Tree As Bio-Indicator Of Automobile Pollution In Dehradun City: A Case Study

Avnish Chauhan
Department of Applied Sciences and Humanities
Teerthanker Mahaveer University, Moradabad, Uttar Pardesh-244001
avnishchauhan_phd@aol.in

Abstract: The plant species selected for the study were *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*, *Delonix regia*. Reduction in chlorophyll ***'a'***, chlorophyll **'*b*'**, total chlorophyll content, ascorbic acid, carotenoid, pH, relative water content and APTI was recorded in the leaf samples of all selected trees collected from polluted site when compared with samples from control area. The data obtained were further analyzed by using two-way ANOVA and also obtained significant changes in all these parameters was found in the leaf samples collected from polluted site trees, exposed to automobile exhaust in comparison to control site. There was maximum (43.36%) reduction of chlorophyll ***'a'*** content in the leaves of *Ficus religiosa* and minimum (26.57%) reduction was in the *Mangifera indica*, while maximum (30.99%) carotenoid was depleted in *Polyalthia longifolia* and minimum (18.42%) depleted in *Mangifera indica* at polluted site as compared to control site. The maximum (44.67%) reduction of ascorbic acid was observed in the leaves of *Delonix regia* and minimum (22.93%) reduction was observed in the leaves of *Polyalthia longifolia*. [New York Science Journal 2010; 3(6):88-95]. (ISSN 1554 – 0200).

Keywords: Air Quality Index, Clock Tower, Chlorophyll, APTI

1. Introduction:

Normal air contains about 78% nitrogen, 21% oxygen, 0.93%, argon 0.038% carbon dioxide, and several other trace gases. Changes in the gaseous composition of earth's atmosphere have become a prime concern for today's world due to human activities. Ambient air pollution in several large cities of India is the amongst the highest in the world (Agarwal, 2005). According to an estimate, dust pollutants comprise around 40% of total air pollution problem in India (Khan et al., 2005). Urban air pollution poses a significant threat to animal, plants and human health, is receiving attention as a growing share of the world's population is now living in urban centers and demanding a clearance urban environment. India and other developing countries have experienced a progressive degradation in air quality due to industrialization, urbanization, lack of awareness, number of motor vehicles, use of fuels with poor environmental performance, badly maintained poor roads and ineffective environmental regulations (Joshi and Chauhan, 2008). Vehicular pollution contributes to 70% of total air pollution in Delhi, 52% in Mumbai and 30% in Calcutta (C.P.C.B., 2003; Ghokale and Patil, 2004). Most of the cities located in Northern India are afflicted with the presence of unusually high concentration of air pollutants viz. SO_2, NO_x, SPM and RSPM. Studies on the impact of automobile pollution on plant response have attracted much interest. Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere. Trees remove gaseous air pollution by leaf stomata and particles by intercepting.

Urban air pollution has become a serious environmental problem to trees and crops (Chauhan and Joshi, 2008). Motor vehicles account for 60-70% of the pollution found in urban environment (1), followed by industries (20-30 %) in India. Trees experience the greatest exposure and influenced greatly by pollutant concentration due to their perennial habit (Raina and Sharma, 2003). Regional impact of air pollution on local plant species is one of the major ecological issues. The climate conditions, the physico-chemical properties of air pollutants and their residence time in the atmosphere have the impact on surrounding plants and animals (Wagh et al., 2006). Presence of trees in the urban environment can thus improve air quality through enhancing the upper of gases and particles (Phearson et al., 1994, Smith, 1991). Trees act as a sink of air pollutants and this reduce their concentrations in the air (Prajapati and Tripathi, 2008).

Chlorophyll itself is actually not a single molecule but a family of related molecules, designated chlorophyll '*a*', '*b*', '*c*', and '*d*'. Chlorophyll '*a*' is the molecule found in all plant cells and therefore its concentration is what is reported during chlorophyll analysis. Accessory pigments absorb energy that chlorophyll ***'a'*** does not absorb. Accessory pigments include chlorophyll '*b*', xanthophylls and carotenoid (Joshi and Chauhan, 2008). The present investigation has been carried out to determine the effects of automobile exhaust on photosynthetic pigments such as chlorophyll ***'a'***, ***'b'***, total chlorophyll, carotenoid, ascorbic acid, relatively humidity, pH and APTI (Air pollution tolerance index) trees grown at the famous Clock Tower of Dehradun and also plants from pollution free atmosphere. All these parameters at polluted site were compared with control site. The concentrations of two and four vehicular were recorded as 110-120 and 35-43, respectively at polluted site.

2. Materials and Methods:

Study Sites:

Polluted site was located at roundabout of famous Clock Tower in Dehradun which is the busiest roundabout in Dehradun city and traffic jam condition prevalent here throughout the day, posses a high number of two wheelers, three wheelers and four wheelers. While the control site was located at Tarla Nagal village, Sahastradhara Road, Dehradun. The control site was situated about 11 kms away from polluted site where pollution level is almost very low, posse's very dense forest and vegetations covers. The fresh leaf samples (in ten replicates of selected trees) were collected from both sites, polluted and control, grown on the edge of the road almost with similar topography or conditions and all these leaves were free from pathogens or any diseases.

Air pollutants (SO_2, NO_x, SPM and RSPM) monitoring data at polluted site was obtained from State Pollution Control Board, Dehradun. However at the control site the concentration of air pollutants was measured with the help of RDS APM 460 by sucking air into appropriate reagent for 24 hours at every 30 days. The SPM and RSPM were analyzed using Respirable Dust Sampler (RDS) APM 460 and operated at an average flow rate of 1.0-1.5 m^3 min^{-1}. Preweighed glass fiber filters (GF/A) of Whatman were used as per standard methods. SO_2 and NO_x were collected by bubbling the sample in a specific absorbing (sodium tetrachloromercuate of SO_2 and sodium hydroxide for NO_x) solution at an average flow rate of 0.2-0.5 min^{-1}. The impinger samples were put in ice boxes immediately after sampling and transferred to a refrigerator until analyzed. And procured into lab within in same day and analyzed immediately for the concentrations level. The concentration of NO_x was measured with standard method of Modified Jacobs-Hochheiser method, (1958), SO_2 was measured by Modified West and Geake method (1956), SPM and RSPM using filter paper methods. The apparatus was kept at a height of 2 m from the surface of the ground. Using air pollutants data the air quality index was calculated. Leaves samples collected from both polluted and control sites. All the plants were matured and well aged. The fresh leaf samples collected from trees (about 5-8 feet height from ground level). The chlorophyll '*a*', chlorophyll '*b*' and total chlorophyll were measured as per standard method of Maclachlan and Zalik (1963). Carotenoid was determined by the method of Duxbury and Yentsch (1956). Ascorbic acid was determined by the method of Sadashivam and Manikam (1991). Ten samples of each of the tree species were analyzed on each sampling date. Similarly replicate samples and analytical blank were also analyzed to check the reliability of data. Relative moisture content by Weatherly (1965) and Air pollution tolerance index (APTI) was estimated using the method of Singh and Rao (1983). Leaf samples of selected trees were collected fortnightly during the study period from the Clock Tower (Polluted site) and 11 km far away from the control site. These were weighed in a single pan electric balance (0.01mg accuracy) for measuring the dust content and then thoroughly washed with double distilled water for further analysis. AQI (air quality index) is then calculated with the concentration values using the following equation (Rao and Rao, 1998).

$$AQI = 1/3\ ((SO_2)/Sso_2 + (NO_x)/S_{NOX} + SPM/S_{SPM}) \times 100$$

The assessment studies were conducted on *Ficus religiosa, Mangifera indica, Polyalthia longifolia* and *Delonix regia* during 2008-2009.

3. Results

Concentrations of Primary Pollutants

The concentration of primary pollutants recorded has been presented in Table -1. Concentration of NO_x at polluted site was 26.68, 27.02 and 27.92 μgm^{-3} during winter, monsoon and summer, respectively, At control site it was reported as 1.69, 1.60 and 1.93 μgm^{-3} during winter, monsoon and summer, respectively. SO_2 recorded at polluted site was 25.29, 25.14 and 26.61 μgm^{-3} during winter, monsoon and summer, respectively. While at the control site it was reported as 2.29, 1.98 and 2.16 μgm^{-3} during the same period. The highest concentration (285.47 μgm^{-3}) of SPM was recorded during summer reason at polluted site, while the lowest concentration (199.04 μgm^{-3}) was recorded during the monsoon. The highest concentration (137.50 μgm^{-3}) of RSPM was recorded during summer season at polluted site while the lowest concentration (89.93 μgm^{-3}) was recorded during monsoon season at polluted site. Using the Table -1 the Air Quality Index (AQI) values were calculated, presented in Table-2. The high value (117.88) of AQI observed during summer at polluted site, whereas the lowest concentration (88.08) was recorded during the monsoon at polluted site. Polluted site was termed under the categories "Severe Air Pollution" (SAP), "Moderate Air Pollution" (MAP), while the control site was termed under the categories of "Light Air Pollution" (LAP). Polluted site is very busy road which bears high number of scooters, motor cycles, three wheelers, cars, buses. As polluted site bears very high traffic volumes and there is traffic jams condition because roads are narrow at two side of Clock Tower roundabout. The higher concentrations of SO_2, NO_x, SPM and RSPM were observed during the study period at polluted site in Haridwar, it may be due to plying of petrol and diesel vehicles (Chauhan, 2008). It has been reported that heavy diesel vehicles emitted 24 times (empirically) more fine particulates than light duty gasoline powered vehicles (13). Chauhan and Joshi (5) found that the concentration of SO_2 and NO_x was under the standard limit of CPCB while the concentration of SPM was higher than the standard limit of CPCB, New Delhi in urban and industrial areas of Haridwar.

Chlorophyll Pigments

Variations in physiological characteristics of the selected tree species exposed to ambient air pollutants are given in Table-3.

Chlorophyll *a* and *b* contents in the leaf samples of *Ficus religiosa* were reported as 1.43±0.08 and 1.13±0.05 mg gm^{-1} at control site whereas these were 0.81±0.06 and 0.61±0.05 mg gm^{-1} respectively, at polluted sites. A decrease of 43.36% in chlorophyll *a* and 46.02% in chlorophyll *b* was recorded at polluted site in comparison to control site. Total chlorophyll content recorded for *Ficus religiosa* was 2.56±0.48 and 1.42±0.09 mg gm^{-1} at control and polluted sites, respectively.

Chlorophyll *a* and *b* contents of *Mangifera indica* were reported as 2.71±0.07 and 2.03±0.09 mg gm^{-1} at control site and 1.99±0.05 and 1.63±0.12 mg gm^{-1} at polluted sites, respectively. A decrease of 26.57% and 19.70% was thus recorded in chlorophyll *a* and *b* contents at polluted site, respectively. Total chlorophyll content recorded at control and polluted sites was 4.74±1.22 and 3.62±0.58 mg gm^{-1}, respectively. There was a reduction of 23.63% in the total chlorophyll content in the leaf samples from the polluted site as compared to control site.

Chlorophyll *a* and *b* contents of *Polyalthia longifolia* were reported as 1.33±0.17 and 0.84±0.12 mg gm^{-1} at control and 0.96±0.44 and 0.59±0.06 mg gm^{-1} at polluted site, respectively. A decrease of 36.84% and 38.54% was recorded in chlorophyll *a* and *b* at polluted site, respectively. Total chlorophyll content recorded at polluted site for *Polyalthia longifolia* was 2.17±0.22 and it was 1.55±0.28 mg gm^{-1} at control site, a reduction of 28.57% in the total chlorophyll content of plant samples from polluted site as compared to control site was recorded.

Chlorophyll *a* and *b* contents of *Delonix regia* were reported as 1.64±0.11 and 1.01± 0.15 mg gm^{-1} at control site and 1.04±0.11 and 0.76±0.14 mg gm^{-1} at polluted sites, respectively, with a decrease of 38.41% and 26.92% in chlorophyll *a* and *b*, respectively. Total chlorophyll content recorded at control site was 2.65±0.14 mg gm^{-1} which was 1.81±0.12 mg gm^{-1} at polluted site, thus in this case there was reduction of 31.70% at the polluted site as compared to control site.

Carotenoid and ascorbic acid

Carotenoid contents of *Ficus religiosa* recorded at control and polluted site were 1.49±0.14 and 1.03±0.07 mg per gm, respectively. A decrease of 30.87% was thus recorded in the amount of carotenoid in the polluted site as compared to control site. Ascorbic acid content recorded was 1.50±0.11 and 0.83±0.07 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 44.67% in ascorbic acid content of samples collected from polluted site as compared to control site.

Carotenoid of *Mangifera indica* recorded at control and polluted sites were 2.66±0.12 and 2.17±0.19 mg per gm, respectively. A decrease of 18.42% was thus recorded in the amount of carotenoid in the polluted site as compared to control. Ascorbic acid content recorded was 2.10±0.11 and 1.57±0.11 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 25.24% in ascorbic acid content of samples collected from polluted site as compared to control.

Carotenoid of *Polyalthia longifolia* recorded at control site was 1.42±0.14 and 0.98±0.16 mg per gm at polluted site. A decrease of 30.99% was thus recorded in the amount of carotenoid in the polluted site as compared to control. Ascorbic acid content recorded was 1.34±0.09 and 1.04±0.09 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 22.39% in ascorbic acid content of samples collected from polluted site as compared to control site.

Carotenoid of *Delonix regia* was recorded at control and polluted sites were 1.30±0.08 and 0.90±0.06 mg per gm, respectively. A decrease of 30.78% was thus recorded in the amount of carotenoid in the polluted site as compared to control site. Ascorbic acid content recorded was 1.49±0.09 and 0.91±0.10 mg per 100 gm at control and polluted sites, respectively. In this case there was a reduction of 38.93% in ascorbic acid content of samples collected from polluted site as compared to control site.

Relative moisture content, dust content, pH and APTI

Relative moisture content of *Ficus religiosa* leaves collected from control site was 68.97±4.33% while it was 55.98±4.61% at polluted site. Thus there was a reduction of 18.83% in relative moisture content of samples collected from polluted site as compared to control. Amount of dust deposited on leaves was higher (0.46±0.02 mg per leaf) in polluted site in comparison to control site (0.10±0.02 mg per leaf). pH of leaves of control site was recorded as 7.59±0.13, where as pH of leaves sampled form polluted site was recorded as 6.43±0.21. Thus a change of 15.28% toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Ficus religiosa* was determined as 8.39±0.17 and 6.25±0.18 at control and polluted sites, respectively.

Relative moisture content of *Mangifera indica* leaves was higher (22.33%) in the plant samples collected from control site as compared to samples collected from polluted site. Amount of dust deposited on leaves was higher (0.53±0.02 mg per leaf) in polluted site in comparison to control site (0.09±0.01 mg per leaf). pH of leaves of control site was recorded as 6.93±0.22, where as pH of leaves sampled form polluted site was recorded as 6.01±0.23. Thus a change of 13.28% toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Mangifera indica* was determined as 9.15±0.11 and 6.71±0.14 polluted site.

Relative moisture content *Polyalthia longifolia* was higher by 17.74% in the plant samples collected from control site. The amount of dust deposited on leaves was higher (0.43±0.05 mg per leaf) in polluted site in comparison to control site (0.08±0.02 mg per leaf). pH of leaf of control site was recorded as 6.47±0.13, where as pH of leaf sampled from polluted site was recorded as 5.73±0.22. Thus a change of 11.44% towards the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Polyalthia longifolia* was determined as 7.01±0.13 and 5.57±0.18 at control and polluted sites, respectively.

Relative moisture of *Delonix regia* was recorded at control site was 70.56±4.15% whereas it was 59.12±4.16% at polluted site. Thus there was a reduction of 16.21% in relative moisture content of samples collected from polluted site as compared to control site. Amount of dust deposited on leaves was higher (0.39±0.06 mg per leaf) in polluted site in comparison to control site (0.08±0.04 mg per leaf). pH of leaves collected from control site was recorded as 6.92±0.37, where as pH of leaves sampled form polluted site was recorded as 5.64±0.29. Thus a change of 18.50% toward the acidic side was recorded in the samples collected from polluted site. Air pollution tolerance index of *Delonix regia* was determined as 8.48±0.17 and 6.59±0.28 at control and polluted sites, respectively.

4. Discussion:

Highest decrease in chlorophyll *'a'* content of the samples collected from polluted site in comparison with control sites was thus recorded in *Ficus religiosa* (43.36%) whereas lowest was for *Mangifera indica* (26.57%). Two-way ANOVA shows that reduction in chlorophyll *'a'*, chlorophyll *'b'* and total chlorophyll contents of *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia* and *Delonix regia* were significant at 0.001% level. The concentrations of chlorophyll *'a'*, *'b'*, total chlorophyll, carotenoid, ascorbic acid, relative moisture content, pH and APTI were always found to be lower at polluted site as compared to control site leaves of the same age Chauhan and Joshi, 2008). Rao and Leblanc, (1966) have also reported reduction in chlorophyll content brought by acidic pollutants like SO_2 which causes phaeophytin formation by acidification of chlorophyll. Reductions in chlorophyll content of a variety of crop plants due to NO_2, SO_2 and O_3 exposure have also been reported by Agrawal et al., (2003). Lerman (1972) has suggested that continuous application of cement dust clog the stomata, so interfering with gaseous exchange.

Highest decreases in carotenoid content was reported for *Polyalthia longifolia* (30.99%) while lowest decreases in *Mangifera indica* (18.47%). Two-way ANOVA shows significant reductions in all selected tree species were significant at 0.001 % level. Carotenoid protects chlorophyll from photoxidative destruction (Sifermann-Harms, 1987). The carotenoid contents of some crop plants were found to decrease in response to SO_2 (Pandey, 1978; Singh and Rao, 1983; Nandi, 1984). Joshi and Swami, (2007) also reported significant reduction in carotenoid content of different plants grown at polluted sites.

Two-way ANOVA shows the decline in ascorbic acid content in all four plant species were significant at 0.001% level. Highest reduction in ascorbic acid content was observed for *Ficus religiosa* (44.67%) and lowest reduction for *Polyalthia longifolia* (22.93%). Ascorbic acid, a natural antioxidant in plants plays significant role in pollution tolerance (Chen et al., 1990). Ascorbic acid is concentrated mainly in chloroplasts (Franke and Heber, 1964).

Relative moisture content of all four tree species was significant at 0.001 % level using two-way ANOVA. A high water content with a plant body may help to maintain its physiological balance under air pollution stress condition. High relative water content favors resistance in plants (Dedio, 1975). *Ficus religiosa* and *Polyalthia longifolia* were significant at 0.01 % level and *Mangifera indica* and *Delonix regia* were significant at 0.001% and 0.05% level, respectively.

The change in pH in the leaf sample collected from polluted site was significant at 0.001% level in four tree species. All the plant samples collected from polluted site exhibited a pH towards acidic side, which may be due to the presence of SO_2 and NO_x in the ambient air causing a change in pH of the leaf sap towards acidic site (Swami et al., 2004). Highest change in dust content was found in *Ficus religiosa* which was significant at 0.001% level. High traffic load contributes high dust fall on the plant leaves this also depends upon the condition of roads (Lone et al., 2005) and size and structure of leaves (Joshi and Swami, 2007). Two-way ANOVA show that reduction in APTI of all four tree species was significant at 0.001 % level. Air pollution tolerant index is an index denotes capability of a plant to combat against air pollution. Plants which have higher index value are tolerant to air pollution and can be caused as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution (Singh and Rao, 1984).

Table 1: Primary air pollutants recorded from control and polluted sites during the study period

Site	NO_x µgm^{-3}			SO_2 µgm^{-3}			SPM µgm^{-3}			RSPM µgm^{-3}			Air Quality Index (AQI)		
	W	**M**	**S**	**W**	**M**	**S**	**W**	**M**	**S**	**W**	**M**	**S**	**W**	**M**	**S**
P	26.68	27.02	27.92	25.29	25.14	26.61	276.11	199.04	285.47	128.02	89.93	137.50	113.69	88.08	117.88
C	1.69	1.60	1.93	2.29	1.98	2.16	92.23	82.14	76.19	34.41	35.80	36.04	32.40	28.87	27.10

Where**:** SPM = Suspended particulate matte, RSPM = Respirable suspended particulate matter, W= Winter, M= Monsoon, S= Summer,

Table 2: Rating scale of AQI values at polluted and control sites

Index value	Remarks	Polluted Site			Control Site		
0-25	Clean air (CA)	Winter	Monsoon	Summer	Winter	Monsoon	Summer
26-50	Light air pollution (LAP)	SAP	MAP	SAP	LAP	LAP	LAP
51-75	Moderate air pollution (MAP)						
76-100	Heavy air pollution (HAP)						
>100	Severe air pollution (SAP)						

Table 3: Changes in the physical and bio-chemical characteristics of tree species due to auto exhaust emission

Parameters	*Ficus religiosa*		*Mangifera indica*		*Polyalthia longifolia*		*Delonix regia*	
	Control Site	**Polluted Site**	**Control Site**	**Polluted Site**	**Control Site**	**Polluted Site**	**Control Site**	**Polluted Site**
Chlorophyll *a* (mg/g)	1.43±0.08	0.81±0.06***	2.71±0.07	1.99±0.05***	1.33±0.17	0.96±0.44***	1.64±0.11	1.04±0.11***
Chlorophyll *b* (mg/g)	1.13±0.05	0.61±0.05***	2.03±0.09	1.63±0.12***	0.84±0.12	0.59±0.06***	1.01±0.15	0.76±0.14***
Total Chlorophyll (mg/g)	2.56±0.48	1.42±0.09***	4.74±1.22	3.62±0.58***	2.17±0.22	1.55±0.28***	2.65±0.14	1.81±0.12***
Carotenoid (mg/gm)	1.49±0.14	1.03±0.06***	2.66±0.12	2.17±0.19***	1.42±0.14	0.98±0.16***	1.30±0.08	0.90±0.06***
Ascorbic Acid (mg/100gm)	1.50±0.11	0.83±0.07***	2.10±0.11	1.57±0.11***	1.34±0.09	1.04±0.09***	1.49±0.09	0.91±0.10***
Relative moisture content (%)	68.97±4.33	55.98±4.61***	66.99±3.17	52.03±3.99***	58.50±2.86	48.12±3.77***	70.56±4.15	59.12±4.16***
Dust deposited (mg/leaf)	0.10±0.02	0.46±0.02**	0.09±0.02	0.53±0.02***	0.08±0.02	0.43±0.05**	0.08±0.04	0.39±0.06*
pH	7.59±0.13	6.43±0.21***	6.93±0.22	6.01±0.23***	6.47±0.13	5.73±0.22***	6.92±0.37	5.64±0.29***
APTI	8.39±0.17	6.25±0.18***	9.15±0.11	6.71±0.14***	7.01±0.13	5.57±0.18***	8.48±0.17	6.59±0.28***

Significant at: *$p < 0.05$, **$p<0.01$, ***$p<0.001$, APTI= Air Pollution Tolerance Index

Conclusion

The study elucidates the changes in photosynthetic pigments due to air pollutants. The study clearly shows that gaseous (NO_x and SO_2) and particulate pollutants such as SPM and RSPM have detrimental effects on selected trees. Changes in photosynthetic pigments directly corresponded to the levels of air pollution at selected sites. The study also elucidates that air pollution emitted form automobiles adversely affecting the ambient air and tree pigments. Moreover it should be noted it may also create adverse impacts on human health too.

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