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Analyzing The Effects of Heavy Metal Contamination in Plant-Based Foods on Human Health. A Comprehensive Review

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Abstract

This review explores the health hazards related to heavy metal toxicity in plant products, including sources, absorption methods, and potential health consequences from contaminated plant-based foods. A thorough literature assessment was undertaken on heavy metal toxicity in plant products and its influence on human health, using databases such as PubMed, Web of Science (WOS) and Scopus. Heavy metals, including Lead, Cadmium, Arsenic, Mercury, and Chromium, Pollute soil, Water and the atmosphere. Consumption of contaminated plant-based foods causes health hazards, particularly for vulnerable populations such as children, pregnant women, and the elderly. Heavy metals in plant products are a global health issue, despite restrictions and monitoring programmes. Soil restoration, agricultural methods, and food diversification are all examples of

mitigation strategies. Consumer awareness and education are critical in encouraging informed food choices and reducing contamination. Interdisciplinary collaboration is required to reduce heavy metal toxicity in plant products, protect human health, and promote safe food production techniques for current and future generations.

Keywords

Plant-based –Products, Human Health, Heavy Metal, Toxicity, Exposure effects.

Introduction:

The term "heavy metals," which refers to any harmful metal, including lighter ones, is commonly used in medical terminology but is defined as having a density of greater than 5g/cm3 (Abdel-Rahman., 2021). These are major environmental pollutants that come from both man-made and natural sources. Soil contains metals in concentrations ranging from less than 1 mg/kg to 100,000 mg/kg. These concentrations can be induced by either direct metal deposition on plant surfaces or the absorption of contaminants by roots (Ahmed et al., 2017). Heavy metal poisoning in the food chain has prompted worries about human health, as it accumulates in soil and water. This study investigates the link between heavy metal toxicity in plant products and its effects on human health (Amuah et al., 2022). It investigates the mechanisms by which heavy metals enter plants, the factors that influence their accumulation, and their transmission to consumers via contaminated plant-based meals

(Awasthi et al., 2022). The study also looks at plants' physiological responses to heavy metal stress and the potential health risks connected with contaminated plant products (Bandeira et al., 2022). It emphasizes the importance of strong regulatory measures, effective monitoring systems, and sustainable agriculture practices in mitigating the hazards. The study calls for multidisciplinary approaches to protecting human health and ensuring the integrity of the food supply. Heavy metal exposure has increased dramatically during the last 50 years as a result of industrial processes and products. Food safety and security have prompted studies into the hazards of heavy metals and poisons in food. The mining, mineral, smelting, and tanning sectors in emerging countries contribute to heavy metal pollution. Heavy metal contamination threatens water, soil resources, and human health. Transition metals cause oxidative damage in plant tissue, and their toxicity in phytochemicals, plant-based extracts, dietary supplements, and medicinal plants is medically significant (Banerjee et al., 2020).

Heavy metals, or non-essential metals, offer major health concerns to humans and animals since they are not biodegradable. Human intake through the food chain has been recorded worldwide, with accumulation in important organs such as the kidneys, bones, and liver (Blaylock and Huang., 2020). Heavy metal pollution is a major ecological concern, and medicinal plants are being identified as a potential source of toxicity. The World Health Organization (WHO) suggests testing medicinal plants for heavy metals and raising quality requirements for herbal medications. This study seeks to determine the source, availability, and health effects of heavy metals in medicinal plants and herbal medications, which have

become popular in African disease treatment, in order to raise awareness and screen plant materials for heavy metal contamination.

Sources of Heavy Metals:

Heavy metals are discharged into the environment through industrial processes, agricultural practices, atmospheric deposition, and natural causes. Industrial operations like mining, smelting, and manufacturing, as well as agricultural practices like chemical fertilizers and pesticides all contribute to crop and plant product pollution. Atmospheric deposition, especially around industrial facilities, exacerbates the contamination (Cherkasova et al., 2021).

Emissions of Heavy Metals:

Heavy metals are emitted into the atmosphere as particulate matter and gases from industrial activity, automobile traffic, and combustion processes. These emissions can travel great distances before settling upon soil and vegetation, where they can be absorbed by plants.

Heavy metals are released into water bodies by industrial effluents, mining runoff and wastewater discharges, damaging both surface and groundwater sources. Irrigation with contaminated water can cause heavy metals to accumulate in the soil and be absorbed by plants, compromising the safety of plant products (Coetzee et al., 2020). Heavy metals build up in soil from a variety of sources, contributing to plant product contamination (Eissa and Negim 2018). Soil works as a sink for heavy metals, allowing them to persist for lengthy periods of time before entering the food chain via plant uptake.

Impact on Human Health:

1. Acute Toxicity: Short-term exposure to high quantities of heavy metals in plant products can induce acute poisoning, characterized by symptoms such as nausea, vomiting, diarrhoea, and abdominal discomfort (Guala et al. 2010). Certain heavy metals, such as lead and mercury, can be neurotoxic, damaging the central nervous system and creating serious health issues (Gülin Gökçen Kesici., 2016).
2. Chronic Health Effects: Long-term exposure to low amounts of heavy metals in plant products has been associated to chronic health problems such as cancer, renal damage, cardiovascular disease, and developmental disorders. Chronic heavy metal consumption through the food can cause toxicants to accumulate in the body, posing serious dangers to human health over time.

   Children, pregnant women, and the elderly are especially vulnerable to the harmful effects of heavy metal exposure (Kamran et al., 2013). Children, in particular, are at risk of developmental problems and cognitive impairment as a result of their higher food consumption body weight and developing physiological systems (Manju Mahurpawar.,2015).

Heavy Metal Toxicity in Plant Products:

Heavy metal pollution in plant products is a severe concern to human health because poisonous components can accumulate in edible sections of plants and then enter the human body through consumption. Heavy metals, including lead, cadmium, mercury, arsenic, and chromium, occur naturally in soil, water, and air. However, human-caused activities such as

industrial operations, mining and farming practices have considerably increased their presence in the environment, resulting in widespread contamination of plant products (Coetzee et al., 2020).

Sources of Heavy Metal Contamination in Plants:

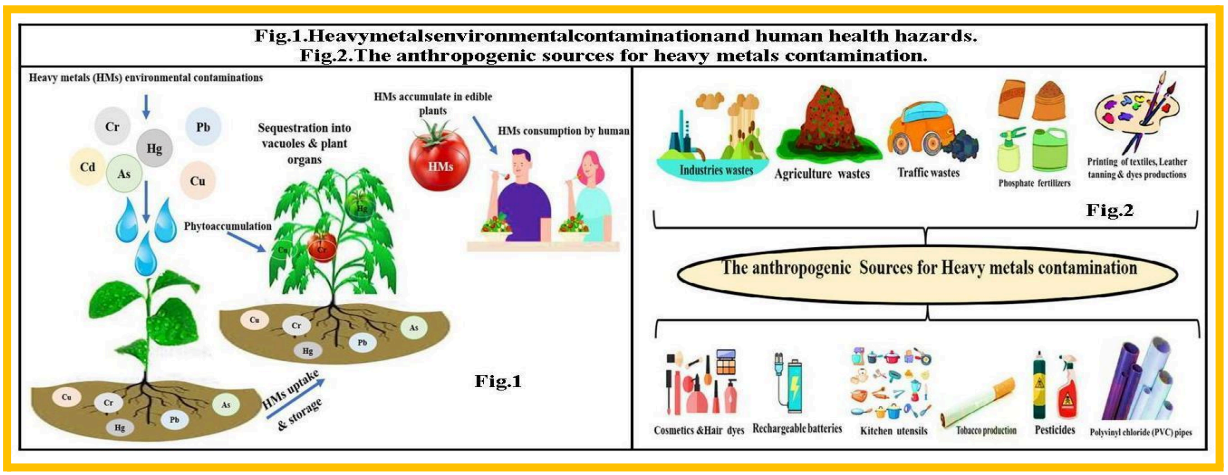
a. **Industrial pollution:** Heavy metals are released into the environment as a result of industrial activities such as emissions, wastewater, and waste disposal Factories and manufacturing facilities are major sources of heavy metal contamination, emitting pollutants into the atmosphere and water that can land on soil and be absorbed by plants (Mao et al., 2019).

b. **Agricultural Practices**: Chemical fertilizers, herbicides and contaminated irrigation water can all contribute to heavy metal deposition in soil and plant absorption (Marc et., 2011). Additionally, using sewage sludge or manure as fertilizer can introduce heavy metals into agricultural fields, posing dangers to plant products.

Natural sources for heavy metals contamination (Source: Sahar J. Melebary et al,. 2023)

c. **Atmospheric Deposition**: Heavy metals released into the atmosphere by industrial sources, car emissions, and other human activities can be deposited on soil and vegetation by precipitation or dry deposition [17]. Atmospheric deposition is an important source of heavy metal pollution in plant products, especially in urban and industrialized settings (Mohammad et al., 2012).

d. **Natural Sources:** Some heavy metals are found naturally in the Earth's crust and can be released into the environment through weathering. Volcanic activity, erosion, and geological formations can all contribute to background levels of heavy metal contamination in soil and water, affecting plant uptake of these elements (Munir et al., 2021).



Source: Sahar J. Melebary et al,. 2023

Heavy metals found in plant products:

i. Arsenic:

Arsenic, a mineral prevalent in groundwater, contributes significantly to the toxic consequences of arsenic. It is found in many plant products, a common cuisine in South-East Asia, particularly India. The concentration of arsenic in plant products (fruits and vegetables) rice surpasses the sanitary food guideline, resulting in overpopulation and increasing output. Field trials were undertaken to minimize arsenic toxicity in rice plants. Arsenic is largely absorbed by people and animals through water and food, with numerous forms of arsenic present in dietary sources (Ohiagu et al., 2022).

ii. Lead (Pb):

Lead (Pb) is a harmful biological pollutant that has been widely used due to its ductility, resistance to corrosion, and low melting point . Its concentrations in uncontaminated soil range from 10-/50 ppm to 100-500 ppm in low-level pollution. Pb's toxic effects on vegetables are unknown, although they can impair plant development by interfering with enzymes, photosynthetic activities, the attraction of water and inorganic nutrients, and cell structural variations (Ahmed et al., 2017). Soil and plant tissues have a major influence on Pb uptake, transportation, and growth in plants, and these factors vary significantly between plant kinds. Pb accumulation in rice considerably enhances leaf chlorophyll, protein and nitrogen molecules, carotenes, and the hill reaction, as well as several enzymatic reactions.

iii. Iron:

Iron poisoning in rice plants occurs when the plant accumulates dangerous levels of iron in its leaves, which is connected to a high concentration of iron (II) in soil solution. This has an impact on rice production because flooded rice paddies have a low redox potential, resulting

in decreased and soluble iron. Iron poisoning can develop in a variety of soil types, including acid sulphate or acid clay soils, as well as sandy soils that have not been sufficiently exhausted. It has the potential to result in significant output reductions and in severe circumstances, crop failure (Remy et al., 2017). The concentration of iron (II) for growth might range between 10 and 500 mg L-1, depending on the plant's nutritional status and reduction products.

iv. Mercury:

Mercury pollution in plant products (fruits and vegetables) is a major global concern and early information on mercury levels and human contact danger is often neglected. The majority of mercury is accumulated in roots and deposited in soils and streams, with agricultural soils heavily polluted by mercury-containing mixtures and soil changes (Sankhla et al., 2020).

v. Zinc:

Zinc deficiency in rice crops is a major nutrient concern, owing mostly to alkaline calcareous soils with organic matter concentration (Salnikow et al., 2008). The sickness develops for two to six weeks following soil submergence. Zinc helps to maintain plant cell membranes by regulating O2 species levels via a NADPH oxidase.

vi. Cadmium:

Cadmium (Cd) is a prominent pollutant in paddy fields, particularly in rice. It may enter the food chain through rice intake and cause harm to people. Plant product and rice absorbs Cd2+ from soils, and its uptake varies according to soil pH (Venkata Naidu et al., 2016). Cd

poisoning can impair physical and morphological growth in higher plants, reduce chlorophyll concentration, and inhibit leaf photosynthesis.

vii. Nickel:

Nickel is necessary for plant development, yet it is scarce. It is a deadly metal that impairs plant growth by changing physical and metabolic processes. Increased anthropogenic activities have resulted in soil contamination, notably in the roots of bean plants, with potentially serious implications (Shen et al., 2023).

viii. Copper:

Copper (Cu) is an important heavy metal in plant growth, development, and protection. Cu is rarely harvested from soil, but anthropogenic activity such as fungicides and slurries can cause it to accumulate to toxic amounts. This study investigates the effect of Cu on plant products (fruits and vegetables) and rice development, grain production, and concentration in brown rice across diverse rice cultivars. The study also evaluates the health concerns of Cu entering the food chain and finds that cultivars with low Cu concentration and high grain production are appropriate for Cu-contaminated areas (Zadorozhnaja et al., 2000). This study seeks to identify acceptable rice cultivars for Cu-contaminated locations.

Table 1: The most frequent heavy metal contaminants and human health risks.

Heavy metals	Sources of heavy metals	Human health hazards

Lead	Thermal power plants, crude petrol, mining, smelting, and paint	Learning difficulties, nervous lesions, fertility problems, Cardiovascular problems, renal dysfunction sand hepatic lesions (Ahmed et al., 2017)
Cadmium	Burning fossil fuels such as coal or oil and municipal trash such as plastics and nickel-cadmium batteries	Lung, prostate, pancreas, and kidney cancers (Zeng et al., 2010)
Mercury	Coal-fired power plants, factories, waste incinerators, and mining for mercury, gold, and other metals cause air pollution.	Nervous, renal, and immune systems affections
Arsenic	The use of polluted water in food preparation the irrigation of crops, industrial activities, and the use of cigarettes all pose health risks.	Skin irritation, and lung, bladder, liver, and renal cancers

Chromium	Polluted soil, air, water, smoking, and food.	Dermatitis, allergies, ulcers, respiratory, gastrointestinal, neurologic, reproductive problems and cancers (Zeng et al., 2010)
Nickel	Diesel oil and fuel oil, and the incineration of waste and sewage	Lung fibrous, cardiovascular difficulties, renal illnesses, and degenerative changes in heart muscle and brain, lung, liver, and kidney tissues lead to cancer of the respiratory system and lungs, which in turn leads to sarcoma of bone, connective tissue, and muscles.
Copper	Irrigation with polluted wastewater	Can affect renal and metabolic functions (Zadorozhnaja et al., 2010)
Zinc	Irrigation with polluted wastewater	Respiratory dysfunction

Health effects and risks from metals in food crops

Heavy metal toxicity impairs plant physiological processes, resulting in stunted development and stress symptoms. Plants absorb heavy metals through their root systems and transport them to edible areas, causing health hazards. Bioaccumulation and biomagnifications enhance heavy metal exposure throughout the food chain (Wuana et al., 2011). Because most heavy metals in soil can accumulate in crops, they can be transferred to other media through the food chain. The bioconcentration factor (BCF) of several heavy metals in the crop–soil interface, particularly in major global staple crops such as wheat and corn, has been documented Contamination causes food safety concerns, as continuous exposure may results in cancer, neurological diseases, renal damage, and developmental defects. Heavy metals such as lead and mercury are very hazardous (Sanaei et al., 2021). Industrialized growth has resulted in increasing heavy metal pollution of plant products (fruits and vegetables) and paddy rice, which can be damaging to both human health and food (Wang et al., 2014). These heavy metals, which include iron, cobalt, copper, manganese, molybdenum, and zinc, are necessary for chemical reactions but can have serious health consequences in living creatures (Verma et al., 2018).

Discussion:

The study focuses on the increasing quantity of heavy metals in plant products like fruits and vegetables, which may have unknown toxicity to people yet are not hazardous. Plants absorb harmful metals from soil and water, producing allergic reactions and perhaps resulting in coma or death. Brown rice also raises the risk of cardiovascular disease and cancer.

Conclusions:

India is an agricultural country that produces a wide range of plant goods such as fruits, vegetables, serels, and pussels, as well as the world's second largest rice crop. Environmental contaminants, food safety and security, and human health are inextricably linked. The concentrations of heavy metals in the environment have increased significantly in recent decades. The sources of heavy metals in food crops vary in the developing and developed world. The deposition of PM on food crops and the use of industrial effluents and sewage sludge as fertilizers are the primary contamination sources in soil–crop systems in developed countries. Heavy metal concentrations in rice can be determined using a range of analytical methods, including HPLC, spectrophotometer, GC-MS, LC-MS, XRF-ED, and paddy-check. Biological remediation, such as phytoremediation and PGPR, can be an environmentally friendly and cost-effective strategy for moderately contaminated soils. Eco-feasible technological innovations such as nano-tools and the awareness of farmers could boost local economies and livelihoods with certain financial guarantees. Heavy metal pollution in the food chain in rice is also a cause of concern, however there is less data.

Conflict of interest: None

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