CHAPTER-III

AMBIENT AIR QUALITY STUDIES

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3.1 Introduction

Vehicular emission is the major contributor to the rising levels of all major air pollutants. It is an issue of prime concern since these emissions are from ground level sources and thus has the greatest impact on the health of the population exposed to it. The increase in the number of vehicles contributes significantly to the total air pollution load in many urban areas. The number of motor vehicles in India has increased from 0.3 million in 1951 to 40.94 million in 1998. Carbon monoxide (CO) and Hydrocarbons (HC) respectively account for 64% and 23% of the total emission load due to vehicles in all cities in the country considered together (CPCB 1995). Table 3.1 gives the total number of registered Motor Vehicles in India as given by the Transport Research Wing, Ministry of Road Transport and Highways, Government of India, Statistics of India. (1951-2002). The ambient air pollution in terms of Suspended Particulate Matter (SPM) in all metropolitan cities in India exceeds the limit set by the World Health Organization (WHO) (Sharma and Mishra, 1998).

Table 3.1 Number of Registered Motor Vehicles (, 000) in India (1951–2002)

Year	All Vehicles	Two Wheelers	Cars, Jeeps, and Taxis	Buses	Goods Vehicles	Others
1951	306	27	159	34	82	4
1961	665	88	310	57	168	42
1971	1865	576	682	94	343	170
1981	5391	2618	1160	162	554	897
1991	21374	14200	2954	331	1356	2533
1999	44875	31328	5556	540	2554	4897
2000	48857	34118	6143	562	2715	5319
2001	54991	38556	7058	634	2948	5795
2002	58863	41478	7571	669	3045	6100

Ambient air pollution is often caused by different sources, which depend on the character of the city. A representative case of a big city such as Delhi has been studied. Table 3.2 highlights the types of air pollutants from different sectors in Delhi (CPCB, 1995) and reflects the significant share of the transport sector in air pollution in Indian cities.

Table 3.2: Sectoral contribution to emissions in Delhi (tones/day)

Pollutant	Transport	Power	Industries	Domestic	Total
TSP	13 (10%)	50 (37%)	60 (44%)	12 (9%)	138
SO_2	11 (6%)	121(68%)	35 (20%)	12 (6%)	179
NO_X	157 (49%)	143 (44%	20 (6%)	3 (1%)	323
HC	810 (76%)	8 (1%)	128 (12%)	117 (11%)	1063
CO	310 (97%)	2 (<1%)	6 (2%)	2 (<1%)	320

As per the report apart from the concentration of vehicles in urban areas, other reasons for increasing vehicular pollution include the types of engines used, age of vehicles, poor road conditions, outdated automotive technologies, poor fuel quality and traffic congestion resulting from clumsy traffic management systems.

3.1.1 Air Quality Profile

In order to determine the air quality status and trends assess health hazards, disseminate air quality data, and to control and regulate pollution, the CPCB (Central Pollution Control Board, GOI) initiated a nationwide framework of NAAQM (National Ambient Air Quality Monitoring) in 1984 with 28 stations at 7 cities. Presently, the network has 295 monitoring stations in 98 cities and towns throughout the country (CPCB, 2003). The present study represents data generated at three AAQM stations at Kolhapur.

The pollutants being monitored are mainly SPM (suspended particulate matter), SO_2 (sulphur dioxide) and NO_x (oxides of nitrogen). SPM is one of the most critical pollutants in terms of its impact on air quality and is also the most common pollutant across all sectors. The ranges of SPM concentration (annual average) in the major metropolitan cities in India are shown in Table 3.3.

Table 3.3: Range of annual averages of SPM in major Indian cities

Sr. No.	City	Area land use	Range of annual average of SPM ($\mu g/m^3$) 1990-98		Mean of annual averages ($\mu g/m^3$)
			Minimum	Maximum	
1.	Delhi	Residential	300	409	355
		Industrial	314	431	381
2.	Mumbai	Residential	196	327	230
		Industrial	150	276	224
3.	Calcutta	Residential	205	491	327
		Industrial	286	640	434
4.	Chennai	Residential	72	118	99
		Industrial	53	147	123
5.	Bangalore	Residential	60	239	158
		Industrial	99	153	125
6.	A'edabad	Residential	198	316	261
		Industrial	201	306	243
7.	H'derabad	Residential	135	184	158
		Industrial	72	259	153

(CPCB, 2000)

As against to the maximum permissible limits laid down by CPCB for annual average concentration of SPM in ambient air - 70 $\mu g/m^3$ in sensitive areas, 140 $\mu g/m^3$ in residential areas and 360 $\mu g/m^3$ in industrial areas, it is clearly evident that the SPM levels are high in most of the metropolitan cities in India.

The future scenario of air pollution in India has been calculated considering the integrated impact from major contributing sectors, i.e. domestic, transport, manufacturing industries and power. In the absence of a comprehensive emission inventory, projections have been made only for SPM, which is the most common pollutant across all sectors and is critical for air quality in many cities.

3.2 Air Quality Studies

Ambient Air Quality data for the three selected sites was monitored for one-year from September 2006 to August 2007. Observations made during the study period are as follows. Twenty four hour a day data was collected for four parameters, those are considered important indicators of air pollution status. Meteorological data was collected from Metrological centre, Agricultural Department at Vadanage, Kolhapur and parameters like Temperature, Humidity, Wind speed and Wind direction were compiled and annual average values were calculated, those are given in Table 3.4.

Table3.4 Monthly Average Meteorological data for the study period (Sep-06- Aug07)

Months	Temperature °C			Humidity %			Wind Speed km/h			Wind Direction
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Average
Sep-06	33.00	20.00	26.50	91.00	49.00	70.00	26.40	4.70	15.55	WNW
Oct-06	34.00	19.00	26.50	92.00	42.00	67.00	15.12	4.85	9.99	WNW
Nov-06	32.00	13.00	22.50	91.00	42.00	66.50	13.20	4.35	8.78	ENE
Dec-06	31.00	11.00	21.00	95.00	21.00	58.00	11.70	4.10	7.90	ENE
Jan-07	34.50	11.00	22.75	90.00	27.00	58.50	11.26	4.05	7.66	ESE
Feb-07	34.00	10.00	22.00	90.00	18.00	54.00	13.85	4.35	9.10	ESE
Mar-07	39.00	13.00	26.00	84.00	17.00	50.50	15.57	4.24	9.91	WNW
Apr-07	40.00	18.00	29.00	84.00	18.00	51.00	15.95	4.25	10.10	WSW
May-07	38.00	19.00	28.50	91.00	32.00	61.50	15.33	4.96	10.15	WSW
Jun-07	34.50	18.00	26.25	96.00	52.00	74.00	26.40	4.60	15.50	SSW
Jul-07	31.00	18.50	24.75	96.00	71.00	83.50	27.50	4.60	16.05	SSW
Aug-07	31.00	17.50	24.25	96.00	76.00	86.00	26.70	4.10	15.40	WSW
Average	**34.33**	**15.67**	**25.00**	**91.33**	**38.75**	**65.04**	**18.25**	**4.43**	**11.34**	

The meteorological data shows that the local weather of Kolhapur city, being in the vicinity of the Western Ghats is moderate. The average annual temperature was 25 ^{0}C with the monthly maximum and minimum temperature being in the months of April (40 ^{0}C) and February (10 ^{0}C) respectively. The humidity values ranged from a maximum of 96% in the three rainy season months of June, July and August. The lowest humidity of 17% was recorded in March 2007. The annual average humidity was 65.04%. The wind speed was modest and ranged from a maximum of 27.5 km/h to a minimum of 4.05 km/h. the average wind velocity was 11.34 km/h. The wind direction was mostly westerly for the six months, easterly for the four months and southerly for remaining two months.

The Ministry of Environment and Forest, Government of India has taken serious note of the growing air pollution in the country, particularly in the metropolis and rapidly growing cities and CPCB prepared ambient air quality standards for the country which are given in Table 3.5 (CPCB, 2003).

Table 3.5: National Ambient Air Quality Standards, CPCB (2003)

Pollutants	Time-weighted average	Concentration in Ambient Air			Method of Measurement
		Industrial Areas	Residential, Rural & other Areas	Sensitive Areas	
Sulphur Dioxide (SO_2)	Annual Average*	80 µg/m^3	60 µg/m^3	15 µg/m^3	- Improved West and Geake Method
	24 hours**	120 µg/m^3	80 µg/m^3	30 µg/m^3	- Ultraviolet Fluorescence
Oxides of Nitrogen as (NO_2)	Annual Average*	80 µg/m^3	60 µg/m^3	15 µg/m^3	- Jacob & Hochheiser Modified (Na-Arsenite) Method
	24 hours**	120 µg/m^3	80 µg/m^3	30 µg/m^3	- Gas Phase Chemiluminesc--ence
Suspended Particulate Matter (SPM)	Annual Average*	360 µg/m^3	140 µg/m^3	70 µg/m^3	- High Volume Sampling, (Average flow rate not less than 1.1 m3/minute).
	24 hours**	500 µg/m^3	200 µg/m^3	100 µg/m^3	
Respirable Particulate Matter (RPM) (size less than 10 microns)	Annual Average*	120 µg/m^3	60 µg/m^3	50 µg/m^3	- Respirable particulate matter sampler
	24 hours**	150 µg/m^3	100 µg/m^3	75 µg/m^3	
*	Annual Arithmetic mean of minimum 104 measurements in a year taken twice a week 24 hourly at uniform interval.				
**	24 hourly/8 hourly values should be met 98% of the time in a year. However, 2% of the time, it may exceed but not on two consecutive days.				

3.2.1 Site 1 (Shivaji University)

Out of the three study stations this was the least crowed location, with no commercial or industrial area around and with very less vehicular traffic. Annual average value for SO_2 was 5.0µg/m^3 and annual Maximum and Minimum values for SO_2 were 8.2 and 3.0µg/m^3 respectively. Maximum and Minimum values for SO_2 were in the month of April 2007 and August 2007 respectively. Minimum value in August indicates effect of rainy season (Table 3.6 and Figure 3.1).

Table 3.6 Monthly average, maximum and minimum values of the four parameters at Site 1 (Shivaji University Campus) from September 2006 to August 2007.

	SO_2			NO_x			RSPM			SPM		
Month	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**	**Minimum**
Sep-06	5.17	5.82	4.58	9.64	11.61	7.98	34.93	44.43	27.08	88.05	103.46	72.91
Oct-06	4.98	6.28	4.30	10.05	11.77	9.05	38.07	47.91	31.94	102.29	145.81	75.68
Nov-06	4.67	5.11	4.21	9.83	13.40	6.84	39.45	48.14	34.02	104.38	141.46	86.09
Dec-06	4.88	5.46	4.22	8.93	10.91	7.95	46.03	53.93	36.11	114.05	136.56	87.49
Jan-07	5.27	5.83	4.54	8.89	9.70	7.80	46.74	57.63	34.02	120.68	148.55	93.04
Feb-07	5.42	6.23	4.72	8.23	9.13	6.76	55.52	99.99	44.44	112.84	126.37	75.69
Mar-07	5.47	6.55	3.57	8.42	10.44	6.12	39.78	50.61	25.69	105.79	125.68	72.90
Apr-07	6.60	8.23	5.70	9.19	9.83	8.67	48.86	59.02	41.89	124.63	163.46	109.29
May-07	5.91	7.22	5.25	8.48	10.16	6.41	45.92	54.16	38.54	109.55	121.93	94.39
Jun-07	5.06	6.38	3.50	7.23	8.62	5.46	46.77	66.66	35.41	101.22	137.48	68.73
Jul-07	3.45	4.25	2.95	5.56	6.69	4.75	30.62	38.88	22.91	66.01	86.79	45.82
Aug-07	3.46	3.72	3.11	5.04	5.55	4.55	35.43	43.51	26.38	76.51	93.04	55.64
Average	**5.0**	**5.9**	**4.2**	**8.3**	**9.8**	**6.9**	**42.3**	**55.4**	**33.2**	**102.2**	**127.5**	**78.1**
Maximum	**6.6**	**8.2**	**5.7**	**10.0**	**13.4**	**9.1**	**55.5**	**100.0**	**44.4**	**124.6**	**163.5**	**109.3**
Minimum	**3.4**	**3.7**	**3.0**	**5.0**	**5.6**	**4.6**	**30.6**	**38.9**	**22.9**	**66.0**	**86.8**	**45.8**

For NO_x annual average value was 8.3μg/m^3 and annual Maximum and Minimum values were 13.40 and 4.55μg/m^3 respectively. Maximum and Minimum values for NO_x were recorded in the month of November 2006 and August 2007 respectively. Here again minimum value of NO_x was in August and indicated effect of rainy season (Table 3.6 and Figure 3.4).

Annual average value for RSPM was 42.3μg/m^3 and annual maximum and minimum values were 99.99 and 22.91μg/m^3 in the month of February 2007 and July 2007 respectively. Minimum value of RSPM in July 2007 indicated effect of rainy season as expected. Annual average value for SPM was 102.2μg/m^3 and annual maximum and minimum values recorded were 163.46 and 45.82μg/m^3 in the months of April 2007 and July 2007 respectively. Here again minimum value of SPM in July 2007 was indicated effect of rainy season on the pollutant (Table 3.6 and Figure 3.7).

One-year data from September 2006 to August 2007 showed that all the four parameters SO_2, NO_x, RSPM, SPM were within the prescribed limits of CPCB (Table 3.5) range as at no time any of the parameters crossed the standard limit. From table 3.6 it is clear that all the four parameters reflected minimum values in the months of July and August due to heavy rains.

3.2.2 Site 2 (Dabholkar Corner)

Out of the three sites, this was the most crowed location due to the busy main traffic square in the developed commercial area including hotels, Central Bus Stand (CBS), and Private travels booking offices etc. The area is active almost throughout the day with heavy vehicular traffic. Annual average value for SO_2 was 10.14μg/m^3 and annual Maximum and Minimum values recorded were 17.03 and 5.14μg/m^3 in the month of

January and July 2007 respectively. Minimum values for the parameter were observed in July indicates effect of rainy season (Table 3.7 and Figure 3.2).

For NO_x annual average values were 35.8μg/m^3 and annual Maximum and Minimum values recorded were 57.68 and 12.78μg/m^3 in the month of April and August 2007 respectively. The minimum value of NO_x in August is indicating effect of rainy season on the parameter (Table 3.7 and Figure 3.5).

Annual average value for RSPM was 91.02μg/m^3 and annual maximum and minimum values for RSPM were 149.30 and 36.80μg/m^3 in the month of October 2006 and November 2006 respectively (Table 3.7 and Figure 3.8). Annual average value for SPM was high i.e. 315.64μg/m^3 and annual maximum and minimum values for SPM were 537.72 and 97.21μg/m^3 in the month of May 2007 and August 2007 respectively (Table 3.7 and Figure 3.11). These values were the highest among the three sites; the minimum value of SPM in August 2007 is indicating effect of rainy season.

The one year data from September 2006 to August 2007 showed that out of the four parameters SO_2, NO_x were below standard limit value throughout the year, while values of RSPM crossed the limit many times in the study year. At the same time SPM values were also beyond the standard limit range throughout the year except in the month of July and August 2007, which was perhaps due to rainy season.

Annual average value of RSPM crossed annual standard limit value; at the same time annual average value of SPM was also crossing annual standard limit value. As far as air quality of Dabholkar corner was concerned RSPM and SPM were beyond annual standard limit values, which were very serious indication of air quality degradation. Air Quality

Table 3.7 Monthly average, maximum and minimum values for the four parameters at Site 2 (Dabholkar corner) from September 2006 to August 2007.

Months	SO_2			NO_x			RSPM			SPM		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Sep-06	9.17	10.97	7.49	32.96	40.94	24.47	92.24	123.61	65.27	324.70	431.24	221.51
Oct-06	9.76	10.93	8.72	40.69	43.71	37.08	116.21	149.30	95.12	422.09	465.26	370.10
Nov-06	8.55	10.16	5.20	38.33	42.15	26.96	76.33	135.41	36.80	317.47	409.01	169.75
Dec-06	10.26	12.24	9.25	35.41	38.44	33.25	86.40	94.44	72.91	339.87	381.93	288.88
Jan-07	12.51	17.03	10.85	37.77	44.35	34.05	106.19	130.55	86.79	405.65	518.72	309.03
Feb-07	11.12	11.92	9.21	40.78	45.42	31.63	95.22	123.60	78.47	345.53	417.58	206.90
Mar-07	12.29	14.14	10.97	44.71	57.23	36.68	105.42	129.62	84.71	415.96	537.72	265.46
Apr-07	12.75	15.14	9.74	45.22	57.68	34.79	104.74	122.21	77.77	362.09	420.82	254.83
May-07	12.09	13.48	9.57	43.90	46.96	41.58	97.21	109.44	77.48	314.37	353.42	232.36
Jun-07	11.72	11.72	9.29	38.24	38.24	28.37	95.18	95.18	72.88	282.98	282.98	211.79
Jul-07	5.97	5.97	5.14	16.98	16.98	15.84	61.05	61.05	54.62	135.86	135.86	117.34
Aug-07	5.45	5.99	5.16	14.08	15.58	12.78	56.05	63.88	45.82	121.15	138.87	97.21
Average	**10.1**	**11.60**	**8.40**	**35.8**	**40.60**	**29.80**	**91.0**	**111.50**	**70.70**	**315.6**	**374.50**	**228.80**
Maximum	**12.7**	**17.00**	**11.00**	**45.2**	**57.70**	**41.60**	**116.2**	**149.30**	**95.10**	**422.1**	**537.70**	**370.10**
Minimum	**5.5**	**6.0**	**5.1**	**14.1**	**15.6**	**12.8**	**56.0**	**61.0**	**36.8**	**121.2**	**135.9**	**97.20**

Index for SPM also indicated poor category (Table 3.12). Also T-Test showed significant results indicating SPM parameter was polluting at Dabholkar corner (Table 3.15). From table 3.7 it is clear that most of the parameters showed minimum values in July and August i.e. due to heavy precipitation during this time of the year.

3.2.3 Site 3 (Mahadwar Road)

This was the most crowed location due to its proximity to the entrance of famous Mahalaxmi Temple and its location in the well developed commercial area in the old city. Though pedestrians always very densely crowded the area, it had modest vehicular traffic. Annual average value for SO_2 was 7.2μg/m^3 and annual Maximum and Minimum values were 13.1 and 3.0μg/m^3 in the month of April and September 2007 respectively (Table 3.8 and Figure 3.3). The concentration of SO_2 was maximum during the summer season.

Minimum value in September indicates effect of rainy season. For NO_x annual average values was 18.3μg/m^3 and annual Maximum and Minimum values for NO_x were 38.1 and 5.3μg/m^3 in the month of April and August 2007 respectively (Table 3.8 and Figure 3.6). The concentration of NO_x was maximum during the summer season and again minimum value in August is indicated effect of rainy season.

Annual average value for RSPM was 60.5μg/m^3 and annual maximum and minimum values for RSPM were 108.3 and 29.2μg/m^3 in the month of March 2007 and September 2006 respectively (Table 3.8 and Figure 3.9). Annual average value for SPM was 180.7μg/m^3 and annual maximum and minimum values for SPM were 353.10 and 53.50μg/m^3 in the month of March 2007 and September 2006 respectively (Table 3.8 and Figure 3.12). Here again minimum value of SPM in September 2006 was indicating effect of rainy season.

One year data from September 2006 to August 2007 shows that out of the four parameters SO_2, NO_x were below standard limit value through out the year while annual average value of RSPM was crossing annual standard limit value, at the same time SPM also crossed the annual standard limit value. As far as air quality of Mahadwar road was concerned RSPM and SPM were crossing annual standard limit values, which was very serious indication of air quality degradation. From Table 3.8 it is clear that most of the parameters show minimum values in July and August due to heavy rains.

Table 3.9: Annual standards for Residential area (CPCB, 2003) and monthly Average, Maximum and Minimum values recorded for the four Air Pollutants at the three study sites (September 2006- August 2007)

	Site 1				Site 2				Site 3			
	SO_2	NO_X	RSPM	SPM	SO_2	NO_X	RSPM	SPM	SO_2	NO_X	RSPM	SPM
Annual STD	60	60	60	140	60	60	60	140	60	60	60	140
Average	5.0	8.3	42.3	102.2	10.1	35.8	91.0	315.6	7.2	18.3	60.5	180.7
Maximum	8.2	13.4	99.99	163.5	17.0	57.7	149.3	537.7	13.1	38.1	108.3	353.1
Minimum	3.0	4.6	22.91	45.8	5.1	12.8	36.8	97.2	3.0	5.3	29.2	53.5

It is evident from the above Table 3.9 that the average or maximum values of SO_2 and NO_X were never close to the annual standards of MPCB at any of the three sites. This also indicated that there is no SO2 or NOx pollution in the city. However, as in case of RSPM and SPM the maximum values at site 1 were higher than the norms. Similarly at site 2 (Dabholkar Corner) the average as well as maximum values of both RSPM and SPM were much higher than the prescribed limits. Site 3 (Mahadawar road) showed mixed results, that the annual average RSPM value was just crossing to the limit and the maximum recorded value was much higher. But in case of SPM the annual average as well as maximum values was much higher than the prescribed annual standard of 140. This indicated that there is severe SPM pollution and moderate RSPM pollution in the city. (Bhaskaran *et al*, 2002) have reported higher concentration of SO_2 and NO_X during summer months, the results of the present study are

Table 3.8 Monthly average, maximum and minimum values for the four parameters at Site 3 (Mahadwar Road) from September 2006 to August 2007.

Month	SO_2			NO_x			RSPM			SPM		
	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum
Sep-06	6.30	9.66	2.97	23.25	29.54	14.57	42.08	63.88	29.16	114.18	204.75	53.45
Oct-06	6.82	7.93	5.54	20.65	25.16	15.82	62.23	68.34	58.88	218.64	312.01	142.63
Nov-06	4.77	6.60	3.38	14.01	23.28	8.36	65.22	79.16	47.32	184.36	297.00	137.59
Dec-06	4.88	5.46	4.22	8.93	10.91	7.95	46.03	53.93	36.11	114.05	136.56	87.49
Jan-07	8.23	10.36	6.70	20.95	28.92	17.07	69.27	108.30	56.74	244.84	353.10	172.21
Feb-07	8.90	10.36	3.38	20.72	28.92	7.95	72.38	108.30	36.11	268.06	353.10	87.49
Mar-07	8.79	10.36	3.38	24.30	28.92	7.95	64.76	108.30	36.11	231.18	353.10	87.49
Apr-07	11.01	13.08	10.07	28.71	38.10	22.26	70.16	92.59	52.08	202.64	272.21	154.84
May-07	9.71	9.89	9.53	25.45	25.70	25.20	73.14	81.70	64.58	215.61	250.45	180.77
Jun-07	7.64	8.95	5.62	18.48	23.47	11.06	67.87	79.16	55.55	176.32	228.46	125.68
Jul-07	4.48	4.85	4.18	7.80	8.40	7.17	47.80	52.77	42.21	104.41	113.87	93.73
Aug-07	4.39	4.83	3.90	6.46	8.75	5.32	44.55	55.55	38.53	94.67	121.51	79.15
Average	**7.2**	**8.5**	**5.2**	**18.3**	**23.3**	**12.6**	**60.5**	**79.3**	**46.1**	**180.7**	**249.7**	**116.9**
Maximum	**11.0**	**13.1**	**10.1**	**28.7**	**38.1**	**25.2**	**73.1**	**108.3**	**64.6**	**268.1**	**353.1**	**180.8**
Minimum	**4.4**	**4.8**	**3.0**	**6.5**	**8.4**	**5.3**	**42.1**	**52.8**	**29.2**	**94.7**	**113.9**	**53.5**

Figure 3.1: Monthly average, maximum and minimum values of SO_2 for site 1 (Shivaji University) from September 2006 to August 2007

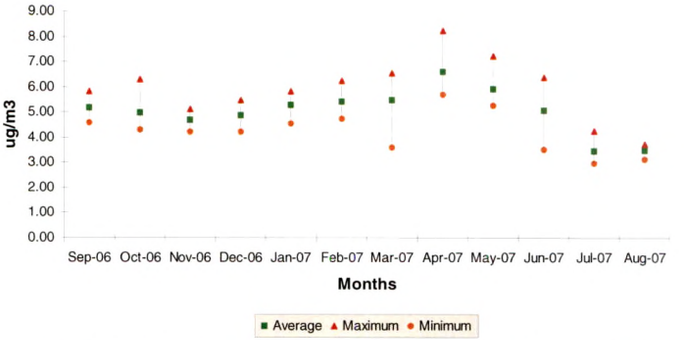


Figure 3.2: Monthly average, maximum and minimum values of SO_2 for site 2 (Dabholkar corner) from September 2006 to August 2007

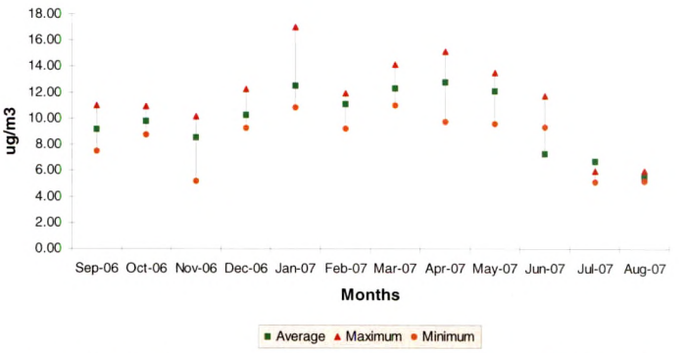


Figure 3.3: Monthly average, maximum and minimum values of SO_2 for site 3 (Mahadwar road) from September 2006 to August 2007

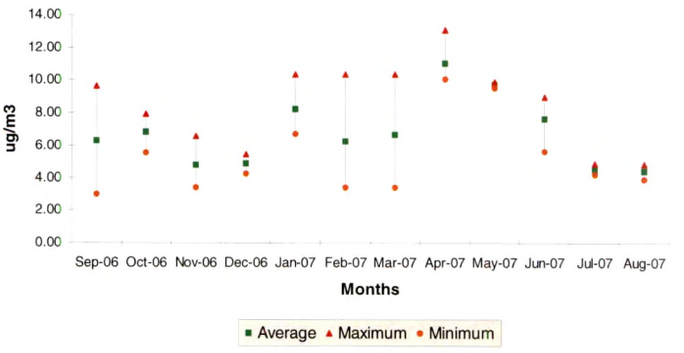


Figure 3.4: Monthly average, maximum and minimum values of NO_X for site 1 (Shivaji University) from September 2006 to August 2007

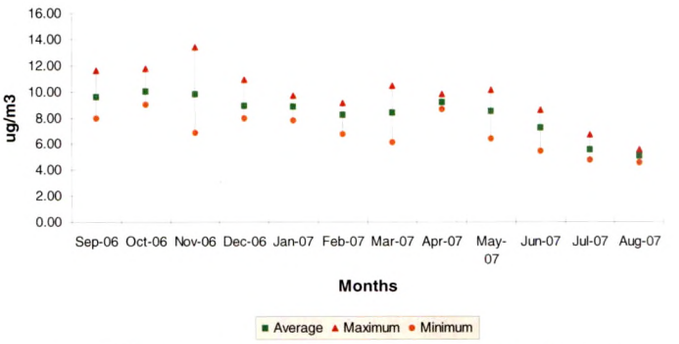


Figure 3.5: Monthly average, maximum and minimum values of NO_X for site 2 (Dabholkar corner) from September 2006 to August 2007

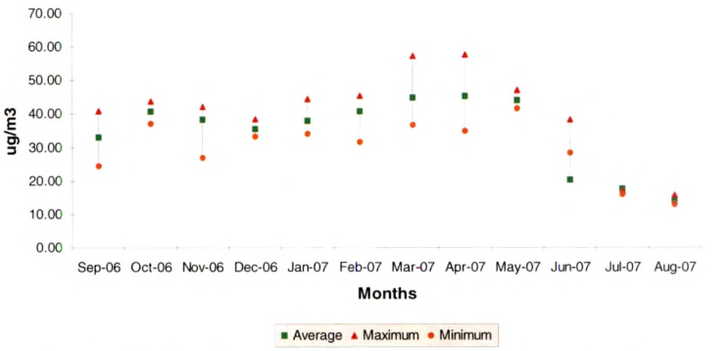


Figure 3.6: Monthly average, maximum and minimum values of NO_X for site 3 (Mahadwar road) from September 2006 to August 2007

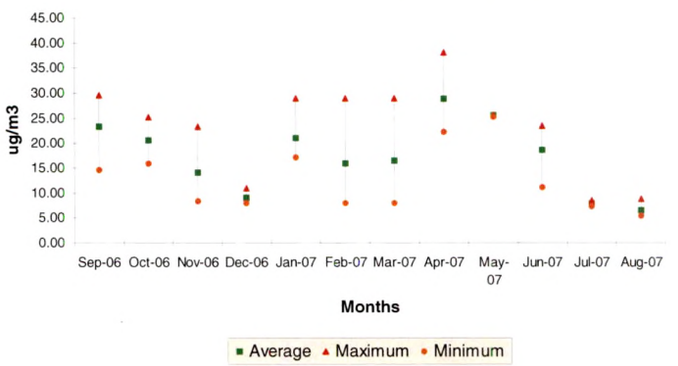


Figure 3.7: Monthly average, maximum and minimum values of RSPM for site 1 (Shivaji University) from September 2006 to August 2007

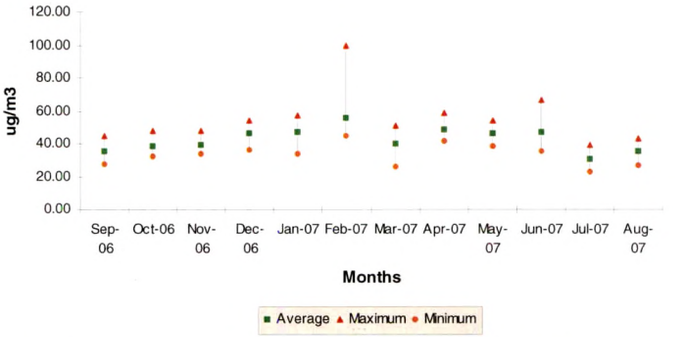


Figure 3.8: Monthly average, maximum and minimum values of RSPM for site 2 (Dabholkar corner) from September 2006 to August 2007

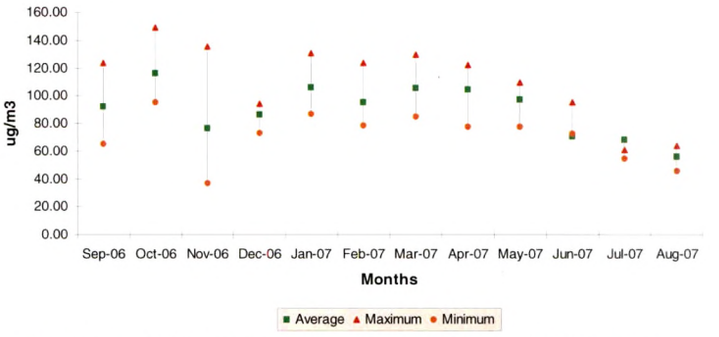


Figure 3.9: Monthly average, maximum and minimum values of RSPM for site 3 (Mahadwar road) from September 2006 to August 2007

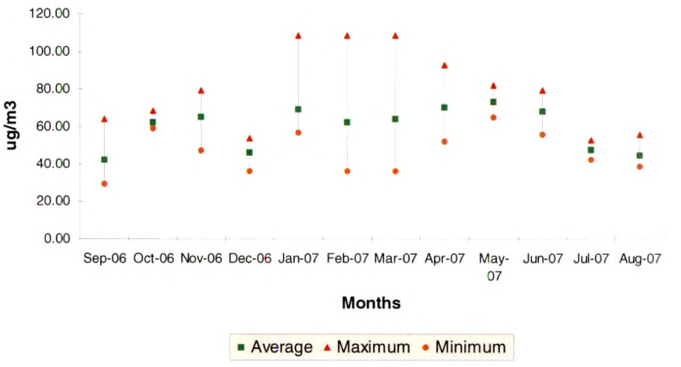


Figure 3.10: Monthly average, maximum and minimum values of SPM for site 1 (Shivaji University) from September 2006 to August 2007

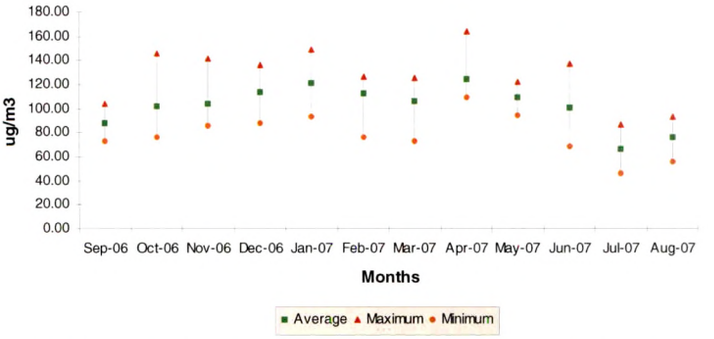


Figure 3.11: Monthly average, maximum and minimum values of SPM for site 2 (Dabholkar corner) from September 2006 to August 2007

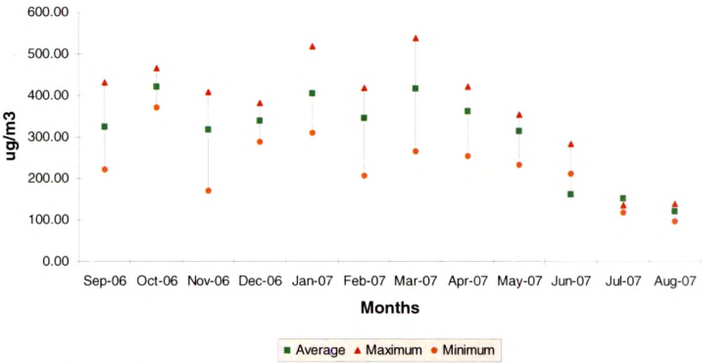
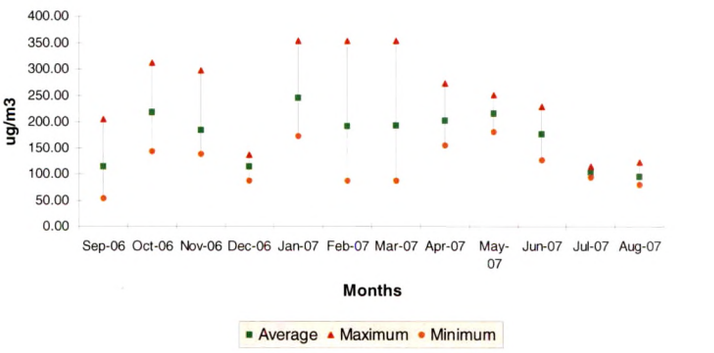


Figure 3.12: Monthly average, maximum and minimum values of SPM for site 3 (Mahadwar road) from September 2006 to August 2007



in conformity with these observations. Impact of rainy season on the SO_2 and NO_X values was because of precipitation and dilution. Similarly the suspended particulates also get settled dawn with rain thus having lower values of RSPM and SPM during rainy months.

3.3 Air Quality Index (AQI)

Good air is the prime resource for sustenance of life. With the technological advancements, vast amount of data about ambient air quality is generated to know the quality of air environment and to administer the appropriate corrective actions wherever necessary. Such an endeavour would result in encyclopaedic volumes of data which may neither give a clear picture to a decision maker nor to a common man who simply wants to know how good or bad is the air. As for the general public, the questionnaire usually will not be satisfied with raw data, time series plots, statistical analysis and other complex findings pertaining to air quality. To address the above concerns, IIT Kanpur through a sponsored project from the Central Pollution Control Board, Delhi had proposed the Indian Air Quality Index (IND - AQI) in simple and lucid terms.

A segmented linear function was used relating the actual air pollution concentrations (of each pollutant) to a normalized number. The basis for these linear functions (for this study) was arrived after considering such functions adopted by other countries. The pollutants included for the proposed IND - AQI were SPM, SO_2, NO_2, PM_{10}, CO and O_3. The following Table 3.10 presents the summary of the break point concentrations and AQI values for India (proposed) for all pollutants.

Table 3.10: Indian Air Quality Index (AQI) for different Pollutants

S.No	Index	Category	SO_2 (24 hr avg) (ug/m^3)	NO_2 (1-hr avg) (ug/m^3)	SPM (24-hr avg.) (ug/m^3)	CO (1-hr avg.) (mg/m^3)	CO (8-hr avg) (mg/m^3)	O_3 (8-hr avg.) (ug/m^3)	PM_{10} (24-hr avg.) (ug/m^3)
1.	0-100	Good	0-80	0-80	0-200	0-4	0-2	0-157	0-100
2.	101-200	Moderate	81-367	81-180	201-260	4.1-25	2.1-12	158-196	101-150
3.	201-300	Poor	368-786	181-564	261-400	25.1-35	12.1-17	197-235	151-350
4.	301-400	Very poor	787-1572	565-1272	401-800	35.1-75	17.1-35	236-784 (1-hr avg.)	351-420
5.	401-500	Severe	>1572	>1272	>800	>75	>35	>784 (1-hr avg.)	>420

Since all the pollutants are not measured in the present study under the National Ambient Air Quality Monitoring Program, it is necessary that at least three pollutant concentrations must be available to calculate and report the index. The over all AQI is based on maximum operator system where the maximum value of sub-index becomes the AQI. To reflect the attainment of NAAQS, the AQI is referred to as Good between the ranges 0 - 100. For the second break point (at the standard of USEPA), the AQI takes the value of 200 and referred to as moderate. In absence of any other pollutant health criteria in India, rest of categorization of Index is based on the USEPA Federal Episode criteria and Significant Harm Level.

IND-AQI is primarily a health related index with the following descriptor words: "Good (0 - 100)", "Moderate (101 - 200)", "Poor (201 - 300)", "Very poor (301 - 400)", "Severe (401 - 500)". On the basis of IIT Kanpur (2008) proposed the Indian Air Quality Index (IND - AQI). This AQI is calculated for the three study locations in Kolhapur city.

3.3.1 Site 1 (Shivaji University)

This station was the less crowed location of the three locations. From the Table no 3.11 it was clear that average values of all parameters were below the standard limit throughout the year i.e. from Sep-06 to Aug-07. All the four parameters i.e. SO_2, NO_x, RSPM, SPM showed good AQI.

Table 3.11: AQI status of Site 1, 2 and 3 for the four parameters

Sites	Month and Year	SO_2	NO_x	RSPM	SPM
Site 1	Average	5.03	8.29	42.34	102.17
	AQI	Good	Good	Good	Good
Site 2	Average	10.14	35.76	91.02	315.64
	AQI	Good	Good	Good	Poor
Site 3	Average	7.16	18.31	60.46	180.75
	AQI	Good	Good	Good	Good

3.3.2 Site 2 (Dabholkar Corner)

At this station all the parameters were showed good AQI, except SPM. SPM parameter was in the poor AQI category. From Table no 3.11 it was clear that SPM values crossed standard limit value i.e. 200 $\mu g/m^3$ throughout the year except in July and August 2007 due to rainy season. RSPM values were also crossed standard limit value number of times during the one year duration. During Oct-06 it was 116.21, in January, March, April 2007 showed values 106.19 $\mu g/m^3$, 105.42$\mu g/m^3$ and 104.74 $\mu g/m^3$ respectively. Average value for RSPM i.e. 91.02 was very close to standard limit value. So at Dabholkar Corner Station SPM was of serious concern and in future RSPM may become serious.

3.3.3 Site 3 (Mahadwar Road)

At Mahadwar Road Station all the four parameters were with in standard limit range except SPM and showed 'good' category for AQI. Table 3.11 indicate SPM values crossed standard limit in Oct-06 with value 218.64. In January, February, March, April and May 2007 showed

values 244.84, 268.06, 231.18, 202.64 and 215.61μg/m^3 respectively. Yearly SPM average for SPM was 180.75, which were quite close to standard limit i.e. 200μg/m^3, which may cross standard limit in near future. So some serious control measures are required to over come future environmental problems.

3.4 Statistical Analysis

Statistical analysis of the data was carried out using student 't' test The data were tested for four parameters to analyse pollution status of three selected sites. For analysis purpose of T-Test values like Average, Standard Deviation, T Calculated, T Table were calculated. The hypothesis is if T Calculated values are greater than T Table values, then that particular parameter is said to be polluting. Depending upon analysis of the four parameters at the three selected sites following are the results.

3.4.1Site 1 (Shivaji University)

This station was the least crowed location of the three locations as far as vehicular traffic was concerned. All the four parameters i.e. SO_2, NO_x, RSPM and SPM were below the standard limit throughout the year i.e. from Sep-06 to Aug-07. From the table 3.14 it was clear that all T Calculated values are less than T Table values and hence all parameters were non polluting. Thus Shivaji University Station shows all parameters were in control limit.

Table 3.14: T-Test values of Sum, Std. Deviation, T Calculated, T table for Site 1

Month and Year	SO_2	NO_x	RSPM	SPM
Standards	80	80	100	200
Average	5.03	8.29	42.34	102.17
Std Dev	0.89	1.60	7.10	17.43
T Cal	-278.73	-148.99	-26.93	-18.62
T Table	2.2010	2.2010	2.2010	2.2010

Abbreviations: Sum: Summation, Std Dev: Standard Deviation, T Cal: T , Calculated Value, T Table: T Table Value

3.4.2 Site 2 (Dabholkar Corner)

At this station out of four parameters three parameters i.e. SO_2, NO_x, and RSPM showed T Calculated values less than T Table values and hence these three parameters were non polluting but in case of SPM from Table 3.15 it is clear that T Calculated value was greater than T Table value, means SPM parameter at this location was polluting as per the norms, that means T Test was significant and showed that out of four parameters SPM was polluting the environment at Dabholkar corner station.

Table 3.15 T-Test values of Sum, Std. Deviation, T Calculated, T table for Site 2

Month and Year	SO_2	NO_x	RSPM	SPM
Standard	80	80	100	200
Average	10.14	35.76	91.02	315.64
Std Dev	2.47	10.15	18.32	97.44
T Cal	-93.70	-14.46	-1.63	3.94
T Table	2.2010	2.2010	2.2010	2.2010

Abbreviations: Sum: Summation, Std Dev: Standard Deviation, T Cal: T, Calculated Value, T Table: T Table Value

3.4.3 Site 3 (Mahadwar Road Station)

At Mahadwar Road Station all the four parameters were within standard limit range. From the table 3.16 it can be seen all T Calculated values are less than T Table values and hence all parameters were non polluting.

Table 3.16 T-Test values of Sum, Std. Deviation, T Calculated, T table at Site 3

Month and Year	SO_2	NO_x	RSPM	SPM
Standard	80	80	100	200
Average	7.16	18.31	60.46	180.75
Std Dev	2.24	7.36	11.81	59.96
T Cal	-107.97	-27.82	-11.11	-1.06
T Table	2.2010	2.2010	2.2010	2.2010

Abbreviations: Sum: Summation, Std Dev: Standard Deviation, T Cal: T, Calculated Value, T Table: T Table Value

Thus Mahadwar Road Station showed all parameters below norms and non polluting. This could because though Mahadwar road site was crowed, it was mainly pedestrians and not vehicular traffic due to the narrow road crowed by devotees visiting the Mahalaxmi Temple.
