**Assessment of Cadmium Levels in Selected Local and Imported Fruits and Vegetables in Iraq: A Study on Environmental and Health Risks**

**Abstract:**

Heavy metals, such as cadmium, are among the most hazardous environmental pollutants that threaten the quality of agricultural products and human health. This study, conducted in Iraq, analyzed 22 plant samples, including the peels and pulp of 11 types of local and imported fruits and vegetables, using precise analytical techniques such as atomic absorption spectrophotometry. The results revealed significant variations in cadmium levels across different plant parts, with concentrations in the pulp being, on average, 4 to 21 times higher than in the peels in 10 out of 11 samples, except for Syrian potatoes, which recorded higher concentrations in the peels. This highlights the influence of soil and surrounding environmental conditions on cadmium uptake. Some samples, such as Syrian cucumbers (0.41 ppm in the pulp), exceeded the permissible limits set by the World Health Organization (0.1 ppm), reflecting the impact of contaminated phosphate fertilizers or irrigation with polluted water. These findings underscore the importance of monitoring the quality of water and fertilizers used in agriculture. Adopting sustainable agricultural practices is crucial to minimizing heavy metal accumulation in crops and ensuring food safety for consumers in Iraq.

**Keywords:** Cadmium, heavy metals, environmental pollution, food quality.

**1- Introduction**

 Cadmium is a toxic heavy metal naturally present in the environment and is considered a major environmental pollutant that adversely impacts human health and plants. Cadmium accumulates in soil and water as a result of industrial and agricultural activities, such as the use of contaminated phosphate fertilizers and irrigation with polluted water containing industrial waste. When absorbed by plants, cadmium can accumulate in edible parts, posing a health risk to humans upon consumption (9).

Heavy metals are among the most dangerous environmental pollutants, posing significant threats to both human health and ecosystems. Heavy metals are defined as chemical elements with high density, such as lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), and nickel (Ni). These elements are characterized by their high toxicity and ability to bioaccumulate in living tissues (1). They enter the environment through various anthropogenic activities, including heavy industries, mining, the use of fertilizers and pesticides, and vehicle emissions (12). Additionally, untreated wastewater and industrial waste contribute to the increased concentrations of these elements in soil and groundwater, which in turn expose agricultural crops to contamination (2).

Agricultural soil serves as a critical medium through which heavy metals enter the food chain. When soil is contaminated, plants absorb these elements through their roots and transfer them to edible parts such as leaves, fruits, and roots (13). Studies have shown that heavy metals can accumulate in agricultural crops, including fruits and vegetables, which form a substantial part of the human diet (14). For instance, recent research indicates that leafy vegetables such as spinach and lettuce can contain high levels of lead and cadmium, especially when grown near highways or industrial areas (7).

Heavy metals reach humans primarily through the consumption of contaminated food, polluted water, and air (3). Once inside the body, these metals accumulate in vital organs such as the liver, kidneys, and bones, causing severe long-term health issues (5). For example, lead is a neurotoxic element that particularly affects children, leading to developmental delays and impaired cognitive functions (4). Similarly, cadmium is a known carcinogen that accumulates in the kidneys, causing kidney failure and osteoporosis (6).

International organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) have established permissible limits for heavy metal concentrations in food and water. For instance, the maximum allowable level of lead in vegetables is 0.1 mg/kg, while the limit for cadmium is 0.05 mg/kg (8). However, numerous studies indicate that the concentration of these elements in some agricultural regions exceeds these limits, posing risks to consumer health (15).

Heavy metals not only impact human health but also have adverse effects on the environment. High concentrations of these elements in soil can degrade soil fertility, reduce microbial diversity, and contaminate groundwater (24). Furthermore, these metals can bioaccumulate in the food chain, affecting other plants and animals (16). For instance, recent studies have shown that fish living in water contaminated with lead and cadmium exhibit high concentrations of these elements, posing risks to human health when consumed (17).

Chronic exposure to heavy metals can lead to severe health conditions, including cancer, cardiovascular diseases, neurological disorders, and kidney failure (25). Research suggests that lead exposure increases the risk of cardiovascular diseases, particularly in adults (18), while cadmium exposure is associated with higher risks of lung and prostate cancers (10).

In Iraq, soil and water contamination with heavy metals is one of the major environmental challenges, especially in regions affected by wars or those relying on untreated wastewater for irrigation (19). Local studies have revealed that lead and cadmium concentrations in some agricultural crops exceed international permissible limits, posing threats to consumer health (20). Consequently, monitoring heavy metal concentrations in food has become essential to ensure food safety and protect public health (21).

In this context, the present study aims to analyze the concentrations of cadmium, in a selection of local and imported fruits and vegetables in Iraq. Advanced techniques, including acid digestion and spectrophotometry, were employed to accurately measure these concentrations. The significance of this study lies in its attempt to identify the sources of contamination and its impact on agricultural crops, while also providing practical recommendations to mitigate the issue. By utilizing up-to-date data and modern analytical methods, the study delivers precise findings that can support the development of effective environmental and health policies.

**2. Materials and Methods**

Samples of fruits and vegetables were collected, including Malus domestica (Apple) (local, Chinese, and Turkish varieties), Citrus × sinensis (Orange) (local, Egyptian, and Turkish varieties), Cucumis sativus (Cucumber) (Syrian, local, and Iranian varieties), and Solanum tuberosum (Potato) (local and Syrian). The samples were peeled, and each sample was divided into two parts: the pulp and the peel. The samples underwent drying, grinding, and digestion processes to prepare extracts for analysis. Heavy metal concentrations were determined using atomic absorption spectrophotometry.

**2.1 Sample Preparation**

The waxy layer of apples, including local (Iraqi) and imported varieties (Turkish and Chinese), was removed. The peels were then separated from the pulp for all types of fruits and vegetables used in the experiment. The peels were placed in designated areas to distinguish between fruit and vegetable samples. Similarly, the pulp of all samples was cut into pieces and distributed with appropriate identification labels.

All samples were placed in a thermal oven set at 190°C for 24 hours until completely dried. Subsequently, the dried samples were ground using an electric grinder to obtain a fine powder. The powdered samples were then subjected to digestion to extract the target compounds and prepare them for analysis (11).

**2.2 Sample Digestion**

The dried and ground plant samples (both peels and pulp) were digested using an acid mixture composed of nitric acid (HNO₃) and perchloric acid (HClO₄). For each sample, 1 g of the plant material was mixed with 5 mL of nitric acid, followed by the addition of 5 mL of perchloric acid. The mixture was left for 24 hours to allow initial digestion.

The samples were then heated on a hot plate at 80°C for one hour. After cooling at room temperature, the mixture transitioned from a dark brown color to a clear solution. The digested samples were filtered using Whatman No.42 filter paper, and the volume of the filtrate was adjusted to 10 mL with deionized water. Finally, the concentrations cadmium (Cd) were measured using an atomic absorption spectrophotometer (26).

**3. Results and Discussion**

The results revealed significant variations in cadmium concentrations between the peels and the edible parts (pulp) of plants, as well as among the different types of fruits and vegetables and their countries of origin. The highest cadmium concentration was observed in Syrian cucumbers, with a pulp concentration of **0.41 ppm**, exceeding the safe limit set by the World Health Organization (WHO) (0.1 ppm). This elevated level can be attributed to the use of phosphate fertilizers contaminated with cadmium impurities or irrigation with wastewater polluted by industrial residues (22). Conversely, the lowest concentrations were recorded in the peels of Turkish apples and Iraqi oranges, measuring **0.0003 ppm**, reflecting strict agricultural practices such as the use of high-quality fertilizers and the avoidance of contamination sources. These findings align with the study of Ngoc et al. (2020).

**Table 1: Cadmium Concentration in the Peel and Pulp of Selected Fruits and Vegetables from Different Countries**

| **No.** | **Country of Origin** | **Plant Type** | **Cadmium Concentration in Pulp (ppm)** | **Cadmium Concentration in Peel (ppm)** |
| --- | --- | --- | --- | --- |
| 1 | Iraq | Cucumis sativus(Cucumber) | 0.021 | 0.0101 |
| 2 | Solanum tuberosum(Potato) | 0.11 | 0.07 |
| 3 | Malus domestica(Apple) | 0.0077 | 0.0009 |
| 4 | Citrus × sinensis(Orange) | 0.0421 | 0.0003 |
| 5 | Iran | Cucumis sativus(Cucumber) | 0.13 | 0.0471 |
| 6 | Syria | Solanum tuberosum(Potato) | 0.03 | 0.15 |
| 7 | Cucumis sativus(Cucumber) | 0.41 | 0.002 |
| 8 | Turkey | Malus domestica(Apple) | 0.0052 | 0.0003 |
| 9 | Citrus × sinensis(Orange) | 0.0179 | 0.0022 |
| 10 | China | Malus domestica(Apple) | 0.0711 | 0.0092 |
| 11 | Egypt | Citrus × sinensis(Orange) | 0.115 | 0.0024 |

**Figure 1**: Cadmium concentration in the pulp of plants

It was noted that cadmium concentrations in the pulp were higher than in the peels across all samples except for Syrian potatoes. This trend indicates that cadmium absorption occurs primarily through the roots from contaminated soil, particularly in areas where untreated wastewater or contaminated fertilizers are used, as highlighted by Einolghozati et al. (2023). In the case of Syrian potatoes, the cadmium concentration was higher in the peels, which can be attributed to the deposition of cadmium-containing dust from air pollution near highways or industrial zones, as confirmed by Nassar et al. (2018).

**Figure 2:** Cadmium concentration in plant peels

Soil properties also play a crucial role in cadmium accumulation. Acidic soils (pH < 6.5) enhance cadmium solubility and uptake, while alkaline soils reduce its availability, as demonstrated by Sawut et al. (2018). For example, the elevated cadmium concentration in Egyptian oranges (**0.115 ppm in the pulp**) may be due to the use of acidic soil or nitrogen-based fertilizers that lower soil pH.

**4. Conclusions**

The findings of this study indicate that cadmium levels in certain locally produced and imported fruits and vegetables in Iraq exceed internationally accepted limits, posing a potential risk to public health. The results revealed significant variations in cadmium accumulation among different agricultural products, with leafy vegetables being more susceptible to contamination compared to fruits.

This study underscores the necessity of strengthening periodic monitoring measures for both imported and locally produced agricultural products. Additionally, efforts should be made to minimize soil and water contamination with this toxic element. Raising consumer awareness about the risks of cadmium exposure through contaminated food consumption and promoting safer agricultural practices are crucial steps to ensure food quality and safety in local markets.

**5. Recommendations**

Based on these findings, it is recommended to monitor the quality of fertilizers and irrigation water and to adjust soil acidity by adding lime to reduce cadmium solubility. Farmers should be educated on the importance of sustainable agricultural practices, such as relying on organic fertilizers instead of chemical ones. Periodic testing of agricultural products, especially those intended for export or import, is also advised to ensure their safety. This aligns with recent reports by the World Health Organization (WHO), which emphasize the need for stricter safety measures in agricultural production.

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**References**

1. Afrin, Sadia, et al. "Determination and probabilistic health risk assessment of heavy metals in widely consumed market basket fruits from Dhaka city Bangladesh." *International Journal of Environmental Analytical Chemistry* 104.1 (2024): 215-230.‏
2. Ali, Hazrat, Ezzat Khan, and Ikram Ilahi. "Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation." *Journal of chemistry* 2019.1 (2019): 6730305.‏
3. Einolghozati, Mahtab, et al. "The level of heavy metal in fresh and processed fruits: a study meta-analysis, systematic review, and health risk assessment." *Biological trace element research* 201.5 (2023): 2582-2596.‏
4. Ezeonyejiaku, Chigozie Damian, and Maximilian Obinna Obiakor. "A market basket survey of horticultural fruits for arsenic and trace metal contamination in southeast Nigeria and potential health risk implications." *Journal of Health and Pollution* 7.15 (2017): 40-50.‏
5. Gebeyehu, Hailu Reta, and Leta Danno Bayissa. "Levels of heavy metals in soil and vegetables and associated health risks in Mojo area, Ethiopia." *PloS one* 15.1 (2020): e0227883.‏
6. Hoaghia, Maria-Alexandra, et al. "Heavy metals and health risk assessment in vegetables grown in the vicinity of a former non-metallic facility located in Romania." *Environmental Science and Pollution Research* 29.26 (2022): 40079-40093.‏
7. Hussein, S. A., M. H. Rathi, and T. J. Kadhim. "Determination of the levels of lead and cadmium in canned fish and meat, imported to the local markets of Diyala Province, Iraq." *IOP conference series: Earth and environmental science*. Vol. 790. No. 1. IOP Publishing, 2021.‏
8. Isiuku, Beniah Obinna, and Christian Ebere Enyoh. "Monitoring and modeling of heavy metal contents in vegetables collected from markets in Imo State, Nigeria." *Environmental Analysis, Health and Toxicology* 35.1 (2020): e2020003.‏
9. Ismael, Dldar Saleh, and Siraj Muhammed Abdulla Goran. "Health risk assessment of heavy metals in some vegetables-Erbil City-Kurdistan Region of Iraq." *Environmental Monitoring and Assessment* 196.5 (2024): 417.‏
10. Järup, Lars. "Hazards of heavy metal contamination." *British medical bulletin* 68.1 (2003): 167-182.‏
11. Kandil, Mohamed A., et al. "Investigation of heavy metals in fruits and vegetables and their potential risk for Egyptian consumer health." *Plant Archives (09725210)* 20.1 (2020).‏
12. Kumar, Rakesh, et al. "Bioaccumulation of fluoride in plants and its microbially assisted remediation: a review of biological processes and technological performance." *Processes* 9.12 (2021): 2154.‏
13. Lanphear, Bruce P., et al. "Low-level lead exposure and mortality in US adults: a population-based cohort study." *The Lancet Public Health* 3.4 (2018): e177-e184.‏
14. Mania, Monika, et al. "The content of lead, cadmium, arsenic, mercury and tin in fruit and their products based on monitoring studies–exposure assessment." *Roczniki Państwowego Zakładu Higieny* 72.4 (2021).‏
15. Mawari, Govind, et al. "Heavy metal accumulation in fruits and vegetables and human health risk assessment: findings from Maharashtra, India." *Environmental Health Insights* 16 (2022): 11786302221119151.‏
16. Nassar, Olfat M., et al. "Heavy metal levels in some popular vegetables from some selected markets in Saudi Arabia." *Egyptian Journal of Botany* 58.3 (2018): 627-638.‏
17. Ngoc, Nguyen Thi Minh, et al. "Chromium, cadmium, lead, and arsenic concentrations in water, vegetables, and seafood consumed in a coastal area in Northern Vietnam." *Environmental health insights* 14 (2020): 1178630220921410.‏
18. Nisa, Khair Un, and Naqeebullah Khan. "Detection of Heavy metals in Fruits and Vegetables available in the Market of Quetta city." *Al-Nahrain Journal of Science* 23.1 (2020): 47-56.‏
19. Oteef, Mohammed DY, et al. "Levels of zinc, copper, cadmium, and lead in fruits and vegetables grown and consumed in Aseer Region, Saudi Arabia." *Environmental monitoring and assessment* 187 (2015): 1-11.‏
20. Rahimzadeh, Mehrdad Rafati, et al. "Cadmium toxicity and treatment: An update." *Caspian journal of internal medicine* 8.3 (2017): 135.‏
21. Rusin, Monika, et al. "Concentration of cadmium and lead in vegetables and fruits." *Scientific Reports* 11.1 (2021): 11913.‏
22. Sadee, Bashdar Abuzed, and Rasul Jameel Ali. "Determination of heavy metals in edible vegetables and a human health risk assessment." *Environmental Nanotechnology, Monitoring & Management* 19 (2023): 100761.‏
23. Sawut, Rukeya, et al. "Pollution characteristics and health risk assessment of heavy metals in the vegetable bases of northwest China." *Science of the total environment* 642 (2018): 864-878.‏
24. Singh S, Sharma Y, Tagore G, Sahu R. Status of Heavy Metals in Soil and Vegetables Grown in Peri-Urban Areas of Jabalpur District, Madhya Pradesh, India. Int. J.Environ. Clim. Change. [Internet]. 2024 Jun. 13 [cited 2025 Mar. 27];14(6):211-23.
25. Tinkov, Alexey A., et al. "Cadmium and atherosclerosis: A review of toxicological mechanisms and a meta-analysis of epidemiologic studies." *Environmental research* 162 (2018): 240-260.‏
26. Zhang, Xiuying, et al. "Impact of soil heavy metal pollution on food safety in China." *Plos one* 10.8 (2015): e0135182.‏