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# Phytoremediation: Harnessing Plants for Cleaner Indoor and Outdoor Air

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***Abstract:***

*Human health is significantly affected by both outdoor and indoor air pollution. Outdoor and indoor pollutants such as particulate matter (PM ), sulfur dioxide ($SO^2$), nitrogen oxides (NOX), carbon monoxide (CO),Volatile organic compounds such as xylene, toluene, formaldehyde, benzene and Poly aromatic hydrocarbons (PAHs) etc. are responsible for heart disease, stroke, chronic obstructive pulmonary disease, lung cancer, acute respiratory infections and neurological impairments etc. that leads to about 7 million premature deaths every year. Phytoremediation is one of the sustainable solutions to tackle with such problems as well as an effective and eco-friendly approach. Phytoremediation technology utilizes plants to improve air quality and reduce health hazards by absorbing, filtration, and degradation of pollutants. Outdoor Pants like neem (Azadirachta indica), white gum (Eucalyptus criminals), black poplar (Populus nigra), black Locust (Robinia pseudoacacia) and peepal (Ficus religiosa) etc. effectively absorb toxins and particulate matter, similarly indoor plants like - spider plant (Chlorophytum comosum), peace lily (Spathiphyllum), and snake plant (Sansevieria trifasciata) etc. also remove a wide range of indoor air pollutants like- formaldehyde, benzene, and carbon monoxide, enhancing air quality. This paper explores the health effects of various pollutants and the role of different outdoor and indoor plants in phytoremediation. Promoting the use of these plants can provide a natural and sustainable way to combat pollution and create healthier living environments.*

***Keywords****:*

*Air pollution, health effects, phytoremediation, outdoor and indoor plants*

## Introduction

The Rising Air Quality Index (AQI) is a burning issue in today's era; AQI is an indicator to measure the level of pollution in the air. Pollution is the introduction of harmful materials into the environment due to rapid industrialization, urbanization and modernization. The harmful materials that are responsible for pollution are called Pollutants. Outdoor AQI considers various pollutants like particulate matter (PM), nitrogen dioxide (NO2), sulfur dioxide (SO2), carbon monoxide (CO) and ozone. Indoor AQI although less standardized, generally takes into account different pollutants like Volatile Organic Compounds (VOCs) like- formaldehyde, toluene, benzene, xylene etc., carbon monoxide (CO) and mold. The various sources of indoor pollution and outdoor pollution are shown in Fig. 1 . Indoor pollution sources include Combustion (burning of fuels like kerosene, wood or coal in furnaces, stoves and fireplaces for heating homes), Building Materials (like paints, adhesives and some flooring materials release VOCs etc.), Household Products includes fresheners, paints and personal care items (Nail paint, nail paint remover and deodorant etc.), Dusting, Smoking, Perfume and Painting etc. and sources of outdoor pollution are Automobiles, Forest fire, Transportation, Volcanic Eruption, Industrial Activities, Fuel burning, Agricultural Practices etc.

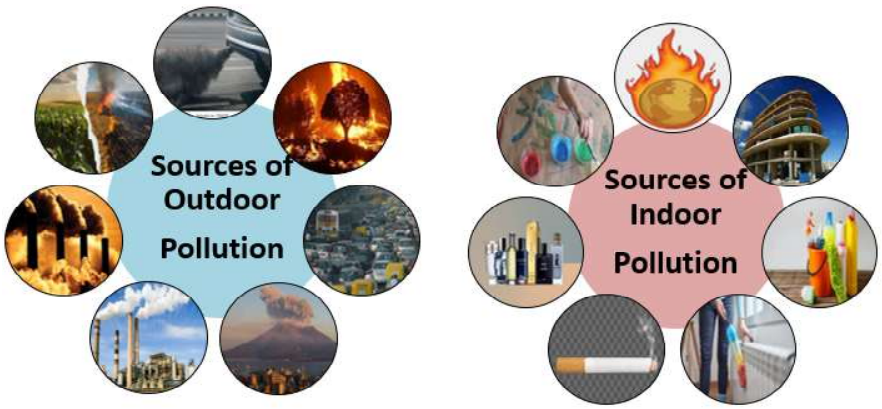


**Fig. 1. The various sources of indoor pollution and outdoor pollution.**

Pollution is a major threat to the ecosystem and imposes a negative impact on all living organisms. Both indoor and outdoor air pollutants, such as carbon monoxide (CO), nitrogen oxides (NOx), sulfur dioxide (SO, ), and volatile organic compounds (VOCs) etc. cause significant health risks to humans. Prolonged exposure to VOCs and NOx increases the risk of cancer (González-Ruíz *et al* 2023) while SO, and CO can cause respiratory problems, headaches, and even cardiovascular issues (Septian *et al* 2024, Garg *et al* 2018).

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Indoor pollutants, often trapped in enclosed spaces, lead to eye irritation, throat discomfort, and breathing difficulties. Outdoor pollution, especially in urban areas, deteriorates air quality, contributing to smog and intensifying conditions like asthma and bronchitis. Sources and effects of outdoor and indoor pollutants are shown in Table 1. & Table 2.

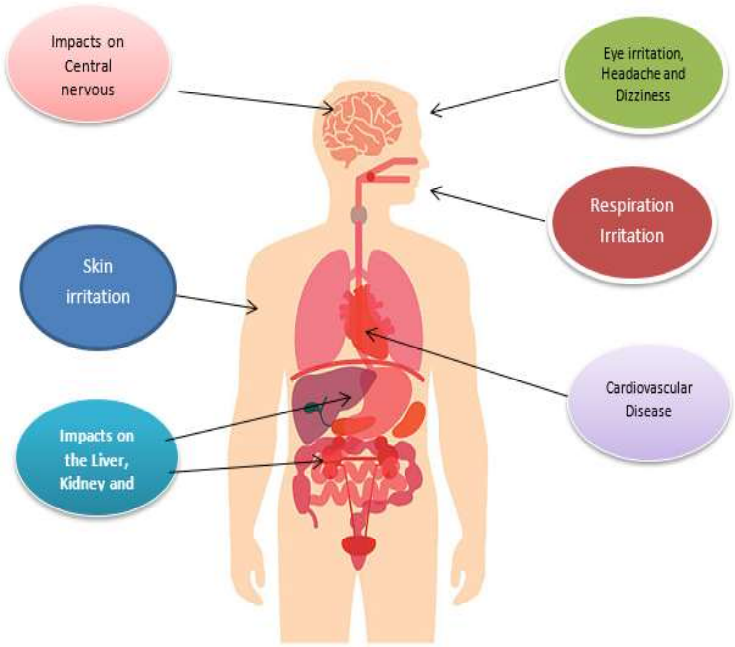
**Table 1. Emission sources and effect of outdoor pollutants on Human Health**

| OUTDOOR POLLUTANTS | | |
|---|---|---|
| **AIR POLLUTANTS** | **EMISSION SOURCES** | **EFFECTS ON HUMAN HEALTH** |
| Ozone | Harmful industrial chemicals, Fuel burning | Respiratory irritant, eye irritant |
| Nitrogen Oxide | Vehicles, Power plants, Fuel burning | Damage to lung, respiratory problem |
| Particulate Matter | Construction sites, Fires | Cardiovascular disease |
| Carbon Monoxide | Fossil fuel burning , heavy machinery | Cardiovascular damages |
| Sulfur Dioxide | Fuel-burning , Power plants , Vehicles | Respiratory problem, eye irritation |
| Lead | Industrial activities, Leaded petrol | CNS, eye irritation |

**Table 2. Emission sources and effect of outdoor pollutants on Human Health**

| INDOOR AIR POLLUTANTS | | |
|---|---|---|
| **AIR POLLUTANTS** | **EMISSIONS SOURCES** | **EFFECTS ON HUMAN HEALTH** |
| Carbon Monoxide | Combustion of wood, Natural gas, Kerosene, Tobacco | Headaches and Dizziness |
| Nitrogen Dioxide | Burning fuels | Respiratory problem |
| Radon | From bedrock through cracks and holes in the foundation and building material (granite) | Lung Cancer |
| Volatile Organic Compound | Paints, cleaning products , building materials, furniture | Respiratory Irritation |
| Biological Pollutants | Plants, Bacteria, Viruses | Allergic Reaction, Respiratory Disease |
| Particulate Matter | Cooking , Combustion activities Tobacco smoke | Respiratory issues, Cardiovascular problems, Risk of cancer |
| Pesticides | Contaminated Soil , Dust | Skin irritation, Neurological problems and Headache |
| Lead | Paint, Dust | Kidney problem , Cardiovascular problem |

**Fig.2. Effects of Outdoor and Indoor Air Pollutants on Human Health**




**Phytoremediation**

Various models and techniques have been proposed to reduce air pollution. Among them phytoremediation is one of the methods that help to remove toxic pollutants from air, soil and water using Plants. One of the best practices of phytoremediation is that it can treat a wide range of pollutants at a time. Moreover it is cost effective as compared to physic-chemical or mechanical methods. Phytoremediation is an emerging technology that uses living plants to remove, degrade or contain environmental contaminants such as heavy metals, pesticides , solvents etc. It works through different plant-dependent mechanisms on the basis of different types and concentrations of contamination .The types of phytoremediation are mentioned below (Dwivedi et. al. 2022) :-

**1. Phytoextraction:-** Plants absorb contaminants , particularly heavy metals through their roots and transport them to store them in their tissues . This method utilizes hyperaccumulator plants to absorb pollutants e.g. *Phytolacca American* and *Salix Schwerin* (Ramzan 2024).

**2. Phytostablization**:-Plants absorb the pollutants by lignin of cell walls and prevent their movement by stabilizing them within the soil and reducing the availability of

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these pollutants for uptake by other plants, few plants that help in this process are *Juncus effuses* and *Carpobrotus equilateral.*

**3. Phytodegradation-** A process where pollutants from environment are incorporated into plant tissues, further metabolized by various enzymes like dehalogenases, laccase and nitroreductase secreted by plant roots like *Blumea Malcolm* and *Spirodela polyrhiza* (Bharathiraja *et al* 2018), that break down organic chemicals which are then absorbed and expelled through transpiration .

**4. Rhizofiltration**:- This technique is used to eliminating hazardous substances and excess nutrients from water by filtering it through roots . This process is commonly used to clean up contaminated groundwater by either planting directly in the contaminated area or transporting contaminated water to the plants e.g. *Helianthus annuus* and *Phaseolus vulgaris* (Lee & Yang 2010)

**5. Phytovolatilization**:- Plants take up pollutants and convert them into less harmful forms of volatile compounds e.g. *Arundo donax* (Guarin 2020) There are some more indoor and outdoor plants as mentioned in Table 3 and Table 4. that help in phytoremediation.

**Table 3. Phytoremediation of indoor pollutants-**

| INDOOR PLANTS THAT ARE RESPONSIBLE FOR PHYTOREMEDIATION | | | |
|---|---|---|---|
| **BOTANICAL NAME** | **COMMON NAME** | **POLLUTANT ABSORBED** | **REFERENCES** |
| 1. Chlorophytum comosum | Spider plant | Formaldehyde | Chuenko et al 2023 |
| 2. Sansevieria trifasciata | Snake Plant | Toluene, xylene | Sriprapat et al 2014 |
| 3. Spathiphyllum | Peace lilies | Benzene | Li et al 2024 |
| 4. Syngonium podophyllum | Arrowhead Vine | Benzene | Sriprapat & Strand, S. E. 2016 |
| 5. Epipremnum aureum | Money Plant | Formaldehyde | Zuo et al 2022 |
| 6. Euphorbia milli | Crown of Thorns | Benzene, Formaldehyde | Siswanto 2017 |
| 7. Fittonia verschaffeltii | Mosaic Plant | Toluene | Zhang et al 2013 |
| 8. Hoya carnosa | Wax Plant | Toluene | Zhang et al 2013 |
| 9. Dracaena deremensis | Corn Plant | Benzene | Mosaddegh et al 2014 |
| 10. Clitoria ternatea | Butterfly Pea | Benzene | Sa et al 2024 |
| 11. Hedera helix | Common ivy | Benzene | Fooladi |

**Table 4. Phytoremediation of outdoor pollutants-**

| OUTDOOR PLANTS THAT ARE RESPONSIBLE FOR PHYTOREMEDIATION | | | |
|---|---|---|---|
| **BOTANICAL NAME** | **COMMON NAME** | **POLLUTANT ABSORBED** | **REFERENCES** |
| 1. Mangifera indica | Mango | PM, $SO_2$ | Priyanka et al 2012 |
| 2. Azadirachta indica | Neem | PM, $CO_2$ & No | Prasad et al 2018 |
| 3. Ficus bengalensis | Banyan Tree | PM,$CO_2$ | Joshi et al 2020 |
| 4. Robinia pseudoacacia | Black Locust. | NO2 | Maheshwari et al 2022 |
| 5. Eucalyptus viminalis | White Gum | NO2 | Maheshwari et al 2022 |
| 6. Glycine Max | Soyabean | Formaldehyde | Giese et al 1994 |
| 7. Helianthus annus | Sunflower | Benzene | Almeida et al 2018 |
| 8. Hibiscus rosa sinensis | China Rose | PM | Maheshwari et al 2022 |
| 9. Zamioculcas zamiifolia | Aroid Palm | VOCs | Maheshwari et al 2022 |
| 10. Populus niger | Black Poplar | NO2 | Maheshwari et al 2022 |

## Conclusion

So, there are many plants (outdoor and indoor) that help to reduce pollution by different ways of phytoremediation. The selection of plants to reduce pollution depends on how and which pollutant they are able to absorb and detoxify them at cellular and molecular levels. Phytoremediation is cost cost-effective and eco-friendly method for removing pollutants from the environment. This paper summarized the different types of outdoor and indoor pollutants, their sources of emission and effects on human health, also different types of plants used for phytoremediation.

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