Original Article

Journal of Food Safety and Hygiene

Journal homepage: http://jfsh.tums.ac.ir

Determination and health risk assessment of heavy metals (arsenic, lead and cadmium) in Iranian rice

Soheyl Eskandari[1], Alireza Bakhtiyari[2*], Saeed Aghebat-Bekheir[3], Yeganeh Hamidi[4], Azadeh Rashidimehr[5], Mahtab Mofatehi[6]

[1]*Food and Drug Laboratory Research Center (FDLRC), Food and Drug Administration (IR-FDA), Ministry of Health and Medical Education (MoHME), Tehran, Iran.*

[2]*Food Safety and Hygiene Division, Department of Environmental Health Engineering, School of Public Health, Tehran University of Medical Sciences, Tehran, Iran.*

[3]*Department of Toxicology & Pharmacology, School of Pharmacy, Tehran University of Medical Sciences, Tehran, Iran.*

[4]*Department of Microbiology, Faculty of Sciences and Modern Technologies, Islamic Azad University, Tehran, Iran.*

[5]*Department of Basic Sciences, Faculty of Veterinary Medicine, Lorestan University, Khorramabad, Iran.*

[6] *Department of Food Hygiene, Islamic Azad University, North Tehran Branch, Tehran, Iran.*

ARTICLE INFO

Article history:
Received 19. 02. 2025
Received in revised form 24. 06. 2025
Accepted 30. 06. 2025

Keywords:
Rice;
Risk assessment;
Daily intake;
Hazard quotient;
Cancer risk

ABSTRACT

Rice is a major component of the human diet, so it can pose serious health risks in case of contamination. This study aimed to evaluate the levels of lead, cadmium, and arsenic in Iranian rice, and the associated health risks for consumers. For this purpose 41 samples of Iranian rice were purchased from market in Tehran city. After removing ash and preparing the samples, they were tested for lead and cadmium using a flame atomic absorption device. Arsenic levels were measured using an Arsenometer. Health risk assessment was conducted using hazard quotient and cancer risk formulas. The level of arsenic (0.16764 ± 56.84 mg/kg) exceeds the maximum tolerance set by the national standard of Iran. However, the levels of lead and cadmium (0.02264 ± 37.86 mg/kg lead and 0.1113 ± 12 mg/kg cadmium) are below the maximum tolerance. Although the HQ (Hazard Quotient) and HI (Hazard Index) for heavy metals are below one, the greatest risk is associated with arsenic. Additionally, the assessment of CR (carcinogenic risk) due to heavy metal exposure in children and adults is less than 10^{-6}. It can be said, long-term consumption of contaminated rice may pose a risk due to the high arsenic content. Further studies are necessary to make definitive decisions and evaluate this issue comprehensively.

Citation: Eskandari S, Bakhtiyari A, Aghebat-Bekheir S, Hamidi Y, Rashidimehr A, Mofatehi M. **Determination and health risk assessment of heavy metals (arsenic, lead. and cadmium) in Iranian rice.** J Food Safe & Hyg 2025; 11(2): 183-194.http://doi.org/10.18502/jfsh.v11i2.20993

1. Introduction

Today, with the increasing population and expansion of urbanization, as well as the globalization of Industry and advancements in technology, environmental pollution has become a significant concern.

*Corresponding author. Tel.: +989379049936
E-mail address: a-bakhtiyari@razi.tums.ac.ir

This issue has become an important part of one of the problems of human societies (1). Heavy metals are among the most important pollutants that enter the environment through natural sources and human activities, including soil erosion, weathering of the earth's crust, agricultural operations using various fertilizers and pesticides, mining, metalworking industries, fossil fuel combustion, discharge of various urban and industrial wastewater and sewage, and irrigation of agricultural soils with contaminated water (2-4). Lead, cadmium, and arsenic are highly toxic metals that pose a serious threat to the body even at low levels. Because of their toxic effects and their capacity to accumulate in tissues, they can enter the body through food, drink, air, and other sources, causing irreparable damage (5, 6). According to the Iranian national standard, the permissible limits of heavy metals lead, cadmium and arsenic in rice are 150, 60 and 150 ppb, respectively (7). Heavy metals, including lead, cadmium and arsenic, threaten human health; the International Agency for Research on Cancer has classified lead in category 2A, meaning it is possibly carcinogenic to humans, and the same organization has classified cadmium and arsenic in category 1, meaning that these elements are definitely and proven carcinogenic to humans (8). Heavy metal contamination has been reported in a wide range of foods, such as: milk (9), fruit juice, Carbonated drinks, tea, coffee (10, 11), poultry (12), fruits (13), vegetables (14, 15), cocoa powder (16), wheat flour (17), olives (18, 19), seafood (20), canned fish (21, 22), other canned food products (23-25), even tap water (26) and bottled water (27). Rice is a staple food and is popular all over the world, especially in Asian countries. The average rice consumption in Iran, Asia, and the world is about 41, 85, and 65 kg per year, respectively (28). More than 90% of the world's rice is produced in Asian countries (29, 30), and China and India are the largest rice producers in the world (31, 32). Due to the very high per capita consumption of this product, the presence of even the smallest contamination in it can pose serious risks to human health (33). One of the different types of contamination that can occur in rice is heavy metal contamination, which has become a global concern (34). Several factors lead to the absorption of heavy metals in crops, especially rice. In addition, human behavior such as industrial cultivation and crop production, such as excessive use of pesticides, insecticides, as well as inadequate pollution control regulations and requirements, can lead to heavy metal contamination of food (35). Rice soil contamination due to the extraction of precious metals (36), irrigation of rice fields with arsenic-contaminated groundwater (37), and use of arsenic-containing insecticides (38) are sources of arsenic contamination in rice. Cadmium is one of the metals that is widely distributed in the environment, the main source of this metal is industrial compounds and phosphate fertilizers, and it is easily absorbed by plants (39). Heavy metal contamination of rice is one of the possible cases of environmental pollution, in which under certain conditions, such as water, soil, and proximity of rice fields to industrial centers and related wastewater, heavy metals enter and accumulate in rice. While rice is one of the main food sources for Iranians, consumption of rice contaminated with heavy metals may pose health and safety risks. Therefore, the priority should be continuous monitoring of heavy metals in rice consumed by households. Given the importance of heavy metals for human health and people's high desire to consume rice, this study aims to evaluate the concentration of heavy metals in Iranian rice and estimates the carcinogenic (CR) and non-carcinogenic (HQ) risks posed by dietary intake.

2. Materials and Methods

2.1. Rice sampling

41 Iranian rice samples were purchased from reputable stores in Tehran and transported to the laboratory in nylon bags. Rice samples were collected from each weighing approximately one kilogram. To determine the risk assessment of rice consumption in terms of heavy metals, different types of Iranian rice were randomly selected. To determine the concentration of heavy metals lead, cadmium, and arsenic, the collected rice samples were washed with distilled water to remove possible contamination, and the samples were dried in an oven at 105°C for 48 h and then stored in polyethylene containers.

2.2. Sample preparation and method for measuring heavy metals

To remove possible contamination, all laboratory containers were washed with acid, rinsed with deionized water, and dried in an oven. The dried rice samples were pounded in a porcelain mortar, crushed, and homogenized; then the samples were transferred to clean crucibles that had been taken out of the oven and cooled in a desiccator, and the crucibles were placed in an oven at a temperature of 600 °C for 12 h to ash the samples. After the ashing process was completed, the crucibles were removed from the oven and placed in a desiccator to cool. In the next step, 65% nitric acid and 30% hydrogen peroxide were added to one gram of each sample in a volume ratio of 2 to 1 until the volume reached 10 mL. To reach the volume of the solution to three mL, it was heated on a laboratory heater and after cooling, it was made up to volume with double distilled water in a 25 mL beaker using Whatman 42 filter paper. Finally, after making the stock solution and the standard salt of the elements at different concentrations, the amounts of lead and cadmium were determined at wavelengths of 283 and 238 nm using a flame atomic absorption spectrometer and arsenic using an arsenometer (40). Results were analyzed using SPSS software and the average of treatments was analyzed using one-way ANOVA.

2.3. Method of health risk assessment

2.3.1. Carcinogenic risk assessment

Carcinogenic risk refers to the increased likelihood of developing cancer during a person's lifetime due to exposure to a carcinogen. In this context, carcinogenicity refers to the assumption that there is a relationship between increasing dose or exposure to a contaminant concentration and increasing risk of cancer. The slope of the line resulting from this relationship is known as the Cancer Slope Factor and its unit is expressed in terms of milligrams of the chemical per kilogram of body weight per day. The United States Environmental Protection Agency (USEPA) recommends a slope factor for cadmium, lead, and arsenic.

The following equation is used to assess carcinogenic risk:

$$CR = ADD \times CSF$$

CR: Carcinogenic risk

CSF: Cancer slope factor

The amount of contaminant received through rice per kilogram of body weight per day (Average Daily Dose) was calculated using the following equation:

$$ADD = \frac{(EF \times ED \times IR \times C)}{(BW \times AT)}$$

ADD: Daily dose in mg/kg/day

EF: Frequency of exposure (365 days in a year)

ED: Frequency of exposure (6 years for children and 60 years for adults)

IR: Rice intake (82 mg/day for adults and 25 mg/day for children)

C: Metal concentration in rice (mg/kg rice)

BW: Average body weight (15 kg for children and 70 kg for adults)

AT: Average duration of exposure to carcinogens and non-carcinogens (2190 kg for children and 10950 kg for adults) (41).

Carcinogenic risk (CR) is the probability that an individual will develop cancer during his or her lifetime due to exposure to a carcinogen. In general, the USEPA states that a risk of less than 1×10^{-6} can be considered negligible, while a risk of greater than 1×10^{-4} is likely to be hazardous to human health. A risk within the permissible risk range of 10^{-6-4} is considered acceptable or tolerable. In this study, the CR for lead (0.0085), cadmium (0.380), and arsenic (1.50) was evaluated based on available toxicological data for SF (42, 43).

2.3.2. Non-carcinogenic risk assessment

In this study, hazard ratios (HQ), which refer to the ratio of heavy metal exposure to the reference dose (RfD), were used to calculate non-toxic effects. The RfD is expressed in mg/kg/day for the specific contaminant. Its value for cadmium, lead and arsenic is 0.001, 0.02 and 0.0003 respectively. If its value is less than one, there is no non-carcinogenic risk, but if its value is greater than one, the carcinogenic risk is unacceptably high (44).

$$HQ = \frac{ADD}{RfD} \qquad HI = \sum_{1}^{i} HQ_s$$

3. Results

3.1. Comparison of heavy metal concentrations with standard concentrations

The findings of the present study can be seen in Table 1; the average concentrations of arsenic, lead, and cadmium in rice samples were 0.16764, 0.02264, and 0.01113 mg/kg, respectively. Arsenic was detected in all samples, and the highest and lowest concentrations of this metal were 0.2818 and 0.002 mg/kg, respectively. The highest lead concentration was 0.22 mg/kg, and the highest cadmium concentration was 0.04 mg/kg.

As indicated in Table 1, the highest value was related to arsenic and the lowest value was related to cadmium. Comparing the average concentrations of these metals with the national standard, arsenic was higher than the maximum tolerance (0.15 mg/kg) but lower than international standards (0.2 mg/kg). However, the amounts of lead and cadmium were lower than the permissible limits of both national and international standards.

Table 1. Concentration of arsenic, lead and cadmium in Iranian rice samples

	ADD		CR		HQ		HI	
	child	adult	child	adult	child	adult	child	adult
Lead	3.77×10^{-8}	5.3×10^{-8}	3×10^{-10}	4.51×10^{-11}	1.89×10^{-6}	2.65×10^{-6}	-	-
Cadmium	1.86×10^{-8}	2.61×10^{-8}	7.1×10^{-9}	9.9×10^{-9}	1.86×10^{-5}	2.61×10^{-5}	-	-
Arsenic	2.79×10^{-7}	3.93×10^{-7}	4.19×10^{-7}	5.89×10^{-7}	9.31×10^{-4}	1.31×10^{-3}	9.52×10^{-4}	1.34×10^{-3}

Maximum Tolerance of heavy metals according to Iran National Standards Organization, 2021, No. 12968
*** Joint FAO/WHO food standards programme Codex committee on contaminants in foods, 14th session, 2021, CF/14 INF/1*

Table 2. Carcinogenic and non-carcinogenic risk results for lead, cadmium, and arsenic in Iranian rice samples.

Concentration of heavy metals (mg/kg)	Arsenic	Lead	Cadmium
Iranian rice (mean ± SD)	0.16764 ± 56.84	0.02264 ± 37.86	0.01113 ± 12
Iran National Standards Organization (INSO)	0.15	0.15	0.06
FAO/WHO	0.2	0.2	0.4

3.2. Carcinogenic risk (CR) and non-carcinogenic risk (HQ)

The results of Table 2 show that the average carcinogenic and non-carcinogenic risk for lead in Iranian rice in children was 3×10^{-10} and 1.89×10^{-6}, respectively, and in adults was 4.51×10^{-11} and 2.65×10^{-6}, respectively, which is within the safe range. The CR for cadmium in children and adults was estimated to be 7.1×10^{-9} and 9.9×10^{-9}, respectively, which is within the safe range for children and adults. The CR for arsenic in Iranian rice in children and adults was also 4.19×10^{-7} and 5.89×10^{-7}, respectively, therefore it is within the safe range. Table 2 shows that HQ and HI for each heavy metal lead, cadmium and arsenic are less than one, and therefore the non-carcinogenic risks are also acceptable.

4. Discussion

Industrial activities can cause water and soil pollution and ultimately lead to the accumulation of these pollutants in the food chain. Rice can be considered one of the main sources of heavy metals entering the human body (45, 46). Rice is widely used in the Iranian diet.

In the present study, the concentrations of three metals (lead, cadmium, and arsenic) were measured in Iranian rice consumed in Tehran.

The concentrations obtained for all three metals, cadmium, lead, and arsenic, were lower than the Iranian and Codex standards. However, some researchers reported that exposure to arsenic even at concentrations lower than the standard can cause skin and urinary tract problems. One of the most important reasons is its high level in rice irrigated with well water (47).

In accordance with the present study, in the study of Mohammadi et al. (2024), the amount of cadmium in the two cities of Lordegan (0.0165 mg/kg) and Ahvaz (0.0295 mg/kg) was lower than the permissible limits of the national standard and Codex, but unlike this study, the amount of lead metal in the two cities of Lordegan (1.1265 mg/kg) and Ahvaz (1.3496 mg/kg) was higher than the Iranian standard and Codex (43). Another similar study in Iran reported an average lead concentration of 0.64 mg/kg in rice grown in Kashan (48) and 0.075 mg/kg in rice grown in Lorestan province (49). Other similar studies showed that the lead concentration in crops grown in uncontaminated soils rarely exceeds 1 mg/kg. Other studies reported that the average lead accumulation in rice grown in northern Iran was 11.5 mg/kg, which was significantly higher than the average concentration recorded in this study (50).

Although the concentration of heavy metals in Iranian rice was below the national and international standards, it is important to note that rice plants have a high ability to accumulate and absorb heavy metals (especially lead). Among the important factors that increase lead concentration in rice are irrigation with wastewater and the use of chemical fertilizers (51). Lead affects humans in various ways as a result of human activities such as gasoline production. This metal affects the nervous system and causes disorders in the renal and hepatic systems, delays in mental and physical development in children, inhibition of hemoglobin synthesis, and damage to the vascular and cardiac systems (45, 46). Recently, even the relationship between lead (along with arsenic and cadmium) and non-alcoholic fatty liver has attracted the attention of researchers (52).

Cadmium is one of the most mobile and harmful elements among heavy metals. It is a major factor in bone lesions, pulmonary failure, hypertension, renal disorders, and cancer (46, 50). In a similar study comparing rice produced in seven provinces of Iran during 1990–2007, the highest and lowest levels of cadmium in rice were 0.64 mg/kg and 0.013 mg/kg in Kashan and Kermanshah provinces. In a study of rice grown in the paddy fields of northern Iran, no cadmium was reported (50). In this study, the average cadmium concentration in soils of Khuzestan province was 0.18 mg/kg, which was the primary phosphate fertilizer of cadmium in the soil of rice fields. Rice roots have a high ability to absorb cadmium (in the divalent form) from water and soil (53).

In another study conducted on conventional rice in the Hoveyzeh and Azadegan plains in 2024 on Anbarbo, Damsiah, Tarom, Indian, and Pakistani rice, arsenic concentrations in five different types of rice consumed were higher than the permissible limit of the Iranian national standard (41). Arsenic accumulates in all grains, but in rice field soils, rice accumulates arsenic in higher amounts due to anaerobic conditions (46). In addition, research has shown that cadmium accumulation in rice is approximately 10 times higher than in other agricultural products (54). The use of other agricultural chemicals such as pesticides, fungicides, insecticides, and fertilizers in rice fields is a primary source of heavy metals that can increase their concentration in the soil (55). However, the cooking process, especially rinsing, can significantly reduce the concentration of heavy metals lead, cadmium, and arsenic in rice (56).

Comparison of the findings of the present study with previous studies shows that there are discrepancies between these findings; these discrepancies are not unexpected given the differences in brands and regions studied. The source of heavy metal contamination of rice can be the discharge of chemical wastewater into the environment and the excessive use of chemical fertilizers containing heavy metals to improve soil properties (57). Numerous studies have been conducted on the contamination of soil and plants with heavy metals in farms. There is also clear evidence that different plant species differ greatly in their ability to absorb, accumulate, and tolerate heavy metals. This indicates that in examining metal toxicity in different and complex plant-soil systems, there are many factors related to soil characteristics, plant characteristics, and other environmental factors. The use of sewage sludge and phosphate fertilizers in agricultural lands and residues from the use of fossil fuels and industrial wastes are among the factors that cause soil pollution (58).

Following the criteria set by USEPA, the non-carcinogenic risk to the health of consumers is not a concern because the HQ and HI values for rice were less than one. In agreement with the present study, in a study conducted on Lordegan and Ahvaz rice, the carcinogenic and non-carcinogenic risks of lead and cadmium, respectively, for both adults and children due to Champa rice consumption were within safe limits (43). Also, in the study by Neisi et al. (2024), HQ and HI were less than one for both adults and children, so eating rice in the studied area is not associated with the non-carcinogenic risk of heavy metals. However, these researchers reported the highest values of arsenic HQ in Tarom rice for children and adults (41), which is also in agreement with the present study.

In the study by Ghaffari et al. (2022), the HQ of cadmium and lead in rice grown in Khuzestan province exceeded 1 (59). HQ for lead and cadmium in rice from Hunan, China were 2.29 and 0.216, respectively, so cadmium had a non-carcinogenic risk potential for individuals (60). A study on the potential of heavy metal contamination of rice, vegetation and soil along the eastern coastline of India showed that HI for adults was 1.561 and 1.360 for children, indicating an adverse effect on their future health (61).

In one study, the carcinogenic risk of cadmium and lead in rice samples grown in Khuzestan was higher than 4-10, which is not consistent with the present study (59). The carcinogenic risk values of cadmium in rice from Hunan, China were reported to be 0.00393 and 0.0343, respectively, which were higher than 4-10, and consumption of this rice has the potential to cause cancer in humans (62). Also, in the study by Nehreen Majed, the carcinogenic risk of cadmium (03-E33.7) was in the carcinogenic range and lead metal was in the safe range (63). In the study by Ting Huan et al. (2021), the carcinogenic risk of arsenic and cadmium exceeded the threshold of the hazard index of 4^{-10}, which indicates a carcinogenic risk to the human body (60). In addition, the difference in the number of samples and different sampling points as cultivated rice could be the reason for the difference in some of the results of these studies.

5. Conclusion

This study investigated the concentrations of three metals, lead, cadmium, and arsenic, in rice consumed in Tehran and assessed the carcinogenic (CR) and non-carcinogenic (HQ) risks of these heavy metals. The average residual concentrations of heavy metals (lead and cadmium) in rice samples were within the permissible limits defined by the National Organization of Standards of Iran and Codex, however, the arsenic concentration was higher than the Iranian national standard and lower than the Codex standard (FAO/WHO). The non-carcinogenic risk assessment for these heavy metals in this study was less than one and within the safe range. The carcinogenic risk was also within the safe range. Given the high arsenic content, long-term consumption of contaminated rice may be risky. On the other hand, more studies should be conducted for further evaluation and definitive decision-making. Also, more careful and continuous monitoring is needed to prevent these heavy metals from entering the food chain.

Ethical considerations

The authors have observed all ethical points in this article, including informed consent (if the study was conducted on human samples), good conduct (if the study was conducted on human samples or laboratory animals), no plagiarism, dual publication, data distortion, and data fabrication.

Funding

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authorship contribution:

Conceptualization: Soheyl Eskandari

Data curation: Soheyl Eskandari

Formal analysis: Saeed Aghebat-Bekheir

Methodology: Azadeh Rashidimehr

Validation: Soheyl Eskandari

Writing – original draft: Alireza Bakhtiyari, Yeganeh Hamidi and Mahtab Mofatehi

Writing – review and editing: Alireza Bakhtiyari

Declaration of competing interest

The authors declare that they have no conflict of interest.

Data availability

Data will be made available in case of request.

Acknowledgement

None

References

1. Skandari A, Mohammadi RM. Health assessment of heavy metals pollutions in some of imported and cultivated rice of Karoon River (Case study: Shadegan city). 2019.
2. Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip. Toxicol. 2014; 7(2):60.
3. Akbari S, Cheraghi M. The concentration of heavy metals Zn, Pb and Cd in rice supplied in the consumer market in Hamadan. 2019; 13-22.

4. Idani E, Geravandi S, Akhzari M, Goudarzi G, Alavi N, Yari AR, et al. Characteristics, sources, and health risks of atmospheric PM10-bound heavy metals in a populated middle eastern city. Toxin Rev. 2020; 39(3):266-74.
5. Dahiya V. Heavy metal toxicity of drinking water: A silent killer. GSC Biol Pharm Sci. 2022; 19(1):020-5.
6. Dehvari M, Jamshidi B, Jorfi S, Pourfadakari S, Skandari Z. Cadmium removal from aqueous solution using cellulose nanofibers obtained from waste sugarcane bagasse (SCB): isotherm, kinetic, and thermodynamic studies. Desalin. Water Treat. 2021; 221:218-28.
7. Organization INS. Food and feed-maximum limit of heavy metals. 1 ed. Tehran: INSO; 2021.
8. Zheng Y, Chen S, Chen Y, Li J, Xu B, Shi T, et al. Association between PM2. 5-bound metals and pediatric respiratory health in Guangzhou: An ecological study investigating source, health risk, and effect. Front Public Health. 2023; 11:1137933.
9. Bakhtiyari A, Shavli GP, Karami L, Yazdanfar N, Sadighara P. Investigating the amounts and risk assessment of lead in raw milk collected from farms in Tehran province in winter, 2022. 2024.
10. Gilani PS, Sadighara P, Saatloo NV, Yazdanfar N, Yousefi M. Determination and health risk assessment of heavy metals content in some common drinks in Tehran, Iran J Agric Food Res. 2025:102014.
11. Aghebat Bekher S, Barzegar-Bafrouei S, Marboutian F, Bakhtiyari A, Matin M, Sadighara M. Determination of lead levels in cold and hot beverages on the Iranian market using the atomic absorption spectrometry method. Caspian J Vet Sci. 2024; 1(1):55-62.
12. Dadmehr A, Sadighara P, Zeinali T. A study on microbial and chemical characterization of mechanically deboned chicken in Tehran, Iran. Int J Environ Health Res. 2022; 32(11):2396-405.
13. Farsani GM, Shariatifar N, Shavali-Gilani P, Nazmara S, Nazari RR, Sani MA, et al. Determination of trace elements content of fruits from Tehran's market using ICP-OES method: A risk assessment study. Environ Monit Assess. 2024; 196(9):784.
14. Alamdari HA, Ali HS, Sadighara P, Khaniki GJ, Landeh KS, Dehghani MH. The health risk assessment of heavy metals in vegetables grown in Babol city, Iran. Int Arch Health Sci. 2023; 10(3).
15. Shokri S, Abdoli N, Sadighara P, Mahvi AH, Esrafili A, Gholami M, et al. Risk assessment of heavy metals consumption through onion on human health in Iran. Food Chem: X. 2022; 14:100283.
16. Mohamadi S, Mahmudiono T, Zienali T, Sadighara P, Omidi B, Limam I, et al. Probabilistic health risk assessment of heavy metals (Cd, Pb, and As) in Cocoa powder (Theobroma cacao) in Tehran, Iran market. Chem Environ Eng. 2024; 34(1):257-72.
17. Saatloo NV, Ebrahiminejad B, Sadighara P, Manafi L, Yazdanfar N, Fallahizadeh S. Quantification and human health risk assessment of cadmium and lead in wheat flour on the Iranian market by atomic absorption spectrometry. Case Studies in Chem. Environ Eng. 2023; 8:100438.
18. Shariatifar N, Mohamadi S, Akbari N, Molaee-Aghaee E, Sadighara P, Zeinali T. Carcinogenic and non-carcinogenic risk assessment of lead in traditional and industrial canned black olives from Iran. Nutrire. 2022; 47(2):26.
19. Haj Heidary R, Golzan SA, Mirza Alizadeh A, Hamedi H, Ataee M. Probabilistic health risk assessment of potentially toxic elements in the traditional and industrial olive products. Environ Sci Pollut Res. 2023; 30(4):10213-25.
20. Negahdari S, Sabaghan M, Pirhadi M, Alikord M, Sadighara P, Darvishi M, et al. Potential harmful effects of heavy metals as a toxic and carcinogenic agent in marine food-an overview. Egypt J Vet Sci. 2021;52(3):379-85.

21. Shokri S, Shokri E, Sadighara P, Pirhadi M. Heavy metals contamination in fresh fish and canned fish distributed in local market of Tehran. Hum Health Halal Metr. 2021; 2(2):12-7.
22. Sadighara P, Mofid V, Mahmudiono T, Rahmani A, Tajdar-Oranj B, Peivasteh-Roudsari L, et al. Concentration of heavy metals in canned tuna fish and probabilistic health risk assessment in Iran. Int J Environ Anal Chem. 2024; 104(8):1719-29.
23. Aslani R, Shavali-Gilani P, Bakhtiyari A, Sadighara P, Yazdanfar N, Yousefi M. Determination and health risk assessment of heavy metals in some canned food in Tehran, Iran. Biol Trace Elem Res. 2025: 1-11.
24. Akbari N, Aslani R, Sadighara P, Yazdanfar N, Yousefi M. Heavy metals in canned eggplant in Tehran, Iran: a health risk assessment study using Monte Carlo simulation. J Agric Food Res. 2025; 21:101996.
25. Shavali -gilani P, Abedini A, Irshad N, Maleknezhad S, Yazdanfar N, Sadighara P. Investigation of heavy metal levels in canned tomato paste, olives, and pickled. Sci Rep. 2025; 15(1):20923.
26. Khanniri E, Esmaeili S, Akbari ME, Molaee-aghaee E, Sohrabvandi S, Akbari N, et al. Determination of heavy metals in municipal water network of Tehran, Iran: A health risk assessment with a focus on carcinogenicity. Int J Cancer Manag. 2023; 16:e137240.
27. Aslani R, Esmaeili S, Akbari ME, Molaee-Aghaee E, Sadighara P, Nazmara S, et al. Determination of heavy metals, nitrate and nitrite in mineral and drinking bottled water in Tehran, Iran: A health risk assessment by Monte-Carlo simulation method. Heliyon. 2024; 10(23).
28. Nemati-Mansour S, Hudson-Edwards KA, Mohammadi A, Asghari Jafarabadi M, Mosaferi M. Environmental occurrence and health risk assessment of arsenic in Iran: A systematic review and Meta-analysis. Hum. Ecol. Risk Assess. 2022; 28(5-6):683-710.
29. Ijachi C, Sennuga SO, Bankole O-L, Okpala EF, Preyor TJ. Assessment of climate variability an d effective coping strategies used by rice farmers in Abuja, Nigeria. Int. J Agric Food Sci 2023; 5(1):137-43.
30. Organization FaA. FAO Rice market monitor: FAO; 2018 [Available from: https://www.fao.org/economic/est/publications/rice-publications/rice-market-monitor-rmm/en/.
31. Fan Y, Zhu T, Li M, He J, Huang R. Heavy metal contamination in soil and brown rice and human health risk assessment near three mining areas in central China. J Health Eng. 2017; 2017(1):4124302.
32. Organization FaA. Faostat rome: FAO; 2022 [Available from: https://www.fao.org/faostat/en/#data/QCL/visualize.
33. iLibrary O. Rice projection: Consumption, per capita [Available from: https://www.oecd-ilibrary.org/docserver/agr_outlook-2015-table125 en.pdf?expires=1719656205&id=id&accname=guest&checksum=44AF8C99C4C05D6A25842D6136C76DD0 .
34. Thielecke F, Nugent AP. Contaminants in grain—a major risk for whole grain safety? Nutrients. 2018; 10(9):1213.
35. Emenike CU, Jayanthi B, Agamuthu P, Fauziah S. Biotransformation and removal of heavy metals: A review of phytoremediation and microbial remediation assessment on contaminated soil. Environ Rev. 2018; 26(2):156-68.
36. Zhu Y-G, Sun G-X, Lei M, Teng M, Liu Y-X, Chen N-C, et al. High percentage inorganic arsenic content of mining impacted and nonimpacted Chinese rice. Environ Sci. Technol. 2008; 42(13):5008-13.
37. Williams PN, Islam M, Adomako E, Raab A, Hossain S, Zhu Y, et al. Increase in rice grain arsenic for regions of Bangladesh irrigating paddies with elevated arsenic in groundwaters. Environ Sci Technol. 2006; 40(16):4903-8.
38. Williams PN, Villada A, Deacon C, Raab A, Figuerola J, Green AJ, et al. Greatly enhanced arsenic shoot

assimilation in rice leads to elevated grain levels compared to wheat and barley. Environ Sci Technol. 2007; 41(19):6854-9.

39. Lawley R, Curtis L, Davis J. The food safety hazard .guidebook. R Soc Chem. 2015

40. Shah A, Niaz A, Ullah N, Rehman A, Akhlaq M, Zakir M, et al. Comparative study of heavy metals in soil and selected medicinal plants. J Chem. 2013; 2013(1):621265.

41. Neisi A, Farhadi M, Angali KA, Sepahvand A. Health risk assessment for consuming rice, bread, and vegetables in Hoveyzeh city. Toxicol Rep. 2024; 12:260-5.

42. Fouladi M, Mohammadi Rouzbahani M, Attar Roshan S, Sabz Alipour S. Health risk assessment of potentially toxic elements in common cultivated rice (*Oryza sativa*) emphasis on environmental pollution. Toxin Rev. 2021; 40(4):1019-34.

43. Mohammadi MJ, Kiani F, Farhadi M, Ghanbari S, Jalili D, Mirzaei L. Evaluation of carcinogenic risk of heavy metals due to consumption of rice in Southwestern Iran. Toxicol Rep. 2024; 12:578.

44. Ijeoma KH, Chima OE, Daniel A, Ayotunde OS. Health risk assessment of heavy metals in some rice brands imported into Nigeria. Commun. Phys Sci. 2010; 5(1, 2, 3).

45. Rahman MA, Rahman MM, Reichman SM, Lim RP, Naidu R. Heavy metals in Australian grown and imported rice and vegetables on sale in Australia: health hazard. Ecotoxicol. Environ Saf. 2014; 100:53-60.

46. Huang Z, Pan X-D, Wu P-G, Han J-L, Chen Q. Health risk assessment of heavy metals in rice to the population in Zhejiang, China. PloS One. 2013;8(9):e75007.

47. Sharafi K, Nodehi RN, Yunesian M, Mahvi AH, Pirsaheb M, Nazmara S. Human health risk assessment for some toxic metals in widely consumed rice brands (domestic and imported) in Tehran, Iran: uncertainty and sensitivity analysis. Food Chem. 2019; 277:145-55.

48. Rabbani D, Mostafaii GR, Dehghani R, Gilasi H, Hosein Abadi Z. Evaluation of heavy metals in Iranian and non-Iranian rice supplied by shopping centers of Kashan, Iran. Int Arch Health Sci. 2015; 2(1).

49. Jafari A, Kamarehie B, Ghaderpoori M, Khoshnamvand N, Birjandi M. The concentration data of heavy metals in Iranian grown and imported rice and human health hazard assessment. Data Brief. 2018;16:453-9.

50. Zazouli MA, Shokrzadeh M, Izanloo H, Fathi S. Cadmium content in rice and its daily intake in Ghaemshahr region of Iran. Afr J Biotechnol. 2008;7(20).

51. Martínez-Cortijo J, Ruiz-Canales A. Effect of heavy metals on rice irrigated fields with waste water in high pH Mediterranean soils: The particular case of the Valencia area in Spain. Agric. Water Manag. 2018; 210:108-23.

52. Sadighara P, Abedini AH, Irshad N, Ghazi-Khansari M, Esrafili A, Yousefi M. Association between non-alcoholic fatty liver disease and heavy metal exposure: A systematic review. Biol Trace Elem Res. 2023; 201(12):5607-15.

53. Fakhri Y, Bjørklund G, Bandpei AM, Chirumbolo S, Keramati H, Pouya RH, et al. Concentrations of arsenic and lead in rice (*Oryza sativa L.*) in Iran: A systematic review and carcinogenic risk assessment. Food Chem. Toxicol. 2018; 113:267-77.

54. Islam MS, Ahmed MK, Habibullah-Al-Mamun M. Apportionment of heavy metals in soil and vegetables and associated health risks assessment. Stoch Environ Res. Risk Assess. 2016; 30(1):365-77.

55. Kongsri S, Srinuttrakul W, Sola P, Busamongkol A. Instrumental neutron activation analysis of selected elements in Thai jasmine rice. Energy procedia. 2016; 89:361-5.

56. Mohajer A, Safaei P, Sleman Ali H, Sarwar Karim H, Sadighara P, Molaee-Aghaee E, et al. The association between toxic metals (As, Pb and Cd) exposure and rice cooking methods: A systematic review and meta-analysis.

Int. J Environ Health Res. 2024; 34(2):839-50.

57. Zhao K, Fu W, Ye Z, Zhang C. Contamination and spatial variation of heavy metals in the soil-rice system in Nanxun County, Southeastern China. Int J Environ Res. Public Health. 2015; 12(2):1577-94.
58. Torabian A, Mahjoori M. Effect of sewage irrigation on heavy metal uptake by leaf vegetables south of Tehran. Soil Water J. 2002; 16(2):188-96.
59. Ghaffari SMMM, Payandeh K, Goosheh M. Health Risk assessment of some heavy metals of local rice cultivars in Khuzestan Province. J Innov Food Sci Technol. 2022; 14(1).
60. Huang T, Deng Y, Zhang X, Wu D, Wang X, Huang S. Distribution, source identification, and health risk assessment of heavy metals in the soil-rice system of a farmland protection area in Hubei Province, Central China. Environ Sci Pollut Res. 2021; 28(48):68897-908.
61. Satpathy D, Reddy MV, Dhal SP. Risk assessment of heavy metals contamination in paddy soil, plants, and grains (*Oryza sativa L.*) at the East Coast of India. BioMed Res Int. 2014; 2014(1):545473.
62. Zeng F, Wei W, Li M, Huang R, Yang F, Duan Y. Heavy metal contamination in rice-producing soils of Hunan province, China and potential health risks. Int J Environ. Res Public Health. 2015; 12(12):15584-93.
63. Real MIH, Azam HM, Majed N. Consumption of heavy metal contaminated foods and associated risks in Bangladesh. Environ Monit Assess. 2017; 189(12):651.