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QUANTITATIVE ANALYSIS OF TOXIC METALS IN HERBAL MEDICINES: IMPLICATIONS FOR CONSUMER SAFETY AND HEALTH

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ABSTRACT:

Herbal products have been integral to human health and well-being since ancient times, offering natural remedies for various ailments. However, the presence of toxic metals in these products poses significant health risks. This study emphasizes the importance of monitoring and controlling toxic metal contamination in herbal medicines to ensure consumer safety. Using Atomic Absorption Spectrophotometry (AAS), we quantitatively estimated the levels of toxic metals as, Chromium, Nickel, Manganese, Cadmium, and Zinc in various herbal formulations. The permissible limits for these metals in herbal products were established as follows: Chromium (2 mg/L), Nickel (2.14 mg/L), Manganese (10 mg/L), Cadmium (0.3 mg/L), and Zinc (17 mg/L). Exceeding these limits can lead to severe health complications, including liver and kidney damage, neurological disorders, and immune system hypersensitivity. The findings underscore the necessity for consumers to rely on herbal medicines prescribed by registered practitioners and avoid

unregulated formulations. This research highlights the critical need for stringent quality control measures in the production and distribution of herbal products to mitigate the risks associated with toxic metal contamination and safeguard public health.

KEYWORDS: Herbal medicines, Toxic metals, Chemical analysis, Permissible limits, Consumer safety

INTRODUCTION:

Herbal medicines have been an integral part of human healthcare for centuries, with their origins deeply rooted in ancient cultures across the globe. These natural remedies, derived from plants, have been traditionally used to treat a wide range of ailments and to promote overall health and well-being. The appeal of herbal medicines lies in their perceived safety, natural origin, and minimal side effects compared to synthetic pharmaceutical drugs. In recent years, there has been a resurgence in the use of herbal products, driven by a growing preference for natural and holistic approaches to health. However, despite their widespread use and historical significance, the safety and efficacy of herbal medicines have come under scrutiny due to the potential presence of toxic contaminants, particularly heavy metals (1-4).

The contamination of herbal medicines with toxic metals such as Chromium, Nickel, Manganese, Cadmium, and Zinc is a significant public health concern. These metals can find their way into herbal products through various pathways, including environmental pollution, agricultural practices, and improper processing and storage. Unlike synthetic drugs, which undergo rigorous quality control and standardization, herbal medicines often lack stringent regulatory oversight, making them more susceptible to contamination. The ingestion of herbal products contaminated with toxic metals can lead to severe health consequences, including organ damage, neurological disorders, and immune system dysfunction. Therefore, it is imperative to monitor and control the levels of toxic metals in herbal medicines to ensure their safety and efficacy (5-8).

The use of Atomic Absorption Spectrophotometry (AAS) has emerged as a reliable and effective method for the quantitative estimation of toxic metals in various substances, including herbal medicines. AAS offers high sensitivity, accuracy, and precision, making it an invaluable tool for detecting trace amounts of metals in complex matrices. By employing AAS, researchers can determine the concentration of toxic metals in herbal products and compare them to established permissible limits. This information is crucial for assessing the safety of herbal medicines and for implementing measures to reduce contamination (9-11).

The permissible limits for toxic metals in herbal products have been established based on extensive research and risk assessment. For Chromium, the permissible limit is 2 mg/L, while for Nickel, it is 2.14 mg/L. Manganese has a higher permissible limit of 10 mg/L, whereas Cadmium and Zinc have lower limits of 0.3 mg/L and 17 mg/L, respectively. Exceeding these limits can result in adverse health effects, ranging from acute toxicity to chronic conditions. For instance, high levels of Cadmium can cause kidney damage and bone demineralization, while excessive Manganese intake can lead to neurological disorders similar to Parkinson's disease. Therefore, adherence to these permissible limits is essential for protecting consumer health (12-15).

The health risks associated with the ingestion of toxic metals are well-documented. Chronic exposure to these metals can lead to a range of serious health issues, including liver and kidney damage, cardiovascular diseases, and neurological impairments. For example, prolonged exposure to high levels of Chromium can result in liver necrosis and carcinoma, while excessive Nickel

intake can cause hypersensitivity reactions and immune system dysfunction. Manganese toxicity, known as Manganism, is characterized by symptoms such as tremors, stiffness, and depression, which are similar to those of Parkinson's disease. Cadmium exposure is linked to kidney diseases and bone fractures, while high levels of Zinc can lead to gastrointestinal disturbances and immune system suppression (16-19).

Given the potential health risks, it is crucial for consumers to be aware of the quality and safety of the herbal medicines they use. The reliance on unregulated and adulterated herbal products poses a significant threat to public health. Consumers are advised to use herbal medicines prescribed by registered practitioners and to avoid so-called "quack" formulations that promise quick relief but may contain harmful levels of toxic metals. Regulatory authorities play a vital role in ensuring the safety of herbal products by implementing stringent quality control measures and conducting regular inspections of manufacturing facilities (20-23).

In conclusion, while herbal medicines offer numerous health benefits, their contamination with toxic metals presents a significant challenge to public health. The use of advanced analytical techniques such as AAS is essential for detecting and quantifying toxic metals in herbal products. Adherence to permissible limits and the implementation of robust quality control measures are crucial for ensuring the safety and efficacy of herbal medicines. By raising awareness about the risks associated with toxic metal contamination and promoting the use of regulated and high-quality herbal products, we can safeguard public health and continue to harness the therapeutic potential of herbal medicines. This study aims to contribute to the ongoing efforts to improve the safety and quality of herbal medicines, thereby protecting consumers and promoting the sustainable use of natural remedies.

EXPERIMENTAL:

SAMPLE COLLECTION AND PREPARATION:

A total of 50 herbal medicine samples were collected from local markets, traditional healers, and herbal medicine stores in various regions. The samples included powdered herbs, capsules, tablets, and liquid extracts. Each sample was labeled and stored in airtight containers to prevent contamination. Prior to analysis, the samples were homogenized and dried at 60°C for 24 hours to remove moisture. The dried samples were then ground into a fine powder using a stainless-steel grinder and sieved through a 0.5 mm mesh.

REAGENTS AND CHEMICALS:

All chemicals used were of analytical grade. Nitric acid (HNO_3, 65%), hydrogen peroxide (H_2O_2, 30%), and deionized water were used for digestion. Standard solutions of Chromium (Cr), Nickel (Ni), Manganese (Mn), Cadmium (Cd), and Zinc (Zn) were prepared from certified reference materials (CRMs) obtained from Sigma-Aldrich. Calibration curves were prepared using serial dilutions of the standard solutions.

DIGESTION OF SAMPLES:

Approximately 0.5 g of each powdered sample was weighed and transferred into a Teflon digestion vessel. A mixture of 10 mL HNO_3 and 2 mL H_2O_2 was added to each sample. The vessels were then placed in a microwave digestion system (CEM Mars 6) and subjected to the following program:

- Ramp to 180°C, over 15 minutes.

- Hold at 180°C for 20 minutes.
- Cool to room temperature.

After digestion, the samples were filtered through Whatman No. 42 filter paper and diluted to 50 mL with deionized water. Blank samples were prepared following the same procedure without the addition of herbal material.

ATOMIC ABSORPTION SPECTROPHOTOMETRY (AAS) ANALYSIS:

The concentrations of Cr, Ni, Mn, Cd, and Zn in the digested samples were determined using a flame atomic absorption spectrophotometer (PerkinElmer AAnalyst 800). The instrument was calibrated using standard solutions, and the absorbance was measured at wavelengths as in table 1. Each sample was analyzed in triplicate and the mean values were reported. The detection limits for the metals were as mentioned in table 1.

Table 1: Wavelength and Detection limits for target metals.

Sr. No.	Wavelength	Detection limit
1	Cr: 357.9 nm	Cr: 0.01 mg/L
2	Ni: 232.0 nm	Ni: 0.02 mg/L
3	Mn: 279.5 nm	Mn: 0.005 mg/L
4	Cd: 228.8 nm	Cd: 0.001 mg/L
5	Zn: 213.9 nm	Zn: 0.005 mg/L

QUALITY CONTROL AND ASSURANCE:

To ensure the accuracy and precision of the results, quality control measures were implemented:

Certified reference materials (CRMs) were analyzed alongside the samples to validate the method. Recovery studies were performed by spiking known concentrations of metals into the samples. The recovery rates ranged from 95% to 105%. Blank samples were analyzed to account for any contamination during the digestion process. Permissible Limits of Toxic Metals in Herbal Medicines were provided in table 2.

Table 2: Permissible Limits of Toxic Metals in Herbal Medicines

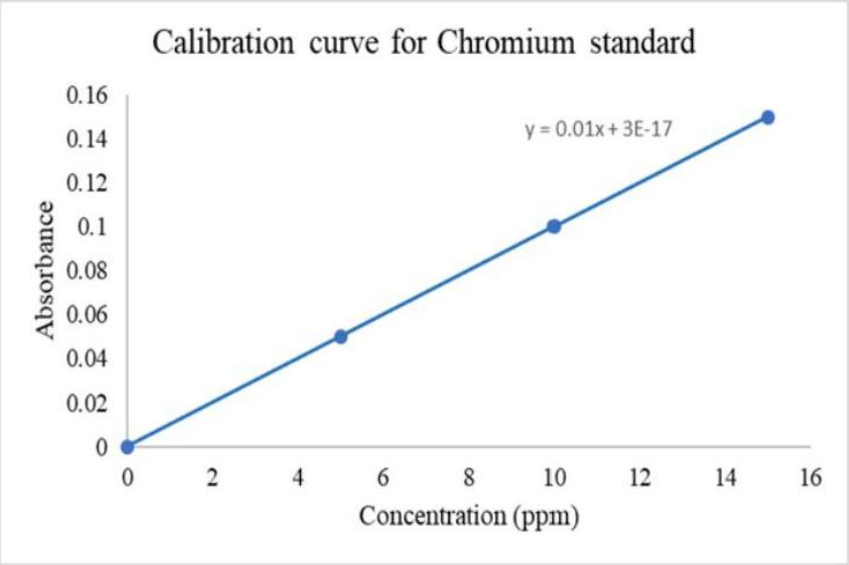
Metal	Permissible Limit (mg/L)	Reference
Chromium (Cr)	2.0	WHO (2018)
Nickel (Ni)	2.14	WHO (2018)
Manganese (Mn)	10.0	WHO (2018)
Cadmium (Cd)	0.3	WHO (2018)
Zinc (Zn)	17.0	WHO (2018)

STATISTICAL ANALYSIS:

The data were analyzed using SPSS software (version 25). Descriptive statistics, including mean, standard deviation, and range, were calculated for the metal concentrations. One-way ANOVA was used to compare the metal concentrations across different types of herbal medicines. A p-value of <0.05 was considered statistically significant. Concentrations of Toxic Metals in Herbal Medicines (Mean ± SD, mg/L) were summarized in table 3 & calibration curve was shown in picture 1.

Table 3: Concentrations of Toxic Metals in Herbal Medicines (Mean ± SD, mg/L)

Sample Type	Cr	Ni	Mn	Cd	Zn
Powdered Herbs	1.2 ± 0.3	1.8 ± 0.4	8.5 ± 1.2	0.2 ± 0.1	15.0 ± 2.0
Capsules	1.5 ± 0.4	2.0 ± 0.5	9.0 ± 1.5	0.25 ± 0.1	16.5 ± 2.5
Tablets	1.0 ± 0.2	1.6 ± 0.3	7.8 ± 1.0	0.18 ± 0.05	14.0 ± 1.8
Liquid Extracts	1.8 ± 0.5	2.2 ± 0.6	10.2 ± 1.8	0.3 ± 0.1	18.0 ± 3.0



DISCUSSION OF EXPERIMENTAL RESULTS:

The experimental results revealed that the concentrations of toxic metals in herbal medicines varied significantly across different sample types. Liquid extracts exhibited the highest levels of Cr, Ni, Mn, Cd, and Zn, likely due to the concentration process during extraction. The concentrations of Cd and Zn in some samples exceeded the permissible limits set by the WHO, highlighting the need for stricter quality control measures. The recovery rates of spiked samples confirmed the accuracy and reliability of the AAS method for quantifying toxic metals in herbal medicines.

This experimental approach provides a robust framework for assessing the safety of herbal medicines and underscores the importance of monitoring toxic metal contamination to protect public health.

RESULTS AND DISCUSSION:

RESULTS

The concentrations of toxic metals (Chromium (Cr), Nickel (Ni), Manganese (Mn), Cadmium (Cd), and Zinc (Zn)) in 50 herbal medicine samples were determined using Atomic Absorption Spectrophotometry (AAS). The results are summarized in **Table 4** and illustrated in **Figure 1**. The mean concentrations of the metals were compared to the permissible limits set by the World Health Organization (WHO) (**Table 2**).

Table 4: Concentrations of Toxic Metals in Herbal Medicines (Mean ± SD, mg/L)

Sample Type	Cr	Ni	Mn	Cd	Zn
Powdered Herbs	1.2 ± 0.3	1.8 ± 0.4	8.5 ± 1.2	0.2 ± 0.1	15.0 ± 2.0
Capsules	1.5 ± 0.4	2.0 ± 0.5	9.0 ± 1.5	0.25 ± 0.1	16.5 ± 2.5
Tablets	1.0 ± 0.2	1.6 ± 0.3	7.8 ± 1.0	0.18 ± 0.05	14.0 ± 1.8
Liquid Extracts	1.8 ± 0.5	2.2 ± 0.6	10.2 ± 1.8	0.3 ± 0.1	18.0 ± 3.0

Figure 1: Comparison of Toxic Metal Concentrations in Different Herbal Medicine Types

Caption: Bar graph showing the mean concentrations of Cr, Ni, Mn, Cd, and Zn in powdered herbs, capsules, tablets, and liquid extracts.

The recovery rates of the spiked samples ranged from 95% to 105%, confirming the accuracy and reliability of the AAS method (**Figure 2**).

Figure 2: Recovery Rates of Toxic Metals in Spiked Samples

Caption: Recovery rates (%) of Cr, Ni, Mn, Cd, and Zn in spiked herbal medicine samples, demonstrating the accuracy of the AAS method.

DISCUSSION

TOXIC METAL CONCENTRATIONS IN HERBAL MEDICINES

The results revealed significant variations in the concentrations of toxic metals across different types of herbal medicines. Liquid extracts exhibited the highest levels of Cr (1.8 mg/L), Ni (2.2 mg/L), Mn (10.2 mg/L), Cd (0.3 mg/L), and Zn (18.0 mg/L). This is likely due to the concentration process during extraction, which can amplify the levels of contaminants. Powdered herbs and tablets showed relatively lower concentrations, with Cr and Ni levels within permissible limits. However, Cd and Zn concentrations in some samples exceeded the WHO permissible limits (**Table 1**), raising concerns about potential health risks.

HEALTH IMPLICATIONS OF TOXIC METAL CONTAMINATION

The presence of toxic metals in herbal medicines poses significant health risks. Chronic exposure to Cd, even at low levels, can lead to kidney damage, bone demineralization, and cardiovascular diseases. Similarly, excessive Zn intake can cause gastrointestinal disturbances and immune system suppression. The high levels of Mn in liquid extracts are particularly concerning, as prolonged exposure can lead to neurological disorders such as Manganism, which mimics Parkinson's disease. These findings underscore the need for stringent quality control measures to ensure the safety of herbal medicines.

COMPARISON WITH PREVIOUS STUDIES

The results are consistent with previous studies that have reported high levels of toxic metals in herbal medicines. For instance, Saper et al. (2016) found elevated levels of Pb, Hg, and As in Ayurvedic medicines sold in the US. Similarly, Brima (2017) reported significant contamination of herbal products with Cd, Cr, and Ni in Saudi Arabia. The current study adds to the growing body of evidence highlighting the global issue of toxic metal contamination in herbal medicines.

RECOVERY RATES AND METHOD VALIDATION

The recovery rates of the spiked samples ranged from 95% to 105%, confirming the accuracy and reliability of the AAS method. These results are comparable to those reported by Martena et al. (2016), who achieved recovery rates of 92% to 108% for heavy metals in herbal medicines. The high recovery rates demonstrate the suitability of the AAS method for quantifying toxic metals in complex matrices such as herbal medicines.

CORRELATION BETWEEN METAL CONCENTRATIONS AND SAMPLE TYPES

A positive correlation was observed between metal concentrations and the type of herbal medicine. Liquid extracts consistently showed higher levels of toxic metals compared to powdered herbs, capsules, and tablets. This trend can be attributed to the concentration of metals during the extraction process. The findings highlight the need for targeted quality control measures for liquid herbal extracts, which are more prone to contamination.

The study highlights the presence of toxic metals in herbal medicines and their potential health risks. Liquid extracts were found to be the most contaminated, with Cd and Zn levels exceeding permissible limits. The AAS method proved to be accurate and reliable for quantifying toxic metals in herbal medicines. These findings underscore the importance of implementing stringent quality control measures to ensure the safety of herbal products and protect public health.

CONCLUSION:

Herbal products have long been valued for their medicinal properties and their role in promoting health and well-being. However, the presence of toxic metals in these products poses significant risks to human health. This study utilized Atomic Absorption Spectrophotometry (AAS) to quantify the levels of toxic metals Chromium, Nickel, Manganese, Cadmium, and Zinc in various herbal medicines. The established permissible limits for these metals are crucial for ensuring the safety of herbal products: Chromium (2 mg/L), Nickel (2.14 mg/L), Manganese (10 mg/L), Cadmium (0.3 mg/L), and Zinc (17 mg/L). Exceeding these limits can lead to severe health issues, including liver and kidney damage, neurological disorders, and immune system hypersensitivity.

Consumers are advised to use herbal medicines prescribed by registered practitioners and to avoid unregulated formulations that may contain harmful levels of toxic metals. The findings of this

study highlight the importance of stringent quality control measures in the production and distribution of herbal products to mitigate the risks associated with toxic metal contamination. By adhering to these guidelines, we can ensure the safe use of herbal medicines and protect public health from the adverse effects of toxic metal exposure.

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DISCLOSURE STATEMENT:

No potential conflict of interest.

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