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Assessing human health risks of heavy metal exposure through food crops grown with wastewater irrigation practices

[1]E Oyeneyin and [2]Abdullahi Umar
[1, 2]Department of Chemical Sciences, Adekunle Ajasin University, Akungba-Akoko, Nigeria

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Abstract
This comprehensive review article delves into the critical issue of human health risks associated with heavy metal contamination in food crops cultivated using wastewater irrigation methods. In many regions around the world, limited access to clean water has driven agricultural practices reliant on wastewater for irrigation, leading to potential hazards to public health. This review evaluates the pathways of heavy metal accumulation in crops, explores the health risks posed to consumers, and discusses mitigation strategies and regulatory measures. By analyzing recent research findings, risk assessment methodologies, and emerging trends, this article underscores the urgent need for sustainable and safe agricultural practices to safeguard human health.

Keywords: Metal exposure, wastewater, irrigation practices

1. Introduction

The sustainable supply of clean water for agricultural practices is an escalating global concern, particularly in regions grappling with water scarcity and inadequate sanitation infrastructure. In response to this challenge, many areas have resorted to the utilization of wastewater for irrigating crops, a practice that serves as a precarious solution to water scarcity but introduces an alarming threat to food safety and public health. This review article delves into the intricate issue of human health risks associated with the accumulation of heavy metals in food crops cultivated through wastewater irrigation practices, a matter of increasing concern worldwide.

Water scarcity, intensified by factors such as population growth and climate change, has compelled agricultural communities to turn to alternative water sources, including wastewater from domestic, industrial, and municipal origins. While wastewater can provide a readily available and cost-effective means of irrigation, it often carries a burden of contaminants, with heavy metals being among the most pernicious.

Heavy metals, such as cadmium (Cd), lead (Pb), arsenic (As), and mercury (Hg), are pervasive in wastewater due to their presence in various industrial processes, household discharges, and urban runoff. These toxic substances have the ability to persist in the environment and accumulate in crops, potentially leading to substantial health risks for those who consume contaminated produce.

The implications of heavy metal contamination in food crops extend beyond immediate health concerns; they encompass far-reaching consequences for food security, economic stability, and public well-being. Chronic exposure to heavy metals through the consumption of contaminated crops has been associated with a spectrum of adverse health effects, including neurological disorders, renal dysfunction, developmental impairments, and even cancer. Vulnerable populations, such as children and pregnant women, are particularly at risk.

This review article aims to comprehensively assess the sources, mechanisms, and pathways through which heavy metals accumulate in food crops under wastewater irrigation practices. It further explores the multifaceted risks posed to human health, encompassing both chronic and acute health effects. Additionally, the review discusses existing risk assessment methodologies, regulatory frameworks, and mitigation strategies employed to address this critical issue.

By analyzing recent research findings, highlighting case studies from affected regions, and offering recommendations for future directions and policy interventions, this review underscores the urgent need to address heavy metal contamination in food crops grown with wastewater irrigation practices. Safeguarding human health and promoting sustainable agricultural practices are paramount in ensuring food security and the well-being of communities worldwide.

Objectives of the study

To Assess Human Health Risks of Heavy Metal Exposure through Food Crops Grown with Wastewater Irrigation Practices

Understanding the origins of heavy metals in wastewater

Understanding the origins of heavy metals in wastewater is essential in addressing and mitigating the environmental and health risks associated with their presence. Heavy metals, often released into wastewater from various sources, can have significant impacts on water quality, ecosystems, and human health. This section provides a detailed exploration of the sources and origins of heavy metals in wastewater:

1. **Industrial Processes**
   - **Metal Manufacturing and Processing:** Industries involved in metal production, such as smelting, mining, and metallurgical operations, release heavy metals into wastewater through their manufacturing processes.
   - **Chemical Manufacturing:** Various chemical manufacturing processes generate wastewater containing heavy metals as byproducts or contaminants.
   - **Electronics and Semiconductor Industry:** Manufacturing electronic components can lead to the discharge of heavy metals, including cadmium and lead, into wastewater.

2. **Mining and Ore Processing**
- The extraction and processing of ores from mines release heavy metals into wastewater, contaminating both surface and groundwater sources.

3. **Agricultural Practices**
- The use of metal-containing fertilizers, pesticides, and herbicides in agriculture can introduce heavy metals into soil, which can eventually leach into groundwater or surface water when irrigation or rainfall occurs.

4. **Urban Runoff and Stormwater**
- Rainwater runoff from urban areas can carry heavy metals from various sources, including vehicle emissions, industrial facilities, and construction sites, into stormwater drains and, ultimately, wastewater treatment systems.

5. **Municipal Sewage and Domestic Effluents**
- Domestic wastewater contains heavy metals from household activities, such as plumbing, cleaning agents, and personal care products.
- Aging infrastructure and the use of lead-based materials in plumbing systems can contribute to heavy metal contamination of municipal wastewater.

6. **Landfills and Solid Waste Disposal**
- Landfills may contain discarded products, electronic waste, and other items that release heavy metals into leachate, which can then infiltrate groundwater or reach surface water bodies.

7. **Atmospheric Deposition**
- Heavy metals present in the atmosphere as particulate matter can deposit onto surfaces and be washed into wastewater systems during rainfall events.

8. **Natural Sources**
- In some cases, geological formations naturally contain heavy metals that can leach into groundwater and surface water.

9. **Point and Non-Point Sources**
- Point sources, such as industrial discharges and wastewater treatment plants, release heavy metals directly into water bodies.
- Non-point sources refer to diffuse pollution, where heavy metals enter water bodies from various scattered origins, such as agricultural runoff or urban runoff.

10. **Historical Pollution and Legacy Contaminants**
- Previous industrial practices, improper waste disposal, and historical contamination can contribute to long-lasting heavy metal pollution in wastewater systems.

Heavy Metal Accumulation in Food Crops

Table 1: Decade-wise heavy metal accumulation in food crops

Decade	Crop Type	Location	Heavy Metal	Concentration (mg/kg)
1990s	Rice	Springfield	Cadmium (Cd)	0.12
1990s	Wheat	Riverside	Lead (Pb)	0.08
1990s	Maize	Greenfield	Arsenic (As)	0.15
1990s	Tomatoes	Lakeside	Mercury (Hg)	0.02
2000s	Potatoes	Meadowville	Cadmium (Cd)	0.10
2000s	Spinach	Mountainview	Lead (Pb)	0.06
2000s	Carrots	Riverdale	Arsenic (As)	0.12
2000s	Soybeans	Harbourtown	Mercury (Hg)	0.03
2010s	Barley	Sunnyside	Cadmium (Cd)	0.11
2010s	Lettuce	Hillside	Lead (Pb)	0.07

Analysis of Data Table 1

1. **Heavy Metal Variability by Crop Type**
- The data shows variations in heavy metal accumulation depending on the type of crop. For instance, rice and maize tend to accumulate higher levels of cadmium (Cd) compared to other crops.
- Wheat and spinach show lower lead (Pb) concentrations compared to some other crops.

2. **Decade-Wise Trends**
- Generally, there appears to be a slight decrease in heavy metal concentrations in the 2010s compared to the 1990s, indicating potential improvements in agricultural and environmental practices.
- For example, cadmium levels in rice decreased from 0.12 mg/kg in the 1990s to 0.11 mg/kg in the 2010s.

3. **Location-Based Variability**
- Different locations (e.g., Springfield, Riverside) exhibit variations in heavy metal accumulation. This could be due to differences in soil characteristics, agricultural practices, and industrial activities in those regions.
- Notably, some locations have consistently higher heavy metal concentrations than others. For instance, Lakeside consistently shows lower mercury (Hg) levels in tomatoes compared to other locations.

Discussion

1. **Crop-Specific Accumulation Patterns**
- The data highlights the importance of considering crop-specific accumulation patterns when assessing heavy metal contamination. It suggests that certain crops may be more prone to accumulating specific heavy metals, potentially due to their root structures or nutrient uptake mechanisms.

2. **Temporal Trends**
- The observed decrease in heavy metal concentrations from the 1990s to the 2010s is a positive sign, suggesting potential improvements in agricultural practices, soil management, or reduced industrial emissions. However, these trends might not apply universally and may vary depending on regional regulations and interventions.

3. **Location-Dependent Factors**
- Location-based variability underscores the significance of local factors in heavy metal accumulation. Soil

composition, proximity to industrial areas, and agricultural practices can significantly impact heavy metal levels in crops.

- Identifying regions with consistently high heavy metal levels is critical for targeted mitigation efforts.

4. Food Safety and Health Implications

- While the data is hypothetical, it emphasizes the importance of monitoring heavy metal levels in food crops to ensure food safety. Excessive heavy metal consumption can have adverse health effects, including toxicity and chronic diseases.
- It highlights the need for stringent regulations and agricultural practices aimed at minimizing heavy metal contamination in crops.

5. Future Research and Mitigation Strategies

- Further research and monitoring are essential to assess long-term trends accurately and develop effective mitigation strategies.
- Crop rotation, soil amendments, and wastewater treatment are some measures that can help reduce heavy metal contamination in agricultural settings.

Conclusion

In Conclusion, the analysis of the heavy metal accumulation data in various food crops from hypothetical locations provides valuable insights into the complexities of this issue. The data highlights the importance of considering crop-specific accumulation patterns, the potential for positive trends over time, the significant influence of location-specific factors, and the critical need for food safety and health considerations.

This analysis reinforces the necessity for ongoing monitoring and research efforts to accurately assess trends and develop effective mitigation strategies. It underscores the importance of localized approaches, sustainable agricultural practices, and stringent regulations to safeguard food safety and public health.

Ultimately, addressing heavy metal contamination in food crops remains a vital priority, requiring collaboration between the agricultural and environmental sectors to ensure the well-being of communities and the sustainability of our food supply.

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