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Quantitative assessment of potentially toxic heavy metals in *solanum tuberosum* l. In relation to vehicular-derived atmospheric pollutants

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ABSTRACT

Solanum tuberosum L., a commercially cultivated crop from the Solanaceae family, presents an excellent choice for a starch source. Moreover, the crop is appreciated as a uniquely versatile vegetable. Transportation-related air pollution has emerged as a potentially lethal issue; however, anthropogenic activities contribute to the increase of dust-like air pollution from trafficked roadways daily. The primary objectives of this research are to identify sources of hazardous, harmful, and abiotic agents, as well as to assess their concentrations in road dust. This research explores the extent of toxicological health concerns associated with crops. Comparative research was conducted to evaluate the stage of harmful toxic metal concentrations (ppm) in crop soil, mature leaves, and edible parts. Various sites along the highly trafficked roads, at distances of 500 metres (high dust), 1000 metres (low dust), and a control area at 1500 metres (no dust), were selected. The harmful, toxic heavy metals examined included lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn), arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), and zinc (Ni). Crops situated near the roads exhibited higher concentrations (ppm) of harmful, toxic heavy metals compared to the control area. Statistical analysis of samples from multiple locations revealed harmful, toxic heavy metal concentrations (ppm) with P values of 0.002, 0.0001, and 0.0003 (P < 0.05 is considered highly significant and very highly significant).

Keywords: *Saccharum officinarum* L., heavy metals, traffic density, toxic chemo stress, human behaviour

INTRODUCTION

The effects of motor vehicle emissions on human health are primarily related to air pollution and are managed through tailpipe emission limits. However, non-tailpipe sources also contribute significantly to heavy metal emissions from automobiles. Long after they have left the atmosphere, the abiotic contamination generated by many concepts continue jeopardise the health of humans and ecosystems, mainly through soil and plant contamination. In this study, we examined five paired sites in Gaviota, California, to assess how vehicle pollution influenced the plants and soils. We investigated the impact of near road on soil metal quantities and HMs levels in many of impotent prevalent roadside flora at each site. The C and N ratios of each sample were then analysed to explore the potential impacts of near road and abiotic on flora. Quantities of all HMs in plants were revealed to be highly and significantly affected by road proximity; plants near highways had metal concentrations that were 8–11 times greater than those further away. Road proximity may have wider implications for physio for consume in area, as evidenced by the fact that plant carbon and nitrogen ratios varied significantly across area kind and were consistently high near highways compared to those further away (Khalid *et al.,* 2018). Typically, soil sample are a patchwork different kinds and exhibit higher levels of HMs because of their sustained buildup in soil and plant parts, facilitated by the continuous release of pollutants, particularly from automobiles. The purpose of this research was to discern how road contamination impacts condition of soil nature by using a photo indicator. Levels of HM content were within acceptable limits for communication soils. The extent of anthropogenic contamination with certain metals could not be decisively assessed by the markers employed. The fact that the aboveground portions of plants exhibit higher concentrations of the aforementioned metals suggests that atmospheric pollution, rather than the metals present in the soil, is responsible (Bartkowiak *et al.,* 2024). Currently, one of the primary issues confronting metropolitan areas is air pollution.

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Heavy metals are particularly significant among air pollutants because of their capacity to endure in nature for long stretches of time without breaking down, lead increasing concentrations in the environment. Bioaccumulation is another tendency associated with heavy metals. Therefore, determining the quantity of HMs is crucial for assessing risk levels and identifying high-risk areas. Generally, plants serve as bio monitors for measuring the levels of HMs in the air. Assessing quantities of HMs found on plants is vital for evaluating their capacity to absorb these contaminants from the atmosphere, which opens the possibility of utilizing them to enhance and monitor air quality. In this study, specific landscape plants collected from areas with varying traffic densities were analysed to ascertain how different heavy metal concentrations correlated with traffic density, leaf samples, commonly used in landscaping studies (Turkyilmaz *et al.,* 2020). Heavy metal contamination generally originates locally, primarily resulting from industrial activities, agriculture, waste incineration, fossil fuel combustion, and traffic. Natural soil contains heavy metals, with those in pristine areas largely attributed to the long-distance transport of atmospheric pollutants, which in turn increases the metal burden. Plants and their surroundings interact, resulting in changes. The physiochemical state of plants, such as the concentrations of essential elements, can reflect environmental factors, including poor air quality. Exposure to pollutants can lead to noticeable harm to plants and, in severe cases, plant death. Environmental pollution negatively alters the physiochemical characteristics of natural resources soil sample potentially restricting the activities of humans and other living organisms or adversely affecting their survival. Human activities from industries and vehicles contribute to ongoing high in nature contamination. The primary source of heavy metal pollution is airborne emissions (Adelasoye and Alamu 2016). In recent years, rapid urbanization, industrialization, and traffic density have exacerbated air pollution, particularly in developing countries. The presence of HMs in these plants signifies a critical health risk to individuals consuming flora grow in urban areas with high air polluted contamination levels. Even when ingested in small amounts, HMs can have detrimental and impact on the fauna body. This study aims to ascertain changes metal in various vegetables cultivated in place with heavy. Depending on the components examined, the variations in abiotic agent's concentrations correlated with traffic contamination. Notably, concentrations of Cr and Co in cleaned fruits to overall traffic contamination, indicating that fruits are capable of absorbing these metals. Given the high concentrations of heavy metals in locations with substantial traffic and industrial activity, these findings underscore the potential risks associated with consuming locally grown produce (Kravkaz *et al.,* 2022). It is well known that roadside soils and flora can become severely contaminated by vehicle emissions containing various heavy metals. This research to determine the base of heavy abiotic in plant, soil samples from roadside locations in Amritsar, Punjab, India, across different traffic volumes. Four HMs were detected in soil and plant samples collect from seven roadside sites, varying by traffic density. Additionally, the carotenoid and total protein amounts in plant samples were determined. Roadside soil samples were analyzed for physio terms, revealing that the soil was non-saline and ranged from slightly to severely alkaline. The concentrations of HMs in plants and corresponding soil samples showed the many abiotic agents for both seasons. While the bioaccumulation terms indicated both metal physio activities in the examined flora, the geo-accumulation index revealed considerable soil contamination. The study suggests a potentially health risk to fauna due to the substantial contamination of roadside soils and vegetation in Amritsar city caused by vehicle emissions (Kaur *et al.,* 2021). The storage of heavy agents poses a critical threat to health of flora and fauna. The significant increase in traffic activity in recent decades may account for the high quantities of HMs found in dust road, especially considering that the TP is distant from major human emission sources. To confirm this hypothesis, we meticulously assessed the distribute of HMs in depth soils located many meters from traffic place, accounting for differ flora types. The results indicated negligible differences in HMs quantities in soil at various distances for traffic. Except for one site deemed to have a severe pollution risk. Which assess pollution chance for these areas, typically ranged between 1 and 2 (low pollution risk). This suggests that while traffic activity has a minimal impact regionally, some localized areas are experiencing higher pollution levels. The maximum concentration of mercury was observed in flora at many metres above sea level, attributed to nature that induce high airborne deposits and more robust complexation with organic materials (An *et al.,* 2022). Air pollution poses a grave danger to nature due to heavy metals (HMs). While plant species are recognized as effective bio-monitors, the specific heavy metals absorbed by different plants and organs, as well as the volume of traffic generated, remain unknown. This study aims to ascertain whether the HMs under investigation are moved from one yearly tree ring to another and whether they origin from automobiles, as well as how the concentrations of HMs vary among many parts about traffic density. The variations in HMs corresponding to many parts types and traffic over recent years were determined in this study (Cobanoglu *et al.,* 2023). This research was the first to employ invasive species as a biomonitoring for certain HMs in many places. For comparison, samples of soil and flora were collection from various sites as road, farmer based on the source extent of HMs present. The (AAS) was utilized to analysis the quantities of all metals in the acid-digested samples, ensuring precise and trustworthy results. As anticipated, HMs quantities in soils and flora decreased from multi near road. The impact was employed to investigate sources of HMs contamination. Our research found that the primary sources included emissions from smelters and vehicle traffic, many by human activities like as crushing plants, wastewater from residential, and commercial activities. Given the toxic of heavy metals to the environment, we were able to alert locals about the potential health hazards due to Cd levels exceeding the World Health Organization's (WHO) recommended limits. This study highlighted that species with strong metal-accumulating potential demonstrate promising characteristics as bioindicators. We also include that other any species could be employed for biomonitor to gain a deeper under of the ecosystem's status in the area and do so more effectively (Ullha and Khan 2022). Due to unregulated rapid fauna activities, HMs concentrations are alarmingly increasing, rendering HMs contamination a significantly nature hazard in recent times (Comaklı and Bingol 2021). Comparative data indicate that the phytochemical content of crops at road traffic sites significantly differs from those at control sites (Singh *et al.,* 2024). The sampling locations were chosen based on their exposure to traffic pollution, both with and without. As noted by Singh and Sharma (2024), the results revealed that crop plants near polluted areas exhibited stunted growth, diminished physiochemical quality, and poor air quality. This study provides a comprehensive overview of the adverse effects that harmful air pollutants have on crop vegetation. Physiochemical analyses disclosed substantial differences in crop quality between contaminated and uncontaminated sites (Singh *et al.,* 2023). A comparative study assessed the impact of traffic and pollution on physiochemical evaluation (Singh *et al.,* 2023). Numerous phytochemicals are found in plants (Kumar and Arya 2022, 2023).

The main goal of this investigation is to assess the presently and potential cytotoxicity of hazardous phytochemicals in *Solanum tuberosum* L., with a focus on their biochemical modulation in response to atmospheric pollutants associated with vehicular emissions.

MATERIAL AND METHOD

Studying of the place

Hapur district is located in the northwest region of (U.P). Hapur, which is between latitudes 28.730579 and 77.775879, has a humid climate that is influenced by the monsoon, resulting in hot summers and chilly winters (Joshi and Swami 2007).

Acquiring the crop sample

Multiple areas along NH-235 were chosen for sampling at Morepur. Multiple locations of very high dusting roads, high dusting 500 meters away, low dust 1000 meters away, and control 1500 meters away were chosen. For this study, *Solanum tuberosum* L. was chosen as the crop species. With the allocated sample number Bot/PB/261, Department of Botany at Chaudhary Charan Singh, University, in Meerut, (UP), India, confirmed and authenticated the taxonomic identification of agricultural samples. To evaluate the effect of dust traffic related air contamination, samples were taken from soil, mature leaves, and mature edible components.

Crop samples and getting samples ready for harmful toxic heavy metals assessment

A digital electronic balance was employed to weigh fresh crop samples, which included mature edible components and mature leaves, after they had been separated and thoroughly dry in oven set at seventy temp. for forty-eight hr. The dried crop samples were ground in a mechanical grinder to a fine consistency for heavy metal analysis. For the initial breakdown, 15 millilitres of a di-acid mixture (Nitric acid, HNO_3, and Perchloric acid, $HClO_4$) were added to a 150-millilitre conical flask containing one gram of each sample (mature leaf and mature edible component). The mixture was then allowed to stand overnight. After the samples partially decomposed, the digestion process was completed by heat conical flasks on a heat plate. The final vol. was adjusted to fifty mL in vol. flasks after samples had been digested and filter use Whatman No. forty two filter paper and washed with DW. The heavy metal contents (ppm) of the well-digested, filtered, and diluted samples, such as multi-HMs, were measured using an AAS in accordance with the methodology (Singh *et al.,* 1999).

Soil samples and getting samples ready for harmful toxic HMs assessment

Air drying was done on the soil sample to remove their moisture content. Once the samples had dried, an uncontaminated, dry mortar and pestle were used to crush them. and finely filtered through a two mm screen. 3-gram sieved soil samples were weighed and digested using a solution of 10 milliliters concentrated Hydrochloric acid (HCl) and 3.5 milliliters concentrated Nitric acid (HNO_3). The next day, the mixtures were heated for two hours at 104°C after being left unheated overnight under the switched-on fume closet. After passing the digested sample DW via a Whatman No. forty two filter paper was added to a 100 millimeter volumetric flask. The solution was transferred into sampling vials to perform an analysis. The concentrations (ppm) of various heavy metals, such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn), in the soil samples were then measured using the Perk-Elmer A Analyst (AAS) (Singh *et al.,* 1999).

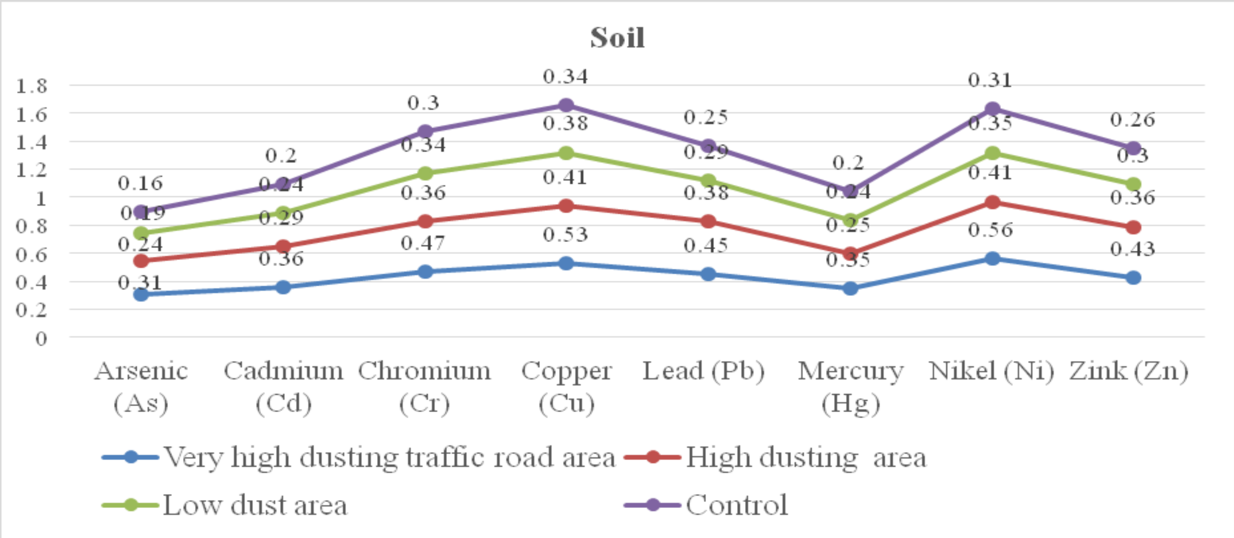
Analysis of Statistical

Analysis of various sample groups was done using a single-factor (ANOVA). The methodology developed by was used to determine least significant difference (LSD) values, which were P = 0.002, 0.0001, and 0.0003 ($P < 0.05$ is considered highly significant and very highly significant) (Gomez 1984).

RESULTS

Assessment of harmful toxic HMs in soil

Throughout observation period, quantities (ppm) of harmful toxic HMs like as were analyzed in soil in multiple areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance and control 1500 meters distance. The concentrations (ppm) of harmful toxic heavy metals, such as arsenic (0.31 > 0.24 > 0.19 > 0.16), cadmium (0.36 > 0.26 > 0.24 > 0.20), chromium (0.47 > 0.36 > 0.34 > 0.30), copper (0.53 > 0.41 > 0.38 > 0.34), lead (0.45 > 0.38 > 0.29 > 0.25), mercury (0.35 > 0.25 > 0.24 > 0.20), nickel (0.56 > 0.41 > 0.35 > 0.31), and zinc (0.43 > 0.36 > 0.30 > 0.26), showed a significant variation across the multi areas. The observe of statistical analysis showed that quantities (ppm) of harmful toxic HMs varied between multi-areas by P=0.0001 ($P<0.05$ is considered very highly significance). The statistical mean values of harmful toxic heavy metals concentrations (ppm) varied from 0.43 > 0.33 > 0.29 > 0.25 in the multi-areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance, and control 1500 meters distance.



Significance at: P= 0.0001 (P<0.05 is regarded very highly significance)

Fig. 1: Soil assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has harmful toxic heavy metals concentrations (ppm)

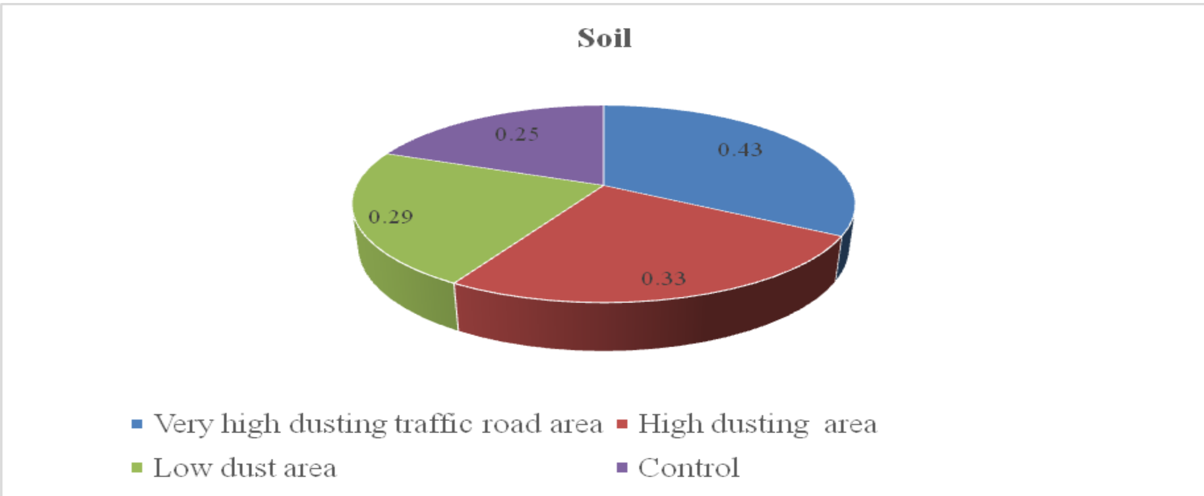
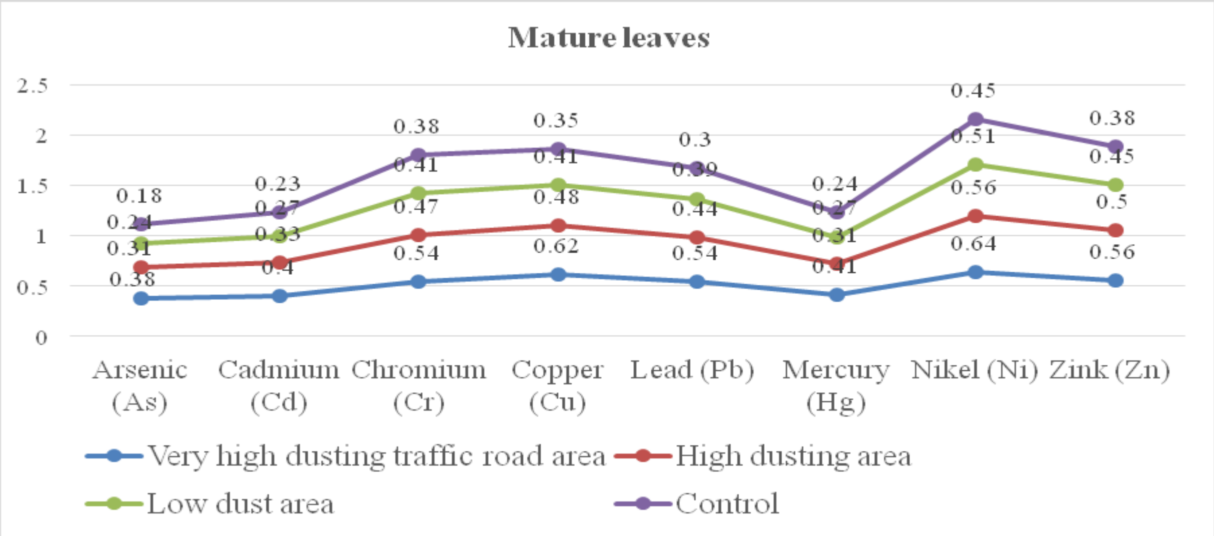


Fig. 2: The soil assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has a mean value of harmful toxic heavy metals concentrations (ppm)

Assessment of harmful toxic HMs in mature leaves

For observation period, concentrations (ppm) of harmful toxic HMs like as were analyzed in mature leaves in multiple areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance, and control 1500 meters distance. The concentrations (ppm) of harmful toxic heavy metals, such as arsenic (0.38 > 0.31 > 0.24 > 0.18), cadmium (0.40 > 0.33 > 0.27 > 0.23), chromium (0.54 > 0.47 > 0.41 > 0.38), copper (0.62 > 0.48 > 0.41 > 0.35), lead (0.54 > 0.44 > 0.39 > 0.30), mercury (0.41 > 0.31 > 0.27 > 0.24), nickel (0.64 > 0.56 > 0.51 > 0.45), and zinc (0.56 > 0.50 > 0.45 > 0.38), showed a significant variation across the multi areas. The observe of statistical analysis showed that quantities (ppm) of harmful toxic HMs varied between multi-areas by P=0.002 (P<0.05 is regarded highly significance). Statistical mean values of harmful toxic heavy metals concentrations (ppm) varied from 0.51 > 0.42 > 0.36 > 0.31 in the multi-areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance, and control 1500 meters distance.



Significance at: P= 0.002 (P<0.05 is regarded highly significance)

Fig. 3: The mature leaves assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has harmful toxic heavy metals concentrations (ppm)

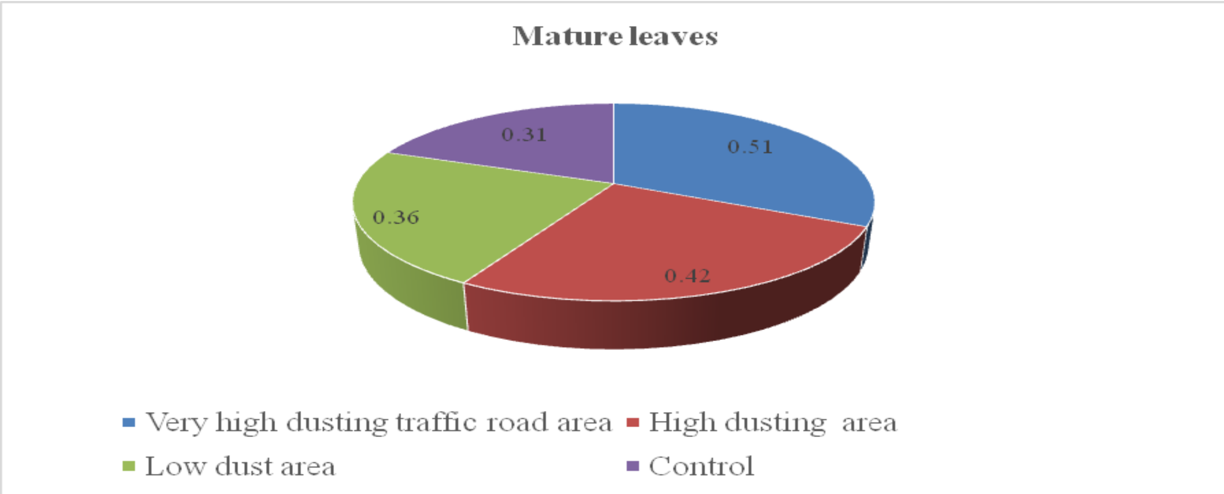
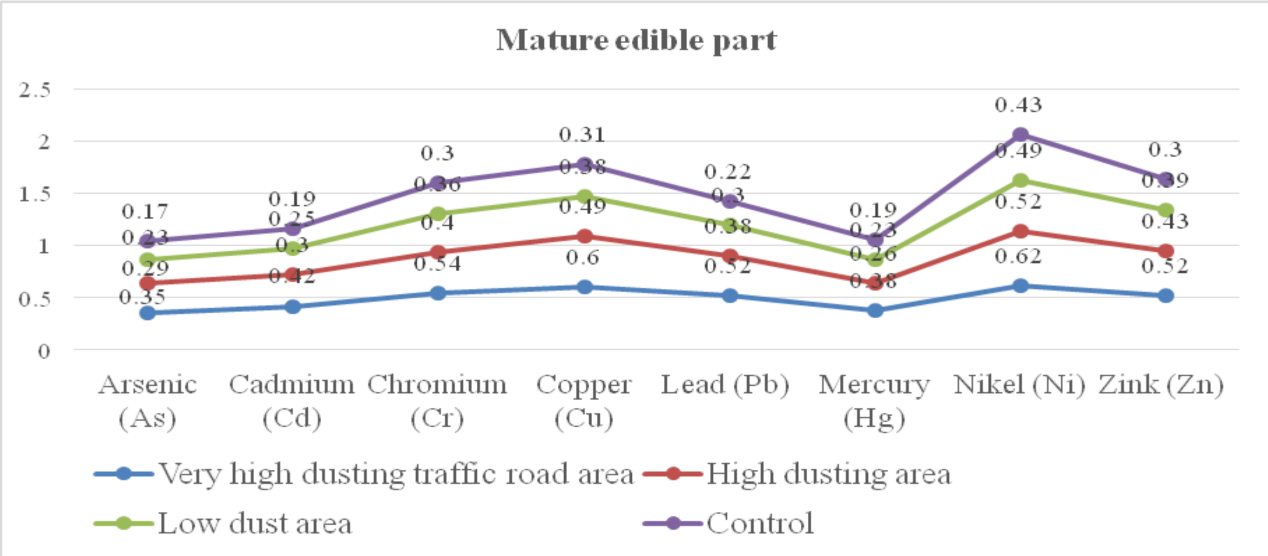


Fig. 4: The mature leaves assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has mean value of harmful toxic heavy metals concentrations (ppm)

Assessment of harmful toxic HMs in mature edible part

Throughout the observation period, concentrations (ppm) of harmful toxic HMs like as were analyzed in mature edible part in multiple areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance, and control 1500 meters distance. The concentrations (ppm) of harmful toxic heavy metals, such as arsenic (0.35 > 0.29 > 0.23 > 0.17), cadmium (0.42 > 0.30 > 0.25 > 0.19), chromium (0.54 > 0.40 > 0.36 > 0.30), copper (0.60 > 0.49 > 0.38 > 0.31), lead (0.52 > 0.38 > 0.30 > 0.22), mercury (0.38 > 0.26 > 0.23 > 0.19), nickel (0.62 > 0.52 > 0.49 > 0.43), and zinc (0.52 > 0.43 > 0.39 > 0.30), showed a significant variation across the multi areas. The observe of statistical analysis showed that quantities (ppm) of harmful toxic HMs varied between multi-areas by P=0.0003 (P<0.05 is regarded very highly significance). Statistical mean values of harmful toxic heavy metals concentrations (ppm) varied from 0.49 > 0.38 > 0.32 > 0.26 in the multi-areas, like very high dusting traffic roads, high dusting 500 meters distance, low dusting 1000 meters distance, and control 1500 meters distance.



Significance at: P= 0.0003 (P<0.05 is regarded very highly significance)

Fig. 5: Mature edible part assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has harmful toxic heavy metals concentrations (ppm)

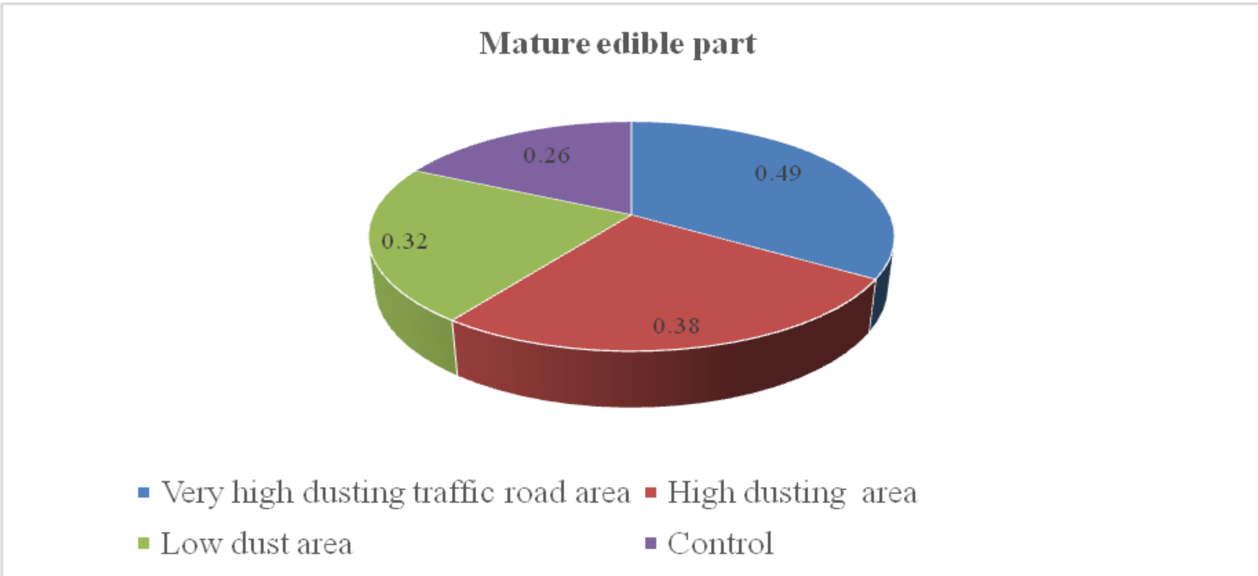


Fig. 6: The mature edible part assessment in areas like the very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance has a mean value of harmful toxic heavy metals concentrations (ppm)

DISCUSSION

This research was carried out on harmful toxic HMs. The harmful, toxic heavy metal concentration (ppm) of soil, mature leaves, and mature edible parts. The carry out work areas like very high dusting traffic roads, high dusting 500 meters distance, low dust 1000 meters distance, and control 1500 meters distance. The concentrations (ppm) of the major harmful toxic heavy metals were ranked in decreasing order at the multiple areas, very high dusting road > high dusting 500 meters distance > low dusting 1000 meters distance > control 1500 meters distance (Singh *et al.,* 2025). In the soil, mature leaves and mature edible part from such records, it was found that quantities (ppm) of harmful toxic HMs in control 1500 meters distance area was found to be less than that of the area very high dusting traffic road, high dusting 500 meters distance, low dust 1000 meters distance, it was also known that the concentration (ppm) of HMs in very high dusting traffic road location was highest than high dusting 500 meters distance area and the concentration (ppm) of harmful toxic heavy metals in high dusting 500 meters distance was higher than the low dust 1000 meters distance. The demonstration that traffic air pollution from vehicles has escalated into a potentially fatal concern. The stomata on leaves and the absorbed root system of crops absorb many harmful, toxic heavy metals that are produced by excessive vehicle emissions. It was discovered that the crop vegetation quality had drastically decreased. Reasons for the low level of harmful toxic heavy metals concentration (ppm) in control area may be, due to rainfall activity in the environment and due to plantation in both the sites of the road harmful toxic heavy metals transmission the low gets done reduce heavy metals movement in control area. A statistical examination of the harmful toxic heavy metals concentration (ppm) between the multiple areas showed P = 0.002, 0.0001, and 0.0003 ($P < 0.05$ is considered highly significant and very highly significant). According to the major, these harmful, toxic heavy metals' statistical mean values were placed in descending order within the multiple areas (Rupesh Kumar Ojha *et al.,* 2024).

This study target to assess the basis of pollution, health concerns associated with many HMs in three commonly consumed vegetables near many roads. Using an (AAS), the levels of HMs in multiple vegetable samples were measured. Base on the diverse land used concept along the roadway, these samples were gathered from five distinct sampling locations. The average levels of HMs (mg/kg) were determined to be many quantities. This suggests that farming, commercial waste, filling stations, and vehicle emissions are some of the common anthropogenic sources of these elements (Salam *et al.,* 2024). To determine the concentrations of HMs and others in the dust, soil, and crop grow along road side, a survey was carried out. Furthermore, the impact of these metals on maize physiologiochemical was evaluated. A sample of plants, soil, and dust was gathered from Millat Road in Faisalabad. Four locations with varying distances from the road (10, 30, and 60 meters) were used to gather samples. Every site was five kilometres away from the others. The concentration of metals in dust, soil, and maize therefore dropped as distance from road high ($P \geq 5$). In plants were highest concentrations of metals in dust, soil, and plants 10 meters away from the roadway. Similarly, maize plants on the side of the road displayed higher metal concentrations along with slower physicochemical (Malik 2022). Among the primary causes of HMs deposition on the flora and soil around highways is vehicle emissions. Traffic congestion on the road has an impact on this. Plants can be adversely affected by heavy metals, which can pose health risks to both flora and fauna in the food chain. The amount of vehicle-induced HMs deposits on the soil vegetation along route was examined in this study. Using aqua regia techniques, flora and soil samples were gathered at ten-kilometer differ time along the other route. The quantities of HMs were then measured using an (AAS). The ANOVA test was used to analyse the data, and differences were assessed at quality data. The observe of the investigation show that amounts of HMs in plants and soils were many quantities mg/kg, respectively. It was ascertained significant HMs load in soil and vegetation along the roadsides was caused in part by vehicle emissions (Olajumoke and Ojo 2020). The heavy metal concentrations of HMs were measured in two natural occurring plant species as well as in the soil beside the road. The study samples were gathered in Turkey along any highway. The mean metal quantities in soil sample were as many quantities HMs ppm (Bingol *et al.,* 2023). The levels of metals in air and leaves were analyzed at four different locations. Air pollution was measured with high-volume sensors. To confirm the amounts of HMs, leaves were analyzed. In all cases examined, the observe signal that quantities of HMs in lettuce leaves are below the EU-mandated limit. In particular, quantities below detect evaluate values were many quantities. HMs quantities in air at four sampling sites were low percentage, even though the sites were near high-density roadways and so more susceptible to high metal concentrations. According to the study findings, Barcelona air has a low concentration of heavy metals, making it safe for urban crops, even those in high-traffic areas (Kim *et al.,* 2017). In Indian soil and other plant components, the amounts of HMs were found to be greater than background levels. The most contaminated road dust was found to contain heavy metals (Bisht *et al.,* 2022). Three different traffic circle locations were used to gather soil samples for multiple heavy metals, both at the roadside and 500 meters from the roadside. According to Sulaiman *et al.* (2018), average levels of heavy metals (mg/kg) in soil samples range from 15.0 to 45.07 for lead, 0.35 to 2.60 for cadmium, 19.05 to 38.0 for copper, and 58.10 to 101.0 for zinc. The quantities of HMs respectively, regardless of road to distance (Szwalec *et al.,* 2020). In this study, edible plant parts from various local markets in the Turkish province of Izmir were examined for concentrations of HMs. However, in non-dust-polluted edible plant samples, the concentrations of these metals varied from quantities. When compared to edible plant samples from dust-polluted areas, the observe show that all heavy abiotic were found in low concentrations in non-dust-polluted areas (Unver *et al.,* 2015). The soil and plant parts are a primary problem for sustainable global development, both in terms of quantity and quality. Unexpected contaminations have had a negative effect on crop quality in recent, endangering both human health and soil and plant part quality. Significant health concerns are posed by HMs that may cause morbidity and death. Thus, the consequences of HMs litter in soil, plant parts of crop subsystems are emphasised and examined in this part, along with the possible disturb to fauna (Rai *et al.,* 2019).

Harmful toxic heavy metal sources in pollutants

Heavy metals are special because, in addition to being dangerous, toxic heavy metal compounds, they can originate from both natural and artificial sources. The special ability of heavy metals to arise from both being natural and man-made sets them apart other hazardous substances. numerous instances of HMs litter in air. Conversely, human activity, particularly industrial operations and business dealings, is mostly to blame for heavy metal pollution (Anastasiadou *et al.,* 2012). HMs litter is mostly caused by road networks, automobile emissions, industrial processes, and other comparable sources. Significant amounts of heavy metals, including some of the most common pollutants, such as multiple abiotic agents, are released by transportation-related emissions. The weathering and degradation of geological materials, atmospheric deposition, and other associated processes are some of the mechanisms that transfer these heavy metals into the dust environment (Bisht *et al.,* 2022). Anthropogenic steps such as road construction, locomotion traffic, and additional causes of heavy metal contamination include coal and ore mining operations, and landfills. HMs found in soil and air can enter through the stomata of leaves and the root system. They can also enter spontaneously through chemical weathering of minerals and air systems. However, these levels are significantly raised by human activities (Lee *et al.,* 2010).

Impact of harmful toxic HMs in crops on human health

Consuming edible portions tainted with HMs can cause critical health objection for people, like as mental growth retardation, gastrointestinal cancer, immune system weakness, and malnutrition (El-Kady and Abdel-Wahhab 2018). Eating food contaminated by heavy metals is closely linked to health risks for humans. HMs can lead to immunological impairment and nutritional deficits by accumulating in fauna bones or adipose tissues via diet. Moreover, some heavy metals are thought to cause intrauterine growth retardation (Rai *et al.,* 2018). Lead poisoning impairs brain development and can cause neurological and cardiovascular problems, especially in children. Cancer, bone fractures and deformities, heart issues, renal issues, high blood pressure, lungs, and neurological can all be brought on by certain heavy metals, especially lead and cadmium (Al-Saleh *et al.,* 2017). A health hazard index quantifies the risks to human health that result from eating food flora litter with multi-HMs. Food crop containing in many abiotic agents according to Zhao *et al.* (2014), a study on health issues, specifically heavy metal-induced cancer. To evaluate flora based on health signal, health risk studies on food crop consumption were conducted in a developing country. Consumption of product part contaminated with environmental pollutants, particularly hazardous heavy metals, known to show negative.

CONCLUSION

This research emphasises the serious threats to nature and fauna health that heavy metals, gaseous contamination from excessive vehicle emissions pose. Crops at dust-impacted, traffic-polluted sites had significantly higher concentrations of these pollutants than those in control areas far from traffic sources, according to the findings, which also show that these pollutants are absorbed by crops through root systems and leaf stomata. The high quantities of HMs and gases in these crops are harm agents that harm plant health and pose serious dangers to humans and animals who eat them. While the bioaccumulation of toxins in edible crop components poses major health risks to people, crops used as wonderful, unique vegetables also contribute to the intake of these contaminants, upsetting the physiological and immune systems of living beings. This emphasises how urgently effective mitigation techniques are needed to lower vehicle emissions and lessen their negative effects on food safety and agricultural systems.

FUTURE PERSPECTIVES

Future acquisition of both quantitative and qualitative data will be essential for accurately assessing the impact of vehicular emissions on crop plants. Insights derived from such investigations are anticipated to facilitate a more thoroughness evaluation of threats relating to with road dust and traffic-related air pollution. Prospective mitigation strategies may include the establishment of vegetative barriers along roadsides, the adoption of dust-reducing infrastructures, the promotion of compressed natural gas (CNG) and electric vehicle technologies, the regulation of vehicular density, and the strategic relocation of agricultural practices away from high-traffic areas. These interventions are expected to safeguard the economic value of crops, enhance their quality, and ensure the health and safety of farmers and consumers involved in agricultural production and food supply chains.

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REFERENCES

Adelasoye, K. A., & Alamu, L. O. (2016). Accumulation of heavy metal pollutants in soil and vegetation and their effects on soil microbial population on roadsides in Ogbomoso, Nigeria. *Journal of Environmental Science and Water Resources*, *5*(1), 001-007.

Al-Saleh, I., Al-Rouqi, R., Elkhatib, R., Abduljabbar, M., & Al-Rajudi, T. (2017). Risk assessment of environmental exposure to heavy metals in mothers and their respective infants. *International journal of hygiene and environmental health*, *220*(8), 1252-1278.

An, S., Liu, N., Li, X., Zeng, S., Wang, X., & Wang, D. (2022). Understanding heavy metal accumulation in roadside soils along major roads in the Tibet Plateau. *Science of the Total Environment*, ***802*,** 149865.

Anastasiadou, K., Christopoulos, K., Mousios, E. and Gidarakos, E. (2012). Solidification stabilization of fly and bottom ash from medical waste incineration facility. *Journal of Hazardous Materials*, ***207*,** 165-170.

Bartkowiak, A., Lemanowicz, J., Rydlewska, M., & Sowinski, P. (2024). The Impact of Proximity to Road Traffic on Heavy Metal Accumulation and Enzyme Activity in Urban Soils and Dandelion. *Sustainability*, ***16***(2), 812.

Bingol, M. S., Çomakli, E., Ozgul, M., Altun, M., & Çomakli, T. (2023. The heavy metals content in leaves and branch of *Hippophae rhamnoides* L. and *Pyrus elaeagnifolia* L. in the highway side (European route E80) in Türkiye. *Environmental Earth Sciences*, ***82***(23), 581.

Bisht, L., Gupta, V., Singh, A., Gautam, A. S., and Gautam, S. (2022) Heavy metal concentration and its distribution analysis in urban road dust: A case study from most populated city of Indian state of Uttarakhand. *Spatial and Spatio-temporal Epidemiology*, ***40*, **100470.

Cobanoglu, H., Sevik, H., and Koc, I. (2023) Do annual rings really reveal Cd, Ni, and Zn pollution in the air related to traffic density? An example of the cedar tree. *Water, air, & soil pollution*, ***234***(2), 65.

Comaklı, E., & Bingol, M. S. (2021). Evaluation of heavy metal accumulations in plant organs and soil white birch (*Betula verrucosa* L.) plantation. *Water, Air, & Soil Pollution*, ***232***, 1-11.

El-Kady, A. A., and Abdel-Wahhab, M. A. (2018) Occurrence of trace metals in foodstuffs and their health impact. *Trends in food science & technology*, ***75***, 36-45.

Gomez, K. A. and Gomez, A. A. (1984) *Statistical procedures for agricultural research*. Johnwiley and sons.

Joshi, P. C. & Swami, A. (2007) Physiological responses of some tree species under roadside automobile pollution stress around city of Haridwar, India. *Environmentalist*, ***27***(3), 365-374.

Kaur, M., Bhatti, S. S., Katnoria, J. K., and Nagpal, A. K. (2021) Investigation of metal concentrations in roadside soils and plants in urban areas of Amritsar, Punjab, India, under different traffic densities. *Environmental Monitoring and Assessment*, ***193*, **1-20.

Khalid, N., Hussain, M., Young, H. S., Boyce, B., Aqeel, M., and Noman, A. (2018) Effects of road proximity on heavy metal concentrations in soils and common roadside plants in Southern California. *Environmental Science and Pollution Research*, ***25***, 35257-35265.

Kim, H. S., Kim, K. R., Kim, W. I., Owens, G., and Kim, K. H. (2017) Influence of road proximity on the concentrations of heavy metals in Korean urban agricultural soils and crops. *Archives of environmental contamination and toxicology*, ***72***, 260-268.

Kravkaz Kuscu, I. S., Kılıc Bayraktar, M., and Tuncer, B. (2022) Determination of heavy metal (Cr, Co, and Ni) accumulation in selected vegetables depending on traffic density. *Water, Air, & Soil Pollution*, ***233***(6), 224.

Kumar, A., and Arya, H. (2022) Phytochemical analysis and synergistic larvicidal action of *Argemone mexicana* L. against third instar larvae of *Aedes aegypti* L. (Diptera: Culicidae). *Journal of Science Innovations and Nature of Earth*.

Kumar, A., and Arya, H. (2023) Phytochemical screening and larvicidal evaluation of leaf extract of *Tinospora cordifolia* L. against *Aedes aegypti* L. (Diptera: Culicidae). *International Journal of Entomology Research*, ***8***(4), 11-19.

Lee, K. Y. and Kim, K. W. (2010) Heavy metal removal from shooting range soil by hybrid electrokinetics with bacteria and enhancing agents. *Environmental Science* and *Technology*, ***44***(24), 9482-9487.

Malik, F. (2022) Assessing heavy metals contamination impact in maize growing along the roadside. *Pakistan Journal of Agriculture, Agricultural Engineering and Veterinary Sciences*, ***38***(1), 7-14.

Olajumoke, E. T., and Ojo, F. P. (2020) Quantifying vehicular heavy metal deposits on roadside soil and vegetation along Akure-Ilesa express road, South-Western Nigeria. *GSC Biological and Pharmaceutical Sci.*, ***12***(1), 054-061.

Rai, P. K., Kumar, V., Lee, S., Raza, N., Kim, K. H., Ok, Y. S., & Tsang, D. C. (2018). Nanoparticle-plant interaction: Implications in energy, environment, and agriculture. *Environment international*, *119*, 1-19.

Rai, P. K., Lee, S. S., Zhang, M., Tsang, Y. F., and Kim, K. H. (2019) Heavy metals in food crops: Health risks, fate, mechanisms, and management. *Environment international*, ***12****5*, 365-385.

Rupesh Kumar Ojha, Dinesh Mani, Devi Prasad Shukla, Himanchal Vishwakarma, Jeetendra Verma, Manoj Kumar and Suraj Patel. (2024) Phytoremediation potential of *Brassica juncea* L. grown in different Cd and Pb polluted sewage irrigated soils. *Annals of Plant and Soil Research* **26**(4): 700-707

Salam, M.A., Akhter, S., Islam, M.S., Dewanjee, S., Siddique, M. A. B., Chakraborty, T. K., and Prakash, V. (2024) Assessment of Heavy Metal Contamination and Health Risk Associated with Cultivated Vegetables along Dhaka-Mymensingh Highway, Bangladesh. *Biological Trace Element Research*, 1-13.

Singh, D., and Sharma, M. K. (2024). Evaluation of Qualitative and Quantitative Phytochemical Constituents in *Saccharum officinarum* L. Exposed to Roadside Traffic-Derived Ambient Air Pollution. *International Journal of Biochemistry Research & Review*, ***33***(5), 33-46.

Singh, D., Anuj Kumar Garg and Manoj Kumar Sharma (2025) Evaluation of potential harmful toxic heavy metals in *Saccharum officinarum* L. due to air contamination from roadside vehicle exposure**.** *Annals of Plant and Soil Research,* **27**(1): 60-69 (2025)

Singh, D., Chhonkar, P. K., and Pandey, R. N. (1999) Soil plant water analysis: a methods manual. *IARI, New Delhi*, 80-82.

Singh, D., Sharma, M. K., and Singh, M. (2023) Assessment of Physical and Biochemical Qualities of *Solanum tuberosum* L. under Roadside Traffic Polluted Area. *Current Agriculture Research Journal*, ***11*(**3).

Singh, D., Sharma, M. K., Kumar, P., and Vashistha, H. (2024) A study on Effect of Ambient Air Pollution from Roadside Traffic on Qualitative and Quantitative Phytochemical Constituents of *Solanum tuberosum* L. *International Journal of Plant & Soil Science*, ***36*(**6), 695-708.

Singh, D., Singh, I., and Sharma, M. K. (2023) Assessment of Growth Rate and Photosynthetic Pigments of *Saccharum officinarum* L. Plantlet under Polluted Area. In *Biological Forum–An Internatonal Journal* (Vol. **15**, No. 5, pp. 725-730).

Sulaiman, M. B., Santuraki, A. H., and Babayo, A. U. (2018) Ecological risk assessment of some heavy metals in roadside soils at traffic circles in Gombe, Northern Nigeria. *Journal of Applied Sciences and Environmental Management*, ***22*(**6), 999-1003.

Szwalec, A., Mundała, P., Kędzior, R., and Pawlik, J. (2020) Monitoring and assessment of cadmium, lead, zinc and copper concentrations in arable roadside soils in terms of different traffic conditions. *Environmental Monitoring and Assessment*, ***192***, 1-12.

Turkyilmaz, A., Cetin, M., Sevik, H., Isinkaralar, K., and Saleh, E. A. A. (2020) Variation of heavy metal accumulation in certain landscaping plants due to traffic density. *Environment, Development and Sustainability*, ***22*,** 2385-2398.

Ullah, R., and Khan, N. (2022) *Xanthium strumarium* L. an alien invasive species in Khyber Pakhtunkhwa (Pakistan): a tool for biomonitoring and environmental risk assessment of heavy metal pollutants. *Arabian Journal for Science and Engineering*, ***47***(1), 255-267.

Unver, M., Ugulu, I., Durkan, N., Baslar, S., and Dogan, Y. (2015) Heavy metal contents of Malva sylvestris sold as edible greens in the local markets of Izmir. *Ekoloji*, ***24***(96).

Zhao, Q., Wang, Y., Cao, Y., Chen, A., Ren, M., Ge, Y., and Li, L. (2014) Potential health risks of heavy metals in cultivated topsoil and grain, including correlations with human primary liver, lung and gastric cancer, in Anhui province, Eastern China. *Science of the Total Environment*, ***470*,** 340-347.