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Evaluation of potential harmful toxic heavy metals in *Saccharum officinarum* L. due to air contamination from roadside vehicle exposure

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ABSTRACT

Saccharum officinarum L., a crop from the Poaceae family, is great for boosting immunity. The crop also serves as a fantastic animal feed. But, dust-like air pollution from dusty traffic roads is increasing daily due to anthropogenic activities, and transportation-related air pollution has become a potentially fatal issue. The main objectives of this research are to evaluate the levels of harmful heavy metals in road dust and to identify their sources. This study looks at the health risks from eating edible plant parts and other crop components. We compared the levels of harmful heavy metals (in parts per million, ppm) in crop soil, mature leaves, and edible tissues. The selected plant locations were: a high dusting traffic road with multiple sites, a high dusting traffic road at 500 meters distance, a low dust traffic road at 1000 meters distance, and a control site at 1500 meters distance. The harmful heavy metals assessed included arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn). The concentrations (ppm) of harmful heavy metals and different gases in crops grown near traffic road locations are higher than the control location. Statistical analysis revealed a P = 0.001, 0.004, and 0.0002 (P<0.05 is considered highly significant and very high significance) in samples of heavy metal concentrations (ppm) between the multilocation.

Keywords: *Saccharum officinarum* L., heavy metals, chemo-accumulation, toxic abiotic stress, human behaviour

INTRODUCTION

Air pollution is one of the most pressing environmental issues, posing a serious risk to health of flora and fauna, particularly in places with high transport systems. A large part of air pollution from transport comes from natural processes. This makes it harder to reduce pollution levels. In areas with high traffic density, this pollution exerts detrimental effects on the health and survival of humans, animals, and plants. Roadside crops and trees are vital for filtering air. They help reduce pollution in the environment (Hashad *et al.,* 2023). This study provides a comparative assessment of the impact of heavy metals and abiotic stress on *Adhatoda vasica,* and *Amaranthus spinosus* etc. in environments impacted by toxic pollution. It explores the complex relationship between heavy metals stress and the ROS and reactive Nitrogen Species responses of medicinal plants. Additionally, the study investigates the adaptive mechanisms that enable plants to cope with heavy metal stress. Emphasis is placed on the importance of mitigation strategies for superoxide radicals, hydroxyl radicals etc countering the toxic effects of heavy metals, as well as on the role of advanced technologies and international collaboration in safeguarding medicinal plants from toxic pollution (Asiminicesei *et al.,* 2024). Crops grown near high-traffic roads exhibit lower levels of phytochemical compounds, both in quantity and quality, indicating the adverse effects of vehicle-induced air pollution on crop vegetation. Data on phytochemical composition show clear differences in crops from road traffic sites compared to control sites (Singh *et al.,* 2024). This investigation focused primarily on analysing various phytochemical compounds across different environments. For comparative analysis, we selected sites with significant pollution and control sites with minimal contamination. Crops grown near polluted areas showed a decline in the quality of several chemical compounds. This highlights how traffic-related air pollution and toxic contaminants harm crop vegetation. Based on analyses of various chemical substances, differences in crop quality between polluted and non-polluted sites are evident (Luo 2024).

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Monitoring and regulating heavy metal contamination in affected areas is imperative, as heavy metal pollution represents a critical global environmental challenge. Traditional methods for estimating heavy metal levels in soils have problems (Sharma *et al.,* 2022). They often delay detection and struggle with the complex ways heavy metals build up in multi-plant systems. These traditional approaches are often complex and time-consuming, leading to increased toxic contamination and prolonged treatment durations (Singh *et al.,* 2023). Human activities are a major contributor to the continual rise in harmful air pollution. This study examines the impact of vehicle-emitted toxic air pollutants on crop vegetation. For comparative analysis, crop samples were collected from sites with both toxic and non-toxic pollution. The study also included birch tree organs, which are widely distributed in the environment and utilized in herbal medicine. The investigation into toxic pollution focused on the analysis of birch pollen and leaves, which present challenges for allergy sufferers and may develop allergenic properties under the influence of various environmental factors. Among the plant organs examined, inflorescences were specifically studied to evaluate heavy metal contamination, representing a novel focus not previously documented in the scientific literature (Makuch-Pietras *et al.,* 2023). The leaf samples, however, showed a particularly high accumulation of heavy metals. The heavy metals concentrations in birch and other plants were significantly above background levels, indicating early contamination of forest ecosystems during the initial stages of motorway operations (Kuklova *et al.,* 2022). The main objective of this research is to assess the levels of potentially harmful heavy metals in *Saccharum officinarum* L. about exposure to dust traffic-related air pollution along roadsides.

MATERIAL AND METHOD

Studying location

Hapur is situated in the northwest of Uttar Pradesh. Hapur has a humid climate, which is impacted by the monsoon and spans from latitude 28.730579 to longitude 77.775879, creating cold winters and hot summers (Joshi and Swami 2020).

Obtaining the sample of the crops

The Morepur (latitude 28.730579 to longitude 77.775879), situated in Hapur district of Uttar Pradesh, four different sites were selected for sampling: one exposed to traffic-induced very high dusty, high dusty, dusty pollution and another with minimal traffic-related air pollution (control site). The control location, located approximately two kilometer from the dust-impacted area, served as a reference for non-dust traffic pollution. *Saccharum officinarum* L. was selected as the crop species for this investigation. The taxonomic identification of crop samples was verified and authenticated by the Department of Botany at C.C.S. University, Meerut, Uttar Pradesh, India, with the assigned sample number Bot/PB/260. Samples were collected from soil, mature leaves, and mature edible parts to assess the effect of dust traffic road-related air pollution.

Crops samplings and preparation of samples for heavy metals analysis

Fresh crop samples, including mature leaves and mature edible parts, were separated and dried completely in a hot air oven set at 70°C for 48 hours before being weighed with a digital electronic balance. For heavy metal analysis, the dried crop samples were finely ground using a mechanical grinder. One gram of each sample (mature leaf and mature edible part) was then transferred to a 150 ml conical flask, and 15 ml of a di-acid mixture (Nitric acid, HNO_3, and Perchloric acid, $HClO_4$) was added for initial decomposition, allowing the mixture to stand overnight. Following partial decomposition, the conical flasks containing the samples were heated on a hot plate to complete the digestion process. After digestion, the samples were filtered through Whatman No. 42 filter paper, rinsed with distilled water, and the final volume was adjusted to 50 mL in volumetric flasks. The thoroughly digested, filtered, and diluted samples were analysed for heavy metals concentrations (ppm) including arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn) using an (AAS), following the protocol (Singh *et al.,* 1999).

Soil samplings and preparations of samples for heavy metals analysis

The moisture content of the soil samples was removed by air-drying them. A clean, dry mortar and pestle were used to crush the samples once they had dried, and they were then finely filtered using a 2 mm sieve. A mixture of 10 millilitres of concentrated Hydrochloric acid (HCL) and 3.5 millilitres of concentrated Nitric acid (HNO_3) was used to digest 3 grams of sieved soil samples after they had been weighed. After being kept unheated overnight beneath the switch-on fume closet, the mixes were heated for two hours at 104°C the next day. A 100 ml volumetric flask was filled with distilled water after filtering the digested sample through a Whatman No. 42 filter paper. To conduct an analysis, the solution was moved into sampling vials. The Perk-Elmer A Analyst (Atomic absorption spectroscopy AAS) is a spectro-analytical procedure for the quantitative measurement of chemical elements. AAS is based on the absorption of light by free metallic ions that have been atomized from a sample) B. Welz, M. Sperling (1999), was then used to determine the concentrations (ppm) of these heavy metals like arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn) in the soil samples (Singh *et al.,* 1999).

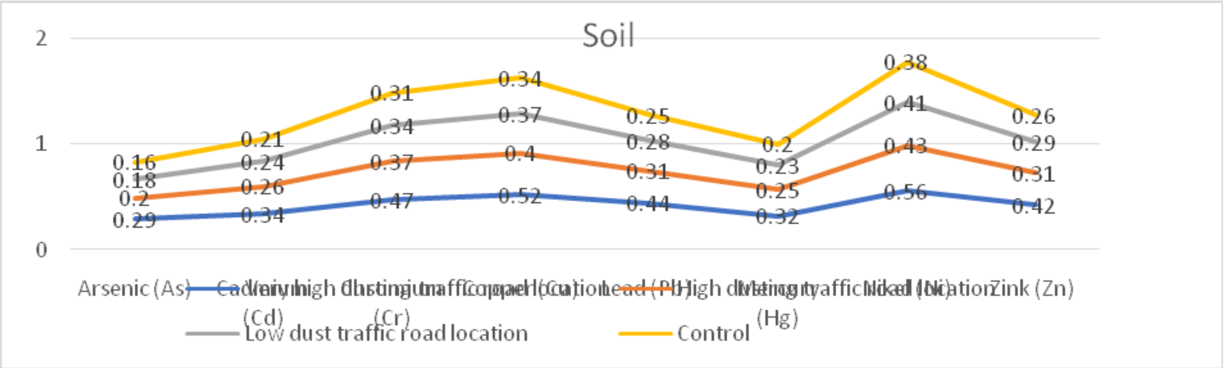
Statistical Analysis

A single-factor analysis of variance (ANOVA) was conducted to analyze the various sample groups. The least significant difference (LSD) values, determined using the method established by were P = 0.001, 0.004, and 0.0002 ($P<0.05$ is considered high significant and very high significant) (Gomez 1984).

RESULTS

Analysis of harmful heavy metals in soil

During the observation period, we found heavy metals in the soil. The metals included arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn). Their concentrations, measured in parts per million (ppm), were taken from these locations: Very high dusting traffic road, High dusting traffic road (500 metres away), Low dust traffic road (1000 metres away) and Control site (1500 metres away). The overall concentrations (ppm) values for heavy metals, including arsenic (0.29 > 0.20 > 0.18 > 0.16), cadmium (0.34 > 0.26 > 0.24 > 0.21), chromium (0.47 > 0.37 > 0.34 > 0.31), copper (0.52 > 0.40 > 0.37 > 0.34), lead (0.44 > 0.31 > 0.28 > 0.25), mercury (0.32 > 0.25 > 0.23 > 0.20), nickel (0.56 > 0.43 > 0.41 > 0.38), and zinc (0.42 > 0.31 > 0.29 > 0.26), indicated a significant difference in the concentrations (ppm) of these heavy metals between the multilocations. Statistical analysis revealed a P= 0.004 ($P<0.05$ is considered high significant) in heavy metals concentrations (ppm) between the multilocations. At the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance, the statistical mean values of heavy metals ranged (0.42 > 0.31 > 0.29 > 0.26).



Significant at: P= 0.004 (P<0.05 is considered highly significant)

Fig. 1: Harmful toxic heavy metals concentrations (ppm) in the soil at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

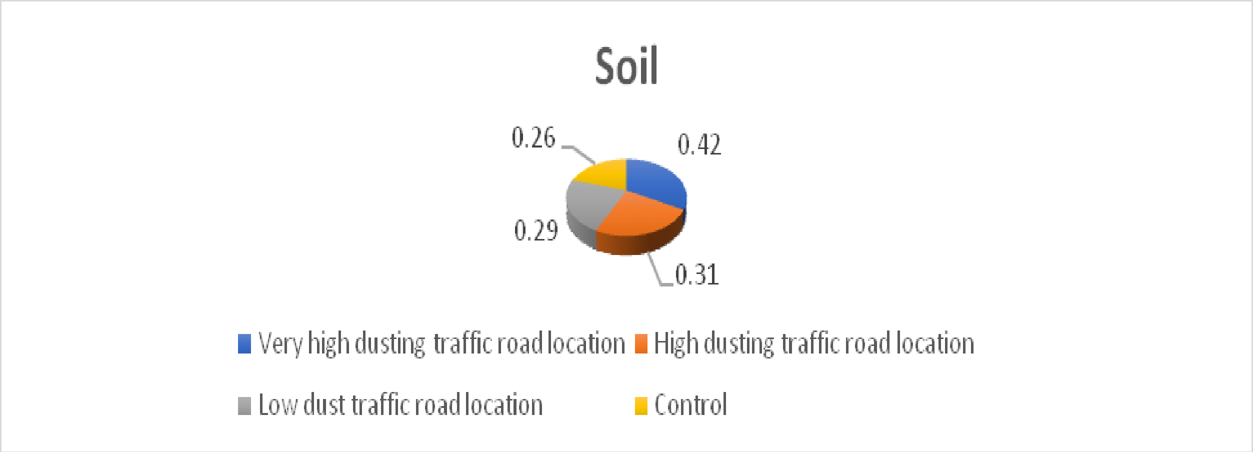
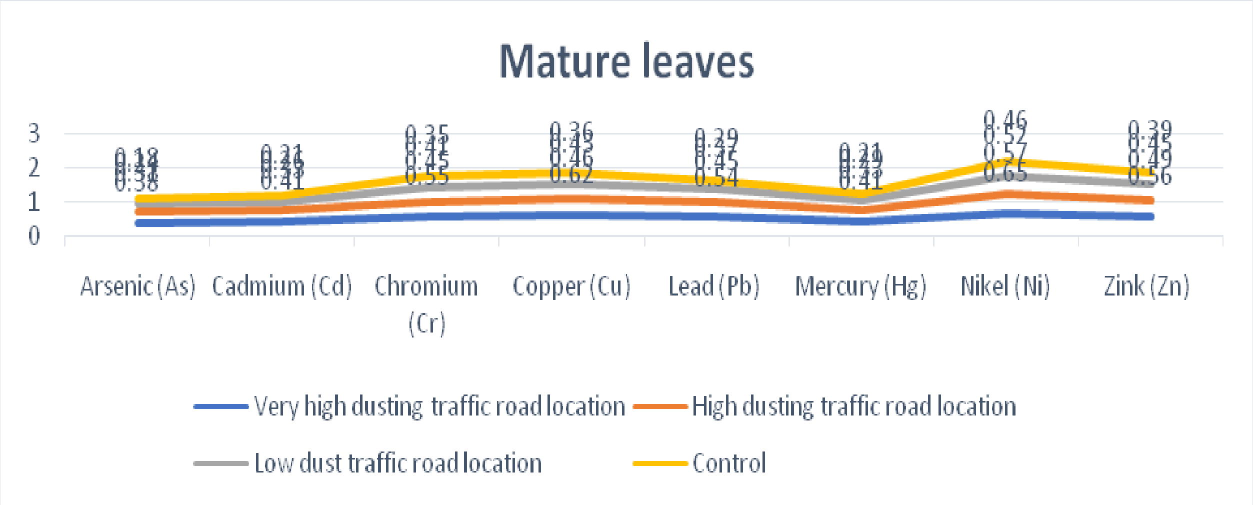


Fig. 2: Mean value of harmful toxic heavy metals in the soil at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

Analysis of harmful heavy metals in mature leaves

The observation period, the heavy metals like arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn), concentrations (ppm) were detected in the mature leaves at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance. The overall concentrations (ppm) values for heavy metals, including arsenic (0.38 > 0.31 > 0.24 > 0.18), cadmium (0.41 > 0.33 > 0.26 > 0.21), chromium (0.55 > 0.45 > 0.41 > 0.35), copper (0.62 > 0.46 > 0.43 > 0.36), lead (0.54 > 0.45 > 0.37 > 0.29), mercury (0.41 > 0.33 > 0.29 > 0.21), nickel (0.65 > 0.57 > 0.52 > 0.46), and zinc (0.56 > 0.49 > 0.45 > 0.39), indicated a significant difference in the concentrations (ppm) of these heavy metals between the multilocation. Statistical analysis revealed a P= 0.001 (P<0.05 is considered high significant) in heavy metals concentrations (ppm) between the multilocation. At the locations very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance, the statistical mean values of heavy metals ranged (0.51 > 0.42 > 0.37 > 0.30).



Significant at: P= 0.001 (P<0.05 is considered highly significant)

Fig. 3: Harmful toxic heavy metals concentrations (ppm) in mature leaves at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

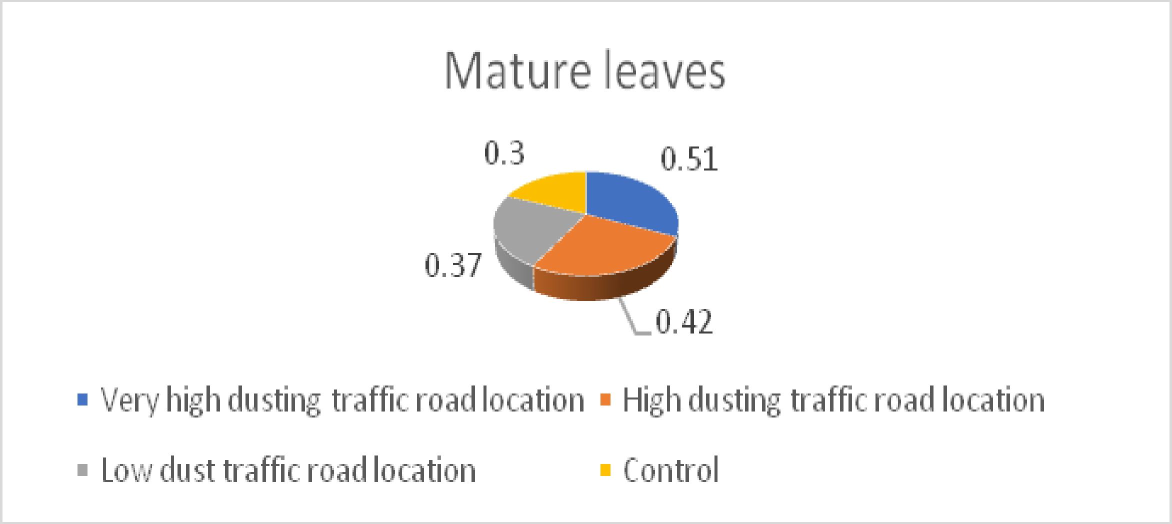
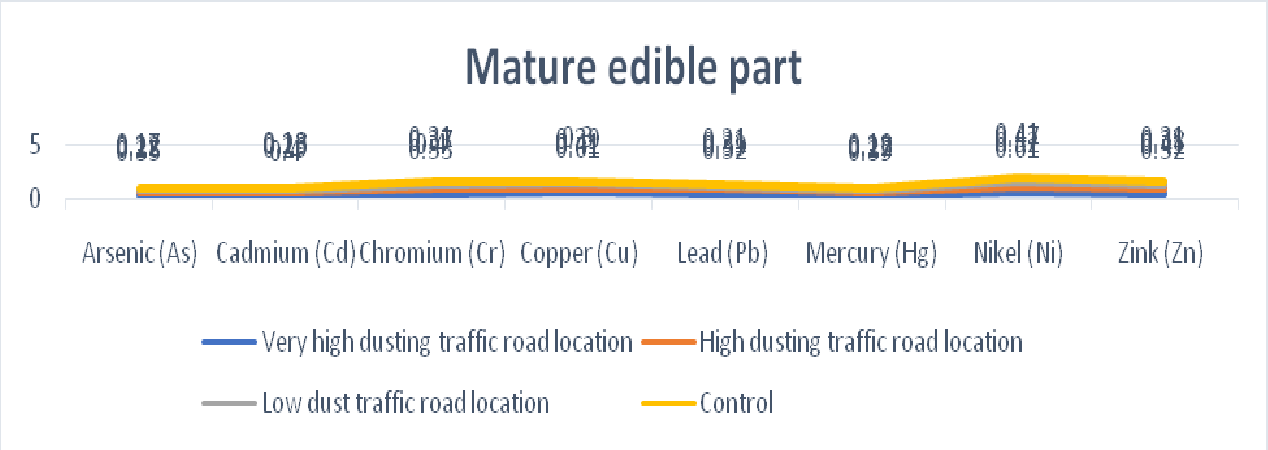


Fig. 4: Mean value of harmful toxic heavy metals in mature leaves at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

Analysis of harmful heavy metals in the mature edible part

The observation period, heavy metals like arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn), concentrations (ppm) were detected in the mature edible part at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance. The overall concentrations (ppm) values for heavy metals, including arsenic (0.35 > 0.28 > 0.22 > 0.17), cadmium (0.40 > 0.29 > 0.23 > 0.18), chromium (0.53 > 0.40 > 0.37 > 0.31), copper (0.61 > 0.41 > 0.39 > 0.30), lead (0.52 > 0.39 > 0.31 > 0.21), mercury (0.39 > 0.27 > 0.22 > 0.19), nickel (0.61 > 0.52 > 0.47 > 0.41), and zinc (0.52 > 0.41 > 0.38 > 0.31), indicated a significant difference in the concentrations (ppm) of these heavy metals between the multilocation. Statistical analysis revealed a P= 0.0002 (P<0.05 is considered very high significant) in heavy metals concentrations (ppm) between the multilocation. At the locations very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance, the statistical mean values of heavy metals ranged (0.49 > 0.37 > 0.32 > 0.26).



Significant at: P= 0.0002 (P<0.05 is considered very high significant)

Fig. 5: Harmful toxic heavy metals concentrations (ppm) in mature edible part at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

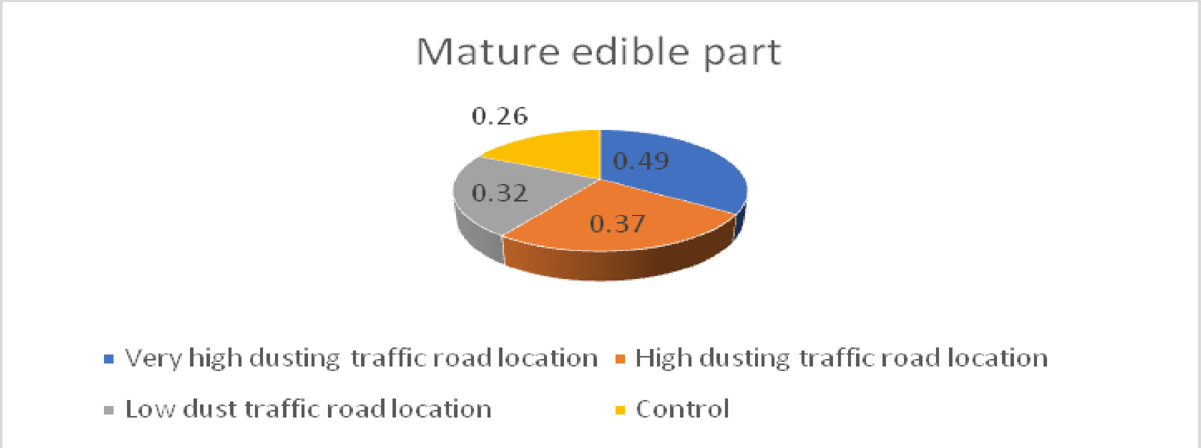


Fig. 6: Mean value of harmful toxic heavy metals in mature edible parts at the locations of the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance

DISCUSSION

This research was conducted on heavy metals like arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), zinc (Zn). The heavy metals concentration (ppm) of soil, mature leaves, and mature edible parts the very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, and control 1500 meters distance multilocation, which was situated away from the traffic road. Major heavy metals of concentration (ppm) were arranged in descending order at in locations (very high dusting traffic road > high dusting traffic road 500 meters distance > low dust traffic road 1000 meters distance > control 1500 meters distance). In the soil, mature leaves and mature edible part from such records, it was found that the concentration (ppm) of heavy metals in the control 1500 meters distance location was found to be less than that of the locations very high dusting traffic road, high dusting traffic road 500 meters distance, low dust traffic road 1000 meters distance, it was also known that the concentration (ppm) of heavy metals in very high dusting traffic road location was higher than the high dusting traffic road 500 meters distance location and the concentration (ppm) of heavy metals in high dusting traffic road 500 meters distance was higher than the low dust traffic road 1000 meters distance. Indicating that traffic air pollution has become a life-threatening hazard. Different toxic heavy metals which are generated as a result of excessive vehicular emissions are entre by the leaves stomata and absorbed root system of crops. The quality of the crop vegetation was found to have significantly declined. Reasons for down level of heavy metals concentration in control location may be, which due to rainfall activity in the environment and due to plantation in both the sites of the road heavy metals transmission the low gets done reduce heavy metals movement in control location. Statistical analysis revealed P = 0.001, 0.004 and 0.0002 ($P<0.05$ is considered high significant and very high significant) in heavy metals concentrations (ppm) between the multilocation. According to major the statistical mean values for these heavy metals arranged to be descending order at in the multilocation.

The heavy metals concentrations of were found to be greater than the background values of Indian soil and other plant parts. In road dust, heavy metals were determined to be the most contaminated (Bisht *et al.,* 2022). The soil samples for multi heavy metals were collected from three distinct traffic circle locations, both at the roadside and 500 meters away from the roadside. The mean concentrations of heavy metals (mg/kg) in the soil samples area from (15.0 to 45.07) for Pb, (0.35 to 2.60) for Cd, (19.05 to 38.0) for Cu, and (58.10 to 101.0) for Zn (Sulaiman *et al.,* 2018). Regardless of the distance from the road, the concentrations of Cd, Pb, and Zn ranged from (0.21–0.58) mg Cd kg^{-1} d.m., (13.60–41.96) mg Pb kg^{-1} d.m., and (40.31–63.97) mg Zn kg^{-1} d.m., respectively (Szwalec *et al.,* 2020). The concentrations of Pb, Zn, and Cd generally decreased as the distance from the road increased. Various plant species consumed by animals were collected along key roadsides. Lead concentrations in plants from the sites ranged from (24 to 142) mg/kg to (24 to 157.67) mg/kg. Copper concentrations in plant and soil samples varied from (28.55 to 115.2) mg/kg and (7.70 to 80.13) mg/kg, respectively. Zinc concentrations in plants and soil samples ranged from (30.8 to 219.23) mg/kg and (13.00 to 120.45) mg/kg, respectively. Nickel concentrations in soil and plant samples ranged from (1.65 to 11.85) mg/kg and (1.83 to 14.87) mg/kg, respectively. In the control site samples, the concentrations of heavy metals (Cd, Zn, Cu, Cr, Pb, and Ni) in plants were determined to be (0.35, 40.00, 88.55, 0.65, 238, and 0.65) mg/kg, respectively (Rupesh Kumar Ojha *et al.,* 2024). The soil samples from the control site showed the following concentrations (0.066, 9.50, 4.83, 55.63, 33.667, and 4.33) mg/kg for (zinc, copper, chromium, lead, and nickel) respectively. These findings indicate significant concentrations of heavy metals in the soil and plants near roadside areas (Ogundele *et al.,* 2015). To assess the impact of traffic emissions on heavy metal concentrations in roadside vegetation, the levels of lead (Pb), copper (Cu), cadmium (Cd), and zinc (Zn) were quantified. Plants from polluted sites exhibited significantly higher concentrations of Pb, Cu, Cd, and Zn compared to those from control areas. Specifically, Pb concentrations in plants at the polluted site ranged from 46.2 to 84.9 µg g^{-1}, with the highest levels observed in multispecies leaves. Elevated concentrations of Cu and Zn were also detected in the multispecies leaves at the polluted site. In contrast, the average concentration of cadmium remained relatively low, with the highest value of 10.5 µg g^{-1} found in leaves. Across all polluted sites, the increase in heavy metal concentrations in plants showed a positive correlation with traffic density. Leaves can therefore be considered a multi-metal indicator when levels of Pb, Cu, Cd, and Zn are elevated (Deepalakshmi *et al.,* 2014). This study aimed to assess the concentration levels of heavy metals, including cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc, in edible plant parts from several local markets in the Turkish province of Izmir. The heavy metals analysed included Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. The study found that the concentrations (µg g−1, dry weight) of these metals in the dust-polluted edible plant samples ranged from (0.035 to 0.262) for Cd, (0.247 to 1.133) for Cr, (1.611 to 43.27) for Cu, (7.425 to 568.6) for Fe, (0.340 to 57.61) for Mn, (0.090 to 2.563) for Ni, (0.032 to 1.712) for Pb, and (5.309 to 75.47) for Zn. In contrast, the concentrations of these metals in non-dusting polluted edible plant samples ranged from (0.026 to 0.172) for Cd, (0.153 to 0.462) for Cr, (0.247 to 68.34) for (Cu, 7.407 to 187.5) for Fe, (0.340 to 49.99) for Mn, (0.042 to 1.332) for Ni, (0.005 to 0.502) for Pb, and (5.314 to 60.37) for Zn. The results demonstrated that all heavy metals were present in lower concentrations in the non-dusting polluted edible plant samples compared to those from the dust-polluted areas (Unver *et al.,* 2015). Both quantitative and qualitative, food is a top concern for sustainable global development. Food quality and human health have been at risk in recent decades due to the detrimental impact of unforeseen pollutants on crop quality. Heavy metals (Hg, As, Pb, Cd, and Cr) pose significant risks to human health, potentially resulting in morbidity and mortality. Therefore, this section emphasizes and examines the implications of heavy metal contamination within soil and food crop subsystems, highlighting its potential hazards to human health (Rai *et al.,* 2019).

Sources of toxic heavy metals in pollutant

The unique feature of heavy metals is that they can come from both natural and man-made sources, apart from harmful toxic heavy metals substances. Unlike other dangerous substances, heavy metals can uniquely originate from both natural and man-made sources, multi of heavy metal contamination in the air pollutant. On the other hand, heavy metal contamination is largely caused by human activity, especially industrial processes and commercial interactions (Anastasiadou *et al.,* 2012). Road networks, vehicular emissions, industrial activities, and similar sources are key contributors to heavy metal pollution. Transportation-related emissions release significant quantities of heavy metals, including arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), nickel (Ni), and zinc (Zn), which are among the most prevalent pollutants. These heavy metals are introduced into the dust environment through mechanisms such as atmospheric deposition, the weathering and degradation of geological materials, and other related processes (Bisht *et al.,* 2022). The anthropogenic activities, including mining waste, residential sewage, industrial discharges Landfills, coal and ore mining operations, and urban stormwater runoff are further sources of heavy metal pollution. Metals can enter soil leaching naturally through chemical weathering of minerals and air systems. The heavy metals present in air and soils enter through leaves stomata, and root system but human activity greatly increases these levels (Lee *et al.,* 2010).

CONCLUSION

This research highlights the significant environmental and health risks posed by heavy metals and gaseous pollutants originating from excessive vehicular emissions. The findings demonstrate that these pollutants are absorbed by crops through root systems and leaf stomata, with concentrations markedly higher in crops located near dust-impacted, traffic-polluted sites compared to those in control areas distant from traffic sources. The elevated levels of heavy metals and gases in these crops act as toxic agents, adversely affecting plant health and posing substantial risks to the animals and humans consuming them. Crops used as livestock fodder can lead to the intake of harmful contaminants, affecting animal health. Also, toxins can build up in the parts of crops we eat, posing serious health risks to humans. This underscores the critical need for effective mitigation strategies to reduce vehicular emissions and limit their impact on agricultural systems and food safety.

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