Chapter 5
Heavy Metal Contamination in Food:
Monitoring, Detection, and Public Health Risks

Matthew Chidozie Ogwu
https://orcid.org/0000-0001-6054-1667
Appalachian State University, USA

ABSTRACT

Heavy metal contamination in food is a growing global concern due to its significant implications for public health and food security. Exposure poses substantial health risks through acute and chronic toxicity, organ-specific effects, and associations with severe health conditions, particularly affecting vulnerable populations. This chapter examines the sources, pathways, and prevalence of toxic metals, including arsenic, lead, mercury, and cadmium, in food systems, with a focus on both natural and anthropogenic contributions. It examines how these metals accumulate in the food chain and outlines their acute and chronic health impacts, particularly among vulnerable populations. The chapter provides an in-depth review of international regulatory standards, dietary risk assessments, and current analytical methodologies, including atomic absorption spectroscopy, inductively coupled plasma mass spectrometry, and portable detection systems. It also presents global monitoring strategies, case studies, and real-world surveillance data that highlight regional disparities and emerging challenges. Innovative approaches such as green chemistry, nanotechnology, and AI-driven tools are discussed as part of future directions. By integrating insights from environmental science, analytical chemistry, toxicology, and public health policy, this chapter provides a comprehensive perspective on the detection, measurement, and mitigation of heavy metals in food, thereby contributing to the development of safer and more resilient food systems worldwide.

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1.0. INTRODUCTION

Heavy metals are defined as metallic elements having relatively high densities and are toxic at low concentrations. They include elements such as lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), and mercury (Hg) etc. (Orecchio et al., 2014; Chen and Ding, 2023). These contaminants can be classified based on their properties, environmental behaviors, and potential health impacts. While some heavy metals, such as copper and zinc, are essential in trace amounts, others are non-essential and pose significant health risks through contamination of food and water (Riyazuddin et al., 2021; Nwizugbo et al., 2023). The presence of these metals in the food supply can arise from various sources, including industrial discharge, agricultural runoff, and atmospheric deposition, particularly emissions from mining and smelting activities (Nkwunonwo et al., 2020; Abdullahi et al., 2021).

Monitoring heavy metals in food is crucial, as these contaminants pose a threat to food safety, ecosystem integrity, and human health (Wuana and Okieimen, 2011; Wang et al., 2023). Regular surveillance and detection of heavy metals in agricultural products, seafood, and processed foods are imperative to assess exposure levels and ensure compliance with health regulations, thereby mitigating risks (Hassan et al., 2020; Wang et al., 2023). Chronic exposure to heavy metals can result in severe health conditions, including neurotoxicity, carcinogenic effects, and developmental issues in children (Tom et al., 2014; Liang et al., 2017). As such, regulatory bodies increasingly focus on establishing stringent guidelines to protect consumers from the adverse effects of heavy metal exposure in food (Igwe et al., 2017; Chen and Ding, 2023). Initial assessments alert health authorities to potential risks, facilitating prompt public health responses. Continuous monitoring enables the identification of trends in heavy metal concentrations, informing policy and regulatory decisions regarding food safety standards (Wieczorek et al., 2020; Riyazuddin et al., 2021). Systematic monitoring enables identification of significant sources of contamination, which can be addressed through targeted interventions. Regions with systematic monitoring networks have successfully mitigated pollution levels through effective policy implementation (Ahmad et al., 2021; Hassan et al., 2020). Advancements in detection technologies, such as biosensors and nanomaterials, enhance the capacity to detect minute levels of heavy metals in food products, making surveillance more efficient and comprehensive (Wang et al., 2023).

Studies indicate that heavy metals can bioaccumulate in the food chain, leading to significant consequences for human health Hassan et al., 2020). For example, crops grown in contaminated soils have been found to contain elevated levels of heavy metals, which can then be ingested by animals and humans (Rahimi et al., 2017; Zaib et al., 2023). Communities, particularly those near industrial sites or agricultural lands, face heightened risks due to localized contamination (Ahmad et al., 2021).

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