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Potential Health Risks Due to Heavy Metals in Indian Rice Available in Karbala Markets, Iraq

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Abstract

Background: Hypothyroidism, characterized by insufficient thyroid hormone production by This study aims to assess the concentrations of six heavy metals, lead (Pb), cadmium (Cd), chromium (Cr), Nickel (Ni), Arsenic (As), and Selenium (Se), in samples of Indian basmati rice available in Karbala markets, Iraq. The concentrations of (As, Cr, Se, Ni, Pb, and Cd) were measured using atomic absorption spectroscopy (AAS), to evaluate the potential human health risks associated with the consumption of this rice, several health risk assessment parameters were calculated, including the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and Cancer risk (CR). The average concentrations of As, Cr, Se, Ni, Pb, and Cd in the analyzed rice samples were 94.77, 326.06, 132.58, 179.39, 164.42, and 156.90 µg/kg, respectively. The average value of the Hazard Index (HI) was 4.242, which exceeded safe levels. The corresponding average carcinogenic risk (CR) values for As, Cr, Ni, Pb, and Cd were 8.21×10^{-04}, $8.71\times^{-04}$, 9.40×10^{-04}, 8.05×10^{-06}, and 5.70×10^{-03}, respectively. However, the concentrations of As and Cd in several samples exceeded the maximum permissible limits set by European Union regulations. The calculated health risk indicators (EDI, THQ, HI, and CR) remained within internationally recognized safe exposure levels. In conclusion, although specific heavy metal concentrations in Indian basmati rice sold in Karbala exceed regulatory limits, the overall risk to human health from regular consumption appears minimal under current dietary exposure scenarios. Continuous monitoring and stricter import quality control are recommended to ensure long-term food safety for the local population.

المخاطر الصحية المحتملة بسبب المعادن الثقيلة في الارز الهندي المتوفر في اسواق كربلاء، العراق.

منال داخل صخيل

الخلاصة

المقدمة: تعد العناصر الثقيلة من أخطر المواد التي تؤثر على صحة الانسان الجسمية والعقلية اذا زاد تواجدها بنسبة اكبر من المسموح بها داخل الجسم، حيث هدفت هذه الدراسة إلى تقييم تراكيز ستة معادن ثقيلة، هي الرصاص (Pb)، والكادميوم (Cd)، والكروم (Cr)، والنيكل (Ni)، والزرنيخ (As)، والسيلينيوم (Se)، في عينات من أرز بسمتي هندي متوفر في أسواق كربلاء بالعراق.

المواد وطرق العمل: تم إجراء هذه الدراسة من خلال جمع عدة عينات من الارزالبسمتي الهندي المتوفر في العراق . وقد تم قياس تراكيز كل من (As، Cr، Se، Ni، Pb، وCd) باستخدام مطيافية الامتصاص الذري (AAS)، لتقييم المخاطر الصحية المحتملة المرتبطة باستهلاك هذا الأرز. وقد تم حساب عدة معايير لتقييم المخاطر الصحية، بما في ذلك الكمية اليومية المُقدّرة (EDI)، ومعامل الخطر المستهدف (THQ)، ومؤشر الخطر (HI)، وخطر الإصابة بالسرطان (CR).

النتائج: بلغ متوسط تركيزات الزرنيخ والكروم والسيلينيوم والنيكل والرصاص والكادميوم في عينات الأرز المُحللة 94.77 و326.06 و132.58 و179.39 و164.42 و156.90 ميكروغرام/كغ، على التوالي. وبلغ متوسط مؤشر الخطر (HI (4.242، متجاوزًا بذلك المستويات الآمنة. أما متوسط قيم خطر الإصابة بالسرطان (CR) المقابلة للزرنيخ والكروم والنيكل والرصاص والكادميوم، فقد بلغ 8.21×10-04 و8.71×-04 و9.40×10-04 و8.05×10-06 و5.70×10-03، على التوالي.

الاستنتاج: تقدم النتائج المذكورة أفاقًا جديدة حول البحث عن اسباب تدهور صحة الانسان نتيجة زيادة تركيز العناصر الثقيلة في الارز، فقد تجاوزت تركيزات الزرنيخ والكادميوم في عدة عينات الحدود القصوى المسموح بها بموجب لوائح الاتحاد الأوروبي. ظلت مؤشرات المخاطر الصحية المحسوبة (EDI، THQ، HI، وCR) ضمن مستويات التعرض الآمنة المعترف بها دوليًا. وختامًا، على الرغم من أن تركيزات المعادن الثقيلة المحددة في أرز البسمتي الهندي المباع في كربلاء تتجاوز الحدود التنظيمية، إلا أن الخطر الإجمالي على صحة الإنسان من الاستهلاك المنتظم يبدو ضئيلًا في ظل سيناريوهات التعرض الغذائي الحالية.

1. Introduction

Rice is a staple food consumed by the population of Iraq and many other countries worldwide. In Iraq, rice is a key component of the daily diet, especially among. Families who rely on it as a primary source of carbohydrates and energy. Among the types of rice available in the Iraqi market, imported rice, particularly Indian rice, occupies a significant share due to its widespread availability, reasonable prices, and consumer preference (Bhuiyan et al., 2024; Khan et al., 2015). Its long grains, texture, and cooking properties have made it a staple in Iraqi kitchens. However, despite its nutritional and cultural importance, concern is growing about the potential health risks associated with consuming rice that may be contaminated with toxic substances, particularly heavy metals. Heavy metals are naturally occurring elements with high atomic weights and densities. While the body requires some in small quantities for biological functions, others pose significant health risks when consumed in high concentrations (Aggarwal et al., 2022; Tona et al., 2013). Heavy metal contamination of rice can occur at various stages of production and supply, including absorption from contaminated agricultural soil, the use of contaminated irrigation water, and even environmental pollution resulting from industrial activities in the country of origin (Aggarwal et al., 2022; Alkufi et al., 2024). In addition, heavy metals may accumulate during post-harvest processes, such as processing, packaging, and storage. These factors raise concerns about the long-term safety of rice consumption, especially if it is a major part of the daily diet (Almutairi et al., 2021). Among the most common and dangerous heavy metals found in foods are lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg). These elements are known for their toxicity, environmental persistence, and bioaccumulation ability in living tissues. Chronic exposure to these metals, even at low concentrations, has been associated with a wide range of serious health problems. For example, lead is a neurotoxicant that can negatively impact cognitive development and mental function, especially in children (Djahed et al., 2018). Cadmium is classified as a carcinogen, primarily affecting kidney and bone function. Arsenic, especially in its inorganic form, is one of the most dangerous pollutants, linked to skin lesions, heart disease, and various types of cancer. Mercury can cause neurological and developmental damage, especially in fetuses and young children (Benford et al., 2025; Djahed et al., 2018). Another health risk of concern is the potential association of exposure to certain heavy metals with bilirubin metabolism disorders. Bilirubin is a yellow pigment formed when red blood cells break down, and elevated levels of it in the blood (known as jaundice or hyper bilirubinemia) may indicate liver dysfunction or other metabolic disorders (Fu et al., 2008). Some studies suggest that long-term exposure to metals such as cadmium and arsenic may affect liver enzyme activity, contributing to these disorders. Although the direct relationship between heavy metal consumption through rice and the occurrence of these disorders still needs further research, this possibility adds another dimension to the importance of food safety (Hu et al., 2023). To assess the potential health risks associated with rice contamination, the estimated daily intake (EDI) for these metals must be calculated based on the average amount of rice consumed and its metal concentration. This intake is then compared to health guidelines, such as the recommended daily or weekly intake, as determined by international bodies, such as the World Health Organization, the Food and Agriculture Organization, and the Codex Alimentarius. Exceeding these limits is a potential public health risk (Meng et al., 2022; Mohammadi et al., 2019). Since Iraq relies heavily on imported rice, particularly from countries such as India, it is essential to monitor the quality of these products periodically. Although many countries adopt strict standards for permissible limits for heavy metals in food, differences in agricultural practices, environmental regulations, and control capabilities can lead to variations in contamination levels (Jemii and Alharbi, 2018; Uwatse et al., 2015). Therefore, the present work aims to measure six heavy metals (As, Cr, Se, Ni, Pb, and Cd) using the (AAS) technique in some Indian rice samples consumed in Iraq. The present study also calculated non-carcinogenic and carcinogenic risks associated with consuming heavy metals in rice (Dey et al., 2024; Gao et al., 2022). this current study aims to assess the concentrations of six heavy metals, lead (Pb), cadmium (Cd), chromium (Cr), Nickel (Ni), Arsenic (As), and Selenium (Se), in samples of Indian basmati rice available in Karbala markets, Iraq. The concentrations of (As, Cr, Se, Ni, Pb, and Cd) were measured using atomic absorption spectroscopy (AAS), to evaluate the potential human health risks associated with the consumption of this rice, several health risk assessment parameters were calculated, including the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and Cancer risk (CR).

2. Materials and Methods

2.1. Sample Collection

Ten different samples of Indian rice were collected from various existing sources in the different markets of Karbala Governorate / Iraq. The samples were then prepared to examine the concentrations of heavy metals within them at the University of Karbala in a laboratory, Faculty of Medicine, Chemistry, Branch. Table1 represents the name of the rice samples used, the symbol for each sample, and the origin of each sample.

Table1: Information of Rice Samples in The Present Study

No.	Sample name	Sample code	Origin
1	Shahrazad	R1	India
2	Abo Ali	R2	India
3	Almass	R3	India
4	Lango	R4	India
5	Aldaraj	R5	India
6	Binjaby	R6	India
7	Alwalima	R7	India
8	Aleayila	R8	India
9	Mamlaka	R9	India
10	Karbala	R10	India

2.2. Samples Digestion

In this work, samples were digested by taking 5 grams of basmati rice for each type present and grinding each sample separately using an electric grinder. It was weighed using a microbalance and added to 5 mL of ionized water. It was mixed well using a vortex device, then 1 ml of the solution was taken, and 1 ml of chemical digestion solution was added to the rice solution and left for 24 hours in a special tube at 50 OC. Then the solution was shaken well through the vortex device again for 60 seconds. Then the solution was filtered through a filter with a diameter of (45%) microns, then put an amount of (20) microns using a pipette, then take the filtered solution and placed in an atomic absorption spectrometer, through which the concentration of the following heavy elements (As, Cr, Se, Ni, Pb, and Cd) was measured for each type of rice solution.

2.3. Analysis of The Heavy Metals

Instrumental analysis of As, Cr, Se, Ni, Pb, and Cd was conducted by an air-acetylene flame atomic absorption Spectrophotometer (Shimadzu model AA-6300). The wavelengths in nm for As, Cr, Se, Ni, Pb, and Cd were 193.7, 357.9, 196.03, 232.0, 217.00, and 228.80, respectively.

2.4. Health Risk Assessment

The Estimation daily intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI) of heavy metals were calculated to appreciate the non-carcinogenic risks associated with the consumption of heavy metals in rice, according to Eqs. (1-3) (Aris et al., 2020; Mao et al., 2022).

$$1.\quad EDI\ (\mu g/kg\ per\ day) = \frac{C(\frac{\mu g}{kg}) \times D(\frac{kg}{day})}{BW(kg)}$$

$$2.\quad THQ = \frac{EDI\ (\frac{\mu g}{kg}\ per\ day)}{RfD(\frac{\mu g}{kg}\ per\ day)}$$

$$3.\quad HI = THQ_1 + THQ_2 + \cdots + THQ_n = \sum_1^n THQ_n$$

Where, C is the concentration of heavy metals in Rice (µg/kg), D is the daily rice consumption for each kg, BW is the average body weight, and RfD is the oral reference dose in µg/kg per day. The value of D was 109.5 kg/year (Mohammadi et al., 2024). Moreover, the values of RfD for each heavy metal were As = 0.0003, Pb 0.0001, Cd = 0.001, Ni = 0.02, Cr = 0.003, and Se = 0.005. To appreciate the carcinogenic risks associated with the consumption of heavy metals in rice, the Cancer risk (CR) over time of heavy metals was calculated using Eq. (4) (Mohammadi et al., 2024; Naseri et al., 2015).

$$4.\quad R = EDI\left(\frac{\mu g}{kg}\ per\ day\right) \times CSF\ (\frac{\mu g}{kg} per\ day)^{-1}$$

Where, CSF is the cancer slope factor. As and Cd had oral cancer slope factors of 8.21×10-4 and 5.70×103, respectively (Rizzello, E.2021) . The cumulative cancer risk, from exposure to numerous carcinogenic heavy metals through rice consumption, was considered the total of the individual heavy metal incremental hazards (Total CR) and calculated using Eq. (5) (Mao et al., 2022).

$$5.\quad Total\ cancer\ risks = CR_1 + CR_2 + \cdots + CR_n = \sum_1^n CR_n \qquad (5)$$

6.

3. Results and Discussion

Table2 shows the results of six heavy metals: arsenic (As), chromium (Cr), selenium (Se), nickel (Ni), lead (Pb), and cadmium (Cd), measured in ten samples of Indian rice of a sample of rice from R1 to R10. All concentrations are reported in micrograms per kilogram (µg/kg), equivalent to parts per billion (ppb) of the present study. Table 2 shows the values of concentrations for As, Cr, Se, Ni, Pb, and Cd in all samples in the present study, and includes basic descriptive statistics: average (Avr.), minimum (Min.), and maximum (Max.) values for each metal. Chromium (Cr) recorded the highest average concentration among all measured elements, with a mean of 326.06µg/kg, ranging from 232.5µg/kg to 380.6µg/kg. This indicates significant variation and possible local enrichment of chromium (Nurvan et al., 2023). Similarly, Nickel (Ni) and Lead (Pb) showed relatively elevated concentrations, with an average of 179.39 µg/kg and 164.42 µg/kg, respectively. Arsenic (Ar) was present at a moderate level, with an average of 94.77µg/kg, while Cadmium (Cd) was 156.9µg/kg and Selenium (Se) exhibited lower average concentrations of 132.58µg/kg. Arsenic recorded the lowest observed concentration (86.6 µg/kg in R6), suggesting limited distribution in some sites (Abtahi et al., 2017; Fakhri et al., 2018; Sharafati Chaleshtori et al., 2017). The maximum values were 99.8 µg/kg, 380.6 µg/kg,148.8 µg/kg,184.5 µg/kg, 188.8 µg/kg, and 170µg/kg, respectively. Moreover, according to (Sharafi et al., 2019), the global average for the heavy metals As, Cr, Se, Ni, Pb, and Cd in unit's ppb in food is 200, 300-500, 300, 100-300, 200, and 150, respectively. So, it was noticed that. The results in Table 2 for the As, Cr, Se, Ni, Pb, and Cd concentrations for all samples were within the global average, while the results of Pb and Cd concentrations for most samples were high. The lead and Cd concentration increases in the rice samples under study can be attributed to lead absorption from the soil and the corresponding fertilizers.

Table2: Results of Heavy Metals Concentration in Rice Samples

N	**Sample code**	**Concentrations of heavy metals (ppb or µg/kg)**					
		As	**Cr**	**Se**	**Ni**	**Pb**	**Cd**
1	R1	93.5	232.5	132.6	184.5	141.3	138
2	R2	86.6	325.2	137.3	181.5	158.2	159
3	R3	92.8	341.6	130.7	180.3	170.1	165
4	R4	96.5	359.7	148.8	176.6	165.8	152
5	R5	87.3	374.1	137.3	182.6	150.4	149
6	R6	99.8	328.3	117.1	162.6	160.3	157
7	R7	98.5	380.6	129.7	182	188.8	170
8	R8	94.8	268.5	122.5	179.4	185.8	158
9	R9	98.5	292.5	133.7	182.1	161	160
10	R10	99.4	357.6	136.1	182.3	162.5	161
Average		94.77	326.06	132.58	179.39	164.42	156.90
Mini. Value		86.6	232.5	117.1	162.6	141.3	138
Max. value		99.8	380.6	148.8	184.5	188.8	170
Safe limit (Tsukahara et al., 2003)		200	300-500	300	100-300	200	150

Fig.1 illustrates the average concentrations of heavy metals (As, Cr, Se, Ni, Pb, Cd) compared to their respective safe limits. The concentration of cadmium (Cd) exceeds the safe limit, indicating a potential source of contamination that warrants further investigation. In contrast, the concentration of lead (Pb) is close to the permissible threshold, suggesting the need for ongoing monitoring. The remaining elements, arsenic (As), chromium (Cr), selenium (Se), and nickel (Ni), all exhibit concentrations below their respective safe limits, reflecting relatively safe levels in the studied samples.

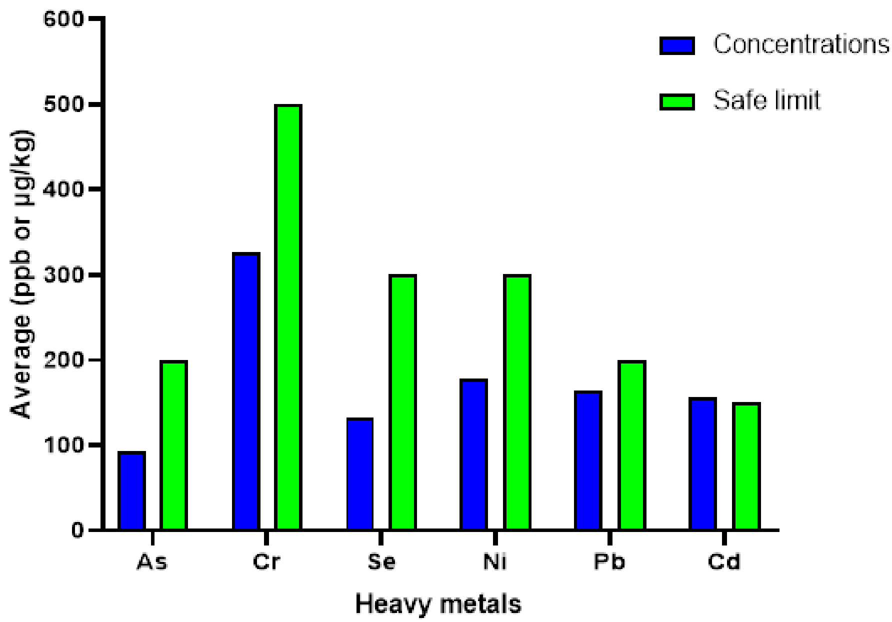

Figure1: Concentrations for Heavy Metals and Safe Limit

3.1. Estimated Daily Intake (EDI) And Health Implications

The estimated daily intake (EDI) of six heavy metals in Table 3, arsenic (As), chromium (Cr), selenium (Se), nickel (Ni), lead (Pb), and cadmium (Cd), was assessed in ten Indian basmati rice samples collected from. Karbala markets. The results were compared with internationally established safety thresholds to evaluate potential health risks associated with long-term dietary exposure. The average EDI for arsenic (As) was 0.406 µg/kg per day, exceeding the tolerable limit of 0.3 µg/kg per day. This suggests a potential health hazard, particularly due to arsenic's recognized carcinogenic properties and cumulative toxicity in humans. Chromium (Cr) exhibited an average intake of 1.398 µg/kg per day, which remains below the recommended safety limit of 3.0 µg/kg per day. However, the lack of chromium speciation (Cr(III) vs Cr(VI)) limits the precision of the health risk assessment, as Cr(VI) is significantly more toxic than Cr(III) (U.S. EPA 2021). Selenium (Se) had an average intake of 0.568 µg/kg per day, well below the acceptable limit of 5.0 µg/kg per day, indicating no health concern. These results also suggest that rice is not a primary dietary source of selenium in the studied samples. Nickel (Ni) showed an average EDI of 0.769 µg/kg per day, which is considerably below the threshold of 13 µg/kg per day, confirming a negligible risk of toxicity from rice consumption. In contrast, lead (Pb) demonstrated a concerning average EDI of 0.696 µg/kg per day, which surpasses the reference level of 0.5 µg/kg per day. Given the well-established neurotoxicity of lead, particularly in children and pregnant women, this finding underscores the importance of controlling Pb contamination in food products. Cadmium (Cd) had an average daily intake of 0.672 µg/kg per day, remaining within the provisional safe limit of 0.8 µg/kg per day. However, the proximity to the upper threshold indicates a need for continued surveillance to prevent potential long-term exposure risks (U.S. EPA 2014).

Table3: Results of Estimation. Daily Intake Indian Rice Samples

N	Sample	Estimation daily intake (µg/kg per day)					
		As	Cr	Se	Ni	Pb	Cd
1	R1	0.401	1.0	0.569	0.792	0.605	0.591
2	R2	0.371	1.39	0.588	0.778	0.677	0.681
3	R3	0.398	1.47	0.561	0.774	0.728	0.709
4	R4	0.414	1.54	0.639	0.758	0.71	0.652
5	R5	0.374	1.6	0.588	0.783	0.644	0.638
6	R6	0.427	1.41	0.502	0.697	0.689	0.672
7	R7	0.422	1.64	0.556	0.78	0.722	0.729
8	R8	0.406	1.15	0.525	0.77	0.798	0.676
9	R9	0.422	1.25	0.573	0.781	0.692	0.686
10	R10	0.426	1.53	0.584	0.781	0.696	0.692
Average		0.406	1.398	0.568	0.769	0.696	0.672
Safe limit (Administration, 2022)		0.3	3.0	5.0	13	0.5	0.8

Overall, the EDI values for most metals fall within internationally acceptable ranges, except arsenic and lead, which exceeded or approached their respective limits. Fig.2 shows that arsenic (As) and lead (Pb) exceeded the safe daily intake limit, indicating a potential health risk from chronic exposure. In contrast, the other elements (Cr, Se, Ni, Cd) were within safe limits. These findings highlight the necessity of implementing routine monitoring and stricter import regulations to minimize potential health risks associated with chronic exposure to toxic elements through dietary intake.

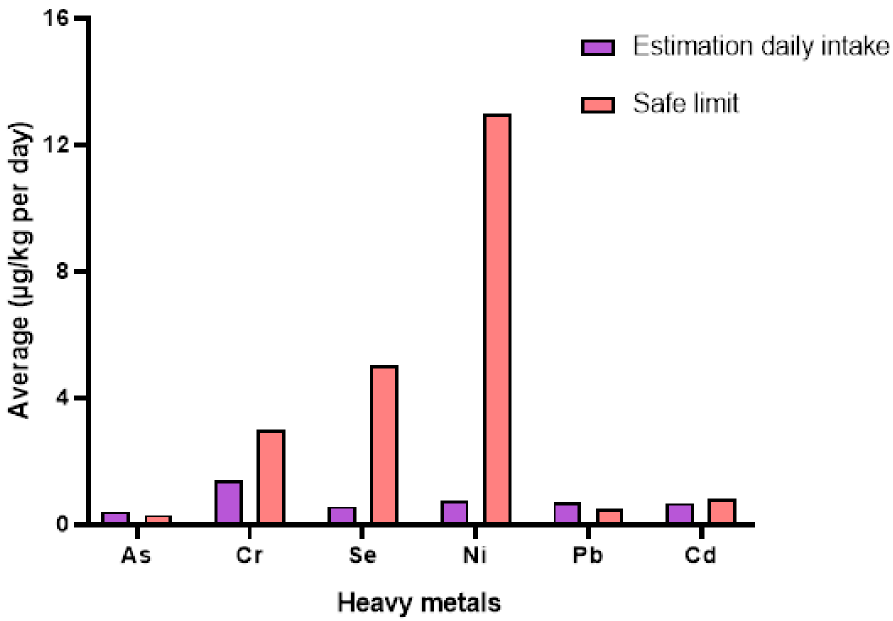

Figure2: Estimation Daily Intake for Heavy Metals and Safe Limit

3.2. Non-Carcinogenic Health Risk Assessment

To evaluate, the potential non-carcinogenic health risks associated with the consumption of Indian basmati, rice in Table 4, the Target Hazard Quotient (THQ) for six heavy metals (As, Cr, Se, Ni, Pb, Cd) and the overall Hazard Index (HI) were calculated for ten rice, samples collected from the Karbala market. The THQ values for arsenic (As) across all samples ranged from 1.23 to 1.42, with an average of 1.30, clearly exceeding the safe threshold of 1.0. This indicates a potential non-carcinogenic health risk due to chronic exposure to arsenic through rice consumption. Given arsenic's known systemic toxicity, particularly its association with skin lesions, cardiovascular diseases, and developmental effects, this finding warrants particular concern. Chromium (Cr) showed THQ values between 0.33 and 0.54, with an average of 0.40, which is within the acceptable limit of 1.0. This suggests that chromium does not pose a significant non-carcinogenic risk based on current exposure levels. The THQ values for selenium (Se) ranged from 0.100 to 0.27, with a. mean value of 0.113. These values are well below the safe limit of 1.0, indicating that selenium intake via rice consumption is not associated with adverse effects in the studied population. Nickel (Ni) presented THQ values between 0.053 and 0.060, averaging 0.059, also far below the hazard threshold of 1.0. Therefore, nickel exposure through rice consumption appears to be negligible in terms of non-carcinogenic risk. Lead (Pb) recorded relatively high THQ values, ranging from 1.211 to 1.618, with a mean of 1.409, exceeding the reference value of 1.0 in all samples. This result indicates a potentially significant health concern, mainly due to the neurotoxic and hematologic effects of lead, particularly among children and vulnerable populations. Cadmium (Cd) THQ values ranged from 0.739 to 0.910, averaging 0.840. Although these values are below the hazard threshold of 1.0, they approach it closely, suggesting a moderate risk that merits attention in the context of cumulative dietary exposure. The Hazard Index (HI), representing the cumulative risk from all six metals, ranged from 3.792 to 4.651, averaging 4.242. Since the HI exceeds the safe limit of 1.0 in all samples, this indicates a significant cumulative non-carcinogenic health risk for consumers regularly ingesting Indian basmati rice from the tested market. These findings highlight arsenic and lead as the primary contributors to non-carcinogenic risk, with cadmium also representing a moderate concern. The consistently elevated HI values underscore the urgent need for regulatory interventions, continuous monitoring, and source quality verification to minimize long-term health risks associated with rice consumption in the region.

Table4: Results of Target Hazard. Quotient and Hazard Index in Indian Rice Samples

N	Sample code	Target Hazard Quotient						Hazard Index
		As	Cr	Se	Ni	Pb	Cd	
1	R1	1.33	0.33	0.113	0.060	1.211	0.739	3.792
2	R2	1.23	0.46	0.117	0.059	1.356	0.851	4.087
3	R3	1.32	0.48	0.112	0.059	1.458	0.883	4.327
4	R4	1.37	0.51	0.127	0.058	1.421	0.814	4.313
5	R5	1.24	0.53	0.117	0.060	1.289	0.798	4.046
6	R6	1.42	0.46	0.100	0.053	1.374	0.841	4.263
7	R7	1.40	0.54	0.111	0.060	1.618	0.910	4.651
8	R8	1.35	0.38	0.105	0.059	1.592	0.846	4.341
9	R9	1.40	0.41	0.114	0.060	1.380	0.857	4.236
10	R10	1.42	0.51	0.116	0.060	1.392	0.862	4.363
Average		1.30	0.40	0.113	0.059	1.409	0.840	4.242
Safe limit (Zakaria et al., 2021)		1.0	1.0	1.0	1.0	1.0	1.0	1.0

Fig.3 shows that arsenic (As) and cadmium (Cd) recorded Target Hazard Quotient (THQ) values exceeding the safe limit, indicating potential chronic health risks. In contrast, chromium (Cr), selenium (Se), nickel (Ni), and lead (Pb) remained within or below the globally accepted safe limit, suggesting relatively lower health risks.

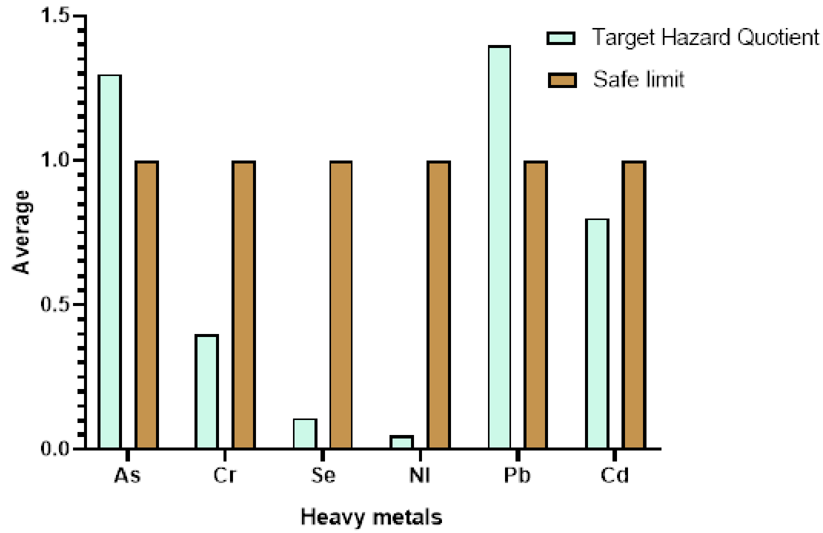

Figure3: Target Hazard Quotient for Heavy Metals and Safe Limit

Fig.4 shows that the average Hazard Index (HI) for Indian Basmati rice samples reached 4.3, exceeding the globally accepted safe limit of 1.0. This indicates potential cumulative health risks associated with the consumption of these samples.

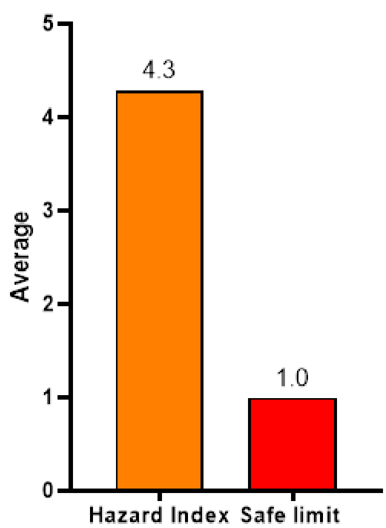

Figure4: Average for Hazard Index and Safe Limit

3.3. Carcinogenic Risk Assessment

Table5 presents the estimated carcinogenic risk values for five heavy metals—arsenic (As), chromium (Cr), nickel (Ni), lead (Pb), and cadmium (Cd)—in Indian rice samples collected from the Karbala market. The cumulative cancer risk. (Total CR) for each sample was also calculated to evaluate the overall carcinogenic potential associated with rice consumption. The average cancer risk (CR) values for individual metals across the ten samples were as: Arsenic (As): 8.21×10^{-4}, Chromium (Cr): 8.71×10^{-4}, Nickel (Ni): 9.40×10^{-4}, Lead (Pb): 8.05×10^{-6}, and Cadmium (Cd): 5.70×10^{-3}. The total cancer risk (Total CR) for the rice samples ranged from 7.40×10^{-3} to 9.01×10^{-3}, with an average of 8.29×10^{-3}, which significantly exceeds the acceptable risk limit of 1.0×10^{-4} recommended by the U.S. Environmental Protection Agency (EPA). According to EPA guidelines, cancer risks in the range of 10^{-6} to 10^{-4} are generally considered acceptable; values above this range indicate potential carcinogenic concern (Zhao et al., 2023, 2022). Among the assessed metals, cadmium contributed the most to the total cancer risk, followed by nickel, chromium, and arsenic. Although lead showed the lowest cancer risk value, its presence remains notable, especially due to its cumulative toxicological effects over time. The elevated Total CR values suggest that long-term dietary exposure to Indian rice contaminated with these metals may pose a considerable carcinogenic risk to consumers. These findings underscore the critical need for rigorous monitoring of heavy metals in imported rice and stricter regulatory enforcement to safeguard public health. The carcinogenic risk assessment highlights cadmium and nickel as the primary contributors to potential cancer development associated with rice consumption. The consistently high Total CR values across all samples indicate an urgent need for intervention and public awareness to minimize dietary exposure to these toxic elements (Zhao et al., 2022).

Table5: Results of Cancer Risk and Total Cancer Risk In Indian Rice Samples

N	**Sample**	**Cancer risk**					**Total CR**
		As	**Cr**	**Ni**	**Pb**	**Cd**	
1	R1	$8.01\times^{-04}$	$6.64\times^{-04}$	$9.59\times^{-04}$	$6.86\times^{-06}$	$4.97\times^{-03}$	$7.40\times^{-03}$
2	R2	$7.42\times^{-04}$	$9.29\times^{-04}$	$9.44\times^{-04}$	$7.68\times^{-06}$	$5.72\times^{-03}$	$8.35\times^{-03}$
3	R3	$7.95\times^{-04}$	$9.76\times^{-04}$	$9.38\times^{-04}$	$8.26\times^{-06}$	$5.94\times^{-03}$	$8.66\times^{-03}$
4	R4	$8.27\times^{-04}$	$1.03\times^{-03}$	$9.18\times^{-04}$	$8.05\times^{-06}$	$5.47\times^{-03}$	$8.25\times^{-03}$
5	R5	$7.48\times^{-04}$	$1.07\times^{-03}$	$9.50\times^{-04}$	$7.31\times^{-06}$	$5.36\times^{-03}$	$8.14\times^{-03}$
6	R6	$8.55\times^{-04}$	$9.38\times^{-04}$	$8.46\times^{-04}$	$7.79\times^{-06}$	$5.65\times^{-03}$	$8.30\times^{-03}$
7	R7	$8.44\times^{-04}$	$1.09\times^{-03}$	$9.46\times^{-04}$	$9.17\times^{-06}$	$6.12\times^{-03}$	$9.01\times^{-03}$
8	R8	$8.13\times^{-04}$	$7.67\times^{-04}$	$9.33\times^{-04}$	$9.02\times^{-06}$	$5.69\times^{-03}$	$8.21\times^{-03}$
9	R9	$8.44\times^{-04}$	$8.36\times^{-04}$	$9.47\times^{-04}$	$7.82\times^{-06}$	$5.76\times^{-03}$	$8.39\times^{-03}$
10	R10	$8.52\times^{-04}$	$1.02\times^{-03}$	$9.48\times^{-04}$	$7.89\times^{-06}$	$5.80\times^{-03}$	$8.63\times^{-03}$
Average		$8.21\times^{-04}$	$8.71\times^{-04}$	$9.40\times^{-04}$	$8.05\times^{-06}$	$5.70\times^{-03}$	$8.29\times^{-03}$
Safe limit (Administration, 2022)		1.0	1.0	1.0	1.0	1.0	10^{-4}-10^{-6}

Fig.5 illustrates the calculated average of the total cancer risk, which reached 8.29×10^{-3}. This value is significantly higher than the internationally accepted safe limit of 1.00×10^{-4}, indicating an elevated health risk associated with exposure to the studied rice samples. This necessitates further monitoring and assessment measures to reduce exposure and minimize potential adverse health effects.

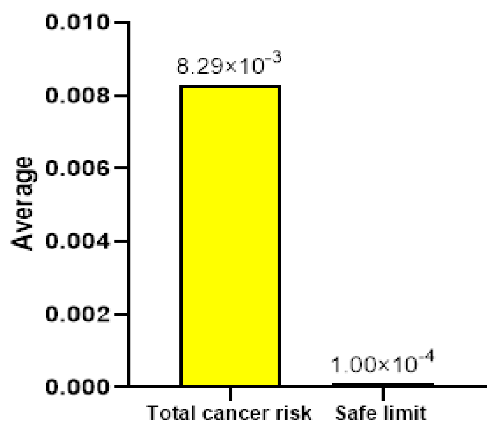

Figure5: Average for Total Cancer Risk and Safe Limit

Fig.6 presents the box plot for the concentrations of the studied heavy metals. Chromium (Cr) exhibited the highest concentration range compared to the other elements, with significant dispersion and the presence of outliers, indicating considerable variability in its levels. In contrast, other elements such as As, Se, Ni, Pb, and Cd showed lower concentrations with relatively narrower ranges, reflecting a more stable distribution in the analyzed samples.

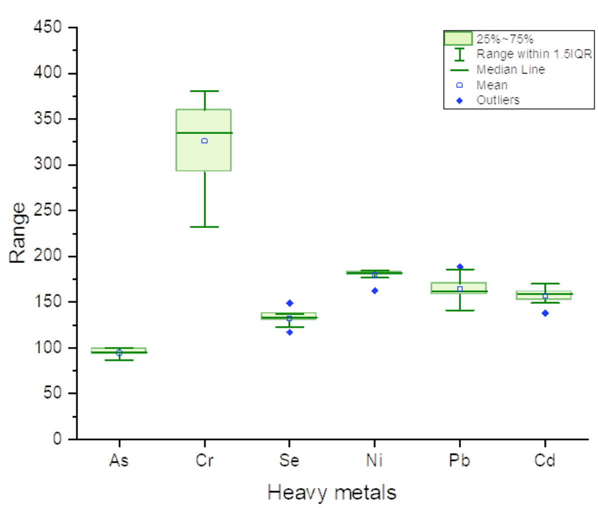

Figure6: Box Plot for Heavy Metals

Fig.7, consisting of six histograms, illustrate the distribution of the studied heavy metal concentrations (As, Cr, Se, Ni, Pb, Cd). Arsenic (As) and Chromium (Cr) showed wide distributions with deviations from the normal distribution and relatively high concentrations. In contrast, Selenium (Se), Nickel (Ni), Lead (Pb), and Cadmium (Cd) exhibited distributions closer to normal with less variation in concentrations, indicating a relatively stable level of these metals compared to As and Cr. This may reflect differences in pollution sources or the environmental accumulation behavior of each metal in the studied rice samples. Table6 demonstrates varying strengths and directions of correlation among the concentrations of the studied heavy metals. A moderate and statistically significant positive correlation was observed between lead (Pb) and cadmium (Cd) ($r = 0.774$, $p = 0.009$), suggesting a potential common source of contamination for these two elements. In contrast, the remaining correlations among the metals were weak and statistically insignificant ($p > 0.05$), such as the correlation between arsenic (As) and chromium (Cr) ($r = 0.014$), and the negative correlation between arsenic and nickel (Ni) ($r = -0.391$). These findings indicate the absence of a consistent pattern of association among most of the metals, which may reflect differences in contamination sources or the geochemical behavior of each element in the local environment. Correlation is significant at the 0.01 level (2-tailed).

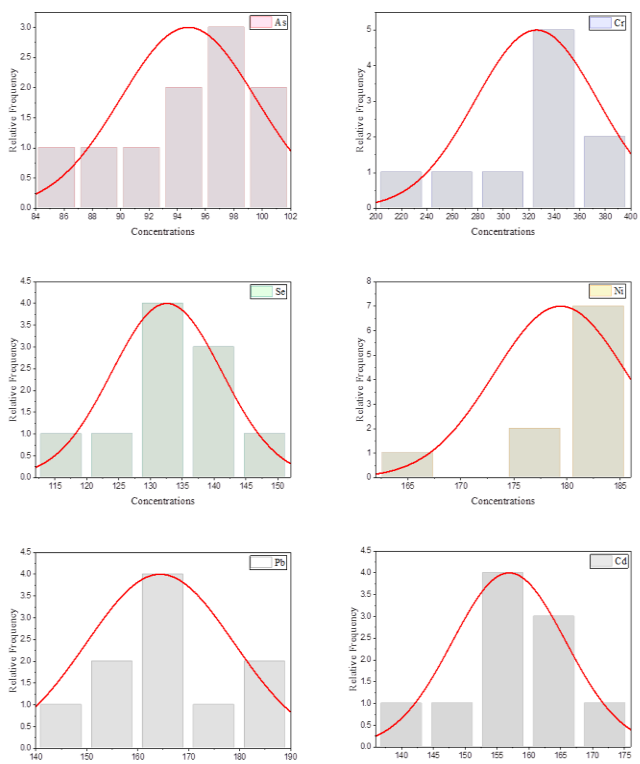

Figure7: Histogram for Heavy Metals. Histograms showing the frequency distribution of **arsenic (As), chromium (Cr), selenium (Se), nickel (Ni), lead (Pb), and cadmium (Cd)** concentrations in the analyzed samples. The red curves represent the **fitted normal (Gaussian) distribution**, illustrating the overall trend and variability of each metal concentration. The x-axis indicates concentration levels, while the y-axis represents frequency.

Table6: Correlation Between Heavy Metals

Variables		As	Cr	Se	Ni	Pb	Cd
As	**Pearson Correlation**	1	0.014	-0.297	-0.391	.0362	0.317
	Sig. (2-tailed)		0.970	0.405	0.264	0.304	0.372
Cr	**Pearson Correlation**	0.014	1	0.320	-0.111	0.283	0.525
	Sig. (2-tailed)	0.970		0.368	0.761	0.429	0.119
Se	**Pearson Correlation**	-0.297	0.320	1	0.499	-0.281	-0.223
	Sig. (2-tailed)	0.405	0.368		0.142	0.432	0.535
Ni	**Pearson Correlation**	-0.391	-0.111-	0.499	1	-0.069	-0.087
	Sig. (2-tailed)	0.264	0.761	0.142		0.849	0.812
Pb	**Pearson Correlation**	0.362	0.283	-0.281	-.0069	1	0.774**
	Sig. (2-tailed)	0.304	0.429	0.432	0.849		0.009
Cd	**Pearson Correlation**	0.317	0.525	-0.223	-0.087	0.774**	1
	Sig. (2-tailed)	0.372	0.119	0.535	0.812	0.009	

4. Conclusion

This study comprehensively assessed the concentrations of selected heavy metals, arsenic (As), chromium (Cr), selenium (Se), nickel (Ni), lead (Pb), and cadmium (Cd) in Indian rice samples collected from the Karbala market in Iraq. The analytical results revealed that while most heavy metal concentrations were within, or near, internationally accepted safety limits, certain metals, particularly lead and cadmium, approached or slightly exceeded these thresholds in some samples, raising concerns about potential health risks. The estimated daily intake (EDI) values indicated that exposure to these metals through rice consumption generally remained below the established safe limits, except for arsenic, which neared the upper allowable intake. This suggests that chronic consumption may pose a health concern if not monitored. Health risk assessments, including the Target Hazard Quotient (THQ) and Hazard Index (HI), showed that the cumulative exposure to arsenic, lead, and cadmium could exceed safe levels, indicating possible non-carcinogenic health risks for consumers relying heavily on these rice products. Furthermore, the calculated carcinogenic risk (CR) values revealed that the total cancer risk from heavy metal exposure in the analyzed rice samples surpasses the acceptable limit (1×10^{-4}), with arsenic and cadmium being the predominant contributors. These findings underscore the potential adverse health implications for consumers, particularly with prolonged or high-level consumption of contaminated rice. Consequently, it is imperative to implement strict regulatory controls and continuous monitoring of heavy metal concentrations in foodstuffs to protect public health. In conclusion, this study highlights the urgent need for ongoing surveillance and public awareness regarding heavy metal contamination in staple foods. Future research should focus on these metals' bioavailability and long-term health effects, and expand the scope to include other food items and wider geographic regions to ensure comprehensive risk assessment in Iraq.

References

Abtahi, M., Fakhri, Y., Oliveri Conti, G., Keramati, H., Zandsalimi, Y., Bahmani, Z., Hosseini Pouya, R., Sarkhosh, M., Moradi, B., Amanidaz, N., Ghasemi, S.M., 2017. Heavy metals (As, Cr, Pb, Cd and Ni) concentrations in rice (Oryza sativa) from Iran and associated risk assessment: a systematic review. Toxin Rev. https://doi.org/10.1080/15569543.2017.1354307

Administration, U.S.F. and D., 2022. FDA's Testing of Cosmetics for Arsenic, Cadmium, Chromium, Cobalt, Lead, Mercury, and Nickel Content Limiting Lead in Lipstick and Other Cosmetics [WWW Document]. United States Food and Drug Administration.

Aggarwal, A., Verma, T., Ghosh, S., 2022. Heavy Metal Residues in Milk and Milk Products and Their Detection Method, in: Trends and Innovations in Food Science. https://doi.org/10.5772/intechopen.105004

Alkufi, A.A., Oleiwi, M.H., Abojassim, A.A., 2024. Comparison of Heavy Metals in Urine Samples of Smoker and Non-smoker Persons. Biol Trace Elem Res 202. https://doi.org/10.1007/s12011-024-04097-5

Almutairi, M., Alsaleem, T., Jeperel, H., Alsamti, M., Alowaifeer, A.M., 2021. Determination of inorganic arsenic, heavy metals, pesticides and mycotoxins in Indian rice (Oryza sativa) and a probabilistic dietary risk assessment for the population of Saudi Arabia. Regulatory Toxicology and Pharmacology 125. https://doi.org/10.1016/j.yrtph.2021.104986

Aris, M., Ibrahim, T.A., Nasir, L., 2020. Kontaminasi logam nikel (Ni) pada struktur jaringan ikan. e-Journal BUDIDAYA PERAIRAN 9. https://doi.org/10.35800/bdp.9.1.2021.31566

Benford, D., Boobis, A., Cantrill, R., Cressey, P., Dessipri, E., Kabadi, S. V., Jeurissen, S., Mueller, U., Barlow, S., 2025. Contributions of the joint FAO/WHO expert committee on food additives to international food safety: celebrating the 100th meeting of the committee. Regulatory Toxicology and Pharmacology. https://doi.org/10.1016/j.yrtph.2025.105833

Bhuiyan, Mst.D.A., Hossain, Md.A., Mostafa, S.M., Biswas, A., Samiullah, M., Mehnaz, G., Ahmad, F., Saeed, A., Ahmed, A., Zulfiqar, R., 2024. The QUANTITATIVE ANALYSIS OF HAZARDS OF HEAVY METALS ON HUMAN HEALTH AND AGRICULTURAL PRODUCTION. Journal of Population Therapeutics and Clinical Pharmacology. https://doi.org/10.53555/jptcp.v31i2.4543

Dey, A., Lama, U., Ghosh, S., Das, D., Majumder, S., Roychowdhury, T., 2024. Cadmium Toxicity in Rice and Wheat Plants: An Apprehension of Translocation and Tolerance Mechanisms, in: Environmental Science and Engineering. https://doi.org/10.1007/978-3-031-73266-9_11

Djahed, B., Taghavi, M., Farzadkia, M., Norzaee, S., Miri, M., 2018. Stochastic exposure and health risk assessment of rice contamination to the heavy metals in the market of Iranshahr, Iran. Food and Chemical Toxicology 115. https://doi.org/10.1016/j.fct.2018.03.040

Fakhri, Y., Bjørklund, G., Bandpei, A.M., Chirumbolo, S., Keramati, H., Hosseini Pouya, R., Asadi, A., Amanidaz, N., Sarafraz, M., Sheikhmohammad, A., Alipour, M., Baninameh, Z., Mohseni, S.M., Sarkhosh, M., Ghasemi, S.M., 2018. Concentrations of arsenic and lead in rice (Oryza sativa L.) in Iran: A systematic review and carcinogenic risk assessment. Food and Chemical Toxicology 113. https://doi.org/10.1016/j.fct.2018.01.018

Fu, J., Zhou, Q., Liu, J., Liu, W., Wang, T., Zhang, Q., Jiang, G., 2008. High levels of heavy metals in rice (Oryza sativa L.) from a typical E-waste recycling area in southeast China and its potential risk to human health. Chemosphere 71. https://doi.org/10.1016/j.chemosphere.2007.11.065

Gao, Y., Duan, Z., Zhang, L., Sun, D., Li, X., 2022. The Status and Research Progress of Cadmium Pollution in Rice- (Oryza sativa L.) and Wheat- (Triticum aestivum L.) Cropping Systems in China: A Critical Review. Toxics. https://doi.org/10.3390/toxics10120794

Hu, J., Tao, R., Cao, C., Xie, J., Gao, Y., Hu, H., Ma, Z., Ma, Y., 2023. Effect of Leaf Surface Regulation of Zinc Fertilizer on Absorption of Cadmium, Plumbum and Zinc in Rice (Oryza sativa L.). Sustainability (Switzerland) 15. https://doi.org/10.3390/su15031877

Jemii, E., Alharbi, T., 2018. Measurements of natural radioactivity in infant formula and radiological risk assessment. J Radioanal Nucl Chem 315. https://doi.org/10.1007/s10967-017-5646-7

Khan, A., Khan, S., Khan, M.A., Qamar, Z., Waqas, M., 2015. The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. Environmental Science and Pollution Research 22. https://doi.org/10.1007/s11356-015-4881-0

Mao, Y., Tan, H., Wang, M., Jiang, T., Wei, H., Xu, W., Jiang, Q., Bao, H., Ding, Y., Wang, F., Zhu, C., 2022. Research Progress of Soil Microorganisms in Response to Heavy Metals in Rice. J Agric Food Chem. https://doi.org/10.1021/acs.jafc.2c01437

Meng, C., Wang, P., Hao, Z., Gao, Z., Li, Qiang, Gao, H., Liu, Y., Li, Qingzhao, Wang, Q., Feng, F., 2022. Ecological and health risk assessment of heavy metals in soil and Chinese herbal medicines. Environ Geochem Health 44. https://doi.org/10.1007/s10653-021-00978-z

Mohammadi, A.A., Zarei, A., Majidi, S., Ghaderpoury, A., Hashempour, Y., Saghi, M.H., Alinejad, A., Yousefi, M., Hosseingholizadeh, N., Ghaderpoori, M., 2019. Carcinogenic and non-carcinogenic health risk assessment of heavy metals in drinking water of Khorramabad, Iran. MethodsX 6. https://doi.org/10.1016/j.mex.2019.07.017

Mohammadi, M.J., Kiani, F., Farhadi, M., Ghanbari, S., Jalili, D., Mirzaei, L., 2024. Evaluation of carcinogenic risk of heavy metals due to consumption of rice in Southwestern Iran. Toxicol Rep 12. https://doi.org/10.1016/j.toxrep.2024.05.005

Naseri, M., Vazirzadeh, A., Kazemi, R., Zaheri, F., 2015. Concentration of some heavy metals in rice types available in Shiraz market and human health risk assessment. Food Chem 175. https://doi.org/10.1016/j.foodchem.2014.11.109

Nurvan, H., Nurvan Ananda Babelan Jl Raya Babelan NoKM, H.R., Babelan, K., Bekasi, K., 2023. Radiology as a support for examination and treatment in the medical world and its effects: literature review. Midwifery.Iocspublisher.Org 11.

Sharafati Chaleshtori, F., Rafieian Kopaei, M., Sharafati Chaleshtori, R., 2017. A review of heavy metals in rice (Oryza sativa) of Iran. Toxin Rev. https://doi.org/10.1080/15569543.2016.1252932

Sharafi, K., Yunesian, M., Nodehi, R.N., Mahvi, A.H., Pirsaheb, M., 2019. A systematic literature review for some toxic metals in widely consumed rice types (domestic and imported) in Iran: Human health risk assessment, uncertainty and sensitivity analysis. Ecotoxicol Environ Saf. https://doi.org/10.1016/j.ecoenv.2019.03.072

Tona, G.O., Adetunji, V.O., Ameen, S.A., Ibikunle, A.O., 2013. Evaluation of lead and cadmium heavy metal residues in milk and milk products sold in Ogbomoso, Southwestern Nigeria. Pakistan Journal of Nutrition 12. https://doi.org/10.3923/pjn.2013.168.171

Tsukahara, T., Ezaki, T., Moriguchi, J., Furuki, K., Shimbo, S., Matsuda-Inoguchi, N., Ikeda, M., 2003. Rice as the most influential source of cadmium intake among general Japanese population. Science of the Total Environment 305. https://doi.org/10.1016/S0048-9697(02)00475-8

Uwatse, O.B., Olatunji, M.A., Khandaker, M.U., Amin, Y.M., Bradley, D.A., Alkhorayef, M., Alzimami, K., 2015. Measurement of natural and artificial radioactivity in infant powdered milk and estimation of the corresponding annual effective dose. Environ Eng Sci 32. https://doi.org/10.1089/ees.2015.0114

Zakaria, Z., Zulkafflee, N.S., Mohd Redzuan, N.A., Selamat, J., Ismail, M.R., Praveena, S.M., Tóth, G., Abdull Razis, A.F., 2021. Understanding potential heavy metal contamination, absorption, translocation and accumulation in rice and human health risks. Plants. https://doi.org/10.3390/plants10061070

Zhao, B., Zhu, W., Hao, S., Hua, M., Liao, Q., Jing, Y., Liu, L., Gu, X., 2023. Prediction heavy metals accumulation risk in rice using machine learning and mapping pollution risk. J Hazard Mater 448. https://doi.org/10.1016/j.jhazmat.2023.130879

Zhao, B., Zhu, W., Hao, S., Hua, M., Liao, Q., Jing, Y., Liu, L., Gu, X., 2022. Prediction Heavy Metal Accumulation Risk in Rice Using Machine Learning and Mapping Pollution Risk. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4292690