Plant and Environment

https://journals.pagepal.org/index.php/PlantandEnvironement

ISSN (Online), 2788-7553; (Print), 2788-7545

https://doi.org/10.54219/2wvjjp40

Exploring the Impact of Urban Vegetation on Particulate Matter Levels and Urban Environment Enhancement

Muhammad Azeem Sabir*[*1], Muhammad Farrakh Nawaz[2], Tanveer Hussain Turabi[1], Gulam Yasin[3], Muhammad Talha Bin Yousaf[4], Muhammad Haroon U. Rashid[5], Usman Zulfiqar[6], Sadam Hussain[7], Junaid Naseer[1] and Sadaf Gul[8]

[1]Institute of Forest Sciences, The Islamia University of Bahawalpur, Pakistan.
[2]Institute of Environmental Studies, University of Karachi, Pakistan.
[3]Department of Forestry and Range Management, Bahauddin Zakariya University, Multan, Pakistan,
[4]Department of Forestry, University of Sargodha, Sargodha, Pakistan,
[5]Department of Forestry and Range Management, University of Agriculture Faisalabad, Pakistan.
[6]Department of Agronomy, Faculty of Agriculture and Environment, The Islamia University of Bahawalpur, Pakistan.
[7]College of Agronomy, Northwest A&F University, Yangling, China
[8]Department of Botany, University of Karachi, Pakistan.

Article Info

Keywords:
Heavy metals; wastewater; EC; SAR; RSC; geographical information system (GIS)

Date:
Received: 31 December 2022
Accepted: 16 May 2023
Published: 15 June 2023

Volume: 04(01)

Abstract

Atmospheric pollution is considered the world's most serious environmental health hazard by the World Health Organization (WHO). A polluted environment was estimated to be responsible for over 6 million causalities worldwide in 2016, twice as many as AIDS, tuberculosis, and malaria combined. Particulate matter (PM) is one of the major atmospheric pollutants from various sources; however, it mainly consists of suspended roadside dust particles. The size of PM depends on its sources and also on elemental composition. To reduce disease incidents worldwide, it becomes necessary to lower the levels of atmospheric pollutants. Great efforts are being made to evaluate and reduce atmospheric pollutants in urban areas. Since the late 19th century, many researchers have been ambitious to understand the nature of atmospheric pollutants and to invent tools and techniques for their mitigation. Urban vegetation acts as a good bio-monitor technique because of its capacity to intercept dust particles and absorb or retain them over time. Urban vegetation also efficiently reduces gaseous air pollutants primarily by their uptake via leaf stomata. This paper discusses the quality of air in urban areas and the significance of urban trees in reducing air pollutants, particularly particulate matter, around the globe. The mineralogical and elemental profiling of urban dust particles concerning their distribution and size have been thoroughly reviewed. Furthermore, the two-way interactions of PM with urban trees in terms of the capacity of urban vegetation to intercept PM and changes in vegetation's physiology in reaction to PM load have been described.

Introduction

The earth's atmosphere consists of various layers extending from the troposphere to the exosphere. However, biologists and environmentalists are more concerned with the quality of the lower part of the troposphere because it contains most

Contact: Muhammad Azeem Sabir azeem.sabir@iub.edu.pk

of the atmosphere's mass and serves as a direct interface among the lithosphere, hydrosphere, and stratosphere (Harikumar *et al*., 2020). The composition of the troposphere's air includes various gases; among them, some are dominant (nitrogen and oxygen), while others are present in minute (argon, water vapors, carbon dioxide) or trace amounts (hydrogen, helium, ozone, etc.) (Sharp, 2017). Along with the gases, depending upon the extent of natural events and anthropogenic activities, this air can also contain variable amounts of pollutants that can be hazardous to life on Earth (Barbulescu *et al*., 2021). These pollutants include hazardous gases (methane, sulfur oxides, ammonia, nitrogen oxides, etc.), particulate matter ($PM_{0.5}$ - PM_{10}), and dust particles. About 90% of ammonia and 80% of methane emissions globally come from agricultural activities, while 60% of sulfur oxides come from energy production and distribution (Li *et al*., 2021).

Ambient air quality standards (AAQS) have been set by the world health organization (WHO) and are accepted globally. As air-borne evaluation factors vary at different levels, several countries have developed air quality standards through environmental organizations and departments (Faridi *et al*., 2023). Optimum concentration levels of those parameters that are not harmful to living organisms are set in AAQS. When concentrations of these parameters go beyond AAQS, breathing issues are very common due to polluted air. Most AAQS-exceeding occurrences are reported globally, which can result in breathing problems and other health issues (Nazarenko *et al*., 2021).

Urban forestry is the management of vegetation, particularly trees, in urban and suburban areas (Ligtermoet *et al*., 2022). Urban forests include all trees within these areas and are often found among the high residential density of people and within an intricate fabric of natural and human-made structures and processes. Urban foresters work to sustain a healthy tree population to meet the increasingly diverse needs of urban society. Now a days, urban vegetation is famous due to the provision of micro-scale services and products such as temperature moderation, carbon sequestration, noise reduction, pollution alleviation, wood, fruit, and medicines, etc. (Nowak *et al*., 2010; Nawaz *et al*., 2018; Yasin *et al*., 2019). Urban trees positively affect air quality through filtration of polluted air, so several countries are enhancing urban trees in their plans (Zia ur Rehman *et al*., 2017; Yasin *et al*., 2020; Yousaf *et al*., 2021a). Several reviews have been published in related location sites, directing on, e.g., dust particles captured through urban trees (Chaudhary and Rathore.,2018). dry deposition on tree canopies (Nguyen *et al*., 2015), green belts, and social justice (Ramsey *et al*., 2019). Several studies have attempted in the past to calculate and estimate the socioeconomic benefits of improving atmospheric quality. However, the role of urban trees on urban atmospheric quality is not yet fully understood (Sabir *et al*., 2020).

This review paper aims to give new insights into air quality and particulate matter. Secondly, it presents the current literature on the interaction of air quality and trees in urban environments. Moreover, this paper addresses the positive relation of urban vegetation with the urban environment from two perspectives: vegetation services to remove particulate matter (PM) load and the effect of PM on urban vegetation's health.

Air particulate matter

There are four main types of air pollution sources: mobile pollution sources, such as cars, buses, airplanes, trucks, and trains. Stationary sources include power plants, oil refineries, industrial facilities, and factories. Regional sources include agricultural areas, cities, and wood-burning fireplaces (Maione *et al*., 2021), and these air pollutants can be directly released into the atmosphere (main emissions) or can be formed through the chemical interaction of precursor substances (Sicard *et al*., 2021). The pollutants generated from the emissions of automobiles normally involve suspended roadside dust, wear and tear of tires and brakes, and tailpipe exhausts (Adamiec *et al*., 2016). Many natural phenomena, including volcanic eruptions and sandstorms, release air pollutants into the atmosphere (Barbulescu *et al*., 2021). Waste, coal mining, and long-distance natural gas transportation are all sources of methane (Maione *et al*., 2021). Suspended particles, spores, ash, ocean salt, and the earth's surface are sources of particulate matter (PM) in the atmosphere (Mandal *et al*., 2023). Although they are synonyms, there is a difference between dust and particulate matter. Dust is made up of fine particles from various sources, i.e., plant pollens, fibers, and outdoor soil minerals, which can be seen with the naked eye, while particulate matter (PM) is made up of very minute solid particles, including dust or liquid droplets invisible from the naked eye (Syahmi *et al*., 2022) Moreover, PM is distinguished into different types, such as $PM_{10,}$ $PM_{2.5,}$ $PM_{1,}$ and $PM_{0.5,}$ having less than 10, 2.5, and 1.0 µm diameters (Hu *et al*., 2023). Among them, $PM_{2.5}$ majorly comes from roadside dust (Anand *et al*., 2022).

Many modern methods to configure atmospheric dust are being practiced. Evaluation of structural characteristics of air-borne dust particles has been performed by microscopic means using automated S.E.M., scanning electron microscope (S.E.M.), and optical microscope (Hildebrandt *et al*., 2022). S.E.M. attached with an energy-dispersive X-ray spectrometer (SEM-EDX) is mostly used to observe the relation of elements with particulates of different structures and particulate morphology (Ram *et al*., 2014b; Niazi *et al*., 2018). Structural determination of dust particulates on abaxial and adaxial leaf surfaces has shown the occurrence of particular little molecules, different hygroscopic particles forming little particles, and agglomerates attached to relatively bigger individual particles (Tomasevic and Anicic, 2010). The particulate size of air-borne dust varies due to elemental contamination (Fujiwara *et al*., 2011a; Niazi *et al*., 2016b). The airborne dust particulate can contain toxic substances and heavy metals like Pb, Zn, Cr, and soot (Tomasevic and Anicic, 2010) However, the adsorption of Zn, Cr, Pb, Cu, Ni, Co, or other metals with atmospheric particulate depends on their size and elemental composition (Shakoor *et al*., 2018). Studies of toxicology showed that the potential health risks of different pollutants rely on those particles' chemical properties (Fussell et al., 2022). Dust particles in the air can be polluted with different heavy metals, which can harm humans. These elements (aluminum, lead, zinc, arsenic, cadmium, nickel, or chromium) can cause the deterioration of the environment in several ways (Fang *et al*., 2006). Ratha and Sahu (1993) analyzed the composition of minerals by X-ray diffraction. They described the existence of iolite, kaolinite, and montmorillonite kinds of clay minerals in the urban soil of Mumbai, India. Avila *et al*. (1997) also reported the spread and origin of mineral elements of African dust particulates in the Montesano Mountain region in Spain. Ma *et al*. (2016) reported that the composition of minerals in urban dust changed with the proportion of particles and the origin. Erichsen *et al*. (2006) reported many clay minerals in the dust by investigating the composition of minerals of the dust from the pavement in Norway. The profiling of minerals of surface and air-borne deposited dust showed the existence of several clay minerals dominated by muscovite, quartz, and calcite, along with iron oxides (Engelbrecht et al., 2016). Fujiwara *et al*. (2011b) studied the occurrence of minerals in size classified as street dust in the capital city of Argentina and reported the existence of clay minerals. Evaluation of dust from roadside and plant canopies about the composition of minerals is considered a complementary tool to atmospheric pollution and the profiling of heavy metals. Various factors are vital in reducing the dust load and its distribution. These factors include soil topography, plant diversity and density, and physiographic and climatic factors (Kimsey *et al*., 2019).

Many incidents of exceeding levels of particulate matter (PM) from the standards of air quality have been recorded in several cities across the globe. Among Asian countries, it was discovered that only two cities have average annual concentrations of PM_{10} within limits set by WHO (20 $\mu g/m^3$), whereas other 58% of these cities have PM_{10} levels above from level of WHO Interim Target-1 of 70 $\mu g/m^3$ (CAI-Asia, 2010). Different European cities have been reported to have exceeded air quality standards such as $PM_{2.5}$, total suspended particulates (T.S.P.), black smoke (B.S.), and PM_{10} (EEA-ETC/AQ, 2001). The Ministry of Environment in New Zealand recorded high levels of PM_{10} along roads due to heavy transport in Auckland (Ministry for the Environment, 2010). Furthermore, increased pollution levels and lower air quality standards in Serbia have been identified (Serbula *et al*., 2013; Lazović et al., 2016). In central London, about 80% of PM_{10} was reportedly produced from vehicular emissions (Miller, 2010). Many cities in India have surpassed the suspended particulate matter (S.P.M.) concentrations more than the recommendations (CAI-Asia, 2010; CPCB, 1999; 2010). Laird *et al*. (2010) reported that the per annum early death rate in India is 40000 persons due to air pollution. Kolkata is also considered top of the most notorious world cities regarding air pollution (D.O.E., 2002). In a recently published report, keeping in view the dust and PM status, "Gurugram" city in the southwest of New Delhi, India, was termed as the most polluted city, whereas "Bangladesh" was the worst polluted country, followed by Pakistan, India, Afghanistan, and Mongolia (Sivalingam, 2019).

Air quality and human health

Generally, air pollutants and dust particulates linked with several contaminants like organic pollutants, heavy metals, and other harmful substances are suspected of causing harmful effects on human health (Beelen *et al*., 2008; Katanoda *et al*., 2011; Raaschou *et al*., 2011; Yousaf *et al*., 2019). Many investigations were made from 1980 to 1990 to estimate the health problems from air contaminants (Dockery and Pope, 1997; Lepeule *et al*., 2012; Masindi and Muedi, 2018). According to the United Nations report, almost six hundred million urban dwellers are directly in contact with high-pressure air pollutants (Cacciola *et al*., 2002; Yakubu, 2017). Air pollution and daily mortality show a strong correlation among them, and these facts were observed when different hospitals and emergency rooms were visited around the world (Yorifuji *et al*., 2010; Raaschou *et al*., 2011; Katanoda *et al*., 2011; Cesaroni *et al*., 2013; Heinrich *et al*., 2013; DeVries *et al*., 2017). The higher concentration of atmospheric dust and particulate PM_{10} and $PM_{2.5}$ enhances the health issues in urban area manifolds (Hoque *et al*., 2020). Some diseases like lung cancer, chronic obstructive pulmonary disease, and respiratory diseases are increasing exponentially (Cox *et al*., 2000; Miron *et al*., 2020). The most common type of cancer is lung cancer; about 1.8 million people worldwide are currently affected by it. It is also reported that 19.4% of cancer-caused deaths are due to atmospheric pollution (Ferlay *et al*., 2013; Cheng *et al*., 2022).

According to a global survey of disease occurrence (IPCC, 2003), air pollution is the deadliest among the top 10 causes of human death (IHME, 2013). Asia is at great risk of air pollution, and about seventy percent of the deaths can be attributed to atmospheric pollution. The three hundred percent increase in the death toll as reported by the Institutes for Health Metrics and Evaluation (IHME), i.e., 74 million more casualties than in 2000 (IHME, 2013). IHME reported that in 2010, in India, about 620000 before-time deaths occurred due to air pollution-related diseases, which is six times more than in 2000 (Institute for Health Metrics and Evaluation, 2013). Premature deaths are caused by air-related diseases like chronic obstructive pulmonary disease (17.32%), stroke (25.48%), lower respiratory infections (6.4%), bronchus ischemic heart disease (48.6%), and trachea (2.02%) (IHME, 2013).

Urban forestry and air quality

These trees provide uncountable and significant services to the community and provide habitat to urban wildlife (Sabir *et al*., 2021). They fight toxic wastes, dust, and noise pollution and are a source of fodder for grazing. Reducing atmospheric dust particles through urban tree interception from atmospheric enhancing quality in an urban environment (Isaifan *et al*., 2020) near roadways (Adedeji et al 2022). The nature of these particles and urban vegetation is important in deciding their relations and particle removal efficiency from the urban environment. Trees canopies, susceptible and highly exposed parts of trees, may act as persistent absorbers in a polluted environment (Piracha et al. 2022). Shrubs are more effective in reducing minute particles from an urban environment than large trees. Trees act as pollutant scouting and pollution receptors in an urban environment. The capacity of tree canopies as a pollutant receptor is normally dependent upon their surface geometry, epidermal and cuticle features, leaf pubescence, and height of trees (Nowak, 2013; Corada Perez., 2023).

Reductions in emission amounts of air particulate can be made by improving technologies but keeping in view the urban development, and it isn't easy to control the numbers of emitters. In such situations, tree canopies are the best local sinks for absorbing hazardous atmospheric pollutants (Mandal *et al*., 2023). Trees can eliminate huge amounts of pollutants from the atmosphere, so they should be included in every plan and step taken to mitigate atmospheric pollution. Many previous studies affirm that urban vegetation, especially perennials, is good for the removal of particulate matter along with pollen, dust, trace elements, spores, salt, and particles (Artaxo *et al*., 2022). Using urban vegetation to diminish air-borne particle concentration is a good alternative to road cleaning or reducing automobiles to improve air quality. Air-borne trace elements are accumulated in various plant parts and have been reported in previous studies (Ram *et al*., 2014b; Diener and Mudu, 2021). Urban vegetation minimizes atmospheric pollution in several ways, i.e., leaf absorption, deposition on leaves, and settling of particulate matter on the windward side of plants when air moves slowly (Wang *et al*., 2022). Indoor studies have also reported improving air quality by removing air particulates from plant surfaces (Han *et al*., 2022). Improvement in urban air quality has been seen by planting extra trees in cities and towns (Khan *et al*., 2022). The deposition of dust on vegetation cover showed that plant parts above the ground surface, i.e., leaves, barks, and other parts which are exposed to air, are generally good suckers in a contaminated atmosphere (Rahman & Husen 2022).

Similarly, Klugmann-Radziemska (2020), checked the dirt's ability to be deposited on tree surfaces near highways. They suggested that dust accumulation was increasing with increasing numbers of vehicles and decreasing with increased distance from that road. Bougainvillea sp. is one of the most grown shrubs in India, and it was examined to explore its capacity to deposit dirt and to be used as a bio aesthetic and dust filter on the roadside (Sharma *et al*., 2005). The Central Pollution Control Board (CPCB) also started an investigation to study the dirt-retaining ability of plants, i.e., plants, trees, and shrubs in several cities in India. There was observed variation in the dust-capturing capacity of each plant (CPCB, 2007). Kulshreshtha *et al*. (2009), investigated the pollution-controlling ability of plants regarding dirt refining and found that dust material from vehicle emissions accumulated on the leaves of roadside plants (Heikkinen, 2016). Dust absorbing capacity of plants planted along roadsides has been shown by (Ram *et al*. 2014b; Intan *et al.*, 2023). Ornamental plants can help control atmospheric pollution and be bio-indicators (Latwal *et al.*, 2023). The absorption of air pollutants by plats is a cost-effective alternative to high-end technologies (Naveen *et al.*, 2023). Trees are also used as bio-monitor and bio-indicator in urban and industrial places to calculate pollution levels and indicate the environment's quality (Kapoor and Chittora, 2017).

Quantification of particulate matter removal

The particulate matter and dust removal capacity of trees and their quantification are gaining popularity today. Several studies were designed to evaluate the reduction of atmospheric pollutants like dust and particulate matter through the canopies of the urban plantation. Urban vegetation can lower the concentrations of atmospheric NO_2, and PM_{10}, and several scientists report it (Yang *et al*., 2005; Escobedo *et al*., 2009; Rawat *et al* 2023). It was estimated that perennial woody vegetation (trees, shrubs, and bushes) in Beijing, Republic of China, reduces 1,261.4 tons of atmospheric pollutants and about 772 tons of PM_{10} removal per annum. Similarly, the reduction in atmospheric pollutants through vegetation in certain cities of the U.S. was estimated to be approximately 711000 metric tons (Anamika and Pradeep, 2016; Mandal *et al.*, 2023). Three to four percent of the removal of annual PM_{10} by plant canopies was observed in West Midlands and Glasgow (Steinhubel and Hala, 1967). Cavanagh, (2008) reported the annual 300-ton removal of atmospheric pollutants through plants in New Zealand. So, improvement of our surroundings through ornamental plants and urban plantation is an easy and cost-effective way (Petrova *et al*., 2022). Cavanagh *et al*. (2009) designed a study to check the potential of trees in sub-urban areas of Christchurch. They found the trees which are planted on the edge of the plantation absorbed more atmospheric pollutants as compared to those trees which are planted on the inner side of the plantation.

The evaluation of the reduction in the concentration of atmospheric pollutants through urban plantations in Chicago suggested that these plantations removed 888 tons of atmospheric pollutants and sequestered 25200 tons of carbon per year (Nowak *et al*., 2010; Ram *et al*., 2015). Studies by Pugh *et al*. (2012) showed the significance of urban plantations in eliminating atmospheric pollutants in different cities worldwide. Also, they reported that urban trees play a vital role in efficiently filtering urban surroundings and improving air quality on street levels. Nowak *et al*. (2013) reported an annual 4.7 tones removal of $PM_{2.5}$ by trees in various cities in the United States. These atmospheric pollutants can be deposited on the surfaces of canopies laterally and vertically.

Factors affecting particulate removal

Chaudhary and Rathore, (2018) suggested that growing trees side by side on roads can reduce particulate matter. The structure of a plant's leaves and canopies affect particulates greatly, while the roughness of the leaves' surface and the size of the stomata affect the efficiency of the plant in trapping pollutants. Leaf surface and plant fresh portion were proved to be more effective in trapping dust particles. Removal of dust particles through the leaf surface also depends on the particle's shape and size (Han *et al*., 2020). The role of the leaf surface and foliage of plants in capturing dust particles was also studied by (Weerakkody et al., 2017). Positioning of the leaf on the main axis, shape, size, and wax deposition play a vital role in the capturing of air-borne dust particles through plants. Plants' foliage can filter many solid particles because of the presence of structures like trichrome and stomata. Meravi *et al*. (2021) observed many variations in plant species according to dust interception capacity. They reported that it depends on canopy size, shape, leaf structures, and leaf surface characteristics like hair and cuticles. When winds blow, some leaves with long petioles easily move to and fro and hence cannot stick to dust for longer. On the other hand, several leaves with short petioles withstand air movements and hold more dust particles for a long time (Ram et al., 2015).

Maity *et al*., (2023) assessed the role of the shape of the canopy for dust filtration and categorized thick and thin belts. Lyu *et al*., (2023). categorized different species of trees according to their dust retention capacity under the same environmental conditions. Kwak *et al*., (2023). reported that the dust absorption ability of roadside plants varies seasonally and found that dust absorption is a cumulative process that can become lesser when washed in the rain, and further deposition increases dust concentration. Fine particles are easily buried in the surfaces of leaves; the probability of their suspension was rejected by Liu *et al*. (2012). The configuration and structure of wax on leaves are determining factors, along with the morphology of leaves. The Epicuticle wax layer and its thickness can affect the quantity of dust deposition (Kubásek *et al*., 2023). Contrasts in the aggregation of dust particles were seen among plant species generally planted in Poland, and the alterations were applied to the differences in wax qualities of several tree species (Kwak *et al*., 2023). However, several other factors, like ambient temperature, light, relative humidity, nutrient availability, and water status, also significantly affect pollution reduction.

Effect of atmospheric pollutants on plant ecophysiology

Plants become ultimate absorbers of air pollutants when exposed to air directly. However, air pollution poses stress on plants in many ways because it contains certain gaseous pollutants, such as VOCs, SO_2, and NO_2, along with particulates. Plants exhibit great diversity in modifications of physiological functioning when they encounter some extra atmospheric pollution load (Table 1). These changes include a change in antioxidant enzyme activities, damage to membrane structure, discoloration of pigments, and produced antioxidant metabolites (Table 2). However, all these changes depend upon the quantum of the particulates to which they are exposed. Vegetation acts as a bio-indicator, showing the pollution load in our surroundings. There can be two categories according to their abilities, i.e., sensitive plants (can be used as indicators) and tolerant plants (can be used as filters for air pollutants). Previous studies show that in the last three decades, a lot of work has been done on the ability of plants to bear air pollution and the effect of atmospheric pollution on plants' physiology. The role of air pollutants in damaging plant growth and productivity was greatly discussed by (Chen *et al*., 2023).

Generally, the physical and chemical properties of atmospheric pollution significantly affect plant morphology and physiology.

Farmer (1993) and Latwal *et al.,* (2023) reported that vegetation with more foliage is more susceptible to air-borne particles. Although (Bukola *et al*., 2023) showed that the high concentration of heavy metals is more toxic for vegetation than cement dust particulates, it is well reported that atmospheric pollution causes damage in plants like epinasty, chlorosis, and necrosis ((Bousbih *et al.,* 2023). The results of exposure of plants to high air pollutants can be devastating and reduce yields to greater extents (Dong & Wang, 2023). It is also reported that atmospheric pollutants negatively affect plant physiology regarding metabolic function, enzyme activity, discoloration of leaves, and reduced photosynthesis (Singh *et al*., 2023). Nihar et al., (2023), showed adverse effects like stunted growth and reduced crop yields by air pollutants. About 60% of atmospheric pollutants in metropolitan cities are due to auto vehicle emissions. Mandal *et al*., (2023) investigated the cuticle changes in tree leaves planted along the road and found that particulate pollution can change the foliar morphology of leaves and induce stress which can identify the impacts of pollution on trees. Mandal *et al*., (2023) reported that particulate matter from vehicular emissions could cause stomata closure, changes in epidermal cells, changes in trichrome, and alterations in was on leaf surfaces. Several experiments show that different physiological, morphological, and anatomical changes occurred in plants due to a polluted environment (Yin *et al*., 2023). Many research groups established that numerous biochemical changes take place in plants like less chlorophyll and carotenoid contents while increased malondialdehyde contents as a response to abiotic stress (Azeem *et al*., 2023).

Liu *et al*. (2023). analyzed that a few biochemical reactions, like reversible bleaching, reduction, and oxidation, significantly affect the number of green pigments in plants. Ebrahimi *et al*., (2023) reported that the reduction in amounts of chlorophyll a was due to its conversion into pheophytin and losses of phytol from chlorophyll b. Also reported decreased amounts of chlorophyll in plants due to chloroplast damage. Carotenoids protect plants photochemically and chlorophyll from light damage (Han *et al*., 2023). Air pollution can also affect carotenoids; their protective function will ultimately be lost, and plants will suffer (Kumar *et al*., 2023). Air pollution causes degradation in chlorophyll levels and discoloration of leaves, while chlorophyll levels indicate photosynthetic activity occurring in plants (Zoufan *et al*., 2023; Singh *et al*., 2023). With the reduction in chlorophyll content, plants having direct contact with air pollutants were seen to have increased lipid peroxidation (Pheomphun *et al*., 2019). When air is full of reactive oxygen species (R.O.S.), the most damaging process is lipid peroxidation, which can affect cells and organelles. Such huge amounts of ROS influence normal physiological and cellular functioning and increase oxidative stress by producing lipid-derived radicals (Umeno *et al*., 2017). A study showed that elements like ascorbic acid, chlorophyll, peroxidase, protein, and nitrate reductase depend on air pollution loads. Neinhuis and Barthlott (2009) observed a reduction in chlorophyll a and b of *Ficus benghalensis* and *Dalbergia sissoo* near higher pollution sites. Industrial pollution decreased 35% and 60% in chlorophyll a and b, respectively, in *Shorea robusta*, *Alstonia scholaris, Peltophorum pterocarpum, Albizia lebbeck*, *Tectona grandis*, *Lagerstroemia speciosa*, and *Delonix regia*. So, it is well documented that heavy dust/particulate load can result in leaf injury and stomata blocking, resulting in reduced photosynthesis and stunted growth, as described in Figure 1.

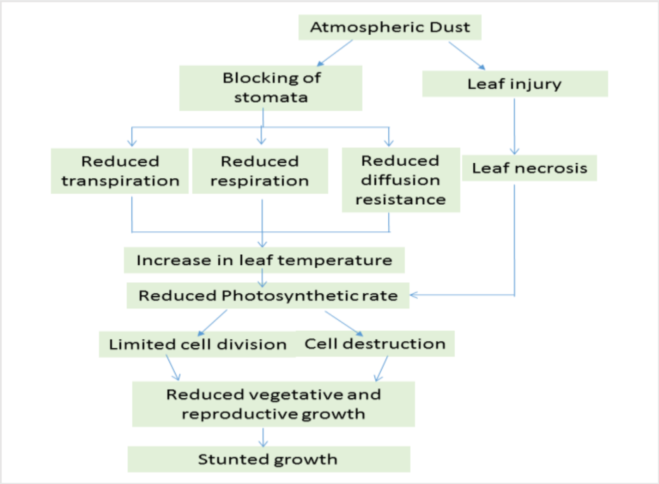

Fig. 1. A conceptual diagram of plant growth against atmospheric dust.

Air pollution tolerance index of urban vegetation

The air pollution tolerance index (APTI) is a tool to evaluate the tree's response to atmospheric pollution. APTI indicates plant species' tolerance rate when exposed to atmospheric pollution (Molnár *et al*., 2020). The same plants having resistance to some parameters of pollution in the atmosphere can be sensitive to other parameters in the same atmospheric conditions (Bera *et al*., 2021). Simply, only one factor cannot make a clear judgment about the tolerance rates of trees against atmospheric pollutants. To evaluate APTI, several important factors, such as total chlorophyll content, pH of leaf extract, ascorbic acid (AA), and relative water content, are equally important. These parameters have been used to calculate the APTI in previous studies (Uka *et al*., 2017). Evaluation of APTI in trees vulnerable to atmospheric pollutants has been studied, and several plants were classified as sensitive and tolerant to a certain type of pollution (Sahu *et al*., 2020). So, vulnerable trees can be grown as bio-indicators of atmospheric pollution, while other tolerant species can be grown for greenery in cities (Irshad *et al*., 2020). Many other studies suggested that the most tolerant species, such as *C. procera* and *A. pungens* could be grown in the locality of pollution sources as a sink for pollution (Chowdhury *et al.*, 2007).

Recommendations for establishing particulate targeting green belts

Previous studies suggest that several trees (*Eucalyptus camaldulensis*, *Pinus halepensis*, and *Ceratonia siliqua*) can play a significant role in ameliorating the urban environment while creating buffer zones. Various poisons, such as weedicides, herbicides, pesticides, nematicides, insecticides, and fungicides, applied in agricultural fields adjacent to urban areas, were found in farm and forest crops, signifying an important service of the urban trees. Including trees on farmland with crops, gardens, and orchids linked with residential areas in the form of a compact wall would be better for reducing atmospheric particulates like air-borne dust and toxic substances. Furthermore, these trees will play a vital role in removing leaching fertilizer and pesticides which can cause important health issues (Zaady *et al*., 2018).

To lower atmospheric pollution, efforts have not yet started, and these strategies must include reducing emission levels and installing absorbers like trees in close vicinities of the contaminated regions. Instead of focusing on the capacity of urban trees to overcome atmospheric pollution, street trees should also be the main priority to reduce air pollution. Tree species with good genetic makeup needed for effective dirt adsorption should be preferred for vegetation in green belts of urban areas. It is recommended that regions of greenery must be situated at high altitude zones and should not be randomized (Morani *et al*., 2011; Cuiyun and Chazhong, 2020). The planting location can be determined using index values considering three main factors: little canopy cover, pollution concentration, and population (Morani *et al*., 2011). The septic mixture of wind velocity, plant species, wind direction, canyon geometry, and canopy volume should be considered scientifically through model-based studies (Pugh *et al*., 2012). Using urban vegetation as pollution control and monitoring sources is effective and eco-friendly. In the future, the Air pollution tolerance index (APTI) tool can be used for planning and managing urban vegetation (Molnár et al., 2020). Several tree species having high dirt accumulation ratio are *Koelreuteriapaniculata*, *Ulmuspumila*, *Syringaoblata*, *Malusmicromalu*, *Weigelaflorida*, *Magnolia denudate*, *Ailanthus altissima*, *Salix babylonica*, *Robiniapseudoacacia*, *Ligustrum victory*, *Euonymus japonicus*, *Prunuscerasifera f. atropurpurea*, recommended to be used in future green belt planning (Liu *et al*., 2017).

CONCLUSION

Atmospheric pollution is one of the major causes of deterioration of air quality in urban areas of the world, ultimately, posing a great health threat to urban dwellers. Recent reports highlight a great correlation between high levels of air-borne pollutants and early mortality in humans, especially in South Asian countries. Air pollutants, particularly particulate matter termed PM_1, $PM_{2.5,}$ and dust particles, are very injurious to health and are largely involved in respiratory diseases, including lung cancer. Urban vegetation plays a vital role in purifying the environment by removing dust particulates, absorbing different toxic gases, and reducing carbon dioxide sequestration. It is the most efficient and cost-effective way of controlling atmospheric pollutants in the modern world. Several vegetation structural factors such as leaf surface area, leaf size, leaf arrangements, etc., and air pollution tolerance capability of different vegetation species are important factors in determining urban vegetation's particulate matter removal potential. Heavy air-borne pollutant load can hinder urban vegetation's physiological functioning and growth, so it is important to consider the air pollution tolerance index (APTI) of different plant species before devising re-vegetation plans for urban areas.

Acknowledgment: We highly acknowledge the funds provided by the Higher Education Commission (HEC), Pakistan, under the NRPU program with project reference number 3897.

Conflict of Interest: All authors express no conflict of interest in any part of the research.

Funding: The funds are provided by the Higher Education Commission (HEC), Pakistan.

Authors Contributions: Conceptualization, M.A.S., M.F.N., and U.Z; methodology, B.M.B, and G.Y.; software, T.H.K., and M.T.B.Y., validation and formal analysis, M.H.R., T.H.K., J.N., and S.H.; resources, M.F.N.; data curation, M.A.S, G.Y., and U.Z.; writing original draft preparation, M.A.S., and U.Z., writing review and editing, M.F.N., S.H., T.H.K., supervision, B.M.B All authors have read and agreed to the published version of the manuscript.

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Contact: Muhammad Azeem Sabir azeem.sabir@iub.edu.pk

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Table 1. The effect of dust on the growth response of vegetation (grasses, shrubs, and trees).

Species	Effect	Source
Beta vulgaris	No starch production	Czaja (1961)
Zea mays	Reduced vegetative and reproductive growth	Farrell *et al*. (2018)
Mangifera indica	Fruit set and leaf lesions	Rao (1971)
Pisum sativum	Increased water loss	Manes *et al*. (2016)
Ficus religiosa	Reduced leaf area index	Meusel *et al*. (2013)
Quercus petraea	Chlorophyll degradation	Williams (1974); Janhall (2015)
Abies alba	Reduced growth	Fluckiger (1987);
Populous nigra	Increased leaf temperature	Gateau-Rey *et al*. (2018)
Pinus sylvestris	Leaf injury	Bohne (1963)
Taxus baccata	Cell destruction	Czaja (1962); Acheampong *et al*. (2019)
Citrus authantium	Increased necrosis	Parish (1910)

Table 2. The effect of atmospheric gas pollutants on plant functioning

Gases	Vegetation type	Effect	Source
SO_2	Broad-leaved plants	Destruction of epidermal cells and interveinal necrosis	Legge and Krupa (2002)
NO_2	Camphor tree	Increase stomatal conductance	Natori and Totsuka (1984) De Almeida *et al*. (2016)
SO_2 and NO_2	Broad bean	Chronic injury and yield reduction	Taylor *et al*. (1987)
O_3	Soybean	Necrotic lesions and chlorosis	Nowak *et al*. (2014)