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Assessment of Air Quality Index for Cities and Major Towns in Tamil Nadu, India

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Abstract

Air Pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment. The Air Quality Index (AQI) is a reporting system and an important tool of risk communication. It informs the public about the level of ambient air quality, and the potential health risk it would impose. AQI converts complex air quality data of various pollutants into a single number (index value), nomenclature and colour. AQI is represented as numeric value varies from 0 to 500. If score is 0, it is the best air quality and if score is 500, it is the worst air quality. There are six AQI categories, namely Good, Satisfactory, Moderate, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts. In Tamil Nadu, under National Ambient Air Quality Monitoring Programme, Ambient Air Quality (AAQ) is being monitored by Central Pollution Control Board in association with Tamil Nadu Pollution Control Board in 28 locations covering cities, major towns and major industrial areas viz. Chennai, Salem, Coimbatore, Madurai, Trichy, Cuddalore, Mettur, and Thoothukudi. The AAQ data from January 2015 to December 2015 for the above cities and towns is collected and AQI is calculated for four months covering four seasons (i.e.,) January (winter), May (summer), July (monsoon), November (post monsoon). Almost all the stations' AQI fall under good and satisfactory category except Trichy where the majority of the days the AQI fall under moderate category. From the AQI of all the stations, it is observed that responsible pollutant is PM_{10}. The other parameter (i.e.,) SO_2 and NO_2 fall under good category for all stations for all days. The higher value of PM_{10} is mainly due to vehicular pollution.

Keywords: Air Quality Index (AQI); Chennai; Cities and major towns; Tamil nadu

Introduction

The systematic pollution of our environment is one of the biggest hazards that humanity faces. People are becoming increasingly aware of the threat posed by pollution and governments are enacting legislations aimed at protecting the environment. Air pollution may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and his environment. These substances include gases (sulphur oxides, nitrogen oxides, carbon monoxide, hydrocarbons, etc.), particulate matter (smoke, dust, fumes, and aerosols), radioactive materials and many others. Most of these substances are naturally present in the atmosphere in low (background) concentrations and are usually considered to be harmless [1].

Literature Review

Indian national ambient air quality standards

An air quality standard is a description of a level of air quality that is adopted by a regulatory authority as enforceable. The basis of development of standards is to provide a rational for protecting public health from adverse effects of air pollutants, to eliminate or reduce exposure to hazardous air pollutants, and to guide national/local authorities for pollution control decisions. With these objectives, Central Pollution Control Board (CPCB) notified Indian National Ambient Air Quality Standards for 12 parameters (Table 1) [2].

Air Quality Index (AQI)

The Air Quality Index (AQI) is a reporting system and an important tool of risk communication. It informs the public about the level of ambient air quality, and the potential health risk it would impose, particularly on vulnerable groups such as children, the elderly, and those with existing cardiovascular and respiratory diseases [3]. People use the AQI to make decisions on outdoor activities; for example, schools and sports organizations may check the latest AQI figures to decide whether outdoor sporting events should be conducted on a certain day [4].

The concept of AQI that transforms weighted values of individual air pollution related parameters (e.g. SO_2, CO, visibility, etc.) into a single number or set of numbers is widely used for air quality communication and decision making in many countries [2]. Air Quality Index converts complex air quality data of various pollutants into a single number (index value), nomenclature and colour. AQI is represented as numeric value varies from 0 to 500. If score is 0, it is the best air quality and if score is 500, it is the worst air quality (Higher AQI higher pollution). There are six AQI categories, namely Good, Satisfactory, Moderate, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts (known as health breakpoints). Air Quality sub-index and health break points are evolved for eight pollutants (PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3, and Pb) for which short-term (up to 24-hours) National Ambient Air Quality Standards are prescribed. Based on the measured ambient concentrations of a pollutant, sub-index is calculated, which is a linear function of concentration (e.g. the sub-index for $PM_{2.5}$ will be 51 at concentration 31 $\mu g/m^3$, 100 at concentration 60 $\mu g/m^3$, and 75 at concentration of 45 $\mu g/m^3$). The worst sub-index determines the overall AQI. AQI categories and health breakpoints for the eight

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pollutants are given in Table 2. Health impacts on each range of AQI are given in Table 3 [2].

Air quality monitoring

In India, CPCB implements the National Ambient Air Quality Monitoring (NAMP) through a Network comprising 544 operating ambient air quality stations covering 224 cities / towns in 26 States and 5 Union territories of the country in compliance with the mandate under the Air (Prevention and Control of Pollution) Act, 1981 to collect compile and disseminate the information on ambient air quality [5]. The air quality monitoring network in India can be classified as (i) online and (ii) manual. The pollutant parameters, frequency of measurement and monitoring methodologies for two networks are very different.

Online monitoring network

These are automated air quality monitoring stations which record continuous hourly, monthly or annually averaged data. In the automatic monitoring stations parameters like PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, etc. are monitored continuously. Data from these stations are available almost in real-time. Thus such networks are most suitable for computation of AQI sub-indices, as information on AQI can be generated in real time. For AQI to be more useful and effective there is a need to set up more online monitoring stations for continuous and easy availability of air quality data for computation of AQI for more Indian cities [6].

Manual

The manual stations involve mostly intermittent air quality data collection, thus such stations are not suitable for AQI calculation particularly for its quick dissemination. In India most of the air quality monitoring stations under NAMP is manually operated stations, and only three criteria pollutants viz. PM_{10}, sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) are measured, at some stations $PM_{2.5}$ and Pb are also measured. The monitoring frequency is twice a week. Such manual networks are not suitable for computing AQI, as availability of monitored data could have a lag of 1-3 days and sometimes not available at all. However, some efforts are required to use the information in some productive manner. Historical AQIs on weekly basis can be calculated and used for data interpretation and ranking of cities or towns for further prioritization of actions on air pollution control [2].

Calculation of AQI

The CPCB has given guidelines on calculating AQI as follows [2]:

1. The Sub-indices for individual pollutants at a monitoring location are calculated using its 24-hourly average concentration value (8-hourly in case of CO and O_3) and health breakpoint concentration range. The worst sub-index is the AQI for that location.
2. All the eight pollutants may not be monitored at all the locations. Overall AQI is calculated only if data are available for minimum three pollutants out of which one should necessarily be either $PM_{2.5}$ or PM_{10}. Else, data are considered insufficient for calculating AQI. Similarly, a minimum of 16 hours' data is considered necessary for calculating sub-index.
3. The sub-indices for monitored pollutants are calculated and disseminated, even if data are inadequate for determining AQI. The Individual pollutant-wise sub-index will provide air quality status for that pollutant.
4. The web-based system is designed to provide AQI on real time basis. It is an automated system that captures data from continuous monitoring stations without human intervention, and displays AQI based on running average values (e.g. AQI at 6 A.M on a day will incorporate data from 6 A.M on previous day to the current day).
5. For manual monitoring stations, an AQI calculator is developed wherein data can be fed manually to get AQI value.

AQI Calculation

$$I_P = \left[\left\{\frac{(I_{HI} - I_{LO})}{(B_{HI} - B_{LO})}\right\} \times (C_P - B_{LO})\right] + I_{LO}$$

Where

I_p = Sub Index for a given pollutant concentration

B_{HI} = Break point concentration greater or equal to given concentration (C_p)

B_{LO}= Break point concentration smaller or equal to given concentration (C_p)

I_{HI} = AQI value corresponding to B_{HI}

I_{LO} = AQI value corresponding to B_{LO}; subtract one from I_{LO}, if I_{LO} is greater than 50

C_P = Pollutant concentration

AQI = Max (I_p) (where p = 1, 2…n; whereas 'n' denotes no. of pollutants)

Material and Methods

Ambient air quality monitoring in Tamil Nadu under NAMP

Tamil Nadu is the eleventh-largest state in India by area and the sixth-most populous. Under NAMP, Ambient Air Quality is being monitored by CPCB in association with Tamil Nadu Pollution Control Board (TNPCB) in 28 locations covering cities, major towns and major industrial areas viz. Chennai, Salem, Coimbatore, Madurai, Trichy, Cuddalore, Mettur, Thoothukudi. All these stations are manual operated stations. The ambient air samples are collected through high volume samplers by running 24 hours and twice a week. Thus in each stations, not less than 108 samplings are done in a year. PM_{10}, SO_2 and NO_2 are monitored. Out of these 28 stations, 10 stations were selected to calculate historical AQI so as to know the air quality of the cities and towns [5]. The location of the stations is given in Table 4.

Chennai is the capital of the state. The population is 46,46,732 (2011 Census). Chennai is located in 13.08389°N and 80.27000°E. The area of Greater Chennai Corporation is 426 km^2. Chennai elevation is 6 m above mean sea level. Chennai is tropical wet and dry climate city. The weather is hot and humid for most of the year. The city gets most of

Pollutant	SO_2	NO_2	$PM_{2.5}$	PM_{10}	O_3		CO (mg/m^3)		Pb	NH_3
Averaging time (hr)	24	24	24	24	1	8	1	8	24	24
Standard	80	80	60	100	180	100	4	2	1	400
Note: All units are in µg/m3 unless mentioned otherwise. Source: CPCB.										

Table 1: Indian national ambient air quality standards.

AQI Category	PM_{10}	$PM_{2.5}$	NO_2	O_3	CO	SO_2	NH_3	Pb
(Range)	24-hr	24-hr	24-hr	8-hr	8-hr (mg/ m3)	24-hr	24-hr	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	0.6 –1.0
Moderate (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	10.1-17	381-800	801-1200	2.1-3.0
Very poor (301-400)	351-430	121-250	281-400	209-748*	17.1-34	801-1600	1201-1800	3.1-3.5
Severe (401-500)	430 +	250+	400+	748+*	34+	1600+	1800+	3.5+
One hourly monitoring (for mathematical calculation only)								

Table 2: Breakpoints for AQI scale 0-500 (Units: µg/m³ unless mentioned otherwise).

AQI	Associated Health Impacts
Good (0–50)	Minimal Impact
Satisfactory (51–100)	May cause minor breathing discomfort to sensitive people
Moderate (101–200)	May cause breathing discomfort to the 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 with short exposure
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 effects even on healthy people and serious health impacts on people with lung/heart diseases. The health impacts may be experienced even during light physical activity

Table 3: Health statements for AQI categories.

S. No.	Sampling station location	Land use pattern
1	Chennai - Adyar	Residential area
2	Chennai- T.Nagar	Commercial area
3	Chennai- Manali	Industrial area
4	Coimbatore – Near Railway Junction	Mixed zone
5	Salem - Kondalampatti	Mixed zone
6	Mettur – SIDCO (Salem District)	Industrial area
7	Madurai – Corporation South Zone Office	Mixed zone
8	Trichy – Main Guard Gate	Traffic zone
9	Cuddalore – SIPCOT Kudikadu	Industrial area
10	Thoothukudi - SIPCOT	Industrial area

Table 4: Sampling station location and the land use pattern.

its seasonal rainfall from the north-east monsoon winds, from mid-October to mid-December. Cyclones in the Bay of Bengal sometimes hit the city. Temperature varies from 24.3°C (min) to 32.9°C (max). Annual rainfall in the region is in the range from 1286 to 1233 mm. The city is situated on the eastern coastal plains. Drained by Cooum river through the centre, Adyar river to the south and Kortalaiyar on the northern fringes. Soil is mostly clay, shale and sandstone [5]. Coimbatore, Salem, Madurai, Trichy, Thoothukudi, Cuddalore are the district headquarters with industrial areas. Mettur in Salem district is an industrial area with thermal power plants and chemical industries [7-9].

The AAQ data from January 2015 to December 2015 for the above 10 stations is collected and AQI is calculated for four months covering four seasons (i.e.,) January (winter), May (summer), July (monsoon), November (post-monsoon). Each month, there are eight set of monitoring data. In some of the months, the no. of data was less due to force of majeure like power failure, rainfall etc.

AQI - Sample calculation

The AAQ survey conducted on 5th January 2015 in Adyar-residential area shows PM_{10} = 44 µg/m³, SO_2 = 14.4 µg/m³, NO_2 = 19.4 µg/m³. The PM_{10} falls in the breakpoint range of 0-50 µg/m³ and the corresponding AQI range is 0-50, SO_2 falls in the breakpoint range of 0-40 µg/m³ and the corresponding AQI range is 0-50, and NO_2 falls in the breakpoint range of 0-40 µg/m³ and the corresponding AQI range is 0-50.

Sub-index calculation

Sub Index for PM_{10} (I_p)

C_P = 44 µg/m³, B_{Lo}= 0 µg/m³, B_{Hi}=50 µg/m³, I_{Lo}=0, I_{Hi} = 50

$$I_P = \left[\left\{\frac{(50-0)}{(50-0)}\right\}\times(44-0)\right]+0$$

$I_P = 44$

Sub Index for SO_2 (I_P)

$C_P = 14.4\ \mu g/m^3$, $B_{Lo} = 0\ \mu g/m^3$, $B_{Hi} = 40\ \mu g/m^3$, $I_{Lo} = 0$, $I_{Hi} = 50$

$$I_P = \left[\left\{\frac{(50-0)}{(40-0)}\right\}\times(14.4-0)\right]+0$$

$I_P = 18$

Sub Index for NO_2 (I_P)

$C_P = 19.4\ \mu g/m^3$, $B_{Lo} = 0\ \mu g/m^3$, $B_{Hi} = 40\ \mu g/m^3$, $I_{Lo} = 0$, $I_{Hi} = 50$

$$I_P = \left[\left\{\frac{(50-0)}{(40-0)}\right\}\times(19.4-0)\right]+0$$

$I_P = 24.25$

AQI = Max (44, 18, 24.25) = 44

Result and Discussion

The ambient air quality level and the calculated AQI for the ten stations are given in the Tables 5 to 14. Almost all the stations' AQIs fall under good and satisfactory category except Trichy where the majority

S. No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	5-Jan-15	44	14.4	19.4	44	18	24	44
2		19-Jan-15	64	13.4	18.4	64	17	23	64
3		21-Jan-15	57	12.4	19.8	57	16	25	57
4		23-Jan-15	46	14.1	20.6	46	18	26	46
5		28-Jan-15	55	13.3	17.8	55	17	22	55
6		30-Jan-15	42	12.4	19.2	42	16	24	42
7	Summer	5-May-15	35	14.1	18.3	35	18	23	35
8		7-May-15	49	15.2	17.3	49	19	22	49
9		12-May-15	44	13.4	16.2	44	17	20	44
10		14-May-15	47	16.2	19.4	47	20	24	47
11		29-May-15	41	15.1	19.1	41	19	24	41
12	Monsoon	3-Jul-15	46	13.3	16.9	46	17	21	46
13		7-Jul-15	66	14.1	17.8	66	18	22	66
14		10-Jul-15	40	14.9	17.1	40	19	21	40
15		14-Jul-15	64	13.4	16.2	64	17	20	64
16		17-Jul-15	55	12.9	16.6	55	16	21	55
17		21-Jul-15	39	11.8	16.5	39	15	21	39
18		24-Jul-15	39	12.4	15.5	39	16	19	39
19		28-Jul-15	16	12.6	19.5	16	16	24	24
20	Post-monsoon	3-Nov-15	37	9.7	13.3	37	12	17	37
21		3-Nov-15	25	10.3	12	25	13	15	25
22		11-Nov-15	32	11.7	14.8	32	15	19	32
23		20-Nov-15	29	9	14	29	11	18	29
24		26-Nov-15	38	14.4	15.6	38	18	20	38
25		30-Nov-15	32	12	15.1	32	15	19	32

Table 5: Chennai-Adyar residential area - Air quality index.

S. No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	2-Jan-15	86	22.7	28.7	86	28	36	86
2		6-Jan-15	88	27.9	29.5	88	35	37	88
3		20-Jan-15	91	32	28.7	91	40	36	91
4		22-Jan-15	78	26.8	26.8	78	34	34	78
5		27-Jan-15	93	28.2	27.5	93	35	34	93
6		29-Jan-15	95	26.8	26.2	95	34	33	95
7	Summer	6-May-15	66	16.6	21.4	66	21	27	66
8		13-May-15	56	15.6	36.7	56	20	46	56
9		15-May-15	77	18.1	23.9	77	23	30	77
10	Monsoon	1-Jul-15	65	16.4	24.6	65	21	31	65
11		6-Jul-15	125	13.6	20.8	117	17	26	117
12		9-Jul-15	81	17.6	22.5	81	22	28	81
13		13-Jul-15	143	15.7	33.3	129	20	42	129
14		15-Jul-15	89	15.1	31.4	89	19	39	89
15		20-Jul-15	137	13.6	21.6	125	17	27	125
16		22-Jul-15	100	14.7	20.6	100	18	26	100
17		27-Jul-15	38	15.7	21.6	38	20	27	38
18		29-Jul-15	92	16.6	22.8	92	21	29	92

19	Post-monsoon	12-Nov-15	65	12.4	NM	65	16		65
20		19-Nov-15	71	15	NM	71	19		71
21		27-Nov-15	56	13.7	18.3	56	17	23	56

Table 6: Chennai-T. Nagar commercial area - Air quality index.

S. No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	5-Jan-15	33	10.2	15	33	13	19	33
2		12-Jan-15	36	11.4	14.1	36	14	18	36
3		19-Jan-15	44	12.6	11.9	44	16	15	44
4		22-Jan-15	37	12.7	13.6	37	16	17	37
5		29-Jan-15	40	10	11.4	40	13	14	40
6	Summer	4-May-15	33	15.6	17.6	33	20	22	33
7		7-May-15	26	13.2	19.6	26	17	25	26
8		11-May-15	35	15.3	17.3	35	19	22	35
9		14-May-15	27	11.6	17.7	27	15	22	27
10		18-May-15	32	14.9	15.1	32	19	19	32
11		21-May-15	44	15.2	14.5	44	19	18	44
12		25-May-15	44	12.8	18.4	44	16	23	44
13		28-May-15	42	13.1	13.9	42	16	17	42
14	Monsoon	2-Jul-15	51	12.9	18.6	51	16	23	51
15		6-Jul-15	17	14.1	20.5	17	18	26	26
16		9-Jul-15	48	12.5	19.3	48	16	24	48
17		13-Jul-15	32	13.1	20.5	32	16	26	32
18		16-Jul-15	31	15.6	16.8	31	20	21	31
19		20-Jul-15	31	15.3	16.7	31	19	21	31
20		23-Jul-15	26	10.9	20.1	26	14	25	26
21		27-Jul-15	46	13.6	16.6	46	17	21	46
22	Post-monsoon	2-Nov-15	59	12.3	17.7	59	15	22	59
23		5-Nov-15	44	13.3	17.2	44	17	22	44
24		9-Nov-15	23	15.7	15.1	23	20	19	23
25		12-Nov-15	49	19.1	19.3	49	24	24	49
26		16-Nov-15		16.4	19.3		21	24	24
27		19-Nov-15	48	14.4	19	48	18	24	48
28		23-Nov-15	47	13.1	19	47	16	24	47
29		26-Nov-15	45	12.6	19.3	45	16	24	45
30		30-Nov-15	34	14.3	21	34	18	26	34

Table 7: Chennai-Manali industrial area - Air quality index.

S. No.	Season	Sampling	24 Hours average in µg/m³			Sub- Index			AQI
		date	PM_{10}	SO_2	NO_2	PM	SO_2	NO_2	
1	Winter	5-Jan-15	50	4.8	23.6	50	6	30	50
2		8-Jan-15	60	4	33.2	60	5	42	60
3		12-Jan-15	54	4.9	28.5	54	6	36	54
4		19-Jan-15	61	4	23.9	61	5	30	61
5		22-Jan-15	64	4	26.3	64	5	33	64
6		29-Jan-15	51	4	24.1	51	5	30	51

7	Summer	4-May-15	37	4	25	37	5	31	37
8		7-May-15	36	4	24.5	36	5	31	36
9		11-May-15	45	4	25	45	5	31	45
10		21-May-15	39	4	27.1	39	5	34	39
11		25-May-15	34	4.9	26.1	34	6	33	34
12		28-May-15	29	4	30.6	29	5	38	38
13	Monsoon	13-Jul-15	39	<4	21.3	39	5	27	39
14		16-Jul-15	70	4.2	25.7	70	5	32	70
15		20-Jul-15	42	<4	22.4	42	5	28	42
16		23-Jul-15	31	<4	26.7	31	5	33	33
17		27-Jul-15	39	<4	24.2	39	5	30	39
18	Post-monsoon	2-Nov-15	25	<4.0	26.8	25	5	34	34
19		5-Nov-15	21	<4.0	30.2	21	5	38	38
20		9-Nov-15	57	<4.0	25	57	5	31	57
21		12-Nov-15	47	<4.0	31.9	47	5	40	47
22		16-Nov-15	32	<4.0	31.9	32	5	40	40
23		19-Nov-15	30	<4.0	31.4	30	5	39	39
24		23-Nov-15	25	<4.0	22.8	25	5	29	29
25		26-Nov-15	66	4.5	23.8	66	6	30	66
26		30-Nov-15	59	<4.0	23.2	59	5	29	59

Table 8: Coimbatore-Near railway junction - mixed zone - Air quality index.

S.No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	2-Jan-15	41	13.8	20.8	41	17	26	41
2		6-Jan-15	99	10.4	23.3	99	13	29	99
3		9-Jan-15	74	11.7	22.4	74	15	28	74
4		13-Jan-15	48	15.9	24.6	48	20	31	48
5		20-Jan-15	105	16.5	26.9	104	21	34	104
6		23-Jan-15	65	16.8	23.4	65	21	29	65
7		27-Jan-15	54	16.8	27.6	54	21	35	54
8		30-Jan-15	60	14.5	24.9	60	18	31	60
9	Summer	5-May-15	55	12	27	55	15	34	55
10		8-May-15	71	14	33	71	18	41	71
11		12-May-15	56	9	48	56	11	60	60
12		15-May-15	63	13	30	63	16	38	63
13		22-May-15	96	11	34	96	14	43	96
14		29-May-15	76	12	28	76	15	35	76
15	Monsoon	3-Jul-15	63	11	25	63	14	31	63
16		10-Jul-15	61	11	20	61	14	25	61
17		14-Jul-15	90	14	29	90	18	36	90
18		17-Jul-15	57	12	23	57	15	29	57
19		21-Jul-15	61	15	25	61	19	31	61
20		24-Jul-15	59	13	22	59	16	28	59
21		28-Jul-15	101	16	28	101	20	35	101
22		31-Jul-15	68	11	21	68	14	26	68
23		3-Jul-15	58	14	20	58	18	25	58
24	Post-monsoon	13-Nov-15	78	17	24	78	21	30	78
25		17-Nov-15	45	14	26	45	18	33	45
26		20-Nov-15	101	17	28	101	21	35	101
27		24-Nov-15	55	16	18	55	20	23	55
28		27-Nov-15	88	19	24	88	24	30	88

Table 9: Madurai-Corporation south zone office - mixed zone - Air quality index.

S.No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	2-Jan-15	46.9	7.4	27.1	47	9	34	47
2		5-Jan-15	49.3	8	25.7	49	10	32	49
3		7-Jan-15	47.2	7.7	23.7	47	10	30	47
4		9-Jan-15	56.8	7.6	22.8	57	10	29	57
5		12-Jan-15	64.9	7.5	25.4	65	9	32	65
6		14-Jan-15	66.1	7.8	22.9	66	10	29	66
7		19-Jan-15	61.7	6.9	23.5	62	9	29	62
8		21-Jan-15	50.2	10	29.1	50	13	36	50
9		24-Jan-15	55.5	10.4	26.5	56	13	33	56
10		28-Jan-15	50.4	7	25.3	50	9	32	50
11		30-Jan-15	46.1	7.9	26	46	10	33	46
12	Summer	6-May-15	58.6	7.7	30.5	59	10	38	59
13		8-May-15	61	8.9	28.7	61	11	36	61
14		11-May-15	63	7.8	29.5	63	10	37	63
15		13-May-15	55.3	8	31.1	55	10	39	55
16		15-May-15	48.7	8.2	26.8	49	10	34	49
17		18-May-15	55.5	8.5	27	56	11	34	56
18		20-May-15	59.9	7.3	24.9	60	9	31	60
19		22-May-15	59	9.2	31	59	12	39	59
20		27-May-15	42.4	8.6	25.7	42	11	32	42
21	Monsoon	14-Jul-15	45.4	7.3	25.6	45	9	32	45
22		16-Jul-15	52.9	7.7	26.2	53	10	33	53
23		20-Jul-15	53.1	7.9	29.7	53	10	37	53
24		22-Jul-15	50.5	7.9	24.2	51	10	30	51
25		24-Jul-15	51.3	8.5	23.7	51	11	30	51
26		27-Jul-15	49.7	10.5	26.8	50	13	34	50
27		29-Jul-15	43.1	7.7	27.9	43	10	35	43
28	Post-monsoon	2-Nov-15	57	7.9	20	57	10	25	57
29		5-Nov-15	47	7.4	28	47	9	35	47
30		10-Nov-15	122	8.6	32	115	11	40	115
31		12-Nov-15	49	8.2	23.3	49	10	29	49
32		16-Nov-15	44	7.6	34.2	44	10	43	44
33		18-Nov-15	44	7.9	29.1	44	10	36	44
34		20-Nov-15	43	8	27.8	43	10	35	43
35		23-Nov-15	44	8.1	28.3	44	10	35	44
36		25-Nov-15	58	7.7	25.4	58	10	32	58
37		27-Nov-15	45	7.3	22.5	45	9	28	45
38		30-Nov-15	48	7.4	28.4	48	9	36	48

Table 10: Salem-Sowdeswari College - Mixed zone – Air quality index.

S.No.	Season	Sampling date	24 Hours average in µg/m³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	5-Jan-15	103	13	15.2	102	16	19	102
2		12-Jan-15	111	15.4	18	108	19	23	108
3		19-Jan-15	86	13.3	17.1	86	17	21	86
4		4-May-15	114	20.2	23	110	25	29	110
5	Summer	11-May-15	90	18.1	20.5	90	23	26	90
6		18-May-15	105	18	21	104	23	26	104
7		25-May-15	113	16	19.4	109	20	24	109
8	Monsoon	14-Jul-15	140	13.9	22	127	17	28	127
9		21-Jul-15	131	14	23	121	18	29	121
10		28-Jul-15	142	14.7	23.5	128	18	29	128
11	Post Monsoon	2-Nov-15	121	11.4	20.8	114	14	26	114
12		16-Nov-15	127	12.6	23.7	118	16	30	118
13		23-Nov-15	95	9.8	18	95	12	23	95
14		30-Nov-15	119	10.19	21	113	13	26	113

Table 11: Trichy-Mainguard gate - traffic area - Air quality index.

S. No.	Season	Sampling date	24 Hours average in µg/m³			Sub-Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	8-Jan-15	41	7	18.5	41	9	23	41
2		12-Jan-15	42	7.4	21	42	9	26	42
3		19-Jan-15	53	6.8	18.5	53	9	23	53
4		22-Jan-15	40	6	15.4	40	8	19	40
5		27-Jan-15	47	8.9	21.8	47	11	27	47
6		30-Jan-15	44	7.5	19.1	44	9	24	44
7	Summer	4-May-15	29	8.1	20.9	29	10	26	29
8		7-May-15	33	9.5	21.1	33	12	26	33
9		11-May-15	41	9.2	22.5	41	12	28	41
10		14-May-15	38	9.6	20	38	12	25	38
11		18-May-15	39	9.6	21	39	12	26	39
12		21-May-15	35	9	22.1	35	11	28	35
13		25-May-15	38	9.3	21.6	38	12	27	38
14		28-May-15	35	8.5	21.6	35	11	27	35
15	Monsoon	16-Jul-15	30	8.3	21	30	10	26	30
16		21-Jul-15	31	9.6	21.2	31	12	27	31
17		24-Jul-15	41	9.3	22.4	41	12	28	41
18		28-Jul-15	39	9.2	20.2	39	12	25	39
19	Post-monsoon	4-Nov-15	41	9.9	14.9	41	12	19	41
20		7-Nov-15	41	8.2	13.1	41	10	16	41
21		11-Nov-15	39	8.2	13.5	39	10	17	39
22		14-Nov-15	41	6.1	12.7	41	8	16	41
23		18-Nov-15	43	7.5	18.9	43	9	24	43
24		21-Nov-15	36	10.5	17.1	36	13	21	36
25		25-Nov-15	40	8.1	17.2	40	10	22	40
26		28-Nov-15	41	8.2	13.8	41	10	17	41

Table 12: Cuddalore SIPCOT office-industrial area - Air Quality Index.

S. No.	Season	Sampling date	24 Hours average in µg/Nm³			Sub- Index			AQI
			PM_{10}	SO_2	NO_2	PM_{10}	SO_2	NO_2	
1	Winter	5-Jan-15	25	10.1	11.4	25	13	14	25
2		8-Jan-15	44	14.2	14.1	44	18	18	44
3		12-Jan-15	85	14.9	15.2	85	19	19	85
4		19-Jan-15	56	14.7	15.9	56	18	20	56
5		22-Jan-15	87	15.3	15.3	87	19	19	87
6		29-Jan-15	48	14.9	16.3	48	19	20	48
7	Summer	4-May-15	95	15.5	20.28	95	19	25	95
8		7-May-15	124	14.92	21	116	19	26	116
9		11-May-15	69	15.39	22.28	69	19	28	69
10		14-May-15	75	14.91	22.86	75	19	29	75
11		18-May-15	157	16.2	21.54	138	20	27	138
12		21-May-15	117	15.39	22.8	112	19	29	112
13		25-May-15	100	15.51	22.56	100	19	28	100
14		28-May-15	79	9.64	13.51	79	12	17	79
15	Monsoon	2-Jul-15	93	15.9	21.49	93	20	27	93
16		6-Jul-15	91	14.96	22.37	91	19	28	91
17		9-Jul-15	81	15.33	24.39	81	19	30	81
18		13-Jul-15	123	16.02	20.69	116	20	26	116
19		16-Jul-15	189	8.23	11.01	159	10	14	159
20		20-Jul-15	201	9.76	16.65	167	12	21	167
21		23-Jul-15	92	10.59	15.45	92	13	19	92
22		27-Jul-15	118	15.99	22.23	112	20	28	112
23	Post-monsoon	2-Nov-15	131	13.05	14.48	121	16	18	121
24		5-Nov-15	109	16.42	21.99	106	21	27	106
25		9-Nov-15	38	5.14	7.05	38	6	9	38
26		12-Nov-15	98	10.15	15.59	98	13	19	98
27		16-Nov-15	99	9.99	13.33	99	12	17	99
28		19-Nov-15	89	15.63	18.96	89	20	24	89
29		23-Nov-15	NM	NM	NM				
30		26-Nov-15	65	15.92	24.71	65	20	31	65
31		30-Nov-15	54	14.38	22.16	54	18	28	54

Table 13: Thoothukudi SIPCOT-industrial area –Air quality index.

S. No.	Season		24 Hours average in µg/Nm³			Sub- Index			AQI
			PM10	SO2	NO2	PM10	SO2	NO2	
1	Winter	2-Jan-15	48	8.7	31.9	48	11	40	48
2		6-Jan-15	58	9.6	33.6	58	12	42	58
3		9-Jan-15	61	8.8	34.1	61	11	43	61
4		13-Jan-15	84	8.9	28.4	84	11	36	84
5		20-Jan-15	63	8.3	27.7	63	10	35	63
6		23-Jan-15	30	8.5	24.9	30	11	31	31
7		27-Jan-15	39	8.7	27.7	39	11	35	39
8		29-Jan-15	68	9.2	27	68	12	34	68
9		31-Jan-15	51	8.5	29.6	51	11	37	51
10	Summer	5-May-15	73	9.6	23.3	73	12	29	73
11		8-May-15	52	7.3	19	52	9	24	52
12		12-May-15	41	8.8	22.3	41	11	28	41
13		15-May-15	43	7.9	20	43	10	25	43
14		19-May-15	46	9.6	25.4	46	12	32	46
15		22-May-15	50	9.3	25.04	50	12	31	50
16		26-May-15	61	8.4	25.3	61	11	32	61
17		28-May-15	67	9.5	26	67	12	33	67
18		30-May-15	49	9.1	25.3	49	11	32	49
19	Monsoon	3-Jul-15	31	8.7	25.9	31	11	32	32
20		7-Jul-15	79	8.7	26.4	79	11	33	79
21		10-Jul-15	60	7.7	25	60	10	31	60
22		14-Jul-15	58	8.9	27.7	58	11	35	58
23		17-Jul-15	36	8.8	25.6	36	11	32	36
24		21-Jul-15	52	9.2	26	52	12	33	52
25		24-Jul-15	45	8.5	23	45	11	29	45
26		28-Jul-15	44	7.5	26.3	44	9	33	44
27	Post-monsoon	3-Nov-15	45	8.4	24	45	11	30	45
28		6-Nov-15	52	7.3	21.4	52	9	27	52
29		13-Nov-15	34	6.4	12.5	34	8	16	34
30		17-Nov-15	19	6	20.4	19	8	26	26
31		19-Nov-15	21	7.3	22.5	21	9	28	28
32		21-Nov-15	28	6.8	21.1	28	9	26	28
33		24-Nov-15	28	6.9	24	28	9	30	30
34		26-Nov-15	56	9.5	28.4	56	12	36	56
35		28-Nov-15	68	9.2	35	68	12	44	68

Table 14: Mettur-SIDCO industrial area - Air quality index.

of the days the AQI fall under moderate category. From the AQIs of all the 10 stations, it is observed that responsible pollutant is PM_{10}. The other parameter (i.e.,) SO_2 and NO_2 fall under good category for all stations for all days.

Chennai-Adyar AQI varies from 24 to 66. Majority of days, AQI falls in good category and in monsoon period AQI falls in satisfactory category. Vehicular pollution is the main cause for increase in PM_{10} level. Chennai-T.Nagar AQI varies from 38 to 129. Almost all the days of monitoring, the air quality is at satisfactory level. Whereas during monsoon period the ambient air quality was at moderate level. It is a commercial area, vehicular movement is the cause for PM_{10} contribution. Chennai-Manali AQI was in the range of 23-59. All most all the days, the air quality was good and in monsoon and post monsoon period it reached to the satisfactory level.

Coimbatore-Near railway junction AQI was in the range of 29-70. In the winter season, the ambient air quality was in the satisfactory level. In other season, the air quality falls under good category. It is a mixed residential area with heavy traffic flow. Madurai AQI was in the range of 41-104. Most of the days, the air quality was in satisfactory level. The maximum index was recorded in winter season. Salem AQI was in the range of 42 – 115. In most of the days, the index was in good and satisfactory level. The maximum index occurred in post monsoon period. In Trichy-Main Guard gate area, the AQI was in the range of 86-128 and most of days the ambient air quality was in moderate level. This is a traffic junction area, hence high contribution of PM_{10}. In Cuddalore-SIPCOT Industrial complex, the AQI was in the range of 29-53. Almost all the days, the ambient air quality is in good level. This Industrial complex is housing chemical and pharmaceutical units, and this Industrial complex is near to the Bay of Bengal getting sea breeze leading for better dispersion. AQI for Thoothukudi –SIPCOT Industrial complex was in the range of 25-167. Most of the days the ambient air quality is in satisfactory or moderate level. The cause of high level of PM_{10} is due to the presence of major power plants, copper smelter plant, fertilizer plant and other units. The AQI of Mettur-SIDCO Industrial Estate was in the range of 26-84 and it falls in good and satisfactory level. The AQI for all the 10 stations are given in pictorial form in Figures 1 to 10.

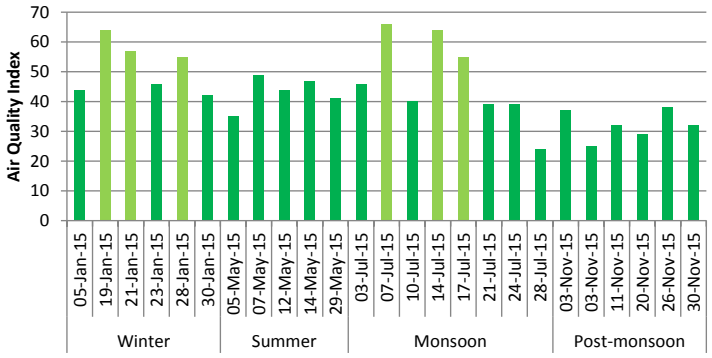

Figure 1: Chennai-Adyar residential area - Air quality index.

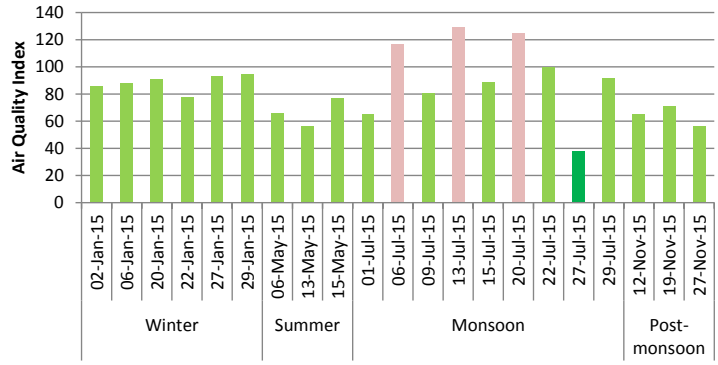

Figure 2: Chennai-T. Nagar commercial zone - Air quality index.

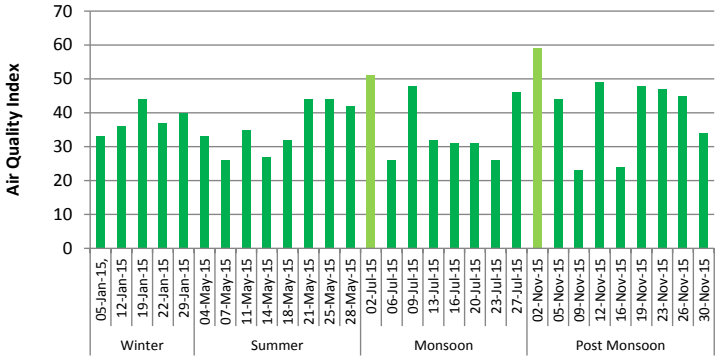

Figure 3: Chennai-Manali industrial area - Air quality index.

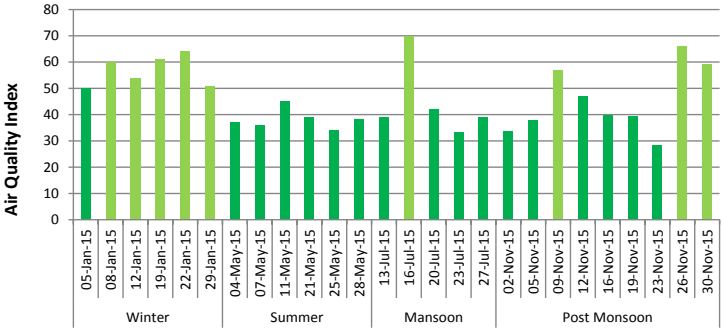

Figure 4: Coimbatore-Mixed zone - Air quality index.

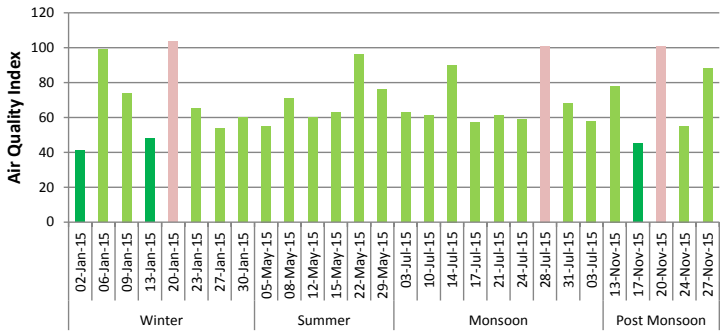

Figure 5: Madurai-Mixed zone – Air quality index.

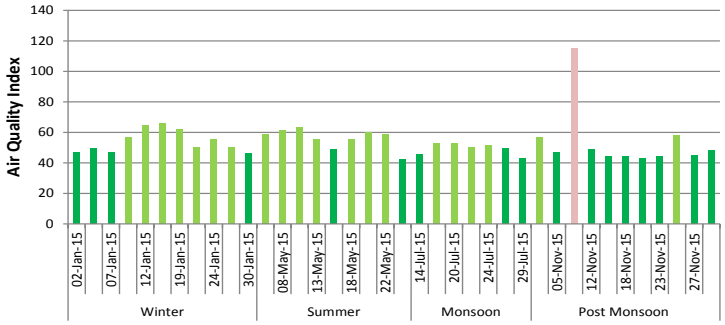

Figure 6: Salem-Sowdeswari College mixed zone - Air quality index.

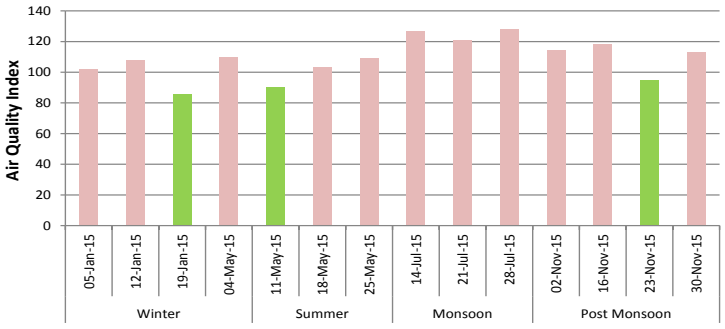

Figure 7: Trichy-Mainguard Gate-Traffic area - Air quality index.

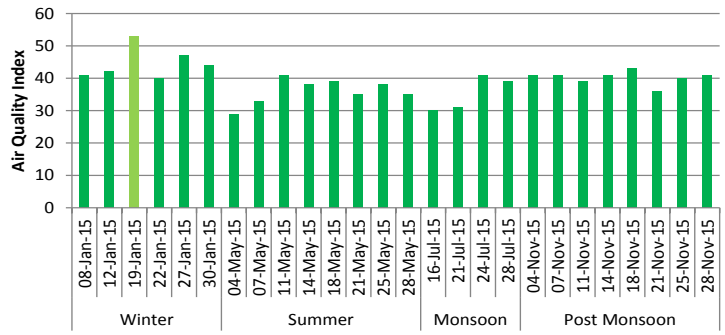

Figure 8: Cuddalore SIPCOT Office industrial area - Air quality index.

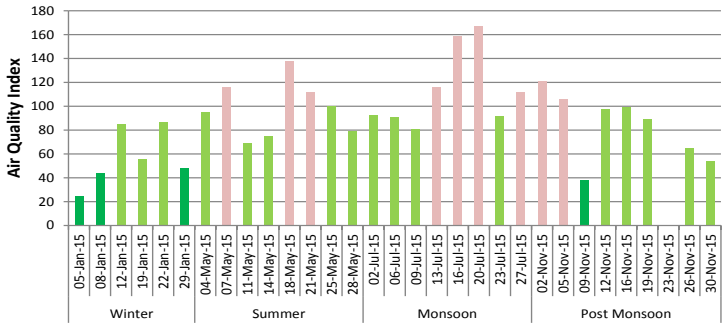

Figure 9: Thoothukudi SIPCOT-Industrial Area - Air quality index.

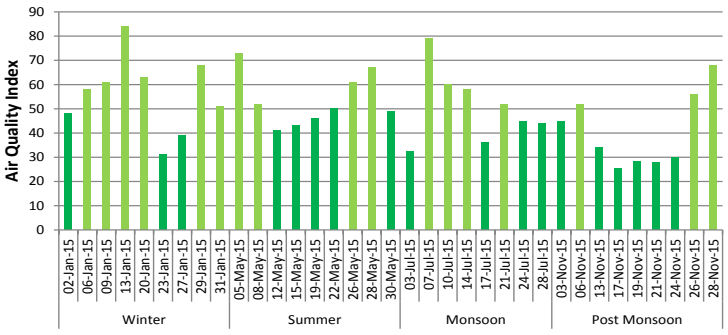

Figure 10: Mettur-SIDCO industrial area - Air quality index.

Conclusion

AQI of cities and towns in Tamil Nadu reveals that PM_{10} is the main contributor for higher value of index. SO_2 and NO_2 are well within the NAAQ standards for 24 hours. The higher value of PM_{10} is mainly due to vehicular pollution. Vehicular emissions are of particular concern because these are ground level sources and thus have the maximum impact on general population. Also, vehicles contribute significantly to the total air pollution load in many urban areas [8-10]. It is to be noted that AQI system is based on maximum operator function by selecting the maximum of sub-indices of various pollutants as overall AQI. Ideally, eight parameters (i.e.,) PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, O_3, NH_3 and Pb having short-term standards should be considered for near real-time dissemination of AQI [2].

The regulating agencies should establish source-receptor relationships in terms of impact of emissions on air quality. Adopting comprehensive policies in an integrated manner and addressing the root causes rather than focusing on issues in isolation and seeking remedies is the key to managing air quality in urban areas [11]. In case AQI category is severe or very poor, necessary steps need to be taken by further regulating the emissions which are causing maximum impact to ambient air quality. Specific actions, such as (i) strict vigilance and no-tolerance to visible polluting vehicles, industries, open burning, construction activities etc.; (ii) regulating traffic; and (iii) identifying sources contributing significantly to rising air quality levels and actions for reducing emissions from such sources are to be taken [12]. In the cities well-constructed clean roads, flyovers, cleaner transport fuel will reduce the ambient air pollution level. AQI is an initiative intended to enhance public awareness and involvement in efforts to improve air quality. People can contribute by maintaining vehicles properly (e.g. get PUC checks, replace car air filter, maintain right tires pressure), following lane discipline & speed limits, avoiding prolong idling and turning off engines at red traffic signals [13-15]. In addition to above, during severe or very poor AQI, people should minimize travel; avoid using private vehicles and instead use public transport, bikes or walk, and carpool; use smaller vehicles [2].

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