

Evaluation of Air Pollution Status and Anticipated Performance Index of some Tree Species for Green Belt development in the holy city of Kurukshetra, India

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Abstract

Urban air pollution is a global problem having considerable impact over health and vegetation. Green belts are recognized as effective tools for alleviation of air pollution. The present study was conducted to calculate the impact of air pollution over biochemical parameters of selected tree species at different locations of the holy city of Kurukshetra, Haryana. The ambient air quality status was monitored at 7 traffic intersections of the city for three consecutive years and the concentration of major air pollutants (SO₂, NO₂ and SPM) was measured. Suspended particulate matter concentration exceeded the prescribed limits of CPCB at all the locations. Air Pollution Tolerance Index (APTI) of 10 common tree species was evaluated by determining biochemical parameters. The Anticipated Performance Index (API) of these plant species was also calculated by considering their APTI values together with other socio-economic and biological parameters. The most suitable plant species for green belt development in urban areas were identified and recommended. *Mangifera indica* and *Eucalyptus tereticornis* were classified in to 'best' category whereas, *Ficus benghalensis* and *Ficus religiosa* were identified as 'good' performers. The plant species identified are recommended for long-term management of air pollution.

Keywords: Air Pollution, Air Pollution Tolerance Index, Anticipated Performance Index, Green belt, Kurukshetra

ABBREVIATIONS

APTI, Air pollution tolerance index; API, Anticipated performance index; CPCB, Central pollution control board; NO₂, Nitrogen dioxide; RSPM, Respirable suspended particulate matter; SO₂, Sulfur dioxide; TSPM, Total suspended particulate matter.

I. INTRODUCTION

Impact of air pollution over environment and human health is a matter of great concern. It is documented to be a threat to urban zones of both developing and developed nations [1]. Rapid development, population growth, urbanization and industrialization have resulted in an increased concentration of various air pollutants, over their ideal limits. An exponential increase in the number of automobiles in cities is contributing towards deterioration of air quality, with an approximate contribution of about 40 to 80% to the total air pollution [2]. Air pollution index of several Indian cities is reported to be highest in the world [3, 4]. Long term exposure to pollutants has considerable impact over human health with increased risk of respiratory and other disorders including lung cancer, asthma and many more [5, 6]. According to an earlier report of World Health Organization, over 8 lakh deaths (1.4% of the global total) can be attributed to urban air pollution [7].

Plants present characteristic response and symptoms in response to particular types and level of air pollution. Reduction in plant height; canopy area; plant biomass; and chlorophyll, ascorbic acid and nitrogen content of plants growing at polluted sites are among the common responses against air pollution [8]. Vegetation plays a vital role in maintaining the ecological balance by actively participating in nutrients cycling and air pollution reduction through active absorption and accumulation [9]. This pollution abatement potential differs with plant species; type and characteristics of air pollutants; and local meteorological conditions [10, 11]. Besides removal of pollutants, trees also contribute towards improvement of local air quality by refining microclimate. Also, they could help in lowering of local air temperature by evapo-transpiration [12]. Urban trees could reduce energy consumption, which in turn alter local meteorology, deposition velocity of air pollutants and anthropogenic air pollutant emissions [13].

Existence of green cover around urban area can improve air quality through enhanced uptake of gases and particulate matter [14]. Development of green belt in and around the polluting source is now being promoted as an environment friendly solution to the globally noticed problem [15] with growing focus towards plants having inherent tolerance against pollutants [16]. Selection of tree species is the most critical factor that governs the success of green belt development. Plants are categorized into Sensitive

or Tolerant, based on their response towards stress agents [17]. Tree species under Sensitive group are early indicators of pollution, while those tolerant, helps in mitigating the overall pollution load [18]. Response of plants towards air pollutants is being assessed by air pollution tolerance index (APTI), which determines inherent quality of plants to encounter air pollution stress. Plant sensitivity and tolerance to air pollutants is determined by studying their impact over basic biochemical parameters viz. ascorbic acid, total chlorophyll, relative water content and leaf extract pH, that are ideal indicators of tolerance levels of plant species [19 - 21]. APTI provides valuable information for green belt designers to select the sensitive as well as tolerant varieties of plant species [22]. APTI values, along with other biological and socio-economic characters generate the Anticipated Performance Index (API) of plants [9].

Despite the increasing evidence of relation between degrading air quality and risk to human health, significant data on ambient air quality of urban areas is scanty and medium size cities or towns in India are at constant threat. Thus, it is necessary to assess the current status of urban air pollution and indigenous site specific plant species, so that proper mitigative measures can be implemented. The present study examines the ambient air quality status at different traffic intersections of the holy city of Kurukshetra and the effect of air pollution on physiological attributes of certain plant species with an aim to select the stress tolerant species for green belt development in and around the city.

II. MATERIALS AND METHODS

A. Study Sites

Kurukshetra city in Haryana, India is the land of the sermon of sacred Gita and hub for religious tourism. The district has geographical area of 1682.53 sq. km and is located between 29°-52' to 30°-12' N latitude and 76°-26' to 77°-04' E longitude. It welcomes a large number of tourists every month, resulting in the increased number of automobiles which contributes towards air and water pollution in the city. To assess the ambient air quality status of the city, sites were categorized as Residential unpolluted site; road transportation site; unplanned commercial site; planned commercial site and intense traffic flow site. Seven sampling stations representing seven traffic intersections (Figure 1) were selected within categorized sites viz. Kurukshetra University Campus (Site-I, Residential unpolluted site), Kurukshetra University Entrance Gate (Site-II, Road transportation site), Kalyan Nagar (Site-III, Residential unpolluted site), City Market (Site-IV, Unplanned commercial site), Urban Sector-17 (Site-V, Planned commercial site), New Bus Stand (Site-VI, Intense traffic flow site) and Pipli-National Highway-1 (Site-VII, Intense traffic flow site).

B. Ambient Air-Quality Monitoring

Ambient air quality was assessed through monitoring major air pollutants viz. Suspended Particulate Matter (SPM), Sulphur dioxide (SO₂) and Nitrogen dioxide (NO₂) following standard methods prescribed by Central Pollution Control Board (CPCB) of India. The study was carried out during the spring season of 2012, 2013 and 2014. The data for spring season of each year was averaged (\pm S.E) for each pollutant for respective sites. The concentration (24h average) of the Total Suspended Particulate Matter (TSPM) and Respirable Suspended Particulate Matter (RSPM) was determined by using High Volume Air Sampler (APM 460 BL). SO₂ was measured by modified West and Gaeke method [23]. SO₂ in ambient air was absorbed in a solution of potassium tetrachloride mercurate (0.04M) and analysed colorimetrically. NO₂ was measured by Modified Jacobs-Hochheiser method [24]. NO₂ in ambient air was absorbed in a solution of sodium hydroxide and sodium arsenite and analysed using colorimetric technique. Suspended particulate matter was measured by gravimetric technique. High volume sampling with Whatmann filter paper was used at an average flow rate being not less than 1.1 cubic m/min.

C. Sample Collection of Plants

For the present study, ten common tree species of similar age group from all the seven sites were selected. These included *Azadirachta indica*, *Dalbergia sissoo*, *Eucalyptus tereticornis*, *Ficus benghalensis*, *Ficus religiosa*, *Mangifera indica*, *Melia azadirachta*, *Psidium guajava*, *Saraca indica* and *Syzigium cumini*. Fully matured leaf samples were collected in the winter season of 2014. The picked leaves were collected in the marked polythene bags and transported to the laboratory to preserve at 4°C for further analysis of ascorbic acid; chlorophyll; relative water content and leaf extract pH. Fresh weight of leaf samples was taken immediately after reaching the laboratory.

D. Biochemical Analysis of Plants

Plant leaf samples were analysed for various biochemical parameters such as ascorbic acid [25], leaf extract pH [26], total chlorophyll and relative water content [27]. The APTI, an empirical value representing tolerance level of a plant to air pollutants, was considered to interpret the impact of pollution on the plants [19]. APTI was calculated using the formula:

$$APTI = [A (T + P) + R]/10$$

Where, A is the ascorbic acid content in mg g⁻¹ of fresh weight; T is the total chlorophyll in mg g⁻¹ of fresh weight; P is the pH of leaf extract and R is the relative content of water, in percentage.

For the selection of most suitable plant species for green belt development, Anticipated Performance Index (API) of plants was calculated. All samples of 70 plants collected from seven sites were evaluated in terms of their API. The API values were calculated by combining the resultant APTI values with some relevant biological and socio-economic characters (plant habit,

canopy structure, type of plant, laminar structure and economic value). Based on these characters, different grades were allotted to plants and scoring as per their grades. The criteria used for calculating API of different plant species are documented in Tables 1-3. Based on the values of API, promising plants were recommended for green belt development.

III. RESULTS AND DISCUSSION

A. Assessment of Air Pollution Status

The average concentrations of various pollutants at seven sampling sites during 3 years of study are recorded in Figures 2-5. These values were compared with ambient air quality standards laid down by CPCB (2009). The concentration of TSPM and RSPM were observed to be more than the prescribed limits ($200\mu\text{g}/\text{m}^3$ and $100\mu\text{g}/\text{m}^3$ respectively) at all the study sites. The average concentration of TSPM ranged from 492 to $619\mu\text{g}/\text{m}^3$ with highest concentration recorded at Site VII (Intense traffic flow site) and least at Site III (Residential unpolluted site). The average concentration of RSPM ranged from 138.5 to $188.4\mu\text{g}/\text{m}^3$. Maximum concentration was recorded at site VII ($188.4\mu\text{g}/\text{m}^3$) and minimum at Residential unpolluted site ($138.5\mu\text{g}/\text{m}^3$). RSPM and TSPM values at intense traffic flow site (VII) were approximately over 1.8 and 3 times higher than the prescribed CPCB limits, respectively. The concentration of gaseous pollutants (SO_2 , NO_2) was found to be within the permissible range of $80\mu\text{g}/\text{m}^3$ at all the sampling sites. Highest value of NO_2 was observed at Site VII ($40.85\mu\text{g}/\text{m}^3$) and lowest at Site III. Concentration of sulphur dioxide ranged from 8.7 to $1.7\mu\text{g}/\text{m}^3$ with maximum value at Site VII and minimum at Site III.

An increasing trend in pollution status was observed at all studied sites in consecutive years. This may be attributed to an yearly increase in the number of tourists along with increase in vehicle load. The city has great pilgrimage centre's for Hindus, and around 860 sites of pilgrimage related to Mahabharata even exist today [28]. It is quite evident from the study that SPM was the major pollutant at all the sampling stations. This increase in levels of SPM above the threshold limits is of alarming concern due to incidence of bronchitis and asthma associated with it [29]. The association of SPM with premature mortality and various morbidity effects have been well-documented in earlier studies [30-32].

Further, high dose of SO_2 plays an important role in the reduction of chlorophyll content [33] and may induce stomatal closure [34]. Air pollutants have been reported to damage the membrane integrity, resulting in increased cell permeability [35]; which is more prominent in case of sensitive species [36]. Increase in cell permeability may cause water loss from the guard cell, resulting in stomatal closure. Although the pollutants studied may or may not have any adverse effects on human health at the recorded concentrations, but a combination of two or more pollutants can have detrimental effects [37].

B. Biochemical Analysis of Selected Plant Species

The biochemical characteristics of selected plants along with their APTI and API values are documented in tabular form (Table 4-10). The plant potential to absorb and adsorb pollutants over their foliar surface depends on several morphological, biochemical and physiological characteristics [9]. Ascorbic acid, an antioxidant found in the growing parts of plants, influences their resistance towards adverse environmental conditions, such as air pollution [25]. High concentration of ascorbic acid in leaves indicates strong air pollution tolerance of plants [38]. Chlorophyll content of plants varies between species; influenced by age of leaf, other biotic and abiotic factors and also with the environmental pollution level [39]. Photosynthetic pigments add towards pollutant tolerance potential of plants [40]. However, are highly prone to damage by the level of air pollutants [41]. Higher pH [42] and relative water content of plant species helps in maintaining its physiological balance under air pollution stress [43].

The changes observed in the air pollution tolerance index of studied plant species from polluted sites were compared to those dwelling in non-polluted sites. Different plant species responded differently to air pollution index referring that higher pollution levels has marked impact over the APTI values, as observed by high values, in comparison to the moderately polluted sites. Higher APTI values indicate higher pollution tolerance and lower index values depict sensitivity towards pollutants. Hence, based on APTI values, plants can be used as indicators of levels of air pollutants [19].

All plant species from different study sites were evaluated and graded as per their Air pollution tolerance index and relevant socio-economic and biological parameters. Evaluation of API revealed that *Mangifera indica* is anticipated to be best performer at both Intense traffic flow sites (site VI and VII) and excellent performer at Road transportation site (Site II); *Eucalyptus tereticornis* is likely to be best performer at Road transportation site (Site II) and both Intense traffic flow sites (Site VI and VII) and very good performer at Residential unpolluted site (Site I) and Unplanned commercial site (Site IV); *Ficus benghalensis* and *Ficus religiosa* could be very good performers at all polluted sites. *Melia azadirachta* is predicted to be moderate performer at all the study sites. On the whole, *Mangifera indica* is evaluated as a good performer for all the study sites. Therefore plantation of *Mangifera indica* in and around the city will be highly beneficial in mitigating and minimize the air pollution levels. Besides having dense canopy of evergreen foliage, it is well known for its economic, religious and aesthetic value [9]. Furthermore, vegetation has inherent potential to serve as excellent quantitative and qualitative indices of pollution [22], and provide a natural mode of noise pollution reduction.

The benefits of trees on urban air quality could be enhanced by systematic green belt development. The key ecosystem service of air pollution reduction could be integrated into the planning and development processes with an aim to maximize the benefits of urban trees.

IV. CONCLUSION

The significant observed differences in the APTI values of selected tree species growing in polluted areas were compared to those from non-polluted sites. Plants having higher APTI value can be used as a sink to manage pollution levels; while plants having low APTI values can be marked as indicator of air pollution. The study proposes that evaluation of anticipated performance of plants can be very useful in the selection of suitable tree species for the greenbelt development. Green belts provide a natural way of cleaning the environment by absorption and diffusion of harmful gaseous and particulate pollutants. The plants identified as excellent, very good and good performer's viz. *Mangifera indica*, *Eucalyptus tereticornis*, *Ficus benghalensis* and *Ficus religiosa*, are recommended for plantation and this efficiency of atmospheric cleaning by trees can be improved by planting more trees of different suitable species for green belt development. These species can also be used for bio-monitoring of air quality status of the city.

V. COMPETING INTERESTS

The authors declare that they have no competing interests

VI. AUTHORS' CONTRIBUTIONS

SC designed the study and drafted the manuscript. JP performed the study and analysis.

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Table – 1

Gradation of plant species based on air pollution tolerance index (APTI) as well as biological parameters of importance (Pathak et al., 2011)

Grading Character		Pattern of Assessment	Grade Alloted
Tolerance	APTI	9.0-12.0	+
		12.1-15.0	++
		15.1-18.0	+++
		18.1-20.0	++++
		20.1-24.0	+++++
Biological	Plant habit	Small	-
		Medium	+
		Large	++
	Canopy structure	Sparse/irregular/globular	-
		Spreading crown/open/semi dense	+
		Spreading dense	++
Type of plant	Deciduous	-	
	Evergreen	+	
Laminar Structure	Size	Small	-
		Medium	+
		Large	++
	Texture	Smooth	-
		Coriaceous	+
		Delineate	-
Hardiness	Hardy	+	
Socio- economic	Economic value	Less than three uses	-
		Three or four uses	+
		Five or more uses	++

Table 2

Anticipated Performance Index (API) of plant species (Pathak et al., 2011)

Grade	Score (%)	Assessment category
0	Up to 30	Not recommended
1	31-40	Very poor
2	41-50	Poor
3	51-60	Moderate
4	61-70	Good
5	71-80	Very good
6	81-90	Excellent
7	91-100	Best

Table 3

Evaluation of plant species based on their biological and socio- economic characters

Name of plant	Tree habit	Canopy structure	Type of tree	Laminar		Ecological value	Hardiness
				Size	Texture		
<i>A. indica</i>	++	++	-	-	-	++	+
<i>D. sissoo</i>	++	++	+	+	+	+	+
<i>E. tereticornis</i>	++	+	+	++	+	++	+
<i>F. benghalensis</i>	++	+	+	++	+	+	+
<i>F. religiosa</i>	++	+	+	++	+	+	+
<i>M. indica</i>	++	++	+	+	+	++	+
<i>M. azadirachta</i>	+	+	+	+	+	++	+
<i>P. guajava</i>	+	+	+	+	+	+	+
<i>S. indica</i>	+	++	+	++	+	+	+
<i>S. cumini</i>	++	++	+	+	-	+	+

Table 4
APTI and API grades of plant species at Site-I (Residential unpolluted site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment Category
				Total Plus (+)	Scoring		
<i>A. indica</i>	9.96	1	7	8	50.0	2	Poor
<i>D. sissoo</i>	9.99	1	9	10	62.5	4	Good
<i>E. tereticornis</i>	10.98	2	10	12	75.0	5	Very Good
<i>F. benghalensis</i>	9.70	1	9	10	62.50	4	Good
<i>F. religiosa</i>	9.44	1	9	10	62.50	4	Good
<i>M. indica</i>	10.34	1	11	12	75.0	5	Very Good
<i>M. azadirachta</i>	10.14	1	8	9	56.25	3	Moderate
<i>P. guajava</i>	11.93	1	7	8	50.0	2	Poor
<i>S. indica</i>	11.27	1	9	10	62.50	4	Good
<i>S. cumini</i>	12.06	2	8	10	62.50	4	Good

Table 5
APTI and API grades of plant species at Site-II (Road transportation site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A. indica</i>	11.24	1	7	8	50.0	2	Poor
<i>D. sissoo</i>	7.21	-	9	9	56.25	3	Moderate
<i>E. tereticornis</i>	20.36	5	10	15	93.75	7	Best
<i>F. benghalensis</i>	10.73	1	9	10	62.50	4	Good
<i>F. religiosa</i>	10.19	1	9	10	62.50	4	Good
<i>M. indica</i>	12.23	2	11	13	81.25	6	Excellent
<i>M. azadirachta</i>	11.80	1	8	9	56.25	3	Moderate
<i>P. guajava</i>	14.53	2	7	9	56.25	3	Moderate
<i>S. indica</i>	9.79	1	9	10	62.50	4	Good
<i>S. cumini</i>	14.51	2	8	10	62.50	4	Good

Table 6
APTI and API Grades of plant species at Site-III (Residential unpolluted site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A. indica</i>	7.63	-	7	7	43.75	2	Poor
<i>D. sissoo</i>	9.80	1	9	10	62.50	4	Good

<i>E. tereticornis</i>	9.0	1	10	11	68.75	4	Good
<i>F. benghalensis</i>	8.03	-	9	9	56.25	3	Moderate
<i>F. religiosa</i>	5.64	-	9	9	56.25	3	Moderate
<i>M. indica</i>	8.31	-	11	11	68.75	4	Good
<i>M. azadirachta</i>	9.38	1	8	9	56.25	3	Moderate
<i>P. guajava</i>	8.93	-	7	7	43.75	2	Poor
<i>S. indica</i>	11.83	1	9	10	62.50	4	Good
<i>S. cumini</i>	8.80	-	8	8	50.0	2	Poor

Table 7
APTI and API grades of plant species at Site-IV (Unplanned commercial site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A. indica</i>	11.29	1	7	8	50.0	2	Poor
<i>D. sissoo</i>	8.85	-	9	9	56.25	3	Moderate
<i>E. tereticornis</i>	13.4	2	10	12	75.0	5	Very good
<i>F.</i>	10.98	1	9	10	62.50	4	Good
<i>F. religiosa</i>	10.45	1	9	10	62.50	4	Good
<i>M. indica</i>	11.77	1	11	12	75.0	5	Very good
<i>M. azadirachta</i>	10.39	1	8	9	56.25	3	Moderate
<i>P. guajava</i>	12.31	2	7	9	56.25	3	Moderate
<i>S. indica</i>	11.25	1	9	10	62.50	4	Good
<i>S. cumini</i>	10.69	1	8	9	56.25	3	Moderate

Table 8
APTI and API grades of plant species at Site-V (Planned commercial site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A. indica</i>	11.29	1	7	8	47.05	2	Poor
<i>D. sissoo</i>	7.21	1	9	10	58.82	3	Moderate
<i>E. tereticornis</i>	10.77	1	10	11	68.75	4	Good
<i>F. benghalensis</i>	9.43	1	9	10	58.82	3	Moderate
<i>F. religiosa</i>	9.44	1	9	10	58.82	3	Moderate
<i>M. indica</i>	10.01	1	11	12	70.58	4	Good
<i>M. azadirachta</i>	10.14	1	8	9	52.94	3	Moderate
<i>P. guajava</i>	12.31	2	7	9	52.94	3	Moderate
<i>S. indica</i>	11.27	1	9	9	52.94	3	Moderate
<i>S. cumini</i>	10.69	1	8	9	52.94	3	Moderate

Table 9
APTI and API grades of plant species at Site-VI (Intense traffic flow site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A.indica</i>	14.08	2	7	9	52.94	3	Moderate
<i>D.sissoo</i>	7.23	-	9	9	52.94	3	Moderate
<i>E. tereticornis</i>	20.87	5	10	15	93.75	7	Best
<i>F.benghalensis</i>	13.97	2	9	11	68.75	4	Good
<i>F.religiosa</i>	14.30	2	9	11	68.75	4	Good
<i>M.indica</i>	19.50	4	11	15	93.75	7	Best
<i>M.azadirachta</i>	13.0	2	8	10	58.82	3	Moderate
<i>P.guajava</i>	17.87	3	7	10	58.82	3	Moderate
<i>S.indica</i>	10.96	1	9	10	58.82	3	Moderate
<i>S.cumini</i>	16.34	3	8	11	68.75	4	Good

Table 10
APTI and API grades of plant species at Site-VII (Intense traffic flow site)

Name of plant	APTI	APTI Grade allotted (+)	Biological parameters grade (+)	Grade allotted		API Grade	Assessment category
				Total Plus (+)	% Scoring		
<i>A. indica</i>	19.12	4	7	11	68.75	4	Good
<i>D. sissoo</i>	6.0	-	9	9	52.94	3	Moderate
<i>E. tereticornis</i>	20.99	5	10	15	93.75	7	Best
<i>F.</i>	12.01	2	9	11	68.75	4	Good
<i>F. religiosa</i>	14.69	2	9	11	68.75	4	Good
<i>M. indica</i>	20.0	4	11	15	93.75	7	Best
<i>M. azadirachta</i>	14.91	2	8	10	58.82	3	Moderate
<i>P. guajava</i>	20.01	5	7	12	70.58	4	Good
<i>S. indica</i>	7.65	1	9	10	58.82	3	Moderate
<i>S. cumini</i>	17.5	3	8	11	68.75	4	Good

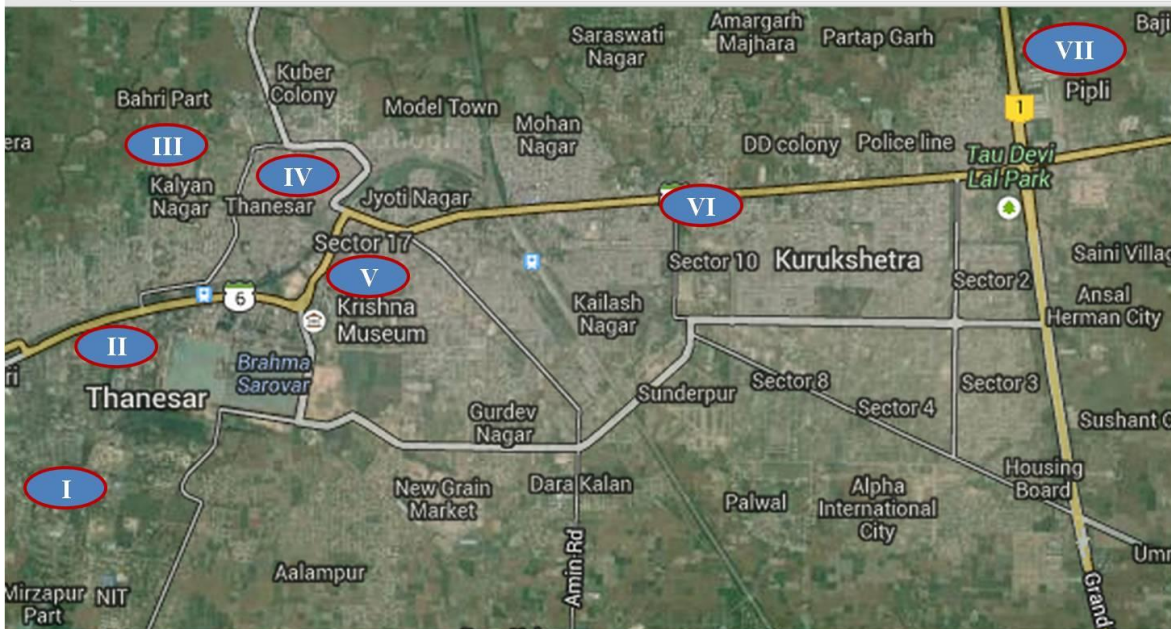


Fig. 1 The study area of Kurukshetra, Haryana and location of air quality monitoring sites

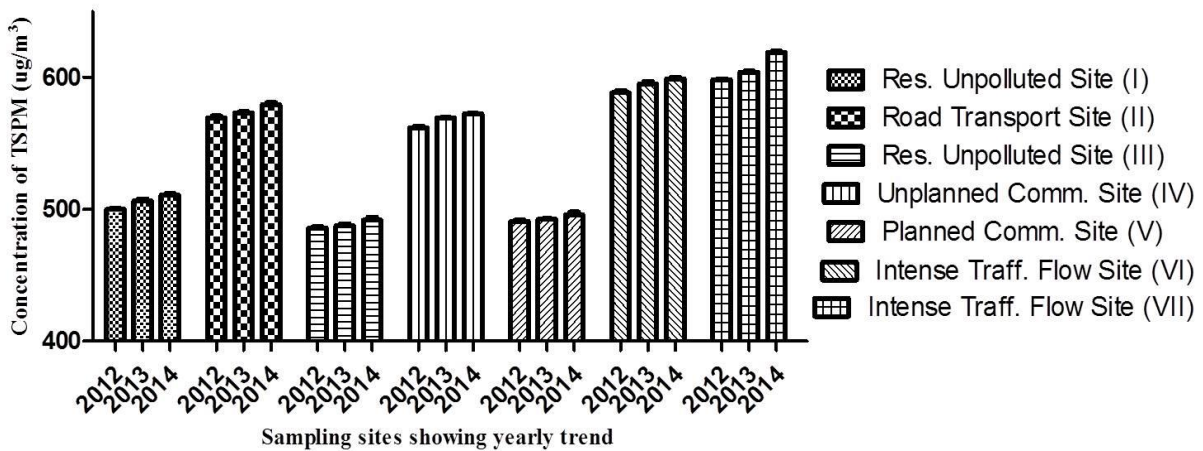


Fig. 2: Average concentration of TSPM (\pm S.E) at various sites during three years of study

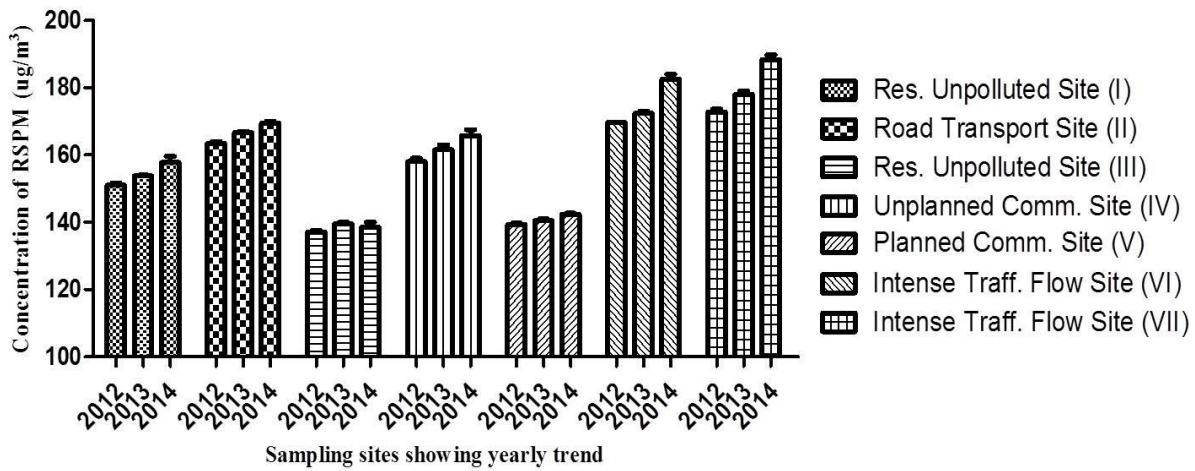


Fig. 3: Average concentration of RSPM (\pm S.E) at various sites during three years of study

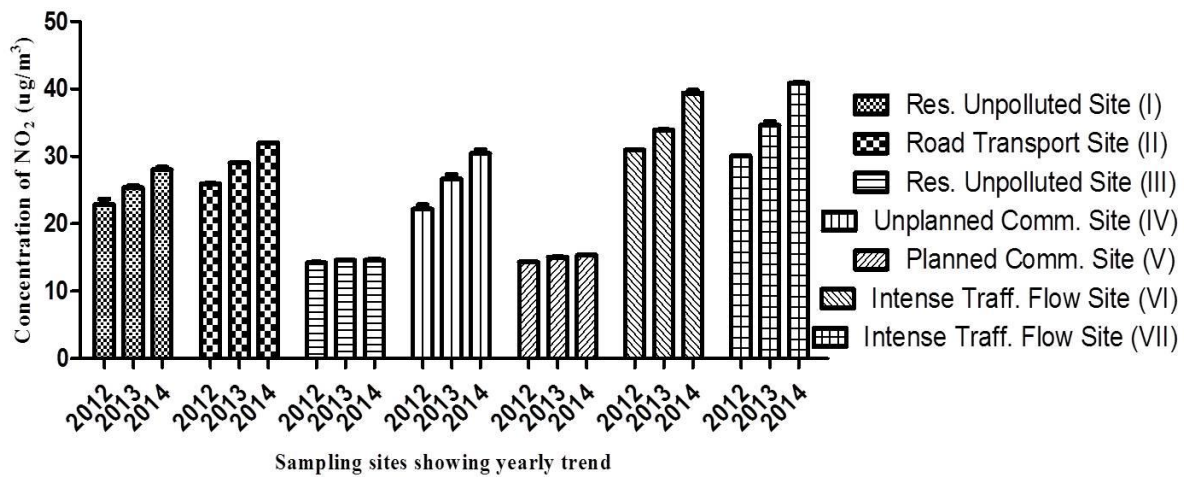


Fig. 4: Average concentration of NO_2 (\pm S.E) at various sites during three years of study

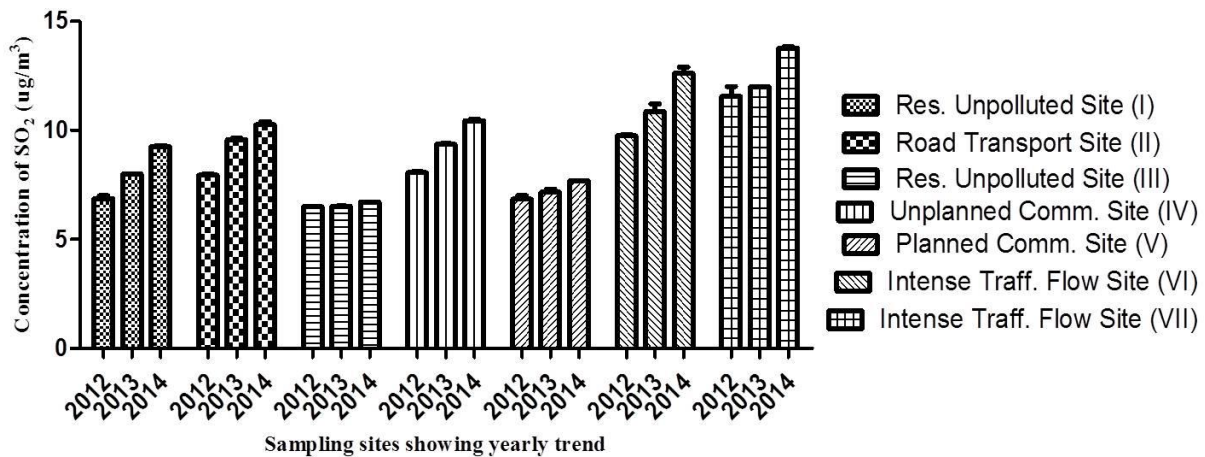


Fig. 5: Average concentration of SO_2 (\pm S.E) at various sites during three years of study