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Air Pollution Tolerance Index (APTI) Used for Assessing Air Quality to Alleviate Climate Change: A Review.

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ABSTRACT

In the present era, rapid development of industrial Science and technology has been improved human life style as a part of developing country on the other hand we are gradually facing immense trouble in terms of pollution. It's an appropriate time for taking necessary step to cheek air pollution. In this circumstance the green technology is the most appropriate means to control and monitor air pollution. The work has found many pathways to link the air pollution and plant in terms of scientific authentication that plants can accumulate the air pollutant. Air Pollution Tolerance Index (APTI) is one of the green technology based tool used for analyzing air pollution of a particular area which leads to develop an idea about the air quality. The restoration strategy whether in urban or rural situations have started adopting Green Belt Development (GBD). This kind of initiative is very imperative to optimize environment especially in urban and industrial localities with the help of plants, selected on the basis of their Air Pollution Tolerance Index.

Keywords: Air pollution, Green technology Air Pollution Tolerance Index (APTI), Green Belt Development.

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INTRODUCTION

In the last couple of decades increasing pollution has become the biggest challenge for the survival of the biological species. India has witnessed a revolution in technological and industrial progress. But the quality of our environment has received very little or no attention. Unexpected explosion of population, industrialization and demographic pressure has further provoked this problem. Rapid industrialization and vehicular traffic especially in the urban areas lead to the deterioration of air quality by adding toxic gases viz. oxidized and reduced forms of nitrogen, Carbon, SO_2, C_6H_6, Vapour, O_3, many others organic molecules. The suspended particles include the various forms of PM2.5, PM10 particulate and heavy metals. Moreover, many expansive engineering devices are measure of pollutants demanding a big budget which has come up to combat the global warming issue but none better than plantation and green vegetation, because of the multipurpose aspect of green plants. The particulates and gaseous pollutants, alone and in combination can cause serious setbacks to the overall physiology of plants as they remains static at their habitat [114, 1, 14, 32]. Air pollutants can directly affect plants via leaves or indirectly via soil acidification [114].

The responses of plants to pollutants may provide a simple method of monitoring air pollutants as well as providing the pollution abatement measures. Therefore, APTI of the plants needs to be monitored and checked for the predominant species that are present in the polluted and non-polluted areas. The response of plants to air pollution at physiological and biochemical levels can be understood by analyzing the parameters viz. Ascorbic acid content [50], chlorophyll content [43], leaf extract pH [65].and relative water content [100]. The tolerance level of the plants that determine resistance and susceptibility [110]. Those plants having higher index value are tolerant and can be used as a filter to mitigate pollution, while plants having low index value can be used as an early warning indicator of air pollution.

The studies have been reviewed to provide background information on air pollution tolerance index and its application. In addition to above, also discussing about different air pollutants and their impact on the physiological activities and anatomical characteristics of plants.

PRESENT SCENARIO OF AIR POLLUTION IN INDIA:

In recent time urban air pollution is a serious problem in India like fastest developing countries. The quality of the urban environment marked effected by tolerant tree species Plantation which causes the cleanliness of life in a city. Due to gradual spread of Indian economy, hasty industrialization and commercialization in urban areas have evoked a concern over its probable impacts on surrounding environment. CPCB (2000c) analyses air quality at various cities in India for the period 1990-98, the most prevalent form of air pollution appears to be SPM show good agreement with traffic-related pollutants although there are many stations at which SO_2 and NO_2 levels exceed permissible limits[60, 92]. Highest PM10 level was found in Indian cities like Mumbai, Bangalore, Lucknow. The annual average limit of suspended particulate matter for industrial areas (360µg/m3) had been frequently violated in most cities [83]. According to CPCB (2000), twelve major metropolitan cities in India produce 0.35 Gg of NOx, 1.91 Gg of CO and 0.67 Gg of VOC annually from vehicular emissions alone. The quantum of vehicular pollutants emitted has been found highest in Delhi followed by Mumbai, Bangalore, Kolkata and Ahmadabad (TERI, 2001a). It was found that from 1990-91 to 1995-96, annual NOX emission from gasoline consumption increased from 3.5 Gg to 4.5 Gg respectively, whereas it was 8 Gg in 1990-91 and 12.8 Gg in 1995-96 from diesel [79]. In recent years it was found that in Kolkata, transportation is the predominant source of NOx due to increased number of motor vehicles [48, 79, 23, 40].

Table 1: SOURCE AND EFFECTS OF AMBIENT AIRPOLLUTANTS [70, 59]**:**

Outdoor pollutant	Pollutant sources
Carbon Monoxide (CO)	Forest burning, volcanic emissions, electric discharges, incomplete burning of fossil fuels is main source, steel and pig iron production, oil refinement, air and railroad traffic.
Nitrogen dioxide (NO2)	Combustion process, burning fuels at high temperatures, road traffic, vehicle engines, industrial activities, and electric energy.
Sulphur dioxide (SO2)	Thermoelectric power stations, industrial processes, cellulose industry, engines, burning of fossil fuels, sulphate aerosols and generation of sulphuric acids droplets (H2SO4).

Carbon dioxide	Burning oil, coal and natural gases
Ozone (O3)	Component of the "photochemical smog". It appears following a reaction that involves mainly nitrogen oxides and volatile organic compounds.
Suspended particulate matter (PM10, PM2.5, SPM)	Mixture of solid and liquid organic plus inorganic materials including nitrates, sulphate, carbon ,sodium chloride, ammonia, mineral dust and water stationary, mobile or natural
Benzene	Mostly from road traffic, fuel evaporation during its storage and distribution.
Heavy metals (Lead, Pb, Cd, As and Hg)	Combustion of gaseous fuels, road traffic (to a large extent), metallurgical industry activities, burning of dangerous (hospital) wastes
Fluorides pollutant compounds	Glassworks, steelworks, aluminum factories, brick kiln, ceramic factories and uranium smelters.
Methane(CH_4)	Cattle and other animal

PLANTS-POLLUTANT INTERACTIONS AND ROLE IN ABSORPTION OF POLLUTANTS:

Primary pollutants such as SO_2, NO_2, CO, SPM etc. enter into plant body through the stomatal apertures during gaseous exchanges. More over Cement dust can raise leaf surface alkalinity (up to pH 12); that hydrolyze lipid and wax componentsas well as denature proteins finally plasmolyzing the leaf [91]. Limestone dust coating of lichen thallus damaged its photosynthetic apparatus [10]. In high Pollution load increase of ascorbic acid content causes the increased rate of production of reactive oxygen species (ROS) during photo oxidation of SO_2 to SO_3 [58]. SO_2 absorption inflicts injury to plants both in visible and invisible form. In favorable environmental condition facilitates stomatal opening causes highly water soluble SO_2 deposition in plants and is ionized to form the hydrogen H^+,SO_3^{2-},HSO_3^- ions depending upon the pH[46]. Free radicals generated oxidation to destroy many physiological activity, amino acids, plant hormone (IAA), chlorophyll and carotene lead to shunted plant growth [11]. In the leaves, NO_2 to form the nitrous acid which converted to ammonia and consequently incorporated in the formation of amino acids and proteins. In combination of SO_2 and NO_2 were more detrimental in yield losses than SO_2 alone [3].Whereas, SPM causes encrustation on leaf cuticle due to particulate penetration into the epicuticular wax may reduce the intensity of incident light and impairing of thermal balance of the leaf. On the other hand Gaseous and particulate fluorides are deposited on plant surfaces and through the leaf stomata moves along transpiration stream accumulate at toxic levels in leaf tips and margin [40] .

Table 2: PLANT SYMPTOMS IN RESPONSE TO AIRPOLLUTION EXPOSURE [115, 27, 109, 70]

Outdoor pollutant	Plant injury/symptoms
Nitrogen dioxide	Interveinal necrotic blotches, serious damage to the vegetation by whitening or destroying the plants tissues, reducing their growth rhythm. Nitrogen oxides are predominantly responsible of both acid precipitation and ground level ozone formation. Waxy coating on leaf surface, smog and acid rains.
Sulphur dioxide	Red brown dieback or banding in pines. Skeletonized leaves and necrosis (high conc.).Inter-venal chlorotic bleaching of leaves (low conc.), negative effect on structure and tissues being visible with the naked eye. Incurs toxicity due to its reducing properties which leads to chlorotic or brownish red colour of leaves.
Ozone	Pigmented or unpigmented spots; Browning of conifer needle tip. Upper surface flecks distal necrosis and stunted needles in pines. Bleaching, necrosis and collapse of leaf (high conc.).
SPM	Visible coating, encrustation, marginal burn.
Fluoride	Red brown distal necrosis in pines. Leaf injury in the form of chlorosis and necrosis of leaf tips and margins.
Ammonia	Tip and margin necrosis, cooked green appearance, bleaching and dead spots along margins.
Chlorine	Interveinal necrotic blotch similar to those by $SO_2$and distal necrosis in pines. Dead spots alongs margins of outer leaves.
Ethylene	Chlorosis, Necrosis, abscission, Dwarfing, premature defoliation. Leaf abscission, epinasty, failure of flower buds to open; stimulation of lateral growth.
Hydrogen Sulphide	Interveinal necrosis blotches. Details necrosis in pines.

Trace Metals	Interveinal chlorosis tip and margin necrosis, Distal necrosis.
Peroxy acetyl nitrate	Lower surface bronzing, chlorosis, early senescence. Suppressed growth, bronzing of lower leaf area and young leaf more affected.
Acid rain	Necrotic spots, Distal necrosis pines.

EFFECTS ON HUMAN HEALTH:

Air pollution is one of the main significant causes of the human health problems. According to World Health Organization, approximately 1.3 million deaths was take place worldwide due to air pollution [31]. Low blood oxygen level, respiratory and cardiovascular diseases caused by Carbon Monoxide defect in lung function and causes bronchitis in asthmatic children associated with NO_2.Changes in pulmonary function and respiratory symptoms after very short periods of exposure to SO_2 [123]. Breathing difficulties and asthma, colds, pneumonia trigger by ozone concentration.

EFFECTS OF AIR POLLUTION ON THE FOUR BIO-CHEMICAL PARAMETERS:

Four Bio-chemical parameters which act as key indicator in the plants are used to assess the changes in the tolerance level of plants with respect to air pollution. Effect of Air Pollution on these Bio-chemical parameters:

Effects on Ascorbic Acid (AA) content:

AA is well known antioxidant compound which increases the tolerance of the plants to oxidative stresses, scavenging free-oxy-radicals, but in addition, it affects the physiological activities of the plants. It acts as a primary substrate in the cyclic pathway for enzymatic detoxification. A number of reactive oxygen species (ROS) produced such as H_2O_2, SO^{3-} , HSO^{3-}, OH^-, and O^{2-} during photo-oxidation of SO^3-to SO^{4-}.The free radical production under SO_2 exposure would increase the free radical scavengers, such as ascorbic acid, super oxide dismutase and peroxidase [112, 31]. Ascorbic acid plays a significant role in cell wall synthesis, photosynthetic carbon fixation, defense and cell division [105].

Effects on Total Chlorophyll content (Chl):

Pollutants not only decrease the chlorophyll content but in certain cases it may increase the chlorophyll content, so chlorophyll is regarded as the index of productivity of plant [1]. High concentration of SO2 that removes phytol group of chlorophyll b, causes destruction of chlorophyll structure into pheophytin by replacement of Mg ++ by two H atoms. Decrease in the concentration of chlorophyll may be disruption of thylakoid membranes in the chloroplasts. Vehicular exhausts that primarily consist of SPM Sulphur dioxide (SO2) and nitrogen oxides (NO_2) are the most phytotoxic pollutants induces visible injury to leaves and leads to reduction in photosynthetic pigments [118]. In the cells, SO_2 dissolves to give bisulfite and sulfite ion at low concentrations it is metabolized by chloroplasts to sulfate [90, 82, 17]. Higher chlorophyll content of trees varies from one individual to other; age of leaf and also with the pollution level as well as with other biotic and abiotic conditions [62]. The concentrations of Chl *a*, *b*, total Chl, carotenoids, AA, relative moisture content, pH and APTI were always lower in leaves of plants of the same age at polluted sites than at the control site [26]. Those tree species having low chlorophyll content have high pollution load. Lower concentration of NO_2 induces the chlorophyll production but at higher concentrations, reduction in photosynthetic pigments was observed [86].

Effects on Relative Water Content (RWC) content:

Relative water content value of all control plant species was found to be higher than the polluted plant species. The Relative Water Content (RWC) indicates change in leaf matrix hydration condition and will generate higher acidity condition when RWC is low. Higher relative water content is advantageous for drought resistance in plants. Low relative water content of leaf means lower rate of availability of water in soil. Excessive water causes weaken causticity [85].Relative water substance is connected with protoplasmic porousness in cells causes loss of water and broke up supplements, bringing about right on time senescence of leaves [4]. Increased RWC in a particular species improves its drought tolerance [25].

Effects on Leaf extract pH:

The more acidic nature demonstrates that the air pollutants, mostly gaseous types, namely SO_2, NO_2 diffuse and form acid radicals in the leaf matrix by reacting with cellular water.These further effects the chlorophyll molecules (Turk and Wirth, 1975). A pH on the higher side improves tolerance against air pollution [4]. The rise in pH could be due to the formation of hydroxide of aluminum in the leaf tissue probably increasing pH of the leaf extract. High pH increases the efficiency of conversion of a hexose sugar to ascorbic acid [41].In the presence of an acidic pollutant, the leaf pH is reduced and the reducing rate is more in sensitive plants compare to that in tolerant plant species [104].

AIR POLLUTION TOLERANCE INDEX (APTI):

The effect of air pollution on the plants can be quantified using a parameter, The Air Pollution Tolerance Index (APTI) was determined using the methods. [110, 45, 99]. These formula using four parameters: total chlorophyll content of the leaf, pH, relative water content (RWC) and the ascorbic acid content(AA). The formula used for calculating APTI is as follows:

$$\mathbf{APTI = APTI = [\{A\ (T+ P)\} + R/10]}$$

Where, R stands for relative water content in mg/g, AA stands for the ascorbic acid of the leaf in mg/g, T stands for the total chlorophyll in leaf of leaf tissue in mg/g, P stands for pH of leaf extract, (110). The index can be considered as a better indicator for comparative purposes among different populations or between different sites for a given population [74]. Air Pollution Tolerance index range:

< 1 =Very Sensitive, 1 to 16 = Sensitive, 17 to 29 = Intermediate, 30 to 100 = Tolerant (Kalyani and Singaracharya, 1995). This method expresses the capacity of a plant to battle against air pollution.

Anticipated Performance Index (API):

Evaluation of anticipated performance index (API) of plant species is useful in the selection of suitable plant species for urban green belt development.In that parameter combining the results of APTI values with some relevant biological and socio-economic characters [47].

ASSOCIATED WORK ON APTI:

From all over the world many people have studied for controlling air pollution. Here in this paper, mention the work from different areas of India on APTI. Industrial activities and Roadside traffic pollution have impact on plant species surrounding the industry.

In the industrial areas:

By using the APTI value comparative study was done on six common road side plants which are collected from industrial (Rourkela) and non-industrial area (Aizawl). *Mangifera indica* and *Bougainvillea spectabilis*, showing minimum difference in their APTI values may be considered as tolerant for both[97]. APTI of plant species shows that the plants growing in industrial areas had higher APTI values followed by the areas of Ratanpani Wild life Sanctuary [102].At the Dehradun District revealed the highest average value of APTI by *Eucalyptus globulus* [76].Also a study summarized *Mangifera indica* higher tolerance for automobile [103]. APTI of Eleven frequently grown plant species around Neyveli Lignite Corporation Limited (NLC) area showed that *Eucalyptus* sp, *Lawsonia inermis* , *Citrus limon* have the higher APTI value [16].From Tiruchirappalli city maximum APTI is observed in *Azadirachta indica* [51].A study of APTI on herb plant species growing at the site around Ambernath MIDC of Maharashtra showed greater tolerance level (APTI>30),[44]. In Pithampur Industrial area highest APTI was observed in *C. gigantea* and lowest in *A. indica* [29]. The study compare the APTI of important moist deciduous forest species found near Malabar cements Ltd., Walayar, so as to identify the trees least affected by particulate pollution[9]. At sites of Rohtak City, Haryana evaluate the variation of biochemical characteristics and APTI of 15 selected tree species. *Ficus virens* and *Eucalyptus obliqua* in green belt areas are identified and recommended for long term air pollution management [37]. The present study was carried within the different intersection points of Haridwar city of Uttarakhand, all species can be used for biomonitoring of polluted [22]. Ten different crop species at four different sites were analyzed to evaluate the Air Pollution Tolerance Index of Durgapur, Burdwan by D. Palit et al. [85]. In Allahabad city, determined APTI value of seven plants for check susceptibility level, *Mangifera indica* is considered as a relatively tolerant species[71].Around Neyveli(NLC) showed that *Terminalia catappa* and *Mangifera indica* have recorded high and low values respectively[36]. In the industrial area of Tarapur, Maharashtra was determined APTI value of 30 plants species for check susceptibility level of plants [56]. In the present study reviled the biochemical responses of some selected tree species with respect to increased air pollution in Durgapur industrial city in India. *Shorea robusta ,Alstonia scholaris ,Peltophorum pterocarpum* and *Albizia lebbeck* were found to be more tolerant [81]. In Varanasi, air pollution tolerance index (APTI) and anticipated performance index (API) were used for select tolerant plant Climbers can be selected for the development of vertical greenery systems (VGSs) [87]. *Cajanus cajan (L.)*, a pulse yielding crop of Fabaceae shows high APTI[78]. For green belt establishment in Varanasi city, Uttar Pradesh. *Ficus infectoria L*. ranks first and is a keystone species (Keller and Schwager, 1977) [122]. Also study APTI of *F. religiosa* (deciduous) and *Carica papay*(evergreen) with difference in rate of sulphur dioxide (SO2) absorption [39]. In the urban city, Delhi, tries to relate the variation in ascorbic acid content with the tolerance and sensitivity of two selected plant species viz. *Azadirachta indica* and *Pongamia pinnata* by calculating their APTI [107]. In Udaipur (Rajasthan), Virudhunagar (Tamilnadu) Baroda city, evaluated the APTI value of plants for selecting plants for plantation [77,117,21].In Annamalainagar (Tamilnadu) ten parameters computed together in a formulation signifying the APTI of Eleven frequently grown plant species [5]. In Yammuna Nagar, Manju Sharma et al. were calculated APTI for ten plant species growing in different industrial areas and Yamuna River belt of Yamuna Nagar [106]. Also in Anand city (Uttrakhand), comparative study understands the effect of air pollution on vegetation composition in disturbed and undisturbed community investigated based on Importance Value Index (IVI) [66]. In Gujarat APTI value of five plants was evaluated [80]. The APTI for various plant species growing in industrial areas of Visakhapatnam shows *Ficus religiosa, Zizypus jujube, Phyllanthus emblica and Cassia fistula* with moderate response [74]. In Varanasi (Uttar Pradesh) was evaluated APTI value to categories plants as sensitive or resistant with respect to air pollutants [39]. In Moradabad, APTI value to see the relative tolerance of 10 plant species was taken from residential, industrial, and commercial area of the city [120]. In Rourkela reveled Seasonal variation in air pollution tolerance indices and selection of plant species for industrial areas [32].Tree species and shrub species to perform well for the development of “Green belt” in University Campus area of Rohtak, on the basis of API values [38]. 50% plant shows APTI values intermediate tolerant in an educational institute in Delhi [35]. In Yogi Vemana University, Kadapa also evaluated APTI of 10 sp. [15]. Assessment of Air pollution Tolerance Index of some herbs plants of Golapbag Campus of Burdwan University in W.B. thus indicating all selected species to be highly tolerant to air pollution [33].

In the road side area:

Periyar University is located in NH47, Bangalore National Highways. The selected plant P. hysterophorus was found to be a tolerant species to pollution in study area [69]. Along the roadsides around Netaji Subhas Chandra Bose (N.S.C.B.) International Airport, Kolkata, India. *Polyalthia longifolia* was found to be least affected by dust deposition as estimated by air pollution tolerance index (APTI) [101]. The ambient air quality monitoring along the NH - 58 through Haridwar and other 3 traffic intersection of the city. Maximum dust interception was done by *Psidium gujava* and species *Ficus religiosa* has highest air pollution tolerance index [57]. U. Pravin et al. examined Air Pollution Tolerance Indices (APTI) shows The highest tolerance species as *Pollyalthia longifolia*[94]. In Salem 12 plant are collected from near road sides of railway junction and from residential area, shows APTI ranges from 02.29 to 12.53 were found to be sensitive to pollution[68]. In the present investigation reveals the most sensitive species is *Ficus religiosa* and the most resistant species is *Samanea saman* and the moderately resistant one is *Azadirachta indica* [13]. APTI has also been calculated and found to *Duranta repens* serve as sink to air pollutants and can be effectively employed for phyto-monitoring auto exhaust pollution along the road side of the busy traffic ways [98]. Jalgaon city is the trade and commercial center of North Maharashtra region with NH-6 passing through the city exposed to heavy vehicular pollution load.It was concluded that *Alstonia scholaris* high APTI value[61]. APTI for various plant species growing at the seven cross-roads of Ahmedabad city. *F. benghalensis*, with highest APTI was found to show tolerant response to automobile pollutants [24]. Pollution tolerance of the abundant street tree species in Ludhiana was studied and most of them were found to have intermediate tolerance[20]. S. Arora examined

APTI Found high in *Alstonia scholaris Linn.* The Lowest in *Azadirachta indica.Juss* . Significant decrease in total chlorophyll pH etc. was observed [12]. A.P. Deepalakshmi et al. revaled Roadside Plants as Bio-indicators of Urban Air Pollution. *Peltophorump terocarpum and Portulaca oleraceaeare tolerant species* [34]. The present study investigate the APTI and dust capturing efficiency of three dominant species *Cassia siamea, Dalbergia sissoo* and *Delonix regia* growing along road sides of Harda[54]. Along the road side at control and polluted site of Aizawl, Mizoram, Highest dust deposition was found in *Ficus benghalensis* [95]. Due to constant vehicular traffic on Najafgarh road network in Delhi, The tolerance index value was found to be maximum for *Dalbergia sissoo*[63]. In Ponnur (Guntur), collected 8 plants from highly polluted road side area and residential colony.[64]. The study selected plants located near road sides of Saradha college, Salem, Tamil Nadu were found to be sensitive to pollution [108]. The Tiruchirappalli City Corporation, obtained results shows, all the plants APTI values and secondary metabolites exhibited significant positive correlation with pollution load [116].

CONCLUSIONS

While summing up it can be said that the determination of Air Pollution Tolerance Index (APTI) of the plant species in urban area is important tool for cheek pollution. A good analysis of a plant species for plantation as per the requirement of the area can actually solve a lot of air quality issues related to a particular area. It is noteworthy that a set of studies have been done on these themes in Asian continent as well as global level. The present paper discus about APTI related works mainly based on different areas of India. Moreover, no research work can be traced on many industrial and heavily polluted lands in India. India's rich biodiversity of both indigenous and exotic trees offers a wide range of choice to restore greenery. Further research is required at large scale in different polluted area to effective control of atmospheric particulate pollution. This work will also very helpful for future research work related to this area. The identification of the tolerant plant species in relation to different pollution level require the more research work to suggests suitable plant species to green-belt development and social-forestry programs.

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