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CASE STUDY

Big challenge in health impact of heavy metal: A case study

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Abstract: Herbal medicines are potential sources of therapeutic aids for human beings. WHO estimates that 80% of the world's population depends on herbal products as their primary form of health care. Herbal plants are widely used nowadays because they have few side effects, are readily available, and are cost-effective. Herbal plants are easily contaminated by absorbing heavy metals from soil, air and water. The primary health concerns of heavy metals are Arsenic, Cadmium, Lead and Mercury. Heavy metal causes countless health-related issues, such as kidney and liver damage, skin cancer, etc. So, the estimation of heavy metals is fundamental. Modern techniques estimate heavy metals in herbal plants such as AAS, ICP-MS, ICP-AES and ICP-OES. This review article mainly contains general information about heavy metals, the health impact of heavy metals on the human body, case studies regarding heavy metal toxicity on human health and analytical techniques used to estimate heavy metals.

Keywords: heavy metals, herbal medicines, analytical techniques

1 Introduction

Herbal plants are extensively utilized as potent remedies for preventing and addressing various health issues. According to the World Health Organization (WHO), approximately 80% of the global population relies on herbal products as their primary source of healthcare [1]. Herbal medicines offer numerous benefits, including minimal side effects, cost-effectiveness, and broad accessibility [2].

Heavy metals are generally defined as metals with relatively high densities, atomic numbers, or atomic weights [3]. Certain heavy metals, like Copper, Selenium, and Zinc, are crucial in maintaining the human body's metabolism. However, non-essential heavy metals such as Cadmium, Lead, Arsenic, and Mercury can lead to various health issues, including kidney and liver damage, as well as skin cancer. Herbal medicines can easily become contaminated with heavy metals from air, soil, and water. These metals are primarily generated by industrial processes and have become significant contaminants. Depending on their properties, medicinal plants in natural habitats can accumulate heavy metals to a certain extent. While metallic elements are essential for living organisms, they become toxic when present in high concentrations [4, 5]. The rapid growth of the global population, combined with widespread industrialisation and technological progress, has led to severe environmental challenges worldwide. One of the significant contributors to these issues is the production and release of toxic metals. Over the past few decades, there has been a significant rise in the levels of heavy metals in soil and surface waters, posing a potential threat to both terrestrial and aquatic ecosystems and human health through the contamination of the food chain. Given the extensive presence of heavy metals in the environment, these harmful residues also make their way into medicinal plants, posing additional risks to human health [6–9]. (Table 1)

Table 1 Limits of heavy metal as per different Pharmacopoeia [10–13]

Name of metals	EP 2017	BP 2018	USP 2018	API Volume IX
Arsenic	-	-	1.5 (μg/g)	3 ppm
Cadmium	1.0 ppm	1.0 ppm	0.5 (μg/g)	0.3 ppm
Mercury	0.1 ppm	0.1 ppm	1.5 (μg/g)	1 ppm
Lead	5.0 ppm	5.0 ppm	0.5 (μg/g)	10 ppm

2 Health impact of heavy metals on human health

Consuming plants contaminated with heavy metals can have severe and lasting effects on their health. Consuming food polluted with heavy metals can reduce essential nutrients in the body, posing significant long-term health risks. Intentional or accidental poisoning due to the ingestion of heavy metal contaminants has caused countless health-related issues, including liver and kidney failure. (Table 2)

Table 2 Health Impact of Heavy metals [14]

Name of Metals	Side Effects
Arsenic (As)	Strongly Carcinogenic. Causes gastrointestinal pain. Damage to the liver and kidney.
Lead (Ld)	Reduction in haemoglobin formation and may cause anaemia. Damage to kidney and liver. Mental retardation. Abnormalities Fertilities and pregnancy.
Mercury (Hg)	Visual disturbance. Numbness. Mental deterioration. Chromosomal disorders in gametes. Convulsion.
Cadmium (Cd)	Hypertension. Several nausea and vomiting. Damage to the liver and kidney.

3 Case studies

An Indian male patient who does not smoke has been experiencing skeletal pain for the past five years. He previously worked in the silver jewellery industry, resulting in high exposure to cadmium. Laboratory analysis using atomic absorption spectroscopy (AAS) revealed that the patient's blood and urine samples contained 3736 nmol/L of cadmium, significantly higher than the standard limits for non-smokers, which are 27–106 nmol/L and 0.5–3.0 μg/g for blood and urine, respectively [15].

Two individuals, a father and son from Uttar Pradesh, India, were recently hospitalised with symptoms including decreased appetite, weight loss, peeling skin on their palms and soles, tingling and numbness in their extremities, and bluish discolouration of their skin. After investigation, they were diagnosed with chronic arsenic poisoning, likely caused by consuming water from a hand pump they have been using for the past six years. Further examination revealed that all eight family members showed signs of chronic arsenic poisoning [16].

Water samples were collected from the Nile River and other water sources in North Sudan, specifically Dongola and Merowe Localities, to estimate the levels of heavy metals. The analysis included metals such as zinc (Zn), lead (Pb), copper (Cu), cobalt (Co), nickel (Ni), cadmium (Cd), molybdenum (Mo), chromium (Cr), iron (Fe), lithium (Li), and mercury (Hg) using ICP-OES. The concentration of heavy metals in the River Nile at both localities exceeded the international guideline limits. This has led to significant health issues, with people in these areas suffering from various types of cancer, including breast cancer, brain cancer, and skin cancer.

The findings suggest that the water from these sources is not safe for consumption, highlighting the urgent need for administrative action to address this critical issue [17]. 48 water samples and 48 sediment samples were collected from the Tembi River and analysed using the GFAAS instrument. The concentrations of Cd, Cr, Cu, Fe, Pb, Ni, and Zn in water and sediment samples exceeded the standard limits. This indicates that the water in the Tembi River is contaminated with heavy metals, making it unsuitable for drinking, washing, and fishing. Immediate regulatory action is necessary to address this issue [18].

A 16-year-old girl presented at the clinic with intense abdominal pain, lack of appetite, nausea, and vomiting. She came from a family of potters and was actively involved in pottery making. Her father had been diagnosed with lead poisoning two years earlier. Given the family history, she was also diagnosed with lead poisoning [19].

4 Methods of detection

4.1 Atomic Absorption Spectroscopy (AAS)

Atomic absorption spectroscopy (AAS) is an analytical technique used to measure the concentration of heavy metals in substances such as herbal medicines. It is commonly used to analyse metals like Arsenic (As), Mercury (Hg), Cadmium (Cd), and Lead (Pb). In this method, a sample is atomised and then exposed to light at a specific wavelength, allowing for the measurement of the absorption of the characteristic wavelengths of the metal atoms present in the sample. This enables the quantification of the metals present in the substance [20] In the AAS, electro-thermal atomisation is used to estimate As, Cd, and Ld, and cold-vapour or hydride atomisation is used to analyse As and Hg. (Table 3)

Table 3 Name of metals and their specific wavelength [10]

Sr. No.	Name of metals	Specific Wavelength
1	Arsenic (As)	193.5 nm
2	Mercury (Hg)	253.7 nm
3	Cadmium (Cd)	228.8 nm
4	Lead (Ld)	283.5 nm

4.2 Inductive coupled plasma mass spectroscopy (ICP-MS)

ICP-MS is commonly employed for the precise analysis of heavy metals due to its ability to simultaneously analyze multiple elements and its longer linear ranges compared to AAS. The linearity of ICP ranges from 4 to 6 orders of magnitude, while AAS ranges from 2 to 3 orders of magnitude [21]. The ICP-MS operates based on the following principles: the ICP creates a high-temperature plasma source at 10,000°C, through which the pre-treated sample is passed. The high-temperature environment ionizes the elements in the sample and directs them further into the MS. Subsequently, the MS separates the ions based on their mass or charge ratio, sending them to an electron multiplier tube detector. This detector then identifies and quantifies each ion [22]. Detection limits range from ppm to ppt [10, 23]. (Table 4)

Table 4 Recommended analytical isotopes and additional masses for ICP-MS

Isotope	Element of Interest
75	Arsenic
106,108,111,114	Cadmium
202	Mercury
206,207,208	Lead

4.3 Inductive coupled Plasma Atomic Emission Spectroscopy (ICP-AES)

In Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES), a high-temperature plasma source is utilized to excite atoms and ions in a sample, causing them to emit light at characteristic wavelengths. A spectrometer then separates and analyzes this emitted light to identify and quantify specific elements present in the sample [24]. ICP -AES consist of two parts: ICP and optical spectrometer. The inductively coupled plasma torch consists of 3 concentric quartz glass tubes.

The radio frequency generator's coil surrounds part of this quartz torch. Argon gas creates the plasma. The advantages of this instrument are its excellent wide dynamic range and limit of detection, low chemical interference, multi-element capability, and a stable, reproducible signal [25].

5 Conclusion

Based on the preceding discussion, it is evident that heavy metals have numerous adverse effects on the human body, such as cancer, liver damage, and abdominal pain. The accumulation of heavy metals in rivers is an ongoing concern, necessitating regulatory intervention. Utilizing inductively coupled plasma (ICP) for estimation is deemed more suitable than atomic absorption spectroscopy (AAS) for analyzing metals in herbal plants. This underscores the significance of accurately assessing heavy metal levels in herbal plants.

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Conflicts of interest

The authors declare that they have no conflict of interest.

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