Role of roadside vegetation in management of urban air quality

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Abstract- *The roadside air pollution mainly emitting from automobile exhaust is causing adverse health effects on humans and also deteriorating the surrounding environment. The use of roadside features in form of designing roadside vegetation has emerged as a better solution in reducing air pollution with various potential benefits and interest. The roadside vegetation besides enhancing scenic beauty and health benefits, also improves local air quality, reduce runoff velocity and control soil erosion. It ensures the restoration of vegetation helps in trapping dust, acts as windbreaker and also helps in controlling floods. The roadside tree planting is also an asset as it helps in achieving the target of tree plantation in the urban areas. The designing of urban roadsides using tree species requires a maneuver in selection, purpose and ecological needs. The features like tree height, leaf area, thickness, tree bark, branches, porosity, coverage, micro-morphology should be considered while selecting the tree species. Moreover designing green urban space under urbanization pressure is also a challenging task and requires a scientific and users strategy. This paper highlights the impact of air pollutants on human health and road side environment. Further the strategies, policies and mitigation of air pollution using urban vegetation are also discussed in this research.*

Keywords- air pollution, phyto-remediation, roadside plantation

I. INTRODUCTION

Air pollution causing 6.7 million deaths worldwide and nearly 89% of premature deaths in Western Pacific and South-East Asia Regions are considered greatest environmental risk to human health. The year 2019 statistics reveals that still 99% global population resides in the air polluted region that even does not follow WHO guidelines (WHO, 2022). The pollutants in form of Particulate matter (PM), Carbon monoxide (CO), Ozone (O_3), Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2) emitting from mineral dust, incomplete combustion of fuel woods and automobiles, photochemical smogs, industries, burning of fossil fuels and the smelting of mineral ores are causing human diseases and ceasing growth and development of the vegetations in the surroundings.

Air pollutants in the form of gaseous phase which includes emission of $NO_2$and SO_2 show impacts on lichens, the wet and dry deposition of sulfur and nitrogen compounds decline the forest, the nitrogen deposition results in ecosystem eutrophication and ground-level ozone emissions shows impacts on semi-natural vegetation (Stevens et al, 2020). The air pollutants show a significant reduction in the leaf length, width, area, and petiole length compared to the same plant species of non-polluted site. The plant species exhibit significant variation in their morphological features from season to season. These reductions were found maximum during summer, followed by autumn, and least during the spring season. The reduction percentage of various leaf attributes of polluted plants increases with the age of the plant and is noted to decrease in non-polluted sites (Leghari and Zaidi, 2013). In some exceptional cases, air pollutants in the form of Nitrogen dioxide (NO_2), Sulfur dioxide (SO_2), Carbone monoxide (CO), Suspended particulate matter (SPM) and Volatile organic compounds (VOCs) cause an increase in length rate in *Eucalyptus camaldulensis* leaves and high width rate, leaf area rate, number of stomata and epidermal cells in *Albizzialebbeck* leaves (Al-Obaidy et al, 2019).

The plant exposed to heavy metal pollution exhibits morphological, physiological, and biochemical modifications and changes in metabolic activities, showing imperative growth and loss in productivity. The plant although exhibit a general defense externally as well as internally to get adapted to this adverse situation, however, there is a need of more relevant techniques to combat stress tolerance in plants (Pandey et al, 2023).

The urban vegetation provides a significant services to the ecosystem (Weber, 2013), however the loss of these vegetation have shown negative impact on ecosystem like reduction in air quality and increase in air pollution, and climate regulation (De Carvalho and Szlafsztein, 2019). A decrease in dense vegetation coverage, increase in poor vegetation areas, and expansion of urban lands has significantly changed the land cover and losses in vegetation; resulting rise in air pollution (Mirsanjari et al 2020).There is a need to address this issue on priority basis to protect public health. Most of the sources of air pollution are beyond control of individuals requiring concrete action by local, national and regional level policy-makers. Application of advance scientific technology like efficient computer modeling tools, to provide decision support and developing high-quality planning documents with a social approach for optimal greenery arrangement seems a better solution to face the adverse situation (Badach et al, 2020).

II. AIR POLLUTION IN URBAN AREAS: A PERTURBING ISSUE

Urbanism as a social construction has continuously changed the living standards emerging as a significant biological challenges and human exposure to pollution leading to mortality, morbidity, reproduction, and individual development (Schell and Denham, 2003). The heterogeneous urbanization has shown inverse impact on land-use patterns and air quality of cities. The particulate matter level of small-sized to large metropolitan cities are not the same at various developmental levels, requiring a well designed planning strategy for minimizing air pollution (Liang and Gong, 2020). The urban areas with high density shows formation of wind-calm or vortex zones, retaining and enhancing air pollution, and affecting the environment and human health. These areas require spatial macroscopic planning strategies, along with mesoscopic block level, and microscopic building level designing to promote the dispersion of air pollutants (Yang et al, 2020).

In order to combat air pollution in urban areas, switching to thinking with natureinstead of technocratic ideas is better alternative. The greening of urban spaces require strategic designing with selection of suitable tree species keeping in mind the open roads and residential areas with high buildings to overcome the pollutants. Finally, restructuring of urban forestry programs, emphasis on research and development, revamping community mobilization and stakeholder involvement, are some other better strategies of pollutant removal in urban areas (Chaudhuri and Kumar, 2022). The planning and cost–benefit analyses of the 'green infrastructure' (GI) processes are challenging. The resilient to 'value engineering' between GI planning and its implementation should be ensured. An open-source specially programmed prototype software for estimation of the site-specific air quality impacts of roadside vegetation barriers can be endorsed to provide information to the practitioners related to site-specific impacts of vegetation barriers, and analyzing emission reduction (Pearce et al, 2021).

III. STRATEGIES AND POLICIES TO MITIGATE AIR POLLUTION

Clean technologies for industry, clean household energy solutions for cooking, clean modes of power generation for transportation and shifting to clean heavy-duty and low-emissions diesel vehicles, energy efficient buildings and green cities, use of alternative sources of power generation likesolar, wind or hydropower are better option in reducing air pollution. There should be a concrete strategy for municipal waste reduction and separation, recycling and reuse and using improved methods of biological and agricultural waste managementlikeanaerobic waste digestion to produce biogas, and economical alternatives for open incineration of solid waste.

Moreover, adopting low-carbon development path for resilient and cost effective health service delivery, for minimizing environmental health risks to communities are some of the best techniques to reduce air pollution. The global air quality guidelines for limiting key air pollutants that causes health risks and also helps providing good practices to promote a gradual shift from high to lower pollutant concentrations is a vital framework in managing air pollution globally (WHO, 2022). The Spatial modelling of air pollution in urban areas using GIS data like LIDAR has emerged as an efficient technique for the measurement of NO_x and O_3 representing spatial interpolations of these pollutants in horizontal and vertical planes and helping in environmental analysis of air pollution(Matejicek, 2005).

IV. AIR POLLUTION REDUCTION TECHNIQUE IN URBAN AREAS

Urban greenspace can play a significant role in the transition to net-zero greenhouse gas emission and air pollution reduction as it promotes sustainable and active transport modes and healthy future cities (O'Regan and Nyhan 2023). Phyto-remediation has emerged as a viable technique to reduce air pollution in urban areas. The analytical study of particulate matter composition on leaf surface of the trees in urban areas in Poland mainly shows high concentration of Carbon, Oxygen, Silicon and Ferrous, and heavy metals like Mangenese, Chromium, Titanium, Lead, Barium, Zinc, Tin, Nickle and rare earth elements. The vines like *Parthenocissusquinquefolia,* shrubs like *Forsythia intermediata* and some conifers like *Quercusrubra*, *Crataegusmonogyna*, *Betulapendula 'Youngii'*, *Acerpseduoplatanus*, *Tiliacordata Mill.* has shown better potentiality of phylloremediation(Konczak et al. 2021).
The air pollution tolerance index study of tree species in polluted area of a town in India reveals that tree species like

Dalbergiasissoo, Cassia auriculata, Mangiferaindica, Jasminumauriculatum, Polyalthialongifolia, were found to be useful in reducing pollution in the area (Dwivedi and Pandey, 2006). Some of the roadside plants show significant anatomical adaptation to resist dust pollutants as in case of *Lantana camera* possessing trichome with reduced anatomical features and *Calatropisprocera* exhibiting modification in the structure of epidermis and stomatal features under exposure to dust pollutants in industrial areas (Tiwari and Pandey, 2017).

V. URBAN GREENERIES AND MITIGATION OF AIR POLLUTION

Urban Green Infrastructure has emerged as a better option in air quality improvement increasing in the forested area, improving human health and wellbeing, and providing wide range of ecosystem services and monetary benefits (Muresan et al, 2022). The urban parks and green space play a significant role in reducing $PM_{2.5}$ concentration and toxicity of the pollutants, black Carbon (BC) due to traffic emissions and urban heat island temperature (Gomez-Moreno et al., 2019; Su et al., 2022; Ryswyk et al, 2019).Some study suggest that varying climate and ecological conditions shows a remarkable effect on removal of air pollutants (Setala et al 2013).

Vegetation traffic barriers comprising suitable plant species with different levels of tolerance to air pollutants is an effective technique in improving roadside pollutants. Selection of the plant species should be based on context and conditions of the site targeting air pollutants. The plant leaf with special micromorphological traits having trichomes and ridges or grooves, the stomata with a characteristic of sub-micrometre particle and gaseous pollutant uptake should be preferred. Moreover some species shows special mechanism of reducing pollen emission and biogenic volatile organic compounds which is another important criterion for species selection to control urban pollutants (Barwise and Kumar, 2020).

The selection of roadside trees should also be on the basis of high pollutant deposition velocity for capturing vehicle-derived ultrafine particles. A study suggested that the leaves of some plant species like silver birch, yew, and elder shows very high capabilities in absorbing airborne ultrafine as well as heavy metal particles thus contribute significantly to improve urban air quality and minimization in human exposure (Wang et al.2019). A case study of Kathmandu reveals that *Cinnamomumcamphora* exhibited highest air pollution tolerance, *Neriumoleander* shows highest dust-capturing potential and these along with *Albiziajulibrissin*can be recommendedfor the roadside plantation (Shrestha et al, 2021).

Designing green urban space

Urbanization pressure has limited the quantity of land for expanding green spaces. Therefore, there is a need of enhancing landscape patterns of green space by preserving large natural patches and new increments around the existing green area to reduce higher pollution emissions (Chen et al, 2022). The presence of urban green areas like botanical gardens has more potential in minimizing Particulate Matter levels compared to areas with less vegetation cover and also provides better air quality (Junior et al, 2022). The design of green space involves potential users as it should be attractive, accessible, and well-maintained where people can socialize and feel safe, with an opportunity to motivate them to use it more often. The use of green space also requires informing and educating people and depends on lifestyle factors, life stages, and individual values (Kruize et al, 2019).

The vegetation planning in urban areas requires careful designing, planning, and cost–benefit analysis with special emphasis on computer simulations for predicting interaction between urban forest and the ambient atmosphere (Leung et al 2011). It has been observed that better planting of vegetation instead of planting more vegetation shows more potentiality in air pollutant reduction (Han, 2020). The vegetation that is common to a particular geographical location significantly influencing neighborhood and municipal scale and under the affect of wind conditions or local air pollution concentration is more preferable in controlling air pollution (Badach et al, 2020).

The roadside vegetation of sufficient height, thickness, and coverage shows better potential in reducing half the downwind air pollutants in the urban areas (Deshmukh et al 2019).Low vegetation close to air pollution sources improve air quality by increasing deposition. The vegetation barriers should be dense and porous to offer large deposition surface area and allow penetration of the air stream. (Janhall, 2015). Green leaf area, tree bark and branches are significant factors for improving air quality in urban areas (Klingberg et al, 2017). Trees with trichomes, waxes, wrinkled leaf surfaces, low Volatile Organic Compound (VOC) emitters and low or moderate Ozone Forming Potential (OFP) have better potential in absorbing pollutants (Baraldi et al, 2019). The hedges or shrubs with heights less than 2 m should be preferred instead of large dense trees to improve roadside air quality (Chen et al., 2021).

VI. CONCLUSION

In conclusionroadside vegetation may be used by policy makers as a tool for minimizing the air pollutants and health impacts of traffic pollution on nearby roads for local populations. Trees reduce Particulate Matter as concentrated clouds of minuscule air pollutant particles get dispersed in the leaves decreasing the risk of inhalation by humans and also the suspended particles get easily trapped in the hairy leaves of trees and later during rains they are washed away by water into drains. Roadside vegetation selection is an important criterion for designing and planting of tree species as the concerns must be long enough to mitigate air pollution near and around the edges.

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