads to much air pollution. Forests play an important role in filtering air pollutants, such as particulate matter (PM), nitrogen oxides (NOx), and ozone. When forests are cleared, these pollutants are released into the atmosphere. Deforestation can form of ground-level ozone, which is a major component of smog. Ozone can irritate the lungs and worsen respiratory conditions such as asthma. It can also damage crops and other vegetation.

3.4 Power plants

The amount of air pollution emitted by a power plant depends on the type of fuel it burns, the efficiency of the plant, and the pollution control measures that are in place. Coal-fired power plants are typically the biggest polluters, but oil-fired and natural gas-fired power plants can also emit significant amounts of pollutants.

3.5 Stubble burning

Stubble burning is an important source of PM in air. This depends on a number of factors, including the type of crop, the amount of stubble burned, and the weather conditions. Stubble burning can have a significant impact on air quality, particularly in areas where it is practiced on a large scale.

4. Results and Discussion

The countries and territories in Asia (both central and south) and Africa have witnessed the most exposure to the PM in the globe (Figure 5). India, Pakistan, and China -these Asian countries are highly populated, and the regions have suffered adversely with high $PM_{2.5}$ concentrations too. Oceania and therein countries achieved the WHO guidelines in 2022. Out of counted (only 19 out of 54) countries in Africa and south Asia, Saudi Arabia, Chad, Egypt, Nigeria, and Uganda recorded poor air quality. Territories and countries of Europe and North and South America have minimal annual average $PM_{2.5}$ concentrations.

Table 1 world air quality report visualization framework 2022

Annual $PM_{2.5}$ breakpoints based on WHO guideline and interim targets	$PM_{2.5}$ ($\mu g/m^3$)	Colour code	WHO levels
Meets WHO guideline	0-5	Blue	Air quality guideline
Exceeds by 1 to 2 times	5.1-10	Green	Interim target 4
Exceeds by 2 to 3 times	10.1-15	Yellow	Interim target 3
Exceeds by 3 to 5 times	15.1-25	Orange	Interim target 2
Exceeds by 5 to 7 times	25.1-35	Red	Interim target 1
Exceeds by 7 to 10 times	35.1-50	Purple	Exceeds target levels
Exceeds by over 10 times	>50.1	Maroon	Exceeds target levels

Source: World Air Quality Report 2022

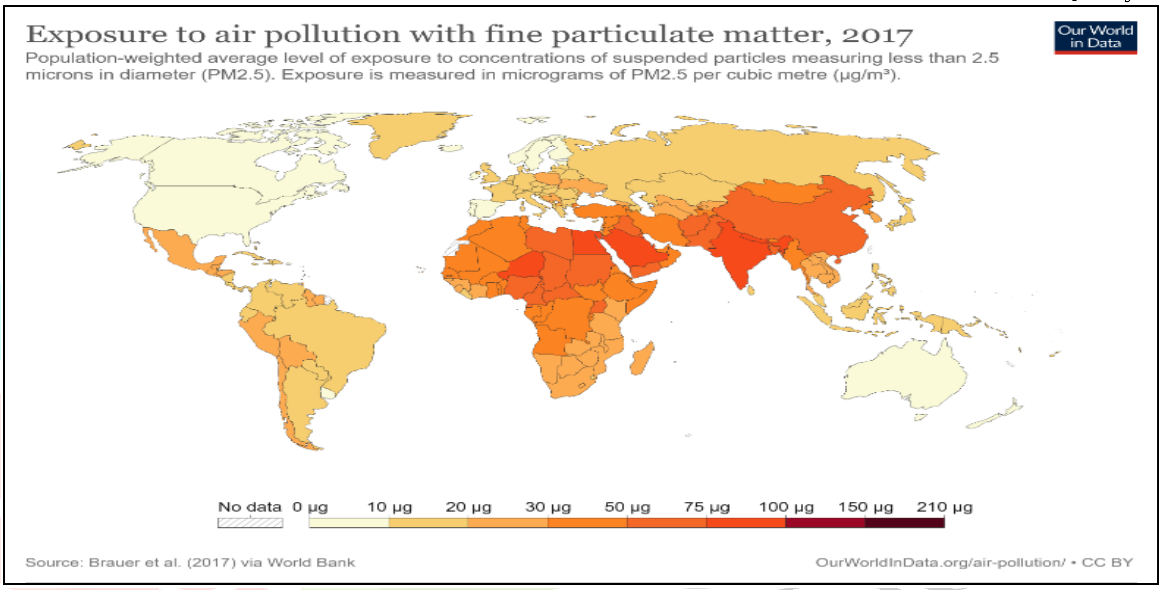

Figure 5 world scenario of $pm_{2.5}$ exposure

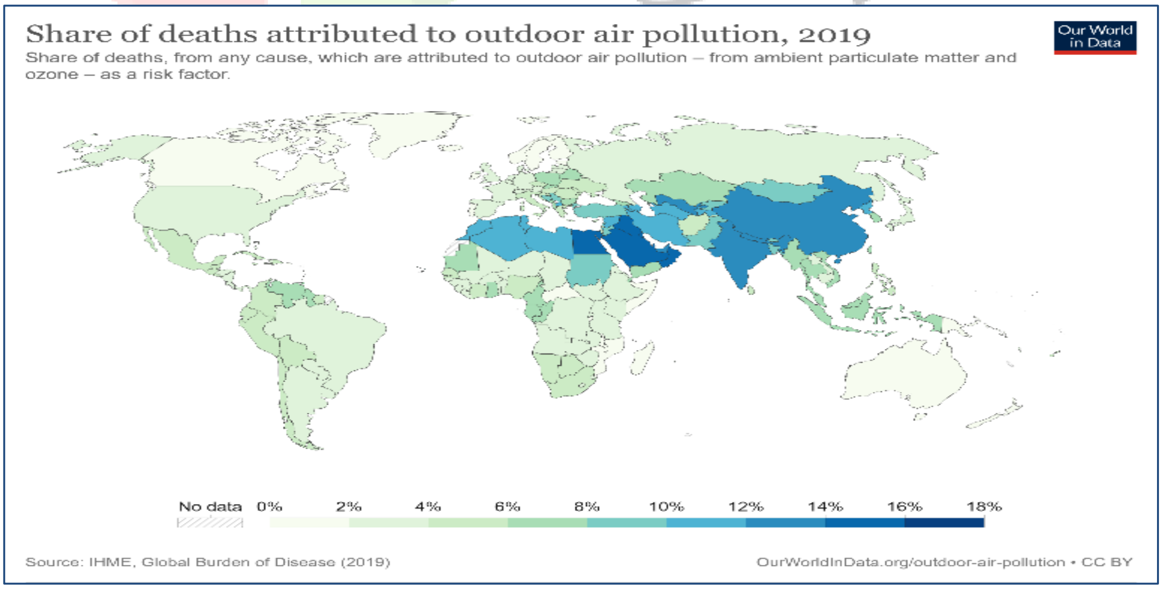

Figure 6 world share of death attributed to outdoor air pollution

Only 5 in India out of 202 air quality monitoring station (Figure 1) have met the WHO annual guideline (Table 1) of under 5 $\mu g/m^3$ (Table 2 & Figure 7). Likewise, 80 cities scored 5.1-35 $\mu g/m^3$. About 117 cities in India exceeded the target level of WHO. The northern part and the Gangetic plain of India has witnessed higher pollution levels than the rest of the region (Figure 2). South and South-Eastern part of India recorded lesser amount of PM concentration. Also, it is noticed that north-eastern part succeeds to reduce PM as it is recorded minimum PM concentration although northeast of India has a small number of ambient air monitoring stations. Hence, insufficient data is available to make a compliment.

Table 2 annual mean $pm_{2.5}$ concentrations of cities in 2022

$PM_{2.5}$ (µg/m^3)	**India**
0-5	5
5.1-10	2
10.1-15	5
15.1-25	31
25.1-35	42
35.1-50	50
>50.1	67
Total	**202**

Source: Compiled by author

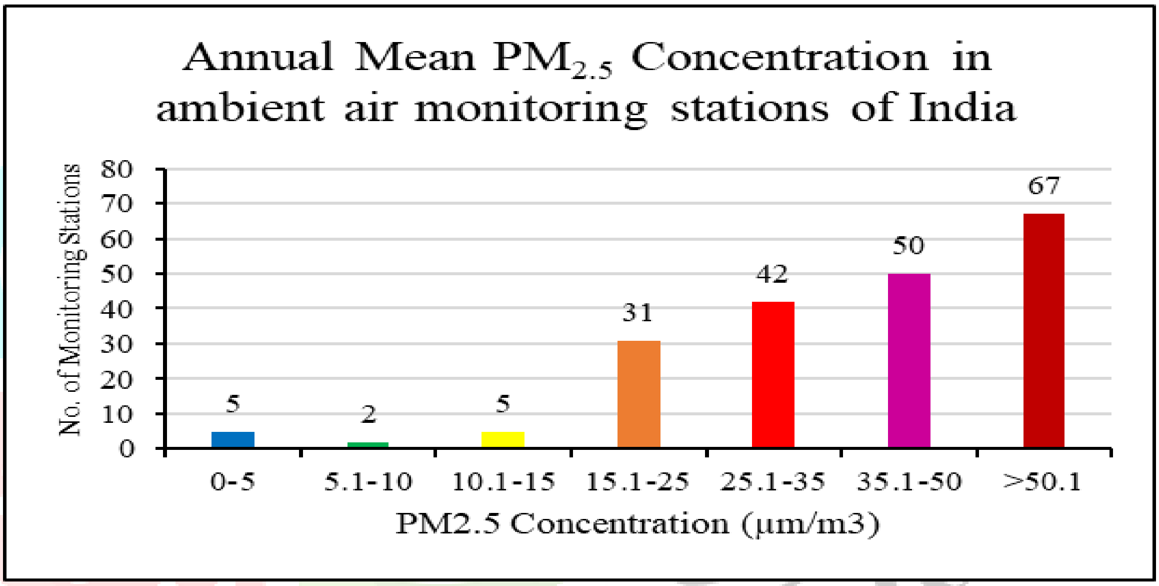

Figure 7 $pm_{2.5}$ concentration in ambient air monitoring stations in India

Source: Compiled by author

In this study, ten highly populated metropolitan cities in India have been selected. All ten cities recorded a high trend of $PM_{2.5}$ concentration (Figure 8). Bengaluru, Chennai and Hyderabad noted a minimal out of the 10 cities' concentration. Delhi (NCT) has witnessed a maximum concentration of $PM_{2.5}$ on a spatio-temporal scale. However, none of the cities met the WHO guideline (less than 5 µg/m^3/year) (Table 1). Chennai is the only city that has actually a gradual decrease of $PM_{2.5}$ concentration over the last 5 years (from 2018 to 2022). Whereas, Delhi had the worst conditions throughout the period (Figure 8). There were a few insufficient data for other cities noted. The concentration of $PM_{2.5}$ had reduced during the COVID-19 pandemic amid the lockdown periods, thereby increasing again.

Furthermore, $PM_{2.5}$ concentration has the seasonal variation (Table 3, Figure 9) and it has a moderate negative correlation with precipitation (Table 4, Figure 11). For $PM_{2.5}$ and Precipitation, it was observed that the *Pearson correlation coefficient (r)* was (−0.43). There was a moderate Pearson correlation coefficient between $PM_{2.5}$ and precipitation which can be seen in (Figure 11). In Figure 10, we can see that, city having lower annual mean rainfall witnessed higher $PM_{2.5}$ concentration except Kolkata, Mumbai and Pune.

Delhi, the capital of India, stands first with a concentration of 92.6 µg/m^3 out of 10 cities. All the months remained to exceed the targets level of WHO except July and August. Chennai (annual mean 25.3 µg/m^3) is far better and has more lively air out of 10 cities in India. The city dwellers suffered adversely during the winter months (December-February) and followed by post-monsoon (October and November), pre-monsoon (March-May) and monsoon (June-September). In Delhi, the maximum and minimum concentrations were for November (176.8 µg/m^3) and August (31.1 µg/m^3). It is assumed that the cities experience low temperatures, wind speed, relative humidity and precipitation in winter that had favoured for resulting in increasing ground-level air pollution due to spent high residence time. The monsoon season has characterized by moderate temperature and wind speed, high relative humidity and maximum precipitation. As a result, the air pollution level as well as $PM_{2.5}$ concentration decreased as the pollutant spent minimal residence time in the air. The pre-monsoon nor-wester brings thunderstorms in the afternoon/evening, which was the reason for the moderate concentration of that substance. A few western disturbances with the presence of all said climatic parameters moderately are featured post-monsoon results in pollution levels remaining medium.

According to the Lancet Planetary Health (2019), India had the world's leading ambient $PM_{2.5}$ levels on a population-weighted average. India witnessed 1.67 million deaths in 2019. It was the highest air pollution-related death by any country in the world (Figure 13). Vehicular emission contributes to $PM_{2.5}$ from 20-36% across Indian cities (Science X Network, 2022). The northern plain contains high levels of $PM_{2.5}$ due to stubble (crop) burning, the location of the Agra-Delhi-Kalka-Saharanpur industrial belt and heavy vehicular emissions (Mandal et al., 2021). In 2022, 12 out of 15 most polluted cities situated in India (World Air Quality Report, 2022). Simultaneously, India is the world's most populous country, with 1.42 billion (UNFPA, 2023). Hence, indoor emissions added more pollution to the existing outdoor pollution. In addition, forest fires led to India's poor air quality last year.

It is well known that ambient air pollution has an adverse impact on human health (Figure 12), most commonly adverse birth outcomes, infant morbidity and mortality, early respiratory health, allergic symptoms, early neurodevelopment, infant growth as well other relevant outcomes (Lin et al., 2023). According to WHO, air pollution is one of the most environmental health risks of our time, with 9 out of 10 people worldwide breathing polluted air. Particulate Matter is primarily generated by fuel combustion in different sectors, including transport, energy, households, industry, and from agriculture (WHO, 2021). A study in China, predict that exalted air quality during the COVID-19 quarantine period avoided a total of 8911 NO_2 related deaths and a total of 3214 $PM_{2.5}$ related deaths, 73% of which were from cardiovascular diseases and chronic obstructive pulmonary disease (COPD) (David J. Hill 2020; Sharma et al., 2020). An increase of 10 μg/m^3 in PM_{10}, SO_2, NO_x, O_3 was attributed to 1.04%, 8.42%, 1.28%, and 0.14% increase in respiratory and cardiovascular diseases (Phosri et al., 2019; Anwar et al., 2021). So, it depicts that particulate matter and other air pollutant causes an adverse health effect especially to older age group (Figure 14) as well enormous death in the study area. The health effect of PM_{10} is decreased compare to $PM_{2.5}$ especially during the rainy season (Lala et al., 2023). There was a noxious effect on human body such as on immune system, adipose tissue, muscle, liver, and brain. M1, classically activated macrophages; M2, alternatively activated macrophages; Th1, T helper type 1; Th2, T helper type 2; GLUT4, glucose transporter type 4 (Rao et al., 2015).

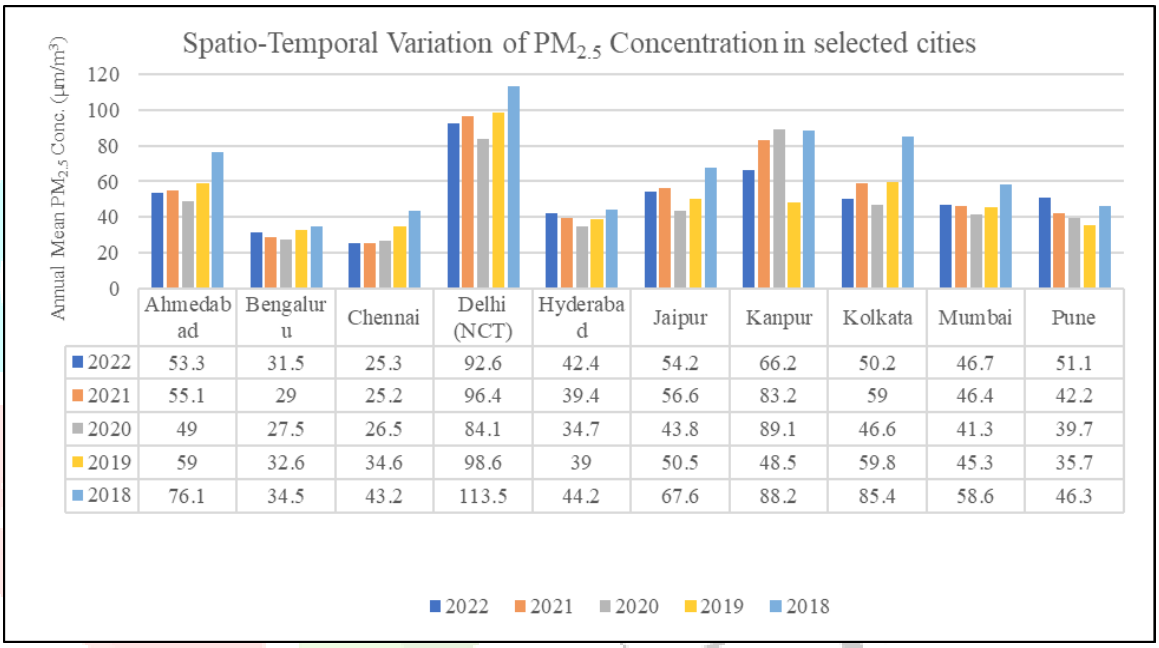

Figure 8 spatio-temporal variation of $pm_{2.5}$ concentration in the selected cities

Source: https://aqicn.org/data-platform/register/

Table 3 Seasonal Variation of $PM_{2.5}$ Concentration in 2022

Cities	Monthly Average $PM_{2.5}$ Concentration (μg/m^3)												Annual Mean
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Ahmedabad Maninagar	132	166.61	130.58	121.4	103.77	100.43	79.9	84.87	80.52	120.61	120.07	105.32	112.17
Bangalore BTM	75.35	117.86	103	129.17	128.7	134.9	119.1	70.67	71.15	88.52	120.45	110.74	105.80
Chennai Alandur Bus Depot	87.32	103.22	104.52	57.15	89.93	90.5	73.1	62.19	115	133.46	94.57	143.87	96.24
Delhi Pusa	220.58	167.75	161.16	156.63	147	121.83	82.35	79.9	96.67	159.23	229.4	234.65	154.76
Hyderabad Central University	117.32	111.59	117.97	95.97	88.32	44.44	39	36.9	42.52	67.79	135.24	119.39	84.70
Jaipur Police Commissonerate	102.84	106.78	118.25	145.38	162.68	131.13	73.32	96.46	120.34	136.08	147.89	158	124.93
Kanpur Neheru Nagar	163.84	152.86	152.94	147.7	140.42	123.93	74.39	70.58	81.03	134	190.83	164.52	133.09
Kolkata Jadavpur	173	143.57	126.71	67.1	81.84	81.13	62.65	66.87	69.93	89.83	167.93	191.32	110.16
Mumbai CSIA	142.9	155.04	137.23	105.2	97.35	53.33	60.39	58.19	62.97	98.13	139.43	143.13	104.44
Pune Nigdi	96.09	90.25	87.81	75.48	45.39	32.17	38.68	30.13	30.57	59.13	140.8	150.75	73.10

Source: Compiled by author (https://aqicn.org/data-platform/register/)

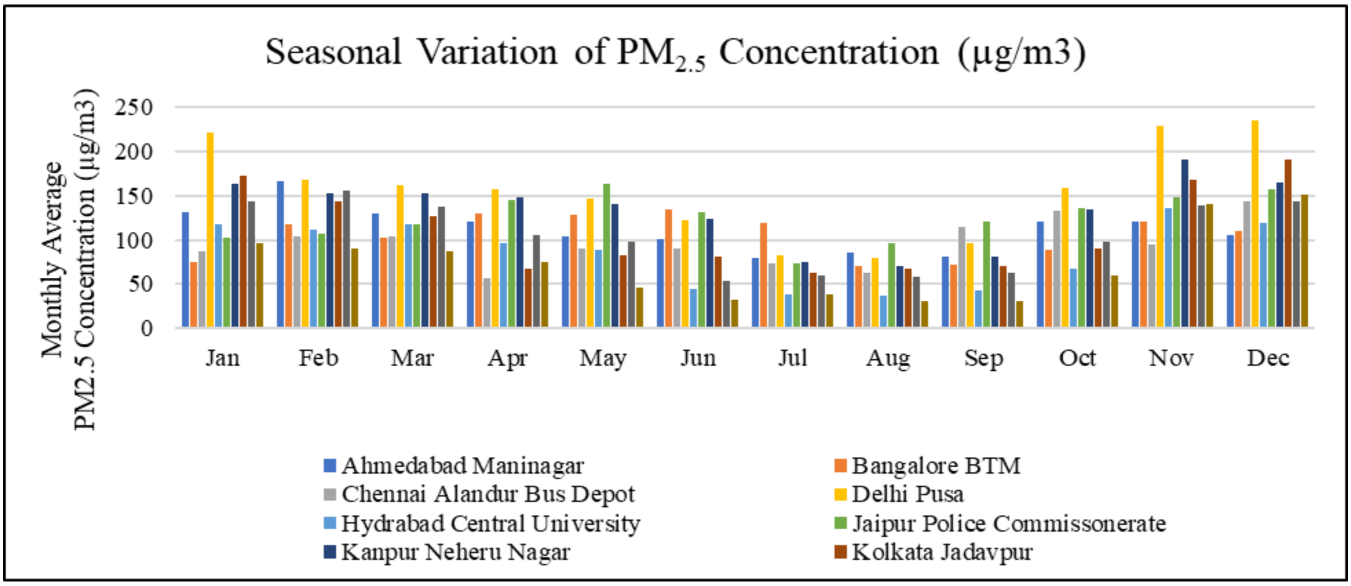

Figure 9 Seasonal Variation of $PM_{2.5}$ in Ten Selected Metropolitan Cities in India

Source: Compiled by author (https://aqicn.org/data-platform/register/)

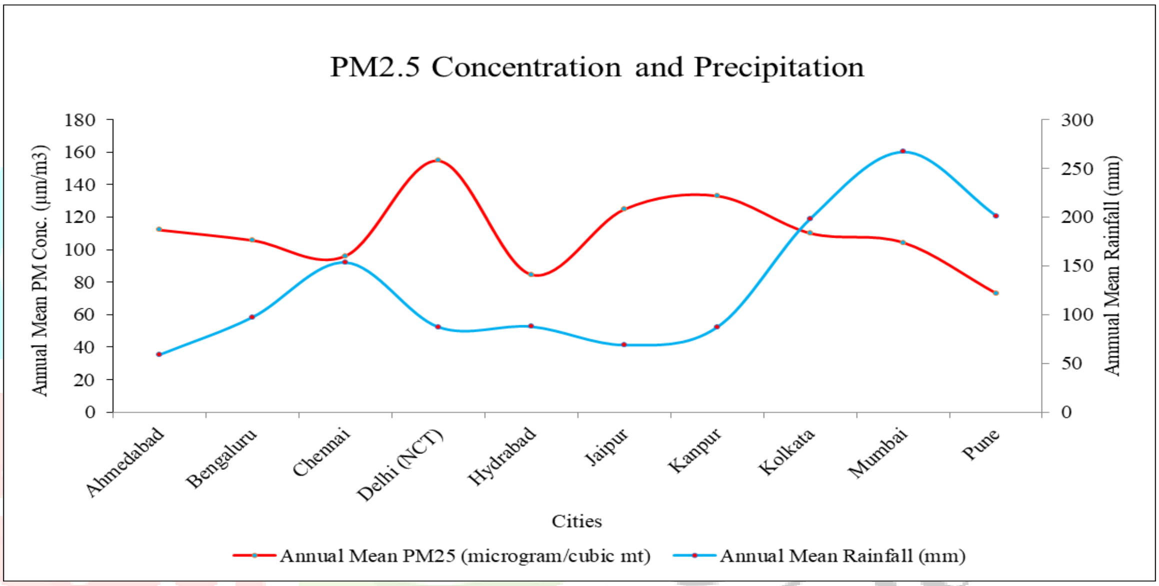

Figure 10 the correlation between particulate $matter_{2.5}$ and precipitation in the selected metropolitan cities in India

Source: Compiled by author

Table 4 correlation between $pm_{2.5}$ concentration and precipitation (selected stations/cities)

Cities	Annual Mean Rainfall (mm)	Annual Mean $PM_{2.5}$ ($\mu g/m^3$)
Ahmedabad	58.89	112.17
Bengaluru	97.43	105.80
Chennai	153.61	96.24
Delhi (NCT)	87.33	154.76
Hyderabad	87.75	84.70
Jaipur	68.89	124.93
Kanpur	87.39	133.09
Kolkata	198.6	110.16
Mumbai	267.01	104.44
Pune	201.35	73.10
Source: Compiled by author		

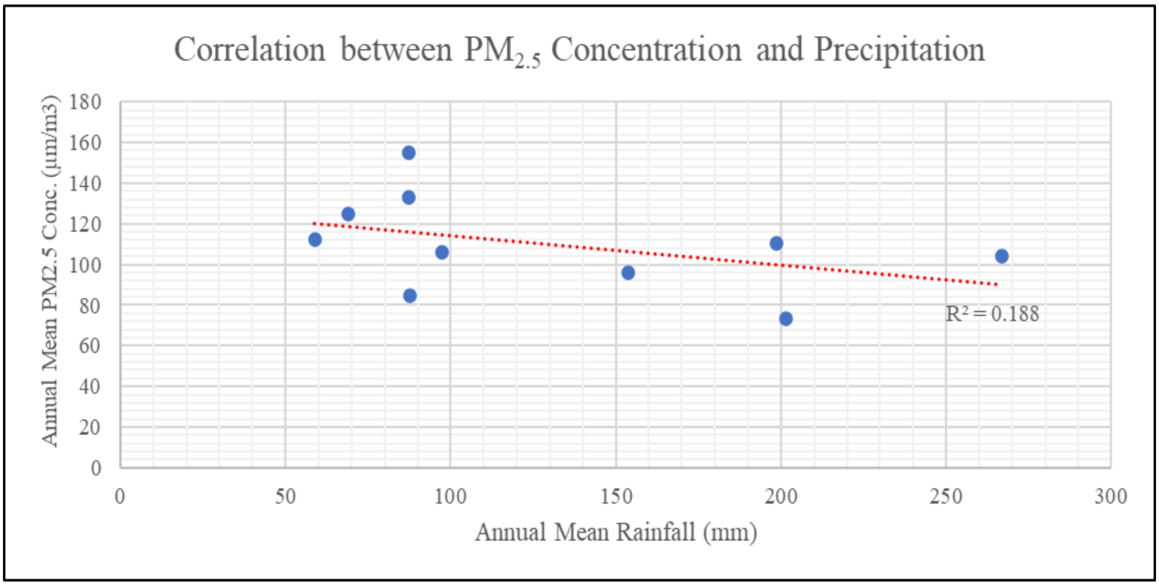

Figure 11 scatter plot showing the correlation between $pm_{2.5}$ concentration and precipitation

Source: Compiled by author

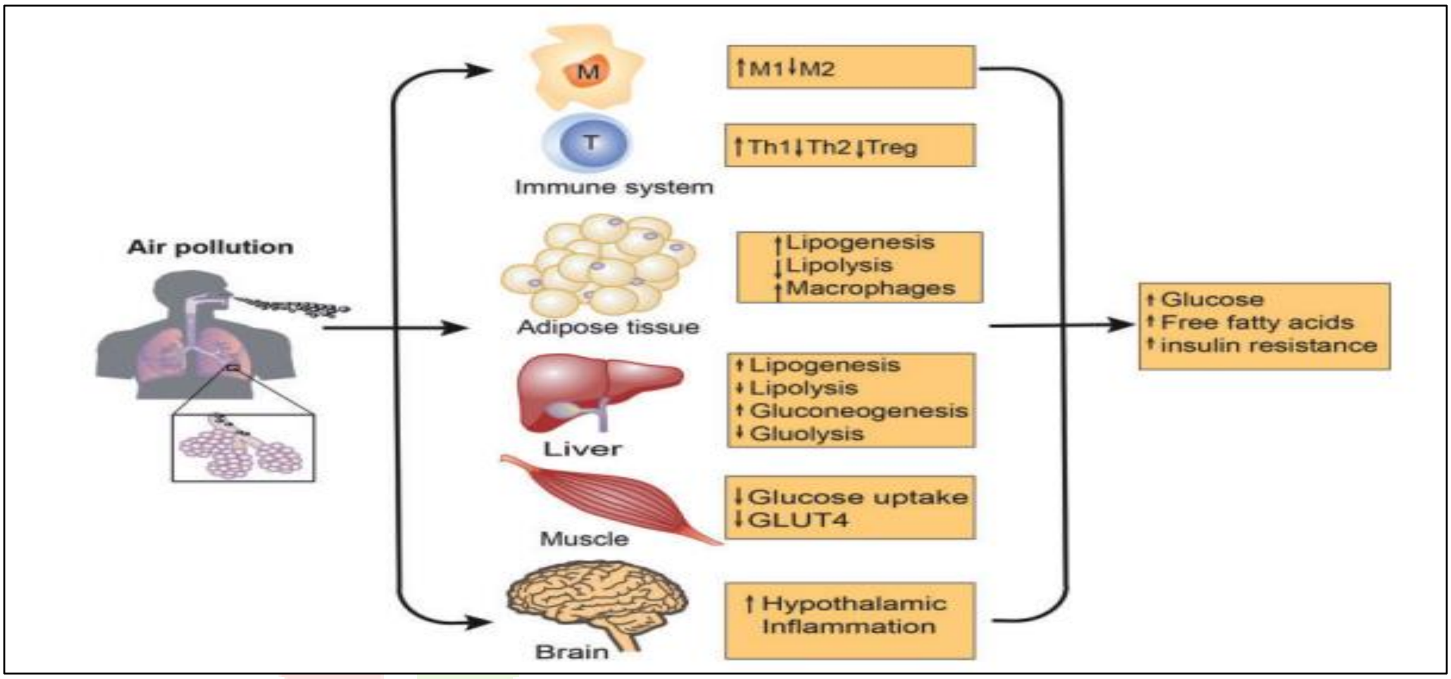

Figure 12 effect of air pollution

Source:(Rao et al., 2015)

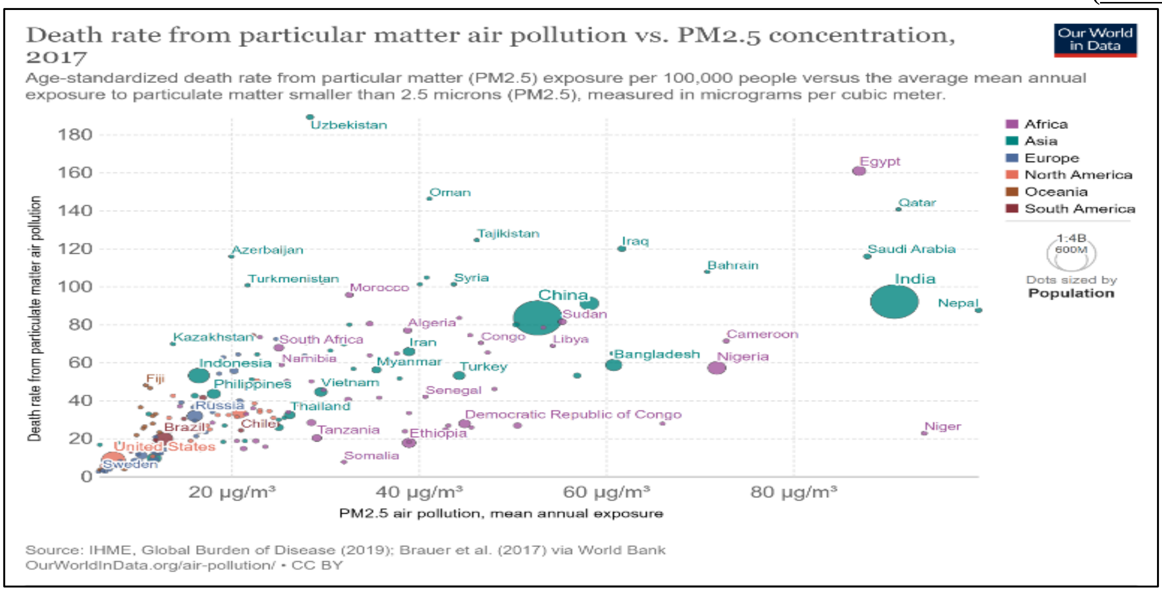

Figure 13 death rate vs. $pm_{2.5}$ concentration

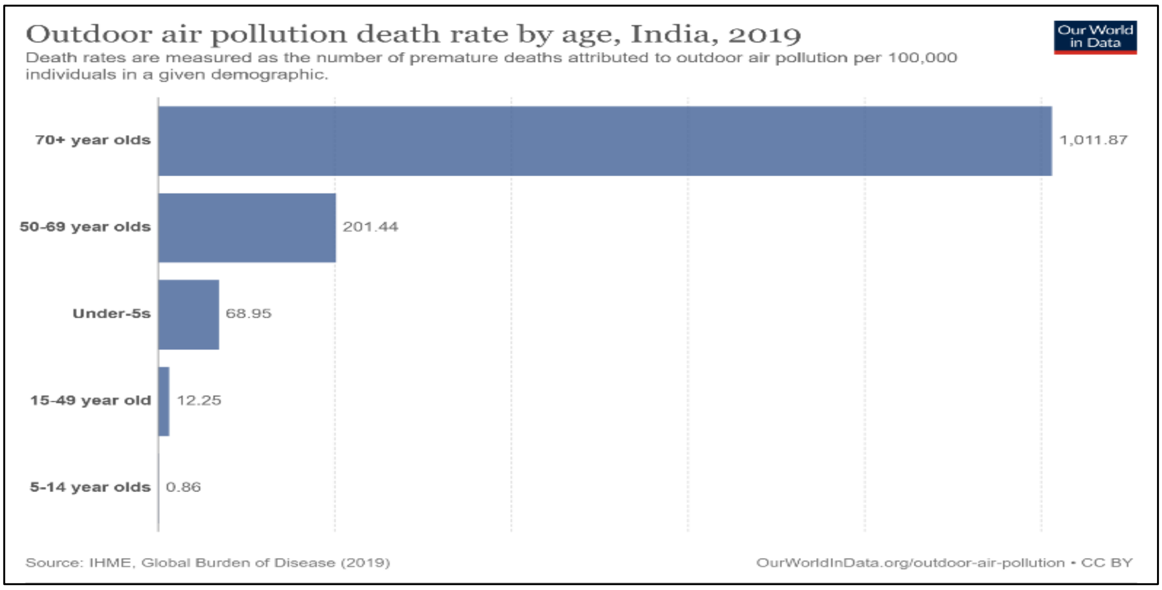

Figure 14 vulnerability by age-group, India 2019

The United Nations (UN) estimates that 4.9 billion inhabitants out of 8.1 billion will be living in cities by 2030 (UNCSD, 2001; Gurjar et al., 2008). Rapid urbanization has resulted in increasing air pollution emissions due to transportation, energy production and industrial activity, all concentrated in densely populated areas (Gurjar et al., 2008). Most of the cities of south east and southern Asia suffer from massive vehicular emission which causes the smog in winter and haze in other period of year. These lead to extensive cardio vesicular and respiratory problem among the city dwellers especially to the infant population.

The combustion of fossil fuel in the cities and megacities leads to increase PM in air and the particles travel through regionally and between continents (Ravindra et al., 2016; Anwar et al., 2021). Biomass burning in the city significantly affects local PM concentrations and there is a strong impact from biomass burning outside of the city on PM concentrations within the city, with contributions of approximately 85% and 89% for PM_{10} and $PM_{2.5}$ respectively (Pimonsree et al., 2018).

A recent study in India shows that there is no such impact of air pollution during monsoon season and the air quality status also found under good and satisfactory category in terms of AQI (Kumar et al., 2018). This variation may be caused due to maximum movement of vehicles in the subcontinent in winter season. Also, low temperature and high humidity in winter tend to create smog and haze which cause unfavorable condition to the inhabitants. Further, the daily average concentration and AQI for particulate matter shows a maximum pollutant concentration during winter months and a general trend of minimum values occurs in monsoon (Mamta et al., 2010). Another study shows that the levels of $PM_{2.5}$ increased in air due to the change in wind direction and the other factors such as temperature inversion, large scale subsidence, advection, and radiative cooling (Shi et al., 2020).

The above results and discussion lead us to an approach in ambient air monitoring and its management. It is observed that during the time of Covid-19, when the lockdown or quarantine was going on all over the country, nitrogen dioxide and particulate matter have been mixed 2.5 less in the air. This was because during the quarantine there was very little traffic on the roads and most of the factories were closed. From this result we can draw a conclusion that the loss of life is less if the amount of $PM_{2.5}$ is mixed in the air otherwise it has a great impact on people's lives.

5. Possible Solution

The Indian government is committed to reducing air pollution. The measures that have been taken so far have had some success, but there is still a long way to go. The government will need to continue to invest in research and development, and to implement new policies and programs in order to achieve its goals.

Table 5 legislations on air pollution in India.

Legislations/Acts	Year of Introduction	Key words
Air (Prevention and Control of Pollution) Act	1981	Control and abatement of air pollution. Entrusts the power of enforcing this act to the CPCB.
The Motor Vehicles Act	1988	Hazardous waste is to be properly packaged, labelled, and transported.
National Clean Air Programme (NCAP)	2014	To Achieve 20% to 30% Reduction in Particulate Matter Concentrations by 2024.
Bharat Stage (BS) IV Standards	2014	Establishes new evaporative emission standards and emission limits of gases (CO, NO_X, $HC+NO_X$) for two wheelers.

5.1 Promoting the use of public transportation

The government have to invest more in public transportation systems in order to reduce the number of vehicles on the road. Public awareness should be more emphasized.

5.2 Encouraging the use of cleaner fuels

The government have to provide subsidies for the use of cleaner fuels, such as compressed natural gas (CNG) and liquefied petroleum gas (LPG) and EVs.

5.3 Protecting existing forests

One of the best ways to reduce air pollution caused by deforestation is to protect existing forests. This can be done through a variety of measures, such as creating protected areas and sustainable forestry practices.

5.4 Replanting trees

Another way to reduce air pollution caused by deforestation is to replant trees. This can help to improve air quality and provide a number of other benefits, such as reducing erosion and providing habitat for wildlife.

5.5 Changing agricultural practices

In some cases, deforestation is caused by agricultural practices, such as clearing land for crops or livestock. Changing agricultural practices can help to reduce deforestation and air pollution. For example, farmers can use less land-intensive crops or adopt practices that help to conserve soil.

5.6 Installing pollution control devices

Power plants can install pollution control devices, such as scrubbers and filters, which can remove pollutants from the exhaust gases.

5.7 Using alternative methods to dispose of crop residues

There are a number of alternative methods to dispose of crop residues, such as composting, baling, and mulching. These methods can help to reduce the amount of stubble that is burned.

5.8 Encouraging farmers to adopt no-till or minimum-till farming practices

No-till and minimum-till farming practices help to reduce the amount of crop residue that is left on the field after harvest. This can help to reduce the need for stubble burning.

5.9 Providing financial incentives to farmers who do not burn stubble

Governments can provide financial incentives to farmers who do not burn stubble. This can help to encourage farmers to adopt alternative methods of disposing of crop residues.

5.10 Improving monitoring of air quality

The government has set up a network of air quality monitoring stations across the country. This information is used to track air quality levels and to identify areas where pollution is a problem.

6. Conclusion

Air pollution has devastating consequences that should deeply concern us all. The continuous degradation of air quality, due to factors such as $PM_{2.5}$ and PM_{10}, poses a serious threat to both human health and the environment. It is alarming to think of the harmful effects that are being inflicted upon us, as well as the irreparable damage being done to our surroundings. When it comes to air quality monitoring, the results are disheartening. What's even more alarming is the fact that indoor air pollution is also a major concern, affecting the very air we breathe within the supposed safety of our homes. The consequences ripple beyond just humans; the environment suffers too. It pains to realize the detrimental impact that air pollution has on both human lives and the ecosystem as a whole. This issue requires urgent attention and action in order to safeguard our future.

Discussing all the above observations, it can be seen that $PM_{2.5}$ is currently one of the major air pollutants that mix into air from various sources and degrade air quality. The emission of $PM_{2.5}$ should be prevented and more attention should be paid to avoid mixing $PM_{2.5}$ in the air. If not, in the near future, all mankind and its environment may suffer greatly.

To reduce particulate matter emissions, the following measures can be taken. Firstly, we have to use alternatives to open burning, such as composting or recycling landscaping debris, household trash, demolition debris, and land-clearing debris. Public transport can be used instead of private transport as well as bicycling, walking can be practiced. Production and use of non-conventional energy needs to be emphasized instead of fossil fuel-based energy. Besides, installation of air purifier in home and office may reduce the harmful effects of particulate matter. It is also recommended that, investing in research and innovation for developing new technologies carried out to control particulate pollution. Lastly, we should follow the new WHO Global Air Quality Guidelines (AQGs) that recommend lower levels of key air pollutants to protect health and mitigate climate change.

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