Assessment of ambient air quality in urban centres of Haryana (India) in relation to different anthropogenic activities and health risks

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Abstract

Considering the mounting evidences of the effects of air pollution on health, the present study was undertaken to assess the ambient air quality status in the fast growing urban centres of Haryana state, India. The samples were collected for total suspended particulate matter (TSPM), respirable suspended particulate matter (PM_{10}), sulfur dioxide (SO_2), and for oxides of nitrogen (NO_2) during different seasons from 8 districts of Haryana during January, 1999 to September, 2000. The four types of sampling sites with different anthropogenic activities i.e. residential, sensitive, commercial and industrial were identified in each city. The ambient air concentration of TSPM and PM_{10} observed was well above the prescribed standards at almost all the sites. The average ambient air concentrations of SO_2 and NO_2 were found below the permissible limits at all the centres. Comparatively higher concentration of SO_2 was observed during winter seasons, which seems to be related with the enhanced combustion of fuel for space heating and comparatively stable atmospheric conditions. Air Quality Index (AQI) prepared for these cities shows that residential, sensitive and commercial areas were moderately to severely polluted which is a cause of concern for the residents of these cities. The high levels of TSPM and SO_2 especially in winter are of major health concern because of their synergistic action. The data from Hisar city reveals a significant increase in the total number of hospital visits/admissions of the patients with acute respiratory diseases during winter season when the level of air pollutants was high.

Keywords: urban centres, TSPM, PM_{10}, vehicles, air quality index, human health.

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1. Introduction

Air pollution has long been recognized as a potentially lethal form of pollution. Entry of pollutants into the atmosphere occurs in the form of gases or particles. Continuous mixing, transformation and trans-boundary transportation of air pollutants make air quality of a locality unpredictable. The growth of population, industry and number of vehicles and improper implementation of stringent emission standards make the problem of air pollution still worse (Ravindra et. al., 2001). The WHO/UNEP report (1992) reveals air pollution problems in metropolitan cities of India as they are heading the list of the most polluted cities of the world. India has 23 major cities of over 1 million people and ambient air pollution levels exceed the WHO standards in many of them (Gupta et. al, 2002). The single most important factor responsible for the deterioration of air quality in the cities is the exponential increase in the number of vehicles. Vehicular pollution contributes to 70 % of total pollution in Delhi, 52 % in Mumbai and 30 % in Calcutta (C.P.C.B., 2003; Gokhale & Patil, 2004; Ravindra et al., 2005).

Pollution in these cities has associated serious to moderate health problems due to high levels of total suspended particulate matter (TSPM), sulfur dioxide (SO_2) and lead (The World Bank report, 1997). At least 500,000 premature deaths and 4 to 5 million new cases of chronic bronchitis are reported each year (WHO, 1992). Further 4% to 8% of premature deaths on a global scale are due to exposure of high levels of particulate matter in ambient air (WHO, 2000). Ambient air levels exceeding the WHO levels in 36 major Indian cities and towns results in 40 thousand premature deaths, around 19 million respiratory hospital admissions and sickness requiring medical treatment and also 1.2 billion incidences of minor sickness annually (Brandon & Homman, 1995).

Despite the increasing evidence of negative impact of air quality on human health (Dockery et al., 1993a,b; Pope et al., 1995; Kunzli et al., 2000), not much data on ambient air quality, a prerequisite for health studies, is available for most of the medium size cities or towns in India, although a large population lives in these cities or towns. Not much information on the air quality of Haryana, which has experienced rapid industrial and vehicular growth during last few decades, is available. In the present study, an attempt has been made to assess the prevailing concentration and trends of the TSPM, PM_{10}, SO_2 and NO_2 in the fast growing urban centers of various cities in relation to different anthropogenic activities. Furthermore, the epidemiological data of Hisar city was evaluated in relation to the health risks of these criteria pollutants.

2.Materials and Methods

2.1. Site specifications

Haryana is a fast developing state of north India situated at 30^0 30' N, 74^0 60' E and around 210-275 m above mean sea level with an area of 44,000 Km^2. The population is about 21.1 million (2001). Approximately 29% people reside in cities. The cities are dominated by various small, medium and large-scale industries. From 1966 to 1997, the total number of industries has increase up to 7 time, whereas a 75 times increase in total number of vehicle has been registered.

Eight major cities namely, Bhiwani, Gurgaon, Faridabad, Sonipat, Panipat, Yamunanagar, Panchkula and Hisar were selected for the ambient air quality monitoring (Fig.1), which have observed considerable growth in commercial and industrial sector during last few years. A total of four sampling sites were selected in each city on the basis of differential population activity and characteristics, which includes residential (R), sensitive (S), commercial (C) and industrial (I) areas. In most of the cases district civil hospital was selected as the sensitive site.

2.2. Sampling and analytical procedure

APM-460 respirable dust samplers (RDS) with provision for gaseous sampling APM-411 (Envirotech, New Delhi) was used for measuring the concentrations of TSPM, PM_{10}, NO_2 and SO_2 in the ambient air. The sampling inlet was placed 1-3 meter above the ground level, depending upon the site available for the RDS. The APM-460 Respirable Dust Sampler has been provided with a cyclone. The cyclone has been designed to provide separation of PM_{10} particles. Atmospheric air was drawn for ~24 hours through the cyclone and 20 X 25 cm glass fiber filter (GFF) sheet at a flow rate of 0.8 to 1.2 m^3min^{-1} and finally the average flow rate was calculated.

As the air with suspended particulate enters the cyclone, coarse non-respirable dust is separated from the air stream by centrifugal forces. The suspended particulate matter falls through the cyclone's conical hopper and gets collected in the cyclonic-cup. The fine dust comprising the respirable fraction of TSPM passes through the cyclone and gets collected on GFF. The amount of non-respirable suspended particulate matter (NRSPM) and respirable particulate per unit volume of air passed was calculated on the basis of the difference between initial and final weights of the cyclone cup and that of the filter paper, and the total volume of the air drawn during sampling. Mass concentration of TSPM was calculated by adding the concentration of PM_{10} and NRSPM. For gaseous (SO_2 and NO_2) sampling the impingers were exposed for ~24 hour at an impingement rate of 1 Litre min^{-1} to get one sample in a day. SO_2 was analyzed by the West-Gaeke method on Spectronic-21 spectrophotometer at wavelength of 560 nm. NO_2 was analyzed employing the Jacob- Hochheiser modified method on a spectrophotometer at wavelength of 540 nm (Lodge, 1989).

2.3. Air quality index (AQI)

The Air Quality Index (AQI) was calculated using the method suggested by Tiwari and Ali (1987). First of all, the air quality rating of each pollutant was calculated by the following formula:

$$Q = 100 \frac{V}{Vs}$$

Where, Q represents quality rating, V the observed–value of the pollutant and Vs the standard value recommended for that pollutant. The Vs values used are as National Ambient Air Quality Standards (Table 1) for different areas.

If total 'n' number of pollutants were considered for air quality monitoring, geometric mean of these 'n' number of quality rating is calculated in the following way:

$$g = \text{antilog} \frac{(\log_a + \log_b + \log_c + \ldots \log_x)}{n}$$

Where 'g' is geometric mean, while 'a, b, c, and x' represents different value of quality rating, and 'n' is number of values of quality rating.

3. Results and Discussions

3.1. Site-specific variations

The average concentration of various criteria pollutants is shown in Table 2. The ambient air concentration of TSPM was observed more than the stipulated standards at almost all the sites. It ranged from 158.3 $\mu g/m^3$ (Sonipat) to 868.0 $\mu g/m^3$ (Faridabad) in residential areas and 104.1 $\mu g/m^3$ (Bhiwani) to 812.1 $\mu g/m^3$ (Hisar) in sensitive areas. Commercial areas also had TSPM concentration above the recommended limit (200 $\mu g/m^3$) and ranged from 191.3 $\mu g/m^3$ (Hisar) to 1756.6 $\mu g/m^3$ (Sonipat), whereas the TSPM levels in industrial areas varies from 126.4 $\mu g/m^3$ (Panipat) to 1075.8 $\mu g/m^3$ (Yamunanagar). Further, it was observed that average concentrations of PM10 ranged from 32.0 $\mu g/m^3$ in sensitive area in Panchkula to 430.0 $\mu g/m^3$ in commercial area in Sonipat and were found lower than the non-respirable suspended particulate matter (range from 39.5 $\mu g/m^3$ in Bhiwani to 1493 $\mu g/m^3$ in Hisar).

The WHO reports (1998, 1999) also shows that, most of the cities in developing world including several cities of India experience the TSPM level above 300 $\mu g/m^3$. The data on PM_{10} is available only for a limited number of cities which reveals that the annual average PM_{10} level ranged from 50 to 100 $\mu g/m^3$ in the year 1995/1996. The highest concentration exceeding 250 $\mu g/m^3$ were observed in Kolkata and New Delhi. Comparison of our results with WHO reports reveals higher levels of particulate matter in the present study. The probable reason for the high levels of atmospheric TSPM and PM_{10} could be due to industrial and agriculture activities.

Gaseous pollutants (SO_2 and NO_2) were found below the permissible limits at all the centres except at few sites in Gurgaon, Faridabad, Sonipat, Panipat and Yamunanagar in January, 1999. The levels of SO_2 during year 2000 sampling period were well below the permissible limit at all the sites. The SO_2 concentrations in the ambient air in cities of developed countries have mostly decreased in the last two or three decades, due to strict emission control, increased use of low sulfur content fuel and industrial restructuring. Consequently, the high SO_2 concentrations in earlier decades have been replaced by annual mean concentration of about 20-40 $\mu g/m^3$ in most cities of the developing countries, and the daily average values rarely exceed 125 $\mu g/m^3$ (WHO, 1998). The levels of SO_2 observed in the present study are in conformity with the above observation.

The residential, commercial and industrial areas in all the cities exhibited lower concentration of whereas sensitive locations in few cities exhibited higher levels NO_2 compared to the prescribed limits. The NO_2 level ranged from 10.6 μg/m^3 (Hisar) to 83.6 μg/m^3 (Gurgaon) and 17.7 μg/m^3 (Bhiwani) to 117.1 μg/m^3 (Yamunanagar) in sensitive and industrial areas, respectively. In most of the cities the annual mean concentration of NO_2 remains moderates or low, not exceeding 40 μg/m^3 (WHO, 2000). However, in the preseny study, the NO_2 values recorded were relatively high.The highest NO_2 levels and the increasing trends are observed in cities with high and increasing vehicular traffic.

Comparative account of cities based on average pollutant concentration shows that Sonipat, Faridabad, Yamunanagar and Hisar were the most polluted followed by Gurgaon, Panipat, Panchkula and Bhiwani (Fig 2). Similar results have been observed by Bhanarkar et al. (2002) in a study to assess the air pollution concentrations in Haryana sub region.

Since fine particulate matter has associated heavy metals and other priority pollutants on its surface, it can pose serious threat to human health with special reference to the respiratory disorders (Dockery et al., 1993a,b; pope et al., 1995). The association of toxic elements with PM_{10} and smaller particles can be even more harmful as these can penetrate deep into the respiratory tract. Hence, high levels of TSPM particularly of PM_{10} are of major concern in health perspectives and there is an urgent need to regulate the ambient air quality especially in sensitive areas because of exposure of sensitive population i.e. the patients.

3.2. Seasonal variations

Seasonal comparison of SO_2 and NO_2 levels shows a higher value in winter than observed in pre-monsoon and post monsoon seasons. Significantly high levels of SO_2 were observed in January 1999 in comparison to the subsequent sampling period. The probable reason for a sharp fall in SO_2 concentration seems to be related with the adoption of EURO I (European emissions and fuel regulations) standards nationwide in the year 2000 for four wheeled light duty and heavy duty vehicles and hence the use of low sulphur diesel (LSD) was recommended and observed. However, higher concentration of SO_2 noticed in few residential and commercial areas during winter season could be related to the enhanced combustion of fuel for space heating. Apart from it, comparatively stable atmospheric conditions in winter may also account for built up concentration of ambient air pollutants (Ravindra et al., 2003 and 2005). The high NO_2 concentrations, combined with the intensive UV radiation, results in photochemical smog with high O_3 concentration, which can adversely affect the human health. Studies conducted by Singh et al., (1997) and Reddy et al., (2004) also confirm similar phenomena in New Delhi and Vishakhapatnam , respectively.

A relative fall in TSPM, PM_{10} SO_2 and NO_2 levels during post-monsoon may be due to the washout of these air pollutants by monsoon rains. Ravindra et al. (2003) have also reported a significant decrease in SO_2 (~38 %), NO_2 (~44 %) and TSPM (~48%) levels just after the initial shower of monsoon in Delhi. An increased concentration of TSPM and PM_{10} was observed in pre-monsoon. The sources of such particulates are vehicular and industrial emissions as also the suspended fine dust carried by the trans-boundary winds from Rajasthan. This unique behavior of winds is generally observed during months each year in Haryana.

3.3. Air Quality Index (AQI)

AQI is developed to provide the information about air quality. From a series of observations, an index (a ratio or number) is derived which is an indicator or measure of some condition or property.The concentration of the major pollutants are monitored and subsequently are converted into the AQI (Table 3) using standard formulae, which in the present case are defined in experimental section. In the present investigation, the TSPM, PM_{10}, SO_2 and NO_2 level in various cities have been used to calculate AQI. The higher value of an index refers to a greater level of air pollution and consequently greater health risks.

The categorization of ambient air quality with respect to the AQI is presented in Table 3. On the basis of AQI, it can be seen that the residential, sensitive and commercial areas were moderately to severely polluted (AQI 50-125) and whereas the industrial areas, on an average, lie in the range of fairly clean (AQI 25-50) to moderately polluted (AQI 50-75) except the industrial area in Yamunanagar, which is moderately to heavily polluted. It should be noted that for industrial area the norms for standard prescribed concentration in comparison to other sites have been relaxed.

3.4. Health risk study of Hisar city

Various air pollutants are known to cause/ aggravate cardiac and respiratory diseases like asthma, bronchitis and emphysema. Individuals with cardiovascular diseases or chronic lung diseases, children and elderly are more susceptible (EPA, 2000). Though the mechanisms are not fully explained, epidemiological evidence suggests that outdoor air pollution is a contributing cause to morbidity and mortality (Bates, 1992; Katsouyanui et al.; Kunzli et al., 2000). State-of-the-art epidemiological research has found consistent and coherent associations between air pollution and various symptoms. Most of the air pollution studies have been conducted in the developed countries. Epidemiological data on the health effects of air pollutants are not abundant for most of the developing countries, where a major proportion of the population lives in environmentally poor conditions.

In the present study the data related to visit of patient for acute respiratory disease was obtained (Table 4) from district civil hospital of Hisar city for the year 1999 and 2002. The comparison of the data shows a significant fall (< 40 %) in the total number of patient who visited during 2002, which besides other reasons can be related to the fall in SO_2 and NO_2 concentration in 2002 after the adoption on Euro I norms. It was also noticed that a large number of patients visited hospitals during the winter season in comparison to other seasons. During winter, cold weather condition with high levels of pollutants may aggravate the condition of sensitive population and hence results in increased hospital visits in the winter months.

4. Conclusion

Based on the study, it can be easily concluded that emission of SO_2 and NO_2 has considerably been reduced after the adoption of LSD and catalytic converters in vehicles. PM_{10} and TSPM are the chief air pollutants in most of the cities of Haryana, which pose the health risks either alone, or in combination with other pollutants. The ambient concentration of all the air pollutants decrease in post-monsoon as the monsoonal rain is responsible for the washing of ambient air pollutants. When compared with respective standards, the AQI of residential and commercial areas is high and indicates the possible threat of air pollutants to the residents of these localities. The present study also reveals a significant increase in the total number of patients admitted for respiratory problems in winter.

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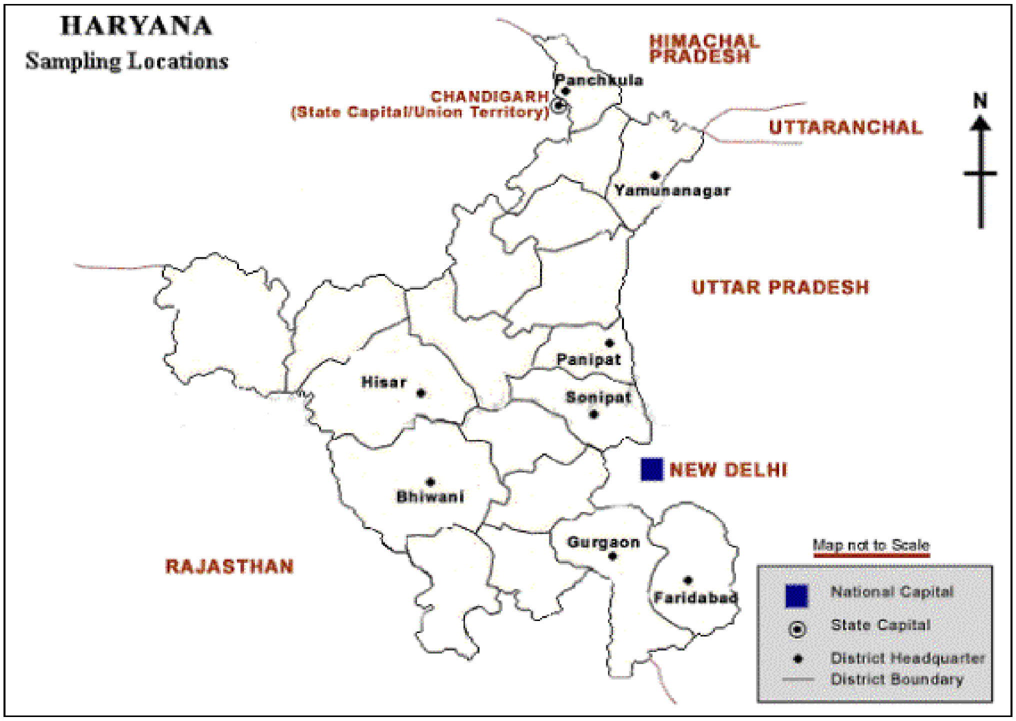

Fig 1: Location of different cities selected for the sampling.

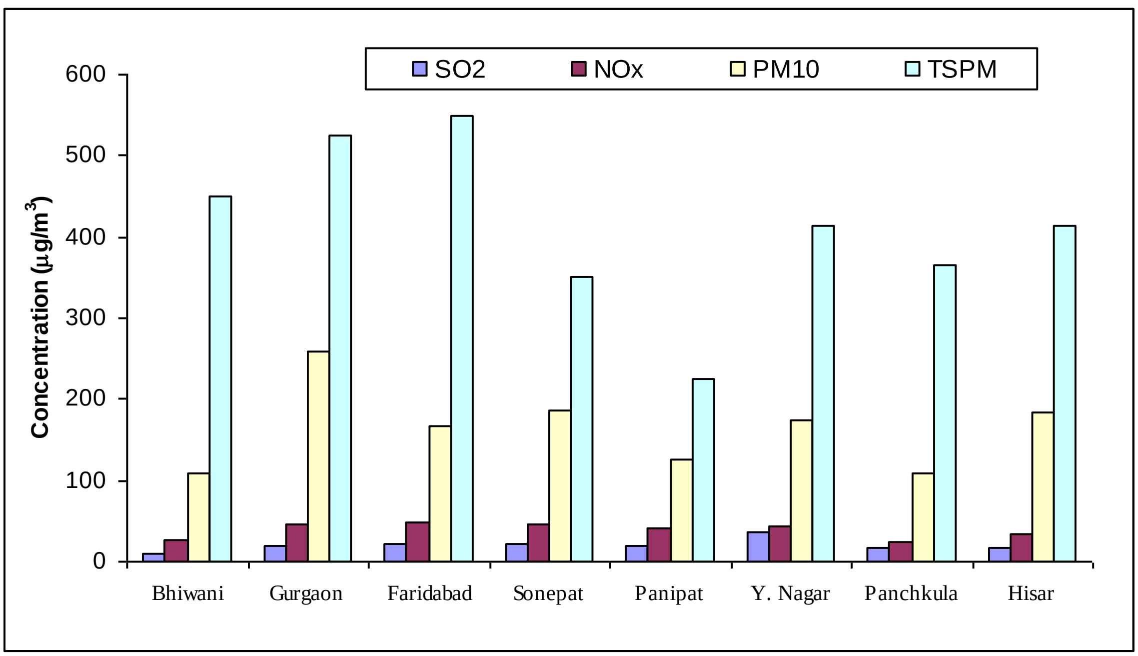

Fig 2: Average concentration of different pollutants ($\mu g/m^3$) in different cities of Haryana

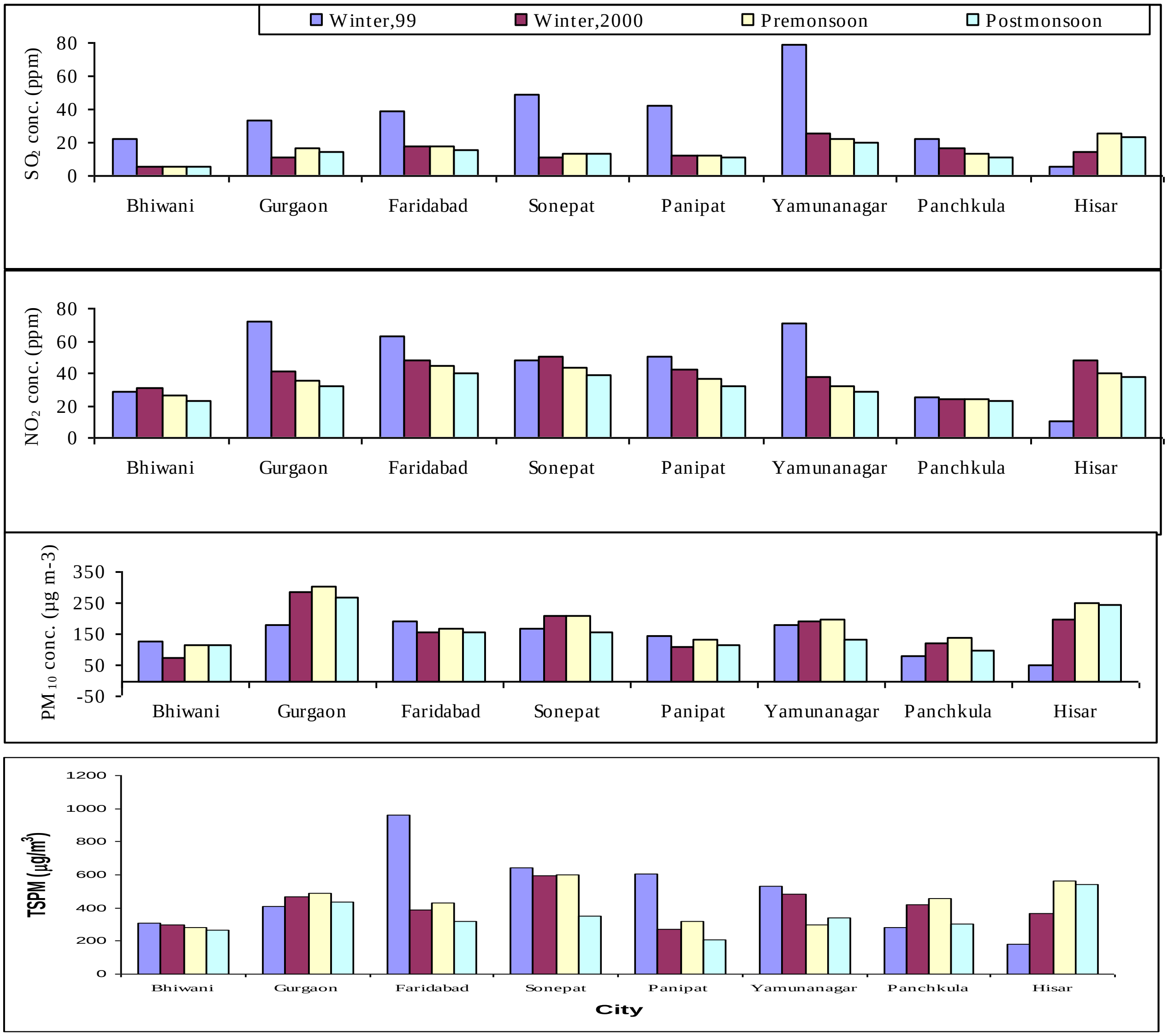

Fig 3: Variation in average SO_2, NO_2, PM_{10} and TSPM levels during different season in various cities of Haryana.

Table 1: National ambient air quality standards for 24 time weighted average.

Pollutants	Concentration in ambient air (μg/m^3)		
	Sensitive area	Industrial area	Residential area
SO_2	30	120	80
NO_2	30	120	80
TSPM	100	500	200

Source: CPCB, 2000

Table 2: The average ambient air concentration of pollutants (μg/m^3) and AQI for different cities of Haryana.

		Jan., 99					**Jan., 2000**					**June, 2000**					**Sept., 2000**				
		SO_2	**NO_2**	**PM_{10}**	**TSPM**	**AQI**	**SO_2**	**NO_2**	**PM10**	**TSPM**	**AQI**	**SO_2**	**NO_2**	**PM10**	**TSPM**	**AQI**	**SO_2**	**NO_2**	**PM10**	**TSPM**	**AQI**
Bhiwani	**R**	25.6	38.5	117	271.7	IV	8.8	36.2	103	571.9	IV	6.4	24.7	120	292.9	III	7	21.7	119	281.6	III
	S	17.9	20.9	111	215.2	VI	2.1	14.8	56.5	104.1	III	2.4	16	108	284.1	IV	2.8	14.8	109	281	IV
	C	28.2	31.9	191	587.3	VII	6.1	51.4	81.6	191.3	IV	7.1	42.2	129	316.8	IV	7.4	36.4	122	312.6	IV
	I	15.6	23.9	84.9	157.3	II	6.8	22.1	59.5	314	II	6.5	21.3	109	229.4	III	6.6	17.7	103	192.5	III
Gurgaon	**R**	25.5	59.4	154	325.6	V	15.1	40.2	318	488.9	V	18.8	32.5	324	495.8	V	15.5	32.5	286	431.6	V
	S	26.9	83.6	200	421.1	VII	14.9	29.4	269	507.2	VII	18.9	24.5	270	508.2	VII	14.4	21.1	245	469.3	VII
	C	53	84.5	215	610	VII	7.4	42	253	480.1	IV	21.5	35.2	308	539.4	VII	18.7	32.3	257	462.8	VII
	I	26.7	58.5	150	271.7	III	8.5	52.1	301	399.4	III	9.4	47.7	305	416.8	V	9.1	42.6	290	387.5	III
Faridabad	**R**	12.9	71.7	130	868	V	5.8	41.6	149	295.2	IV	7.5	40.3	172	326.6	IV	7.9	39.4	153	261.5	V
	S	16.7	45.1	149	504.2	VII	4.9	31.4	133	315.2	VII	5.4	31.9	138	329.2	VII	5.2	32.2	129	279	V
	C	94.9	97.7	261	1618	VII	10.2	49.8	171	582.3	V	14.2	52.7	186	579.8	V	11.6	44.8	176	432.1	IV
	I	31.9	35.1	220	857.5	III	48.5	69.2	161	349.4	IV	41.9	54.4	181	486.4	IV	39.5	41.5	165	292	IV
Sonepat	**R**	87	19.7	123	413.3	V	5.5	44.8	115	158.3	IV	5.1	44.9	116	195.1	III	4.8	44.2	74.2	161.6	III
	S	49.8	78.4	122	403.6	VII	15.3	25.5	127	231.4	VI	14.2	29.2	138	256.5	VI	13.8	25.4	110	234.2	IV
	C	46.6	74	322	1535.5	VII	15.6	73.5	430	1756.6	VII	16.7	52.9	409	1684.8	VII	16	45.7	326	804.2	VI
	I	11	20.2	104	227.1	II	8.4	57.1	158	235.9	IV	17	48.7	172	261.1	IV	16.6	42	122	208.4	III
Panipat	**R**	83.4	40.9	171	719.2	VII	13.5	29.3	78.1	228.8	III	10.2	25.9	106	274.2	III	9	21.9	99	189.9	III
	S	42.3	34.4	78.2	243.9	VII	6.8	30.5	118	335.1	VI	5.4	26.9	131	361.1	V	4.9	21.6	123	245.2	V
	C	NA	93.4	199	1124.4	VII	11.6	49	161	374.4	V	16.6	46.1	172	395.3	V	15.7	41.4	156	271.5	IV
	I	43	31.5	138	338.5	III	16.2	59.3	86.7	151.7	III	16.9	47	128	235	III	16	42.1	84.2	126.4	III
Y.Nagar	**R**	55.4	48.7	147	387.4	VI	31.9	50.8	129	306.6	V	30.3	25.5	119	392.2	IV	23.9	24.2	92.5	208.2	IV
	S	53.8	50.1	119	252.3	VII	7.8	17.4	109	221.7	V	7.4	19.4	104	234.2	V	6.4	17.2	84.9	202.3	IV
	C	78.7	69.2	148	413.2	VII	8.5	30.3	225	589.7	V	9.4	35.9	173	572.9	IV	8.9	33.5	127	428	IV
	I	129	117	303	1075.8	VII	55.2	53.2	298	807.6	V	43.1	46.7	392	809.3	V	39.9	41.3	235	512.8	IV
Panchkula	**R**	17	17.5	80.2	286.5	III	8.6	24	120	285.7	III	6.2	23.6	123	307.5	III	6.1	22.5	104	242.3	III
	S	8	17.5	32	108.3	IV	8.4	17.4	72.4	162.5	V	7.6	21.8	109	218.6	V	7.7	21	51.4	134.2	IV
	C	41.1	33.5	80.4	395.7	V	8.4	21.5	173	700.2	V	8.7	24.4	184	721.4	IV	9.1	24.6	116	430	IV
	I	23	30.2	126	328.5	III	39.9	33.5	116	521.4	IV	30.3	27.2	143	582.7	IV	23.6	25	109	408.2	III
Hisar	**R**	3.7	10.2	61.7	159.5	II	3.3	10.1	104	282.9	III	13.8	16.3	108	306.5	III	10.1	11.1	105	282.4	III
	S	4.1	10.6	52.8	137.6	III	3.8	20.1	123	313.9	V	24.5	24.7	343	812.1	VII	22.2	20.5	319	804.5	VII
	C	16.4	19.9	77.9	244.5	III	20.9	82.2	392	885	VII	29.3	56.2	386	844.3	VII	28.4	55.2	381	805.9	VII
	I	NA	NA	NA	NA		27.4	80.7	170	270.4	IV	36.1	64.2	172	292.6	IV	33.9	61.8	161	278.8	IV

NA- Data not available;R- Residential;S- Sensitive;C- Commercial and I- Industrial

Table 3: Air quality categories based on AQI.

Category	AQI of ambient air	Description of ambient air quality
I	Below 10	Very clean
II	Between 10-25	Clean
III	Between 25-50	Fairly clean
IV	Between 50-75	Moderately polluted
V	Between 75- 100	Polluted
VI	Between 100-125	Heavily polluted
VII	Above 125	Severely polluted

Table 4: Data on patients with respiratory disease, collected from District Civil Hospital, Hisar.

Months/ Year		Patient visited			Patient admitted		
		Male	Female	Total	Male	Female	Total
January	1999	*	*	995	*	*	31
	2002	287	251	538	47	31	78
February	1999	249	201	450	16	12	28
	2002	*	*	*	*	*	*
March	1999	209	128	347	19	12	31
	2002	138	72	210	12	9	21
April	1999	168	140	318	15	5	20
	2002	*	*	*	*	*	*
May	1999	*	*	*	*	*	*
	2002	30	42	72	7	5	12
June	1999	281	173	454	18	14	32
	2002	111	97	208	6	3	9
July	1999	382	212	594	24	18	42
	2002	121	87	208	7	2	9
August	1999	288	176	464	19	11	30
	2002	130	74	204	17	4	21
September	1999	212	194	406	30	15	45
	2002	140	64	204	15	3	18
October	1999	304	207	521	50	18	68
	2002	*	*	*	*	*	*
November	1999	385	270	655	62	24	86
	2002	*	*	*	*	*	*
December	1999	634	390	1024	120	60	180
	2002	*	*	*	*	*	*

* No data available