
Role of Plants in Indoor Air Remediation

Parul Chauhan,

Jaypee Institute of Information Technology, Noida

Mahender Singh Rawat,

Jaypee Institute of Information Technology, Noida

Pammi Gauba*

Department of Biotechnology, Jaypee Institute of Information Technology, Noida

*Corresponding Author

ABSTRACT

The increase in pollution everywhere, due to increase in urbanisation and industrialisation, attracts the major concern of all the authority and the people at global level look forward to find out the way to resolve it. Pollutants are the substances that cause pollution and that affect the environment. Though the efforts were to control air pollution have traditionally focused on the outdoor air, it is now apparent that high concentrations of contaminants are common inside most private and public buildings (indoor air). The concerns about public health problems increase here due to indoor air pollution and are based on the fact that states, urban residents usually spend more than 90 percent of their time indoors, and the concentrations of some contaminants are higher in indoors than outdoors, and some of the pollutants personal exposures are not characterized effectively by outdoor measurements. This review is mainly focusing on the indoor air pollution its categories, sources and remediation by the use of some of the listed indoor plant.

KEYWORDS: *Pollution; pollutants; Remediation; Indoor&Outdoor; Plants.*

INTRODUCTION

Environment has become the biggest concern of the society and now the concern for its conservation and protection is increasing among the people all over the world. The biggest problem is that there are various kind of pollution including air, water, soil, noise, radioactive, geothermal, light, visual, space, personal pollution etc. Studies are going on each of them and measures are being taken to reduce them [1]. The primarily focus in this article is on indoor air pollution, and its types, its effects on health & environment, and how to reduce it. Air pollution is defined as presence of any undesirable component in the air (indoor/outdoor) that deteriorates its

quality and disturbs its natural composition and chemistry [2].

Whenever we come across air pollution; the causes that come to our mind are vehicle or manufacturing exhaust, volcanic eruption, forest fires, burning fossil fuels, dry soil erosion, etc. These all are air pollutants causing outdoor pollution. We never think of indoor pollutants and indoor air pollution [3]. Indoor air quality is of great importance since it has an effect on human health especially in developing countries where people spend 90% of their time indoors. It has been reported that indoor air is 12 times more polluted than the outdoor air [4]. Indoor air pollutants primarily originate from building products, emission, human activities inside the building and infiltration of outdoor air and have increased as a result of lower gas exchange rates of newer, more energy-efficient buildings [5]. The main indoor pollutants are: carbon monoxide, particulate matter, nitrogen oxides, Sulphur oxides, arsenic, fluorine, volatile and semi-volatile organic compounds, ozone, radon, Trichloroethene (TCE), hydrocarbons, lead, asbestos, aldehydes, etc. Exposure to such pollutants can cause various kinds of acute and chronic illness including various pulmonary, cardiac, neurological, reproductive, developmental disorders and diseases and in some cases may even lead to cancer [6].

TYPES OF INDOOR AIR POLLUTION

Air pollution has a drastic impact in developing countries because here, wood, charcoal and animal dung are still used for cooking and heating purposes. In developing countries people rarely use proper ventilation condition in their houses and

ended up breathing many harmful gases and contaminants.

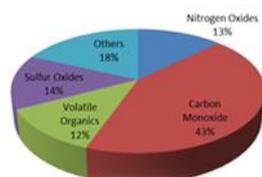


FIGURE 1. Types of gases and their amount present in outdoor air pollution[9,10].

Every year about 3 million people die prematurely due to indoor air pollution.([6].In some cases indoor air pollution sources are unknown that causes health issues that is because of sick building

syndrome([7]. According to WHO report Sick Building Syndrome (SBS) describes as the medical condition where people in a building suffer from symptoms of illness or feel unwell for no apparent reason. SBS increases with the time people spend in the building which also affect their work performance and personnel relationships [8].

There are number of indoor air pollutants and have various sources from where they originate in houses and office buildings, some pollutants can be drawn from outdoor sources, hence all these pollutants get trapped and accumulates indoor [10].Table 1 shows the different types of pollutants, their sources and effects on human health

Table 1: Various indoor pollutants, their sources and effects on human health.

Sr. No	Name of pollutant	Sources	Effects	References
1.	Carbon monoxide	Fuel ,tobacco combustion	Interferes with the blood's ability to carry oxygen to the brain, heart and other tissues. Also headaches, fatigue and reduced reflexes due to CO exposure.	[11]
2.	Particulate Matter	Fuel, Tobacco combustion, cleaning, fumes from cooking oils.	Increases Personal Discomfort. Various Lung and Cardiovascular Disorders.	[12]
3	Nitrogen oxides	Fuel combustion	Increased Susceptibility to infections, pulmonary diseases, impairment of lung function, and irritation in eyes, nose and throat.	[13]
4.	Sulphur Oxides	Coal combustion	Impairs lung functions adversely.	[13]
5.	Arsenic and fluorine	Coal combustion	Diarrhea, Numbness, Skin lesions, Hyperkeratosis, Muscle cramping and Death.	[14]
6.	Volatile and semi-volatile organic compounds	Fuel/Tobacco combustion, furnishing construction material, fumes from cooking, consumer products.	Toxic and Carcinogenic Effects.	[10]
7.	Aldehydes	Furnishing, Construction materials, Cooking.	Cancer, Decreases Immunity, Breathing Problems, Headache.	[10]
8.	Pesticides	Consumer products, Dust from outside.	Malignant Tumor, Genetic changes, blood and nerve disorders, Endocrine Disruption, Reproductive effects.	[15]
9.	Asbestos	Wear or demolition of construction materials.	Mesothelioma(lung cancer),cancer of kidney ,brain, urinary bladder gall bladder throat voice box etc.	[16]
10.	Lead	Wear of painted surfaces.	Attack on brain and central nervous system to cause coma.	[12]
11.	Biological pollutants	Moist areas, ventilation systems, furnishings.	May causes allergy. Hypersensitive situation occur.	[10]
12.	Radon	Soil under buildings, Construction materials.	Cancer in miners, increase the risk of lung cancer caused by smoking, leukemia	[17]
13.	Ozone	Photocopier, printers	Coughing, throat irritation, pain, burning or discomfort in the chest when taking a deep breath, chest tightness, wheezing and shortness of breath.	[14]
14.	Hydrocarbons	Fuel combustion.	Causes cancer, Failure of Nervous System, Tumor , etc.	[10]
15.	Trichloroethene (TCE)	Adhesive solvents, Paints, Building and Furniture material, Fabricated metals.	Effects on CNS, Liver, Kidney, Reproductive and immune system and may also affect foetal development during pregnancy.	[18]

AIR REMEDIATION METHODS

There are several methods used traditionally improve indoor air quality.

HEPA filter: These filter help in grasping all the accumulated dust particles like lead particles, brominated fire-retardant chemicals (PBDEs). HEPA filters used with vacuum give best results. They are commonly known as air purifiers, which are very beneficial for the allergic people as it can capture large amount of biological and chemical allergens [19].

Mopping: It is a very old method to clean all dusts particle settled down on the floor surfaces that is left behind by vacuum cleaner. Due to water all the dust get stick to mops fibre and provide the clean surface [19].

Ventilation: In a household deodorant spray, nail paint, polishing, cleaner, cooking etc. can release many VOCs that connected to many health problems. Ventilation help in maintaining the air flow, exhaust fans in kitchens, proper windows and sunlight exposure in home removes foul odour, germs and indoor polluted air [20].

Ban on Smoking: Smoking leads to emission of Volatile organic compounds, Particulate Matter and carbon monoxide due to burning tobacco, it produces a foul smelling smoke which is harmful for the person which is smoking as well as for the passive people in house also as they inhale the same air. So avoiding smoking in house it can prevent many carcinogenic diseases [20].

Beeswax Candles: They are not only an alternative to the paraffin candles but they also ionize the air to neutralize toxic compounds and other contaminants. Beewax candles produce the ions which combined with free floating chemical ions making them heavier and hence fall off to ground [21].

Salt Lamps: made up of Himalayan Pink Salt can also help in purification of indoor air. These lamps pull toxins from environment and neutralize them rendering the air pure. The principle behind their working is hygroscopy, they attract water molecules with toxins. Hence, when lamp is lit up then water

is evaporated back into the air leaving behind the particles. These lamps work in off mode too [21].

Activated Charcoal or Carbon filters: They are also used as air purifiers due to its adsorptive property, When air passes through filters the carbon adsorbs all the contaminants and air get purified [21].

Many of these methods are in use since a long time and they are very effective. Due to urbanisation and industrialisation the level of pollution is much higher now. So, more efficient methods needed to improve the indoor air quality. There must be less expensive, natural and required low maintenance. As HEPA filters, Beeswax Candles, Activated Charcoal Filters cannot be cleaned very frequently making them non-replaceable and expensive.

Due to the stated limitations of traditional methods a newer natural technique has come in account. That is bioremediation, which is a waste management technique that uses organisms to remove or neutralize pollutants from contaminated site (Soil, Water and air). This eradication of pollutants can be both in-situ and ex-situ. The removal, detoxification or stabilization of contaminants is by using the natural biological, chemical or physical activities of green plants. For organic pollutants, it makes use of mechanism like phytostabilization, phytovolatilization, rhizodegradation and rhizofiltration. Similarly for inorganic pollutants, mechanisms used are phytovolatilization, phytostabilization, rhizofiltration and phytoaccumulation.

This is a natural, low cost and solar energy driven process that is quite effective and eco-friendly [22]. Precisely, “the use of Plant-based systems to lower the concentration or change the bioavailability of pollutants in soil or water is commonly referred to as Phytoremediation” [23]. A lot of work has been done on phytoremediation of soil and water and relatively fewer studies have focused on the ability of plants to take up pollutants from indoor air [22,23].

Table 2: Summarizes various indoor plants and the pollutants eradicated by them.

S r. N o.	PLANT	BENZENE	OZONE	TOULENE AND XYLENE	FORMALDEHYDE	TRICHLOROETHYLENE	AMMONIA	HYDROCARBON	REFERENCES
1.	Phoenix roebelenii (Dwarf date palm)	No	No	Yes	Yes	No	No	No	29,31
2.	Dypsis Lutescens (Areca palm)	No	No	Yes	Yes	No	No	No	25,31
3.	Nephrolepis exaltata (Boston fern)	No	No	Yes	Yes	No	No	No	29
4.	Nephrolepis Obliterate (Kimberly queens fern)	No	No	Yes	Yes	No	No	No	29
5.	Hedera helix (English ivy)	Yes	No	Yes	Yes	No	Yes	Yes	26,29
6.	Liriope spicata (Lily turf)	No	No	Yes	Yes	No	No	No	29
7.	Chlorophytum comosum (Spider plant)	No	Yes	Yes	Yes	No	No	Yes	27,29 24
8.	Epipremnum aureum(money plant)	Yes	No	Yes	Yes	No	No	No	27
9.	Spathiphyllum wallisii (peace lily)	Yes	No	Yes	Yes	Yes	Yes	Yes	26,28, 29
10.	Anthurium andraeanum (Flamingo lily)	No	No	Yes	Yes	No	Yes	Yes	29
11.	Aglaonema modestum (Chinese Evergreen)	Yes	No	No	Yes	No	No	No	29
12.	Chamaedorea seifrizii (Bamboo Palm)	No	No	Yes	Yes	No	No	No	29

13	Rhapis Excelsa (Broadleaf lady palm)	No	No	Yes	Yes	No	Yes	No	29
14	Sansevieria trifasciata “Laurentii” (Variegated snake plant, mother-in-law’s tongue)	Yes	Yes	Yes	Yes	Yes	No	No	27,29
15	Philodendron Cordatum (Heartleaf philodendron)	No	No	No	Yes	No	No	Yes	30,31
16	Philodendron bipinnatifidum (Selloum philodendron)	No	No	No	Yes	No	No	Yes	30,31
17	Philodendron domesticum (Elephant ear philodendron)	No	No	No	Yes	No	No	Yes	30,31
18	Dracaena marginata (Red-edged dracaena)	Yes	No	Yes	Yes	Yes	No	No	29,31
19	Dracaena fragrans “Massangeana” (Cornstalk dracaena)	Yes	No	No	Yes	Yes	No	No	29
20	Ficus Benjamina (Weeping Fig)	No	No	Yes	Yes	No	No	Yes	29
21	Gerbera jamesonii (Barberton daisy)	Yes	No	No	Yes	Yes	No	No	31
22	Chrysanthemum morifolium (Florist’s Chrysanthemum)	Yes	No	Yes	Yes	Yes	Yes	No	29
23	Ficus Elastica (Rubber plant)	No	No	No	Yes	No	No	No	24

24	Dendrobium spp. (Dendrobium orchids)	No	No	Yes	No	No	No	No	29
25	Dieffenbachia spp. (Dumb Canes)	No	No	Yes	No	No	No	Yes	29
26	Homalomena wallisii (King of hearts)	No	No	Yes	No	No	No	No	29
27	Phalaenopsis spp. (Moth orchids)	No	No	Yes	No	No	No	No	29
28	Aloe vera (Aloe vera)	Yes	No	No	Yes	No	No	No	29
29	Dracaena deremensis “JANET CRAIG” (Janet Craig)	Yes	No	No	Yes	Yes	No	No	28,29
30	Dracaena deremensis “WARNECKEI” (Warneckeii)	Yes	No	No	Yes	Yes	No	No	28,29
31	Musa Oriana (Banana)	No	No	No	Yes	No	No	No	31

There are various varieties of plants that remove different pollutants from the air such as *Pelargonium domesticum*, *Ficus elastica* and *Chlorophytum comosum* that efficiently remove benzene. *C. comosum* also removes TCE [24]. Plants species like as *Hedera helix*, *hoya carnosa*, *Asparagus densiflorus* remove VOCs [4]. *Sansevieria trifasciata* (snake plant), *Chlorophytum comosum* (spider plant) and *Epipremnum aureum* are helpful in removal of ozone [25,27]. According to NASA report of 1989, Data from 2 years study was generated on various indoor plants growing in soil and microorganism found in their surrounding soil environment. It was found that bacterial counts were directly dependent on plants ability of removing pollutants. Bacterial isolates like *Alcaligenes*, *Bacillus*, *Micrococcus*, *Myxococcus*

etc. were found in soil in which commonly known as mother in law's tongue had been growing. Similarly Bacteria such as *Aureobacterium*, *Bacillus*, *Curtobacterium*, *Micrococcus*, *Pseudomonas*, and *Streptomyces* were found in soil of Peace Lily root was effective [32].

CONCLUSION

Inefficient and polluting household energy systems hold back development through resulting ill health effects, constraints on environmental impacts, and other factors. Although there is a trend toward cleaner and more efficient energy with increasing prosperity, little improvement is in prospect for more than 2 billion of the world's poorest people, particularly in South Asia and Sub-Saharan Africa. The number of people who were relying on

traditional biomass is actually expected to increase until 2030.

The development of new energy technologies has a role to play in addressing this problem, many effective interventions are also available. The single greatest challenge is to dramatically increase the access of poor households to cleaner and more efficient household energy systems. Much valuable experience has been gained from successful—and unsuccessful—programs in household energy over the past three to four decades. Despite their experiences, coherent, evidence-based policy is lacking in most of the countries concerned, where the lessons from experience now need to be implemented. Implementation will require greater awareness of the problem at international and national levels, provision of support for national collaborative action, and a focus on supporting appropriate, mainly market-based interventions.

Better information is crucial to this effort, including stronger evidence of the health effects of IAP exposure; assessment of the social, economic, and environmental benefits of interventions; and indicators to monitor progress. Economic analysis can help bring the case for action into policy, but it needs to be applied at country level and to include a wider range of benefits. Results from analysis at the regional level show that interventions can be cost-effective, particularly improved stoves, as long as these interventions can deliver substantial exposure reductions in practice. This conclusion, as well as its qualification, is important given the expectation that biomass will remain the principal household fuel in many developing countries for more than 20 years. The balance of effort and resources put into promoting cleaner biomass interventions rather than cleaner fuels, or vice-versa, will be an important policy issue for many countries and for the international community.

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With a range of innovative projects and programs under way in a number of countries and regions of the world, now is an important time to focus attention and effort on achieving the health, social, and economic gains that should result from improvements in household energy systems in developing countries

FUTURE ASPECTS

The growing population and improved standards of living suggest that air pollution will persist and it will be an increasing problem until and unless the population is controlled which at present seems a nearly impossible thing to happen. Since we are all aware about the effects of air pollution on both health and environment it is necessary to wake up and do something to protect the present and future generations. Future researches will most likely happen in the highly populated countries like China, India, United States of America, etc. where the problem is more and air pollution is prominent. Since a lot of work has been done on outer air pollution, indoor air pollution now needs attention and need to be worked upon. With regard to indoor air pollution studying the characteristics of different household plants the pollutants that they are stabilizing or removing from the air, should be done. Even if certain plant is not that much efficient or effective is eliminating certain pollutant optimisation needs to be done to increase its potential of remediation. The pollutants on which not much work is done should be identified focused and worked upon. Development of transgenic indoor plants at a faster pace to enhance the process of phytoremediation. Guidelines can be set for emission of particular pollutant in schools, offices, buildings or houses. Finally if one really wants to fight air pollution and get rid of this problem each and every individual will need to do his or her part as a whole[33].

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