

## Screening Urban Tree Species for Air Quality Enhancement: A review

### Abstract:

Air pollution poses a significant global challenge, particularly in urban areas, due to factors like industrialization, urbanization, increased vehicular traffic, and high energy consumption. In India, vehicle emissions, industrial activities, and power plants are major contributors to deteriorating air quality, with vehicles alone responsible for substantial carbon monoxide and hydrocarbon emissions. Unplanned urbanization and population growth further exacerbate pollution levels. Urban air pollution is linked to millions of deaths and respiratory illnesses annually, especially in developing countries. Vegetation plays a crucial role in mitigating air pollution by absorbing gaseous pollutants and particulate matter through leaves. Plants also act as bioindicators, displaying characteristic responses to specific pollutants. They employ mechanisms like leaf absorption, particulate deposition, and fallout on the leeward side to cleanse the atmosphere. Bio-monitoring with plants is a cost-effective method to assess environmental pollution impacts, highlighting the vital role of urban green spaces in improving air quality and public health. In summary, the screening of trees for pollution abatement is essential in urban planning. The APTI, coupled with assessing the dust-capturing capacity and emission reduction of trees, aids in categorizing them as sensitive indicators or effective pollution sinks.

**Key words:** air pollution tolerance index, bioindicators, urban air pollution, bio-monitoring, mitigation by trees

### Introduction

Clean air is a diminishing resource in today's communities, with each person taking about 20,000 breaths daily. This constant intake of air exposes our bodies to various pollutants such as carbon monoxide, carbon dioxide, and hydrocarbons, which can significantly impact human health. Air pollution has evolved into a global challenge affecting both developed and developing nations, exacerbated by factors like urbanization, industrialization, increased traffic, rapid economic growth, and high energy consumption (Chandawat *et al.*, 2011). Urban areas, in particular, grapple with a complex mix of air pollutants, whose composition varies over time and across cities due to changing emission patterns. In India, urban air quality faces significant threats from vehicle emissions, industrial activities, and power plants.

Vehicles, contributing to 70% of carbon monoxide, 50% of hydrocarbons, and a substantial portion of other pollutants, play a major role in deteriorating air quality, with two-wheelers being significant contributors (CPCB, 2009). Unplanned urbanization, rapid industrialization, a surge in vehicular fleets, population growth, and inadequate urban planning are among the key drivers of escalating air pollution levels (Jayanthi and Krishnamoorthy, 2006). The last six decades have witnessed a staggering increase in urban populations globally, leading to heightened environmental pollution (Lebowitz, 1995; Tripathi *et al.*, 2008; Dwivedi *et al.*, 2008). In India, urban population tripled from 1951 to 2011, reaching 1.21 billion, constituting 25.7% of the total population. The urbanization trend has been marked by a surge in large cities and metropolitan areas, contributing significantly to air pollution (Directorate of Census Operation, India, 2012).

The World Health Organization estimates that urban air pollution causes over 2 million deaths annually in developing countries, with millions suffering from respiratory illnesses linked to air pollution in major cities (WHO, 2002). Outdoor and indoor pollutants pose acute health risks to humans and plants. Vegetation plays a crucial role in cleansing the atmosphere by absorbing gaseous pollutants and particulate matter through leaves. Plants exhibit characteristic responses to specific pollutants, making them effective bioindicators (Agrawal *et al.*, 2003; Oliva and Mingorance, 2006; Han and Naeher, 2006). Plants employ three mechanisms—leaf absorption, deposition of particulates on leaves, and fallout on the leeward side—to remove air pollutants. Bio-monitoring with plants is a cost-effective method to assess the impact of environmental pollutants. Many trees efficiently trap and absorb pollutants, serving as sinks for various air pollutants (Chandawat *et al.*, 2011).

### **Urban air pollution:**

In the context of increasing urban air pollution, the selection of plant species for urban areas should consider not only aesthetic and practical factors but also their ability to enhance air quality (Babu *et al.*, 2013). Bio-monitoring of plants through an Air Pollution Tolerance Index (APTI) can be a valuable tool to evaluate the sensitivity of plants to air pollution. This index considers parameters such as ascorbic acid, total chlorophyll content, leaf pH, and relative water content to categorize trees as sensitive or tolerant (Tripathi *et al.*, 1999; Raina and Sharma, 2003). As plant responses vary, identifying tolerant and sensitive species is crucial for developing green belts around urban areas.

The impact of atmospheric pollution, particularly in urban areas, is a growing concern due to the continuous release of toxic gases and substances from industries and automobiles. Chennai, being a metropolitan city and industrial center, faces challenges from both industrial and vehicular emissions. This chapter reviews relevant literature on the environment of urban areas, past and present trends of air pollutants in urban cities, the importance of trees in urban areas, plant responses to air pollution, and the mechanisms of action of specific pollutants.

## **Environment of Urban Area**

According to the United Nations Environment Programme (UNEP), over 1 billion people are exposed to outdoor air pollution annually. Urban air pollution, linked to up to 1 million premature deaths each year, results from various anthropogenic sources, including automobiles, industries, power generation systems, construction projects, and solid waste. The primary contributors to air pollution in urban areas are automobiles, industries, and domestic fuel combustion. Both developed and developing countries face challenges related to mobile and vehicular pollution, with motor vehicles responsible for a significant portion of urban pollution.

## **Past and Present Trends of Air Pollutants in Urban Cities**

In India, major metropolitan cities have experienced serious air pollution issues, with vehicular emissions contributing about 60-70% and industrial emissions about 20% to ambient air pollution. The trends of major air pollutants, such as sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and particulate matter, have varied over the years. While SO<sub>2</sub> emissions have shown a decreasing trend since 1980, NO<sub>x</sub> emissions have increased, especially in metropolitan cities. Particulate pollutants are also a significant concern, affecting air quality.

## **Importance of Trees in Urban Areas**

Plants, particularly trees, play a crucial role in mitigating air pollution in urban areas. They act as efficient filters, absorbing air pollutants and particulate matter. Trees in urban environments contribute to improving air quality by providing a large surface area for pollutant absorption and reducing pollution levels. Plantation in parks, residential localities, and along streets and roads serves as a bio-mitigating measure to enhance environmental quality.

## **Plant Responses to Air Pollution**

## **Visible Symptoms**

Air pollutants can induce visible symptoms on plants, classified as chronic or acute. Sulfur dioxide (SO<sub>2</sub>) exposure results in acute injury symptoms such as necrosis and chlorosis on leaves. Nitrogen dioxide (NO<sub>2</sub>) uptake predominantly occurs through stomatal openings, leading to increased stomatal conductance. Particulate pollutants can cause visible symptoms, including various necrotic lesions, depending on the plant species and pollutant concentrations.

## **Uptake of Pollutants**

The leaves, particularly stomatal openings, are the most susceptible parts of plants to acute injury due to air pollutants. The entry of pollutants, such as SO<sub>2</sub> and NO<sub>2</sub>, occurs through stomatal openings and cuticles. Cuticular resistance, wind speed, and leaf characteristics influence the entry of pollutants into leaves. Reactive pollutants like ozone (O<sub>3</sub>) might react with cuticular waxes, leading to penetration through damaged cuticles.

## **Mechanism of Action**

### **Sulfur Dioxide**

The response of stomata to SO<sub>2</sub> entry depends on leaf age, concentration, and pollutant combinations. SO<sub>2</sub> dissolves in apoplastic water, forming sulphite and bisulphite ions. These ions can be detoxified by oxidizing them to less toxic sulphate ions. Disturbances to biochemical functions and cell structure due to SO<sub>2</sub> exposure may precede visible symptoms or growth reductions.

### **Nitrogen Dioxides**

Nitrogen dioxide (NO<sub>2</sub>) primarily enters leaves through stomatal openings, similar to SO<sub>2</sub>. Once inside, it dissolves to form nitrate, nitrite, and protons. The ease of dimerization of NO<sub>2</sub> may lead to the production of free radicals and free radical chain reactions. Chronic exposure to NO<sub>2</sub> may reduce stomatal conductance, affecting plant health.

### **Air Pollution**

Air pollution poses a significant threat to the environment and human health. Recognizing the impact of air pollution on plant species, researchers have developed the Air Pollution Tolerance Index (APTI) as a tool to assess and select plants that can thrive in polluted environments. The APTI combines four physiological and biochemical parameters—leaf extract pH, relative water content, ascorbic acid, and total chlorophyll content—to

provide a comprehensive measure of a plant's tolerance to air pollution (Das and Prasad, 2010). Several studies have employed APTI to evaluate the tolerance of different plant species to air pollution in various regions. In Ghaziabad urban area, Mishra and Pandey (2011) identified plants such as Bauhinia, Pongamia, Citrus, and Enterolobium as sensitive with low APTI values, while Azadirachta, Psidium, Mangifera, Bougainvillea, Lagerstromia, Morinda, Hibiscus, Ixora, Polyalthia, Achras, and Cassia were categorized as tolerant. Similarly, Taneer and Albert (2013) ranked *Psidiumguajava* as the most tolerant and *Ocimumgratissimum* as the most sensitive species to air pollution stress.

A study in Pithampur Industrial area by Aarti *et al.*, (2012) revealed variations in APTI values among six plant species, with *Calotropis gigantea* exhibiting the highest tolerance. The highest reduction in APTI was observed in the industrial area sector-3, indicating severe air pollution. Krishnaveni *et al.*, (2013) reported Nerium oleander as an intermediate tolerant species, while *Ficusbenghalensis*, *Psidiumguajava*, *Spathodeacampanulata*, and *Opuntiaficusindica* were identified as sensitive species. Chandawat *et al.*, (2011) calculated APTI for various plant species in Ahmedabad city, with *Ficusbenghalensis* showing the highest tolerance at all sites. In Rourkela and Aizawl, *F. bengalensis* and *Mangiferaindica* were found to be tolerant, respectively (Rai *et al.*, 2013). Babu *et al.*, (2013) reviewed APTI for seven plants in polluted and control sites, finding all plants sensitive to air pollution. Miria and Khan (2013) identified *Mangiferaindica* as highly pollution-tolerant, recommended for urban areas. The study in Delta state (Nigeria) ranked *Psidiumguajava* as the least tolerant and *Mangiferaindica* as the most tolerant species (Agbaire and Esiefari *et al.*, 2009). Tripathi *et al.*, (2009) assessed APTI for various plant species in the Brass city, categorizing them as high, moderate, and sensitive tolerance. Cement industries, major contributors of suspended particulate matter (SPM), were studied by Radhapriya *et al.*, (2012).

About 37% of the plant species around cement industries showed tolerance, including *Mangiferaindica*, Bougainvillea, and *Psidiumguajava*, while 33% were highly susceptible, including *Thevetianeriifolia* and *Saracaindica*. In Kotagiri Municipal Town, Senthilkumar and Paulsamy (2011) identified six tree species with higher APTI values, suggesting their priority for plantation programs. Similarly, Jyothi and Jaya (2010) studied trees and shrubs along National Highway - 47, finding *Polyalthialongifolia* and *Clerodendroninfortunatum* to be tolerant varieties. In conclusion, the Air Pollution Tolerance Index (APTI) serves as a valuable tool for assessing and selecting plant species that can thrive in polluted environments. Numerous studies have applied APTI to evaluate the tolerance of various plant

species, providing valuable insights for urban planning, greenbelt development, and environmental conservation. Understanding the relative tolerance of plant species contributes to the development of sustainable ecosystems in the face of increasing air pollution challenges.

### **Pollution Mitigation by Trees**

Plants play a crucial role in both monitoring and mitigating pollution in urban and industrial environments. Studies have shown that plants are adversely affected by ambient air pollutants, and their physiological responses can be indicative of the environmental quality. Kapoor *et al.*, (2013) demonstrated the successful growth of *Dalbergiasissoo* in areas with mild pollution and frequent droughts, suggesting its potential as a bio-monitor for air pollution. Llinares *et al.*, (1992) investigated nitrogen concentration changes in various plant parts such as leaves, petioles, and branches of different species, including *Alnusglutinosa* and *Elaeagnus angustifolia*. Diazotrophic plants like *Elaeagnus* exhibited an average nitrogen value of 3.23%, emphasizing the role of plants in nutrient cycling.

Dust trapping efficiency was studied by Chandawat (2011), who observed that *Ficusbenghalensis*, *Ficusreligiosa*, and *Ficusglomerata* had high dust trapping efficiency, making them effective in areas with elevated pollution levels. The study indicated that the leaves of plants in polluted areas accumulated more dust compared to those in control and low-polluted areas across different seasons. Zhang *et al.*, (2013) investigated the tolerance of six landscape tree species to sulfur dioxide (SO<sub>2</sub>) stress. *Ilex rotunda* was identified as a species that grew normally under SO<sub>2</sub> stress conditions and could effectively absorb SO<sub>2</sub>. This highlights the potential of certain tree species in mitigating specific pollutants. Tzvetkova and Kolarov (1996) suggested that *T. argentea* and *A. glandulosa* could serve as good bioindicators, and *Q. cerris* exhibited high resistance to industrial emissions. Urban trees were recognized for their crucial role in cleansing airborne particulate pollution in human environments (Chakre, 2006). A modeling study conducted across the United States by Nowak *et al.*, (2006) demonstrated that urban trees have a substantial impact on improving air quality by removing pollutants such as O<sub>3</sub>, PM, NO<sub>2</sub>, SO<sub>2</sub>, and CO.

The total annual air pollution removal by urban trees was estimated at 711,000 metric tons, with a calculated value of \$3.8 billion. This emphasizes the potential economic and health benefits of urban tree canopies. In addition to the removal of various pollutants, trees within cities were found to be effective in reducing fine particulate matter (PM<sub>2.5</sub>) concentrations, contributing to improved air quality and human health (Nowak *et al.*, 2013).

The study estimated the annual PM<sub>2.5</sub> removal by trees in different U.S. cities, emphasizing the role of trees in enhancing air quality. Plants are widely used as bioindicators in air quality biomonitoring studies due to their immobility and sensitivity to prevalent air pollutants (Nali and Lorenzini, 2007). Various plant parts, such as lichens, mosses, ferns, grass, tree bark, tree rings, tree leaves, and pine needles, have been employed in trace element air monitoring programs (Szczepaniak and Biziuk, 2003; Morselliet al., 2004). Mosses, in particular, have been recognized as effective bioindicators of heavy metal pollution due to their ability to accumulate contaminants from wet and dry deposition (Onianwa, 2000).

Lichens, known for their sensitivity to specific pollutants, have been termed "permanent control systems" for air pollution assessment (Conti and Cecchetti, 2001). Kovacs (1992) recommended ruderal plants as bioaccumulative indicators due to their ability to accumulate metals without visible injury. Different types of trees, including coniferous and deciduous species, have been utilized to detect aerial heavy metal pollution. Coniferous trees, such as *Pinus spp.*, have been employed for their ability to indicate pollution over longer periods (Ataabadiet al., 2010; Baslaret al., 2009). Broad-leaved species sensitive to metal contamination include *Betula pendula*, *Fraxinus excelsior*, *Sorbusaucuparia*, *Tiliacordata*, and *Malusdomestica* (Mulgrew and Williams, 2000). Studies have shown that ecophysiological behaviors of trees, such as photosynthetic rate, transpiration rate, stomatal conductance, and intercellular carbon dioxide concentration, vary among different species and under different environmental conditions (Kumar, 2011; Babu, 2012).

The physiological activities of trees, such as photosynthesis and transpiration, are influenced by factors like light, temperature, and water availability. Babu (2012) recorded higher transpiration rates in afforested plantations, with *Gmelinaarborea* exhibiting significantly higher transpiration rates compared to other species. Similarly, a study by Saraswathi and Paliwal (2008) found variations in transpiration rates between *Albizialebeck* and *Cassia siamea* under different drought stress levels. The ecophysiological behavior of trees is not only influenced by environmental factors but also by genetic variations among species and provenances. Studies have reported significant variations in net photosynthetic rates among different tree species and provenances (Kundu and Tigerstedt, 1999; Wu and Ma, 1988).

## **Conclusion**

In summary, plants, especially trees, play a vital role in mitigating pollution through various mechanisms, including pollutant removal, dust trapping, and tolerance to specific pollutants. Their ecophysiological behaviors provide valuable insights into the environmental conditions and air quality. Harnessing the potential of different tree species in urban and industrial settings can contribute to cleaner air, improved health, and a sustainable environment.

#### **Disclaimer (Artificial intelligence)**

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. ChatGPT was used for editing this manuscript.

#### **References**

- Aarti, Chouhan, Iqbal Sanjeeda, R.S. Maheshwari and A. Bafna. 2012. Study of air pollution tolerance index of plants growing in Pithampur Industrial Area Sector 1, 2 and 3. **Research Journal of Recent Sciences**, 1: 172-177.
- Agbaire, P.O. and E. Esiefarienrhe. 2009. Air Pollution Tolerance Indices (APTI) of some plants around Otorogun Gas Plant in Delta State, Nigeria. **J. Al. Sci. Environ. Manage**, 13(1):11-14.
- Agrawal, M., B. Singh, M. Rajput, F. Marshall and J.N.B. Bell. 2003. Effect of air pollution on peri-urban agriculture: a case study. **Environmental Pollution**, 126: 323-329.
- Ataabadi, M., M. Hoodaji and P. Najafi. 2010. Heavy metal biomonitoring by plants grown in an industrial area of Isfahan Mobarakeh Steel Company. **Journal of Environmental Studies**, 35(53): 83-92.
- Babu, G. Buchchi, Nazaneen Parveen, K. Naveen Kumar and M. Sridhar Reddy. 2013. Evaluation of Air Pollution Tolerance index of plant species growing in the Vivinity of cement industry and Yogi Vemana University campus. **Indian Journal of Advances in Chemical Sciences**, 2(1):16-20.
- Babu, Narendra. 2012. Quantifying carbon sequestration potential in fast growing trees through afforestation. **M.Sc. Thesis**, Tamil Nadu Agricultural University, Coimbatore.

- Chakre, O.J. 2006. Choice of eco-friendly trees in urban environment to mitigate airborne particulate pollution. **J. Hum. Ecol.**, **20(2)**: 135-138.
- Chandawat, D.K., P.U. Verma and H.A. Solanki. 2011. Air Pollution Tolerance Index (APTI) of tree species at cross road of Ahmadabad city. **Life Sciences Leaflets**, **20**:935-943.
- Chandawat, Deepika. 2011. Effects of air pollution on physiology and metabolism in road-side plants growing at Ahmadabad. **Ph.D, Thesis**, Gujarat University, Gujarat.
- Conti, M.E. and G. Cecchetti. 2001. Biological monitoring: Lichens as bioindicators of air pollution assessment - A review. **Environmental Pollution**, **114(3)**:471-492.
- CPCB. 2009. Ambient air quality data. Central Pollution Control Board, New Delhi. <http://www.cpcb.nic.in/bulletin/del/2009html>.
- Das, Sasmita and Pramila Prasad. 2010. Seasonal variation in Air Pollution Tolerance Indices and selection of plants species from industrial area of Rourkela. **IJEP.**, **30(12)**: 978-988.
- Directorate of Census Operation, India. 2012. Internet address: <http://www.censusindia.gov.in>
- Dwivedi, A.K., B.D. Tripathi and Shashi. 2008. Effect of ambient air sulphur dioxide on sulphate accumulation in plants. **J. Environ. Biol.**, **29**: 377-379.
- Han, X. and L.P. Naeher. 2006. A review of traffic-related air pollution exposure assessment studies in the developing world. **Environ. Intern.**, **32**: 106-120.
- Jayanthi, V. and R. Krishnamoorthy. 2006. Status of ambient air quality at selected sites in Chennai. **IJEP**, **25**: 696-704.
- Kapoor, C.S., B.R. Bamniya and K. Kapoor. 2013. Efficient control of air pollution through plants, a cost-effective alternative: studies on *Dalbergiasissoo*Roxb. **Environ. Monit. Assess.**, **185**: 7565-7580.
- Kovacs, M. 1992. Trees as biological indicators. **In**: Biological indicators in environmental protection. Kovacs, (Ed.), Ellis Horwood, New York. pp. 97-100 and 72-86.
- Krishnaveni, M., R. Chandrasekar, L. Amsavalli, P. Madhaiyan and S. Durairaj. 2013. Air Pollution Tolerances Index of plants at Perumalmalai Hills, Salem. **Int. J. Pharm. Sci. Rev. Res.**, **20(1)**: 234-239.
- Kumar, Suresh. 2011. Carbon sequestration potential and baseline carbon studies through afforestation. **M.Sc. Thesis**, Tamil Nadu Agricultural University, Coimbatore.
- Kundu, S.K. and P.M.A. Tigerstedt. 1998. Variation in net photosynthesis, stomatal characteristics, leaf area and whole plant phytomass production among ten provenances of neem (*Azadirachta indica*). **Tree Physiol.**, **19**: 47-52.

- Lebowitz, M.D. 1995. Exposure assessment needs in studies of acute health effects. **Sci. Total Environ.**, **168**: 109-117.
- Llinares, F., D. Munoz-Mingarro, N. Acero and A. Probanza. 1992. Temporal variation of the total nitrogen concentration in aerial organs of nitrogen fixing and non fixing riparian species. **Orsis**, **7**:125-130.
- Miria, A. and Anisa Basheer Khan. 2013. Air pollution Tolerance index and carbon storage of selected urban trees - A comparative study. **International Journal of Applied Research and Studies**, **2(5)**:2278-9480.
- Morselli, L., B. Brusori, F. Passarini, E. Bernardi, R. Francaviglia and L. Gatelata. 2004. Heavy metal monitoring at a Mediterranean natural ecosystem of Central Italy trends in different environmental matrixes. **Environment International**, **30(2)**:173-181.
- Mulgrew, A. and P. Williams. 2000. Biomonitoring of air quality using plants, WHO Collaborating Centre for Air Quality Management and Air Pollution Control. WHO CC, Berlin.pp. 822-938.
- Nali, C. and G. Lorenzini G. 2007. Air quality survey carried out by schoolchildren: an innovative tool for urban planning. **Environmental Monitoring and Assessment**, **131(1-3)**:201-210.
- Nowak, J. David, Satoshi Hirabayashi, Allison Bodine and Robert Hoehn. 2013. Modeled PM<sub>2.5</sub> removal by trees in ten U.S. cities and associated health Effects. **Environmental Pollution**, **178**:395-402.
- Oliva, S. and M.D. Mingorance. 2006. Assessment of airborne heavy metal pollution by aboveground plant parts. **Chemosphere**, **65(2)**:177-182.
- Onianwa, P.C. 2000. Monitoring atmospheric metal pollution: A review of the use of mosses as indicators. **Environmental Monitoring and Assessment**, **71(1)**:13-50.
- Radhapriya, P., A. NavaneethaGopalakrishnan, P Malini and A. Ramachandran. 2012. Assessment of air pollution tolerance levels of selected plants around Cement Industry, Coimbatore, India. **J. Environ. Biol.**, **33**: 635-641.
- Rai, Prabhat Kumar, Lalita, L.S. Panda, Biku Moni Chutia and M. Muni Singh. 2013. Comparative assessment of Air Pollution Tolerance Index (APTI) in the industrial (Rourkela) and non industrial area (Aizawl of India: An eco-management approach. **African Journal of Environment Science and Technology**, **2013 7(10)**: 944-948.
- Raina, A.K. and A. Sharma. 2003. Effects of vehicular pollution on the leaf micromorphology, anatomy and chlorophyll contents of *Syzygiumcumini*L. **Indian Journal of Environmental Protection**, **23(8)**: 897 - 902.

- Saraswathi, S.G. and K. Paliwal. 2008. Diurnal and seasonal trends in photosynthetic performance of *Dalbergiasissoo*Roxb. and *Hardwickiabinata*Roxb. from a semi-arid ecosystem. **Photosynthetica**, **46**: 248-254.
- Sentilkumar, P. and S. Paulsamy. 2011. Evaluation of air pollution tolerant tree species for Kothagiri Municipal Town, the Nilgiris, Tamil Nadu. **Journal of Research in Biology**, **2**:148-152.
- Szczepaniak, K. and M. Biziuk. 2003. Aspects of the biomonitoring studies using mosses and lichens as indicators of metal Pollution. **Environmental Research**, **93(3)**: 221-230.
- Tanee, F.B.G. and E. Albert. 2013. Air pollution tolerance indices of plants growing around Umuebulu Gas Flare Station in Rivers State, Nigeria. **African Journal of Environmental Science and Technology**, **7(1)**: 1-8.
- Tripathi, A., D.S. Tripathi and V. Prakash. 1999. Phytomonitoring and NO<sub>x</sub> pollution around silver refineries. **Environ. Pollut.**, **25**: 403-410.
- Tripathi, A., P.B. Tiwari, Mahima and D. Singh. 2008. Assessment of atmospheric pollution from toxic heavy metals in Brass city of India. **Plant Arch.**, **8**: 267-270.
- Tripathi, Anamika, P.B. Tiwari, Mahima and Dharmveer Singh. 2009. Assessment of air pollution tolerance index of some trees in Moradabad city, India. **Journal of Environment Biology**, **30(4)**: 545-550.
- Tzvetkova, Nikolina and DimitarKolarov. 1996. Effect of air pollution on carbohydrate and nutrients concentrations in some deciduous tree species. **J. Plant Physiol.**, **22(1-2)**: 53-63.
- World Health Organization. 2002. "World Health Report: Reducing risk, Promoting healthy life, World Health Organization. Geneva, Switzerland. [www.who.int/whr/en/](http://www.who.int/whr/en/).
- Wu, X.M. and J. Ma. 1988. Provenance variation of photosynthesis and tolerance to water stress in *Platycladus (Thuja) orientalis* Franco. **ScientiaSilvaeSinicae**, **24**: 448-453.
- Zhange, Xizi, Ping Zhou, Weiqiang Zhang, Weihua Zhang and Yongfeng Wang. 2013. Selection of landscape tree species of tolerant to sulfur dioxide pollution in subtropical China. **Open Journal of Forestry**, **3(4)**: 104-108.