Assessment Of Ambient Air Quality Status In Urbanization, Industrialization And Commercial Centers Of Uttarakhand (India)

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Abstract: Development in industrialization, urbanization and expansion of the Haridwar city has resulted in increase of air pollution like SO_2, NO_x, SPM and RSPM in urban and industrial areas of Haridwar (Uttarakhand), India. This investigation represented the assessment of ambient air quality with respect to PM_{10} (RSPM), SPM, oxides of nitrogen (NO_x) and sulphur dioxide (SO_2) at four sites namely Shivalik nagar, SIDCUL, Clock Tower, and Bhadrabad. Meteorological parameters like temperature, relative humidity, wind speed and rainfall were also recorded simultaneously during the sampling period. Monthly and seasonal variation of these pollutants have been observed and recorded. The annual average and range values have also been calculated. It has been observed that the concentrations of the pollutants are high in winter in comparison to the summer or the monsoon seasons. Investigation results elucidates that industrial activities, indiscriminate open air burning of coal by the local inhabitants for cooking as well as cooking purpose, vehicular traffic etc. are responsible for the high concentration of pollutants in this area. In the present study, it was noticed that the SPM and PM_{10} levels at residential and industrial areas exceeds the prescribed limits as stipulated by Central Pollution Control Board (CPCB) New Delhi, India. Apart from this the SO_2 and NO_x levels in residential, industrial and commercial areas remain under prescribed limits of CPCB. [New York Science Journal 2010;3(7):85-94]. (ISSN: 1554-0200).

Keywords: Air pollutants, industrial area, urbanization area, commercial area, AQI

Introduction

Air pollution is one of our most serious problems, faced by developing as well as developed countries. Most of the cities in developing countries suffer from serious outdoor air pollution due to poor control of industrial emission and improper maintenance of vehicles (Ravindra et al., 2003). The advent of industrial revolution and increase demand of vehicles has increase the air pollutants concentration all over the world. The release of air pollutants in atmosphere is the direct effect of industrialisation and urbanization which are essential to meet the growing demands to the increasing population. Such activities can not be stopped as they are directly related to the development of the society (Varma et al.,1994). Industrialization and urbanization bring with them the unwanted adverse air pollutants, namely suspended particulate matter (SPM), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) (Reddy and Suneela, 2001). Suspended particulate matter (SPM) refers to the mixture of solid and liquid particles in air. In a broader sense the term applies to matter in the atmosphere classed into particles having a lower size limit of the order of 10^{-3}µm and an upper limit of 100 µm. SPM, a complex mixture of organic and inorganic substances, is a ubiquitous air pollutant, arising from both natural and anthropogenic sources. Particulate matter (PM) that is 10µm or less in diameter is called as respirable suspended particulate matter (RSPM) or PM_{10}, it penetrates the respiratory system. RSPM is generally grouped into three modes: ultra fine (size range less than 0.1µm), fine (0.7-1µm) and coarse (1-10µm) (Fenger, 1999; Mohanraj and Azeez, 2004). Respirable dust particle is the term for particles found in the air, including dust, dirt, soot, smoke and liquid droplets. Particles can be suspended in the air of long periods (Senthlinathan, 2005). Most of cities in Northern India are afflicted with the presence of unusually high concentration of PM10 in the ambient environment posing a serious risk to human health (Tandon et al., 2008).

The issue of urban air quality is receiving increasing attention as a growing share of the world's population is now living in urban centers and demanding a cleaner urban environment (Gurjar et al., 2008). Air pollution is a serious public health problem in most of the metropolitan areas in India. The increased air pollutant concentrations in urban area are responsible for deficits in pulmonary functions, cardiovascular disease, neurobehavioral effects, morbidity and mortality (WHO, 1987). According to the United Nations report (UN, 2003) the global urban population continues to grow faster than the total population of the world. About, 3 billion people are living in urban settlements. In, number of urban centers has grown from 1827 in 1901 to 5161 in 2001. The population residing in urban areas has also increased from 25.8 millions in 1901 to 285.3 millions in 2001

(Sri Muruganandam and Shiva Nagendra, 2007). The United Nations (UN) estimates that 4.9 billion inhabitants out of 8.1 billion will be living in cities by 2030 (UNCSD, 2001). Rapid industrialization followed by consequential population and economic growth surrounding industrial nuclei have often serious concern for the environmental deterioration on surrounding areas (Reddy et al., 2004).

The major anthropogenic sources of air pollutants are industrial emissions, domestic fuel burning, emissions from power plants and transportation activities. In India, specifically in Delhi, vehicular pollution contributes 67% of the total air pollution load, which are approximately 3,000 metric tones per day (Central Pollution Control Board, 1999). It is estimates that diesel combustion emits 84 g/km of particulates as compared to 11 g/km in CNG (Nylund and Lawson, 2000). An air quality index is one of the important tolls available for analyzing and reprinting air quality status uniformly (Swami and Tyagi, 1999).

Materials and Methods

Haridwar is one of the most important holy cities of India, located in newly carved state of Uttarakhand. Haridwar is extended from latitude 29° 58' in the north to longitude 78°13' in the east and has subtropical climate. It is about 60 km in length from east to west and about 80 km in width from north to south. District Haridwar lies in the foot hills of Shivalik ranges. Total area of district Haridwar is 2,360 km^2 with a population of 14, 44,213 (as per 2001 census). It receives millions of tourists every month. The study was carried out at three different sites of Haridwar, namely Shivalik nagar (referred to as site-1), industrial area in SIDCUL (referred to as site-2) and control area (referred to as site-4) and one site from Dehradun which is commercial area (referred to as site-3). Dehradun is a capital of newly formed state Uttarakhand which known for its beauty in the world, extended from latitude 30° 31' in the north to longitude 78° 03' in the east. Dehradun is bounded in the north by the higher range of lesser Himalaya and in south by the younger Shivalik mountain ranges.

Concentration of air pollutants viz. NO_x, SO_2, SPM and RSPM was measured with the help of RDS APM 460 by sucking air into appropriate reagent for 24 hours at every 30 days and after air monitoring it procured into lab and analysis for the concentration level. The SPM and RSPM were analyzed using Respirable Dust Sampler (RDS) APM 460 and operated at an average flow rate of 1.0-1.5 m^3 min^{-1}. Preweighed glass fiber filters (GF/A) of Whatman were used as per standard methods. SO_2 and NO_x were collected by bubbling the sample in a specific absorbing (sodium tetrachloromercuate of SO_2 and sodium hydroxide for NO_x) solution at an average flow rate of 0.2-0.5 min^{-1}. The impinger samples were put in ice boxes immediately after sampling and transferred to a refrigerator until analyzed. The concentration of NO_x was measured with standard method of Modified Jacobs- Hochheiser method (1958), SO_2 was measured by Modified West and Geake method (1956), SPM and RSPM using filter paper methods. The apparatus was kept at a height of 2 m from the surface of the ground. However data of air pollutants for Dehradun City were collected from Uttarakhand Environment Protection and Pollution Control Board website. AQI (air quality index) is then calculated with the concentration values using the following equation (Rao & Rao, 1998).

Results and Discussion

Table 1 represents the characterization of four selected monitoring sites. Figure1 represents the monthly variation of PM_{10}, RSPM, NO_x and SO_2 at four monitoring sites. The seasonal variation of PM_{10}, RSPM, NO_x, SO_2 and AQI in terms of range and the average values are depicted in Table 2. The annual ambient air quality status in the form of the arithmetic mean and geometric mean are shown in Table 3. Monthly variation in air quality index (AQI) and its rating scale at four monitoring sites have been shown in Table 4. However Table 5, 6, 7, 8 shows the Correlations (Pearson) of meteorological parameters and air pollutants at site 1, 2, 3 and 4, respectively, during study period. The meteorological data with respect to temperature, humidity, rainfall and wind speed were collected from the study sites (Table 9).

It was observed from the meteorological data that the highest temperature attained was during the month of May at site 1, 2 and 4, whereas highest temperature during June at site 3 and the lowest in the month of December at site 1, 2 and 4, while lowest during January at site 3. Highest humidity was recorded during the month of December at site 1, 2 and 4, whereas highest humidity during August at site 3 and the lowest in the month of May at site 1, 2 and 4, while the lowest during April at site 3. Highest rainfall was recorded during July at site 1, 2 and 4, however at site 3 during August. In the case of wind speed, highest observed during June at site 1, 2 and 4, while highest during April and October.

RSPM or PM_{10}

It is observed from Fig 1 and Table 2 that the average PM_{10} concentration was found to be much higher during winter (November-February) in comparison with the monsoon (July-October) and the summer (March-June). This trend is the same in all the four monitoring stations. In winter, anti-cyclonic conditions prevails, which characterized by calm or light winds and restrict mixing depth due to stable or inversion atmosphere lapse rate, resulting in little dispersion or dilution of pollutants, which, in turn, helps in the build-up of pollution concentrations to higher levels. Monsoon experiences the lowest SPM levels at four monitoring sites (except site-2), which is because of the dust by intermittent precipitation. At site 1 (Table 5) correlation of PM_{10} with temperature (r = 0.60, $p<0.05$); PM_{10} with rainfall (r = 0.75, $p<0.01$); PM_{10} with wind speed (r = 0.61, $p<0.05$) and PM_{10} with SPM (r = 0.71, $p<0.01$). At site 2 (Table 6) correlation of PM_{10} with rainfall (r = 0.65, $p<0.05$). While at site 3 (Table 7) correlation of PM_{10} with temperature (r = 0.51, $p<0.01$); PM_{10} with SPM (r = 0.96, $p<0.01$) and PM_{10} with AQI (r = 0.94, $p<0.01$).

SPM

From Fig 1 and Table 2 it is elucidate that annual average of SPM values were maximum as per standard set by CPCB during the study period at site 1, 2 and 3. The average SPM levels were relatively high during winter in comparison with monsoon and summer at all four monitoring sites. During winter at all selected sites were experienced calm or light winds, resulting in little dispersion of pollutants causes higher levels of SPM. At site 1 (Table 5) correlation of SPM with temperature (r = 0.64, $p<0.05$); SPM with rainfall (r = 0.86, $p<0.01$); SPM with PM_{10} with wind speed (r = 0.71, $p<0.01$) and SPM with AQI (r = 0.70, $p<0.05$). At site 3 (Table 7) correlation of SPM with temperature (r = 0.75, $p<0.01$); SPM with PM_{10} (r = 0.96, $p<0.01$); SPM with NO_x (r = 0.60, $p<0.05$); SPM with SO_2 (r = 0.66, $p<0.05$) and SPM with AQI (r = 0.99, $p<0.01$) and While at site 4 (Table 8) correlation of SPM with temperature (r = 0.67, $p<0.05$); SPM with rainfall (r = 0.61, $p<0.05$) and SPM with wind speed (r = 0.85, $p<0.01$).

NO_x

The annual average of NO_x concentration levels are comparable at the four monitoring sites (Table 3), but did not cross the reference levels of 80/120 μgm^{-3} at any four sampling sites. At site 1 (Table 5) correlation of NO_x with AQI (r = 0.68, $p<0.05$). At site 2 (Table 6) correlation of NO_x with temperature (r = 0.66, $p<0.05$) and NO_x with humidity (r = 0.79, $p<0.01$) and While at site 3 (Table 7) correlation of NO_x with SPM (r = 0.60, $p<0.05$); NO_x with SO_2 (r = 0.75, $p<0.01$) and NO_x with AQI (r = 0.68, $p<0.05$).

SO_2

From Table 3, it is observed that the annual average of SO_2 values were higher than the prescribed limit of CPCB at site 1, 2 and 3. The average SO_2 levels were relatively high during winter (Table 2) in comparison with both the summer and monsoon. Lower levels of SO_2 during monsoon can be attributed to the prevalence of high wind speeds and precipitation. At site 3 (Table 6) correlation of SO_2 with SPM (r = 0.66, $p<0.05$); SO_2 with NO_x (r = 0.75, $p<0.01$) and SO_2 with AQI (r = 0.73, $p<0.01$) and While at site 4 (Table 8) correlation of SO_2 with temperature (r = 0.79, $p<0.01$) and SO_2 with humidity (r = 0.69, $p<0.05$).

AQI

The seasonal variation of AQI values are shown at four monitoring sites (Table 2). It is observed that the average AQI value was found to be much higher during winter in comparison with the monsoon and the summer. From Table 3 and 4 it is observed that annual average of AQI found to be between 73.88-88.88, 43.44-47.94, 51.00-80.67 and 17.33-22.65 at site 1, 2, 3 and 4, respectively. At site 1 (Table 5) correlation of AQI with rainfall (r = 0.58, $p<0.05$); AQI with SPM (r = 0.70, $p<0.05$) and AQI with NO_x (r = 0.68, $p<0.05$). While at site 3 (Table 7) correlation of AQI with temperature (r = 0.71, $p<0.01$); AQI with PM_{10} (r = 0.94, $p<0.01$); AQI with SPM (r = 0.99, $p<0.01$); AQI with NO_x (r = 0.68, $p<0.05$) and AQI with SO_2 (r = 0.73, $p<0.01$).

Above results shows that concentration of particulate matter (PM_{10} and SPM) were higher than the prescribed limits by CPCB, whereas NO_x and SO_2 remained under prescribed limit. The higher concentrations of PM_{10} and SPM attributed that site 1 and 2 posses a high traffic volume through out the day, while site 3 posses high number loaded and heavy transportation vehicles and beside this there are large number of industries which contribute air pollutants in ambient air.

Rajasekhar et al., (1999) reported that the higher concentration of SPM exceeds the permissible limits, this may be attributed of automobile pollution. The major sources of SO_2 are combustion, metallurgical industries such as smelting, automobile exhaust and automobiles. Jain et al., (2004) reported the suspended particulate matter has found to higher that of CPCB standards. Apart from the emission factors of vehicles, the SPM concentration would be mainly affected by the moving vehicles, wind and the thermal turbulence produced by the hot vehicle exhaust gas. Another factor that can affect the particulate matter concentration is rainfall (Lam et al., 1999). Many studies indicated that the total and respirable suspended particulate matter in the ambient air would be affected by various meteorological factors like wind speed, wind direction, solar radiation, relative humidity as well as source conditions (Leung and Lam 1993, Monne et al., 1995, Prendiz et al., 1995). The natural sources of particulate matter in the atmosphere are the erosion of soil by wind, salt particles from oceans, forest fires, volcanic residues, plant pollen and seeds.

Manmade sources are households grates, automobile exhaust, thermal power stations, iron and steel plants, foundries, cement factories, petrochemical refineries, paper mills, agricultural operations and so on (Gurtu et al., 2001). The diesel engine produces high level of very small particles (Gupta, 1999). Sandhu et al., (2004) reported that the high concentration of RSPM in all commercial site due to plying of diesel vehicles. Motor vehicles also generate a range of particulate matter through the dust produced from brakes, clutch plates, tires and indirectly through the re-suspension of particulates on road surfaces through vehicles–generate turbulence (Watkins, 1991). Joshi et al., 2006; Chauhan and Joshi, 2010 found that the concentration of gaseous pollutants viz SO_x and NO_x was under the permissible limits as per CPCB while the concentration of particulate pollutants (SPM and PM_{10}) was higher the permissible limits as per CPCB in Haridwar city.

Table 1: Characterization of four monitoring sites

Sampling station location	Zonal activities	Major sources of pollution in 2 km radius
Shivalik Nagar (Site-1)	Residential/Commercial	• Transportation activities • Coal burning • Spray painting works • Poor road conditions • Construction works • Poor maintained vehicles • Very close and surrounded by two industrial areas
SIDCUL (Site-2)	Industrial	• Coal burning • Spray painting works • Poor road conditions • Construction works • Steel and Iron Plant • Soap manufacturing works • Biscuit factory • Oil mill • Polythene factory • Bricks factory • Battery and Generator factory • Glass factory • Scrub factory • Transportation activities • Poor maintained vehicles
Clock Tower (Site-3)	Commercial	• Transportation activities • Poor maintained vehicles
Control Area (Site-4)	Agricultural land	• Unpaved road • Agricultural activities

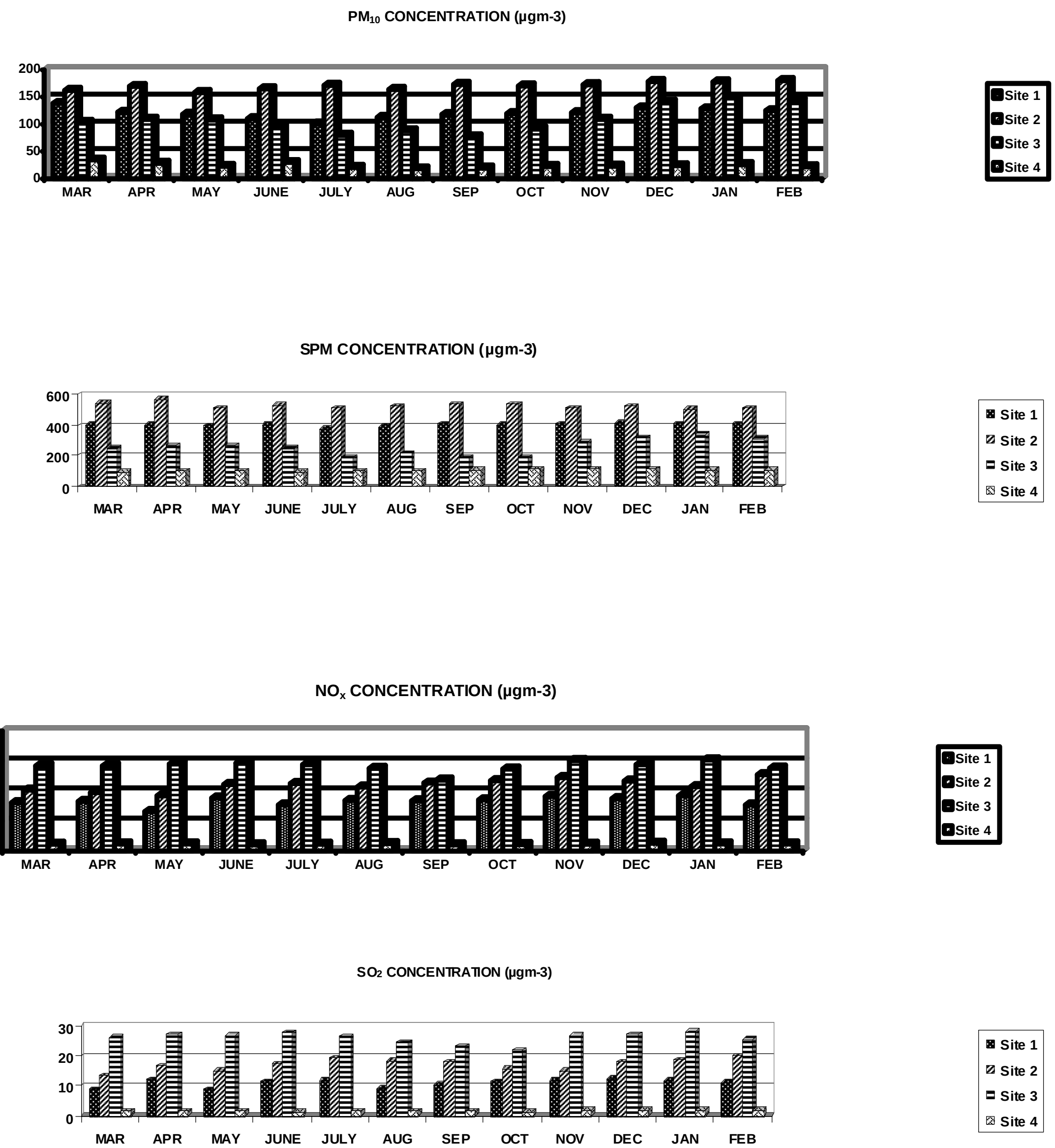

Figure1. Monthly variation of PM_{10}, SPM, NO_x and SO_2

Table 2: Seasonal variation of PM_{10}, SPM, NO_X, SO_2 and AQI at four selected sites in Haridwar District

Air Pollutants	Site I			Site II			Site III			Site IV		
	Summer	**Monsoon**	**Winter**	**Summer**	**Monsoon**	**Winter**	**Summer**	**Monsoon**	**Winter**	**Summer**	**Monsoon**	**Winter**
PM_{10} (μgm^{-3})	110.23-138.40 [122.32]	100.60-119.70 [112.80]	121.55-130.26 [126.38]	158.49-169.54 [163.96]	164.23-173.24 [169.87]	172.59-180.12 [177.26]	97.38-109.04 [104.49]	76.71-91.25 [84.01]	109.43-149.43 [135.50]	22.83-34.37 [28.90]	18.34-22.49 [20.32]	21.96-25.90 [23.92]
SPM (μgm^{-3})	398.44-404.50 [401.83]	375.11-407.12 [394.18]	410.28-414.52 [412.04]	512.70-568.40 [539.83]	509.11-540.12 [527.21]	507.43-522.25 [512.28]	245.89-267.25 [257.10]	187.19-216.31 [197.14]	286.42-338.56 [314.33]	94.57-103.40 [98.69]	98.47-109.40 [104.87]	106.00-111.32 [109.80]
NO_x (μgm^{-3})	13.24-17.67 [15.89]	15.36-17.12 [16.54]	15.44-18.40 [17.38]	18.46-22.23 [20.12]	21.33-23.50 [22.50]	21.47-25.49 [23.71]	28.35-29.31 [28.76]	23.66-28.81 [26.38]	27.63-30.37 [29.24]	2.12-2.34 [2.32]	2.12-2.54 [2.30]	2.34-2.57 [2.42]
SO_2 (μgm^{-3})	8.64-11.88 [10.21]	9.08-11.67 [10.63]	11.12-12.30 [11.75]	13.33-17.47 [15.60]	15.63-19.46 [17.88]	14.88-20.12 [17.90]	26.21-28.01 [27.03]	21.72-26.56 [24.03]	25.52-28.17 [26.87]	1.28-1.43 [1.37]	1.22-1.48 [1.37]	1.80-1.93 [1.87]
AQI	75.63-79.63 [77.85]	73.78-79.27 [77.02]	78.81-88.88 [82.56]	43.44-47.94 [45.91]	45.59-46.99 [46.36]	44.32-46.62 [45.64]	64.67-68.33 [67.08]	51.00-57.67 [54.08]	74.33-80.67 [75.75]	17.33-23.47 [20.57]	17.95-19.81 [19.01]	19.43-20.43 [19.97]

Range values and average values of PM_{10}, SPM, NO_X, SO_2 and AQI

Table 3: Annual ambient air quality status at four monitoring sites

Sampling Sites	PM_{10} (μgm^{-3})			SPM (μgm^{-3})			NO_x (μgm^{-3})			SO_2 (μgm^{-3})			AQI		
	Range	Arithmetic Mean	Geometric Mean	Range	Arithmetic Mean	Geometric Mean	Range	Arithmetic Mean	Geometric Mean	Range	Arithmetic Mean	Geometric Mean	Range	Arithmetic Mean	Geometric Mean
Site I	100.60-138.40	120.50	120.12	375.11-412.47	402.68	402.54	13.24-18.40	16.60	16.54	8.64-12.30	10.86	10.79	73.78-88.88	79.14	79.06
Site II	158.49-180.12	170.36	170.24	507.43-568.40	526.44	526.14	18.46-25.49	22.11	22.02	13.33-20.12	17.12	17.01	43.44-47.94	45.97	45.96
Site III	76.71-149.43	108.00	105.58	187.19-338.56	256.19	251.29	23.66-30.37	28.28	28.22	21.72-28.17	25.97	25.91	51.00-80.67	65.64	64.96
Site IV	18.34-34.37	24.38	24.00	94.57-111.32	104.21	104.05	2.12-2.57	2.34	2.34	1.22-1.93	1.54	1.52	17.33-22.65	19.85	19.78

Table 4: Monthly variation in AQI and its rating scale at four monitoring sites

Months	Site 1		Site 2		Site 3		Site 4	
	AQI	Rating Scale	AQI	Rating Scale	AQI	Rating Scale	AQI	Rating Scale
March	77.17	SAP	45.76	LAP	64.47	MAP	22.65	CA
April	79.26	SAP	47.94	MAP	67.61	MAP	18.84	CA
May	75.63	MAP	43.44	MAP	67.31	MAP	23.47	CA
June	79.33	SAP	46.50	MAP	64.85	MAP	17.33	CA
July	73.38	SAP	45.59	MAP	55.38	MAP	17.95	CA
August	75.81	MAP	45.99	MAP	57.69	MAP	18.57	CA
September	79.20	SAP	46.99	MAP	50.77	LAP	19.69	CA
October	79.27	SAP	46.88	MAP	52.28	MAP	19.81	CA
November	88.88	SAP	45.24	MAP	71.47	MAP	20.02	CA
December	81.48	HAP	46.27	LAP	76.61	HAP	20.43	CA
January	81.06	HAP	44.43	LAP	80.81	HAP	19.43	CA
February	78.81	HAP	46.62	LAP	74.17	MAP	19.99	CA

Table 5: Correlations (Pearson) of meteorological parameters and air pollutants at site 1 during study period

	Temperature	Humidity	Rainfall	Wind Speed	PM_{10}	SPM	NO_x	SO_2
Humidity	-0.74**							
Rainfall	0.59*	0.03						
Wind Speed	0.57	-0.25	0.64*					
PM_{10}	-0.60*	0.12	-0.75**	-0.61*				
SPM	-0.64*	0.12	-0.86**	-0.53	0.71**			
NO_x	-0.45	0.48	-0.13	-0.18	0.18	0.43		
SO_2	-0.41	0.31	-0.20	0.04	-0.12	0.30	0.54	
AQI	-0.56	0.33	-0.58*	-0.48	0.36	0.70*	0.68*	0.50

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 6: Correlations (Pearson) of meteorological parameters and air pollutants at site 2 during study period

	Temperature	Humidity	Rainfall	Wind Speed	PM_{10}	SPM	NO_x	SO_2
Humidity	-0.70*							
Rainfall	0.58*	0.07						
Wind Speed	0.61*	-0.30	0.66*					
PM_{10}	-0.77	-0.12	-0.65*	-0.55				
SPM	0.38	-0.48	-0.11	-0.12	-0.24			
NO_x	-0.66*	0.79**	-0.16	-0.22	0.04	-0.40		
SO_2	-0.17	0.45	0.34	0.26	-0.25	-0.38	0.41	
AQI	0.03	0.09	-0.02	-0.11	0.14	0.69*	0.29	0.22

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 7: Correlations (Pearson) of meteorological parameters and air pollutants at site 3 during study period

	Temperature	Humidity	Rainfall	Wind Speed	PM_{10}	SPM	NO_x	SO_2
Humidity	-0.04							
Rainfall	0.44	0.76**						
Wind Speed	-0.05	-0.64*	-0.45					
PM_{10}	-0.05**	-0.64	-0.45	0.30				
SPM	-0.75**	-0.39	-0.57	0.27	0.96**			
NO_x	-0.31	-0.27	-0.21	0.61	0.50	0.60*		
SO_2	-0.17	-0.31	-0.20	0.36	0.50	0.66*	0.75**	

AQI	-0.71**	-0.39	-0.54	0.31	0.94**	0.99**	0.68*	0.73**

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 8: Correlations (Pearson) of meteorological parameters and air pollutants at site 4 during study period

	Temperature	Humidity	Rainfall	Wind Speed	PM_{10}	SPM	NO_x	SO_2
Humidity	-0.78**							
Rainfall	0.59*	-0.02						
Wind Speed	0.72**	-0.44	0.68*					
PM_{10}	0.03	-0.30	-0.24	0.30				
SPM	-0.67*	0.45	-0.61*	-0.85**	-0.52			
NO_x	-0.29	0.23	-0.03	-0.43	-0.10	0.18		
SO_2	-0.79**	0.69*	-0.39	-0.55	-0.07	0.53	0.54	
AQI	-0.16	-0.24	-0.53	-0.29	0.21	0.03	0.21	0.06

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

Table 9: Monthly variation in temperature, humidity, rainfall and wind speed as recorded from different study sites during 2007-08

S.NO	Months (March 2007 - Feb. 08)	Temperature (°C)				Humidity (%)				Rainfall (m.m.)				Wind Speed (m/sec)			
		Site-1	Site-2	Site-3	Site-4	Site-1	Site-2	Site-3	Site-4	Site-1	Site-2	Site-3	Site-4	Site-1	Site-2	Site-3	Site-4
1	March	24.0	24.5	18.9	24.0	79	78	67	79	49	49	82	49	0.6	0.6	0.7	0.8
2	April	36.0	36.6	26.6	36.0	61	63	49	62	36	36	16	36	0.5	0.5	0.8	0.6
3	May	37.4	37.7	27.6	37.0	57	59	53	58	40	40	22	40	0.6	0.9	0.7	0.8
4	June	36.0	36.3	28.9	36.0	70	71	65	70	176	176	79	176	1.7	1.6	0.8	1.5
5	July	33.0	33.4	26.6	32.8	86	87	85	88	287	287	792	287	1.4	1.3	0.7	1.2
6	August	32.6	32.6	26.2	32.6	84	85	87	85	273	273	846	273	0.4	0.6	0.4	0.6
7	September	29.0	29.3	25.9	29.0	81	83	79	81	43	43	255	43	0.6	0.6	0.3	0.5
8	October	20.2	20.4	21.9	20.0	79	80	67	80	0.0	0.0	10	0.0	0.3	0.3	0.8	0.2
9	November	17.0	17.3	17.3	16.8	89	88	72	90	0.0	0.0	0.0	0.0	0.1	0.2	0.6	0.4
10	December	9.6	9.0	12.4	10.0	90	89	71	94	7	7	6	7	0.3	0.4	0.6	0.2
11	January	14.0	13.1	11.6	14.5	85	84	69	93	12	12	13	12	0.4	0.5	0.7	0.3
12	February	13.0	12.2	13.9	13.2	89	88	67	91	0.0	0.0	19	0.0	0.5	0.6	0.7	0.4

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