3

Effect of Air Pollutants on Vegetation in Tropical Climate: A Case Study of Delhi City

Sumanth Chinthala and Mukesh Khare
Indian Institute of Technology Delhi
India

1. Introduction

Urban air pollution is a serious problem in both developed and developing countries (Li, 2003). As a rapidly expanding centre of government, trade, commerce and industry, Delhi, the Indian capital, has been facing many air pollution related problems. The vehicular exhaust contributes significantly to the pollution load in Delhi. The plant species are severely affected by various pollutants emitted from different sources e.g. SO_x, NO_x and particulates. To maintain ecological balance in this fastly developing capital, there is an immediate necessity to assess the effect of the air pollutants on the plant speices so that the strategies can be formulated and implemented to protect the species. Plants remove air pollutants by three mechanisms: absorption by the leaves, deposition of particulates and aerosols over leaf surfaces, and fallout of particulates on the leeward side of the vegetation (Tewari, 1994; Rawat and Banerjee, 1996). As a result, the chlorophyll concentrations in the leaf which is responsible for the photosynthetic activity may decrease (Seyyednejad et al, 2011). Hence, the ability of the plant to tolerate the air pollution gets affected. Plantation of tolerant tree species will have a marked effect on varied aspects of the quality of the urban environment and the cleanliness of life in a city (Bamnia et al, 2011). The Anticipated Performance Index (API) has been used as an indicator to assess the capability of some of the predominant species present in Delhi. Further, the air pollution tolerance index (APTI) of the plants needs to be monitored and checked for the predominant species that are located in the city.

2. Topography of Delhi

Delhi is positioned with the Great Indian Desert (Thar Desert) of Rajasthan to the west and southwest, central hot plains to the south and gangetic plains of Uttar Pradesh/Uttaranchal to the east while cooler hilly regions to the north. It is situated at latitude 28º24′17″ and 28º53′00″ North; Longitude 76º45′30″ and 77º21′30″ (East) at elevation of 216 m above the mean sea level (msl). Delhi's climate is very hot in summer (April - July) and cold in winter (December - January). The average temperature can vary from 25º C to 45º C during the summer and 22º C to 5º C during the winter respectively. The topography of the city is manly urban plain having two main features - the Ridge and the river Yamuna. The Ridge refers to an area inhabited by extraordinary plants and fierce animals.

3. Air quality status in Delhi

The Air quality in Delhi is primarily affected by the vehicular exhausts, small scale industries, power plants and biomass burning. The relative contribution of various sources for the air pollution in Delhi has been shown (Table 1&2). It can be found that the vehicular exhausts contribute a significant amount to the air pollution in the city. The pollutants include SPM, RSPM, SOx, NOx and Benzene. It has also been reported that the benzene concentration has exceeded seven times that of the permissible limit during the winter season. In summers, the concentration of the pollutant has been below the permissible standards prescribed. A Source apportionment study to identify the sources of the benzene is to be carried out (DPCC, 2011).

Sl No	Sector	Percentage of emissions
1	Roads (Paved and Unpaved)	52-53
2	Area sources	18-20
3	Vehicles	3-5%
4	Industrial	20-22

Table 1. Prominence of Sources of PM_{10} for Delhi city (Source: CPCB, 2010).

Sl No	NOx		SOx	
	Sector	Percentage of emissions	Sector	Percentage of emissions
1	Industrial	78-80	Industrial	98
2	Vehicular	18-20	Vehicular	1
3	Area Sources	2-3	Area Sources	1

Table 2. Prominence of Sources of NOx and SOx for Delhi city (Source: CPCB,2010).

4. Vegetation covers in the city

The landscape of Delhi consists of a broad spectrum of environments ranging from the city forests to highly modified artificial landscapes in certain parks (Khera et al, 2009). Among the 260 different varaities of species present in delhi, only 42 species are native species. The most dominant speicies is *Prosporis Juliflora*, a tree from central America that was introduced around 1915 in order to afforest the central ridge forests. The other commonly found tree species in Delhi include, Eucalyptus sp., Ficus benghalensis, Ficus religiosa, Mangifera indica, Melia azedarach, and Syzygium jambolanum, Alstonia scholaris, Azadirachta indica, and Cassia fistula. Since the majority of the tree species are not a native varaities, their ability to sustain and sequestrate the air pollutants needs to be evaluated at regular intervals. The features of the predominant tree species has been shown in the table 3.

The effect of air pollutants is showing a significant effect on the vegetation in the city. The predominant species, *Prosporis Juliflora* in the capital's central ridge has been considered as most sensitive to air pollution (Seyyednjad et al, 2011). With the presence of the most sensitive species in a vast area in the heart of a city, the amount of pollutants absorbed by the vegetation may get reduced. Further, some of the tree species may emit VOC's which play an important role in the atmospheric chemistry affecting the local air quality.

Sl no	Name	Scientific name	Family
1	Shoe Babool	Leacena leucophloea	Mimoseae
2	Gulmohar	Delonix regiosa	Caesalpiniaceae
3	Neem	Azardirachta indica	Meliaceae
4	Vilayati kikkar	Acacia farnesiana	Mimoseae
5	Bankayan	Melia azedarch	Meliaceae
6	Bottle brush	Calistemon citrinus	Myrtaceae
7	Torch Tree	Ixora parviflora	Rubiaceae
8	Chikkoo	Archise sapota	Sapotaceae
9	Arjun	Terminalia arjuna	Combrataceae
10	Babool	Accacia nelotica	Mimoseae
11	Shesham	Delbergia sisso	Papilionaceae
12	Jangal Badam	Terminalia catappal	Combrataceae
13	Ashoka	Polyalthia longifolia	Annoniaceae
14	Kanju, Papadi	Holiptelia integrifolia	Ulmaceae
15	Amrood	Psidium guyaua	Myrtaceae
16	Mahua	Madhuca indica	Sapotaceae
17	Mulberry	Morus alba	Moraceae
18	Semal	Bombax ceiba	Bombaceae
19	Popular	Populus trimuloides	Siliaceae
20	Plums	Prunus Comminis	Rosaceae
21	Lemon	Citrus lemon	Rutaceae
Sl no	Name	Scientific name	Family
22	Kanchnar	Bauhinia Variegata	Caesalpiniaceae
23	Bel	Aegle marmelos	Rubiaceae
24	Satni	Alstonia Scholaris	Apocynaceae
25	Mango	Magnifera Indica	Anacardiaceae
26	Blue gum	Eucalyptus globulus	Myrtaceae
27	Jamun	Syzygium cuminii	Myrtaceae
28	Peepal	Ficus religiosa	Moraceae
29	Teak	Tectona grandis	Verbenaceae
30	Kadam	Anthosephalus cadamba	Rubiaceae
31	Wolly Mopming Glorry	Argyreia roxburghira	Caesalpiniaceae
32	Amaltas	Cassia fistula	Caesalpiniaceae
33	Banyan tree	Ficus bengalensis	Moraceae
34	Indian rubber	Ficus elastica	Moraceae

Table 3. Predominant Tree species in Delhi (CPCB, 2007).

Regional as well as global scale VOC emission, from vegetation, may dominate over anthropogenic sources of emission (Guenther et al., 1995). Out of the nine commonly occurring tree species in Delhi, VOC emissions were found in six species, namely, *Eucalyptus sp.*, *Ficus benghalensis*, *Ficus religiosa*, *Mangifera indica*, *Melia azedarach*, and *Syzygium jambolanum*, at higher concentrations. Further it has also been observed that that these emissions are dependent up on sunlight and temperature (Tingey et al., 1979; Lamb et al., 1987; Padhy and Varsheney, 2005).

5. Quantifying the effects of air pollution using APTI and API

The effect of air pollution on the plants can be quantified using a parameter, air pollution tolerence index (APTI) (Singh and Rao, 1993). The APTI is a function of total chlorophyll content of the leaf, pH, relative water content and the ascorbic acid content. The APTI for a particular tree species is given in eq (1)

$$APTI = (A\,(T+P) + R)/10 \tag{1}$$

Where A= Ascorbic acid content in mg/g dry weight,
T= Total Chlorophyll content in mg/g dry weight,
P= pH of the Leaf extract,
R = Relative water content (%)

The plant species can be convinently grouped based on the APTI values (Table 4).

Sl no	APTI	Response
1	30 -100	Tolerant
2	29-17	Intermediate
3	16-1	Sensitive
4	<1	Very sensitive

Table 4. Grouping of plants using APTI (Source: Lakshmi et al, 2006).

Further, the parameters of the APTI have been correlated with the increasing concentration of the pollutants. It has been found that the relative water content , total chlorophyll are negatively correlated and ascorbic acid is positively correlated with all the pollutants. The pH values are negatively correlated in the case of NO_x (Table 5).

	Relative water content	pH	Total chlorophyll	Ascorbic acid
SPM	Negative	Positive	Negative	Positive
RSPM	Negative	Positive	Negative	Positive
SO_2	Negative	Positive	Negative	Positive
NO_2	Negative	Negative	Negative	Positive

Table 5. Correlation between Air pollutants and Biochemical parameters (Govindaraju et al, 2011).

The APTI index shows the effect of the pollutants only on the biochemical parameters. In order to combat air pollution by planning the green belt development in a particular area, many socio-economic factors are to be considered. Hence the anticipated performance index has been used to determine the same (Govindaraju et al, 2011). The method contains a grading system where a tree species is graded based on various parameters. The API has been calculated for predominant tree species in Delhi. The table 6 shows the parameters used to grade the performance of a particular tree species. It includes the parameters like APTI along with the socio-economic parameters. Based on the current grading system, a tree can secure a maximum of 16 positive points. These points were scaled to a percentage system and based on the score obtained, the category has been assessed. Table 7 shows the assessment categories along with the scores.

Grading Character	Parameter	Pattern of assessment	Grade alloted
Tolerence	APTI	9.0-12.0 12.1-15.0 15.1-18.0 18.1-21.0 21.1 -24.0	+ ++ +++ ++++ +++++
Biological and Socio -economic	Plant habit	Small Medium Large	- + ++
	Canopy Structure	Sparse /Irregular/ Globular Spreading crown/open/ semi dense Spreading dense	- + ++
	Type of Plant	Decidious Evergreen	- +
Laminar structure	Leaf Size	Small Medium Large	- + ++
	Texture	Smooth Coriacious	- +
	Hardness	Delineate Hardy	- +
	Economic Value	Less than Three uses Three or Four uses Five or more uses	- + ++

Table 6. Gradation of plant species based on APTI as well as morphological parameters and socio – economic importance (Govindaraju et al, 2011).

Grade	Score (%)	Assesment 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 7. Anticipated performance Index (API) for species (Govindaraju et al, 2011).

To determine the effect of air pollutants on the tree species in Delhi, the API values have been calculated. Since the data on the APTI values of the tree species considered are not available, the analysis is performed for both the extreme cases i.e for maximum APTI and for the minimum APTI. Table 8 and 9 shows the maximum and minimum values of the API obtained.

It can be shown from the table 9 that even though the APTI of a species is negligible (less than 9) , but still the API of a plant species are securing a reasonable grades. Out of the eight species, three are *good*, two are *moderate*, two are *poor* and one is *very poor*.

Sl	Species	a	b	c	d	e	f	g	h	Total	(%)	Category
1	Prosporis juliflora	+	+	+	-	-	++	+	+++++	11	68.7	Good
2	Eucalyptus sp	++	+	+	++	+	++	+	+++++	15	93.7	Best
3	Ficus benghalensis	++	+	+	++	+	++	+	+++++	15	93.7	Best
4	Ficus religiosa	++	+	+	++	+	+	+	+++++	14	87.5	Excellent
5	Mangifera indica	++	+	+	++	+	++	+	+++++	15	93.7	Best
6	Alstonia scholaris	++	-	+	++	+	+	+	+++++	13	81.2	Excellent
7	Azadirachta indica	++	++	-	-	-	++	+	+++++	12	75	Very good
8	Cassia fistula	++	++	-	++	+	+	+	+++++	14	87.5	Excellent

Table 8. Maximum API for the predominant plant species in Delhi.

Sl	Species	a	b	c	d	e	f	g	Total	(%)	Category
1	Prosporis juliflora	+	+	+	-	-	++	+	6	37.5	Very poor
2	Eucalyptus sp	++	+	+	++	+	++	+	10	62.5	Good
3	Ficus benghalensis	++	+	+	++	+	++	+	10	62.5	Good
4	Ficus religiosa	++	+	+	++	+	+	+	9	56.2	Moderate
5	Mangifera indica	++	+	+	++	+	++	+	10	62.5	Good
6	Alstonia scholaris	++	-	+	++	+	+	+	8	50	Poor
7	Azadirachta indica	++	++	-	-	-	++	+	7	43.7	Poor
8	Cassia fistula	++	++	-	++	+	+	+	9	56.2	Moderate

where a= plant habitat; b= canopy structure; c= type of plant; d=leaf size; e= texture; f= economic importance; g= hardiness ; h = APTI.

Table 9. Minimum API for the plant species in Delhi.

Since the Delhi's most predominant species is showing very poor performance, it can be said that if the APTI value decreases, the API may not indicate the performance of a plant species. Since the reduction in the APTI values may also affect the other biochemical and socio-economic parameters, a modified index is proposed by adding a negative weightage. For every unit reduction in the positive value of the APTI, a negative weightage is proposed.

Further, it has been found that among all the pollutants, SPM has the maximum effect on the biochemical parameters; and NOx has the least effect. The pollutants can be arranged in the following order. SPM> RSPM> SO_x> NO_x (Govindaraju et al, 2011). To incorporate the effect of increase of the concentrations of these pollutants, an additional weightage of 1, 0.75, 0.5 and 0.25 may be added to the negative weightage, respectively. This additional weightage will be added only when the concentration of the polluants exceed the specified standards.

Sl	APTI	Weightage	SPM	RSPM	SO_x	NO_x
1	+++++	0	1	0.75	0.5	0.25
2	++++	1	1	0.75	0.5	0.25
3	+++	2	1	0.75	0.5	0.25
4	++	3	1	0.75	0.5	0.25
5	+	4	1	0.75	0.5	0.25

Table 10. Proposed negative weightage allocation for varying APTI values and under different environmental conditions.

Thus, the incorporation of the negative weightage in the calculation of the API for existing plant species can make it more practical if applied for the city like Delhi.

6. Conclusions

It can be concluded that due to the increasing pollution load on the plants, the vegetation in the city is under extreme stress. To ensure that the generated pollutant load is removed from the atmosphere, the quantification of the effect of the pollutants on the tree species should be made at regular intervals to ensure that they perform well under pollutant stresses. Further, the source apportionment studies have to be conducted to identify the pollutants like benzene which are exceeding the permissible standards during winter. Aditionally, the effect of the water contamination and other miscellaneous factors may add additional stress to the vegetation which needs to be considered to ensure that the species sustain in a polluted environment.

7. References

Bamnia, B.R., Kapoor, C.S., Kapoor, K and kapasya, V (2011) "Harmful effects of air pollution on physiological activites of Pongamia pinnita (L.) Pierre", Clean technology environmental policy, Springer. DOI 10.1007/s10098-011-0383-z.

CPCB (2007) "Phytoremediation of particulate matter from ambient environment through dust capturing plant species", Abstracted from www.cpcb.nic.in *on January 2nd , 2012.*

CPCB (2010) "Air quality monitoring, emission inventory and source apportionment study for Indian cities", National Summary Report, Abstracted from www.moef.nic.in on January 5th , 2011.

DPCC (2011) "A Background note on status of PM_{10}, $PM_{2.5}$, NO_x and Benzene", Unpublished Report.

Govindaraju, M., Ganeshkumar, R.S., Muthukumaran, V.R and Visvanathan, P (2011) "Identification and evaluation of air-pollution-tolerant plants around lignite-based thermal power station for greenbelt development", Environmental Science Pollution Research,DOI 10.1007/s11356-011-0637-7.

Guenther, A., Hewitt, C.N., Erickson, D., Fall, R., Geron, C., Graedel, T., Harley, P., Klinger, L., Lerdan, M., Mckay, W.A., Pierce, T., Scholes, B., Steinbrecher, R., Tallamraju, R., Taylor, J. and Zimmerman, P (1995) "A global model of natural volatile organic emissions", Journal of Geophysical Research, 100, 8873–8892.

Khere, N., Mehta, V and Sabata, B.C (2009) "Interrelationships of birds and habitat features in urban green spaces in Delhi, India", Urban Foresty and Urban greeining, Volume 8, Issue 3, 2009, 187-196.

Lakshmi, P.S., K.L. Sravanti and N. Srinivas, (2009) Air pollution tolerance index of various plant species growing in industrial areas. The Ecoscan., 2: 203-206.

Lamb, B., Guenther, A., Gay, D., Westberg, H., (1987) "A nationalinventory of biogenic hydrocarbon emissions". Atmospheric Environment, 21, 1695–1705.

Li, M.H. (2003) "Peroxidase and superoxide dismutase activities in fig leaves in response to ambient air pollution in a subtropical city" Arch. Environ. Contamination toxicology, 45: 168-176.

Padhy and Varsheney (2005) "Isoprene emission from tropical tree species", Environ Pollut. 2005 May;135(1):101-9.

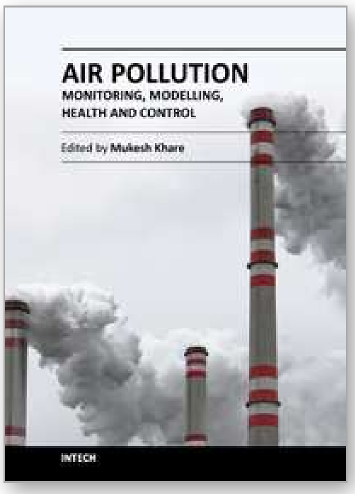
Rawat, J.S., Banerjee, S.P., (1996) "Urban forestry for improvement of environment' Journal of Energy Environment Monitoring 12 (2),109–116.

S.M. Seyyednjad, K. Majdian, H. Koochak and M. Niknejad, (2011) "Air Pollution Tolerance Indices of Some Plants Around Industrial Zone in South of Iran". Asian Journal of Biological Sciences, *4: 300-305.*

Singh, S. K. and Rao, D. N. (1983). Evaluation of plants for their tolerance to air pollution. In Proceedings of the Symposium on Air Pollution Control, November, pp. 218-224.

Tewari, D.N., (1974) Urban forestry. Indian Forester 120 (8), 647–657.

Tingey, D.T., Manning, M., Grothaus, L.C., Burns, W.F., (1979) The influence of light and temperature on isoprene emission rates from live oak. Plant Physiology 47, 112–118.



Air Pollution - Monitoring, Modelling, Health and Control
Edited by Dr. Mukesh Khare

ISBN 978-953-51-0381-3
Hard cover, 254 pages
Publisher InTech
Published online 21, March, 2012
Published in print edition March, 2012

Air pollution has always been a trans-boundary environmental problem and a matter of global concern for past many years. High concentrations of air pollutants due to numerous anthropogenic activities influence the air quality. There are many books on this subject, but the one in front of you will probably help in filling the gaps existing in the area of air quality monitoring, modelling, exposure, health and control, and can be of great help to graduate students professionals and researchers. The book is divided in two volumes dealing with various monitoring techniques of air pollutants, their predictions and control. It also contains case studies describing the exposure and health implications of air pollutants on living biota in different countries across the globe.