International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2017; 5(4): 716-720

Received: 28-05-2017
Accepted: 29-06-2017

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Air pollution tolerance index (APTI) of tree species: A review

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Abstract
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 used as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution. Plants play an important role in monitoring and maintaining the ecological balance by actively participating in the cycling of nutrients and gases like carbon dioxide, oxygen and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the environment. The tolerant species of plants function as pollution “sink” and therefore a number of environmental benefits can be desired by planting tolerant species in polluted areas. For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential.

Keywords: Air Quality Index, air pollutants, pollution, APTI

Introduction
A number of harmful gases are added to the atmosphere causing air pollution as the result of emission from industries and other wastes. They adversely affect air quality and make it unfit for living organisms (Chouhan *et al*., 2012, Joshi *et al*., 2009, Kuddus *et al*., 2011 and Bhattacharya *et al*., 2013) [8, 17, 21, 5]. Impact of air pollution on environment especially on local plant species leading to adverse health effects on human beings is one of the major issues. Since, plants acts as a sink for air pollution, it reduces pollution level in the atmosphere (Hamraz *et al*., 2014) [15]. Hence, this study was aimed to assess the biochemical changes and its role in air pollution tolerance index, a major factor that gives sensitivity, tolerance to plants. Air pollution tolerant index is an index denotes capability of a plant to combat against air pollution (Dwivedi *et al*., 2008 and Vinita *et al*., 2010) [10]. The air pollution tolerance index (APTI) based on four parameters has been used for identifying tolerance levels of plants species (Beg *et al*., 1990 and Chauhan, 2010) [3, 7]. The four parameters are: Chlorophyll, Ascorbic acid, pH, and Relative water content.

Plants which have higher index value are tolerant to air pollution and can act as sink to mitigate pollution, while plants with low index value show less tolerance and can be used to indicate levels of air pollution. Air pollution can directly affect plants via leaves or indirectly via soil acidification. It has also been reported that when exposed to air pollutants, most plant experience physiological changes before exhibiting visible damage to leaves. Some plants thrive in environments that others would find toxic, these plants can clean-up various sources of man- made pollution; both organic (petrochemical) and inorganic (heavy metal toxins) (Escobedo *et al*., 2008, Prajapati and Tripathi 2008, Miria and Khan 2013) [11, 31, 26]. Trees remove a significant amount of pollution from the atmosphere as part of their normal functioning. They directly increase the quality of the air in the city and its surrounding area and should be considered as an integral part of any comprehensive plan aimed at improving overall air quality (Singh and Rao 1983) [33].

Air pollution alongside the roads, in urban and industrial area get adsorbed, absorbed, accumulated or integrated in the plant body and if toxic may injure them in various ways. The level of injury will be high in sensitive species low in tolerant ones. The sensitive species help in indicating air pollution and tolerant one help in abatement of air pollution (Dhankar *et al*., 2015 [9], Begum and Harikrishna 2010 [4], Gupta *et al*., 2016) [13]. The tolerant species of plants function as pollution “sink” and therefore a number of environmental benefits can be desired by planting tolerant plant species in polluted areas.

For this purpose, evaluation of plants with respect to their tolerance level to air pollution may be essential. Consequently, air pollution tolerance index (APTI) based on biochemical parameter is generally employed for identifying tolerance level of plant species.

2. Biochemical parameters

2.1 Relative water content

Relative water content was determined and calculated by the method as described by.

2.2 Total chlorophyll content

The leaf chlorophyll content was estimated by using method given by Chouhan *et al*., (2012) [8].

2.3 pH

The pH of leaf extract was determined by using pH meter with buffer solution pH 4 and pH 9.

2.4 Ascorbic acid content

The ascorbic acid content was estimated by using method given by Nwadinigwe (2014) [28].

2.5 Air pollution tolerance index (APTI)

The air pollution tolerance index of the selected species was calculated using the following formula given by Singh and Rao (1983) [33].

2.6 Anticipated performance index

By combining the resultant APTI values with some relevant biological and socio-economic characters (plant habit, canopy structure, type of plant, laminar structure & economic values), the API was calculated for different species. Based on these characters, different grades (+ or -) are allotted to plants. Different plants are scored according to their grades as per the procedure outlined by Mondal *et al*., (2011) [14, 27].

Begum and Harikrishna (2010) [4] studied tolerance of plant species with respect to APTI values and heavy metal concentration (cadmium, zinc and lead). It was observed that *Ficus religiosa*, *Azadirachta indica* and *Pongamia pinnata* were the most tolerant species in the industrial area where the research was conducted. These plants can be considered as tolerant species in the industrial areas. The APTI values for remaining species are reported lower and are considered as sensitive species.

Ogunrotimi *et al*., (2017) [29] evaluated the sensitivity and tolerance levels of the 12 tree species from 3 major roads to air air pollution using APTI and results showed that the APTI of the tree species ranged between 9.2 and 12.7 the highest in case of the highest value was obtained in *Polyalthia longifolia* and the lowest value in *Psidum guajava*. It was concluded that *P. longifolia, M. indica, G. arborea, T. grandis and T. catappa* were the most tolerant to air pollution of all the tree species.

Dhankar *et al*., (2015) [9] evaluated the variation of biochemical characteristics and air pollution tolerance index of 15 selected tree species growing at industrial, residential and campus sites of Rohtak City, Haryana, and North India. The results showed that the most suitable tree species are *F.virens* and *E.obliqua* in green belt areas are identified and recommended for long term air pollution management.

Lohe *et al*., (2015) [23] determined APTI for seven tree species in Nagal village of Dehradun city, India and the results showed that on the basis of air pollution tolerance index among all the tree species *Eucalyptus globus* exhibited the highest degree of tolerance at all sites. Marimuthu and Lavanya (2014) [25] assessed the APTI of plant species at 2 locations near the road sides of railway junction and residential area and the results showed that air pollution tolerance index was high for *Syzygium cumini* in location 1 and *Ficus benghalensis* in location 2.

With rapid industrialization and random urbanization environmental pollution has become a serious problem and to mitigate this problem Kumar *et al*., (2013) [22] suggested that plants play an essential role in cleansing the pollution from the environment. So plantation of such eco-friendly plant species is recommended which has high capacity to reduce the pollution.

In Ahvaz (Iran), Gholami *et al*., (2016) [12] analysed air pollution tolerance index in polluted areas in six plant species, namely, *Conocarpus*, *Myrtus, Prosopis, Eucalyptus, Ziziphus* and *Lebbek*, which are abundant in the Ahvaz region. The results showed that *Myrtus* is resistant to plant pollution, whereas *Prosopis* is sensitive to plant pollution. In addition, the results of assessment of the above mentioned index showed that plants with higher APTI can be used as reducers of pollution and plants with lower APTI can be used to measure air pollution. Also, dust deposition on leaf surfaces was determined to observe the extent of particulate deposition. The highest and the lowest deposition rates were observed in *Myrtus* (maximum 80.3 gsm^{-2} in polluted site) and *Lebbek* (minimum 10.7 gm^{-2} in blank site), respectively.

Panigrahi *et al*., (2014) [30] in a study found that *Mangifera indica* was the most tolerant species with an APTI value of 20.80 followed by *Bougainvillea spectabilis* (20.32) > *Nerium indicum* (18.94) > *Azadirachta indica* (18.73) > *Clatropi sprocera* (18.10). studied APTI values of six plant species and the order of tolerance of plants towards air pollution noticed was: *Saraca indica* (13.71) > *Azadirachta indica* (12.98) > *Shorea robusta* (12.64) > *Eucalyptus* spp. and *Ficus religiosa* (12.61) >*Tectona grandis* (12.43).

Krishnaveni *et al*., (2013) [19] studied APTI of plant species in Perumalmalai hill, Salem District, Tamil Nadu using four physiological and biochemical parameters namely, leaf extract pH, ascorbic acid, total chlorophyll and relative water content. The results concluded that *Nerium oleander* having APTI value of 16.65 was identified as intermediate species tolerant to pollution. Whereas, *Ficus benghalensis, Psidium guajava, Spathodea campanulata, Opuntia ficus indica* having APTI score of 15.92, 15.41, 9.92, 9.74 was identified as a sensitive species.

Yannawar and Bhosle (2014) calculated the APTI values of plants growing along roadsides in Nanded city and found that *Azadirachta indica*, *Moringa oleifera*, *Euginia jambolana* and *Tamarindus indica* were found to be tolerant while *Mangifera indica*, *Polyalthia longifolia*, *Ficus benghalensis*, *Delonix regia*, *Acacia nilotica*, *Leucaena leucocephala* and *Dalbergia sissoo* were found to be immediately tolerant and *Ficus religiosa*, *Phyllanthus emblica*, *Ficus glomerata* and *Eucalyptus* spp. were found to be sensitive.

Gupta *et al*., (2016) [13] in National Capital Region Delhi, India, evaluated APTI and API of four plant species namely Arjun (*Terminaliya arjuna*), Morus (*Morus alba*), Sheesham (*Dalbergia sissoo*) and Ashok (*Polyathia longifolia*) in order to categorise them against air pollution and their usefulness for green belt development. The results indicated that APTI values for all four species are sensitive and can be used as biological indicators. Also, API values suggested that *Terminaliya arjuna* and *Morus alba* are very good performers

(API=5) whereas *Dalbergia sissoo* and Ashok *Polyathia longifolia* as only good performers (API=4).

Chauhan (2010) [7] reported that in *Ficus religiosa*, *Mangifera indica*, *Polyalthia longifolia*, *Delonix regia* there was reduction in chlorophyll 'a', chlorophyll 'b', total chlorophyll content, ascorbic acid, carotenoid, pH, relative water content. APTI was recorded in the leaf samples of all selected trees collected from polluted site when compared with samples from control area. 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*.

Tripathi *et al*., (2009) [35] studied relative tolerance of ten different plant species and found that *Pongamia pinnata*, *Pithecolobium dulcis*, *Holoptelea intregifolia* and *Sarraca indica* were the tolerant; *Ficus rumphii*, *Azadirachta indica*, *Grewilia robusta* as moderately tolerant and *Alstonia scholaris*, *Cassia simea* and *Bauhinia variegata* are the sensitive species. Similarly, Thawale *et al*., (2011) also studied the biochemical changes in four selected plant species, viz., *Azadirachta indica*, *Mangifera indica*, *Delonix regia* and *Cassia fistula* of residential, commercial, and industrial areas of Nagpur city in India. The correlation study revealed that air pollutants, plant leaves characteristics and foliar biochemical features (i.e., chlorophyll, ascorbic acid content, pH and relative water content) of plants found to alter their responses to air polltion. The changes in air pollution tolerance index of plants was also estimated which revealed that these plants can be used as a biomarker of air pollution.

While studying examining the APTI of six plant species around Otorogun gas plant in Delta state, Nigeria, Agbaire and Esiefarienrhe (2009) [2] found to have maximum tolerance to air pollution in *Emilia samtifolia* and minimum in *Psidium guajava*. Similarly, Agbaire (2009) [1] examined APTI of ten plant species around the Erhoike - Kokori oil exploration station of Delta state, Nigeria and results showed that the order of tolerance is as follows: *Psidium guajava* < *Elaesis guineensis* < *Musa paradisiaca* < *Bambosa bambosa* < *Anacadium occidentale* < Terminalia *catappa* < *Manihot exculenta* < *Impereta cylindrical* < *Chromolaena odorata* < *Mangifera indica*.

The study conducted by Radhapriya *et al*., (2012) around cement industry, Coimbatore, India revealed that all the plants surrounding the cement industry are indicative of high pollution exposure comparable to the results obtain for control plants. Based on the APTI value, it was observed that about 37% of the plant species were tolerant. Among them *Mangifera indica*, *Bougainvillea species*, *Psidum quajava* showed high APTI values. 33 percent of the species, including *Thevetia neriifolia*, *Saraca indica*, *Phyllanthus emblica* and *Cercocarpus ledifolius* showed low APTI values. 15% each of the species were at the intermediary and moderate tolerance levels.

Jyothi and Jaya (2010) [18] while working alongside national highway number 47 in Thiruannathapuram, Kerala evaluated the APTI of selected tree species viz., *Polyalthia longifolia* (Sonner) Thw, *Clerodendron infortunatum* L, *Eupatorium odoratum* L. and *Hyptis suaveolus* (L). Results indicated that, the *Polyalthia longifolia* (Sonner) Thw, expressed highest APTI values and proved to be a tolerant variety and other as sensitive species to air pollutants. Similar study was done by Chandawat *et al*., (2011) [6] at the seven cross-roads of Ahmedabad city, India and results concluded that the tolerance of tree species was in order was *Ficus benghalensis* >*Ficus religiosa* > *Ficus glomerata* followed by *Azadiracta indica* > *Polyalthia longifolia*.

Gupta *et al*., (2011) [14] evaluated the APTI of ten plant species collected from an urban area by analyzing important biochemical parameters. High values of APTI were recorded in *Psidium guajava* (31.75%); *Swietenia mahoganii* (28.08%); *Mangifera indica* (27.97%); *Polyanthia longifolia* (25.58%) and *Ficus benghalensis* (25.02%). The Anticipated Performance Index of these plant species was also calculated by considering their APTI values together with other socio-economic and biological parameters. According to APTI most tolerant plant species for green belt development were *Ficus benghalensis* (87%); *Mangifera indica* (87%); *Swietenia mahoganii* (87%) and *Saraca indica* (81%).

Joshi and Bora (2011) [16] examined the dust interception efficiency and APTI of 8 plant species by using four biochemical parameters; relative water content, leaf pH, ascorbic content and total chlorophyll. The results showed that combining variety of these parameters give more reliable results than those of individual parameter. Maximum dust interception was done by *Psidium gujava* and species *Ficus religiosa* has highest air pollution tolerance index. The study indicated that ambient air pollution has negative impact on physiological characteristics of plant.

Meerabai *et al*., (2012) [24] studied the effect of pollutants released from an industry on physiology of Cajanus cajan (L.) at Kurnool, Andhra Pradesh, India. The total chlorophyll content, ascorbic acid, relative water content and pH of the leaf extract was measured following the standard methods. The study showed an increase in APTI of the leaves collected from polluted site. The percentage increase in APTI was 13.14. This indicates the tolerance capacity of the crop to a polluted smoke releasing from the industry and the crop may be recommended to the farmers of urban area for their economic growth.

Krishnaveni *et al*., (2012) [20] evaluated the APTI of leaves of 30 selected herbal tree and plant species (leaves) in the Periyar University Campus (Salem) Tamil Nadu, India. The results showed that among the herbal trees *Embilica offficinalis* (95.81), *Callistomon citrinus* (86.96), *Pithecellobium dulce* (84.30) had highest APTI value. Similarly, among the herbal plant *Withania somnifera* (88.30), *Chrysanthemum coronariums* (82.27), *Mirabilis jalaba* (74.54), had highest APTI value. Whereas, among the herbal trees *Brosassus flabellifev* (26.16) Ficus *bengalensis* (26.89), *Tectona grandis* (31.19), had lowest APTI. *Vetiria zizanioibes* (28.23), *Abutilon ludicum* (28.35), *Punica granatum* (28.41), had lowest APTI among herbal plants.

As we know, population of our country is increasing and because of industrialization, urbanization and expansion of roads the problem of air pollution is increasing day by day. Air pollution reduction is considered as the most compelling challenge that leads to integral attempts. Air pollution can be prevented by variety of ways. One of the impressive and well recognized ways for the recovery of environment and reduction of pollution is planting of trees and shrubs. Remediation and monitoring of air pollution can be done by evaluating the tolerance ability of plants to air pollution. Hence, by determining Air Pollution Tolerance Index (APTI), screening of tolerant plant species can be done for the plantation in the polluted area to mitigate the problems of air pollution.

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