



Heavy metal tolerance of selected flowering and non-flowering plants in NCR-Delhi region

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ABSTRACT

The study aimed to evaluate the heavy metal tolerance and accumulation capacity of 7 different plant species (*Azadirachta indica*, *Alstonia scholaris*, *Ficus religiosa*, *Terminalia arjuna*, *Ficus infectoria*, *Cassia fistula* and *Polyalthia longifolia*) located at different sites (Lutyens area, IARI Pusa, Anand Vihar and NTPC Badarpur) at Delhi NCR. The heavy metal was determined and calculated the heavy metal burden and their relationship with the leaf dust accumulation. In addition, the correlations of heavy metals with Air Pollution Tolerance Index (APTI) were also determined. The results showed the significance variations in the accumulation of metals by the plant species and sample locations. The plant leaves samples collected from NTPC Badarpur site exhibited higher mean value of metal burden (20.84 g kg⁻¹), while lowest was found at IARI Pusa site (11.4120.84 g kg⁻¹). Among the 7 plant species *Terminalia arjuna* exhibited highest mean total heavy metal burden of 26.79 g kg⁻¹ with 0.124 mg of dust deposition followed by *Alstonia scholaris* heavy metal burden (26.33 g kg⁻¹) with 0.083 mg of dust deposition, while the lowest heavy metal burden was found in *Cassia fistula* (4.87 g kg⁻¹) followed by *Azadirachta indica* (7.72 g kg⁻¹) and *Polyalthia longifolia* (8.89 g kg⁻¹), respectively. A positive correlation (r=0.78) of heavy metal burden and leaf dust and negative correlation between metal burden and APTI were found.

Key words: Heavy metals, metal accumulation, leaf dust, APTI.

INTRODUCTION

The environment pollutant such as particulate matters and heavy metals such as cadmium, mercury, arsenic, zinc, chromium are affecting the human and living organism due to their persistence, toxicity and bioaccumulative natures (Ali *et al.*, 1; Khalid *et al.*, 5; Yan *et al.*, 16). Moreover, these heavy metals are responsible for the disrupt the biochemical and physiological process in plants by disrupt the cellular homeostasis, reduction of respiration rate, enzymatic activity and photosynthesis process in plants and increased the level of reactive oxygen species, generate oxidative stress and interfere with nutrient uptake, which resulted in inhibition of seed germination and root elongation in plants (Mohamed *et al.*, 9). The exposure of these heavy metals interferes the biochemical, physiological and biomolecule process in plants and altered their anatomical and morphological properties (Ejaz *et al.*, 3).

Therefore, understanding the accumulation and tolerance of heavy metals is very important to elucidate the mechanisms and physiological changes that occur in plants under stress conditions. Plants respond to

heavy metal stress through a range of morphological, physiological, and biochemical adaptations, including metal exclusion, compartmentalization, chelation, and activation of antioxidant defence systems. However, several plant species such as *Erigeron canadensis*, *Populus alba*, *Morus alba*, *Ficus religiosa*, *Ficus bengalensis*, *Eucalyptus globus*, *Azadirachta indica*, *Hevea brasiliensis* and others are considered heavy metal tolerant plant species, and they have the ability to cope with higher levels of heavy metals present in the environment (Ejaz *et al.*, 3; Kandpal and Rai, 4). Such species are of considerable importance in urban and industrial ecosystems, where they not only survive under metal-contaminated conditions but also contribute to the mitigation of environmental pollution through the absorption and accumulation of pollutants. The ability of these plants to maintain normal physiological functioning under heavy metal stress is closely associated with their Air Pollution Tolerance Index (APTI) and their capacity to accumulate dust and particulate matter on leaf surfaces. APTI serves as a reliable indicator of a plant's tolerance to air pollution, while leaf accumulated dust reflects the extent of particulate deposition and the plant's role in phytoremediation. Several studies have been conducted on the heavy metal tolerance capacity of different plant species with respect to minimizing environmental stress and pollutants (Mishra *et al.*, 8; Moustakas, 10; Narayanan and Ma, 11; Wijerathna

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et al., 15). However, information on the relationship between heavy metal accumulation, heavy metal burden, APTI, and leaf accumulated dust in plant species growing under contaminated environments remains limited. Therefore, the present study aimed to determine heavy metals, heavy metal burden, and their relationship with APTI and leaf accumulated dust.

MATERIALS AND METHODS

Based on the primary survey the major tree species such as *Azadirachta indica*, *Alstonia scholaris*, *Ficus religiosa*, *Terminalia arjuna*, *Ficus infectoria*, *Cassia fistula* and *Polyalthia longifolia* and experimental sites (Lutyens area, IARI Pusa, Anand Vihar and NTPC Badarpur) in urban Delhi NCR was selected for the study to determine heavy metal tolerance capacity of selected plants.

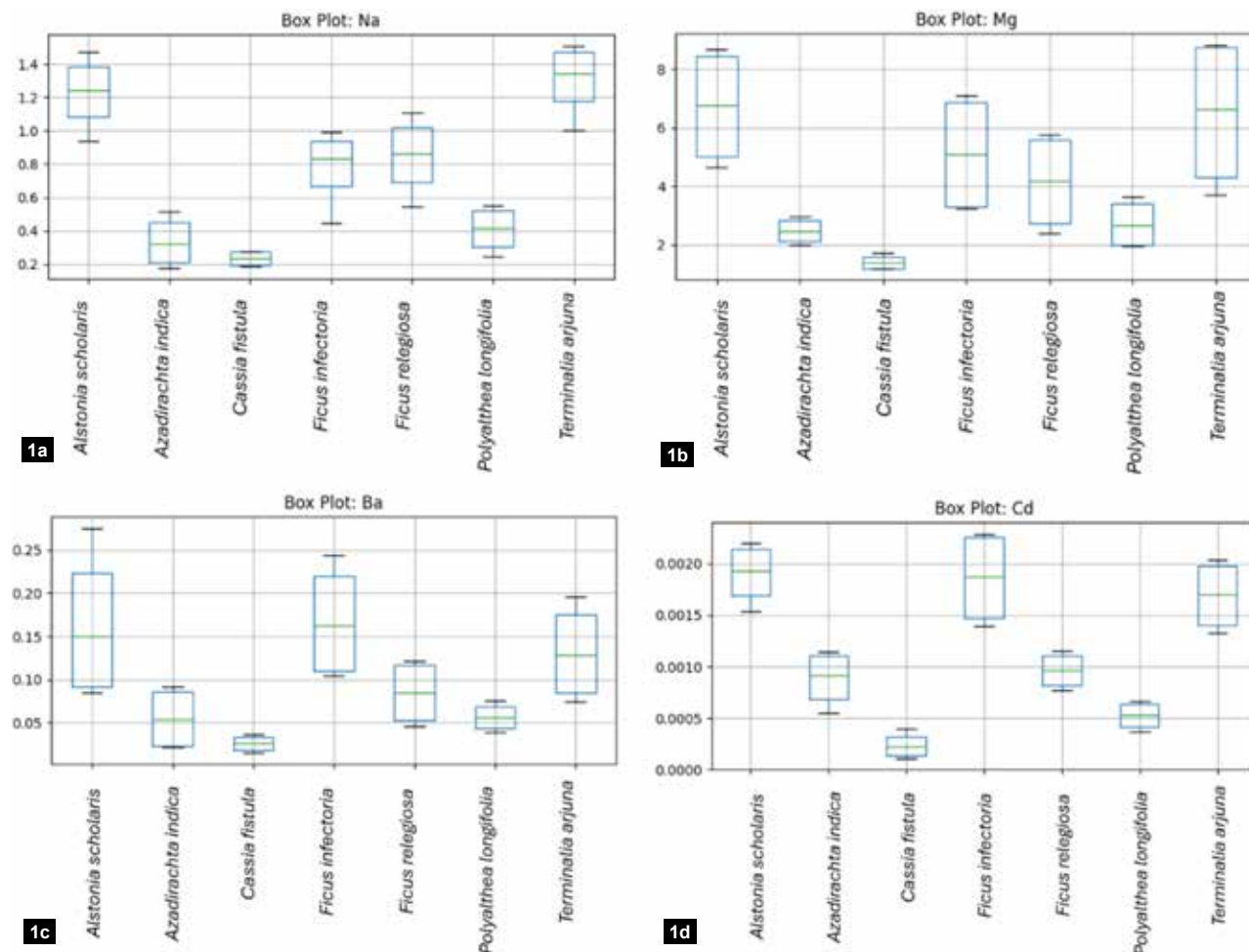
The heavy metal (Sodium (Na), Molybdenum (MO), Barium (Ba), Chromium (Cr), Cobalt (Co), Copper (Cu), Cadmium (Cd), Nickel (Ni), Lead (Pb), Zinc (Zn), Iron (Fe), Manganese (Mn) and Magnesium

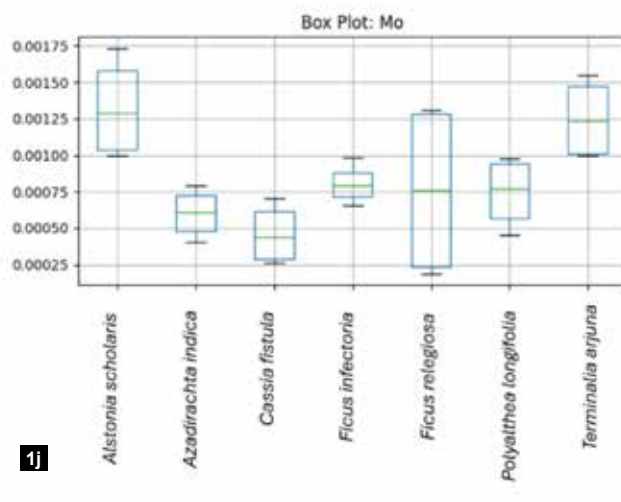
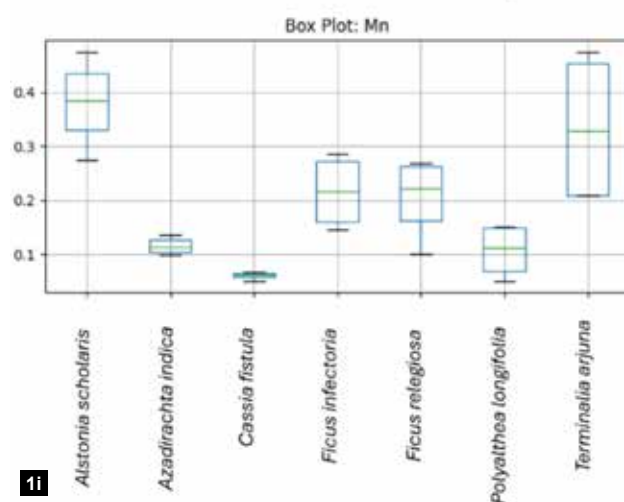
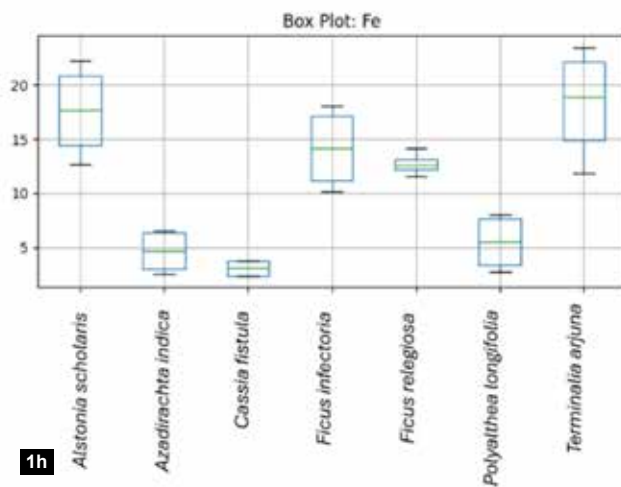
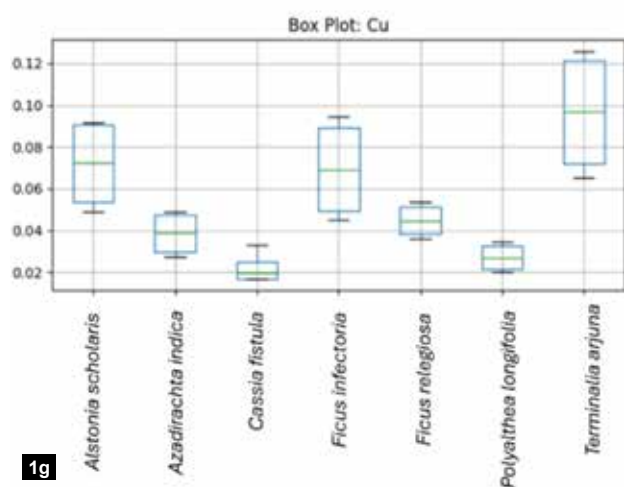
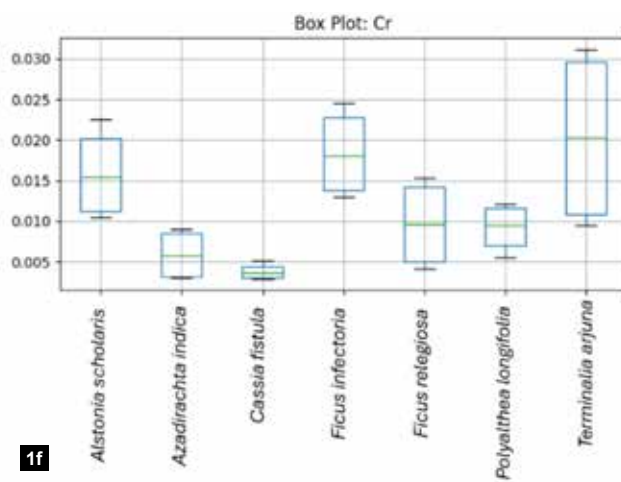
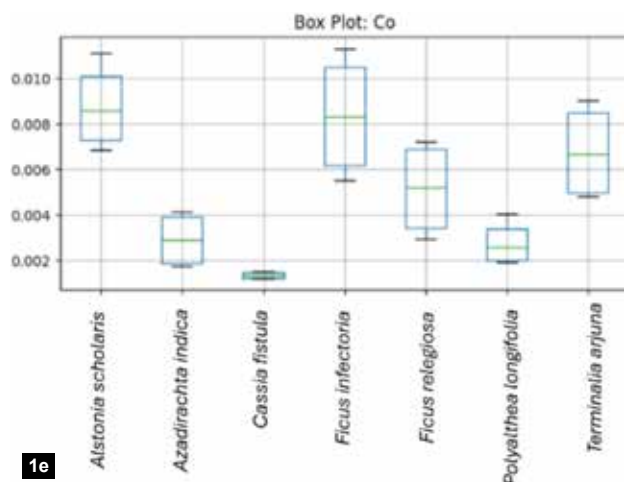
(Mg) in the selected tree species was determined (Liang *et al.*, 7; Panda *et al.*, 12). The value of the heavy metals was reported as g kg⁻¹.

The average value (n=3) of the 7 different plant leaf data was reported as results. The data were statistically analysed using Two Way ANOVA with appointed Post hoc Duncan multiple range test at 0.05% (p<0.05) of significance level. Origin Pro was used to assess the correlation between the heavy metal burden and leaf dust accumulation.

RESULTS AND DISCUSSION

The average results of the sodium (Na) accumulation by the selected plant species are shown in Fig. (1a). Na accumulation by the plant species was found in the pattern of *Terminalia arjuna* > *Alstonia scholaris* > *Ficus religiosa* > *Ficus infectoria* > *Polyalthia longifolia* > *Azadirachta indica* > *Cassia fistula*. Across all the study sites, the highest accumulation (1.00– 1.50 g kg⁻¹) of Na was exhibited in *Terminalia arjuna* plant followed by *Alstonia scholaris*, which ranged (0.94– 1.47 g kg⁻¹), respectively across





all the study sites. The lowest value of Na was exhibited in *Cassia fistula* followed by *Azadirachta indica* compared to other plants species. This higher accumulation of Na in plant species such as *Terminalia arjuna* and *Alstonia scholaris*. This might be possible

due to higher capacity to absorb Na from soil to plant tissues (Moustakas, 10).

The species wise and location wise variation in the accumulation of Magnesium (Mg) were observed among the plant species (Fig. 1b). *Alstonia*

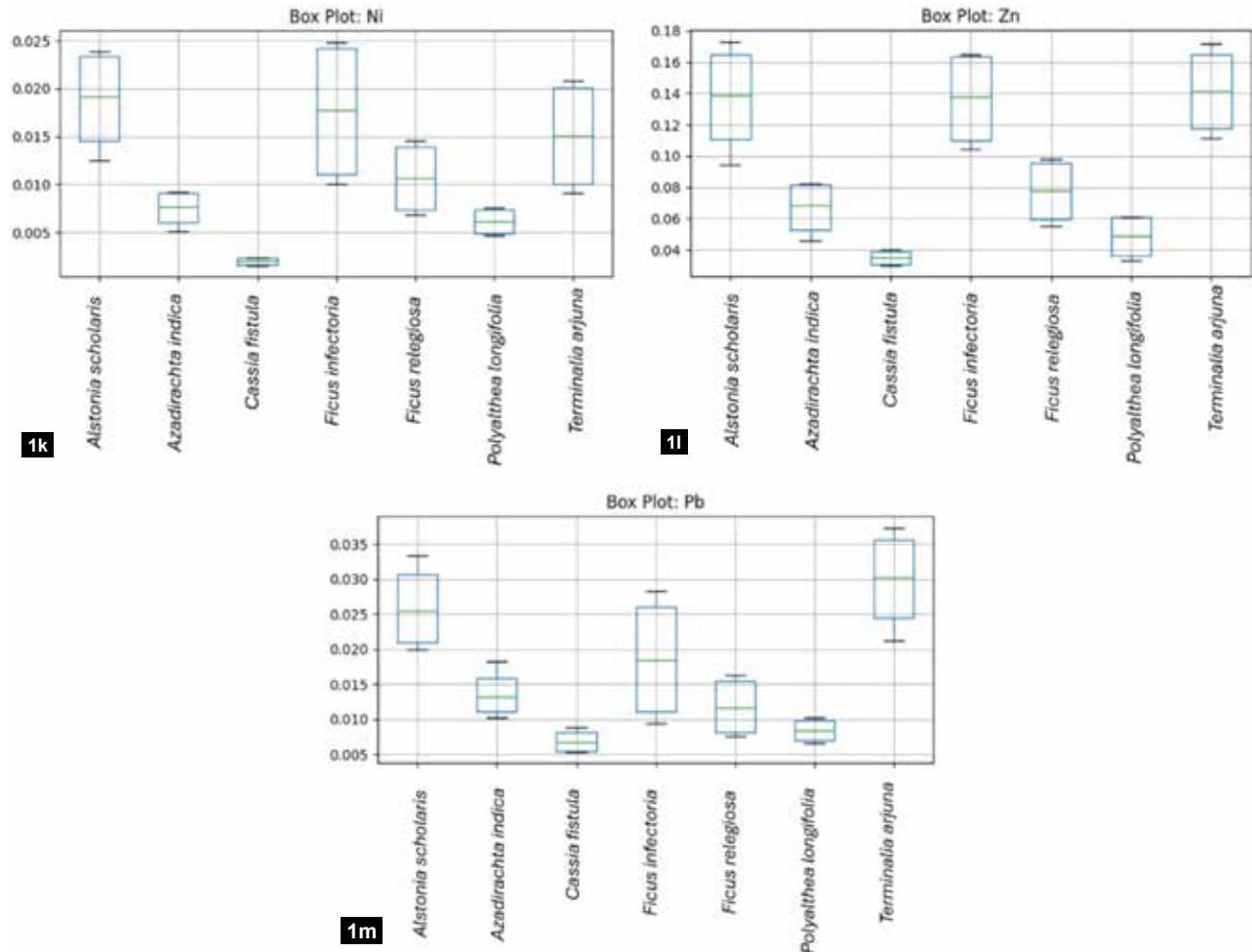


Fig. 1. Assessment of heavy metal tolerance capacity of selected urban plant species.

scholaris plant species showed the significant higher average value of Mg accumulation (6.70 g kg^{-1}) followed by *Terminalia arjuna* (6.44 g kg^{-1}) ranged from 5.13 to 8.67 g kg^{-1} and 4.52 to 8.82 g kg^{-1} , respectively among the locations. The plant located at NTPC Badarpur and Anand Vihar showed higher concentrations of Mg among the plants. The lowest accumulation of Mg was found in *Cassia fistula* plant followed *Azadirachta indica* and *Polyalthia longifolia*, respectively. The accumulation of lower concentration of Mg may be attributed to species specific variations, root absorption and regulation in internal nutrients (Narayanan and Ma, 11)

The accumulation of Barium (Ba) was varied among the plant species and locations, which indicated the site and species-specific exposure to accumulation and tolerance capacity (Fig 1c). The plants species *Alstonia scholaris* ($0.084 - 0.275 \text{ g kg}^{-1}$) and *Ficus infectoria* ($0.103 \text{ g kg}^{-1} - 0.244 \text{ g kg}^{-1}$) exhibited higher accumulation of Ba compared to other species. On

contrary, *Cassia fistula* showed the lowest concentration of Ba followed by *Azadirachta indica*, respectively. The consistently higher accumulation of Ba by *Alstonia scholaris* plants indicates a potential ability for uptake and retention of Ba. The accumulation of the metals such as Ba and others may depend on the species of plants and their metal regulation mechanism along with the capacity of plant tissue to absorption and retention of metal (Narayanan and Ma, 11).

The cadmium (Cd) levels had a wide range of variation among the various plant species and between sampling sites (Fig 1d). Among the plant species, *Alstonia scholaris* showed highest cadmium levels ($0.001903 \text{ g kg}^{-1}$), followed by *Ficus infectoria* ($0.001858 \text{ g kg}^{-1}$) and *Terminalia arjuna* ($0.001689 \text{ g kg}^{-1}$), but the lowest was in *Cassia fistula* ($0.000238 \text{ g kg}^{-1}$). The variation observed between different plant species might be due to differences in metal absorption and accumulation between species (Panda et al., 12).

The considerable variation in the plant species and location was recorded in the accumulation of Cobalt (Co). Among the 7 plant species *Alstonia scholaris* exhibited the higher accumulation of Co heavy metal followed by *Ficus infectoria*, while the lowest concentration was exhibited in *Cassia fistula* (Fig 1e). The plant species *Alstonia scholaris* showed the higher mean value of Co ($0.008796 \text{ g kg}^{-1}$) followed by *Ficus infectoria* ($0.008373 \text{ g kg}^{-1}$), respectively. The higher accumulation of the Co by these plant species indicated their specie specific ability of the uptake cobalt accumulation compared to other plant species. Moreover, the variation in the Co accumulation of plant species may also varied location wise, which indicated their environmental exposure (Narayanan and Ma, 11).

Fig. 1(f) shows the chromium (Cr) tolerance capacity of the plant species. The findings suggested the significant variation in the Cr tolerance capacity of the plant species and location dependent. The plant located at NTPC Badarpur exhibited higher concentration of Cr followed by Anand Vihar. Among the plant species, *Terminalia arjuna* exhibited higher concentration of Cr across the location ranged from 0.009 to 0.031 g kg^{-1} , while the lowest accumulation was observed by *Cassia fistula*, respectively. The variation in the accumulation of Cr in plant may depends on the environmental exposure, plant species and their tolerance capacity of metal accumulation (Panda *et al.*, 12).

The highest copper (Cu) concentration was observed in *T. arjuna* grown in NTPC Badarpur ($0.125806 \text{ g kg}^{-1}$), while lowest Cu concentration was recorded in *C. fistula* in IARI Pusa ($0.016910 \text{ g kg}^{-1}$) (Fig. 1g). Consistent higher concentration of Cu in *T. arjuna* may imply higher ability of this species to take up and accumulate copper. On the other hand, the observed low concentrations of Cu in *C. fistula* samples imply limited Cu accumulation in *C. fistula*. The differences in Cu concentrations can be related to the differences in environmental exposure, tolerance and retention capacity of plants (Narayanan and Ma, 11).

The levels of iron (Fe) varied greatly among the various plants that were analyzed as well as among the various sites of sampling (Fig 1h). The accumulation of Fe at the various sampling sites was as follows: NTPC Badarpur > Anand Vihar > Lutyens Area > IARI Pusa. Among the various species studied, the *Terminalia arjuna* and *Alstonia scholaris* showed comparatively higher accumulation of Fe while *Cassia fistula* had the lowest concentration of Fe at all sampling sites. The high levels of Fe at NTPC Badarpur and Anand Vihar might be due to differences in Fe availability in environment, anthropogenic

factors. The presence of higher environmental pollutant at polluted locations such as NTPC Badarpur and Anand Vihar, resulted presence and absorption of higher level of Fe in the plant species.

Manganese (Mn) content in the plant species showed in Fig. (1i). The order of Mn accumulation in the different sampling sites has been found to be NTPC Badarpur > Anand Vihar > Lutyens Area > IARI Pusa. of the studied species, *A. scholaris* and *T. arjuna* have relatively high Mn concentrations, while *C. fistula* has relatively low concentrations. This variability can be associated with differences in environmental Mn availability and local anthropogenic activity. In addition, the interspecific variation could be due to the different mechanisms of uptake, sequestration, translocation, and physiological regulation in plants (Panda *et al.*, 12).

Fig. 1 (j) showed the species wise variation in the tolerance and uptake capacity of Molybdenum (Mo). *Alstonia scholaris* exhibited the highest tolerance concentration of Mo followed by *Terminalia arjuna*, while lowest value of Mo was observed in *C. fistula*, respectively. The findings suggested that the variation in the accumulation of Mo depends on the sample location and other conditions including physiological status, environmental factors etc. The range of Mo accumulation from 0.0010 - $0.00172 \text{ g kg}^{-1}$ in *Alstonia scholaris* and 0.0010 - $0.00155 \text{ g kg}^{-1}$ in *Terminalia arjuna* were varied and location and sampling site may influence the accumulation capacity of plant species.

The concentrations of Nickel (Ni) showed a wide range of variation for the plants tested. The highest Ni concentration was found in the sample of *Ficus infectoria* taken from NTPC Badarpur ($0.024829 \text{ g kg}^{-1}$), whereas the lowest concentration was detected in the plant sample of *Cassia fistula* obtained from IARI Pusa ($0.001549 \text{ g kg}^{-1}$) (Fig 1k). In relation to the tested plant species, *Ficus infectoria* and *Alstonia scholaris* proved to accumulate larger amounts of Ni, while *Cassia fistula* showed the lowest concentration levels.

Fig. 1 (l) showed the considerable difference in the zinc (Zn) content between the plant species and sites studied. *A. scholaris*, *T. arjuna*, and *F. infectoria* showed higher levels of zinc accumulation whereas, *C. fistula* showed lower levels of Zn accumulation. The plants at NTPC Badarpur had higher Zn concentration compared to others. However, interspecific variation in the uptake of zinc may be due to different metal uptake and regulation physiology.

Lead (Pb) is an environmental pollutant that is toxic in nature and is one of the greatest concerns from environmental and health perspectives (Collin *et al.*, 2; Tahir *et al.*, 14). The concentration of Pb varied

considerably among the examined plant species and locations (Fig 1m). The highest concentration of Pb was noted in *Terminalia arjuna* of NTPC Badarpur ($0.037299 \text{ g kg}^{-1}$), while the next highest was seen in *T. arjuna* from Anand Vihar ($0.035059 \text{ g kg}^{-1}$) and in *Alstonia scholaris* of NTPC Badarpur ($0.033271 \text{ g kg}^{-1}$). On the other hand, the lowest concentration of Pb was found in *Cassia fistula* of IARI Pusa ($0.005330 \text{ g kg}^{-1}$).

The heat map shows the standardized heavy metal burden (Z-scores) of seven plant species for metals (Na, Mo, Ba, Cr, Co, Cu, Cd, Ni, Pb, Zn, Fe, Mn, and Mg) (Fig. 2). The colour scale reflects the relative abundance of metals, where yellow and green denote positive Z-scores and dark blue and purple denote negative Z-scores. *Terminalia arjuna* showed the highest metal-burden Z-scores among all plants, which were mainly high in Cu and Pb and additionally elevated in Na, Mo, Cr, Cd, Zn, Fe, Mn, and Mg. *Ficus infectoria* had a relatively high Z-score for Ba, Cr, Co, Cd, and Zn. *Alstonia scholaris* had moderate to high metal burdens, particularly for Mo and Mn. The plant species such as *Azadirachta indica*, *Cassia fistula*, and *Polyalthia longifolia* had mostly negative Z-scores for most metals, which indicated relatively low metal burdens,

The bar graph above shows the mean total heavy metal burden (g kg^{-1}) in relation to the dust present on the leaves of seven different plant species, which provides an indication of the total amount of particulate metal burden that these plants have managed to retain on their leaf surfaces (Fig. 3). There is a marked interspecific variation in terms of the total metal burden present. *Terminalia arjuna* had the highest mean total heavy metal burden of 26.79 g kg^{-1} , followed by *Alstonia scholaris*, which had 26.33 g kg^{-1} , suggesting that these two plants were able to retain more of the metal-containing particles in the atmosphere. *Ficus infectoria* had an intermediate total metal burden of 20.72 g kg^{-1} , while *Ficus religiosa* had 18.16 g kg^{-1} . However, *Polyalthia longifolia* (8.89 g kg^{-1}), *Azadirachta indica* (7.72 g kg^{-1}), and *Cassia fistula* (4.87 g kg^{-1}) had lower metal burdens.

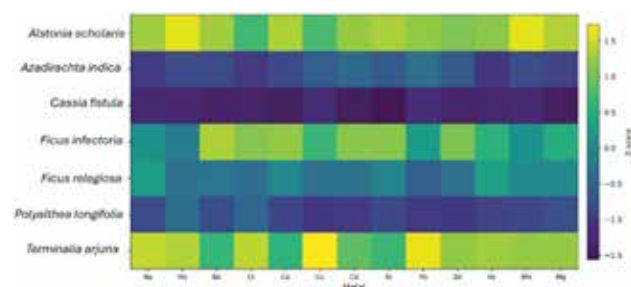


Fig. 2. Standardized heavy metal burden profile of plant species (Z-Score).

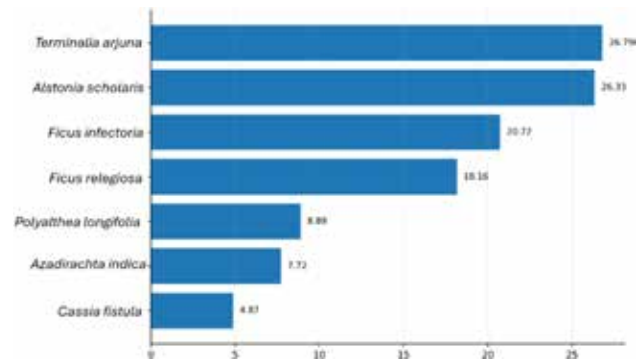


Fig. 3. Total heavy metal burden in dust accumulated on plant leaves.

g kg^{-1}), and *Cassia fistula* (4.87 g kg^{-1}) had lower metal burdens.

Fig. 4 demonstrated a negative correlation between the metal burden and the APTI: plants exposed to or retaining more metals are not necessarily more tolerant to air pollution. Pearson correlation coefficient equals $r = -0.48$ and hence represents a moderate negative correlation. The most significant exception is *Terminalia arjuna*, which demonstrates high metal load (26.8 g kg^{-1}) and the highest APTI (12.7). However, *Alstonia scholaris* demonstrated a high metal burden (26.3 g kg^{-1}), and lowest APTI (9.5). The overall trend indicates that there is a connection between APTI and foliar heavy-metal burden as they are different yet inter-related responses of plants to air pollution.

Fig. 5 hierarchical clustering analysis indicated that all the plant species were separated into two major clusters at a relatively large linkage distance. The first cluster comprised *Polyalthia longifolia*, *Azadirachta indica*, *Cassia fistula*, and *Ficus religiosa*,

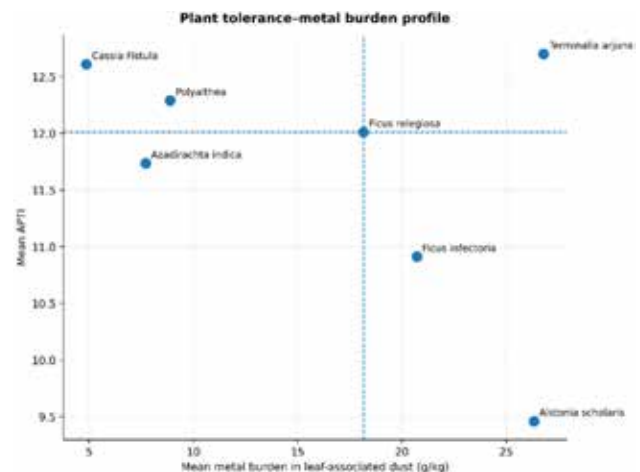


Fig. 4. Plant tolerance metal burden profile of plant species.

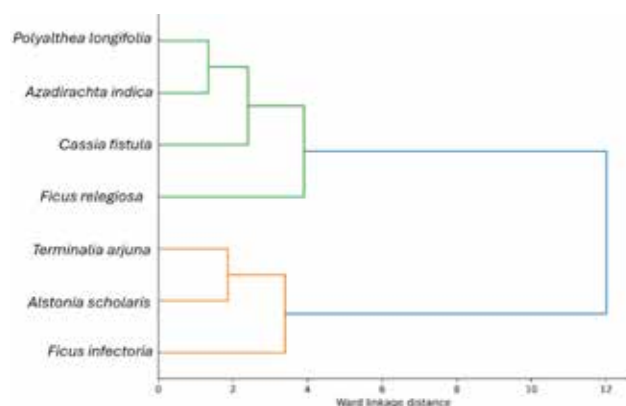


Fig. 5. Hierarchical clustering of plant species against heavy metal burden in leaf associated dust.

which exhibited comparatively lower and more similar heavy-metal burdens. Within this cluster, *Polyalthia longifolia* and *Azadirachta indica* showed the greatest similarity, as indicated by their early fusion at a low linkage distance, followed by their association with *Cassia fistula*. *Ficus religiosa* subsequently joined this group, indicating an intermediate but still relatively similar metal-burden profile. The second major cluster consisted of *Terminalia arjuna*, *Alstonia scholaris*, and *Ficus infectoria*, representing species with comparatively higher heavy-metal burdens in leaf-associated dust. *Terminalia arjuna* and *Alstonia scholaris* formed the closest pair, followed by the incorporation of *Ficus infectoria*, suggesting similarities in their overall metal-retention profiles. The two major clusters only merged at a substantially larger Ward linkage distance, indicating pronounced dissimilarity between the low-burden and high-burden species groups.

The scatter graph (Fig. 6) showed positive correlation between deposition of dust and total heavy metal load for all plants. From the Pearson correlation coefficient value ($r = 0.78$), there is a strong positive correlation which shows that plants with higher dust deposition also have high total metal load. *Terminalia arjuna* has high dust deposition (0.124 mg) and high total metal load (26.8 g kg⁻¹), while *Alstonia scholaris* also has high total heavy metal load (26.3 g kg⁻¹) with low dust deposition (0.083 mg). The increase in regression and correlation values indicates that dust deposition on leaves is an important factor determining the loading of atmospheric heavy metals on plants.

The study demonstrated that the plant species and location specific variance in the heavy metal accumulation in the 7 tree species. Among the locations, NTPC Badarpur sampling site was found most polluted and showed higher metals and metal

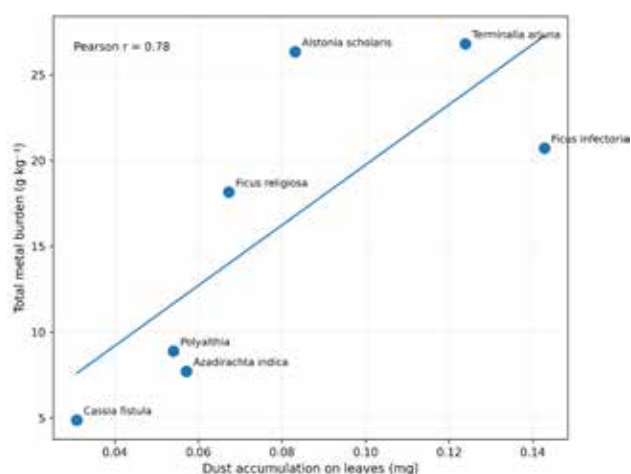


Fig. 6. Relationship between heavy metal burden and leaf associated dust accumulation.

burden compared to other locations. The plant species including *Terminalia arjuna* and *Alstonia scholaris* showed potential ability to accumulate heavy metals and retained dust on leaf surface compared to others. The positive correlation between heavy metal burden and leaf dust indicated an important contribution for the accumulation of heavy metal from environment for mitigate air pollution. Overall, *Terminalia arjuna*, *Alstonia scholaris* and *Ficus infectoria* can be considered as potential bio monitors to assessing air pollution and heavy metal from the environment.

AUTHOR'S CONTRIBUTION

Conceptualization of research (SS, NK); Designing of the experiments (SS, NK); Contribution of experimental materials (SS, NK); Execution of field/lab experiments and data collection (SS, NK); Analysis of data and interpretation (SS, NK); Preparation of the manuscript (SS, NK).

DECLARATION

The authors declare that there is no conflict of interest.

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REFERENCES

1. Ali, H., Khan, E. and Ilahi, I. 2022. Environmental and human health risks associated with heavy metal contamination in soil and plants. *Environ.*

- Res. **207**: 112160. <https://doi.org/10.1016/j.envres.2021.112160>
2. Collin, M. S., Venkatraman, S. K., Vijayakumar, N., Kanimozhi, V., Arbaaz, S. M., Stacey, R. S. and Swamiappan, S. 2022. Bioaccumulation of lead (Pb) and its effects on human: A review. *J. Hazard. Mater. Adv.* **7**: 100094. <https://doi.org/10.1016/j.hazadv.2022.100094>
 3. Ejaz, U., Khan, S. M., Khalid, N., Ahmad, Z., Jehangir, S., Fatima Rizvi, Z. and Raposo, A. 2023. Detoxifying the heavy metals: A multipronged study of tolerance strategies against heavy metals toxicity in plants. *Front. Plant Sci.* **14**: 1154571. <https://doi.org/10.3389/fpls.2023.1154571>
 4. Kandpal, H. and Rai, J. P. N. 2024. Detect urban trees air pollution sensitivity & tolerance by leaf trait analysis in the industrial zone of Kumaun Himalaya Uttarakhand India. *Urban Clim.* **55**: 101932. <https://doi.org/10.1016/j.uclim.2024.101932>
 5. Khalid, N., Aqeel, M., Noman, A., Khan, S. M. and Akhter, N. 2021. Interactions and effects of microplastics with heavy metals in aquatic and terrestrial environments. *Environ. Poll.* **290**: 118104. <https://doi.org/10.1016/j.envpol.2021.118104>
 6. Kour, B. and Raina, A. K. 2014. Assessment of air pollution tolerance levels of some plant species of Jammu. *Environ. Conserv. J.* **15**(1&2): 89-93. <https://doi.org/10.36953/ECJ.2014.151212>
 7. Liang, J., Fang, H. L., Zhang, T. L., Wang, X. X. and Liu, Y. D., 2017. Heavy metal in leaves of twelve plant species from seven different areas in Shanghai, China. *Urban For. Urban Green.* **27**: 390-398. <https://doi.org/10.1016/j.ufug.2017.03.006>
 8. Mishra, A., Lal, B. and Kumar, R. 2024. Air quality monitoring and its impact on local tree species in and around mining areas of Dhanbad District, Jharkhand, India. In *Spatial Modeling of Environmental Pollution and Ecological Risk* (pp. 9-40). Woodhead Publishing. <https://doi.org/10.1016/B978-0-323-95282-8.00016-X>
 9. Mohamed, H. I., Ullah, I., Toor, M. D., Tanveer, N. A., Din, M. M. U., Basit, A. and Rehman, M. U. 2025. Heavy metals toxicity in plants: Understanding mechanisms and developing coping strategies for remediation: A review. *Bioresour. Bioprocess.* **12**(1): 95. <https://doi.org/10.1186/s40643-025-00930-4>
 10. Moustakas, M. 2023. Molecular mechanisms of metal toxicity and plant tolerance. *Int. J. Mol. Sci.* **24**(9): 7810. <https://doi.org/10.3390/ijms24097810>
 11. Narayanan, M. and Ma, Y. 2023. Metal tolerance mechanisms in plants and microbe-mediated bioremediation. *Environ. Res.* **222**: 115413. <https://doi.org/10.1016/j.envres.2023.115413>
 12. Panda, L. L., Aggarwal, R. K. and Bhardwaj, D. R. 2018. A review on air pollution tolerance index (APTl) and anticipated performance index (API). *Curr. World Environ.* **13**(1): 55. <http://dx.doi.org/10.12944/CWE.13.1.06>
 13. Panda, L. L., Aggarwal, R. K. and Sharma, A. 2020. Leaf dust accumulation and its heavy metal status in selected plant species growing alongside the road in sub-temperate condition of Himachal Pradesh during different season. *Int. J. Chem. Stud.* **8**(2): 2494-2500. <https://www.doi.org/10.22271/chemi.2020.v8.i2a1.9125>
 14. Tahir, U., Zameer, M., Ali, Q., Rafique, A., Ali, S. M., Arif, M. U. and Ali, D. 2023. Toxicity assessment of heavy metal (Pb) and its bioremediation by potential bacterial isolates. *Environ. Monit. Assess.* **195**(9): 1047. <https://doi.org/10.1007/s10661-023-11632-9>
 15. Wijerathna, N., Ukwattage, N. L. and De Silva, N. 2026. Assessment of air pollution tolerance of urban park tree species using the air pollution tolerance index: A case study from Kandy City, Sri Lanka. *J. Park.* **1**(2): 10. <https://doi.org/10.3390/jop1020010>
 16. Yan, Y., Jarvie, S., Liu, Q. and Zhang, Q. 2022. Effects of fragmentation on grassland plant diversity depend on the habitat specialization of species. *Biol. Conserv.* **275**: 109773. <https://doi.org/10.1016/j.biocon.2022.109773>

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