



POLLUTION IMPACT ON PLANT SPECIES AROUND BEAWAR REGION INDUSTRIAL ZONE – AN APTI STUDY

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Abstract: Air pollution has become a major global concern, significantly impacting human health and the environment. It is responsible for one in every nine deaths annually (World Health Organization, 2016). The rapid industrialization, urbanization, and increasing transportation have worsened air quality, particularly in residential and urban areas, making air pollution a key issue for governments worldwide. Green plants can absorb air pollutants and act as a natural sink, making greenbelts an effective way to control air pollution. By planting more greenery, we can reduce the harmful effects of pollution and improve air quality, especially in urban areas. The Air Pollution Tolerance Index (APTI) is a modern tool used to assess the tolerance of plant species to air pollution. By measuring factors such as ascorbic acid content, total chlorophyll content, relative water content, and pH of leaf extract, APTI provides valuable insights into how plants respond to pollution. Plants with lower APTI values are more sensitive to air pollution, while those with higher values are more tolerant. These tolerant species can be used for developing green belts in urban areas, helping to mitigate pollution. APTI categorizes plants into sensitive, intermediate, and tolerant groups based on their tolerance levels. This method provides a reliable way to assess plant species' resilience to air pollution and supports the selection of plants for environmental conservation, particularly in polluted industrial areas. The use of APTI is essential for identifying plants that can effectively help reduce pollution and improve urban air quality. The present study aimed to assess the Air Pollution Tolerance Index (APTI) of plant species of industrial area in the Beawar region, Rajasthan, India.

Keyword – Air pollution, Air pollution tolerance index, urbanization.

Introduction

Air pollution occurs when harmful substances—whether biological, chemical, or physical—contaminate the air, making it unsafe for humans, animals, and plants. It is one of the biggest environmental issues in the modern world, mainly caused by human activities such as industrial emissions, vehicle exhaust, and the burning of fossil fuels like coal and petrol.

As cities expand and industries grow, the quality of air is worsening, leading to serious health risks and environmental damage. The presence of pollutants in the air can affect both urban and industrial areas, making it necessary to monitor and control pollution levels to protect people and nature.

Plants constantly experience changing environmental conditions. Transpiration, a natural process that helps plants regulate temperature and support respiration, also plays an important role in reducing air pollution. By cooling the surrounding air, transpiration slows down chemical reactions that create harmful secondary pollutants. (Dhruti Patel*, J. I. Nirmal Kumar(2018)).To survive, they have developed various defense mechanisms, including signaling, tolerance, and resistance strategies.

However, air pollution remains a serious threat to plant health, agriculture, and ecosystems. Pollutants such as tropospheric ozone, nitrogen oxides, and particulate matter can disrupt plant growth, reduce crop yields, and weaken ecosystem stability. Understanding how plants respond to air pollution is crucial for protecting agricultural production and maintaining ecological balance. (Dhruti Patel*, J. I. Nirmal Kumar(2018))

Several factors affect how plants react to air pollution, including chlorophyll content, ascorbic acid levels, leaf pH, and water content. When plants experience stress, their chlorophyll levels drop due to the production of reactive oxygen species (ROS), which are tiny molecules that can damage plant cells. This reduction in chlorophyll slows down photosynthesis, harms leaves, and affects how the plant breathes through its stomata. On the other hand, plants with higher levels of ascorbic acid can protect themselves from damage and maintain their functions under stressful conditions.

The ability of trees to capture fine particulate matter (PM_{2.5}) varies from their ability to trap larger particles like PM₁₀. However, all tree species contribute to air purification as their leaves can hold dust, suspended particles, and other air pollutants. Trees with rough or irregularly shaped leaf surfaces are particularly effective at absorbing toxic pollutants through pores of different sizes. (Ngakan Ketut Acwin Dwijendra, Mohammad Javad Mohammad, et al. (2022)).

Despite efforts to combat climate change and improve technology, ecosystems and farmlands worldwide still face high levels of air pollution, including tropospheric ozone (O₃), nitrogen oxides (NO_x), and particulate matter (PM). Rapid urbanization and industrial growth worsen air quality, posing ongoing challenges to environmental and agricultural sustainability. (Elina Oksanen, Sari Kontunen-Soppela (2021))

The Air Pollution Tolerance Index (APTI), developed by Singh and Rao (1983), helps measure how well plants can tolerate air pollution based on their leaf characteristics. Plants with high APTI values are more resistant to pollution and can help absorb pollutants in urban and industrial areas, while plants with low APTI values are more sensitive and act as indicators of poor air quality.

Different plant species exhibit varying levels of sensitivity and response to air pollution, as indicated by their Air Pollution Tolerance Index (APTI) values. Species with lower APTI function as bioindicators, signaling poor air quality, while those with higher APTI are more resistant and can be effectively utilized for creating urban green belts. The majority of the studied plants were found to be moderately sensitive to air pollution. (Dhruti Patel*, J. I. Nirmal Kumar(2018))

Air Pollution in Industrial Areas

Industrial areas are among the most polluted regions because factories release large amounts of toxic gases and particulate matter into the air. The level and type of pollution depend on the raw materials used in industrial processes. As industries expand, the number of vehicles, power plants, and construction activities also increases, making air pollution even worse. People living and working near these areas are more likely to suffer from respiratory diseases, heart problems, and other health conditions due to constant exposure to pollutants.

The Role of Plants in Reducing Air Pollution

Nature has its own way of cleaning the air, and plants play a major role in this process. Trees and vegetation help in reducing air pollution by absorbing harmful gases and trapping dust particles on their leaves. Expanding tree plantations in industrial and urban areas is an effective and environmentally friendly way to improve air quality.

However, not all plants can survive in highly polluted areas. Some plants are very sensitive to pollution, while others are tolerant and can survive in harsh conditions. Understanding which plants can tolerate pollution is essential for creating green belts—large areas of trees and plants that act as natural filters for polluted air.

Air Pollution Tolerance Index (APTI): Identifying Pollution-Resistant Plants

The Air Pollution Tolerance Index (APTI) is a scientific method used to measure how well a plant can withstand pollution. This index is determined by analyzing four key factors in plant leaves:

1. **pH level** – Measures the acidity of the leaf, which indicates how much pollution it has absorbed.
2. **Ascorbic Acid (Vitamin C) Content** – Works as an antioxidant that helps the plant fight pollution stress.
3. **Total Chlorophyll Content** – Determines how well the plant is performing photosynthesis, which is important for its survival in polluted areas.
4. **Relative Water Content (RWC)** – Shows how well a plant retains water under stressful conditions caused by pollution.

Based on their APTI values, plants are classified as:

- **Sensitive Plants (APTI ≤ 11):** These plants are weak against pollution and can be used as bioindicators to show how polluted an area is.
- **Moderately Tolerant Plants (APTI 12-16):** These plants have some resistance to pollution and can survive in moderate pollution levels.
- **Tolerant Plants (APTI ≥ 17):** These are strong plants that can survive in highly polluted areas and are ideal for planting in industrial zones.

Anticipated Performance Index (API): Selecting Plants for Urban Forests

Apart from APTI, another important tool for choosing plants for urban forest development is the Anticipated Performance Index (API). This index not only considers how tolerant a plant is to pollution but also its overall benefits to the environment and society. It helps in selecting the best trees for reducing pollution, improving biodiversity, and providing shade and oxygen in cities.

How APTI and API Can Help Fight Air Pollution

With increasing industrialization, vehicle emissions, and urban expansion, pollution levels are rising at an alarming rate. To control pollution and improve air quality, cities and industries must adopt green solutions such as planting pollution-resistant trees and developing green belts.

Using the Air Pollution Tolerance Index (APTI) and Anticipated Performance Index (API), experts can identify the best plants for absorbing pollutants, purifying the air, and creating healthier environments.

By strategically planting trees and vegetation in industrial and urban areas, we can significantly reduce pollution, protect public health, and build sustainable and eco-friendly cities for future.

Parameters of the Air Pollution Tolerance Index (APTI)

The APTI is calculated by evaluating key physiological and biochemical characteristics of tree species that reflect their capacity to tolerate air pollution. The parameters commonly used in the assessment include:

1. **Leaf Water Content (LWC):**
Leaf water content is an important indicator of plant health and hydration. Pollution can disrupt a tree's water retention ability, leading to dehydration, cellular damage, and reduced photosynthetic efficiency.
2. **Leaf Chlorophyll Content (LCC):**
Chlorophyll is vital for photosynthesis, and its presence in leaves directly impacts the plant's ability to convert sunlight into energy. Pollution, particularly from SO₂ and NO₂, can damage chloroplasts and reduce chlorophyll levels, hindering photosynthetic capacity.
3. **Leaf pH:**
The pH of leaf tissues can be altered by air pollutants, which may interfere with enzymatic functions and overall metabolic processes. A drop in pH is often a sign of oxidative stress caused by exposure to pollution.

4. Ascorbic Acid (Vitamin C) Content:

Ascorbic acid serves as an antioxidant that helps neutralize the damaging effects of free radicals generated by pollutants. Higher levels of ascorbic acid in tree leaves indicate better tolerance to environmental stress caused by pollution.

$$\text{FORMULA:- } \text{APTI} = \frac{A(T+P)+R}{10}$$

- A= Ascorbic acid content of the leaves
- T= Total chlorophyll content of the leaves
- P= pH of leaf extract
- R= Relative Water Content of leaf (%)

For comparative purposes between populations or between sites for a given population, the index may be deemed a superior indicator.

S.N.	APTI value or range	Response/Degree or Level of Tolerance
1.	30-100	Tolerant
2.	17-29	Immediately tolerant
3.	1-16	Sensitive
4.	<1	Highly sensitive

The APTI integrates these parameters into a numerical value that categorizes tree species based on their pollution tolerance, helping researchers, urban planners, and environmentalists select appropriate species for urban planting and conservation efforts.

Effects of Air Pollution on Trees

Trees are highly susceptible to the effects of air pollution, which can impair their physiological processes, hinder growth, and even lead to premature mortality. Common pollutants that affect tree health include:

1. **Sulfur Dioxide (SO₂):**
SO₂ is a significant air pollutant emitted by industrial activities and transportation. When absorbed by tree foliage, it can cause direct damage to leaf tissues, leading to chlorosis, necrosis, and a reduction in photosynthetic efficiency. Prolonged exposure to SO₂ can result in reduced tree growth and vitality.
2. **Nitrogen Dioxide (NO₂):**
NO₂ contributes to the formation of ground-level ozone, which is toxic to plant tissues. Exposure to NO₂ can cause oxidative damage, leading to leaf discoloration, reduced stomatal conductance, and impaired photosynthesis. Over time, this weakens the tree, making it more vulnerable to other stresses such as diseases and pests.
3. **Particulate Matter (PM):**
Fine particles, particularly PM_{2.5} and PM₁₀, can accumulate on the surface of tree leaves, blocking stomatal pores and reducing gas exchange. This interference with photosynthesis reduces the tree's ability to absorb carbon dioxide and produce oxygen, further compromising tree health.
4. **Ozone (O₃):**
Ground-level ozone is another harmful pollutant that causes oxidative stress in trees. Ozone exposure can lead to reduced chlorophyll content, leaf injury, and stunted growth. It also increases a tree's susceptibility to secondary infections and pest attacks.

Impact of APTI on Tree Health

The APTI provides a systematic approach to identifying tree species that can thrive in polluted urban environments. Species with higher APTI values are more resistant to the damaging effects of air pollution, exhibiting better growth rates, greater photosynthetic activity, and overall enhanced health. Conversely, species with low APTI values are more vulnerable to the stresses of pollution, leading to stunted growth, leaf damage, and decreased reproductive success.

Air pollution tolerance index (APTI) is an inherent quality of plants that enables them to withstand air pollution stress. This factor has become a prime concern, especially in both industrial and non-industrial areas. Consequently, monitoring and assessing the APTI of predominant plant species in polluted and non-polluted regions is essential for understanding their resilience and role in mitigating environmental pollution.(Prabhat Kumar Rai,et al (2013))

Plants from industrial areas tend to have more acidic leaf pH due to pollutants like sulfur oxides (SO_x) and nitrogen oxides (NO_x), while those from non-industrial areas generally have neutral or slightly alkaline leaf pH. Acidic leaf pH is linked to greater sensitivity to air pollution and reduced photosynthesis, whereas a higher pH enhances tolerance. (Prabhat Kumar Rai,et al (2013))

Plants from industrial areas had higher relative water content (RWC) compared to those from non-industrial areas. Higher RWC helps plants maintain physiological balance under stress conditions like air pollution, preventing water loss and supporting normal biological functions. This suggests that plants with higher RWC are more tolerant to air pollution and drought.(Prabhat Kumar Rai,et al (2013))

Ascorbic acid is an antioxidant found in all growing plant parts, helping plants resist environmental stress, including air pollution. The leaves of plants from industrial areas had higher ascorbic acid content compared to those from non-industrial areas. This increase is linked to pollution exposure, as higher pollution levels trigger the production of reactive oxygen species (ROS), leading to a rise in ascorbic acid. Since ascorbic acid helps reduce stress, its higher concentration in industrial-area plants suggests greater tolerance to air pollution.

Chlorophyll content indicates a plant's photosynthetic activity, growth, and biomass development. It varies based on species, leaf age, pollution levels, and environmental conditions. plants from industrial areas had lower chlorophyll content compared to those from non-industrial areas. Higher pollution levels were associated with reduced chlorophyll, as certain pollutants negatively affect its production.(Prabhat Kumar Rai,et al (2013))

Role of APTI in Urban Planning and Environmental Management

Understanding the pollution tolerance of tree species through the APTI is invaluable for effective urban planning and environmental management. By selecting pollution-tolerant tree species, urban planners can create green spaces that not only offer aesthetic and recreational benefits but also contribute to mitigating the adverse effects of air pollution. These trees can act as biofilters, absorbing pollutants and improving the overall air quality. Moreover, pollution-tolerant species can help reduce urban heat island effects and enhance biodiversity in cities.

In areas with high levels of air pollution, such as industrial zones and major transportation corridors, the strategic use of pollution-tolerant species is crucial. By planting trees with high APTI values, cities can create more resilient urban ecosystems that help combat the negative impacts of pollution on human health and the environment.

Conclusion

The Air Pollution Tolerance Index (APTI) is a valuable tool for assessing the ability of tree species to withstand the harmful effects of air pollution. The index allows for the identification of species that can thrive in polluted urban environments, thereby supporting the creation of more sustainable, resilient green spaces. By incorporating pollution-tolerant trees into urban planning, cities can not only improve air quality but also enhance biodiversity, reduce environmental stress, and foster a healthier living environment for residents. As air pollution continues to pose a significant threat to both human health and the environment, the application of APTI in urban forestry is essential for developing effective strategies to address these challenges.(Saif Shahrukh, et al(2023))

Different plant species respond uniquely to air pollution, reflected in their Air Pollution Tolerance Index (APTI) values. Plants with lower APTI act as bioindicators, signaling pollution levels through visible damage, while higher APTI plants are more resistant and ideal for green belt development in urban and industrial areas.(Leela Kaur,et al (2023))

Studies show that most of plant categorize based on their tolerances or sensitivity levels to air pollutants. APTI of plants has been described with four biochemical parameters: total chlorophyll, relative water content (RWC), ascorbic acid and leaf extract pH. Pollution-induced alterations in a single parameter may not depict a clear picture of the situation. So, four biochemical parameters are considered to obtain an empirical value representing the APTI of plants (Nadgorska-Socha, et al (2017)). The progressive loss of chlorophyll and the yellowing of leaves are common indicators of air pollution, which adversely affect photosynthesis. Ascorbic acid plays a crucial role as an electron donor in the photosynthetic process. Photosynthetic activity is strongly dependent on pH (Heber U(1976)). These biochemical parameters are dependent on each other and most responsive to air pollution. Based on APTI values, low APTI plant species can be used in low pollution areas as bio-indicators, while high APTI plant species can be used in highly polluted areas to mitigate air pollution (Bharti SK,et al(2018)). By strategically planting a mix of sensitive and tolerant species, cities can both monitor air quality and reduce pollution naturally, making urban spaces healthier and more sustainable

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