ROLE OF PLANTS IN MITIGATION OF AIR POLLUTION

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ABSTRACT

With advancement in science and technology, human beings have indeed succeeded in alleviating the living standards filled with comfort and luxury. The side effect of this advancement which could not be neglected now is environmental pollution. Atmosphere is one of the most polluted spheres of Earth.As per report of WHO in 2012, outdoor air pollution is believed to cause an estimated 1.3 million annual deaths worldwide, as well as an increased risk of respiratory and cardiovascular diseases. Continuous exposure to pollutants like VOCs (Volatile Organic Compounds), Particulate matter, ozone, radon, lead, biological contaminants etc. within the buildings are further worsening the indoor air quality too. Phytoremediation has emerged as a sustainable tool to counter the massive problem of air pollution. The present study emphasizes the need of increasing use of plants both outdoor and indoor as pollution moderators. Plants act as natural sinks of air pollutants and vital resource having several ecological and economic importances. Numerous species of herbs, shrubs and trees have been reported to recover indoor as well as outdoor air quality by absorbing particulate as well as gaseous pollutants. Plants having more stomatal density are found to be more effective against air pollutants. Trees like Ficus religiosa (Peepal), Azadirachta indica (Neem), Polyalthia longifolia (Ashok), Cassia fistula (Amaltas) and C. siamea (Kassod), Delonix regia (Gulmohar), Bombaxceiba (Cotton tree), Mangifera indica (Mango) etc. and indoor plants like Nephrolepsis exaltata (Boston fern), Chrysanthemum morifolium (Pot mum) and phoenix roebelenii (dwarf date palm),Rhapis excels (lady palm), Scindapsus aureus (golden pothos) and Chlorophytum elatum var. vittatum (spider plant) etc. have been proved as air purifiers.

Keywords: *Air pollution, Indoor plant, Phytoremediation, Pollution sink, Volatile Organic Compounds (VOCs),*

I. INTRODUCTION

The most superior species is rapidly converting the planet earth into an inhabitable place to live forcing the increasing rate of pollution. In lieu of industrialization and urbanization the earth and its resources are exploited to its maximum. Environmental pollution has reached to such a stage that biological species are struggling for its existence. Human beings are also facing the health impacts due to increased pollution. None of the spheres of earth remain untouched by pollution. Be it hydrosphere, lithosphere or atmosphere, each one is experiencing abnormal levels of pollution. Atmosphere is polluted the most. Major sources of atmospheric pollution are industrial emissions, vehicles, construction activities, mining, dust particles and other anthropogenic activities. With advancement in science and technology, human population has also increased dramatically. This increasing demographic pressure is the root cause of exploitation of natural resources and environmental pollution. In most developed as well as developing countries people generally spend about 90% of their time inside the buildings such as houses, offices and

factories (Jenkinsetal.,1992; Snyder, 1990). Thus the importance of indoor air quality to human health is even more than the outdoor air quality. The indoor air is found out to be more polluted than outside building air(Ingrosso, 2002; Orwelletal., 2004;Zabiegala, 2006.).Indoor air is mostly polluted by Volatile Organic Compounds (VOCs) (Wolkoff, 2003**;** Mendes etal.,2013**).**VOCs have got average indoor levels several times more than that of the outdoor air (Rehwagenetal., 2003**;**Magnusson etal., 2012; Zhu andJia, 2012). Indoor air pollutants infiltrate from the outside (Be´ruBe´etal., 2004), released by products and anthropogenic activities carried out within the building. Indoor air pollutants include volatile organic compounds (VOCs), particulate matter, ozone, radon, lead, and biological contaminants (Destaillatsetal., 2008). Indoor air might contain VOCs derived from furnishings, building materials, paints, adhesives, clothing, solvents, combustion appliances, varnishes and potable water (Maroni etal.,2006;Zabiegala, 2006).

II. PHYTOREMEDIATION

There are various ways and means to mitigate the environmental pollution. Plantation of trees, shrubs and herbs has been one of the effective methods. Phytoremediation is using plants to remove toxins—is an attractive and cost effective way to improve air quality and can play important role in controlling air pollution. Appropriate planning and planting scheme determined by the degree and nature of pollution, selection of pollution lenient and dust absorbing trees and shrubs should be done for bioremediation of environmental pollution. For selecting the plant species for pollution control the following important characteristics could be considered. Plants should be ecologically compatible, evergreen, high absorption of pollutants, low water requirement, large leaved, indigenous, minimum care, pollutant resistant, agro-climatic suitability, height and spread, Canopy architecture, Growth rate, Aesthetic effect, Pollution tolerance and dust scavenging capacity. Before planting such trees their local ecological relationship with human environment has to be studied properly. Due to air borne pollen grains these trees may cause allergic problems such as asthma and hay fever. Insect-pollinated trees with short flowering periods and less pollen productivity should be selected for urban plantation (Chakre, 1984).For pollution control it is also suggested that wind-pollinated tree species, flowering during rainy season can also be planted, as rains will wash out extra pollens. The tree to be planted should be moderately free of insects and diseases and there should not be dropping of useless fruits (Cerbera odollam), seed pods (Acacia auriculaeformis), twigs and leaves (Dyera costulata). Trees with affinity to descent large and heavy fruits (Durio spp.) and emanatepooraroma (Sterculia foetida) must be avoided in the urban landscape. Trees such as Tamarind (Tamarindus indicus) having smaller compound leaves are generally more efficient particle collectors than larger leaves. It is reported that leaves of Mango (Mangifera indica), Ashoka (Polyalthea longifolia), Pongamia (Derris indica) and Umbrella (Thespepsia populnea) trees captures higher amounts of dust as compared to other plants (Shetye and Chaphekar, 1989). Evergreen trees are found to be more efficient in terms of air pollution control as compared to deciduous trees (Dochinger, 1973). Many trees like Ficus religiosa, Azadirachta indica, Cassia fistula and C. siamea, Delonix regia,Bombax ceiba, Lagerstroemia indica, Jacaranda mimosifolia, Plumeria rubra, Syzygium cumini and several other roadside and street trees are found more suitable in urban environment (Pokhriyal and SubbaRao, 1986; Chee and Ridwan, 1984). Several studies have been conducted to examine the ability of outdoor

vegetation, particularly trees, to remove numerous airborne particles, including radioactive elements, pollen, spores, salt, and precipitation (Zulfacar, 1975;Smith and Staskawicz, 1977**;**Smith, 1990; McPherson and Nowak, 1993).It has been observed that there is reduction of as much as 75% of atmospheric dust over wooded areas as compared to over relatively non-vegetated, populated areas (Rotschke, 1937). Vegetation has been found acting as a natural filter, instigating particles to be retained on the vegetative surface through sedimentation, impaction, or precipitation. Trees in outdoor atmosphere have been reported to collect dust on surface of leaf,trichomes and even on growing fungal mycelium (Smith and Staskawicz, 1977). Air pollution tolerance index (APTI) works as a trustworthy technique in selecting plants as tolerant and sensitive species in terms of air pollution. Tolerant species serve as sink of air pollutants and thus can help in decline of air pollutants to certain degree if planted in and around industrial vicinity and along traffic islands. Air Pollution Tolerance Index for plants was calculated using the formula (Singh and Rao, 1983)**:**

$$\mathbf{APTI} = \frac{\mathbf{A\ (T+P)\ +R}}{\mathbf{10}}$$

Where, A =Ascorbic Acid (mg/g), T =Total Chlorophyll (mg/g), P = pH of the leaf extract and R = Relative water content of leaf (%)

Plants having higher APTI values are more tolerant towards air pollutants and thus act as better pollution moderators as compared to plants having low APTI value. Some of the plant having higher APTI value is mentioned below in Table 1.

Table 1. Air pollution tolerance index of common trees calculated by average of biochemical parameters from summer and winter season± SD (Joshi et al., 2016).

Plant species name	**Ascorbic acid content**	**Total chlorophyll content**	**pH**	**Relative water content**	**APTI**
Polyalthialongifolia	0.20±0.01	0.42±0.03	6.68±0.11	89.69±1.83	9.11±0.26
Pongamiapinnata	1.59±0.37	0.58±0.35	6.92±0.08	80.01±2.99	9.19±0.27
Putranjivaroxburghii	8.35±0.19	0.53±0.06	6.25±0.13	91.97±2.70	14.85±0.45
Ficusracemosa	0.97±0.03	0.37±0.01	5.55±0.45	92.87±3.01	9.86±0.20
Mangiferaindica	1.49±0.41	0.51±0.01	6.47±0.31	89.88±1.17	10.03±1.44
Ficushispida	0.49±0.04	0.55±0.15	5.75±0.91	90.08±3.37	9.31±0.67
Morindacitrifolia	1.30±0.01	0.70±0.16	6.31±0.06	83.53±3.13	9.26±0.30
Ficusbenghalensis	0.58±0.05	0.36±0.01	6.18±0.91	87.96±3.21	9.17±0.21
Cassia fistula	1.55±0.05	0.67±0.02	6.79±0.45	78.50±3.17	9.00±0.72
Azadirachtaindica	1.39±0.02	0.41±0.05	6.21±0.13	73.56±2.56	8.27±0.26

Plants are efficient enough not only to reduce outdoor air pollution but various studies have reported the effects of some plants on the enhancement of indoor air quality by absorbing air-borne contaminants such as VOCs (Wolvertonand Wolverton, 1993; Giese etal., 1994; Agrawal etal., 2003; Kim etal., 2008; Woodetal., 2001; Wood etal., 2002;Orwell etal.,2004).Occupational health of the employees working and their productivity were improved by raising indoor plants. (Levyetal., 2010; Lu etal.,2007). Several indoor plant species have eliminated benzene or hexane at concentration levels of 50 and 150 ppm, respectively which are several orders of magnitude more than the levels that can be encountered in the

indoor air (Song etal., 2007; Wood etal., 2002; Orwell etal., 2004). The features of indoor air can be amended byplanting indoor plants. Plants actually decreases amount of carbon dioxide, with some species reducing concentrations during the night also (Razaetal.,1991).Plants may increase the wellbeing level for humans, especially in heated interior spaces by increasing indoor relative humidity following addition of moisture into the air (Lohr,1992). Apart from this, several interior plants have been reported to reduce levels of several poisonous gases, including formaldehyde and nitrogen dioxide, from contaminated air with the help of associated microorganisms (Wolvertonetal., 1984, 1985, 1989). Such outcomes of plants generally assist to recover the indoor air quality. Plants which produce airborne pollens and spores are not suitable for indoor plantation as they may hamper air quality (Burge etal.,1982; Owen etal., 1992). Not only trees in outdoor atmosphere but indoor plants have been also found effective in reducing particulate matter in the indoor air. Common low-light tolerant species of interior plants, including Aglaonema sp., Chamaedorea seifrizii, Dracaena marginata, Epipremnu maureum, and Spathiphyllum sp., were used to study the removal of indoor air quality. Plant design can power the efficacy of particulate matter removal, particularly for particles in certain size ranges (Smith, 1990).

Vegetation with rough surfaces is more effective in capturing particulate matter than smooth vegetation. Choosing different plant species, such as Episcia sp. or Tolmiea menziesii (species with prominent pubescence) might increase the rate of particulate matter accumulation in interiors. A reduction of more than 20% of particulate matter has been reported with plantation of foliage plants. Nephrolepsis exaltata (Boston fern), Chrysanthemum morifolium(Pot mum) and phoenix roebelenii (dwarf date palm) were found to be quite effective in removing formaldehyde with 1863 µg, 1450 µg and 1385 µg removed per hour respectively. Dwarf date palm was most effective in removing xylene at rate of 610 µg removed per hour. Rhapis excels (lady palm) is quite effective in removing ammonia at a rapid rate of 7,356 µg removedper hour (Wolverton and Wolveton,1993). Another study by Wolverton et al., (1984)reported Scindapsus aureus (golden pothos), Syngonium podophyllum (nephthytis), and Chlorophytum elatum var. vittatum (spider plant) to effect the removal of formaldehyde from contaminated air at initial concentrations of 15-37 ppm. In the study, the spider plant proved most efficient by effecting the removal of up to 2.27 µg formaldehyde per cm^2 leaf surface area in 6 h of exposure. The speedy submission of this plant air-purification system is recommended in energy-efficient homes that have a great threat of formaldehyde concentrating in the air, due to outgassing of urea-formaldehyde foam insulation, particle board fabrics and various others synthetic materials. The group of plants found potent to remove organic chemicals from indoor air was studied by Wolvertonetal., (1989). The studied common indoor plants were determined by joint agreement between the National Aeronautics and Space Administration (NASA) and The Associated Landscape Contractors of America (ALCA). Plants reported to have efficiency for reducing indoor air pollution and studied therefore, are listed below in Table 2.

Table 2. Indoor plants studied for air pollution control

Common Name	Scientific Name
Bamboo palm	Chamaedorea seifritzii
Chinese evergreen	Aglaonema modestum
English Ivy	Hedera helix
Gerbera daisy	Gerbera jamesonii
Janet Craig	Dracaena deremensis "Janet Craig"
Marginata	Dracaena marginata
Mass cane/Corn cane	Dracaena massanqeana
Mother-in-Law's tongue	Sansevierialaurentii
Pot mum	Chrysanthemum morifolium
Peace lily	Spathyphyllum "Mauna Loa"
Warneckei	Dracaena deremensis "Warneckei"
Ficus	Ficusbenjamina
Heart leaf philodendron	Philodendron oxycardium
Elephant ear philodentron	Philodendron domesticum
Golden pothos	Scindapsus aureus
Green spider plant	Chlorophytumelatum

III. CONCLUSION

In view of the existing state of urban air pollution, apart from other technological solutions, there is emergent necessity for extensive plantation both outdoor and indoor. Addition of the plants having pollution controlling capacity will not only increase the aesthetic beauty but will also make urban dwellings green and free of pollution. Appropriate planting system will bring healthy life and wellbeing even among the vulnerable groups of human beings especially children and old people. Planting indoor plants would definitely help in up gradation of indoor air quality. The trees in addition to plants not only provides oxygen, reduces CO_2 and other toxic gases , also helps in removing VOCs as well as particulate matter present in the outdoor as well as indoor atmosphere acting as a natural filter. India being a mega-diversity nation possesses huge diversity of plant species, thus offers a wide range of choice to restore our outdoor as well as indoor atmospheric condition. Plantation on a massive scale is recommended for controlling airborne gaseous as well as particulate pollution in urban climate. There is important requirement of brainstorming sessions among stakeholders like horticulturist, environmentalist and town planners to understand the ecological impact of selected plant species before plantation. Thus, extensive research is mandatory to utilize the floral diversity in mitigation of atmospheric pollution both indoor and outdoor.

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REFERENCES

1. Agrawal, M.; Singh, B.; Rajput, M.; Marshall, F.; Bell, J.N.,(2003). Effect of air pollution on peri-urban agriculture: a case study. Environ Pollut.,126(3), 323–329.
2. Be´ruBe´, K.A.; Sexton, K.J.; Jones, T.P.; Moreno, T.; Anderson, S.; Richards, R.J., (2004). The spatial and temporal variations in PM10 mass from six UK homes. Sci. of the Total Environ.,324, 41–53.
3. Burge, H.A.; Solomon, W.R.; Muilenberg, M.L., (1982). Evaluation of indoor plantings as allergen exposure sources. J. Allergy Clin. Immunol., 70,101-108.
4. Chakre, O. J.,(1984).Atmospheric pollens: The organic pollutants. Science Service, 3(8): 4.
5. Chee, T. Y.; Ridwan, S., (1984).Fast-growing species of trees suitable for urban roadside and shade planting. Malaysian For., 47, 263-284.
6. Destaillats, H.;Maddalena, R.L.; Singer, B.C.; Hodgson, A.T.;McKone,T.E.,(2008). Indoor pollutants emitted by office equipment: A review of reported data and information needs. Atmos. Environ., 42, 1371–1388.
7. Dochinger, L. S., (1973). Miscellaneous Publication No.1230.USDA, Forest Service, Upper Darby, Pa, 22.
8. Giese, M.; Bauer-Doranth, U.;Langebartels, C.; Sandermann, H. Jr., (1994). Detoxification of formaldehyde by the spider plant (ChlorophytumcomosumL.) and by soybean (Glycine max L.) cell-suspension cultures. Plant Physiol., 104:1301–1309.
9. Ingrosso, G.,(2002). Free radical chemistry and its concern with indoor air quality: An open problem. Microchem. J., 73:221–236.
10. Jenkins, P.L.; Phillips, T.J.; Mulberg, E.J.;Hui, S.P.,(1992). Activity patterns of Californians—Use of and proximity to indoor pollutant sources. Atmos. Environ., 26, 2141–2148.
11. Joshi, N; Joshi,A.;Bist,B., (2016). Air Pollution Tolerance Index of Some Trees Species from the Industrial area of Tarapur, Int. J. Life. Sci. Scienti. Res., 2(2), 173-182.
12. Kim, K.J.;Kil, M.J., Song, J.S.;Yoo, E.H.,(2008). Efficiency of volatile formaldehyde removal by indoor plants: contribution of aerial plant parts versus the root zone. Hortscience., 133(4), 521–526.
13. Levy, J.I.;Clougherty, J.E., Baxter, L.K.; Houseman, E.A.;Paciorek, C.J., (2010). Evaluating heterogeneity in indoor and outdoor air pollution using land-use regression and constrained factor analysis. Res Rep Health Eff Inst., 152, 5–80.
14. Lohr, V.I., (1992). The contribution of interior plants to relative humidity in an office. In The Role of Horticulture in Human Well-being and Social Development (edited by Relf D.). Timber Press, Portland, Oregon, 117-119.
15. Lu, C.Y.; Ma, Y.C.; Lin, J.M.; Li, C.Y.; Lin, R.S.; Sung, F.C., (2007). Oxidative stress associated with indoor air pollution and sick building syndrome-related symptoms among office workers in Taiwan. InhalToxicol.,19(1), 57–65.
16. Magnusson, R.;Hägglund, L.;Wingfors, H., (2012). Broad exposure screening of air pollutants in the occupational environment of Swedish soldiers deployed in Afghanistan. Mil Med., 177(3), 318–325.
17. Maroni, M.;Seifert,B; Lindvall, T.,(1995). Indoor air quality: A comprehensive reference book. Elsevier, Amsterdam, The Netherlands.

18. McPherson, E.G.; Nowak, D.J., (1993). Value of urban greenspace for air quality improvement: Lincoln Park, Chicago, Arborist News 2(6), 30-32.
19. Mendes, A.; Pereira, C.; Mendes, D.;Aguiar, L.;Neves, P.; Silva, S.;Batterman, S.; Teixeira, J.P.,(2013). Indoor air quality and thermal comfort-results of a pilot study in elderly care centers in portugal. J Toxicol Environ Health A., 76(4–5), 333–344.
20. Orwell, R.L.; Wood, R.L.;Tarran,J.;Torpy,F.; Burchett, M.D., (2004). Removal of benzene by the indoor plant/substrate microcosm and implications for air quality. Water Air Soil Pollut., 157,193–207.
21. Owen, M.K.; Ensor, D.S.; Sparks, L.E., (1992). Airborne particle sizes and sources found in indoor air. Atmospheric Environ., 26A, 2149-2162.
22. Pokhriyal, T.C.; SubbaRao, B. K., (1986).Role of forests in mitigating air pollution. Indian For. 112: 573-582.
23. Raza, S.H.;Shylaja, G.; Murthy, M.S.R.; Bhagyalakshmi, O., (1991). The contribution of plants for CO2 removal from indoor air. Environment Int., 17, 343-347.
24. Rehwagen, M.; Schlink, U.;Herbarth, O., (2003). Seasonal cycle of VOCs in apartments. Indoor Air, 13(3), 283–291.
25. Rotschke, M., (1937) Untersuchungenüber die Meteorologie der Staubatmosphäre. Veroff. Geoph. I. Leipzig 11, 1-78. Reported in Geiger R. (1965). The Climate Near the Ground, p. 367. Harvard University Press, Cambridge, Massachusetts.
26. Shetye, R. P.; Chaphekar, S. B., (1989). Some estimation on dust fall in the city of Bombay, using plants. In: Prog. in Ecol., 4, 61-70.
27. Singh, S. K.; Rao, D. N., (1983). Evaluation of plants for their tolerance to air pollution. In: Proceedings Symposium on Air Pollution Control, (Indian Association for Air Pollution Control, New Delhi, India), 1,218-224.
28. Smith, W.H., (1990). Air Pollution and Forests: Interactions between Air Contaminants and Forest Ecosystems, 2, 147-180. Springer, New York.
29. Smith, W.H.; Staskawicz, B.J., (1977). Removal of atmospheric particles by leaves and twigs of urban trees: some preliminary observations and assessment of research needs. Environmental Man., 1, 317-330.
30. Snyder, S.D.,(1990). Building interior, plants and automation. Prentice Hall, Englewood Cliffs, NJ., 295-299.
31. Song, J.E.; Kim, Y.S.;Sohn J.Y., (2007). The impact of plants on the reduction of volatile organic compounds in a small space. J PhysiolAnthropol., 26(6):599–603.
32. Wolkoff, P., (2003). Trends in Europe to reduce the indoor air pollution of VOCs. Indoor Air, 13(6), 5–11.
33. Wolverton, B.C.; Wolverton, J.D., (1993).Plants and soil microorganisms: removal of formaldehyde, ethylbenzene, and ammonia from the indoor environment. J. of Mississippi Academy. Sci., 38(2), 11–15.
34. Wolverton, B.C.; Johnson A.; Bounds, K., (1989). Interior Landscape Plants for Indoor Air Pollution Abatement. National Aeronautics and Space Administration, Stennis Space Centre, Mississippi.
35. Wolverton, B.C.; McDonald, R.C.; Mesick, H.H., (1985). Foliage plants for indoor removal of the primary combustion gases

carbon monoxide and nitrogen dioxide. J. Mississippi Academy. Sci., 30, 1-8.

36. Wolverton, B.C.; McDonald, R.C. and Watkins E.A. (1984). Foliage plants for removing air pollutants from energy-efficient homes. Economic Botany, 38, 224-228.
37. Wood, R.; Orwell, R.;,Tarran, J.; Burchett, M., (2001). Pot-plant really do clean indoor air. The Nursery Papers, No. 2001/2, 1-4. NIAA (Nursery Ind. Assocn. Aust.) Sydney, Australia.
38. Wood, R.A.; Orwell, R.L.; Tarran, J.; Torpy, F.; Burchett, M.D.,(2002). Potted plant-growth media: interactions and capacities in removal of volatiles from indoor air. J. of Environ. Horticulture and Biotechnol., 77, 120–129.
39. Zabiegala, B.,(2006). Organic compounds in indoor environments. Polish J. Environ. Stud,. 15,383– 393.
40. Zhu, X.;Jia C., (2012). Apportioning variability of polycyclic aromatic hydrocarbons (PAHs) and chlordanes in indoor and outdoor environments. J Environ Monit, 14(7), 1926–1934.
41. Zulfacar, A., (1975). Vegetation and urban environment. J. Urban Planning Dev. Div. Proc. Amer. Soc.Civil Eng., 101, 21-33.