PHYTOREMEDIATION OF OUTDOOR AIR: A REVIEW

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Abstract

For the purpose of improving a country's economy, urbanization, industrialization, and technical advancement all had detrimental environmental effects. One of the most serious consequences of the aforementioned phenomenon is air pollution. Various air pollutants emitted by natural and anthropogenic sources have been found to have negative effects on the environment and human health after prolonged exposure. Insufficient technologies are used to reduce air pollution as a result of problems in the industry sector, including high maintenance costs, machine failure, and expensive technical equipment. Technological innovations like phytoremediation, which is sustainable and friendly to the environment, are being used to improve outdoor air quality. Cost efficiency, convenience of *in-situ* application, eco-friendly treatment, and the ability to improve the aesthetic value of the nearby environment are advantages of phytoremediation over other conventional remediation approaches. Numerous studies in the field of the outdoor air phytoremediation have found highly beneficial results, but also challenges in applying the suggested method. Plant tolerance to pollutants, environmental parameters, plant-specific features, composition of air pollutants, uncertainty in plant-microbe interactions, and plant antagonism have all emerged as a result of the use of plants in outdoor air pollution remediation. To become a complementary or alternative tool for engineering-based remediation methods, the remedy process must be optimized with supplementary treatments or the best combination junction with other methods must be found.

Key words: *air pollution, phytoremediation, sustanaible outdoor air pollution remediation technique*

Introduction

Urbanization, industrialization, and technological advancement for the purpose of expanding a nation's economy all had unfavorable environmental consequences. By 2050, 68 % of the world's population, up from more than 55 % today, is anticipated to reside in urban areas [1]. The most essential element for live organisms to survive and function, air, is excessively polluted due to the global urbanization. Although there are some natural sources of air pollution, such as volcanic eruptions, wind-blown dust, and forest fires, the majority of pollution is caused by anthropogenic sources such as industrial processes, fossil fuel combustion, waste treatment, construction, and agricultural activity. Chemical complexes used in pesticides, insecticides, fungicides, household cleaning materials, fabrics, paints, sofas, and other products, are another major cause of air pollution [2]. In addition to comprehending how air pollutants are produced, it is essential to know how they are transported and how they interact with the environment. Gaseous contaminants have the ability to travel great distances and harm species in areas further downstream. The production of secondary air contaminants during this trans-boundary transit also had an impact on the aerosol size distribution [3]. Common pollutants with anthropogenic origins include particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), potential toxic elements (PTEs), sulfur dioxide (SO_2), and secondary pollutants like ozone (O_3). However, natural air pollutants like radon and biogenic volatile organic compounds (BVOCs) are abundant [2]. People are exposed to approximately 200 different air pollutants in anthropo-ecosystems, some of which can impact citizens' life quality and well-being by increasing respiratory and cardiovascular diseases and mortality. With 400,000 cases per year in Europe, air pollution has been identified as the single greatest environmental health risk, leading to approximately 4.2 million premature deaths annually [3]. Climate change is also one of the consequences of air pollution. The combined effects of air pollution and climate change reduce future ecosystem productivity and water availability [3]. Anthropogenic emissions should be eradicated, prevented, or minimized in accordance with regulations. Following the prevention of pollutant emissions at the source, science-based methods are required to treat existing air pollutants. As a result, the development of technologies to remove/reduce air pollution has arisen as a key concern for the worldwide community.

Conventional air pollution remediation techniques

Air pollution abatement strategies must be implemented in order to reduce the air pollution. Air pollutants are controlled at the source through various policies and laws that require polluters to reduce their emissions. To reduce the impact of air pollution, emission control systems and air remediation technologies such as incineration, filtration, adsorption, photocatalysis, ozonation, ionization, electromagnetic precipitation, and wet scrubbers are used [3]. Nature-based solutions are becoming more popular means of reducing air pollution (NBS). NBS for dealing with atmospheric pollution allude to plants ability to absorb and catabolize practically any of airborne contaminants, as well as efficient pollutant deposition onto vegetation rather than artificial surfaces [1]. Furthermore, new environmentally friendly and sustainable technologies, such as phytoremediation, are being implemented. The benefits of phytoremediation over other conventional remediation technologies include cost effectiveness, ease of *in-situ* use, eco-friendly treatment, and the ability to raise the aesthetic value of the immediate environment. Additionally, phytoremediation can be used to long-term remediation of a wide spectrum of environmental contaminants.

Phytoremediation: sustanaible air pollution remediation technique

Phytoremediation is a relatively recent approach based on engineered application of plant species for the elimination of hazardous compounds through processes such as separation, accumulation, and stabilization [4,5,6,7]. The applied plant species root system and the absorption process that takes place there play a key part in the phytoremediation procedure. Polluting substances and water are separated from the treated matrix via absorption, after which the degradation process begins. Water movement through the plant is encouraged by evapotranspiration, which occurs above ground. Microbes inhabit plant roots (rhizosphere) and shoots or above-ground organs (phyllosphere) as heterotrophs. Microbes can help plants withstand abiotic and biotic challenges by absorbing nutrients and water and creating plant hormones, inhibitory allelochemicals, and siderophores [3]. Phytoremediation is a process that includes seven approaches: phytoextraction, phytovolatilization, phytodegradation, phytostabilization, rhizodegradation, rhizofiltration, and hydraulic control [3]. The surface of leaves and stems is known to adsorb considerable amounts of contaminants in the case of air pollution. Phyllosphere microbiome, which inhabit these surfaces, may therefore be of paramount relevance. Because some of the absorbed pollution makes its way into the plant, leaf endophytes are of a particular importance. By degrading, transforming, or sequestering contaminants, these phyllospheric and endophytic microbiome can detoxify a portion of contaminants. Rainfall also results in pollutants pouring down to the soil just beneath the plant, where they come into touch with the soil, the rhizosphere, and the roots of the plant [3].

Using phytoremediation to improve outdoor air quality

An overview of phytoremediation for improving outdoor air quality is provided in **Table 2.**

Table 2. Enhancing outdoor air quality with phytoremediation

Location	Pollutants	Observations/Suggested Measures	References
Tabriz, Iran	O_3, SO_2, NO_2, CO, $PM_{2.5}$	In 2015, shrubs and trees removed 238.4 t of air contaminants, and an increase of the elimination up to 814.46 t over the next 20 years is expected if appropriate, feasible urban forest management is performed.	[8]
North Katowice, Poland	PM	Among vines, shrubs, and coniferous trees, *Parthenocissus quiquefolia* and *Betula pendula* 'Youngii' accumulated the highest amounts of PM in their wax. The accumulated PM contained carbon, oxygen, silicon, iron, and heavy metals.	[9]
Fifteen different urbanized areas in Sydney, Australia	PM	The leaf traits were not the specific factor to determine the deposition capacities of plants. Among investigated plants, *N. glabra*, *C. comosum variegatum*, *P. Xanadu*, and *S. wallisii* entrapped the most amount of PM.	[10]
Surabaya town, Indonesia	Lead (Pb)	*Wedelia trilobata* and *Syzigium olein* are grown on the main roads and exposed to heavy metals. *Wedelia trilobata*, having wider leaves, absorbed more heavy metals than *Syzigium oleina* showing a smaller leaf surface area.	[11]
Beijing Forestry University, Beijing, China	$PM_{2.5}$	Compared to broadleaved plant species, needle-leaved coniferous species accumulated higher amounts of $PM_{2.5}$. The $PM_{2.5}$ removal capacity of broadleaved species was correlated to the number of grooves and trichomes.	[12]
Hanoi, Vietnam	PM	Leaves with a lower area, hydrophilic traits, and a high abaxial stomatal density entrapped more PM; accordingly, *Muntingia calabura* showed the highest PM removal capacity among 49 screened plant species.	[13]
Birmingham New Street railway, United Kingdom	PM_1, $PM_{2.5}$, PM_{10}	*Hebe albicans Cockayne*, *Hebe x youngii Metcalf*, *Buxus sempervirens* L., and *Thymus vulgaris* L., which have small leaves, revealed the highest PM removal capacity. Leaves with adaxial surfaces showed higher PM densities compared to those with abaxial surfaces.	[14]

Kunming City, Southwest China	PM	*Platanus acerifolia* and *Magnolia grandiflora* showed the highest PM removal among deciduous and evergreen trees, respectively. PM entrap capacity depends not only on the leaf characteristics, but also on the pollution grade; *Loropetalum chinense*, *Osmanthus fragrans*, and *Cinnamomum japonicum* exhibited significant accumulation of PM in traffic and university campus areas, whereas showing moderate removal efficacy in an industrial area.	[15]
Trivandrum City, Kerala, India	Air Pollution Tolerance Indices (APTI)	Based on APTI, plants showing the highest APTI, *Agave americana*, *Anacardium occidentale*, *Cassia fistula*, *Cassia roxburghii*, *Mangifera indica*, and *Saraca asoca*, were suggested for near areas presenting heavy vehicular air pollution, and plants showing the next highest APTI for greenbelts.	[16]

Conclusion

Controlling air pollution is far more difficult than controlling soil and water pollution, and new inventive ideas and approaches are necessary to meet this requirement. Nevertheless, air quality can be enhanced by phytoremediation, which incorporates plants and their microbiomes. Because of its substantial advantages, such as being eco-friendly, cost-effective, and having publically applicable procedures, phytoremediation is an emerging prospective tool for improving *in-situ* air conditions. Phytoremediation has been shown to reduce the effects of numerous air pollutants and to cause minimum environmental disruption in treatment areas, but the removal efficacy of phytoremediation is still being studied. Because of the use of plants in outdoor air pollution remediation, the following issues have emerged: *plant tolerance to pollutants*, *environmental parameters* (wind, precipitation, temperature, pH, solar intensity, water availability), *plant-specific features* (surface roughness, thickness, ultrastructure, pubescence, wax content, leaf size, and structure), *composition of air pollutants*, *uncertainty in plant-microbe interactions*, and *plant antagonism*. These characteristics provide obstacles in phytoremediation methods and should be taken into account when developing an effective phytoremediation approach for outdoor air pollution. The techniques applicability in highly polluted air has not been clearly demonstrated. Optimizing the remedy process with supplementary treatments or finding the best combination junction with other methods is required to become a complementary or alternative tool for engineering-based remediation methods.

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