



A Three-Tier Approach as a Next-Gen Sustainable Solution for Mitigation of Urban Air Pollution

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Air pollution is air contaminated by anthropogenic or naturally occurring substances in high concentrations for a prolonged time, resulting in adverse effects on human and environmental health (W.H.O. 2022a). Almost the entire global population (99%) breathes air that exceeds WHO air quality limits and threatens their health (W.H.O. 2022b). A record number of over 6000 cities in 117 countries are currently monitoring air quality, with people in low and middle-income countries suffering the highest exposures (W.H.O. 2022b). The annual monitoring data based on demographic analysis indicates that humans of all ages residing in China and Indian Subcontinent (almost half of world population) are severely affected by the same. In 2021, 86 of the 100 most polluted cities in the world were located in China and the Indian Subcontinent (World Air Quality Report 2021). Efficient management of urban air pollution is matter of global concern. Exploration of all the physical, chemical, biological, socio-technical design, and awareness-raising methods are not proving efficient enough to meet the needs in the current scenario (Manisalidis 2020). Until the transition to clean energy sources is reached, micromanagement of the aforementioned methods as a synchronized archetype could help in resolving the issue copiously (Wei et al. 2017).

Principally, evolution to urban green infrastructure encompassing the features of urban gardening viz. vertical and terrace gardens, green pockets, indoor green designs, etc. along with urban farming concepts are predicted to be the primary sinks for urban air pollutants (Schneider et al. 2020). Interestingly, it has been projected that globally, the ariel surfaces of plants have an area of at least 4×10^8 Km² (Kembel et al. 2014). Plant leaves are able to adsorb or absorb air pollutants, a concept know as phytoremediation that has been tried and tested in practically all possible

situations (Han et al. 2022). Here we direct attention to maximizing the potential of urban green infrastructure by application of ecologically safe microorganisms with the potential of colonizing leaf surface (Phylloplane) for absorption, biodegradation, and bio-transformation of urban air pollutants thereby synergistically adding to the phytoremediation potential of the colonized host.

Hence, here we present a novel viewpoint for improving the efficiency of available bioresources by their repackaging into a three-tier system as a next-generation solution for mitigation of urban air pollution. A three-tier approach by leveraging the potential upper phylloplane symbiotic microorganisms to act the primary biofilters (1°), the leaves (and ariel tissues) as the secondary (2°) engines for bio-transformation, and finally the endophytes as the innermost transformers (3°) for complete neutralization of urban air pollutants (Fig. 1).

1 Future Course of Actions

The aforementioned triple level maneuver most certainly will require the following considerations prior to field deputation:

(1) **Categorical Syllogism:** On-site testing of all the permutations and combinations of (a) phyllospheric microorganism-plant-endophyte combinations with (b) factual levels of urban air pollutants as mixtures.

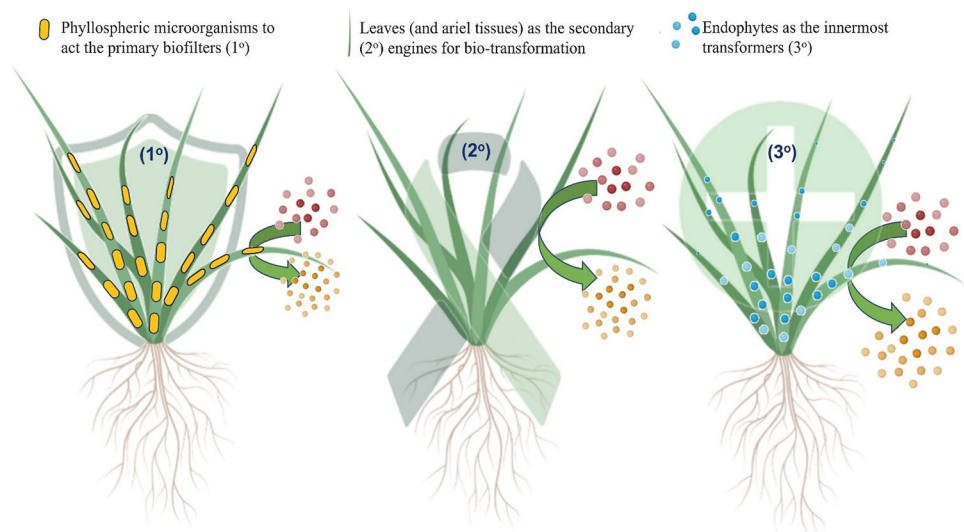
(2) **Abiotic Stress Tolerance:** Urban green infrastructure fundamentally rests on the selection of plant species resilient to a variety of abiotic stresses including, chemical, UV, heavy metal, heat, drought stress, etc. This principle should be extrapolated for phyllospheric microorganisms and interpolated for testing resilience in endophytic population.

(3) **Avatar Version 2.0:** In the present scenario, it is still not possible to isolate, culture and identify a hugely diverse population of both extra-cellular and intracellular microorganisms. The gravity of the challenge can be analogical to

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Fig. 1 A three-tier approach as a next-gen sustainable solution for mitigation of urban air pollutants



the fact that the director of popular movie ‘Avatar’ had to first develop a Fusion Camera System for shooting the movie in stereoscopic 3D.

(4) **The Lockdown Effect:** During the Covid-19 lockdown, the outdoor air pollution levels were significantly reduced due to restricted human and industrial activities. On the contrary, indoor air pollution (due to cooking, heating, smoking, floor cleaners, aerosols, etc.) became the matter of concern. Hence, the efforts proposed in this article should not only focus on outdoor settings but also on the indoor landscapes.

Author contributions CK, TM, and SS were involved in idea generation. CK was involved in manuscript preparation. TM, SM and SS edited the manuscript. All the authors reviewed and edited the content.

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Declarations

Conflict of Interest The authors declare that they have no conflict of interest.

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