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Assessment of air pollution tolerance index of some trees in Moradabad city, India

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Abstract: *To see the relative tolerance of the plant species, ten different plant species i.e. Ficus rumphii, Pongamia pinnata, Alstonia scholaris, Holoptelea integrifolia, Saraca indica, Pithecolobium dulcis, Cassia simea, Bauhinia variegata, Azadirachta indica and Grewelia robusta was taken from residential (SI), industrial (SII) and commercial (SIII) area of the city as this flora is very much common to the Brass city and is planted on the roadside. The quality of air with respect to SPM, SO_2 and NO_2 has been also assessed on respective sites to see its effect on biochemical parameters of the leaves i.e. pH, total water content, chlorophyll and ascorbic acid and evaluate the (air pollution tolerance index(APTI) of various plants. It was concluded that Pongamia pinnata 15.8, Pithecolobium dulcis 34.8, Holoptelea integrifolia 55.8 and Saraca indica 52.0 have very high APTI value over control so these are considered as high tolerant tree species, Ficus rumphii 35.7, Azadirachta indica 30.5 and Grewelia robusta 34.3 have slightly more APTI value over control so these are considered as moderately tolerant tree species and Alstonia scholaris 21.5, Cassia simea 6.09 and Bauhinia variegata 18.22 have less APTI value than control, so these are sensitive species respectively. One way ANOVA finds the obtained values to be highly significant ($p<0.001$) at the industrial site. Thus present findings show that Brass and allied industries are the prominent sources responsible for the elevated level of air pollutants at the industrial site.*

Key words: *Air pollution tolerance index, Sensitive species, Tolerant species, Moradabad*
PDF of full length paper is available online

Introduction

However, increase in industrialization, unplanned urbanization, alarming increase in vehicles fleet, population growth and underestimated future plan of city development are the major triggers for the increases in the air pollution level in the city (Jayanthi and Krishnamoorthy, 2006).Exposure assessment studies carried out in the developing world on several air pollutants are reviewed (Agrawal *et al.,* 2003; Oliva and Mingorance, 2006; Han and Naeher, 2006) and it is known that pollutants in the outdoor and indoor environments are associated with acute adverse effects on health of human and plants (Lebowitz,1995; Tripathi *et al*., 2008; Dwivedi *et al*., 2008).

Plants developed characteristic response and symptoms in response to particular types and level of air pollution. Such information can be used in the field surveys of air pollution and the concept of plants as indicators of air pollution was firstly developed by clements. Vegetation naturally cleans the atmosphere by absorbing gases and particulate matter through leaves as plant leaf may act as a persistent absorber when exposed to the polluted environment. Sensitive plant species are suggested as bio-indicators (Tripathi *et al*., 1999; Raina and Sharma, 2006). Bio-indicators may be very useful due to their high sensitivity towards a broad (DeTemmerman *et al*., 2004). Different plant species showed a different behavior for different pollutants and any plant part could be indifferently used as biomonitors (Mingorance *et al*., 2007).

According to Singh and Rao (1983) a formulae has been adopted to determine the air pollution tolerance index (APTI) of various plant species considering upon the four biochemical parameters *i.e.* total chlorophyll, ascorbic acid, leaf extract pH and relative water content. Thus the present work aims to evaluate the air pollution tolerence index (APTI) of different plant species growing near residential, commercial and industrial area of the city as to provide a particular plant species to grow in respective areas.

Materials and Methods

Moradabad is known as'Peetal nagri' as it is famous for brassware industries and comarising of 4 million population (www.moradabad.nic.in). Numerous sources emit air pollutants including several major and minor Brass industries along with other industries located within the city. Moradabad is one of the semi-arid zones towards the north-west of India with extreme summer and winter conditions. It is located at an average height of 76.19 mts above sea level in the western gangetic plain of Indian subcontinent at latitude 28.15 N and longitude 74.49 E. The study area was classified into three zones-Residential area *i.e.* PTC (S I) which is almost free from pollution so somewhere it is treated as a control area, commercial area *i.e.* Town hall (S II) is characterized by high traffic density and commercial activities almost throughout the day and Industrial area *i.e.* Mughalpura (S III) is characterized by heavy industrial activity (mainly brasswares).

The study was carried out for the period of one year *i.e.* since 1st August, 2005 to 31st July, 2006 to study ambient air pollution status of Moradabad city with reference to different parameters such as SPM, SO_2 and NO_2. SPM samples were collected with the help of high volume sampler at the rate of three samples per week on glass fiber filter paper – EPM 1000 for 24 hr. with air flow rate of 1-1.5 $m^3\ min^{-1}$. The difference in initial and final weights of the filter paper gave the total quantity of SPM collected over the 24 hr period.The values of SPM were reported in $\mu g\ m^{-3}$. Measurement of SO_2 ($\mu g\ m^{-3}$) in the ambient air is based on the West-gaeke method (West and Gaeke,1956). NO_2 ($\mu g\ m^{-3}$) gas was analyzed by the modified method of Jacob and Hochheisher (1958).

Ten locally available roadside tree species such as *Ficus rumphii, Pongamia pinnata, Alstonia scholaris, Holoptelea integrifolia, Saraca indica, Pithecolobium dulcis, Cassia simea, Bauhinia variegata*, *Azadirachta indica* and *Grewelia robusta* in and around the different sites were selected for the study. The fresh leaf samples of selected trees from different sites were carried aseptically to the laboratory and all the four parameters *i.e.* total chlorophyll, ascorbic acid, pH and relative water content was estimated by the following methods.

The total chlorophyll (mg g^{-1}) content was determined using the method of Maclachlan and Zalik (1963).Extraction and analysis of ascorbic acid (mg g^{-1}) in fresh leaves were performed using the method of Keller and Schwager (1977). For the pH estimation 0.5 g of leaf material was ground to paste and dissolved in 50 ml. of distilled water and this extract was measured by using calibrated digital pH meter. Relative water content (%) was estimated by taking leaf sample of the plants. Leaves were washed thoroughly and the excess of water was removed with filter paper. The initial weight of the sample was taken W_1 and kept in an oven at 60°C until constant weight was obtained and the final weight was taken as W_2. Finally the air pollution tolerance index will be determined for all the ten tree species according to Singh and Rao (1983). All data were presented as mean of three replicates, ± standard deviation and data were statistically analyzed by one factor analysis of variance (ANOVA) to study the statistical relationship.

Results and Discussion

Annual average concentration of major air pollutants *i.e.* SPM, SO_2 and NO_2 at different locations and National Ambient Air Quality Standard are summarized in Table 1. In the light of values of SPM (658.44 $\mu g\ m^{-3}$), SO_2 (119.83 $\mu g\ m^{-3}$) and NO_2 (98.41 $\mu g\ m^{-3}$) it was observed that Mughalpura (SIII) is the most polluted site and PTC (SI), having the concentration of SPM (159.47 $\mu g\ m^{-3}$), SO_2 (61.91 $\mu g\ m^{-3}$) and NO_2 (74.83 $\mu g\ m^{-3}$), is the least polluted area of Moradabad. In Table 1 means of individuals parameters are compared in different months within column.

All the three data were converted uniformly by using log10 and put the same for statistical analysis such as analysis of variance (ANOVA) and found that annual average concentration of SPM is significantly higher (658.44 $\mu g\ m^{-3}$, $p<0.01$) at Mughalpura site (SIII).Major source of SPM in this area is polishing, cutting, grinding and scrapping of metals on a large scale as was supported by other authors also (Tripathi *et al.,* 1990; Baptista *et al.,* 2008; Tripathi *et al.,* 2008).

Air pollution tolerance index (APTI) and observed values of different parameters *i.e.* total chlorophyll, ascorbic acid, pH and relative water content of corresponding plants are given in Table 2. APTI values of each plant at all the locations have been arranged in descending order as -

PTC (SI): *Ficus rumphii >Grewelia robusta>Holoptelea integrifolia>Alstonia scholaris>Bauhinia variegata>Pithecolobium dulcis>Saraca indica>Azadirachta indica>Pongamia pinnata> Cassia simea* .

Town hall (SII): *Holoptelea integrifolia>Grewelia robusta> Ficus rumphii>Saraca indica>Pithecolobium dulcis >Azadirachta indica>Alstonia scholaris>Pongamia pinnata>Bauhinia variegata> Cassia simea.*

Mughalpura (SIII): *Holoptelea integrifolia>Saraca indica>Ficus rumphii>Pithecolobium dulcis>Grewelia robusta > Azadirachta indica >Alstonia scholaris>Bauhinia variegata> Pongamia pinnata>Cassia simea.*

According to observed APTI values *Ficus rumphii* shows the highest value (32.56) at PTC which is a residential site and *Holoptelea integrifolia* shows the highest value at Townhall site (49.5) as well as Mughalpura site (55.8) which are commercial and industrial sites respectively but *Cassia simea* shows lowest values at SI (6.48), at SII (5.0) and at SIII (6.09).

At the residential Site (SI), the highest APTI values were reported in *Ficus rumphii* (32.56) , *Grewelia robusta* (32.99) and *Holoptelea integrifolia* (28.03). The lowest APTI values were reported in *Pongamia pinnata* (7.79) and *Cassia simea* (6.48).

At commercial Site(SII), the highest APTI values were reported in *Holoptelea integrifolia* (49.5), *Grewelia robusta* (36.9) and *Ficus rumphii* (34.31) and the lowest APTI values were observed in *Cassia simea* (5.0) and *Bauhinia variegata* (7.35). High APTI values were reported in the species *Holoptelea integrifolia* (55.8) and *Saraca indica* (52.0) growing at the industrial area while the low values in the plant species *Cassia simea* (6.09) , *Pongamia Pinnata* (15.8) and *Bauhinia variegata* (18.2).

Although all the species showed significant ($p<0.01$) variation for all the biochemical parameters *i.e.* total chlorophyll, ascorbic acid, pH and relative water content. The extent up to which plant species were affected varied from species to species and site to site (Mashitha and Pies, 2001; Klumpp *et al.,* 2003). The results indicate that leaves of all the plant species were healthy and green at SI in comparision to SII and SIII. Among all the ten species only three plant species *Alstonia scholaris, Bauhinia variegata*, *Cassia simea* are selected as sensitive species because these species have more APTI values at SI in comparison to SII and SIII

Table - 1: Air pollution status of respective sites

	PTC (SI)			Town hall (SII)			Mhghalpura (SIII)		
	SPM	SO_2	NO_2	SPM	SO_2	NO_2	SPM	SO_2	NO_2
Mar.	174.65±6.15^{1}	15.18±0.73^{1}	17.28±0.71^{2}	279.24±13.96^{4}	42.51±2.07^{1}	41.42±1.89^{2}	854.06±27.78^{1}	85.4±3.20^{2}	60.4±2.20^{2}
Apr.	189.24±7.19^{ns}	15.24±0.37^{ns}	18.19±0.83^{ns}	280.31±13.65^{ns}	42.63±3.17^{ns}	42.53±1.70^{ns}	768.16±31.64^{1}	89.4±2.22^{ns}	61.2±1.98^{ns}
May	191.53±8.32^{ns}	16.87±0.82^{ns}	20.58±0.98^{ns}	282.32±11.99^{ns}	43.87±4.71^{ns}	42.57±2.13^{ns}	855.22±29.50^{1}	87.4±3.95^{ns}	63.4±3.20^{ns}
Jun.	214.56±9.65^{ns}	19.64±0.59^{1}	22.19±1.08^{ns}	283.14±12.36^{ns}	45.27±5.17^{ns}	43.68±1.20^{ns}	863.57±41.09^{ns}	84.1±2.04^{ns}	65.1±4.19^{3}
Jul.	126.89±6.20^{3}	11.45±0.48^{3}	8.56±0.41^{3}	174.58±9.79^{3}	22.58±2.20^{3}	33.57±4.20^{2}	496.2±29.19^{3}	74.4±3.36^{1}	57.8±1.91^{1}
Aug.	128.21±6.41^{ns}	12.48±0.26^{ns}	9.76±0.40^{ns}	175.87±10.19^{ns}	22.98±1.97^{ns}	34.87±3.98^{ns}	502.5±19.21^{ns}	75.1±4.16^{ns}	59.4±1.78^{ns}
Sep.	129.42±3.71^{ns}	14.63±0.32^{ns}	11.58±0.56^{ns}	177.49±11.91^{ns}	24.67±2.19^{ns}	36.38±1.23^{ns}	538.1±21.12^{ns}	77.5±2.32^{ns}	62.7±2.17^{ns}
Oct.	130.47±6.20^{ns}	15.67±0.65^{ns}	12.87±0.63^{ns}	178.38±13.13^{ns}	24.49±3.30^{ns}	37.85±0.90^{ns}	558.2±16.36^{ns}	79.1±3.19^{ns}	63.9±2.65^{ns}
Nov.	141.52±9.32^{ns}	17.58±0.60^{ns}	20.45±0.25^{3}	243.87±15.86^{3}	65.27±4.37^{3}	60.57±2.96^{3}	589.2±32.13^{ns}	95.1±3.30^{3}	71.8±1.32^{1}
Dec.	149.57±5.69^{3}	18.49±0.69^{ns}	21.87±1.53^{ns}	244.86±13.13^{ns}	66.37±3.47^{ns}	61.98±3.59^{ns}	624.3±20.20^{ns}	97.1±4.20^{ns}	73.1±2.59^{ns}
Jan.	162.43±6.90^{ns}	20.48±1.00^{ns}	23.57±1.12^{ns}	247.81±18.69^{ns}	68.17±4.12^{ns}	63.52±2.69^{ns}	671.2±19.13^{ns}	98.4±3.12^{ns}	75.1±1.32^{ns}
Feb.	175.42±9.12^{ns}	22.89±0.99^{1}	25.24±1.23^{ns}	248.67±20.69^{ns}	69.28±5.13^{ns}	65.42±2.47^{ns}	580.6±22.04^{1}	101.5±3.30^{ns}	76.2±1.45^{3}
A.A	159.49	16.72	17.68	234.71	44.84	47.03	658.44	87.04	65.84
NAAQS	140	60	60	140	60	60	360	80	80

All values are means (n=3)±SD, Means of individual parameters are compared in different month within column, ^{3} = Highly significant, $p<0.001$; ^{2} = Significant, $p<0.01$, ^{1} = Less significant, $p<0.05$, ns = non significant, $p>0.05$, All values in µg m^{-3}, A.A=Annual average, NAAQS=National ambient air quality standard

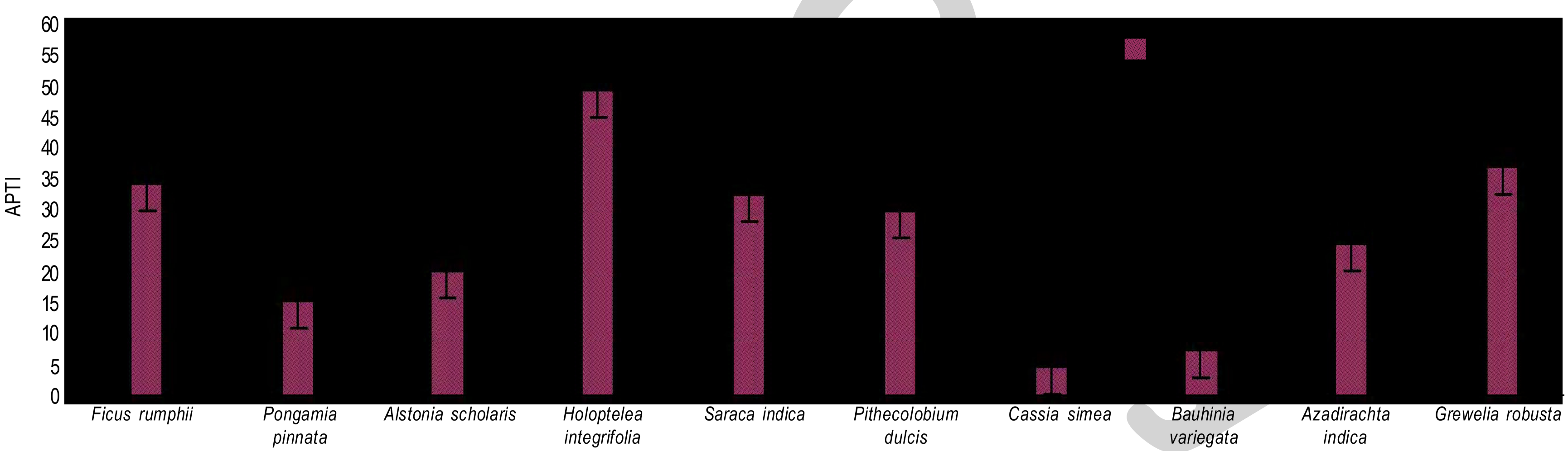

Fig. 1: Air pollution tolerance index(APTI) of trees growing in different sites of Moradabad city ± SD

Table - 2: pH, relative moisture, chlorophyll and ascorbic acid contents of trees growing in different areas

Sampling area	Plant speceis									
	Ficus rumphii	*Pongamia pinnata*	*Alstonia scholaris*	*Holoptelea integrifolia*	*Saraca indica*	*Pithecolobium dulcis*	*Cassia simea*	*Bauhinia variegata*	*Azadirachta indica*	*Grewelia robusta*
Residential area(SI)										
pH	12.25 ± 1.44^{3}	5.76 ± 1.60^{3}	11.2 ± 1.41^{2}	9.41 ± 1.06^{ns}	9.1 ± 0.88^{ns}	10.53 ± 1.20^{ns}	4.22 ± 0.90^{3}	8.48 ± 0.93^{1}	9.15 ± 1.15^{ns}	12.5 ± 1.66^{ns}
Relative moisture content(%)	68.12 ± 1.89^{3}	40.81 ± 1.72^{3}	72.41 ± 1.01^{3}	58.5 ± 1.05^{3}	50.41 ± 1.50^{3}	70.56 ± 1.43^{3}	42.26 ± 1.46^{3}	55.31 ± 1.33^{3}	70.62 ± 0.54^{3}	65.8 ± 1.511^{2}
Total chlorophyll (mg g^{-1})	12.1 ± 1.09^{1}	8.31 ± 0.88^{1}	11.2 ± 1.41^{ns}	12.32 ± 1.96^{ns}	10.2 ± 1.11^{ns}	9.7 ± 0.92^{ns}	4.3 ± 0.91^{2}	9.38 ± 1.49^{2}	12.7 ± 1.26^{ns}	11.7 ± 0.99^{ns}
Ascorbic acid (mg g^{-1})	10.62 ± 1.49^{3}	2.64 ± 1.15^{3}	8.6 ± 0.94^{3}	10.21 ± 0.85^{ns}	10.5 ± 1.33^{ns}	9.15 ± 1.08^{ns}	2.65 ± 0.53^{3}	11.46 ± 0.85^{3}	7.65 ± 0.522^{2}	10.5 ± 0.91^{ns}
Commrecial area (SII)										
pH	12.63 ± 0.64^{1}	12.00 ± 0.60^{ns}	7.5 ± 0.25^{ns}	8.9 ± 1.32^{ns}	12.00 ± 0.60^{ns}	10.67 ± 0.78^{ns}	4.55 ± 0.23^{ns}	8.35 ± 8.35^{ns}	9.11 ± 0.88^{ns}	12.9 ± 1.32^{ns}
Relative moisture content (%)	75.5 ± 0.031^{2}	45.99 ± 01.28^{3}	68.62 ± 1.67^{3}	34.65 ± 0.96^{3}	75.00 ± 1.01^{3}	75.66 ± 1.56^{ns}	35.61 ± 1.73^{3}	57.15 ± 1.50^{3}	57.9 ± 1.60^{ns}	75.9 ± 1.12^{3}
Total chlorophyll (mg g^{-1})	12.6 ± 0.62^{1}	11.53 ± 0.81^{ns}	8.2 ± 0.87^{2}	8.5 ± 1.17^{ns}	12.00 ± 0.60^{2}	10.72 ± 0.17^{ns}	1.75 ± 0.46^{3}	11.07 ± 1.06^{3}	9.2 ± 0.94^{ns}	12.6 ± 1.05^{2}
Ascorbic acid (mg g^{-1})	10.62 ± 0.17^{2}	5.00 ± 1.84^{3}	8.6 ± 1.15^{2}	10.21 ± 0.13^{ns}	10.5 ± 0.28^{ns}	10.54 ± 0.28^{ns}	3.55 ± 1.11^{3}	4.65 ± 0.57^{ns}	11.5 ± 0.78^{3}	11.5 ± 0.74^{ns}
Industrial area (SIII)										
pH	13.00 ± 0.58^{2}	6.81 ± 1.16^{3}	8.00 ± 0.64^{ns}	14.6 ± 0.96^{3}	14.00 ± 0.80^{ns}	12.00 ± 0.60^{ns}	5.64 ± 0.96^{3}	8.4 ± 0.78^{1}	10.4 ± 0.18^{ns}	12.2 ± 0.83^{ns}
Relative moisture content (%)	60.5 ± 1.22^{1}	50.81 ± 0.68^{3}	70.2 ± 1.75^{3}	85.71 ± 1.96^{3}	85.00 ± 1.70^{ns}	75.00 ± 1.01^{3}	40.00 ± 1.37^{3}	75.00 ± 1.02^{3}	68.7 ± 1.68^{3}	78.00 ± 0.95^{3}
Total chlorophyll (mg g^{-1})	7.51 ± 0.26^{1}	11.84 ± 1.02^{2}	10.71 ± 0.72^{ns}	15.65 ± 1.50^{3}	15.00 ± 1.41^{ns}	11.6 ± 0.64^{1}	2.42 ± 0.26^{3}	13.6 ± 1.35^{3}	13.6 ± 1.35^{ns}	11.5 ± 0.77^{ns}
Ascorbic acid (mg g^{-1})	14.5 ± 0.98^{2}	5.76 ± 1.98^{3}	7.5 ± 0.24^{ns}	15.62 ± 1.48^{3}	15.00 ± 1.41^{ns}	11.6 ± 0.63^{1}	2.6 ± 0.53^{3}	5.6 ± 0.91^{ns}	9.6 ± 0.16^{2}	11.2 ± 0.70^{ns}

All values are means (n=3)± SD. Means of individual parameters are compared in different plants within row. ^{3} = highly significant, $p<0.001$; ^{2} = significant, $p<0.01$; ^{1} = less significant, $p<0.05$; ^{ns} = non significant, $p>0.05$

(Fig. 1).The variation in biochemical parameters in the leaves can be used as indicators of air pollution for early diagnosis of stress or as a marker for physiological damage prior to the onset of visible injury symptoms (Mandal and Mukherji, 2000; Agrawal, 2003; Joshi and Swami, 2007).

A considerable loss in total chlorophyll , in the leaves of the sensitive plants as *i.e. Bauhinia variegata* and *Cassia simea* was reported, at Site SII ($p<0.001$) and SIII ($p<0.001$); supports the argument that the chloroplast is the primary site of attack by air pollutants such as SPM, SO_2 and NO_2. Air pollutants make their entrance into the tissues through the stomata and cause partial denaturation of the chloroplast and decreases pigment content in the cells of polluted leaves (Tripathi *et al*.,1999; Mandal and Mukherji, 2000; Wang and Lu, 2006). Mean concentrations of all the parameters of *Saraca indica* at SIII and *Pithecolobium dulcis* at SII are found insignificant ($p>0.05$) *i.e.* as the local sources contributing these parameters equally at both the sites and *Holoptelea integrifolia* and *Cassia simea* shown highly significant values ($p<0.001$) of all the parameters at SIII (Table 2).

Present investigation revealed a great deal of variation in the ascorbic acid content in all the plant species at all the sites (Table 2) and the increased level of ascorbic acid reported may be due to the defense mechanism of the respective plants (Tripathi and Gautam, 2007; Cheng *et al*., 2007) .

APTI of ten different plant species at residential ,commercial and industrial area are given in Fig. 1. Among all the plant species *Pongamia pinnata, Holoptelea integrifolia, Saraca indica* and *Pithecolobium dulcis* have much more high APTI values *i.e.* 15.8, 55.8, 52 and 34.8 respectively than the residential area (SI) so these plant species are termed as tolerant plants. Some plant species as *Ficus rumphii, Azadirachta indica* and *Grewelia robusta* have slightly more APTI values *i.e.* 35.7, 30.5 and 34.3 respectively than the residential area (SI) are termed as moderately tolerant plants and remaining plant species as *Alstonia scholaris, Cassia simea* and *Bauhinia variegata* have low APTI *i.e.* 21.5,6.09 and 18.2 respectively than the residential area(SI) are termed as sensitive plants and they can be treated as bioindicators of pollution. Sensitive species are those either not found in the contaminated area or occur only in low abundance (Skelly, 2003) .

Air pollutants in urban and industrial area may get absorbed, accumulated or integrated in the plant body and if toxic,may injure the plants in various ways (Ishii *et al*., 2007; Singh *et al*., 2008).The rate and total amount of pollutant taken up from the air can affect photosynthesis, respiration, leaf conductance and leaf longevity. All of these factors in trees adversely affect canopy carbon fixation and net accumulation of chlorophyll. In sensitive species the level of injury was found high resulting in less chlorophyll and vice-versa in tolerant species. Nrusimha *et al*. (2005) have recorded the similar observation as the sensitive species, help in indicating air pollution and tolerant ones help in abatement. This fact is also supported by many workers as they studied the physiological response under heavy industrial pollution stress (Chang *et al*., 2004; Hong Xia *et al*., 2006; Jing *et al*., 2007).

Some plants can also be used as an active biomonitor of heavy metal pollution (Calzoni *et al.*, 2007) as these are supposed to be an alternative to conventional instrumentation of environmental pollution control due to advantage such as allowing the monitoring of large area and to the low plant cultivation and maintenance cost.

Thus on the basis of above study ten common growing trees are categorized into tolerant, moderately tolerant and sensitive plant species according to their air pollution tolerance index values. The plants which are tolerant can be used as scavengers for identification and impact of combating air pollution in the city's polluted area where non-ferrous smelting is done at a large scale. Workers are facing so many health problems as they are directly exposed to toxic metal fumes in these industries(epidemiological studies in detail has to be done still).Green belt plantation around the air polluting unit can never be a claim for the removal of air pollutants at the region, but effectively planted trees in the green belt may potentially remove the toxic gases in considerable amount (Skelly, 2003; Leena *et al*., 2003; Shanningrahi *et al*., 2004). So this study is useful for the better understanding and management of air quality as well as in selection of suitable plant species (with high APTI) for plantation in industrial area as well as roadside and this may become one of the strategy for the abatement of city's air pollution because it will have a marked effect on many aspects of the quality of the urban environment and the richness of life in a city.

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