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

Navjot Singh Kaler, Parveen Kashyap, Heerendra Prasad and Thiyam Jefferson Singh

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, Mria 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 [8], 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 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 Psidium guajava. It was concluded that P. longifolia, M. indica, G. arborea, T. grandis and T. arbutina 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 Persea americana and Eucalyptus globulus in green belt areas are identified and recommended for long term air pollution management.

Lohar 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 globulus 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 Lebek, 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 Lebek (minimum 10.7 gsm⁻² in blank site), respectively. Panigrahi et al., (2014) [90] 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) > Clatropis sprocer (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, Eugenia 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 (Terminalia arjuna), Morus (Morus alba), Sheesham (Dalbergia sissoo) and Ashok (Polyalthia 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 Terminalia arjuna and Morus alba are very good performers.
International Journal of Chemical Studies

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 in 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) [15] studied relative tolerance of ten plant different species and found that Pongamia pinnata, Pithecellobium dulcis, Holoptelea integrifolia and Saraca indica were the tolerant; Ficus rumphii, Azadirachta indica, Grewilila 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 pollution. 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 et al. (2009) [2] found that highest air 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, Psidium guajava showed high APTI values. 33 percent of the species, including Thevetia nerifolia, Saraca indica, Phyllanthus emblica and Cercocephalus 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 Thrissurpatharam, Kerala evaluated the APTI of selected tree species viz., Polyalthia longifolia (Sonner) Thw, Clerodendron infortunatum L., Eupatorium odoratum L. and Hypis 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 mahogianii (28.08%); Mangifera indica (27.97%); Polyalthia 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 mahogianii (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 guajava 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.

Meerababi et al., (2012) [24] studied the effect of pollutants released from an industry on physiology of Cajanuss 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 Emblica officinalis (95.81), Callistemon citrinus (86.96), Pithecellobium dulce (84.30) had highest APTI value. Similarly, among the herbal plant Withania somnifera (88.30), Chrysanthemum coronarium (82.27), Mirabilis jalaba (74.54), had highest APTI value. Whereas, among the herbal trees Brosassus flabellifere (26.16) Ficus benghalensis (26.89), Tectonagrandis (31.19), had lowest APTI. Vetiver zizanioides (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.

3. References
33. Singh SK, Rao DN. Evaluation of plants for their tolerance to air pollution. In: Proceedings Symposium on Air Pollution Control. Indian Association for Air Pollution Control, New Delhi, India. 1983; 1:218-224.