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Assessment of Heavy Metal Contamination in Locally Cultivated Medicinal Plants

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***Abstract*: The past few years have witnessed a notable rise in global trade in medicinal plants, prompting concerns about the safety and quality of locally cultivated herbal materials. This investigation aims to evaluate the presence of heavy metal contamination, specifically Iron (Fe), Copper (Cu), and cadmium (Cd), in locally cultivated medicinal plants commonly used in traditional and alternative medicine practices. Samples were obtained from a range of local markets and herbal shops. Atomic Absorption Spectroscopy was used for the quantitative analysis of heavy metals, following the appropriate digestion protocols. The results revealed that a significant portion of the examined samples exceeded the permissible limits set by the World Health Organization (WHO) and national pharmacopeias, with cadmium identified as the most common contaminant. Possible sources of contamination encompass polluted soils, industrial emissions, and insufficient post-harvest handling. The results indicate the urgent need for robust quality control standards, effective traceability systems, and regular screening of locally cultivated botanicals. This investigation highlights the significant health risks associated with heavy metal exposure from herbal remedies. It emphasises the need for regulatory alignment in the global herbal trade to ensure consumer safety and therapeutic reliability.**

Keywords: Medicinal plants, Contamination, Pollution, Industrialization, Health risk

I. INTRODUCTION

The global health and wellness domain has experienced a significant resurgence of interest in traditional and herbal medicine (Chaachouay & Zidane, 2024). A substantial segment of the global population, particularly in developing countries, relies on medicinal plants as their primary healthcare resource, driven by a quest for natural remedies, a belief in reduced side effects, and the influence of cultural heritage (Theodoridis et al., 2023). This growing demand has driven the establishment of an extensive and intricate international trade network, through which raw plant materials and completed herbal products are sourced from various regions worldwide. Nonetheless, this worldwide supply chain, although advantageous in broadening access to conventional remedies, presents a significant and frequently overlooked public health issue: the risk of heavy metal contamination (Zamani et al., 2025).

Heavy metals are characterised by their relatively high density and specific toxicity levels, making them persistent pollutants in the environment. Cadmium (Cd), arsenic (As), Lead (Pb), and mercury (Hg) are commonly recognised as significant contributors to the contamination of medicinal plants (Angon et al., 2024). In contrast to organic pollutants, these elements lack biodegradability and have the potential to accumulate in the environment, especially within soil and water systems. The origins of this contamination are complex, stemming from both natural geological formations and extensive human activities. Industrial emissions, mining activities, and agricultural runoff from polluted fertilisers and pesticides, along with the improper disposal of waste, all play a significant role in introducing these toxic elements into the ecosystems where medicinal plants are grown (Adnan et al., 2024).

Plants, as living entities, exhibit an impressive capacity to uptake minerals and nutrients from their surroundings. This process lacks selectivity, allowing for the uptake of heavy metals found in the soil and water as well. The degree of this absorption fluctuates based on the plant species, the particular metal, the soil chemistry, and the contamination level (Asiminicesei et al., 2024). Upon entering the plant, these metals are distributed to various regions, such as the leaves, stems, roots, and fruits, which are frequently utilised in medicinal formulations. Additional contamination may arise during post-harvest processing activities, including drying, grinding, and storage, particularly if unsanitary practices or contaminated equipment are employed. This positions heavy metal contamination as a subtle yet widespread risk across the entire production cycle (Wang et al., 2023a).

The health risks posed to humans by the consumption of medicinal plants contaminated with heavy metals represent a critical concern that requires thorough examination. In contrast to the immediate dangers posed by a single high-dose exposure, the hazards associated with herbal products frequently manifest as chronic issues, stemming from prolonged, low-level consumption of these contaminants (Luo et al., 2021). The human body possesses a finite ability to eliminate heavy metals, resulting in their gradual accumulation in different organs and tissues over time. This may lead to a variety of serious health complications. Chronic lead exposure is known to induce neurotoxicity, which can result in cognitive and developmental issues, particularly in children. Additionally, it may lead to anemia and kidney damage (Wani et al., 2015). Cadmium is identified as a carcinogenic substance in humans and is linked to kidney failure and bone disease (Rasin et al., 2025). Arsenic is known to be carcinogenic and is associated with skin lesions, neurological disorders, and cardiovascular diseases (Fatoki & Badmus, 2022). Mercury poisoning, especially from specific traditional medicines, poses a significant threat, leading to serious neurological and renal harm (Zhao et al., 2022). The insufficient awareness among consumers, coupled with the lack of clear labeling regarding potential contamination, significantly heightens these risks (Zahir et al., 2025).

The worldwide dynamics of the medicinal plant trade pose considerable obstacles to the implementation of effective regulation and quality assurance (Ngai & Shaw, 2025). Although advanced nations have created their own pharmacopoeias and regulatory frameworks, there remains an absence of unified international standards for heavy metal limits in herbal products (Tan et al., 2020). This inconsistency creates a gap that allows products deemed unsafe in one nation to be legally imported and sold in another, as well as locally cultivated plants. Moreover, the intricate and frequently unclear supply chains of imported medicinal plants pose challenges in tracing the product's origin and validating its quality from cultivation to consumption (Mphaga et al., 2024).

Considering the public health risks and regulatory challenges, evaluating heavy metal contamination in imported and locally cultivated medicinal plants transcends a simple scientific endeavor; it is an essential aspect of safeguarding consumer welfare and shaping public health policy (Vinogradova et al., 2023). This evaluation involves a systematic approach that starts with meticulous sample collection to guarantee the representativeness of the product under examination. The essence of the evaluation, nonetheless, resides in the application of advanced analytical methods. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and Atomic Absorption Spectroscopy (AAS) are among the most advanced methods available for detecting and quantifying heavy metals. ICP-MS is highly regarded for its exceptional sensitivity, minimal detection limits, and capacity to analyse numerous elements at once, rendering it perfect for screening various potential contaminants (López-Botella et al., 2023).

The data produced from these analyses is subsequently evaluated against the established permissible limits defined by national and international regulatory authorities, such as the World Health Organization (WHO) and several national pharmacopoeias (for instance, the United States Pharmacopeia and the European Pharmacopoeia) (Johnston & Holt, 2014; Sarma et al., 2023). This analysis facilitates the assessment of whether the product presents a health hazard. The results from these evaluations play a vital role in shaping regulatory choices, setting import alerts, and directing consumer advisories. In a landscape characterised by the ongoing expansion of global trade and the rising interest in traditional medicine, it is crucial to possess a thorough and complex understanding of heavy metal contamination (Borsellino et al., 2020). This knowledge is vital for protecting public health and guaranteeing the safety and effectiveness of imported and locally cultivated medicinal plants (Kaggwa et al., 2022).

Commonly, the following plants are listed in Table 1 and are used to study metal contamination; they are readily available in villages and cities (Fig. 1).

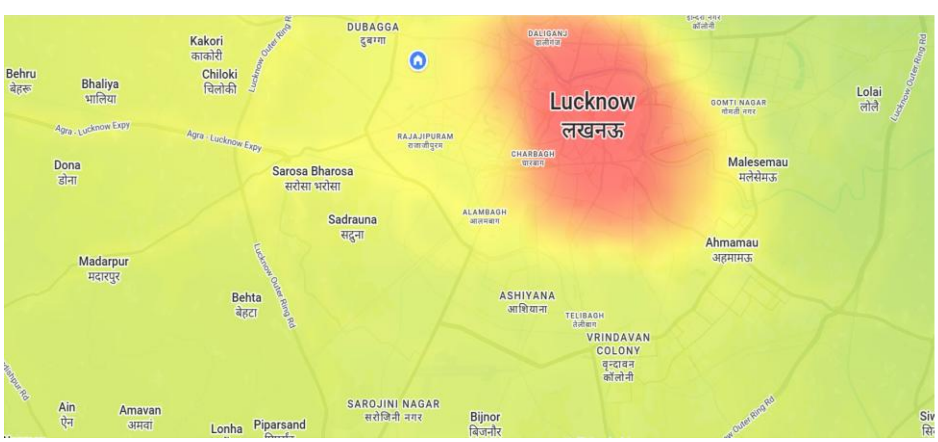

Figure 1: A satellite map view of Alambagh, Lucknow

TABLE 1

S. No.	Plant Name	Scientific Name	Family	Part Used	Medicinal Used	Collection Area
1	Madar	Calotropis	Apocynaceae	Leaf	Antiseptic and Sialogoguev, Oil used in the treatment of Respiratory Catarrhs, Diphtheria. Diphtheria. Leaves serve as a counter-irritant to inhibit milk secretion in cases of mammary abscesses.	Alambagh Lucknow
2	Dhatura	Datura stramonium	Solanaceae	Leaf	Asthma, Cardiac pains, Swellings, Tumors, and Rheumatic pains.	Alambagh Lucknow
3	Sadabahar	Catharanthus roseus	Apocynaceae	Leaf	Leukaemia, Diabetes as Hemostatics as Tranquilizers, to lower Blood Pressure, and as Disinfectants	Alambagh Lucknow
4	Babool	Accacia nilotica	Fabaceae	Bark	Pain-relieving, alternative, and therapeutic approaches for fever. Eradication of Intestinal Parasites, Including Gingivitis Leprosy, Dental and Oral Hygiene, Decoction, Diarrhea and Digestive Ailments, Dysentery, Skin Eruptions, Bed Sores,	Alambagh Lucknow
5	Chilly	Capsicum Sp.	Solanaceae	Fruit	Antibacterial, addresses obesity, enhances circulation, regulates blood pressure, and reduces cholesterol levels, Pain-Killing Rubs for Arthritis and Diabetes Nerve Damage.	Alambagh Lucknow
6	Bathuva	Chinopodium album	Amaranthaceae	Plant	Treat Nutritional Deficiencies, Soothe Burns, and Stomach Aches.	Alambagh Lucknow
7	Tulsi	Ocimum sanctum	Lamiaceae	Leaf	Itching, Pains, Leucorrhoea, Hydrocele, Nocturnal Emissions, Itching, Pains, Leucorrhoea, Hydrocele, Nocturnal Emissions	Alambagh Lucknow
8	Neem	Azardirachta indica	Meliaceae	Bark	Pain-relieving, alternative, and therapeutic approaches for fever management. Suppression of Flower Bile, Elimination of Intestinal Worms, and Reduction of Phlegm	Alambagh Lucknow
9	Doob	Cynedon dactylone	Poaceae	Plant	Antimicrobial, Antiviral, Treatment of Urinary Tract Infections, Prostatitis, Syphilis, Dysentery, and Diabetes	Alambagh Lucknow
10	Papaya	Carica papaya	Caricaceae	fruit	Digestive enzyme for protein, celiac disease	Alambagh Lucknow

Origins of Heavy Metal Pollution

Heavy metals can infiltrate medicinal plants through various pathways (Chen et al., 2021).

1. Soil Contamination: Plants cultivated in polluted soils take up heavy metals via their root systems. Fertilisers, particularly those based on phosphate, frequently include cadmium and lead as contaminants (Alengebawy et al., 2021).

2. Irrigation Water: The application of untreated industrial the use of wastewater for irrigation results in the introduction of metals such as mercury and arsenic into the plant ecosystem (Verma, 2025).

3. Atmospheric Deposition: Industrial emissions and vehicular exhausts contribute to the deposition of lead and other metals onto soil and plant surfaces (Al-Sabbagh & Shreaz, 2025).

4. Herbicide and Pesticide Use: Certain agrochemicals contain metal components or are tainted with metals, leading to bioaccumulation in plant systems (Verma, 2025).

5. Post-Harvest Handling: Throughout the processes of drying, grinding, or storage, plants have the potential to absorb metals from equipment, packaging materials, or contact with contaminated surfaces (Nakra et al., 2025).

The Main Sources of Metal Exposure are -(Briffa et al., 2020)

Natural Resources

a) Weathering of Rocks and Minerals
b) Erosion
c) Flood

Anthropogenic Activity

Human activity encompasses the various actions and impacts that individuals and societies have on the environment, such as pollution, deforestation, urbanization, and industrialization, frequently resulting in ecological and climate alterations (Zhou & Gu, 2024).

1. Industrialization

Following the industry, heavy metals are present in the effluents (S. N. Khan et al., 2023), are illustrated in Table 2.

TABLE 2

Industry	**Heavy metals are present in the effluent**
Chlor alkali	Cd, Cu, Zn, Cr, Hg
Electroplating	Cd, Ni, Cr, Zn
Heater	Cr
Batteries	Pb, Cd, Hg
Paint +dyes	Cr, Pb, Hg, Cr, Se
Textile	Cr
Paper pulp	Hg
Petroleum +refining	Cr, Zn, Pb, Cu, Cd
Fertilizers	Ar, Cd, Cr, Hg, Mn, Zn
Motor vehicles	Cd, Cr, Hg, Zn, Se
Pesticides	Hg, Se, Pb

2. **Mining Activity** - Cu, Pb, Zn, Fe, Cr, Mg.
3. **Weste Disposal** - Pb, Cd, Zn, Hg, Cu, Ni.
4. **Urban Effluent Discharge** - Cd, Cu, Pb, Hg, Mg, Cr, Zn.
5. **Vehicle Exhaust** - Pb, Ca, Fe, Cu, Particulate matter.
6. **Fertilizer** - Ar, Cd, Co, Cd, Hg, Mo, Zn, Ni.
7. **Sewage Sludge in Agriculture Land** - Cu, Cr, Zn, Cd, Ni.

Metal accumulation

Metal accumulation denotes the increase of heavy metals within organisms, soils, or aquatic environments, frequently as a result of environmental pollution, industrial operations, or natural occurrences (Balzani et al., 2022).

1. Roots
2. Above-ground plant tissues

Fate of Heavy Metal in Plants & Animals

The destiny of heavy metals in flora and fauna encompasses absorption, tissue accumulation, disruption of biological processes, potential toxicity, and biomagnification within the food chain, influencing health and ecosystems (Nkwunonwo et al., 2020).

1- Iron (Fe)
2- Manganese (Mn)
3- Zinc (Zn)
4- Copper (Cu)
5- Lead (Pb)
6- Nickel (Ni)
7- Chromium (Cr)
8- Cadmium (Cd)

Arsenic

Arsenic, with an atomic number of 33 and an atomic weight of 74.92, is a metalloid that is frequently encountered in natural settings, particularly within sulphide ores. In India, individuals generally consume between 0.02 and 0.35 mg of arsenic each day through food, water, and air. Trace amounts can indeed promote plant growth; however, higher concentrations, especially from contaminated irrigation water, can hinder crop yields by disrupting root function and nutrient absorption. Prolonged exposure in humans results in a gradual decline in health. Common manifestations frequently encompass ongoing weakness, feelings of nausea, decreased appetite, episodes of vomiting, and instances of diarrhea (Gorgojo-Martínez et al., 2022). Prolonged exposure has significant implications for the respiratory system, resulting in increased mucus production, and may also contribute to liver dysfunction or jaundice. Consequently, while minor quantities might offer biological advantages, prolonged exposure at elevated levels presents considerable risks to agriculture and public health, highlighting the necessity for ongoing monitoring and effective mitigation strategies (Abu Bakar et al., 2025).

Cadmium

Cadmium, with an atomic number of 48 and an atomic weight of 112.41, is a rare metallic element that was identified in 1817. The entry into the environment occurs mainly via mining, metal processing, electroplating, PVC manufacturing, Ni-Cd battery production, and specific pigments. Cadmium acts as a potent inhibitor of enzymes, interfering with vital metabolic functions. While instances of acute poisoning are rare, prolonged exposure to low levels can result in significant health complications, especially chronic lung damage and renal tubular disorders. The enduring presence of cadmium in the environment and its propensity for bioaccumulation highlight its importance as a public health and ecological issue, necessitating rigorous oversight and regulation of industrial emissions (Genchi et al., 2020).

Iron

Iron, with an atomic number of 26 and an atomic weight of 55.84, stands out as the most prevalent element throughout the Earth and ranks as the fourth most abundant in the crust. This element exhibits various oxidation states, spanning from - 2 to +6, with the +2 (ferrous) and +3 (ferric) forms being the most prevalent in natural and biological contexts (Williamson, n.d.). Iron is a crucial trace element found in nearly all living organisms. This component is integral to heme-containing proteins and enzymes, facilitating essential functions like oxygen transport, electron transfer, and cellular respiration. The ability of iron to participate in redox reactions renders it essential for energy production and metabolic regulation in various life forms (Venkataramani, 2021).

Chromium

Chromium, with an atomic number of 24 and an atomic weight of 51.99, is an element that is extensively found in the Earth's crust. It exists in multiple oxidation states ranging from Cr^{2+} to Cr^{6+}, with the trivalent (Cr^{3+}) and hexavalent (Cr^{6+}) forms being the most relevant in industrial applications. The main natural source is chromite ore, which comprises approximately 68% chromium. Chromium metal and its compounds play a crucial role in the production of stainless steel, ferrochromium, specialised alloys, and chrome-based pigments. These substances find extensive applications in leather tanning, mordant dyeing, food preservation, and serve as anticorrosive agents in cooling systems. The adaptability of chromium renders it essential in various sectors (Al-Battashi et al., 2016).

II. MATERIALS AND METHODS

Preparation of samples

Plant part used for the sample preparation.

Sample Collection:

Five samples per category were collected; roadside sites were within 10 m of highways, while non-roadside sites were located over 500 m away.

Washing and drying

Plant parts underwent a thorough rinsing process with tap water, followed by a wash with distilled water. Subsequently, they were cut into small pieces and dried in an oven. Upon achieving complete dryness, each component of the plant was meticulously ground into a fine powder for subsequent analysis. In order to reduce the potential for contamination, all glassware underwent a meticulous washing process with distilled water and was subsequently dried in an oven before being utilised. This standardised preparation guarantees that the samples are maintained in a clean, uniform state, making them appropriate for precise chemical or elemental analysis (Wang et al., 2023b). Thorough cleaning, drying, and grinding are critical processes to ensure reliability and reproducibility in laboratory studies that involve plant materials.

Analytical Techniques for Heavy Metal Estimation (Jain et al., 2024)are illustrated in Table 3.

TABLE 3

Technique	Description	Pros/Cons
Atomic Absorption Spectroscopy (AAS)	Most widely used for Pb, Cd, As, Hg	Accurate, affordable, needs digestion
Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	Highly sensitive for trace detection	Expensive, requires skilled operation
X-ray Fluorescence (XRF)	Non-destructive elemental analysis	Portable, but less sensitive
UV-Visible Spectrophotometry	Suitable for preliminary screening	Less specific

Element analysis of medicinal plants by the AAS Technique

Portions of the dried, powdered samples were carefully weighed and subsequently digested in a mixture of concentrated acids (HCl and HNO_3) through gentle heating (Moradi et al., 2026). The resulting clear solution underwent filtration and was subsequently diluted to suitable levels for analysis. Elemental determinations were performed utilising a Perkin-Elmer 3100 atomic absorption spectrometer, which was fitted with appropriate cathode lamps. The concentrations of different elements were determined through the comparator method utilizing A.R.-grade standard solutions of the relevant elements. This procedure guarantees precise quantification through the provision of clear digests, reduction of interference, and the use of high-purity standards for calibration, thus upholding accuracy and dependability in elemental analysis (Lokhande et al., 2010).

Measurement of Metals in Plants

Collected samples were washed and dried. Dried and powdered samples (1 gm) have been kept overnight in HNO_3: $HClO_4$ (3:1, v/v) and digested at 70–80 ^{0}C on a hot plate in a borosilicate glass conical flask. The solution was evaporated to dryness until the tissue was completely digested, followed by an increase in temperature to 105 °C to concentrate the volume to approximately 0.5–1.0 ml. The residue was subsequently redissolved and diluted to a final volume of 20 ml using distilled water. Every sample underwent analysis in triplicate to guarantee precision and consistency. The levels of heavy metals were assessed through the use of an atomic absorption spectrophotometer. This procedure guarantees comprehensive digestion, appropriate dilution, and accurate quantification of metals, while conducting triplicate analysis reduces experimental error and enhances the credibility of the results.

Metal Concentration (**µg/g**) or **mg/kg** = X- Y x V / W

Where,

X= Reading of sample in ppm on AAS

Y= Reading of Blank sample in ppm on AAS

V=final volume of Digested samples

W= Dry weight of the plant in gm.

III. Results and Discussion

The presence of heavy metal contamination in the environment has been recognised for some time. These metals are found naturally in small amounts within plants, and numerous ones are vital micronutrients for both flora and fauna. Nonetheless, anthropogenic actions greatly elevate their concentrations in the environment. Significant human-induced sources encompass industrial activities, farming methods, vehicle emissions, coal-powered energy facilities, and city waste incinerators.

This study involved the analysis of heavy metals Cu, Fe, and Cd in various parts of selected medicinal plants gathered from both roadside areas and locations further away from the road. Table 1 outlines the botanical names, families, common names, and medicinal applications of these plants, whereas Table 3 details the concentrations of the metals. The findings presented in Table 3 indicate that the digestion procedure was thoroughly executed, and there was significant variability in heavy-metal content across the samples.

Samples collected from both roadside and non-roadside locations surpassed the permissible limit for cadmium set by the WHO in 1998, which is 0.3 mg/kg. Sadabahar exhibited notably elevated cadmium concentrations. Cadmium exhibits significant toxicity to plants when present at concentrations ranging from 5 to 10 mg/kg, with all analysed plant parts showing varying levels of this element. The presence of these metals could affect the therapeutic properties of the plants, yet higher levels may present potential health risks.

The concentrations of Fe and Cu observed fell within the range documented in a variety of foods, highlighting their significance as essential elements. Although these metals play an essential role in human health, their excessive presence can lead to various disorders. Iron, while generally not categorised as a toxic heavy metal because of its essential physiological functions, can pose risks when present in excessive amounts. Among the plants examined, Madar exhibited the highest concentration of Fe at 49.97 mg/kg, and details of the results are described in Table IV a,b,c. The findings of this study emphasize the significant impact of environmental factors on metal accumulation and stress the importance of monitoring medicinal plants to ensure their safe use.

TABLE 4 (A)

Results of Iron

Plant Name	Iron		
	Away from the road	Close to the road	Difference
Madar	49.97	67.02	17.05
Dhatura	26.58	43.61	17.03
Sadabahar	22.33	31.67	9.34
Babool	48.88	56.55	7.67
Chilly	7.67	9.34	1.67
Bathuva	5.27	5.87	0.60
Tulsi	30.02	38.22	8.20
Neem	25.38	25.51	0.13
Doob	14.96	15.48	0.52
Papaya	39.56	43.12	3.56

TABLE 4 (B)

Results of Copper

Plant Name	Copper		
	Away from the road	Close to the road	Difference
Madar	0.36	0.53	0.17
Dhatura	1.88	9.53	7.65
Sadabahar	4.56	7.63	3.07
Babool	6.05	14.66	8.61
Chilly	4.01	5.38	1.37
Bathuva	1.06	1.11	0.05
Tulsi	0.33	0.37	0.04
Neem	1.43	4.23	2.80
Doob	1.24	2.46	1.22
Papaya	0.27	2.16	1.89

TABLE 4 (C)

Results of Cadmium

Plant Name	Cadmium		
	Away from the road	Close to the road	Difference
Madar	1.36	1.67	0.31
Dhatura	0.81	1.96	1.15
Sadabahar	5.02	10.62	5.6
Babool	0.65	1.8	1.15
Chilly	1.66	2.21	0.55
Bathuva	3.53	3.77	0.24
Tulsi	2.61	2.88	0.27
Neem	1.61	3.96	2.35
Doob	1.46	1.67	0.21
Papaya	1.88	2.13	0.25

Comparison view: - Result data with comparison are elaborated in Fig.2,3,4

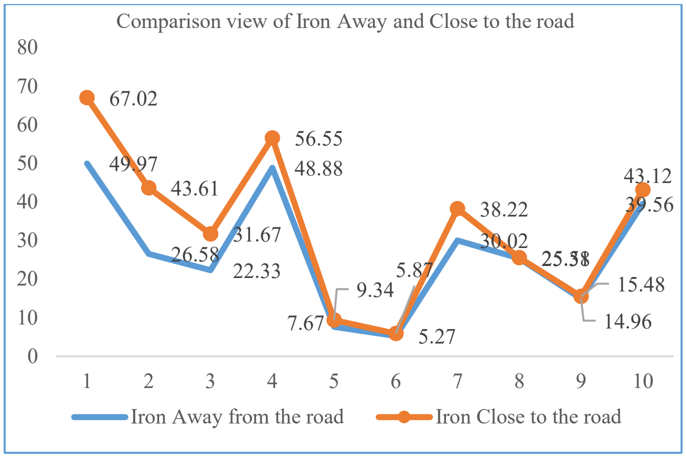

Figure 2: Comparison view of Iron Away and Close to the road

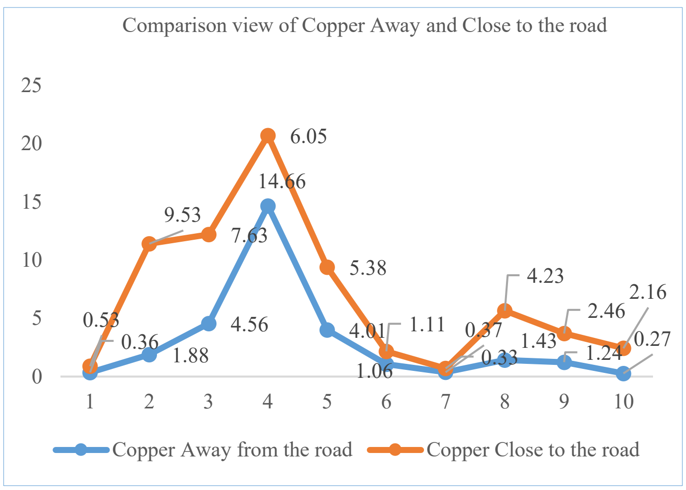

Figure 3: Comparison view of Iron Away and Close to the road

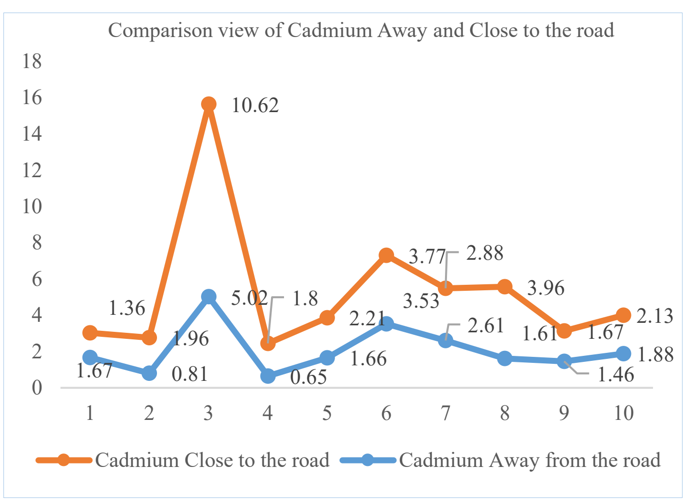

Figure 4: Comparison view of Iron Away and Close to the road

Health Risks Associated with Heavy Metal Contamination

Heavy metal contamination poses significant health risks, including organ damage, neurological disorders, developmental issues, cancer, and compromised immune function, typically arising from extended exposure via contaminated food, water, or air (Järup, 2003).

Bioaccumulation: Define bioaccumulation and discuss the process by which heavy metals can build up in the human body over an extended period (Nnaji et al., 2023).

Toxicity: Examine the distinct health impacts associated with various heavy metals, including neurotoxic effects, kidney toxicity, and potential carcinogenic properties (Jomova et al., 2025).

Vulnerable Populations: It is important to note that specific groups, such as pregnant women and children, exhibit a heightened vulnerability to these risks (Kimberly Ernstmeyer 1, 2022).

International and Domestic Regulatory Issues

Global organizations like the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) have established guidelines regarding the permissible levels of heavy metals in herbal medicines and raw plant materials (Alawadhi et al., 2024). The World Health Organisation sets maximum limits for various contaminants in herbal products, specifically 10 mg/kg for lead, 0.3 mg/kg for cadmium, 1.0 mg/kg for arsenic, and 0.5 mg/kg for mercury. Even with these guidelines in place, the level of enforcement differs greatly across countries, and numerous developing nations do not possess strong regulatory frameworks or adequate testing infrastructure to oversee imported herbal materials and locally cultivated plants as well (Kumar & Gupta, 2012).

Furthermore, herbal products are frequently promoted and utilised with the belief that "natural" signifies "safe," resulting in insufficient regulation and a lack of consumer awareness about potential contamination risks. In certain areas, the sale of medicinal plants occurs without adequate labeling, traceability of origin, or quality assurance, complicating the evaluation of exposure levels and the accountability of producers (Gamil et al., 2025). The absence of transparency raises significant issues regarding imported herbs, particularly when traceability throughout the supply chain is either restricted or entirely lacking (M. Khan et al., 2022).

IV. Conclusion

The presence of heavy metal contamination in medicinal plants poses a significant and frequently neglected threat to public health. Given the worldwide dependence on herbal remedies, it is essential to guarantee their safety through thorough monitoring and regulation. Recognising sources of contamination, including polluted soil, water, or inadequate processing, is the initial step toward effective management. Contemporary analytical methods facilitate precise detection, whereas sustainable cultivation and harvesting approaches contribute to the prevention of harmful metal accumulation. Enhancing consumer awareness and implementing quality standards are both essential. Addressing this issue necessitates a collaborative approach involving various stakeholders, including regulatory bodies and the herbal medicine industry. Coordinated action is essential for preserving the therapeutic value of medicinal plants and safeguarding consumers from concealed health risks. Ensuring the purity and safety of herbal products goes beyond mere scientific or regulatory hurdles; it stands as a critical public health imperative that demands our attention.

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