Indian Journal of
Advances in Chemical Science

Article

Application of Phytoremediation for Indoor Air Pollution Control: A Review

Samridhi Dwivedi[1], B. S. V. Prakash[2], Alfred Lawrence[1]*

[1]Department of Chemistry, Isabella Thoburn College, Lucknow, Uttar Pradesh, India, [2]Department of Botany, Lucknow Christian Degree College, Lucknow, Uttar Pradesh, India

ABSTRACT

Air pollution irrespective of their source of origin tends to increase in atmosphere. Various air pollutants include volatile organic compounds, particulate matter, and other persistent organic pollutants. These pollutants pose various health hazards on human beings including cancer. It has been prominently recognized to cause burden on eco-system and human well-being. However, some remediation techniques are available in the market yet their high maintenance cost, lesser durability, and complex principals make them an inappropriate option for air pollution control. Phytoremediation enters as a cost-effective, low-maintenance, eco-friendly, and energy-saving option. Phytoremediation involves different plant organs for absorption and decomposition of pollutants. The review presents an overview of the existing technologies of phytoremediation. Furthermore, it highlights the loopholes in the technologies which may be useful for the researchers in the field to present more promising and effective work in near future.

Key words: Air pollution, phytoremediation, air pollution mitigation, volatile organic compounds, particulate matter

1. INTRODUCTION

Indoor air quality (IAQ) is one of the rising concerns in today's era attributed to the fact that people are spending majority of their time in encased environment with highly sealed constructions which, however, elevate thermal competence thereby reducing ventilation of fresh air. Anthropogenic activities in urban areas inevitably initiate release of air pollutants. At present, approximately 55% of the population globally resides in urban settlements which is further expected to increase till 2050. This exposure to numerous indoor air pollutants results in detrimental health effects. The World Health Organization has recognized a group of symptoms which are caused due to accumulated indoor air pollutants commonly called as "Sick Building Syndrome" [1]. The levels of air pollutants in indoors are higher than outdoor as outdoor air pollutants mix with certain indoor pollutants such as CO_2 resulting in degrading of IAQ which is observable in highly constricted buildings. Out of many technologies available for mitigation of indoor air pollutants, phytoremediation emerges as an environmentally friendly and economic approach. Plants are widely known to metabolize and assimilate toxic pollutants. The mechanism opted by plants includes degradation and absorption of air pollutants. Where absorption involves plant surface above ground degradation involves plant metabolites. Numerous studies have been found to be reporting the absorption capacity of plants for different pollutants such as formaldehyde, xylene, ozone, and benzene. Based on the survey of the vast literature available on phytoremediation, this review article summarizes different plants widely employed for remediation of various indoor air pollutants [2,3]. Further the review also illustrates the mechanism involved and the removal efficiency of pollutants along with the experimental conditions adopted for the same. The cited references have been found with the list of keywords including "plant, air pollutants, phytoremediation, and mechanism of phytoremediation."

2. AVAILABLE MITIGATION TECHNIQUES

Number of technologies are presently available in market for air purification. Some of which includes adsorption, incineration, photocatalysis, and ozonation. [4,5]. A brief review of the available technologies is given in Table 1.

Among all, filtration has been mostly commonly adopted technique. However, the efficiency of filters reduces as they become saturated further promoting microbial growth. As a result, new hazardous material is generated which needs to be disposed appropriately [6]. Biofilters have also been recently introduced where pollutants are removed or transformed into plants nutrient in the rhizosphere of the plant. These are widely implemented due their economic availability and esthetic value promoting mental comfort in surroundings [7].

3. MECHANISM OF PHYTOREMEDIATION

In the course of air pollutant mitigation, pollutants are effectively absorbed through phyllosphere of plants stems and leaves. Further the pollutants absorbed are transferred to rhizosphere and soil as a result of rainfall and leaf fall. At the end, after scavenging these pollutants in rhizosphere and pyllosphere, plants perform metabolization, excretion, or sequestration of air pollutants [8,9]. In addition, phytoremediation is assisted with biodegradation in which microbes detoxify thereby, promoting growth of the plant. Seven approaches are involved in phytoremediation which includes pytovolatilization, pytostabilization, phytoextraction, pytodegradation, rhizofilteration, rhizodegradation, and hydraulic control [10]. The strategies are briefly explained in the Table 2.

***Corresponding author:**
Alfred Lawrence,
Email: alfred__lawrence@yahoo.com

ISSN NO: 2320-0898 (p); 2320-0928 (e)
DOI: 10.22607/IJACS.2022.1003012

Received: 8th July 2022;
Revised: 30th July 2022;
Accepted: 12th August 2022

Table 1: Existing mitigation technologies for air pollutants

Technique	Pollutant	Mechanism
Electrostatic Precipitation	PMs, NO_2, SO_2, NH_3	Trapping with electric field
Adsorption	NO_2, SO_2, VOCs	Pollutants retained on surface
Membrane Separation	VOCs	Use of semipermeable membrane to diffuse pollutants.
Thermal Oxidation	VOCs	Complete combustion to CO_2 and H_2O
Filtration	PMs, VOCs	Removal of pollutants via fibrous membrane
Catalytic Oxidation	NO_2, SO_2, VOCs	Adsorption and oxidation of pollutants on the surface
Non-Thermal Plasma	NO_2, SO_2, VOCs, PMs	Ionised gas binds with pollutants to form non-toxic products
Wet Scrubbing	PMs, SOx	Removal of pollutants through alkaline solution or water
Selective Catalytic Reduction	NOx	Reduction into urea or ammonia in catalytic bed

VOC: Volatile organic compounds, PM: Particulate matter

Table 2: Strategies involved in phytoremediation

Strategy	Mechanism	Site	Example	Concerned Pollutants
Pytovolatilization	Pollutants are diffused and converted into volatile compounds.	Pyllosphere	*Arundo donax*	VOCs, HMs, POPs
Pytostabilization	Lignin of cell wall absorbs pollutants and accumulates the same in the rhizosphere.	Rhizosphere	*Juncus effusus* *Carpobrotus aequilaterus*	PMs, HMs, VOCs.
Phytoextraction	Utilizes hyperaccumulator plants to absorb pollutants	Phyllosphere, Rhizosphere	*Phytolacca americana* *Salix schwerinii*	PM, HM, VOC
Pytodegradation	Pollutants are incorporated into plant tissues. Further metabolized by laccases, dehalogenases and nitro reductases.	Phyllosphere, Rhizosphere	*Blumea malcolmii* *Spirodela polyrhiza*	POPs, VOCs
Rhizofilteration	Absorbs and precipitate pollutants from aqueous environment.	Rhizosphere	*Helianthus annuus* *Phaseolus vulgaris*	PMs, POPs, HMs.
Rhizodegradation	Oxygen transfer and microbial growth in root of the plant.	Rhizosphere	*Sorghum×drummondii* *Typha angustifolia*	VOCs, PMs

4. PHYTOREMEDIATION OF DIFFERENT AIR POLLUTANTS

4.1. Phytoremediation of Organic Pollutants

Certain persistent organic pollutants such as benzene, xylene, toluene, formaldehyde contaminate the indoor air. Based on existing studies, numerous plants have been identified as potential contender in remediating organic pollutants [11-13]. A brief of the study is depicted in the Table 3.

4.2. Phytoremediation of Inorganic Pollutants

Inorganic pollutants in indoor air involves CO_2, SOx, NOx, and particulate matter (PMs). PM is one of the most prominent indoor air pollutants. These are present in various size ranging from coarse to fine, superfine, and ultrafine [14-17]. Plants capture PMs, reducing their local impacts. A brief overview of the plant's species recognized for the removal of PMs is listed in Table 4.

4.3. Phytoremediation of Heavy Metals

Plants absorb heavy metals through their roots further transporting them to xylem. Heavy metals such as Zn, Cd, Pb, Fe, Ni, and Cu are stored by plants until being harvest. Pytochelatins are also produced by plants which chelate metal ions further reducing their toxicity. Hence, hyperaccumulator species with high concentration tolerance are generally employed. Some examples of such plants include *Brassica juncea*, *Helianthus annuus*, *Festuca arundinacea*, *Populus* spp., *Thlaspi caerulescens*, and *Salix* spp. [18-25]. The mechanism of phytoremediation of metals is depicted in Figure 1.

5. CONCLUSION

Indoor air pollution control is way more challenging. However, phytoremediation involves an effective removal of pollutants in an eco-friendly and cost-effective manner. Plants have been proved to successfully abate numerous pollutants that are present indoors such as volatile organic compounds, PAHs, PMs, CO_2, Sox, and NOx. The factors which help in selection of the plants are crucial for the process. The present review summarized the species and the mechanism adapted for particular pollutant. In majority of the studies, the adsorption effect of plants was judged by the adsorption capacity for pollutant. The major drawbacks in the most phytoremediation techniques were the small surface area to volume ratio. Furthermore,

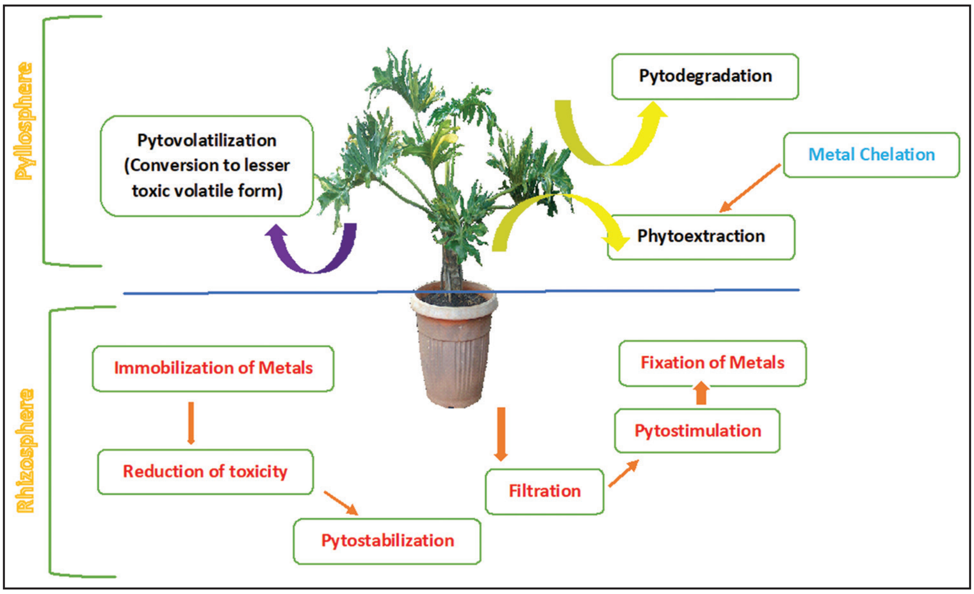

Figure 1: Mechanism of phytoremediation of heavy metals.

Table 3: Plants employed for organic pollutant abatement

Pollutants	Plant Employed for abatement	Purification Capacity (mg/m^3)
Formaldehyde	*Sansevieria trifasciata*	1.90
	Epipremnum aureum	1.87
	Chlorophytum comosum	1.78
	Ficus elastica Roxb. ex Hornem	1.27
Benzene	*Epipremnum aureum (Linden et Andre) Bunting*	1.10
	Chlorophytum comosum f. variegata	1.87
	Hedera nepalensis var. sinensis (Tobl.) Rehd	0.60
	Spathiphyllum kochii Engl. & K. Krause	11.75
Xylene	*Sansevieria trifasciata*	0.70
	Chlorophytum comosum	0.56
	Ficus elastica Roxb. ex Hornem.	0.27
	Epipremnum aureum	0.83

Table 4: Plants employed in inorganic pollutants mitigation

Particle size	Plant Species employed	Purification Capacity PM density
PM_{10}	*Monstera deliciosa* Liebm	6247.04 ppm (82.6%)
$PM_{2.5}$	*Platanus acerifolia* (Ait.)	-
	Nerium oleander L.	-
	Cedrus deodara (Roxb.) G. Don	-
	Trimezia gracilis	10,997.38 ppm (48.5%)
PM_1	*Buxus sempervirens* Linn.	-
	Juniperus chinensis	-

the remediation strategy becomes straighter and more distinct in a non-ventilated environment making the usage of phytoremediation more advantageous in indoor settings.

6. REFERENCES

1. S. Bandehali, T. Miri, H. Onyeaka, P. Kumar, (2021) Current state of indoor air phytoremediation using potted plants and green walls, ***Atmosphere***, **12(4)**: 473.
2. C. Gubb, T. Blanusa, A. Griffiths, C. Pfrang, (2022). Potted plants can remove the pollutant nitrogen dioxide indoors, ***Air Quality, Atmosphere and Health***, **15(3)**: 479-490.
3. H. Teiri, Y. Hajizadeh, A. Azhdarpoor, (2022) A review of different phytoremediation methods and critical factors for purification of common indoor air pollutants: An approach with sensitive analysis, ***Air Quality***, ***Atmosphere and Health***, **15:** 373-391.
4. Y. Han, J. Lee, G. Haiping, K. H. Kim, P. Wanxi, N. Bhardwaj, R. J. Brown, (2022) Plant-based remediation of air pollution: A review, ***Journal of Environmental Management***, **301:** 113860.
5. P. J. Irga, T. J. Pettit, F. R. Torpy, (2018) The phytoremediation of indoor air pollution: A review on the technology development from the potted plant through to functional green wall biofilters, ***Reviews in Environmental Science and Bio/Technology***, **17(2)**: 395-415.
6. B. X. Y. Lee, T. Hadibarata, A. Yuniarto, (2020) Phytoremediation mechanisms in air pollution control: A review, ***Water***, ***Air, and Soil Pollution***, **231(8)**: 437.
7. B. Zhang, D. Cao, S. Zhu, (2020) Use of plants to clean polluted air: A potentially effective and low-cost phytoremediation technology, ***BioResources***, **15(3)**: 4650-4654.
8. Z. Wei, Q. Van Le, W. Peng, Y. Yang, H. Yang, H. Gu, C. Sonne, (2021) A review on phytoremediation of contaminants in air, water and soil, ***Journal of Hazardous Materials***, **403:** 123658.
9. H. Lee, Z. Jun, Z. Zahra, (2021) Phytoremediation: The sustainable strategy for improving indoor and outdoor air quality, ***Environments***, **8(11)**: 118.
10. H. Samudro, S. Mangkoedihardjo, (2021). Indoor phytoremediation using decorative plants: An overview of application principles, ***Journal of Phytology***, **13(6)**: 28-32.
11. A. Franzetti, I. Gandolfi, G. Bestetti, E. P. Schioppa, C. Canedoli,

D. Brambilla, D. Cappelletti, B. Sebastiani, E. Federici, M. Papacchini, R. Ambrosini, (2020) Plant-microorganisms interaction promotes removal of air pollutants in Milan (Italy) urban area, ***Journal of Hazardous Materials***, **384:** 121021.
12. O. Okparavero, T. Coker, (2020) ***Use of Ornamental Plant as Phytoremediation in Reducing the Risk of Covid 19: A Review***, Ilaro: The Federal Polytechnic.
13. A. Roy, T. Bhattacharya, M. Kumari, (2020) Air pollution tolerance, metal accumulation and dust capturing capacity of common tropical trees in commercial and industrial sites, ***Science of The Total Environment***, **722:** 137622.
14. H. Raza, T. Bibi, T. Bibi, M. J. Asim1, H. Bilal, C. Rasheed, M. B. Shoukat, A. Ur Rehman, (2021) Role of phytoremediation in removing air pollutants: A review, ***Cross Current International Journal of Agriculture and Veterinary Sciences***, **3(6)**: 54-59.
15. A. Prigioniero, D. Zuzolo, U. Niinemets, C. Guarino, (2021) Nature-based solutions as tools for air phytoremediation: A review of the current knowledge and gaps, ***Environmental Pollution***, **277:** 116817.
16. S. Papazian, J. D. Blande, (2020) Dynamics of plant responses to combinations of air pollutants, ***Plant Biology***, **22(Suppl 1)**: 68-83.
17. B. Bhargava, S. Malhotra, A. Chandel, A. Rakwal, R. R. Kashwap, S. Kumar, (2021) Mitigation of indoor air pollutants using areca palm potted plants in real-life settings, ***Environmental Science and Pollution Research***, **28(7)**: 8898-8906.
18. P. Anerao, R. Kaware, A. K. Khedikar, M. Kumar, L. Singh, (2022) Phytoremediation of persistent organic pollutants: Concept challenges and perspectives. In: ***Phytoremediation Technology for the Removal of Heavy Metals and Other Contaminants from Soil and Water***, Amsterdam, Netherlands: Elsevier Science, p375-404.
19. R. Yadav, P. Pandey, (2020) Assessment of air pollution tolerance index (APTI) and anticipated performance index (API) of roadside plants for the development of greenbelt in urban area of Bathinda City, Punjab, India, ***Bulletin of Environmental Contamination and Toxicology***, **105(6)**: 906-914.
20. A. James, (2022) Phytoremediation of Urban air pollutants: Current status and challenges. In: ***Urban Ecology and Global Climate Change***, Hoboken: John Wiley and Sons, p140-161.
21. J. Pandit, A. K. Sharma, (2020) A review of effects of air pollution on physical and biochemical characteristics of plants, ***International Journal of Chemical Studies***, **8(3)**: 1684-8.
22. A. A. El-Khatib, N. A. Barakat, N. A. Youssef, N. A. Samir, (2020) Bioaccumulation of heavy metals air pollutants by urban trees, ***International Journal of Phytoremediation***, **22(2)**: 210-222.
23. K. Isinkaralar, (2022) Temporal variability of trace metal evidence in *Cupressus arizonica*, *Platanus orientalis*, and *Robinia pseudoacacia* as pollution-resistant species at an industrial site, ***Water Air and Soil Pollution***, **233(7)**: 1-12.
24. S. Mortazavi, M. Hatamimanesh, F. Veysanlou, (2021) A comparative study on the capability of tree species in Urban afforestation to accumulate heavy metals, ***Journal of Advances in Environmental Health Research***, **9(1)**: 79-90.
25. G. Yasin, S. Ur Rahman, M. T. B. Yousaf, M. F. Azhar, D. M. Zahid, M. Imtiaz, B. Hussain, (2021) Phytoremediation potential of *E. camaldulensis* and *M. alba* for copper, cadmium, and lead absorption in Urban areas of Faisalabad City, Pakistan, ***International Journal of Environmental Research***, **15(4)**: 597-612.

***Bibliographical Sketch**

Ms. Samridhi is working as a Ph.D. scholar in the field of Atmospheric Chemistry at ISABELLA THOBURN COLLEGE Lucknow. She has Completed her masters from Deen Dayal Upadhaya Gorakhpur University in Chemistry in 2018 . During her masters' she was actively involved in research work related to atmospheric chemistry . Her first paper included assessment of pollutants such as BTEX,VOCs etc. and its ecological impacts .Simultaneously with her M.Sc. degree she also obtained a diploma in Industrial Chemistry to have a better insight of the extent of advancement in the field. Her scientific interest embraces computational docking ,mapping ,modelling and simulation of pollutants along with their assessment and remediation.

B. S.V. Prakash is working as Associate Professor in Department of Botany, Lucknow Christian Degree College,Lucknow, U.P. India. He has a vast expertise in the field of Ecology of sand dunes and Plant adaptations.

Alfred Lawrence (Ph.D) is working as a faculty in Department of Chemistry, Isabella Thoburn College, Lucknow, India. He has done his Post-Doctoral from Purdue University, USA and has more than 52 International research publications.