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Evaluation of fine particulate matter and ambient air quality on the metropolitical city: A regional study

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Abstract

The air pollutants and air quality index (AQI) data were collected from Tamil Nadu Pollution Control Board (TNPCB) for the period of twelve years in order to analyse the characteristics of air quality, pollutants in atmosphere and concentrations of sulphur dioxide, particulate matter, nitrous oxide and total suspended particles in the Chennai city. Results from the current study revealed that total suspended particles were found to be major pollutant in the atmosphere of Chennai city as compared to other pollutants. The average air quality index of kilpauk over 12 years found decreased than T.Nagar and Nungambakkam and found increased as compared with Anna nagar and Adyar areas. The air pollutants concentrations found linearly decreased trend over the twelve years due to motor vehicle policies of government. Instead, nitrous oxide and sulphur dioxide pollutants were still considered to be hazardous and most of them were emitted from the vehicles and it is considered as a major environmental threat in metropolitan cities. The possible reasons for higher emission of pollutants and poor air quality in the atmosphere were discussed in the current study.

Keywords: Pollution, NOx, Environmental research, Air quality.

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1.Introduction

The consequences of pollution have been and are taking a toll on the ecosystem of both biotic and abiotic organisms. Due to various anthropological activities, the severity of it has been increasing, which has the urgency to address it promptly. Among the various forms of pollution, Air pollution is one of the major issues, which directly or indirectly makes way to cause other forms of pollution. Recently, Studies from many epidemiologists suggested that, air pollution is one of the major causes of various infections in the respiratory and cardiovascular system in our body, which has the potential to affect the rate of mortality and morbidity in human beings [1].

Air pollution is one of the most toxic form of pollution, due to the fact the particulate matter present in the affected atmosphere is in miniscule scale. The air quality in a particular area is based upon the size of the particles present in the air. Usually, the air in the atmosphere consists of various size of particles, ranging from small solid particles to very tiny droplets. These particles are divided into large particles, which is usually gleaned from the soil and rocky particles, and the particulate particles, which are gleaned during extraction and combustion of fossil fuels, smoke from the industries, etc. The U.S. Standards of Health has suggested that, the particles with diameter of less than 10 micrometres are considered to be “Inhalable particles” [2]. The particulate particles are even finer, of even less than or equal to 2.5 micrometres. This poses a risk to the lungs, because smaller particles, which are potentially toxic can penetrate deeper into the lungs, which can lead to various diseases [3,4,5]. Due to this complexity, various standards and guidelines have been issued by different countries, to keep the Air Quality Index on a check. The World Health Organisation has suggested the Guidelines of Air Quality, which is being 25 mg/m^3 as the daily mean and about 10 mg/$m^3$for $P.M_{2.5}$ as the annual average [6]. These standards are used as references, which can also be used to compare the health of a community.

Various studies and research have found the relationship between the mortality rates and the levels of particulate in air. In these findings, the seasons of when the data was procured, affected the results invariably, which acted as one of the modifying factors for the studies. The study by Tang et. Al, stated that by following the regulations, such as providing designated coal-free areas, use of clean fuel etc., and abutting by the AQG in Taiyuan, China proved to be beneficial. The health of the people showed a great progress along with a decline in pre mature deaths [7]. The analysis by Medina et.al, concluded that increase in the levels of $P.M_{10}$, in the atmosphere, which is usually due to traffic, led to increase in the people getting admitted to hospitals, especially due to pneumonia. This analysis led to the conclusion that; the air pollution can have adverse effects on the health of the people in a particular area [8]. Through the detail study of the mortality rate and the air pollution in California, Ostro et al could come to a conclusion that the levels of $P.M_{2.5}$ in the environment could be fatal for people, especially those who come under the category of elderly who are diabetics. Moreover, they also concluded that the mortality rate at one area is directly or indirectly related to the levels of $P.M_{2.5}$ in the atmosphere in that particular area [9]. In China, due to rapid urbanisation and industrialisation, there is a significant spike in the pollution levels, as well as proportionately, the mortality levels. The study conducted by Zhang et. Al, showed that there is a very large proportionate possibility and association of P.M levels in the atmosphere with the increasing mortality rates in China [10]. Seoul was found to be having problems in increasing rate of premature deaths among the elderly people. It was also found to have increasing levels of particulate matter in the air due to pollution from industries and traffic. Several Stringent measures were taken to control the levels of Particulate matter in the air, which abided by the AQG of the WHO, which in turn showed a great improvement in the rates of premature mortality in individuals [11].

Usually, to come to a proper conclusion, various factors are taken into consideration. The concentrations of Particulate matter, of diameter less than 10 micrometres ($P.M_{10}$), $PM_{2.5}$, Sulphur dioxide (SO_2), Nitrogen oxide (NO_2), and Ozone (O_3) are taken into consideration. This study is done to evaluate the Particulate Matter and its behaviour with the atmosphere in Chennai, in order to have a possible discussion about the Air Quality Guidelines and the association between the various factors like Mortality rates and the Air Pollution levels.

1.1 Data acquisition

The Air Quality Index (AQI) values in the year from 2007 to 2018 were collected from Pollution Control Board of Tamilnadu (TNPCB). The Air Quality Index (AQI) values measured at eight monitoring stations in Chennai is converted to arithmetic scale from 0 to 500. Table 1 depicts the air pollutant concentration, Air Quality Index (AQI) values and limits.

The air pollutant concentrations of PM_{10}, $PM_{2.5}$, SO_2 and NO_x between 2007 and 2018 are obtained from Tamil Nadu Pollution Control Board (TNPCB). Rainfall data during 2007 and 2016 is obtained from DMS Teynampet.

Table 1. Air Quality Index (AQI) value and limits for pollutant concentration

Concentration Range	AQI Category					
	Good	Satisfactory	Moderately Polluted	Poor	Very Poor	Severe
PM10	0-50	51-100	101-250	251-350	351-430	430+
PM2.5	0-30	31-60	61-90	91-120	121-250	250+
NO2	0-40	41-80	81-180	181-280	281-400	400+
O3	0-50	51-100	101-168	169-208	209-748	748+
CO	0-1.0	1.1-2.0	2.1-10	10-17	18-34	34+
SO2	0-40	41-80	81-380	381-800	801-1600	1600+
NH3	0-200	201-400	401-800	801-1200	1200-1800	1800+
Pb	0-0.5	0.5-1	1.1-2.0	2.1-3.0	3.1-3.5	3.5+

2. Evaluation of ambient air quality in Chennai City

2.1 Variation of AQIs

The Air Quality Index Values (AQI) can be categorised in to six classes based on the concentration of major pollutants in the atmosphere as per Ambient Air Quality Standard of India (2009). They are severe, poor, very poor, moderately polluted, satisfactory and good. The categorization in entirely based on the health impact of humans due to concentration levels of air pollutants in the atmosphere. The months, which corresponded to each class, for the five main areas Adyar, T.Nagar, Anna Nagar, Kilpauk and Nungambakkam in Chennai were evaluated and designated as Zone 1, Zone2, Zone 3, Zone 4 and Zone 5 respectively. The air quality classes for Chennai are shown in table 2 and table 3. Prior to current air quality standards enforced on November 2009, India followed air quality standards notified on 1994 and then revised on 1998.

In 2014, India launched a quality parameter scale referred as Air quality index to easily categories the pollutants in the atmosphere based on the severity and health impact of humans, easily understandable to the public. The air quality in the atmosphere can be measured based on the following major pollutants namely PM_{10}. $PM_{2.5}$, Nitrous oxide, Carbon monoxide, NH_3, O_3, Lead and Sulphur dioxide for a average period of 4 hours. The measurement was made based on the National Ambient Air Quality Standards (NAAQS) and the maximum reading were considered as a AQI value for the respective city.

Table 2. Air quality classes in Chennai (2007-2013)

Pollution Classes	2007		2008		2009		2010		2011		2012		2013	
	Month	%	Month	%	Month	%	Month	%	Month	%	Month	%	Month	%
Good			3	6.25	2	3.33	6	10						
Satisfactory	10	16.7	5	10.41	8	13.33	6	10	12	20.3	12	23.1	27	56.25
Moderately Polluted	3	5	2	4.16	6	10	6	10	2	3.38	5	9.61	21	43.75
Poor	12	20	12	25	7	11.7	10	16.7	10	17	5	9.61		
Very Poor	35	58.3	20	41.6	37	61.67	32	53.3	30	50.8	29	55.76		
Severe			6	12.5					5	8.47	1	1.92		

Table 3. Air quality classes in Chennai (2014-2018)

Pollution Classes	2014		2015		2016		2017		2018		Total	
	Month	%	Month	%	Month	%	Month	%	Month	%	Month	%
Good	3	5.17	11	19.29	3	5.17	3	5	1	1.81	32	4.7
Satisfactory	47	81.03	34	60	40	69	19	31.66	15	27.27	235	34
Moderately Polluted	8	13.79	12	21.05	15	25.86	37	61.6	36	65.4	152	22.6

Poor	1	1.6	3	5.4	60	8.8
Very Poor					183	27.1
Severe					12	1.7

2.2 Variation of AQIs in Zone 1, Chennai

Air quality classes in Zone 1 were evaluated from 2007 to 2018.It is revealed from the study, air quality was “good” about 21.98% “satisfactory” about 69.5% and “moderately polluted” about 8.5% exceeded the guidelines of ambient air pollutants and protection of health stated by the National ambient air quality standards.

2.3 Variation of AQIs in Zone 2, Chennai

Air quality classes in T.Nagar were evaluated from 2007 to 2018. It is revealed from the study, air quality was “satisfactory” about 22.46% “moderately polluted” about 27.53% “poor” about 11.59% and “very poor” about 38.4%, exceeded the guidelines of ambient air pollutants and protection of health stated by the National ambient air quality standards

2.4 Variation of AQIs in Zone3, Chennai

Air quality classes in Anna Nagar were evaluated from 2007 to 2018. It is revealed from the study, air quality was “satisfactory” about 28.1% “moderately polluted” about 29.5% “poor” about 12.23% “very poor” about 29.5% and “severe” about 0.7%, exceeded the guidelines of ambient air pollutants and protection of health stated by the National ambient air quality standards

2.5 Variation of AQIs in Zone 4, Chennai

Air quality classes in Kilpauk were evaluated from 2007 to 2018. It is revealed from the study, air quality was “good” about 0.7% “satisfactory” about 32.1% “moderately polluted” about 23.3% “poor” about 15.5% “very poor” about 27% and “severe” about 0.7, exceeded the guidelines of ambient air pollutants and protection of health stated by the National ambient air quality standards

2.6 Variation of AQIs in Zone 5, Chennai

Air quality classes in Nungambakkam were evaluated from 2007 to 2018. It is revealed from the study, air quality was “satisfactory” about 12.2% “moderately polluted” about 27.3% “poor” about 2.8% “very poor” about 48.1% and “severe” about 9.4%, exceeded the guidelines of ambient air pollutants and protection of health stated by the National ambient air quality standards

2.7 Annual average AQIs of Chennai.

Annual average AQIs for various areas of Chennai during 2007 to 2018 are evaluated which is shown in Fig.1. Compared to other areas in Chennai, the mean value of AQI (65.1) of Zone1 was lower than that of Zone 2, Zone3, Zone 4 and Zone 5 and the mean value of AQI (244.78) of Zone 5 is higher when compared to other areas. Annual variation of AQIs for various areas of Chennai is shown in Fig.1.Results revealed that ambient air quality in Zone 1was apparently better than other areas in Chennai, but it was worse in Zone5 and Zone 2. Annual average AQIs for various areas of Chennai is shown in table 4.

The above zones were seriously polluted at various levels based on several factors include metrological conditions and economic development. Most portions of Tamilnadu falls under climate of Tropical savannah and fewer regions come under humid sub-tropical climate. Due to northeast trade winds, Tamilnadu receives major portion of rainfall and some portion of rain may get in monsoon season. 38% of rainfall occurs during June to September and 42% of rainfall occurs during October to December. Between these months ambient air pollutants were diluted and dispersed. During the rainy season, the concentrations of pollutants in the atmosphere were comparatively less as compared with other seasons. It can also be seen those concentrations of ambient air pollutants in Zone 1 were comparatively lower than other areas. Annual average AQIs and rainfall in Chennai between 2007 and 2016 were shown in Fig.2.

3. Annual variations of prominent pollutants

3.1 Annual variations of prominent pollutants in Zone 1

Annual mean concentrations of ambient air prominent pollutants in Zone1 from 2007 to 2018 are shown in Fig.3.Although annual mean concentrations showed a downward trend in the year 2010 and after 2014, TSPM like PM_{10} and $PM_{2.5}$ remained the prominent pollutant in ambient air in Chennai city. Annual mean concentrations of PM_{10} in the year 2012 and 2018 were higher than the Central Pollution Control Board (CPCB) standard limits (60 µg/m³) and also the annual mean concentrations of $PM_{2.5}$ in the year 2007,2008,2009 and 2011 were higher than the CPCB standard limits (40 µg/m³).

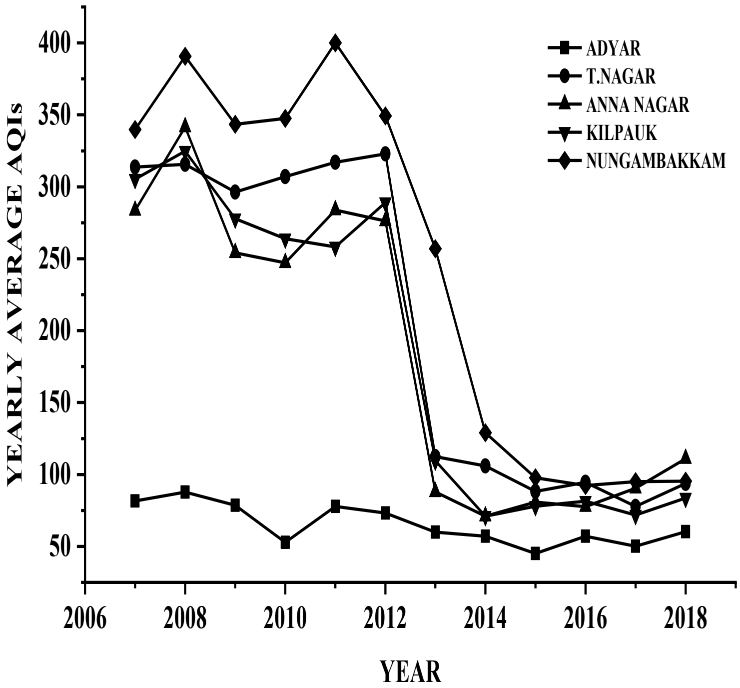

Figure 1. Annual variation of AQIs for various areas of Chennai, 2007 -2018.

Table 4. Annual average AQIs for the various areas of Chennai

Year	Adyar	T. Nagar	Anna Nagar	Kilpauk	Nungambakkam
2007	81.6	313.67	283.5	305.25	339.8
2008	87.7	315.67	341.5	324.78	390.7
2009	78.58	296.3	254.1	277.75	343.45
2010	52.75	307.08	247.16	263.91	347.58
2011	77.8	317	283.8	258.16	400
2012	73.16	322.9	276.3	289	349.25
2013	60	112.41	87.9	109.58	257
2014	57.08	106	71	71	129
2015	45.08	88.25	80.83	78	97.8
2016	57.08	94.6	77.58	81.5	92.41
2017	50.14	77.82	90.38	71.8	95.1
2018	60.3	93.85	111	83.6	95.36
Mean	65.105833	203.79583	183.75417	184.5275	244.7875

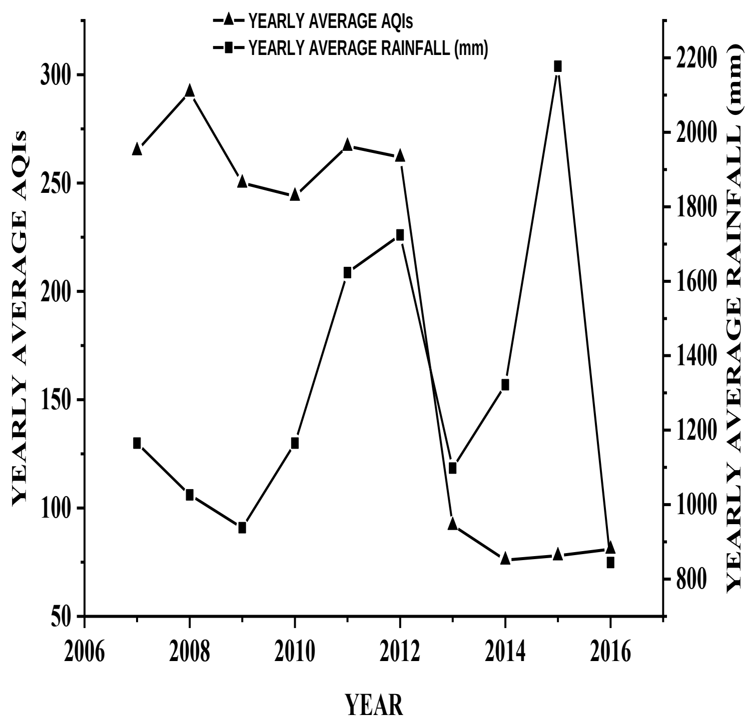

Figure 2. Yearly average AQIs and rainfall in Chennai, 2007-2016.

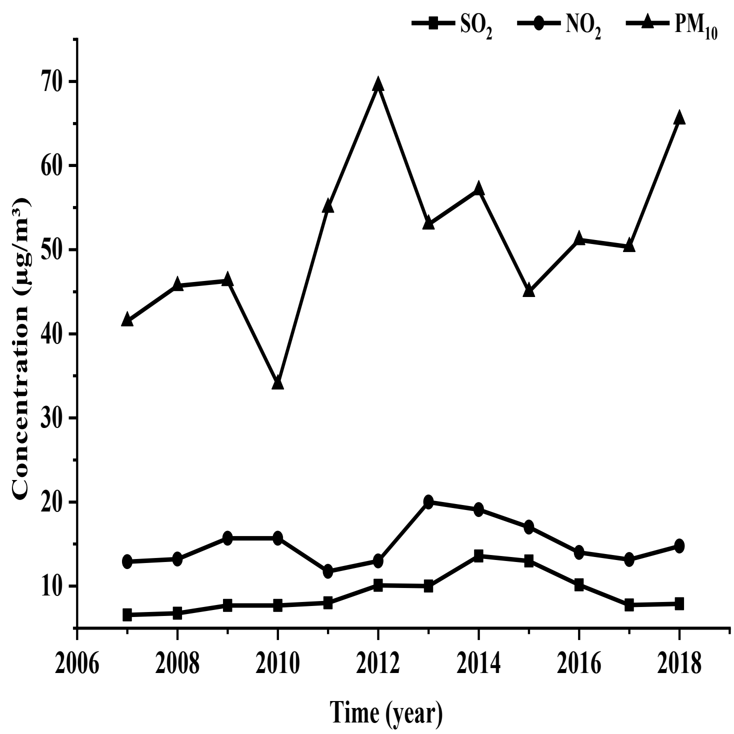

Figure 3. Annual mean concentrations of ambient air prominent pollutants in Zone 1, 2007-2018.

3.2 Annual variations of prominent pollutants in Zone 2

Annual mean concentrations of ambient air prominent pollutants in Zone 2 from 2007 to 2018 are shown in Fig.4.Although annual mean concentrations showed a downward trend after 2013, TSPM like PM_{10} and $PM_{2.5}$

remained the prominent pollutant in ambient air. Annual mean concentrations of TSP over 12 years were higher than Central Pollution Control Board (CPCB) standard limits. NOx reaches the maximum value of 32 µg/m³ in the year 2010, but it is below the standard limit (40 µg/m³).

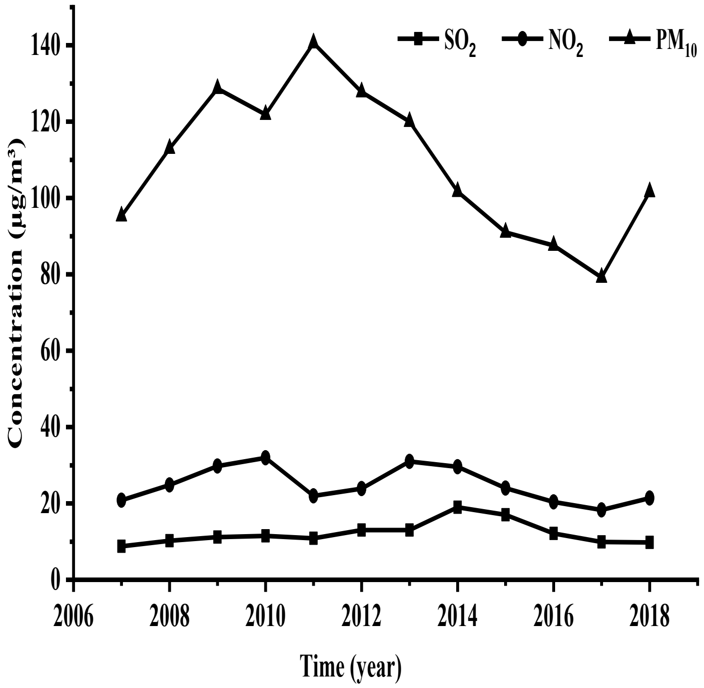

Figure 4. Annual mean concentrations of ambient air prominent pollutants in Zone 2, 2007 – 2018.

3.3 Annual variations of prominent pollutants in Zone 3

Annual mean concentrations of ambient air pollutants in Zone 3 from 2007 to 2018 are shown in Fig.5.TSPM remained the prominent pollutant in ambient air. Annual mean concentrations of TSP over 12 years were higher than the Central Pollution Control Board (CPCB) standard limits. Annual mean concentrations of NO_x (41.3 µg/m³) exceeded the CPCB standards in the year 2008. TSPM remained the prominent pollutant in ambient air. Annual mean concentrations of TSP over 12 years were higher than the Central Pollution Control Board (CPCB) standard limits. NO_x reaches the maximum value of 31µg/m³ in the year 2010, but it is below the standard limit (40µg/m³). Annual mean concentrations of ambient air pollutants in Zone 4 from 2007 to 2018 are shown in Fig.6.

3.5 Annual variations of prominent pollutants in Zone 5

Annual mean concentrations of ambient air pollutants in Zone 5 from 2007 to 2018 are shown in Fig.7. TSPM remained the prominent pollutant in ambient air. Annual mean concentrations of TSP over 12 years were higher than the Central Pollution Control Board (CPCB) standard limits. NO_x reaches the maximum value of 34 µg/m³ in the year 2010, but it is below the standard limit (40 µg/m³).

4. Monthly variations of prominent pollutants in Chennai

4.1 Monthly variation of prominent pollutants in Zone 1

Monthly variation of ambient air pollutant in Zone 1 during 2007 to 2018 is shown in Fig.8. The prominent pollutant in ambient air is TSP for the whole year. The prominent pollutant in ambient air in Adyar was TSPM such as PM_{10} (October and December) and $PM_{2.5}$ (May, June and July) was serious. Pollution is higher in June, July and august and lower in other consecutive months. This implies that pollution is related to weather background such as monsoon circulation.

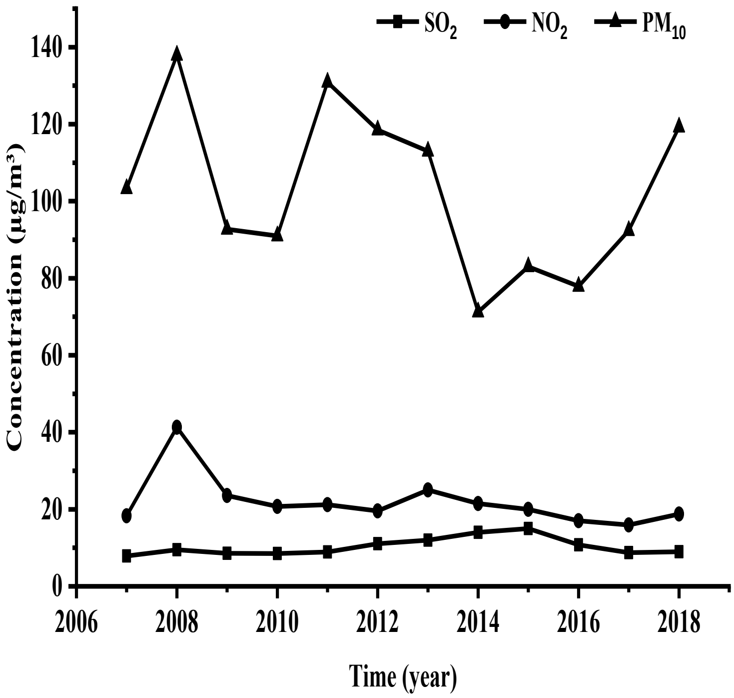

Figure.5 Annual mean concentrations of ambient air pollutants in Zone 3, 2007 – 2018.

3.4 Annual variations of prominent pollutants in Zone 4

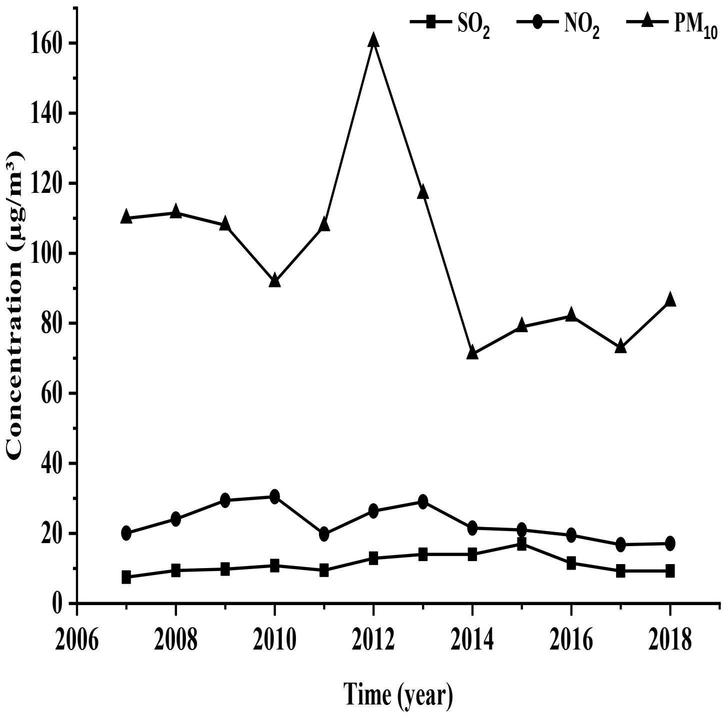

Figure 6. Annual mean concentrations of ambient air pollutants in Zone 4, 2007 - 2018.

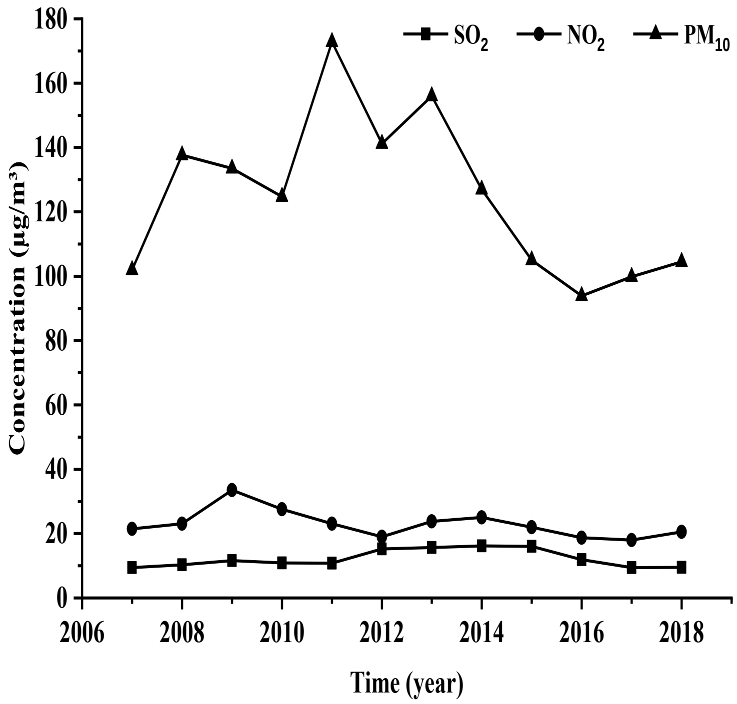

Figure 7. Annual mean concentrations of ambient air pollutants in Zone 5, 2007 – 2018.

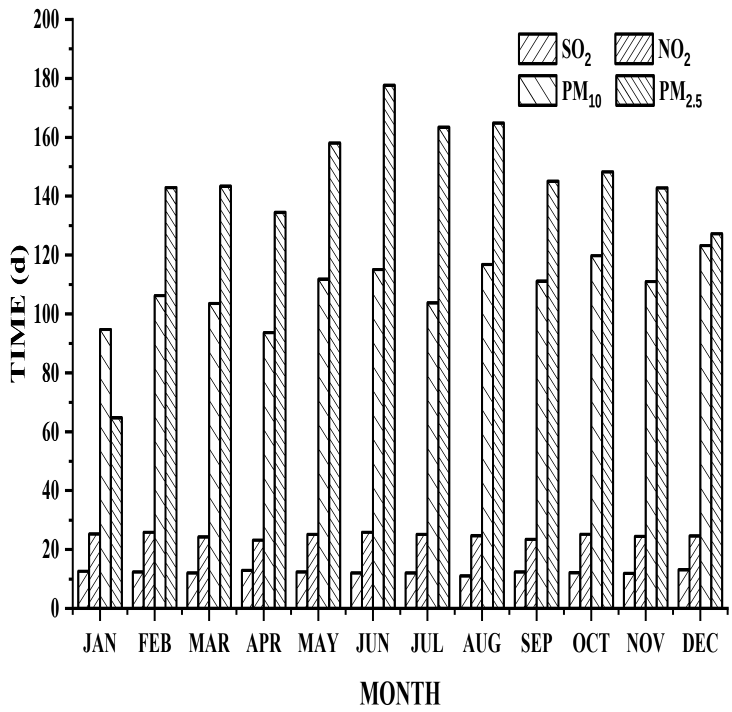

Figure 8. Monthly variation of ambient air pollutant in Zone 1, 2007 – 2018.

4.2 Monthly variation of prominent pollutants in Zone 2

Monthly variation of ambient air pollutant in Zone 2 during 2007 to 2018 is shown in Fig.9. The prominent pollutant in ambient air in Zone 2 was TSPM such as PM_{10}(May,June, October and December) and $PM_{2.5}$ (May,June, July and August) was serious.NO_2 pollution in ambient air of T.Nagar was serious. Pollution is higher in May, June, July and august and lower in other consecutive months. This implies that pollution is related to weather background such as monsoon circulation, because September, October and November month receives moderate rainfall in recent years.

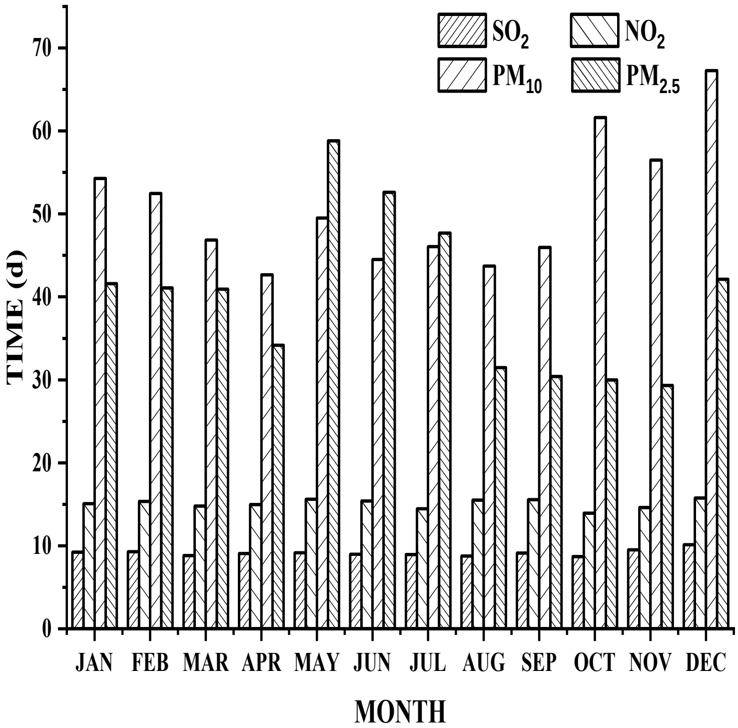

Figure 9. Monthly variation of ambient air pollutant in Zone 2, 2007 – 2018.

4.3 Monthly variation of prominent pollutants in Zone 3

Monthly variation of ambient air pollutant in Zone 3 during 2007 to 2018 is shown in Fig.10. The prominent pollutant in ambient air in Zone 3 was TSPM such as $PM_{2.5}$(May, June, July, August and September) and PM_{10}(Feb, Mar, June, July, Aug, Sep and Oct) was serious. Pollution from NO_2 in ambient air of Zone 3 was serious. Pollution is higher in May, June, July, August and September and lower in other consecutive months. This implies that pollution is related to weather background such as monsoon circulation.

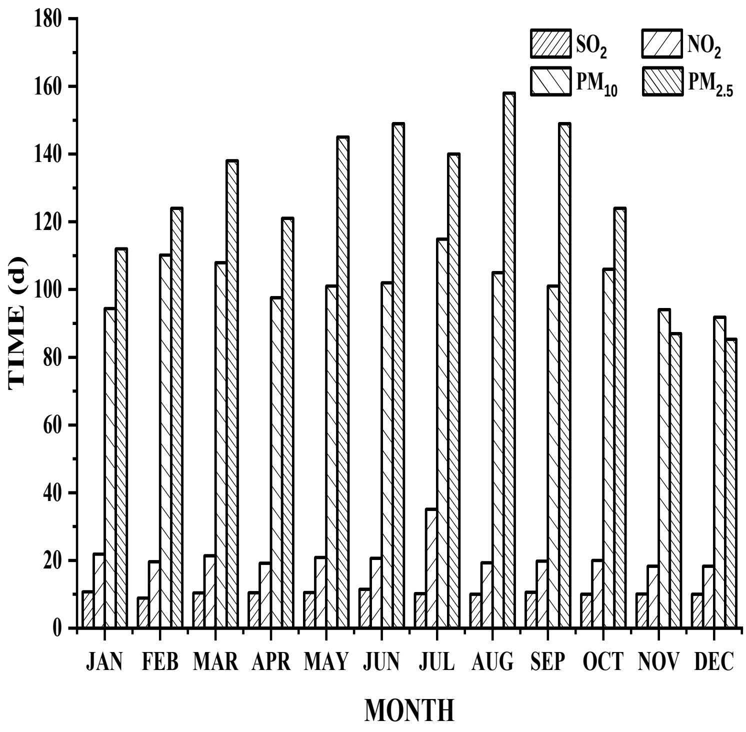

Figure 10. Monthly variation of ambient air pollutant in Zone 3, 2007 – 2018.

4.4 Monthly variation of prominent pollutants in Zone 4

Monthly variation of ambient air pollutant in Zone 4 during 2007 to 2018 is shown in Fig.11. The prominent pollutant in ambient air in Zone 4 was TSPM such as $PM_{2.5}$ (March, May, June, July and September) and PM_{10} (February, March, April, May, July, September, October and December) was serious. Pollution is higher in March, May, June and September and lower in other consecutive months. This implies that pollution is related to weather background such as monsoon circulation, because September, October and November month receive moderate rainfall in recent years.

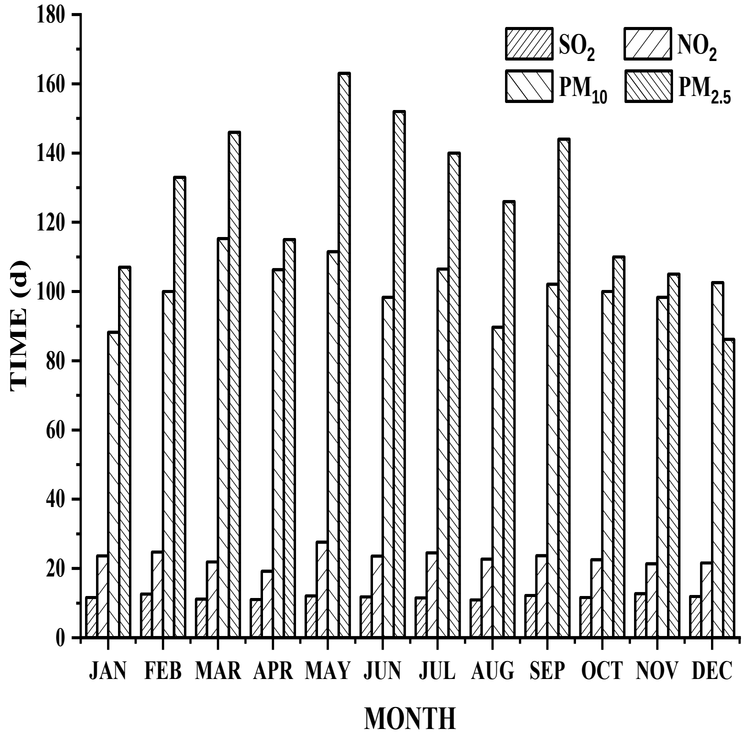

Figure 11. Monthly variation of ambient air pollutant in Zone 4, 2007 – 2018.

4.5 Monthly variation of prominent pollutants in Zone 5

Monthly variation of ambient air pollutant in Zone 5 during 2007 to 2018 is shown in Fig.12.The prominent pollutant in ambient air in Zone 5 was TSPM such as PM_{10} (May, July, August and September) and $PM_{2.5}$ (May,June, July, August, and September) was serious. Pollution from NO2 in ambient air of Zone 5 was serious, implying that waste gas pollution produced by all kinds of vehicles had become a significant problem. Pollution is higher in May, June, July, August and September and lower in other consecutive months. This implies that pollution is related to weather background such as monsoon circulation.

5. Results and Discussion

From this study, it is revealed that the air quality standards of Chennai city have attained the National ambient air quality standards due to various efforts taken to enhance the ambient air quality during the year between 2007-2018. Total suspended particles were considered to significant pollutants in ambient air atmosphere of Chennai city over the past 12 years. In addition, the concentration level of nitrous oxide, sulphur dioxide and total suspended particles were reduced linearly due to the significant efforts taken to enhance the air quality of metropolitan cities. Instead, nitrous oxide and sulphur dioxide pollutants were still considered to be hazardous and most of them were emitted from the vehicles and it is considered as a major environmental threat in metropolitan cities.

Air Quality Index (AQI) during the months December, January, May, June and July were considered to high as compared to August, September and November. The variation in AQI was due to prevailing weather conditions.

From the results, it is revealed that weather conditions, rainfall and monsoon were dependent on atmospheric air quality. Chennai authorities have taken several steps to control the air quality and maintain the sustainable environment and achieved great progress in reducing the pollutant concentration in the atmosphere. Traffic congestion in metropolitan cities and the concentration of pollutants has been increased considerably over the last 15 years. The green belt areas have steadily increased. Under the rule 110, the honourable chief minister of Tamilnadu set forth a rule for banning the one time use and throwaway plastics on July 2018 and the rule should be implemented from Jan-2019. Green award 2018 for district collectors, Industries and colleges/university/centre of excellences.

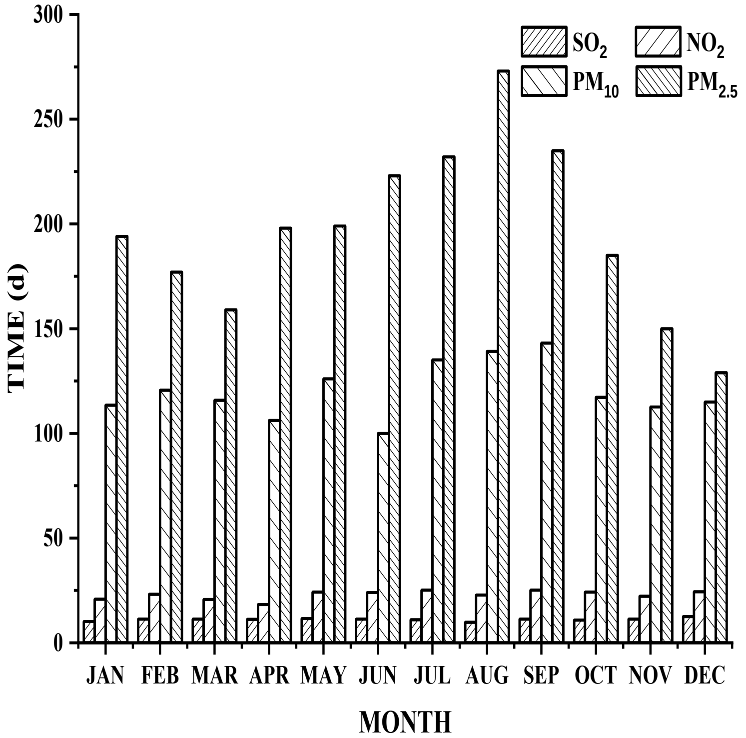

Figure 12. Monthly variation of ambient air pollutant in Zone 5, 2007 – 2018.

The rapid growth of urbanisation and development of economy and Chennai society, similar to other metropolitan cities and developing cities in the country, facing serious consequences to maintain the air quality standards for the sustainable environment. The sulphur content is found to be low in coal originated from India, rather the concentration of sulphur dioxide in the atmosphere has increased to about 30% during the year 2011-2012 due to higher consumption of coal and increased industrial activities. According to the State Transport Authority of Tamil Nadu, newly registered transport vehicles in Chennai city is 24069 during 2017 to 2018 and non-transport vehicles is 337876 during 2017 to 2018.

An enormous number of heavy trucks ply in the major cities due to rapid development of commercial shipping industry. The increased movement of trucks causes significant increase in pollutant concentration. In Tamilnadu, India, major proportion of electricity demands was satisfied by means of thermal power plants. Almost 5 million tons of coal were consumed annually by the Ennore and north Chennai thermal plants to produce electricity to the areas surrounding the metropolitan city. The percentage of sulphur used in power plants is less than 0.5%. The reduction in particulate matter concentration and sulphur emission were mainly achieved by means of desulfurization units and it showed immediate benefits to achieve the air quality standards. SO_2 emissions from the power plants account 59% and industries 27% due to their dependency on coal. For NO_2 emissions vehicle exhaust accounts for 60% in Chennai. The major sources of pollutants in greater Chennai were generated from the variable sources include dust generated from road (9%), burning waste materials (3%), vehicle emission (34%), domestic waste (4%), generator set (2%) and the sources from brick kilns (3%), industries (22%) and power plants (11%). In addition, the pollutants generated from the households by means using non electric and non-gas stoves is almost around 18%. The Chennai municipality operates two waste collection and land fill stations with a maximum collection capacity of 2100 tons for each day located at perungudi and kodungaiyur.

Approximately 50% of the waste which were uncollected is put fire at 1000 makeshift sites in Chennai at least once in a week. The brick kiln clusters are located predominately to the west of the Chennai city. Here the rectangle bricks were allowed to dry under the sun and prepared for firing in the fixed 50 m chimney to disperse emissions.

6. Conclusion

Sustainable environment can be achieved by controlling the emission of pollutants in the atmosphere. The possible factors to control the air quality in the Chennai city were depicted as follows:

- The rapid development of Chennai economy and increased usage of coal utilisation in industries due to shortage of electric power system results in high pollutant emissions. In addition, pollutants were also generated from the vehicles.
- In order to achieve profit, most of the manufacturing industries and enterprises in Chennai use large quantities of petroleum and coal for the energy needs. The total air pollutant emissions increase significantly due to improper control measures and increased consumption of energy.
- For the past 10 years, Chennai city has faced severe drought and the ground water level reduces significantly and facing water crisis. There is a lack of strong downdrafts, updrafts and landing typhoons in the Chennai city causes minimum dilution and diffusion of air pollutants in the atmosphere.
- The adjacent cities in the Chennai region influence the ambient air pollution significantly. The major causes for the pollutants in the atmosphere may be due to urban atmospheric pollutant emissions from the adjacent cities of Chennai. In near future, Chennai is expected for high construction activities, utilising renewable energy and clean fuels, increase the cover of vegetation and implementation of environmental protection policies in the metropolitan cities. The atmospheric air quality can be enhanced by adhering to international standards and agreements in order to control the climate change. The total concentration of pollutant emission in the atmosphere can be controlled by increasing the green cover by one million hectare every by twelfth five-year plan.

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