Indian Journal of Ecology (2024) 51(5): 1093-1098
DOI: https://doi.org/10.55362/IJE/2024/4359

Manuscript Number: 4359
NAAS Rating: 5.38

Assessment of Roadside Ornamental Trees Potential For Mitigating Heavy Metal Pollution in Ludhiana, Punjab

J. Verma, P. Singh and R. Singh
Department of Floriculture & Landscaping, Punjab Agriculture University, Ludhiana-141 004, India
E-mail: jayothiverma@gmail.com

***Abstract*:** This study examined heavy metal (HM) concentrations in roadside soil and ornamental tree leaves to identify trees with high bioaccumulation potential for mitigating HM pollution. Samples were collected from a highway site and PAU university campus, focusing on several heavy metals. The analysis revealed notable bioaccumulation factors (Bf) for chromium (Cr), nickel (Ni), copper (Cu), and lead (Pb) in the leaves of various tree species. Specifically, *Heterophragma adenophyllum* demonstrated strong affinity for zinc (Zn) and cadmium (Cd), while *Cassia siamea* showed significant uptake of Cu and Zn. These findings highlight the potential of certain tree species to help address heavy metal contamination in urban areas.

***Keywords*:** Heavy metals (HM's), Ornamental trees, Bioaccumulation factor (Bf), Pollution, Affinity

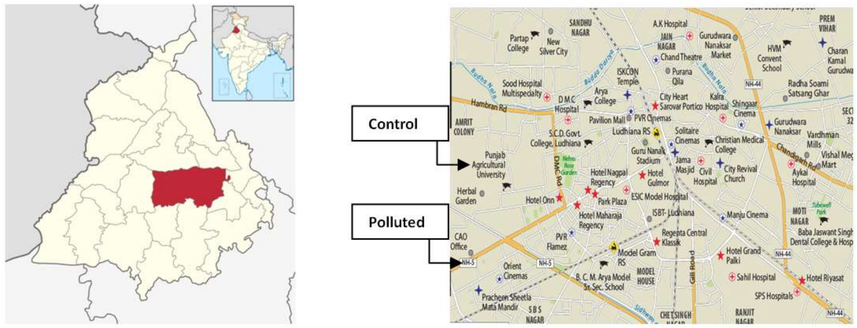
Air pollution, primarily caused by industrialization and vehicular emissions, remains a significant global concern (Latif et al 2018). Among its components, heavy metals (HMs) pose direct and indirect risks to human health, exacerbated by anthropogenic activities such as industrial growth and increasing vehicular traffic in urban areas (Ugolini et al 2013, Hu et al 2014). Certain HMs, including arsenic, cadmium, chromium, mercury, and lead, are particularly hazardous to both plant and human health (Szyczewski et al 2009), while others like copper, selenium, and zinc are essential for plant growth at lower concentrations (Wuana and Okieimen 2011, Rehman et al 2018). The non-biodegradable nature of HMs leads to their accumulation in soil and the human body, posing long-term environmental and health risks (Nagajyoti et al 2010).

Vehicular emissions significantly contribute to elevated HM levels along urban roadside environments (Chen et al 2016, Wang et al 2022). Components of vehicles such as iron, copper, and zinc, present in alloys, tires, pipes, and wires, contribute to HM emissions through mechanical wear and tear over time (Ozaki et al 2004). This accumulation is concerning due to the persistence of HMs in the environment. Given the global urgency of this issue, numerous studies have investigated HM contamination along roadsides (Hu et al 2014, Mihailovic et al 2015). Plants, particularly trees, play a crucial role as bio-monitors by absorbing HMs from soil through their roots or from the air via stomata(Hosseini et al 2020, Kord et al 2010). Thereby, plants accumulate HM 's in their different body parts process known as phytoremediation, which is economical, sustainable, and eco-friendly method to protect environment (Hosseini et al 2020).Previous research has demonstrated the effectiveness of various plant species in monitoring HM impacts on their surrounding environments (Anjum et al 2021, Onder and Dursun 2006). Trees, with their extensive leaf and root surface areas, are particularly effective in this regard (Tomasevic et al 2008, Estrabou et al 2011, Li et al 2022). This study focuses on evaluating HM concentrations in selected roadside ornamental trees and soil, aiming to contribute to our understanding of HM distribution and bioaccumulation in urban environments.

MATERIAL AND METHODS

The study was conducted in Ludhiana, which experiences a semi-arid climate characterized by three distinct seasons: summer, monsoon, and winter. The city's average annual precipitation is 809.3 mm. The study area specifically focused on National Highway 5, and lies between the North latitude of 30°46'38" and the east longitude of 76°33'23". This highway, known for high vehicular traffic and associated emissions, was selected as the polluted site (study area). As a contrast, Punjab Agricultural University campus served as the control site. The polluted conditions of Ludhiana, stemming from intensive urbanization and industrialization, provided a suitable context for investigating pollution-related phenomena in this study.

Sampling of plant and soil material: The soil and leaf samples of selected tree species (*Acacia auriculiformis, Alstonia scholaris, Cassia fistula, Cassia siamea, Chukrasia tabularis, Dalbergia sissoo, Heterophragma adenophyllum,* and *Putranjiva roxburghii*) were collected from both sites (0–1 m from the road edge). Control soil and plant leaf



a) b)

samples were collected from PAU, Ludhiana (100 m away from the road). Soil samples were collected 0, 10, 15, and 20 cm deep from each site along with both sites of road, and five representative samples of each site were prepared by the quadrant method (Rosa et al 2018). For accurate heavy metal analysis, leaf samples from five trees of each species, were harvested from each site during the mid-growing season, to ensure full leaf development (fully mature leaf) and reliable data on metal accumulation. The permissible limits for heavy metals in soil and plant leaves according to different standards, presented in Table 1.

Soil and plant samples analysis: The heavy metal content in soil samples was assessed using the method developed by Lindsay and Norvel (1978). Concentrations of heavy metals (Cr, Fe, Ni, Cu, Zn, Cd, and Pb) were determined using an ICP Spectrometer (ICP-MS 7700 Series). Similarly, heavy metal concentrations in leaf samples were analyzed using an ICP Spectrometer (Model iCAP 6000 Series). The heavy metals (Cr, Fe, Ni, Cu, Zn, Cd and Pb) were estimated by injecting filtered samples into Inductively Coupled Plasma Emission spectrophotometer and amount expressed in mg kg^{-1}(Ammann 2007). Bioaccumulation factor (Bf) is the plant potential to take up HMs (or any other chemical) from the soil/growth media and it can be calculated as a leaf to soil ratio of the HM concentration (Alahabadiet al 2017). Bf was worked out to determine HM accumulation potential of an individual tree species.

Statistical analysis: The data were analyzed using a factorial randomized block design. and comparison was performed by Tukey's test at a 5% significant level using SAS software computer version 9.2.

RESULTS AND DISCUSSION

Heavy metal concentrations in soil: The concentrations of heavy metals (chromium, iron, nickel, copper, zinc, cadmium, and lead) showed significant differences between two locations (Table 2). The content of metals (Cr, Fe, Ni, Cu, Zn, Cd, and Pb) in the soil across two sites exhibited significant variability. All examined metals were elevated in roadside soils compared to the control site soil. HM concentrations between control and polluted site soil ranged from 1.98 to 18.74mg $kg^{-1}$for Cr, 993.77 to 11947.86 mg $kg^{-1}$for Fe, 1.54 to 14.66 mg kg^{-1} for Ni, 3.09 to 19.61mg kg^{-1} for Cu, 9.12 to 68.16mg kg^{-1} for Zn, 0.49 to 0.55mg kg^{-1} for Cdand 3.01 to 16.78mg kg^{-1} for Pb. Levels of all metals were under permissible limits in both the locations. Despite being in within permissible limits, the elevated concentrations suggest that the polluted site is experiencing environmental stress, possibly due to industrial activities or pollution sources.

These findings are consistent with previous studies that have documented increasing HM (Fe, Ni, Cr, Zn, Cu, Cd and Pb) concentrations in polluted environments (He and Yang 2015). The high levels of heavy metals can have detrimental effects on soil health, plant growth, and overall ecosystem stability (Telo da Gama 2023). The highway site soil exhibited higher concentrations of heavy metals compared to the campus site, attributed to its high traffic volume (Elbagermi et al 2012, Wang and Zhang 2018). The detrimental effects of various heavy metals on both plants and humans, highlighting the need for effective management and mitigation strategies to address heavy metal contamination in Table 3.

Heavy metal concentrations in selected tree leaves: The concentration of heavy metals shows a significant increase of approximately 74.5% in polluted areas (106.52 mg kg^{-1}) compared to control sites (61.04 mg kg^{-1}) (Table 4). In comparing heavy metal concentrations between polluted and control sites, *Alstonia scholaris* shows the greatest increase at polluted site 119.43%, while *Cassia siamea* has the smallest increase at 39.45%, respectively. This trend indicates that all species significantly accumulate more heavy metals in polluted areas compared to control sites suggesting that the variations in HM levels are due to the impact of vehicular traffic (Ogutucu et al 2021). The percentage increases in heavy metal concentrations from control to polluted sites, ranked from highest to lowest, highlight several significant trends. Cu shows the most dramatic rise, with increase of 5,875%, and Cr shows the smallest increase at 20.2%. . Levels of Zn, Ni and Pb surpass permissible limits, at both sites in all tree species suggesting notable pollution, conversely, Cu, Cd, and Cr are generally within acceptable ranges, though some species show elevated levels, particularly in polluted sites. Pb is a significant pollutant from auto exhaust (Muzychenko et al 2017). Ni in roadside plant may originate from engine oil, fuel, tire and brake wear, and the corrosion of nickel alloy components (Gupta 2020, Khalid 2018). Zn is commonly associated with roadside plants due to its extensive use in construction and transportation (Barber et al 2017). Overall roadside plants, being exposed to heightened anthropogenic activities, may exhibit increased accumulation of heavy metals in their leaves (Ogutucuet al 2021).

The study demonstrates that different tree species have varying capacities for accumulating heavy metals from the environment as it depends on leaf surface area quality, stomata size, and HM's particle size (Lei et al 2006, Ugolini et al 2013, Singh et al 2017). *Alstonia scholaris* is the most effective heavy metal accumulator, making it ideal for phytoremediation, while *Cassia fistula* and *Cassia siamea* show the least affinity for heavy metals. The study also highlighted differential affinity of selected roadside trees towards these heavy metals, suggesting their potential as bio-indicators. *Alstonia scholaris* exhibit highest

Table 2. Heavy metal contents (mg kg^{-1}) in soil samples from control and polluted locations

Heavy metal	Control site	Polluted site	Percent increase in polluted location (%)
Chromium (Cr)	1.98[b]	18.74[a]	846.46
Iron (Fe)	993.77[b]	11947.86[a]	1102.28
Nickel (Ni)	1.48[b]	14.66[a]	890.54
Copper (Cu)	3.09[b]	19.61[a]	534.63
Zinc (Zn)	9.12[b]	68.16[a]	647.37
Cadmium (Cd)	0.49[b]	0.55[a]	12.24
Lead (Pb)	3.01[b]	16.78[a]	457.48
Overall location (Mean)	144.71[b]	1726.62[a]	-

* Different letters in each row are significantly different at P≤0.05 by Turkey's Test

Table 1. Acceptable limits of heavy metals (HM's) in soil and plant leaf samples

Sample	Standards	Cd	Cu	Pb	Zn	Ni	Cr
Soil (mg kg^{-1})	Indian Standard (Awashthi 2000)	3-6	135-270	250-500	300-600	75-150	-
	WHO(2006)	-	140	84	-	107	-
	European Union Standards (EU 2006)	3.0	100	300	300	50	100
Plant (mg kg^{-1})	Indian Standard (Awashthi 2000)	1.5	30.0	2.5	50.0	1.5	20.0
	WHO/FAO (2007)	0.2	40.0	5.0	60.0	-	-
	European Union Standards (EU 2006)	0.2	-	0.30	-	-	-

Table 3. Effects of heavy metals on plant and human health

Heavy metal	Effects on plants	Effects on humans	References
Pb	• Reduces growth and chlorophyll content • Causes leaf and root damage • Interferes with nutrient uptake	• Neurotoxicity, especially in children • Kidney damage • Developmental and cognitive impairments	Alloway 2013, Tchounwou et al 2012, Alengebawy 2021
Cd	• Inhibits seed germination and growth • Causes leaf chlorosis and necrosis • Interferes with enzyme activity	• Causes kidney damage and osteoporosis • Carcinogenic effects • Impaired respiratory function	Alloway 2013,Jarup 2003,Satarug et al 2011, Haider et al 2021
Cr	• Affects photosynthesis and growth • Causes root and shoot damage • Alters enzyme activity	• Causes respiratory issues and skin ulcers • Impairment of liver and kidney function • Carcinogenic	Kapoor et al 2022
Ni	• Causes reduced seed germination • Inhibits root growth and development • Alters photosynthetic activity	• Respiratory issues and dermatitis • Nausea, vomiting, and diarrhoea • Potentially carcinogenic	Hassan et al 2019, Genchi et al 2020
Cu	• Causes leaf necrosis and chlorosis • Inhibits root growth • Impairs nutrient absorption	• Causes gastrointestinal distress • Liver and kidney damage • Neurological problems	Balali-Mood et al 2021,Mir et al 2021
Zn	• Leads to leaf chlorosis and stunted growth • Affects root and shoot development • Interferes with enzyme functions	• Causes gastrointestinal issues • Impaired immune function • Possible disruption of growth and development	Ali et al 2013

Table 4. Metal concentration (mg kg^{-1}) in the leaf of selected roadside tree species growing at the control and polluted locations

Tree species	Location	Heavy metals (mg kg^{-1})							Mean (Location)	Mean (Specie)
		Fe	Cu	Zn	Cd	Cr	Ni	Pb		
Acacia auriculiformis	Control	340.11^{m}	1.62^{n}	21.23^{n}	0.05^{g}	16.30^{i}	5.93^{i}	5.55^{ef}	55.83^{b}	78.96^{e}
	Polluted	639.83^{d}	6.36^{f}	37.93^{f}	0.14^{c}	17.62^{e}	6.41^{e}	6.37^{c}	102.09^{a}	
Alstonia scholaris	Control	422.70^{j}	4.93^{i}	28.26^{l}	0.10^{de}	17.22^{h}	6.22^{h}	5.78^{de}	69.32^{b}	110.74^{a}
	Polluted	968.80^{a}	10.88^{d}	52.34^{b}	0.22^{a}	18.35^{b}	6.88^{b}	7.65^{a}	152.16^{a}	
Chukrasia tabularis	Control	336.23^{n}	2.65^{m}	23.45^{m}	0.08^{ef}	17.65^{e}	6.34^{f}	5.31^{f}	55.96^{b}	75.85^{f}
	Polluted	585.70^{f}	5.86^{g}	47.79^{c}	0.09^{ef}	17.76^{d}	6.67^{c}	6.27^{c}	95.73^{a}	
Cassia fistula	Control	321.60^{o}	4.64^{j}	18.81^{p}	0.09^{e}	17.30^{g}	5.97^{i}	4.80^{g}	53.32^{b}	73.21^{g}
	Polluted	573.83^{g}	10.14^{e}	37.44^{g}	0.17^{b}	17.49^{f}	6.42^{e}	6.16d^{c}	93.09^{a}	
Cassia siamea	Control	319.47^{p}	3.34^{l}	20.45^{o}	0.09^{e}	17.30^{g}	6.27^{g}	5.33^{f}	53.18^{b}	63.68^{h}
	Polluted	437.73^{h}	14.22^{b}	36.33^{h}	0.12^{dc}	17.83^{d}	6.85^{b}	6.20^{dc}	74.18^{a}	
Dalbergia sissoo	Control	375.51^{l}	0.24^{o}	29.67^{k}	0.10^{de}	17.34^{g}	6.25^{gh}	5.81^{de}	62.13^{b}	81.08^{d}
	Polluted	607.58^{e}	14.33^{a}	46.49^{e}	0.17^{b}	18.05^{c}	6.49^{d}	7.15^{b}	100.04^{a}	
Heterophragma adenophyllum	Control	426.57^{i}	3.94^{k}	35.09^{i}	0.08^{ef}	17.61^{e}	6.29^{g}	5.50^{ef}	70.73^{b}	97.68^{b}
	Polluted	762.61^{b}	11.14^{c}	66.31^{a}	0.29^{a}	18.34^{b}	6.67^{c}	7.10^{b}	124.64^{a}	
Putranjiva roxburghii	Control	409.19^{k}	5.10^{h}	31.15^{j}	0.06^{fg}	17.60^{e}	6.28^{g}	5.81^{de}	67.88^{b}	89.04^{c}
	Polluted	675.38^{c}	14.32^{a}	46.70^{d}	0.12^{de}	19.61^{a}	7.56^{a}	7.61^{a}	110.19^{a}	
Overall Mean	Control								61.04^{b}	
	Polluted								106.52^{a}	

accumulation of Fe and Pb as compare to other species under study. Similarly, *Dalbergia sissoo* for (Cu), *Heterophragma adenophyllum* for (Zn & Cd) and *Putranjiva roxburghii* showed amassing for (Cr & Ni). The absorption ability of a plant species changes with the leaf properties of the plant as well as with plant species (Shahid *et al* 2017). These findings can guide the selection of tree species for environmental cleanup and management of heavy metal pollution. The bioaccumulation factor of the HMs in the selected roadside tree leaves varies with site and tree species (Patel et al 2015, Greksa et al 2019). Among the tree species studied, the overall Bioaccumulation Factor (Bf) for trees, follow the order: *Putranjiva roxburghii* (0.438) >*Alstonia scholaris* (0.433) >*Heterophragma adenophyllum* (0.396) >*Acacia auriculiformis* (0.362) >*Cassia siamea* (0.337) = *Cassia fistula*(0.334) >*Chukrasia tabularis* (0.316) >*Dalbergia sissoo* (0.272). Species with higher Bf values like *Putranjiva roxburghii, Alstonia scholaris* and *Heterophragma adenophyllum* are more adept at accumulating heavy metals and are therefore preferable for phytoremediation in highly contaminated soils.

CONCLUSION

The study highlights the variable capacity of different tree species to accumulate heavy metals. *Alstonia scholaris* emerged as the most effective accumulator, particularly in polluted areas, along with others such as *Dalbergia sissoo*, *Heterophragm aadenophyllum*, and *Putranjiva roxburghii*, which demonstrates significant potential for use in phytoremediation efforts. The capacity for heavy metal accumulation varies with leaf properties and species characteristics, supporting the need for tailored approaches in environmental management. Mostly HMs under consideration was within permissible limits, but the substantial exceedance in Zn, Ni and Pb levels in plant leaves underscore specific contamination concerns. HM accumulation is a major health concern globally. In Ludhiana, high traffic and industrial activities contribute to Pb buildup in roadside plants, raising health risks and highlighting a pressing issue in India. Continued monitoring, along with the use of appropriate tree species for phytoremediation, will be essential for mitigating the impacts of heavy metal pollution and improving soil and plant health.

REFERENCES

Alahabadi A, Ehrampoush MH, Miri M, Aval HE, Yousefzadeh S, Ghaffari HR Ahmadi E, Talebi P, Fathabadi ZA, Babai F and Nikoonahad A 2017. A comparative study on the capability of different tree species in accumulating heavy metals from soil and ambient air. *Chemosphere* **172**: 459-467.

Alengebawy A, Abdelkhalek ST, Qureshi SR and Wang MQ 2021. Heavy metals and pesticides toxicity in agricultural soil and plants: Ecological risks and human health implications. *Toxics* **9**(3): 42.

Ali H, Khan E and Sajad MA 2013. Phytoremediation of heavy metals-concepts and applications. *Chemosphere* **91**(7): 869-881.

Alloway BJ 2013. *Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability* (3rd ed.), Dordrecht: Springer Netherlands.

Ammann AA 2007. Inductively coupled plasma mass spectrometry (ICP MS): A versatile tool. *Journal of Mass Spectrometry* **42**(4): 419-27.

Anjum S, Hussain M, Hameed M and Ahmad R 2021. Physiological, biochemical and defense system responses of roadside vegetation to auto-exhaust pollution. *Bulletin of Environmental Contamination and Toxicology* **107**(5): 946-954.

Awashthi SK 2000. *Prevention of Food AdulterationAct no 37 of 1954*. Central and State Rules as Amended for 1999, Ashoka Law House, New Delhi.

Balali-Mood M, Naseri K, Tahergorabi Z, Khazdair MR and Sadeghi M 2021. Toxic mechanisms of five heavy metals: mercury, lead, chromium, cadmium, and arsenic. *Frontiers in Pharmacology* **12**: 643972.

Chen JP, Wang LK, Wang MHS, Hung YT and Shammas NK 2016. *Remediation of Heavy Metals in the Environment* New York: CRC Press, Taylor & Francis Inc, p 131.

Elbagermi MA, Edwards HGM and Alajtal AI 2012. Monitoring of heavy metal content in fruits and vegetables collected from production and market sites in the Misurata area of Libya. *International Scholarly Research Notices* **2012**(1): 827645.

Estrabou C, Filippini E, Soria JP, Schelotto G and Rodriguez JM 2011. Air quality monitoring system using lichens as bioindicators in Central Argentina. *Environmental Monitoring and Assessment* **82**: 375-383.

European Union 2006. Commission Regulation (EC) No. 1881/2006 of 20 December 2006 setting maximum levels for certain contaminants in soil and foodstuffs. *Official Journal of the European Union L* **364**: 5-24.

Genchi G, Carocci A, Lauria G, Sinicropi MS and Catalano A 2020. Nickel: Human health and environmental toxicology. *International Journal of Environmental Research and Public Health* **17**(3): 679.

Greksa A, Ljevnaic-Masic B, Grabic P, Benka V, Radonic B, Blagojevic B and Sekulic M 2019. Potential of urban trees for mitigating heavy metal pollution in the city of Novi Sad, Serbia. *Environmental Monitoring and Assessment* **191**(10): 636.

Gupta V 2020 Vehicle-generated heavy metal pollution in an urban environment and its distribution into various environmental components. In *Environmental Concerns and Sustainable Development* (Vol. 1), *Air, Water and Energy Resources,* pp 113-127.

Haider FU, Liqun C, Coulter JA, Cheema SA, Wu J, Zhang R and Farooq M 2021. Cadmium toxicity in plants: Impacts and remediation strategies. *Ecotoxicology and Environmental Safety* **2**(11): 111887.

Hassan MU, Chattha MU, Khan I, Chattha MB, Aamer M, Nawaz M and Khan TA 2019. Nickel toxicity in plants: reasons, toxic effects, tolerance mechanisms, and remediation possibilities: A review. *Environmental Science and Pollution Research* **26**: 12673-688.

He Z and Yang X 2015. Heavy metal contamination of soils: Sources, indicators, and assessment. *Journal of Environmental Indicators* **9**:17-19.

Hosseini NS, Sobhanardakani S and Cheraghi M 2020. Heavy metal concentrations in roadside plants (*Achillea wilhelmsii* and *Cardaria draba*) and soils along some highways in Hamedan, west of Iran. *Environmental Science and Pollution Research* **27**:13301-13014.

Hu Y, Wang D, Wei L, Zhang X and Song B 2014. Bioaccumulation of heavy metals in plant leaves from Yan'an city of the Loess Plateau, China. *Ecotoxicology and Environmental Safety* **110**: 82-88.

Jarup L 2003. Hazards of heavy metal contamination. *British Medical Bulletin* **68**(1): 167-182.

Kapoor RT, Mfarrej MFB, Alam P, Rinklebe J and Ahmad P 2022. Accumulation of chromium in plants and its repercussion in animals and humans. *Environmental Pollution* **301**: 119044.

Khalid N et al 2018. Effects of road proximity on heavy metal concentrations in soils and common roadside plants in SouthernCalifornia. *Environmental Science and Pollution Research* **25**: 35257-35265.

Barber LB, Paschke SS, Battaglin WA, Douville C, Fitzgerald KC, Keefe SH, Roth DA and Vajda AM 2017. Effects of an extreme flood on trace elements in River water from urban stream to major River Basin. *Environmental Science & Technology* **51**(18): 10344-10356.

Kord B, Mataji A and Babaie S 2010. Pine (*Pinus eldarica* Medw.) needles as indicators for heavy metals pollution. *International Journal of Environmental Science and Technology* **7**(1): 79-84.

Latif MT, Othman M, Idris N, Juneng L, Abdullah AM, Hamzah WP and Jaafar AB 2018. Impact of regional haze towards air quality in Malaysia: A review. *Atmospheric Environment* **177**: 28-44.

Lei WANG, Liu LY, Gao SY, Eerdun HASI and Zhi WANG 2006. Physicochemical characteristics of ambient particles settling upon leaf surfaces of urban plants in Beijing. *Journal of Environmental Sciences* **18**(5): 921-926.

Li Y, Xu Z, Ren H, Wang D, Wang J, Wu Z and Cai P 2022. Spatial distribution and source apportionment of heavy metals in the Topsoil of Weifang City, East China. *Frontiers in Environmental Science* **10**: 893938.

Lindsay WL and Norvell WA 1978. Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal* **42**: 421-428.

Mihailovic A, Budinski-Petkovic L, Popov S, Ninkov J, Vasin J, Ralevic NM and Vucinic-Vasic M 2015. Spatial distribution of metals in urban soil of Novi Sad, Serbia: GIS-based approach. *Journal of Geochemical Exploration* **150**: 104-114.

Mir AR, Pichtel J and Hayat S 2021. Copper: uptake, toxicity and tolerance in plants and management of Cu-contaminated soil. *Biometals* **34**(4): 737-59.

Muzychenko I, Jamalova G, Mussina U, Kazulis V and Blumberga D 2017. Case study of lead pollution in the roads of Almaty. *Energy Procedia* **113**: 369-376.

Nagajyoti PC, Lee KD and Sreekanth TVM 2010. Heavy metals, occurrence and toxicity for plants: A review. *Environmental Chemistry Letters* **8**(3): 199-216.

Ogutucu G, Ozdemir G, Acararıcın Z and Aydın A 2021. Trend analysis of lead content in roadside plant and soil samples in Turkey. *Turkish Journal of Pharmaceutical Science* **18**(5): 581-588.

Onder S and Dursun S 2006. Air borne heavy metal pollution of *Cedruslibani* (A. Rich.) in city center of Konya (Turkey). *Atmospheric Environment* **40**(6): 1122-1133.

Ozaki H, Watanabe I and Kuno K 2004. Investigation of the heavy metal sources in relation to automobiles. *Water, Air, and Soil Pollution* **157**: 209-223.

Patel K, Sharma R, Dahariya N, Yadav A, Blazhev B, Matini L and Hoinkis J 2015. Heavy metal contamination of tree leaves. *American Journal of Analytical Chemistry* **6**: 687-93.

Rehman K, Fatima F, Waheed I and Akash MSH 2018. Prevalence of exposure of heavy metals and their impact on health consequences. *Journal of Cellular Biochemistry* **119**(1): 157-184.

Rosa DD, Tres G, Broti-Rissato B, Lorenzetti E, Guimaraes VF and Feiden A 2018. Rooting Platanus (*Platanus acerifolia* (Aiton) Willd.) cuttings in Marechal Cândido Rondon-PR, razil: Influence of lesions at cutting bases and depth of planting. *Acta Agronomica* **67**(1): 109-113.

Satarug S, Garrett SH, Sens MA and Sens DA 2011. Cadmium, environmental exposure, and health outcomes. *Ciencia &Saudecoletiva* **16**(5): 2587-2602.

Shahid M, Dumat C, Khalid S, Schreck E, Xiong T and Niazi NK 2017. Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. *Journal of Hazardous Materials* **325**: 36-58.

Singh H, Savita, Sharma R, Sinha S, Kumar M, Kumar P, Verma A and Sharma SK 2017. Physiological functioning of *Lagerstroemia speciosa* L. under heavy roadside traffic: An approach to screen potential species for abatement of urban air pollution. *Biotechonology* **7**(61): 1-10.

Szyczewski P, Siepak J, Niedzielski P and Sobczynski T 2009. Research on heavy metals in Poland. *Polish Journal of Environmental Studies* **18**(5): 755-768.

Tchounwou PB, Yedjou CG, Patlolla AK and Sutton DJ 2012. Heavy metal toxicity and the environment. Molecular, clinical and environmental toxicology. *Environmental Toxicology* **3**: 133-164.

Telo da Gama J 2023. The Role of Soils in Sustainability, Climate Change, and Ecosystem Services: Challenges and Opportunities. *Ecologies* **4:** 552-567.

Tomasevic M, Vukmirovic Z, Rajsic S, Tasic M and Stevanovic B 2008. Contribution to biomonitoring of some trace metals by deciduous tree leaves in urban areas. *Environmental Monitoring and Assessment* **137**: 393-401.

Ugolini F, Tognetti R, Raschi A and Bacci L 2013. Quercus ilex L. as bio-accumulator for heavy metals in urban areas: effectiveness of leaf washing with distilled water and considerations on the tree's distance from traffic. *Urban Forestry & Urban Greening* **12**(4): 576-584.

Wang A, Guo Y, Fang Y and Lu K 2022. Research on the horizontal reduction effect of urban roadside green belt on atmospheric particulate matter in a semi-arid area. *Urban Forestry & Urban Greening* **68**: 127449.

Wang M and Zhang H 2018. Accumulation of heavy metals in roadside soil in urban area and the related impacting factors. *International Journal of Environmental Research and Public Health* **15**(6): 1064.

WHO/FAO 2007. *Joint FAO/WHO Food Standard Programme Codex* Alimentarius Commission 13th Session Report of the Thirty-Eight Session of the Codex Committee onFood Hygiene. Houston, United States of America, ALINORM 07/30/13.

Wuana RA and Okieimen FE 2011. Heavy metals in contaminated soils: A review of sources, chemistry, risks and best available strategies for remediation. *International Scholarly Research Notices* **2011**(1): 402647.

Received 08 June, 2024; Accepted 21 September, 2024