GESA
GLOCAL ENVIRONMENT & SOCIAL ASSOCIATION

International Journal of Biological Innovations
http://ijbi.org.in | http://www.gesa.org.in/journals.php
https://doi.org/10.46505/IJBI.2025.7103
IJBI 7(1): 22-29 **(2025)**
E-ISSN: 2582-1032

ASSESSMENT OF PARTICULATE MATTER PM_{10} AND $PM_{2.5}$ AND THEIR IMPACT ON *NEOLAMARCKIA CADAMBA* AND *CASCABETA THEVETIA* IN REWA (M.P.), INDIA

Shrishti Singh* and Atul Tiwari

Department of Environmental Biology, A.P.S. University, Rewa (M.P.), India

**Corresponding author*: srishtithakur2098@gmail.com

Article Info:
Research Article
Received
13.10.2024
Reviewed
31.01.2025
Accepted
21.02.2025

Abstract: Foliar surface of the plant is continuously exposed to the surrounding atmosphere and is the main receptor of particulate matter ($PM_{2.5}$ and PM_{10}). Particulate matters affect the photosynthesis, respiration, transpiration and allow the penetration of phytotoxic gaseous pollutants. The present exploration was undertaken during June 2023 to July 2024 to study the seasonal variation in particulate matter accumulation on leaves and their impact on roadside two common tree species namely *Neolamarckia cadamba* and *Cascabeta thevetia* in the region of Rewa city. Authors found that maximum particulate matter accumulation occurred during winter followed by summer and minimum in rainy season in both the species. *Neolamarckia cadamba* showed more particulate matter accumulation on leaves in comparison to *Cascabeta thevetia.* Particulate matter accumulation in different plant species not only depends upon the sources and amount of pollutants in the environment but also depends on morphological characteristics of plants like leaf size and surface, texture, hair, wax, length of petiole, weather condition and wind direction. These roadside trees can be used in the abatement of pollutants as they act as natural purifiers.

Keywords: Air pollution, Micro-morphological traits, $PM_{2.5}$, PM_{10}, Rewa, Roadside trees.

Cite this article as: Singh S. and Tiwari A. (2025). Assessment of particulate matter PM_{10} and $PM_{2.5}$ and their impact on *Neolamarckia cadamba* and *Cascabeta thevetia* in Rewa (M.P.), India. *International Journal of Biological Innovations*. 7(1): 22-29. https://doi.org/10.46505/IJBI.2025.7103

INTRODUCTION

Air pollution has become a major global public health issue, leading to 6.67 million deaths worldwide and 1.67 million deaths in India annually (HEI, 2020). With the increase in urbanization, environmental problems increased and new cities that are estranged from nature emerge (Karagulian *et al*., 2015; Belkayali and Güloğlu, 2019). Plants used in roads, which determine the direction of city's development, provide such contributions in reducing the noise, creating a living space for wildlife, providing micro climate as well as providing aesthetic contributions such as setting a background for architectural structure of the city and screening the undesired sceneries (Singh *et al*., 2014; Perez *et al*., 2016). Urban roadside plantation takes on an important task in increasing the environmental quality by absorbing air-sourced pollutants (particulate matters, heavy metals, etc.), beyond all of these contributions (Kazi *et al*., 2021).

Particulate matter of size less than 10μm (PM_{10}) and PM of size less than 2.5 μm ($PM_{2.5}$) in air are known to cause several ailments in human including cardiovascular diseases, uncontrolled blood pressure, lung disorders, asthma, defective blood coagulation, deep vein thrombosis, lung cancer and also death (Baccarelli and Bollati, 2007). About six thousand premature deaths annually were recorded alone in India due to polluted air (Kanwade *et al*., 2020). As India is a developing country, the population density is higher, which contributes to higher intake fractions of PM (Apte *et al*., 2012). Transportation emissions have been considered one of the most important sources of fine particulate matter in cities (Ozdemir, 2019).

The lower levels of air pollutants were experienced during COVID-19 lockdown due less transportation (Verma and Prakash, 2020; Hammer *et al*., 2020). All types of pollution and excessive anthropogenic activities badly influence the tree growth hence the biodiversity (Prakash and Verma, 2022; Singh *et al.,* 2023). Dust pollution cause negative impact on plants as it affects respiration, transpiration, reduced photosynthesis and cause leaf fall with tissue death (Farooq *et al.,* 2000; Shrivastava and Joshi, 2002; Chauhan, 2010). Salvador *et al*. (2012) reported higher $PM_{2.5}/PM_{10}$ ratio during winter due to meteorological parameters including less rainfall or precipitation conditions, low temperature, high fog events occurring in this season, lower boundary layer depth and stable atmospheric conditions, which limit $PM_{2.5}$ dispersion in ambient atmosphere (Aldabe *et al*., 2011; Malandrino *et al*., 2013; Lorga *et al*., 2015; Munir *et al*., 2017; Xu *et al*., 2018). The lowest concentration during monsoon season may be attributed to washout by rainfall and due to higher relative humidity, which reduces re-suspension of dust (Jayamurugan *et al*., 2013; Asl *et al*., 2018; Sari *et al*., 2019).

Trees are bio-monitors and sink for air pollutants but better sinking ability comes from trees with high tolerance for air pollution (Chaudhary and Rathore, 2019; Mandal *et al.,* 2023; Yuniati *et al*., 2024), and dense vegetation could effectively block the penetration of road particulate matter (Lukowskie *et al*., 2020; Roy and Bhattacharya, 2020; Zheng *et al*., 2021). Among the evergreen, coniferous plants are an excellent choice for air purification due to the abundant wax layer on the needles, smaller leaves, and more complex shoot structures (Freer-Smith *et al*., 2005).

The ability of leaves to act as dust receptors depends upon their surface geometry, orientation, phyllotaxy, epidermal and cuticle features, leaf pubescence, leaf and branch density, leaf micro morphology (roughness, trichomes and wax), canopy type and plant height (Burkhardt, 2010; Rasanen *et al.,* 2013; Sgrigna *et al*., 2015). Smaller plants with short petioles and rough surface accumulate more dust than larger plants with long petioles and smoother leaf surface (Thakar and Mishra, 2010). The proposed research work aimed to investigate the ability of roadside tree species to capture or retain ambient air particulate matters with particular reference to foliar micro morphological traits and to quantify the total particulate matter (TPM), PM_{10} and $PM_{2.5}$ of both tree species growing along roadside of Rewa City of Madhya Pradesh, India.

.

MATERIALS AND METHODS

Study sites:
The present study was conducted in Rewa city of Madhya Pradesh, which is situated in the central part of India. It is the administrative center of Rewa Divison. It lies between 24°18' and 25°12' north latitude and 81°2' and 62°18' east longitudes. Rewa has a humid subtropical climate, with cold, misty winter, a hot summer and a humid monsoon season. The average temperature being around 30°C (86°F).The geographical area of Rewa district is 6,314 km. Rewa district is bounded on east and south-east by Sidhi , on the south- east by Sidhi, on the south

by Shahdol and on the west by Satna district, Rewa city is lies about 450 km north-east of state capital Bhopal and 130 km south of Prayagraj city. Air quality monitoring at 6 selected sites of Rewa city have been carried out viz; Sirmour square (Site 1), PTS Square (Site 2), New Bus Stand (Site 3), Old Bus Stand (Site 4) and Prakash Square (Site 5) along with control site APS University Campus (Site 6) of Rewa city for one year (June 2023 to July 2024).

Leaf Sample Collection:

Nearly equal size of 20 leaves from both tree species *Neolamarckia cadamba* (Kadam) and *Cascabeta thevetia* (Kaneir*)* growing along different roadsides of the city collected from a height of approximately 2 meter (ambient height) within one day to minimize temporal changes. The leaf samples collected in the zip lock plastic bags during monsoon, winter and summer months with lesser wind speed. During collection, samples immediately closed and labelled in plastic bags to avoid contamination and transported into the laboratory and kept in freezer at 4^{O}C.

Quantitative Analysis of Particulate Matter (PM):

The PM measurement conducted using a rinse and weigh methodology developed by Chen *et al*. (2017). Briefly, the collected leaves of each species soaked in distilled water for 60 minutes and PM fractions of 3 categories (large, coarse, fine) rinsed off from the leaves by using 200 ml distilled water and fine brush. Dust removed from both surfaces of leaves. For each site, a new clean brush was used for dust removal to avoid the carryover of dust from the previous samples. The resulting rinse water first filtered through a 100 μm through Whatman paper filters Type 91 (retention 10 μm) (Whatman, UK). In this way, the PM_{10} fraction of surface PM obtained, which consists of PM in the 10-100 μm diameter range. The obtained filtrate then filtered through Whatman paper filters Type 42 (retention 2.5 μm) (Whatman, UK), separating from the filtrate the $PM_{2.5}$ fraction containing between 2.5 and 10 μm particles. The filters used to the analysis first soaked in distilled water for 2 hours and then dried at 105°c in a drying chamber for 3 hours to remove soluble impurities, and then they placed in a balancing chamber for 48 hours to stabilize the humidity change.

Filters weighted before and after using electronic top balance. The resulting weight of PM 10-100 and 2.5-10 only account 90% of original rinsing liquid and therefore divided by 0.9 to obtain the total PM 10-100 ($W_{PM10-100}$) and PM 2.5-10 ($W_{PM2.5-10}$). The PM 2.5 mass then calculated as a difference between the WTSP and the sum of $W_{PM10-100}$ and $W_{PM2.5-10}$. To facilitate the species comparison, leaf area normalized PM accumulation results (i.e. in the unit of μg cm^{-2}) required. Therefore, the leaf surface area obtained with the help of suitable methods.

RESULTS AND DISCUSSION

The result of particulate matter (PM) on the leaves of two tree species under study, growing at polluted sites (S1, S2, S3, S4, S5) and controlled site (S6) during analysis is summarized in figure1 and figure 2. It was observed that both tree species showed higher particulate matter accumulation in winter followed by summer and lowest in rainy season. The average particulate matter accumulation was noticed higher in *Neolamarckia cadamba* (PM2.5=0.132, PM10= 0.068, TPM= 0.182 $\mu g/cm^2$). Average amounts of PM2.5, PM10 and total PM i.e. TPM per unit area of leaf surface of *Neolamarckia cadamba* species are given in Table 1.

Leaves of *Neolamarckia cadamba* at Site-2 (PTS Square) had highest deposits of this fraction as compared to lowest deposit on leaves of Site- 6 (University campus) and lower average particulate matter accumulation observed in *Cascabeta thevetia* (PM2.5 = 0.081, PM10 = 0.092, TPM = 0.145 $\mu g/cm^2$). Average amounts of PM2.5, PM10 and TPM per unit area of leaf surface of this species are given in Table 2.

Leaves of *Cascabeta thevetia* at Site-3 (New Bus Stand) had highest deposits of this fraction as compared to lowest deposit on leaves of Site- 6 (University campus). Similarly, Site 6 (University campus) was observed to have very less average concentration of particulate matters (PM2.5, PM10, TPM) during study period. This site is situated towards the peripheral of the town and there is less movement of the traffic from the other mentioned sites and the atmosphere is clean and a number of green plants are present which contributes the lesser average value of pollutants of the region. This observation is also been corroborated with the work of Giri *et al.* (2006). Both of them found that high concentration of particulate matter in some selected places of Pakistan and Kathmandu, which is attributed due to traffic volume, length of days and meteorological condition.

The basic data have been computed with suitable statistical approach (ANOVA) to observe the inter- as well as intra-sites seasonal differences in concentrations of various pollutants for the year 2023-2024. This trend of seasonal variation in pollutant concentrations under present investigation supports the finding of other workers (Bhaskar and Mehta, 2010; Guttikunda and Jawahar, 2011; Nair *et al.*, 2014; Singh *et al.*, 2021).

Higher particulate matter accumulation on *Neolamarckia cadamba* leaves may be due to their rough foliar surface with depression in the middle of the leaves; small petioles that reduce movement of leaves in wind and shortness of the plants also must be taken into account. Lower particulate matter accumulation on *Cascabeta thevetia* may be due to medium height of the plants. The higher concentration of particulate matter accumulation was noticed during winter season (due to low temperature, wet surface of leaves that help in particulate matter capturing) followed by summer (due to high temperature and strong wind speed) and lowest in rainy season (due to washing leaves). Particulate matter accumulation in different plant species not only depends upon the sources and amount of pollutants in the environment but also depends on morphological characters of plants like leaf size, texture, hair, length of petiole, weather condition and wind direction (*Prajapati et al.*, 2006; Harrison *et al.*, 2021).

Table 1: Average Particulate matter $PM_{2.5}$, PM_{10} and TPM accumulation ($\mu g/cm^2$) in *Neolamarckia cadamba* (Kadam tree).

Seasonal particulate matter content $\mu g/cm^2$ on the leaf surface of *Neolamarckia cadamba* (Kadam tree) growing at road sides of Rewa city during the year 2023-2024.												
Study site	**$PM_{2.5}$ ($\mu g/cm^2$)**				**PM_{10} ($\mu g/cm^2$)**				**Total PM ($\mu g/cm^2$)**			
	Rainy	**Winter**	**Summer**	**Average**	**Rainy**	**Winter**	**Summer**	**Average**	**Rainy**	**Winter**	**Summer**	**Average**
S1	0.077	0.117	0.810	0.335	0.059	0.089	0.071	0.073	0.139	0.254	0.163	0.185
S2	0.063	0.123	0.083	0.090	0.06	0.082	0.066	0.069	0.140	0.251	0.132	0.174
S3	0.072	0.128	0.092	0.097	0.043	0.083	0.061	0.062	0.139	0.249	0.186	0.191
S4	0.071	0.130	0.091	0.097	0.045	0.082	0.062	0.063	0.143	0.222	0.177	0.181
S5	0.066	0.118	0.096	0.093	0.056	0.091	0.064	0.07	0.142	0.249	0.188	0.193
S6	0.058	0.102	0.078	0.079	0.058	0.089	0.062	0.05	0.132	0.247	0.131	0.170
Average	0.068	0.120	0.208	0.132	0.054	0.086	0.064	0.068	0.139	0.245	0.163	0.182

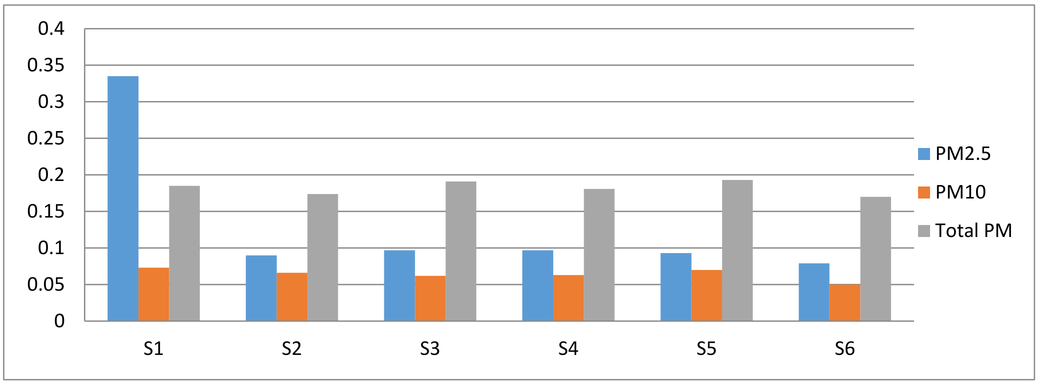

Fig.1: Seasonal variation of Particulate matter $PM_{2.5}$, PM_{10} and TPM accumulation ($\mu g/cm^2$) in *Neolamarckia cadamba* (Kadam tree).

Table 2: Average Particulate matter $PM_{2.5}$, PM_{10} and TPM accumulation ($\mu g/cm^2$) in *Cascabeta thevetia* (Kaneir).

Seasonal particulate matter content $\mu g/cm^2$ on the leaf surface of *Cascabeta thevetia* (Kaneir) tree growing at road sides of Rewa city during the year 2023-2024												
Study site	$PM_{2.5}$ (μg/cm²)				PM_{10} (μg/cm²)				Total PM (μg/cm²)			
	Rainy	Winter	Summer	Average	Rainy	Winter	Summer	Average	Rainy	Winter	Summer	Average
S1	0.077	0.077	0.072	0.075	0.063	0.121	0.083	0.089	0.136	0.165	0.142	0.148
S2	0.093	0.093	0.073	0.086	0.069	0.126	0.089	0.095	0.149	0.174	0.138	0.154
S3	0.092	0.092	0.072	0.085	0.068	0.112	0.099	0.093	0.153	0.174	0.132	0.153
S4	0.091	0.091	0.071	0.084	0.073	0.102	0.096	0.09	0.109	0.172	0.132	0.138
S5	0.086	0.086	0.066	0.079	0.077	0.125	0.093	0.098	0.133	0.176	0.129	0.146
S6	0.076	0.077	0.070	0.074	0.075	0.12	0.062	0.086	0.106	0.163	0.131	0.133
Average	**0.086**	**0.086**	**0.071**	**0.081**	**0.071**	**0.118**	**0.087**	**0.092**	**0.131**	**0.171**	**0.134**	**0.145**

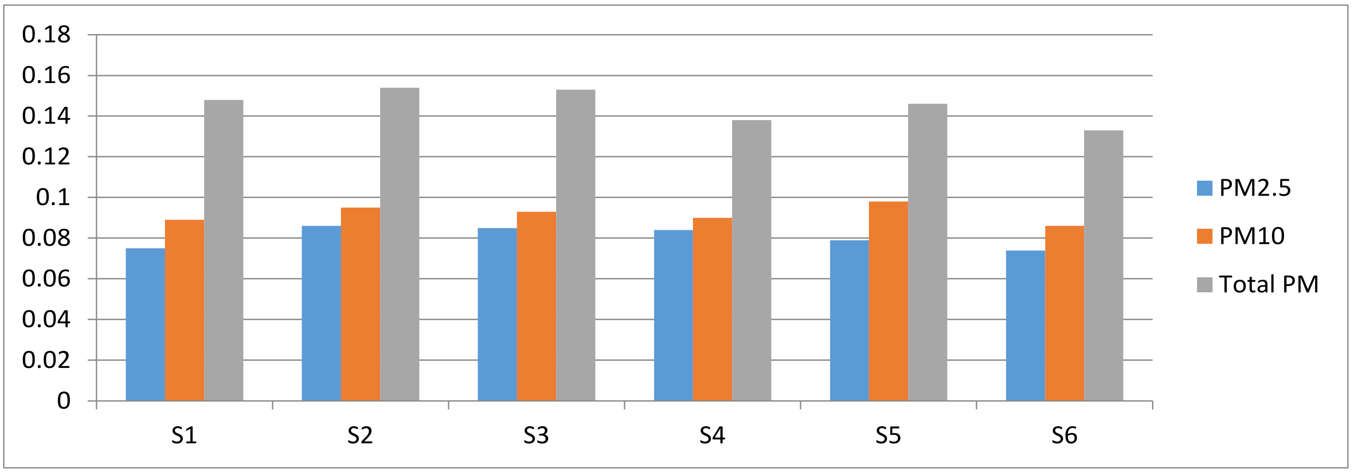

Fig. 2: Seasonal variation of Particulate matter $PM_{2.5}$, PM_{10} and TPM accumulation ($\mu g/cm^2$) in *Cascabeta thevetia* (Kaneir).

CONCLUSION

Plants play an important role in monitoring and maintaining the ecological balance and also provide enormous leaf area for impingement, absorption and accumulation of air pollutants to reduce the pollution level in the environment. The present finding indicate that the exhaust released from automobiles and diesel engine vehicles cause abnormal changes in the micro morphological characters of leaves of tree species and these changes could be considered as indicator of environmental stress.

REFERENCES

1. **Aldabe J., Elustondo D. and Santamarıa C.** (2011). Chemical characterization and source apportionment of PM2.5 and PM10 at rural, urban and traffic sites in Navarra (North of Spain). *Atmos. Res.* 10(2): 191-205. 10.1016/j.atmosres.2011.07.003.
2. **Asl F.B., Leili M., Vaziri Y., Arian S.S., Cristaldi A., Conti G.O. and Ferrante M.** (2018). Health impacts quantification of ambient air pollutants using AirQ model approach in Hamadan, Iran. *Environmental Research.* 161:114-121. 10.1016/j.envres.2017.10.050.
3. **Apte J.S., Bombrun E., Marshall J. D. and Nazaroff W.W.** (2012). Global intra-urban intake fractions for primary air pollutants from vehicles and other distributed sources. *Environmental science and technology.* 46(6):3415-3423. 10.1021/es204021h
4. **Baccarelli A. and Bollati V.** (2009). Epigenetics and environmental chemicals.

Curr Opin Pediatr. 21(2):243-251. 10.1097/mop.0b013e32832925cc

5. **Belkayalı N. and Güloğlu Y.** (2019). Physical and social barriers for disabled urban park users: case study from Kastamonu, Turkey. *Forestist.* 69(1):35-43. 10.26650/forestist.2019.414498.
6. **Bhaskar B.V. and Mehta V.M.** (2010). Atmospheric particulate pollutants and their relationship with meterology in Ahemdabad. *Aerosol and Air quality Research*. 10:301-315. https://doi.org/10.4209/aaqr.2009.10.0069
7. **Burkhardt J.** (2010). Hygroscopic particles on leaves: Nutrients or desiccants? *Ecol. Monogr.* 80:369-399. https://doi.org/10.1890/09-1988.1
8. **Chauhan A.** (2010). Photosynthetic pigment changes in some selected trees induced by automobile exhaust in Dehradun, Uttarakhand. *New York Science Journal*. 3(2): 45-51.
9. **Chaudhary I.J. and Rathore D.** (2019). Dust pollution: its removal and effect on foliage physiology of urban trees. *Sustain. Cities Soc.* 51: 1-10. https://doi.org/10.1016/j.scs.2019.101696
10. **Chen L., Liu C., Zhang L., Zou R. and Zhang Z.** (2017). Variation in Tree Species Ability to Capture and Retain Airborne Fine Particulate Matter ($PM_{2.5}$). *Scientific Reports*. 7:3206. https://doi.org/10.1038/s41598-017-03360-1
11. **Farooq M., Arya K.R., Kumar S., Gopal K., Joshi P.C. and Hans R.K.** (2000). Industrial pollutants mediated damage to mango (*Mangifera Indica)* crop: A case study. *J. Environ. Biol.* 21:165-167.
12. **Freer-Smith P.H., Beckett K.P. and Taylor G.** (2005). Deposition velocities to *Sorbus aria, Acer campestre*, *Populus deltoids trichocarpa* 'Beaupre', *Pinus nigra* and *Cpuressocyparis leylandii* for coarse, fine and ultra fine particles in the urban environment. *Environ Pollut.* 133(1):157-167. 10.1016/j.envpol.2004.03.031.
13 **Giri D., Murthy K., Adhikary P.R. and Khanal S.N.** (2006). Ambient Air quality of Kathmandu valley as reflected by atmospheric particulate matter concentrations (PM 10). *International Journal of Environmental Science and Technology*. 3(4):403-410. https://doi.org/10.1007/BF03325949
14. **Guttikunda S. and Jawahar P.** (2011). Urban air pollution analysis in India. Urban Emission. Info., New Delhi, India.
15. **Hammer T., Gao H., Pan Z. and Wang J.** (2020). Relationship between aerosols exposure and lung deposition dose. *Aerosol Air Qual. Res*. 20:1083-1093. https://doi.org/10.4209/aaqr.2020.01.0033
16. **Harrison R.M., Allan J., Carruthers D., Heal M.R., Lewis A.C., Marner B., Murrells T. and Williams Andrew** (2021). Non-exhaust vehicle emissions of particulate matter and VOC from road traffic: A review. *Atmospheric Environment.* 262:118592. https://doi.org/10.1016/j.atmosenv.2021.118592
17. **HEI** (2020). Health Effect Institute, 75 Federal Street, Suite 1400, Boston, MA. https://www.healtheffects.org/annual-report-2020
18. **Jayamurugan R., Kumaravel B., Palanivelraja S. and Chockalingam M.P.** (2013). Influence of temperature, relative humidity and seasonal variability on ambient air quality in a coastal urban area. *International Journal of Atmospheric Environment.* Article ID 264046. https://doi.org/10.1155/2013/264046
19. **Kanawade V. P., Srivastava A. K., Ram K., Asmi E., Vakkari V., Soni V.K., Varaprasad C. and Sarangi C.** (2020). What caused severe air pollution episode of November 2016 in New Delhi? *Atmospheric Environment..* 222: 117125.
20. **Karagulian F., Belis C.A., Dora C.F.C., Prüss-Ustün A.M., Adair-Rohani H. and Amann M.** (2015). Contributions to cities' ambient particulate matter (PM): A systematic review of local source contributions at global level, *Atmospheric Environment.*120:475-483. https://doi.org/10.1016/j.atmosenv.2015.08.087.

21. **Kazi E., Shaikh Y., Tikle S., Beig G., Shaikh V.S., Kulkarni S. and Dhulop V.P.** (2021). Effect of air pollutants on urban roadside trees in Shivjinagar and Pashan area, Pune city *E.S. Food & Agroforestry.* 5:29-37. 10.30919/esfaf508

22. **Lorga G., Raicu C.B. and Stefan S.** (2015). Annual air pollution level of major primary pollutants in Greater Area of Bucharest. *Atmos. Pollut. Res.* 6(5):824-834. 10.5094/APR.2015.091

23. **Łukowski A., Popek R. and Karolewski P.** (2020). Particulate matter on foliage of *Betula pendula, Quercus robur*, and *Tilia cordata*: Deposition and ecophysiology. *Environ. Sci. Pollut. Res.* 27:10296-10307. https://doi.org/10.1007/s11356-020-07672-0

24. **Malandrino M., Di Martino M., Ghiotti G., Geobaldo F., Grosa M.M., Giacomino A. and Abollino O.** (2013). Inter-annual and seasonal variability in PM10 samples monitored in the city of Turin (Italy) from 2002 to 2005. *Microchemical Journal.* 107: 76-85. 10.1016/j.microc.2012.05.026

25. **Mandal M., Popek R., Przybysz A., Roy A., Das S. and Sarkar Abhijit** (2023). Breathing Fresh Air in the City: Implementing Avenue Trees as a Sustainable Solution to Reduce Particulate Pollution in Urban Agglomerations. *Plants. 12*(7):1545. https://doi.org/10.3390/plants12071545

26. **Munir S., Habeebullah T.M., Mohammed A.M.F., Morsy E.A., Rehan M. and Ali K.** (2017). Analyzing PM2.5 and its association with PM10 and meteorology in the arid climate of Makkah, Saudi Arabia. *Aerosol Air Qual. Res.* 17: 453-464. https://doi.org/10.4209/aaqr.2016.03.0117

27. **Nair N., Bamniya B.R., Mahecha G.S. and Dhavan S.** (2014). Analysis of ambient air pollution and determination of air quality status of Udaipur, Rajasthan, India. *International Research Journal of Environmental Sciences.* 3(6): 5-10.

28. **Ozdemir H.** (2019). Mitigation impact of roadside trees on fine particle pollution. *Science of The Total Environment.* 659: 1176-1185. 10.1016/j.scitotenv.2018.12.262

29. **Perez M.A., Tegebu F.N. and Steenbergen F.** (2016). Roadside planting in Ethiopia: turning a problem into an opportunity, *Sustainability in Environment*. 1(2): 98-115. 10.22158/se.v1n2p98

30. **Prajapati S.K., Pandey S.K. and Tripathi B.D.** (2006). Monitoring of vehicles derived particulates using magnetic properties of leaves. *Environ. Monit. Assess*. 120:169-175. 10.1007/s10661-005-9055-y

31. **Prakash S. and Verma A.K.** (2022). Anthropogenic activities and Biodiversity threats. *International Journal of Biological Innovations.* 4(1): 94-103. https://doi.org/10.46505/IJBI.2022.4110.

32. **Räsänen J.V., Holopainen T., Joutsensaari J., Ndam C., Pasanen P., Rinnan Å. And Kivimäenpää M.** (2013). Effects of species-specific leaf characteristics and reduced water availability on fine particle capture efficiency of trees. *Environ. Pollut.* 183: 64-70. 10.1016/j.envpol.2013.05.015

33. **Roy A. and Bhattacharya T.** (2020). Air pollution tolerance, dust capturing capacity of native tropical trees for green belt development in Dhanbad and Bokaro city, Jharkhand, India. *J. Indian Chem. Soc*. 97: 635-643.

34. **Salvador P., Artınano B., Viana M., Alastuey A. and Querol X.** (2012). Evaluation of the changes in the Madrid metropolitan area influencing air quality: analysis of 1999–2008 temporal trend of particulate matter. *Atmos. Environ*. 57:175-185. 10.1016/j.atmosenv.2012.04.026

35. **Sari M.F., Tasdemir Y. and Esen F.** (2019). Major air pollutants in Bursa, Turkey: their levels, temporal changes, interactions, and sources. *Environmental Forensics.* 20(2):182-195. 10.1080/15275922.2019.1597782

36. **Sgrigna G., Saebo A. and Gawronski S.** (2015). Particulate matter deposition on Quercus ilex leaves in an industrial city of central Italy. *Environmental Pollution*. 197: 187-194. 10.1016/j.envpol.2014.11.030

37. **Shrivastava N. and Joshi S.** (2002). Effect of automobile air pollution on the growth of some plants at Kota. *Geobios*. 29:281-282. 10.12944/CWE.12.2.26

38. **Singh S., Mishra R.M., Singh P. and Singh M.** (2021). Leaf dust accumulation and its impact on chlorophyll content of *Azadirachta indica* and *Bauhinia variegata* developing in the proximity of J.P. cement plant, Rewa (M.P.) India. *International Journal of Biological Innovations*. 3(1): 173-178. 10.46505/IJBI.2021.3117

39. **Singh R.R., Goyal N. and Kaur N.** (2014). Importance of roadside vegetation. *International Journal of Progresses in Civil Engineering (IJPCE)*. 1(1): 2394-4684.

40. **Singh R., Verma A.K. and Prakash S.** (2023). The web of life: Role of pollution in biodiversity decline. *International Journal of Fauna and Biological Studies*. 10(3): 49-52. 10.22271/23940522.2023.v10.i3a.1003

41. **Thakar B.K and Mishra P.C.** (2010). Dust collection potential and air pollution tolerance index of tree vegetation around Vedanta Aluminium limited, Jharsuguda. *The Bioscan*. 3:603-612.

42. **Verma A.K. and Prakash S.** (2020). Impact of Covid-19 on Environment and Society. *Journal of Global Biosciences*. 9 (5): 7352-7363.

43. **Xu Y., Xu W. and Mo L.** (2018). Quantifying particulate matter accumulated on leaves by 17 species of urban trees in Beijing, China. *Environmental Science and Pollution Research*. 25(13): 12545-12556. 10.1007/s11356-018-1478-4

44. **Yuniati R., Handayani L., Khoerunnisa I., Halimah Putrika A. and Hemelda N.M.** (2024). The capacity of trees to remove particulate matter and lead and its impact on tree health. *Biodiversitas*. 25:2541-2551. 10.13057/biodiv/d250826

45. **Zheng T., Zhang S., Li X.B., Wu Y. and Peng Z.R.** (2021). Impact of vegetation on particle concentrations in roadside environments. *Environ. Pollut*. 282: 117067. 10.1016/j.envpol.2021.117067.