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Interaction of Urban Vegetation Cover to Sequester Air Pollutants from Ambient Air Environment

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1. Introduction

Acute air pollution problem is being faced in urban agglomeration due to economic expansion, increase in population, increased industrial activities and exponential growth in automobiles. The air pollution from these sources is imposing threat to urban human health. The morbidity and mortality caused by air pollution result in long term reduction of productivity and ultimately in overall deterioration of economic condition (Dockery & Pope, 1994; Anderson et al., 1992; Schwartz et al., 1996). In India the particulate matter problem is very significant due to the huge number of vehicles plying on the road, number of power plants, combustion processes, dust storms and domestic emissions (Gurjara et al., 2004). In the recent studies, exceeding levels of PM10 are observed (TERI, 1997; Chelani et al., 2001).

The trees in urban environment are continuously exposed to air pollutants, which play an important role in maintaining ecological balance by actively participating in the nutrients cycle. Many trees are effective for trapping and absorbing air pollutants and acts as sink to several air pollutants (Allan & Krupa, 1986; Bell & Treshow, 2002; Farmer, 1993; Barker & Tingey, 1992; De Kok & Whaltey 1984; De Kok & Stulen, 1998; Treshaw & Anderson, 1989; Nowak *et al*. 1997; Shyam *et al*., 2006). Hence it is more beneficial to see the impact of pollution on vegetation especially on roadside trees. (Gajghate & Hasan, 1999; Kotoh *et al*. 1989; Kozhauharov *et.al*. 1985; Ninave *et.al*., 2001; Mellios *et al*., 2006; Mutena, 2004; Tommervik *et al*., 1995).

Nagpur City is the best place to study the interactions of atmospheric pollutants such as SO_2, NO_2 and suspended particulate matter (SPM) on vegetation, as it is high traffic zone with industrial area on the outskirts as well as have good vegetation cover in the city. Nagpur city is very well known as second Green City in India. Plantations are actively carried out every year in the city with the active participation of local administration and non-governmental organizations (NGOs). The city is also richly dotted by well maintained parks, plantations, forest patches and agricultural fields. This has given lush green aesthetic appearance to the Nagpur city.

Present research is carried out, to study the status of urban pollution in relation to biodiversity in the Nagpur city using ambient air quality monitoring, remote sensing for landuse cover, ground truth and anatomical and biochemical responses of the trees to air pollution.

2. Materials and methods

2.1 Sampling locations

The Nagpur city is situated in between 20^0 30′ and 21^0 30′ N latitude and 78^0 30′ and 79^0 30′ E longitude. The strategic situation of the Nagpur City in the central part of India has lead a rapid expansion of city and ever increasing environmental problems with reference to pollution of air, water and soil. Ambient air quality monitoring, vegetation survey and remote sensing study have been carried out in three different areas of the city having different activities namely industrial (MIDC), commercial (Itwari) and residential (NEERI Campus).

2.2 Remote sensing study

In order to strengthen the baseline information on existing land use pattern, the remote sensing data has been collected for Nagpur area lying between (21^0 03′ – 21^0 13′) N longitude (79^0 00′ – 79^0 10′) E latitude. The satellite data was acquired from the IRS P6 (RESOURCESAT -1) LISS III Scene (Path 99, Row 57 dated 04 Nov-2004; CD format) and the collateral data were used from Reference map, Toposheets 55 o/4 and 55 k/16.

2.3 Biological survey

Biological survey was carried out at these three sampling sites. The species of plants, their abundance and diversity were recorded and correlated with land use pattern of vegetation obtained through remote sensing imagery.

2.4 Air pollution tolerance index (APTI)

The plants namely *Bougainvellia spectabilis, Azadirachta indica, Pongamia pinnata* and *Polyalthia longifolia* growing in these area were selected for studying their biochemical responses to the impact of air pollution. The leaf samples were analyzed for pH (P) of leaf extract (Singh and Rao, 1993), Chlorophyll (T) (Arnon, 1949), ascorbic acid (A) (Singh, 1977) and Relative water content (R). Air pollution Tolerance Index (APTI) which gives an empirical value representing tolerance level of a plant to air pollution was used to interpret the impact of pollution on the plants. The APTI is calculated by the formula as A(T+P)+R/10.

2.5 Air monitoring

SPM in ambient air was measured by using standard High volume (Hi-vol) sampling technique. Gaseous samples were collected in absorbing solutions by tapping air and collected samples were analyzed using standard wet chemical method (Katz, 1977).

3. Results and discussions

3.1 Vegetation cover in study area through remote sensing

The land use / land cover status in Nagpur urban area as per IRS P6 LISS-III is shown in figure. 1. Eight different classes are identified in the Nagpur namely settlement, water bodies, fallow land, scrubland, bare soil/sand, vegetation-1, vegetation-2 and vegetation-3. Normalized Differentiation Vegetation Index (NDVI) values were computed for Nagpur City. The entire area has been classified into five categories namely non-vegetation, vegetation-1, vegetation-2, vegetation-3, and vegetation-4. The percentage compositions of these classes in Nagpur City were non-vegetation (58.79%), vegetation-1 (17.40%), vegetation-2 (14.86%), vegetation-3 (3.77%), and vegetation-4 (5.19%) respectively.

The percentage compositions of different classes of vegetation (Table 1, Figure 1) in residential area are non-vegetation (71.23%), vegetation-1 (8.87%), vegetation-2 (8.82%), vegetation-3 (4.89%) and vegetation-4 (6.19%). The percentage compositions of different classes in industrial area are non-vegetation (74.08%), vegetation-1 (10.18%), vegetation-2 (7.31%), vegetation-3 (4.51%), and vegetation-4 (3.92%). Similarly, the percentage compositions of different classes in commercial area are non-vegetation (89.38%), vegetation-1 (6.18%), vegetation-2 (3.34%), vegetation-3 (0.49%) and vegetation-4 (0.61%). Table 1 show that the vegetation cover is highest at residential area i.e. 28.77%, lowest in commercial area i.e. 10.62% and moderate in industrial area i.e. 25.92%. Similarly the density, abundance and diversity of plants are highest at residential area while it is lowest in commercial area. The density and diversity of plants is medium at industrial area.

Classification Category	Residential Area		Industrial Area		Commercial Area	
	(Area in Km^2)	Area in %	(Area in Km^2)	Area in %	(Area in Km^2)	Area in %
Non-vegetation	19.547	71.23	20.330	74.08	24.529	89.38
Vegetation – 1	2.434	8.87	2.793	10.18	1.695	6.18
Vegetation – 2	2.420	8.82	2.007	7.31	0.917	3.34
Vegetation – 3	1.342	4.89	1.238	4.51	0.133	0.49
Vegetation – 4	1.700	6.19	1.075	3.92	0.618	0.61
Total (Vegetation)	7.896	28.77	7.113	25.92	3.363	10.62
Total Area	27.443	100	27.443	100	27.443	100

Table 1. Inventory of vegetation cover at different air quality monitoring locations

3.2 Floral diversity and abundance

The field survey of plants in Nagpur City showed a total of 103 plant species consisting of 45 tree species, 13 shrub species, 30 herb species, 8 species of climbers, 1 species of bamboo and 5 species of grasses. The density and diversity of plants were not equally distributed throughout the Nagpur City. The numbers of plants are more in well-planned residential area with adequate space for maintenance of green cover. Density and diversity of the plants is more in residential areas. Around 100 plants species were observed in residential areas with higher abundance of most of the species (around 800 trees/ha). The dominant plants were *Azadirachta indica*, *Albizzia procera*, *Annona squamosa*, *Leucaena lecocephala, Ipomoea fistulosa*, *Lantana camara*, *Alternanthera sessilis*, *Ageratum conizoides, Calotropis gigantia, Parthenium hysterophorus. Cyanodon dactylon and Dactyloctenium*. Among trees *Azadirachta indica, Leucaena leucocephala* are most abundant species. The shrub *Calotropis procera and Lantana camara* are abundant species. (Table 2).

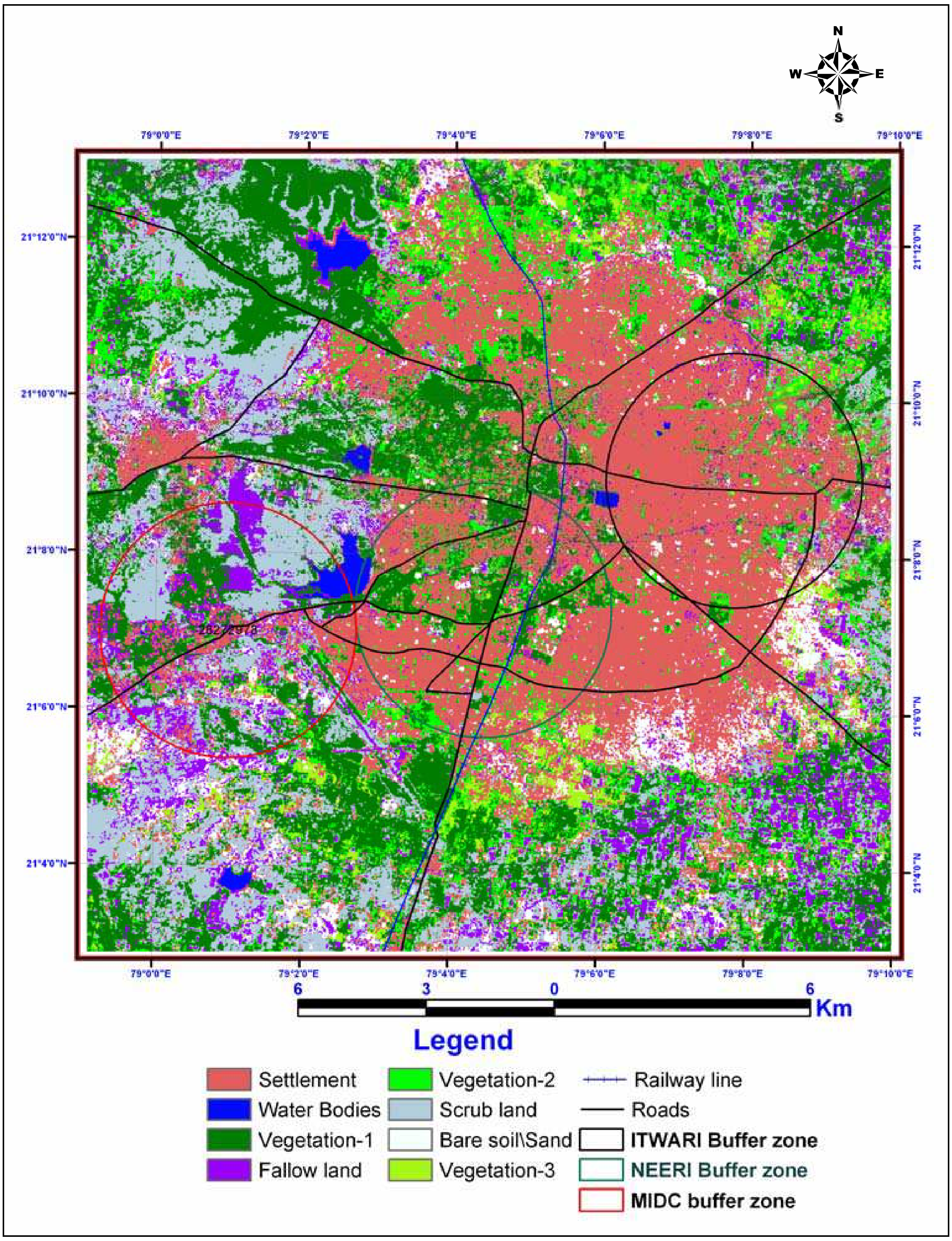

Fig. 1. Vegetation cover at Nagpur city

The industrial area has moderate amount of vegetation cover, which consist of avenue plantations, greenbelts and vegetation around industrial complexes. A total of 59 species of plants were recorded from this area. The density of trees is around 200 trees./ha. The dominant plants were *Azadirachta indica, Cassia fistula* and *Cassia siamea.* While among herbs *Parthenium hysterophorus*, *Ageratum conizoides* and *Alternanthera sessilis* were the most abundant species.

Sr. No.	Abundance Class	Abundance Scale (Species cover)	Species		
			Tree	Shrub	Herb
1	5	76-100%	*Azadirachta indica*	*Calotropis procera*	*Parthenium hysterophorus*
2	4	51-75%	*Leucaena leucocephala*	*Lantana camara*	*Ageratum conyzoides, Alternanthera sessile*
3	3	26-50%	*Albizzia procera*	*Ricinus communis*	*Malvastrum tricuspidatum*
4	2	6-25%	*Cassia siamea*	*Vitex negundo*	*Tridax procumbens, Ocimum sanctum*
5	1	up to 5%	*Psidium guajava*	*Indigofera tinctoria*	*Ricinus communis, Tinospora cordifolia*

Table 2. Abundance of major plant species in Nagpur urban area

The commercial area is the old part of the city with narrow lanes, closely set houses, shops and hectic commercial activity. Avenue plantation is negligible. Gardens and other plantation are almost absent. Thus, less number of plant species (32 species) were observed, the important species were *Azadirachta indica* and *Cassia siamea.*

3.3 Air quality status

Annual ambient air quality data is presented in Table 3. The annual average values of SPM varied ranged from 124, 134 and 195 g/m^3 at residential, industrial and commercial sites respectively. Highest concentrations of SPM were recorded in commercial site. The reason for high SPM at commercial site is due to vehicular emissions, re-suspension of dust, commercial and domestic use of fuel etc. (NEERI Report, 2001).

The annual average values of NO_2 concentration were ranged from 18, 15 and 21 g/m^3 at residential, industrial and commercial sites and those of SO_2 in air ranged from 6, 9 and 7 at residential, industrial and commercial sites respectively.

The residential area showed lowest levels of air pollutants as compared to those in industrial and commercial places. Though the values of SO_2 and NO_2 in residential, industrial and commercial areas are well below the standards, SPM values exceed the standards for commercial area i.e. 140 g/m^3. Thus the ambient air quality is satisfactory in Nagpur city. However the rapid expansion of city, increasing number of automobiles and proposed big industrial area indicate that Nagpur would also be classified as polluted city if preventive environmental management measures are not undertaken.

Air Pollutant	Residential Site			Industrial Site			Commercial Site			Co-relation Coefficient
	N	AM	SD	N	AM	SD	N	AM	SD	
SPM	70	124	77	54	134	101	51	195	107	0.00278
SO_2	92	6	2	83	9	9	82	7	4	0.65
NO2	92	18	18	83	15	14	82	21	21	0.709

N: Sampling Days
AM: Arithmetic Mean
SD: Standard Deviation

Table 3. Annual Arithmetic Mean of SPM, SO_2 & NO_2

3.4 Sequestration of air pollutants by vegetation cover

The concentration of air pollutants was observed to be highest in industrial area followed by commercial area and residential area in decreasing order. It appears that ambient air quality in these microhabitats of Nagpur city is governed by sources of pollution as well as vegetation cover in that area. Table 3 shows that the biodiversity is highest in residential area followed by industrial area and commercial area in decreasing order.

Considering the air pollutant concentration in industrial area as 100%, the air pollutants SPM and SO_2 showed decrease in their concentration by 31.28% and 36.39% for SPM and 22.22% and 33.33% for SO_2 in commercial and residential area respectively. Thus filtering capacity of the plants is well known and these are utilized in greenbelt and in avenue plantation for filtration and reduction of dust concentration in air (Rao *et al*, 1993; Olszyk, 1984). The trees are also well known for acting as sink for SO_2 (Butterbach *et al*., 1997; Shen *et al*., 1995). The densities of trees (No/hector) were observed to be co-relating with reduction in ambient SPM and SO_2 concentration (Fig. 2 and 3).

Similarly the biodiversity of plants is also observed to be positively co-related with reduction in ambient concentrations of SO_2 and SPM. It is thus evident that increase in number of trees and increase in biodiversity helps in effective sequestration of air pollutants especially SO_2 and SPM. The ambient NO_2 concentration was observed to vary from 15 to 21 $\mu g/m^3$ (Fig 4). Each distribution pattern did not co-relate with number of trees or biodiversity of the area.

It has been reported that plant has high preference for SO_2 and extremely law preference for NO_2 to be absorbed and metabolized in the plant tissue. The preference for the plants for air pollutants has been investigated by Hill (1971) and Bennet and Hill (1973, 1975) that appear to follow the following order.

$$HF > SO_2 > Cl > NO_2 > O_3 > PAN > NO > CO$$

Smith (1981) assess pollutant removal efficiency of a model forest hector developed by USEPA which consisted of 95% year old plants will observed that, this forest patch annually removes 748 tonnes of SO_2 while only 0.38 tonnes of NO_2 is removed from atmosphere.

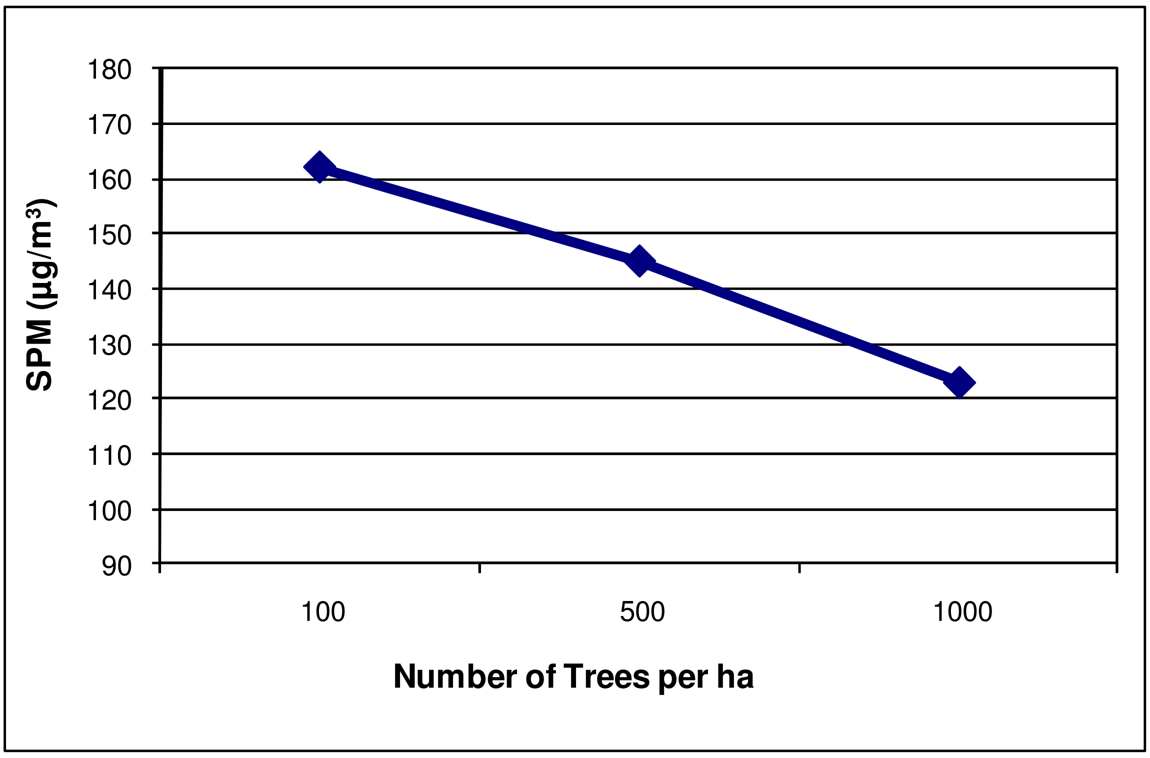

Fig. 2. Relationship between number of trees (per ha) and ambient SPM concentration (Slope: 0.04 and Intercept: 166.17)

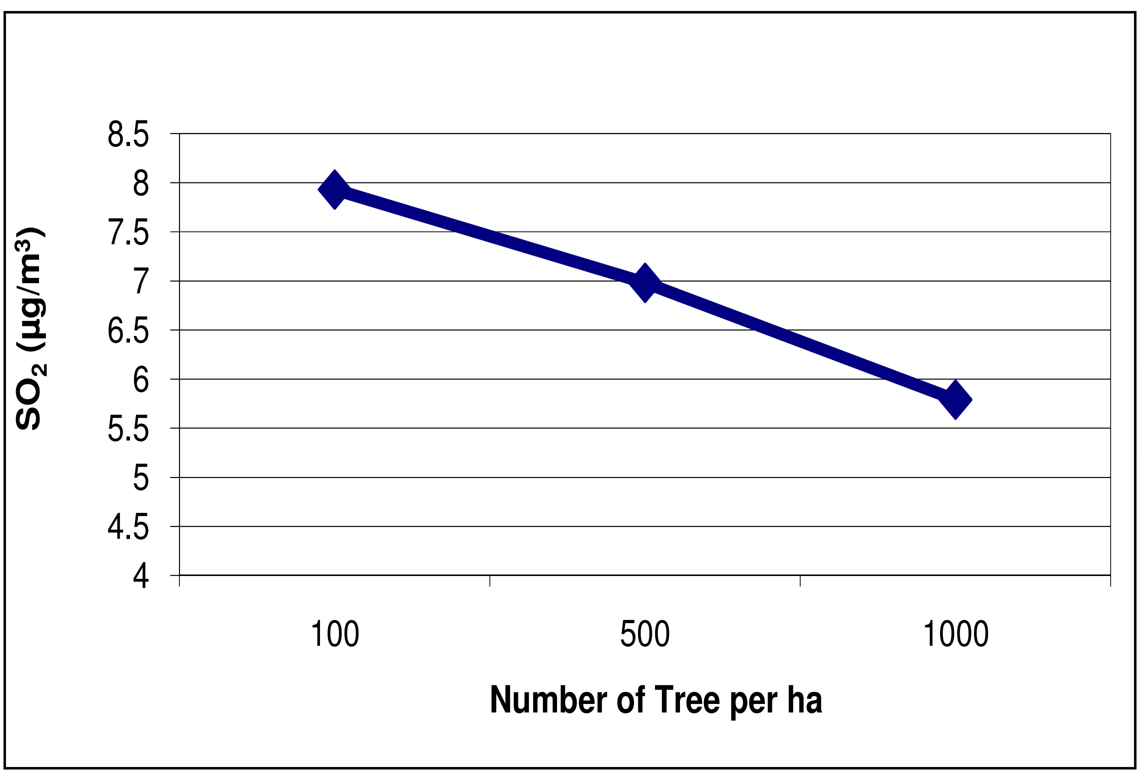

Fig. 3. Relationship between number of trees (per ha) and ambient SO_2 concentration (Slope: 0.00238; Intercept: 8.17)

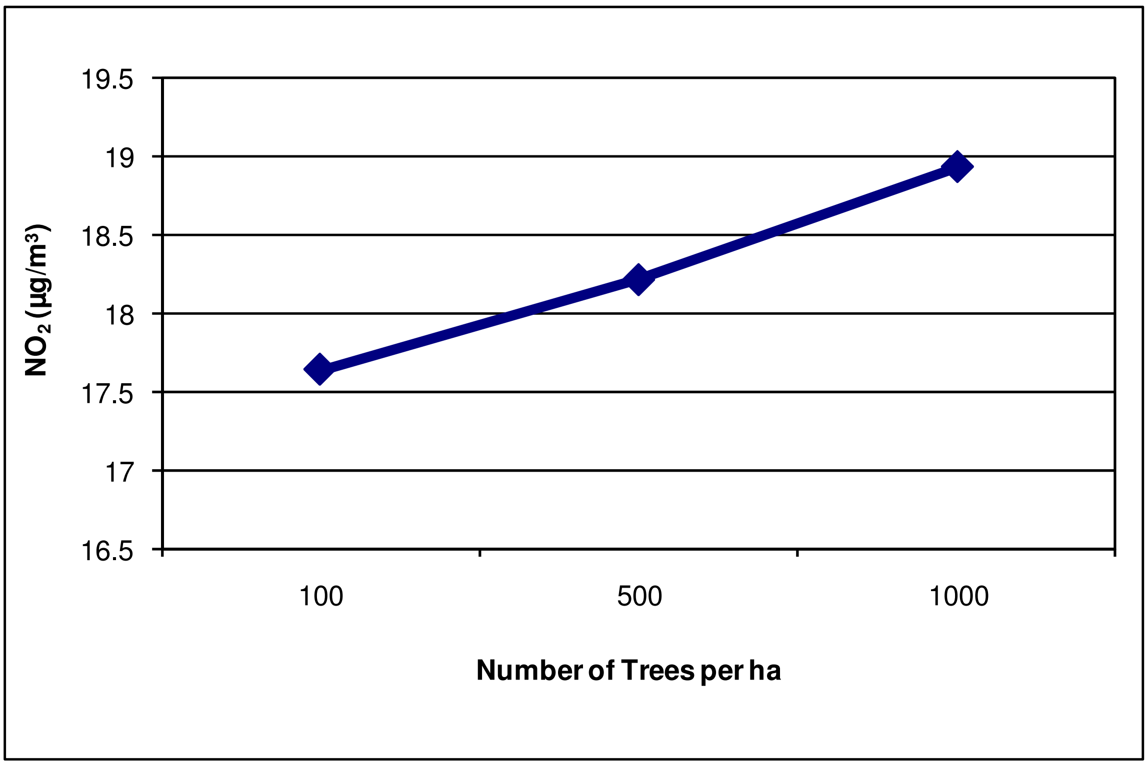

Fig. 4. Relationship between number of trees (per ha) and ambient NO_2 concentration (Slope: 0.00238; Intercept: 8.17)

3.5 Air pollution tolerance index (APTI)

The forgoing discussion shows that present level of pollutants are lower than the prescribed limits except SPM. However these chronic levels are prevailing for a long time i.e. more than 20 years. It is the vegetation cover that is acting as sinks to the air pollutants and playing important role in keeping the levels of pollution well below the standards. However the vegetation cover is relatively less in the commercial area and shows impact of air pollution. The vegetation of Nagpur city is exposed to dust pollution, which may affect the biochemical make up and tolerance capability of plants to the air pollution. The Air Pollution Tolerance Index for the plants from residential, commercial and industrial area is shown in figure III respectively. The APTI of the plants from residential area ranged from 13.09 to 61.39 and from 16.69 to 31.44 in commercial area whereas from 22.02 to 83.15 for plants in industrial area. APTI values of the four common trees in polluted area were found to vary from 16.69 to 83.15 and the plants are listed according to their tolerance or sensitivity to pollution. The four species selected for APTI studies are tolerant to air pollutants in the geographical area of Nagpur city. Next to *Azadiracta sp*. with APTI value (61.36) *Baugainvellia sp*. was found to have APTI index values of 16.87 at residential area, 27.44 at commercial area and 27.83 in industrial area. *Polyalthia* sp. which ranks next showed APTI values of 18.40 at residential area, 21.64 and 22.12 at commercial and industrial area respectively (Fig. 5). Though these species showed different sensitivity, they all appear to be tolerant to air pollution as their APTI values showed to be increased in polluted environment. This may probably be the reason that the plants develop tolerance and detoxify the absorbed pollutants and as a result other biochemical constituents are not affected in such plants. This

can be taken as an indication of the development of detoxification mechanism in the plant necessary for the tolerance.
This work has indicated the suitability of *Azadirachta indica* as the most tolerant species, suitable as sink for air pollution. It can be utilized for urban plantation and greenbelt development in industrial area to reduce the level of air pollution. However more research is necessary on a wide variety of trees, shrubs and herbs to prepare a biological sensitivity map of flora. The vast database would be useful in identifying tolerant plants, sink plants and management program.

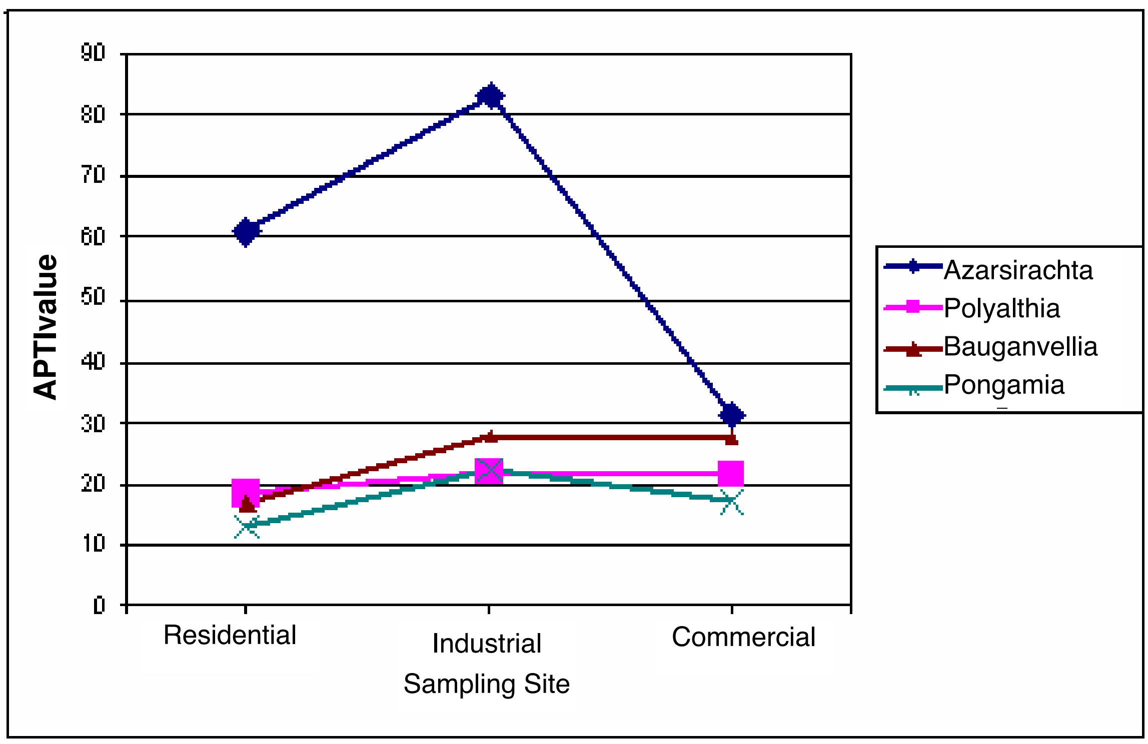

Fig. 5. APTI values of four tree species in different sampling sites

4. Conclusion

The consequences of complex effects of combinations of several atmospheric pollution and climate change in particular may threaten vegetation in ecosystem of urban atmosphere. The levels of pollutants SPM, NO_2 and SO_2 were highest at commercial site followed by industrial and then residential site. Status of air quality with respect to NO_2 and SO_2 showed the values within the range while SPM level is higher than the standard value except at commercial place. In response to these changing conditions plants adopt to their changed environment by showing different air pollution tolerance index. Out of four species namely *Azadirachta, Polyalthia, Baugainvellia* and *Pongamia,* only the *Azadirachta* is having the best air pollution tolerance index. This study can be helpful to identify the plant species for greenbelt development as one of the control measures for reduction of ambient concentration of air pollution. This tolerant species may be used for avenue plantation and beautification of the city. The vegetation is denser at residential site, while it is moderate at industrial site. Though the industrial area shows moderate air pollution but the small green belts in and around the industries do not allow the air pollutants to raise upto higher limits. Similarly at commercial location the lack of vegetation causes increase in the levels of NO_2, SO_2 and SPM. This proves that the plants are the best sinks for all types of air pollutants. More work in this area is needed for more precise information on expected changes in vegetation exposed to air pollutants. Similar studies can be extended to identify air pollution tolerant species at different environmental pollution level in different climatic conditions, which can be used to maintain the air quality level within the permissible level.

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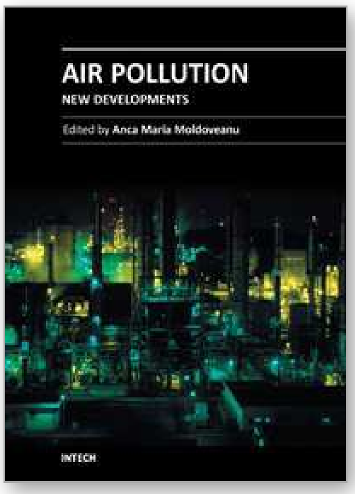

Air Pollution - New Developments
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Today, an important issue is environmental pollution, especially air pollution. Due to pollutants present in air, human health as well as animal health and vegetation may suffer. The book can be divided in two parts. The first half presents how the environmental modifications induced by air pollution can have an impact on human health by inducing modifications in different organs and systems and leading to human pathology. This part also presents how environmental modifications induced by air pollution can influence human health during pregnancy. The second half of the book presents the influence of environmental pollution on animal health and vegetation and how this impact can be assessed (the use of the micronucleus tests on TRADESCANTIA to evaluate the genotoxic effects of air pollution, the use of transplanted lichen PSEUDEVERNIA FURFURACEA for biomonitoring the presence of heavy metals, the monitoring of epiphytic lichen biodiversity to detect environmental quality and air pollution, etc). The book is recommended to professionals interested in health and environmental issues.