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ORIGINAL ARTICLE

Assessment of Heavy Metals in Rice Brands and their Potential Risk on Public Health

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KEYWORDS

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ABSTRACT: The accumulation of heavy metals in crops irrigated with wastewater is a serious environmental problem. Wastewater irrigation is widespread, particularly for rice due to its high water demands. This can lead to heavy metal accumulation in rice and subsequent entry into the human body, posing detrimental health effects. This study investigated heavy metal accumulation in 12 rice brands (6 imported and 6 domestic) from the Bushehr city market in Iran. The mean values of lead, arsenic, and cadmium in domestic rice brands were 0.246±0.194, 0.074±0.025, and 0.150±0.124 mg kg^{-1} respectively, while in imported rice brands they were 0.086±0.031, 0.085±0.021, and 0.031±0.007 mg kg^{-1} respectively. The mean lead and cadmium levels in domestic rice brands slightly exceeded the FAO/WHO limit, while the mean arsenic concentration was below the limit. To protect human health and reduce food contamination with heavy metals, preventive measures such as regular monitoring of heavy metals in food must be taken.

INTRODUCTION

Food security at the personal, domestic, public, regional, and global levels can be achieved when everyone has adequate economic, physical, and safety resources at all times. To create a healthy and dynamic life, the need for nutritious foods is a priority and essential. Regardless of food safety, its qualitative aspects mean that there are no unnecessary elements in the food that endanger human health [1, 2]. Rice contains carbohydrates, Zinc, Copper, Magnesium, vitamin B6, and Thiamine. The share of rice in the production of calories needed by the body on a global scale is 20.50%, in developing countries 29.20%, and in Asia 31.60% [3].

The highest daily uptake of Heavy metals (HMs) is due to eating of grains and vegetables [4]. Crops such as rice, corn, wheat, potatoes, and soy are widely used as

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food. These crops, especially rice, which is a strong absorbent of As (Arsenic) and Cd (Cadmium), are the foundation of mankind's diet in large areas of the world and can be the main source of Heavy metal (HM) contamination in living creatures [5].

Rice is a primary food in large areas of the world, particularly in Asia, where soil and water pollution have been reported in countries including China, India, Iran, Thailand, Bangladesh, and Vietnam with high levels of HMs [6]. Mines, industrial processes, insecticides, chemical manure, and cars exhaust emissions are the major origin of HMs pollution in the environment [7, 8]. The HMs may agglomerate at levels of poisonous concentrations that can impair human quality of life [9, 10]. HMs are not biodegradable. Thus, they remain in ecosystems for a long time. Soils become contaminated with HMs through irrigation, which may be present in harvested crops [11]. Crops in the vicinity of contaminated sites can absorb and agglomerate these metals (Ms) and pose potential hazards to living creatures [12, 13]. In Japan, Itai-itai and Minamata diseases are examples of contamination with HMs [14]. As, Pb (Lead), and Cd have highly toxic effects on humans health and are ranked first, second, and seventh on the U.S. Environmental Protection Agency's list of priority hazardous substances, respectively [15]. Figure 1 shows the adverse effects of exposure to Pb, As, and Cd.

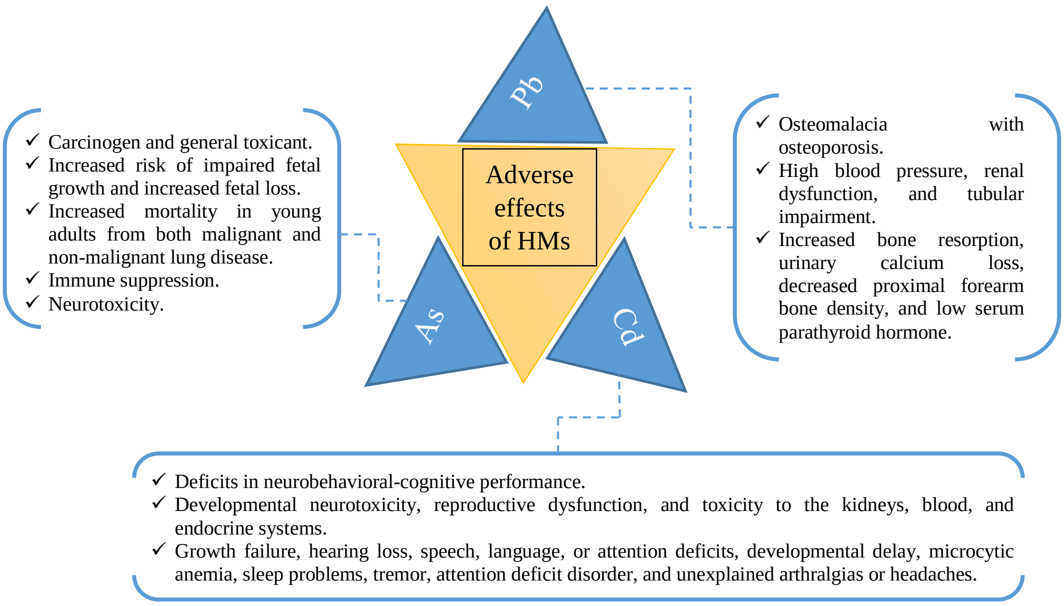

Figure 1. Adverse effects of exposure to HMs including Pb, As, and Cd [16-18].

Prolonged use of small values of HMs can cause chronic syndrome and dysfunction of internal organs. The main route of encounter to HMs in humans is mainly by the food-crop-soil pathway. HMs contaminated plants, which are used as livestock and human feed, are a potential route for HMs to reach the animal and human body. HMs, including As, Cd, and Pb are commonly poisonous to mankind's and plants [19]. The most poisonous form of As is inorganic arsenic and is one of the carcinogenic compounds on humans. As exposure causes neuropathy, gastrointestinal disease, cardiovascular disease, cancer, and other disorders. The half-life of Cd in the human body is high. High absorption of Cd through contaminated foods can cause gastritis, diarrhea, and vomiting, while prolonged absorption of low doses of Cd can lead to bone-cracking and kidney disease [15]. Prolonged exposure to Pb can cause changes in the nervous system, loss of nerve function, delayed response, and impaired perception. In children, it can lead to behavioral disorders, learning, and concentration problems [13]. It is important to reduce the accumulation of HMs in cereals, especially rice, which is one of the most commonly used cereals around the world. The bioavailability of HMs largely related to the total level of HM in the soil, its physical and chemical properties, and plant species [20, 21]. Therefore, information on the condensation of HMs in foodstuffs and how they are absorbed through food is of great importance for evaluating mankind's health risk [22]. Due to concerns about food safety, high toxicity, and high amounts of HMs, including Pb, Cd, and As in rice, which is one of the most widely consumed foodstuffs in Iran, the present study evaluates HMs in rice brands (RBs) including imported and cultivated in Bushehr province, Iran.

MATERIALS AND METHODS

Sampling area

Attempts have been made to select samples that are one of the most widely used and reputable brands. Therefore, by examining the presence of imported and cultivated RBs in the consumer market and referring to different supermarkets randomly, 6 imported RBs and 6 cultivated RBs were selected. These examples represent the most consumed brands in the Iranian market. Samples were randomly sampled from each brand for 3 consecutive months, a total of 36 samples and approximately 500 g of each sample were randomly sampled three times per HM, and an average of three experiments was reported as the final result [23]. To observe the ethical principles of research, the names of RBs are not stated and each brand is represented by a letter.

Sample preparation method

To remove possible contamination from all glassware used in the analysis, they were washed at first with 15% acetic acid, then with high purity water and placed into the oven for drying. First, some rice from each brand was properly purified, afterward weighed 2 g, and dried at 105°C for 48 hours, then re-weighed to evaluate the value of water. Rice samples were digested using perchloric-nitric acid (70%). A mixture of the perchloric and nitric dilution was added to each rice sample. It is kept at 25°C for 30 minutes. Then placed on a hot plate. The temperature is boosted step by step until the liquid reaches boiling point. The boiling was continued until the evaporation process was performed and the perchloric foams were formed. The heating was stopped until 3 ml of vivid liquid remained. Then double distilled water was added to the sample and 25 ml of the dilution was digested. The digested liquid was examined for the content of Pb, As, and Cd using flame atomic absorption spectroscopy. HMs levels were expressed in terms of dry weight by mg kg^{-1} unit.

Statistical analysis

First, the Kolmogorov-Smirnov test was applied to measure the normality of the data from the normal distribution. T-test was applied to investigate the significant difference in the concentration of HMs in cultivated and imported rice and the data were analyzed using SPSS software version 20.

Calculate the value of metals received through cultivated and imported rice

Provisional tolerable weekly intake (PTWI) indicates contaminant levels for safe intake after a period weekly. To calculate the amount of PTWI, we need to compute the daily intake rate (DIR), which can be calculated with the following formula:

$$\text{DIR}=\frac{\text{CHMs}\times\text{DU}}{\text{ABW}}$$

CHMs: concentration of HMs in rice (μg g^{-1}), DU: day to day uptake of rice (kg/person), ABW: average body weight (60 kg).

Weekly intake (WI) of HMs each person was measured from WI of rice in Iran. Then the obtained levels were compared with the maximum PTWI of each HM in imported and cultivated brands. Estimated weekly intake (EWI) and PTWI were calculated through WHO/FAO guidelines. EWI (mg kg^{-1} body weight per week) can be computed using the bellow formula:

$$\text{EWI}=\text{WE}\left(\frac{\text{Bodyweight}}{\text{weekly rice eating}}\right)\times\text{C}$$

C: Average values of metals in rice (mg kg^{-1} dry weight)

WE: weekly rice consumption (grams per week) for the general public of Iran (110 grams per person multiplied by 7 per day as defined through the Iranian Institute of Standards and Industrial Research).

RESULTS AND DISCUSSION

The values of HMs (Pb, As, and Cd) for cultivated rice (6 brands including A to F) and imported rice (6 brands including G to L) are shown in Table 1. The results of statistical analysis and PTWI levels of cultivated and imported rice are shown in Tables 2 and 3, respectively.

Table 1. Heavy metal levels (lead, arsenic, and cadmium) in cultivated and imported rice.

N	Brand	Pb (M±SD)[a]	As (M±SD)	Cd (M±SD)
1	A	0.482±0.051	0.079±0.008	0.194±0.012
2	B	0.131±0.006d	0.042±0.004	0.078±0.005
3	C	0.549±0.030	0.10±0.010	0.394±0.010
4	D	0.11±0.010	0.11±0.008	0.04±0.005
5	E	0.092±0.005	0.071±0.006	0.152±0.010
6	F	0.117±0.007	0.045±0.005	0.040±0.005
Total Mean		0.246±0.194	0.074±0.025	0.150±0.124
7	G	0.041±0.004	0.055±0.005	0.025±0.002
8	H	0.123±0.010	0.068±0.007	0.037±0.003
9	I	0.067±0.004	0.082±0.006	0.027±0.003
10	J	0.101±0.005	0.115±0.005	0.042±0.003
11	K	0.120±0.005	0.086±0.005	0.025±0.002
12	L	0.067±0.004	0.108±0.004	0.035±0.002
Total Mean		0.086±0.031	0.085±0.021	0.031±0.007

[a]Mean ± Standard Deviation

Table 2. Statistical analysis results on cultivated and imported rice.

HM	Rice type	M±SD[a]	DF	P-value
Pb	Cultivated	0.246±0.194	17	0.081[b]
	Imported	0.086±0.031	17	$P<0.05$[c]
Ar	Cultivated	0.074±0.025	17	$P<0.05$[c]
	Imported	0.085±0.021	17	$P<0.05$[c]
Cd	Cultivated	0.150±0.124	17	$P<0.05$[c]
	Imported	0.031±0.007	17	$P<0.05$[c]

[a] Mean ± Standard Deviation, [b]No significant difference ($p>0.05$), [c]Statistically significant ($P<0.05$)

Table 3. Rate of provisional tolerable weekly intake in cultivated and imported rice.

N	Brand	Pb	As	Cd
1	A	6.179	1.014	2.492
2	B	1.682	0.537	1.004
3	C	7.042	1.286	5.060
4	D	1.428	1.354	0.572
5	E	1.186	0.921	1.952
6	F	1.501	0.877	0.513
	TM[a]	3.169	0.949	1.931
	S[b]	25	15	7
7	G	0.521	0.708	0.321
8	H	1.576	0.876	0.474
9	I	0.854	1.050	0.345
10	J	1.298	1.474	0.536
11	K	1.538	1.105	0.317
12	L	0.855	1.385	0.454
	TM	1.107	1.099	0.408
	S	25	15	7

[a]Total mean (μg kg^{-1} body weight) [b] Standard intake μg/kg body weight

HMs levels in cultivated rice brands

In Iran, about 4.80% of the total agricultural land is used for rice cultivation [24]. Mean±SD levels of Cd, As, and Pb in RBs were in the range of 0.150±0.0124, 0.074±0.025, and 0.246±0.194 mg kg^{-1}, respectively. The values of Cd, As, and Pb were in the range of 0.033 to 0.118, 0.32 to 0.117, and 0.083 to 0.596, respectively. Among domestically produced rice, the levels of lead, arsenic, and cadmium were 66.67%, 100%, and 50% lower than the FAO/WHO limit, respectively (standard levels of Cd, As, and Pb are 0.10, 0.20, and 0.20 ppm, respectively). The highest levels of Pb, As, and Cd was observed in cultivated RBs C, D, and C, respectively, and the lowest levels of Pb, As, and Cd was observed in cultivated RBs E, B, and F, respectively. Data analysis showed that there was a significant difference between the levels of As and Cd in cultivated rice ($P<0.5$).

Pb, As, and Cd levels are shown in Figure 2, 3, and 4, respectively, compared to the levels approved by FAO/WHO and the Iranian Institute of Standards and Industrial Research (ISIRI).

In one study, the amount of Cd in cultivated RBs in Yazd province, Iran was reported below the allowable limit [25]. In another study performed on RBs cultivated in the East Azarbaijan province, Iran the levels of Cd and As were reported to be above the FAO/WHO range [26]. Numerous studies have been conducted on cultivated RBs in Khuzestan province, Iran [27, 28], Kermanshah province, Iran [29], East Azarbaijan province, Iran [30], Shiraz province, Iran [31], Tehran province, Iran [32], Gilan province, Iran [33], Italy [34], and Sweden [35] that were consistent with our study. A study conducted in northern Iran showed more Pb than our study [36].

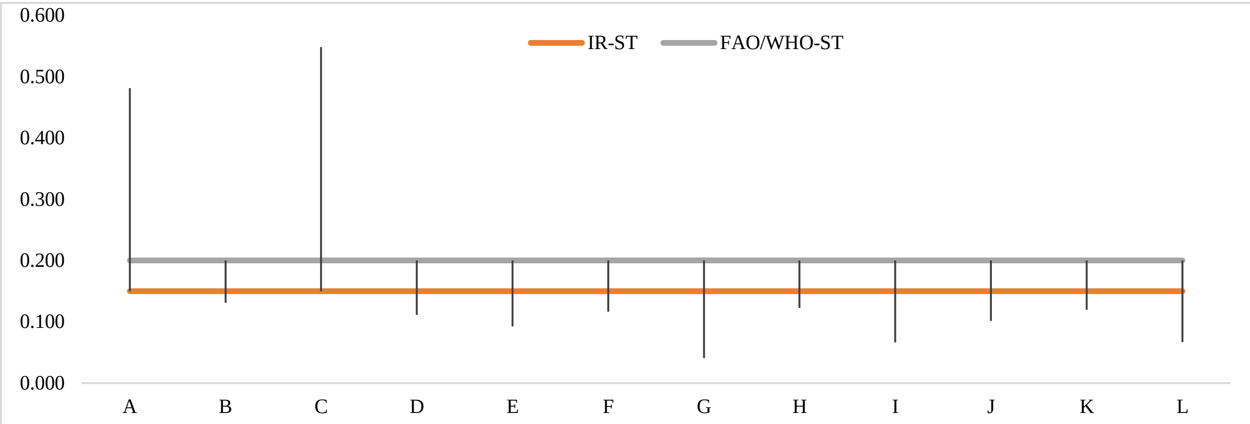

Figure 2. Lead levels in comparison with a limit of FAO/WHO and ISIRI.

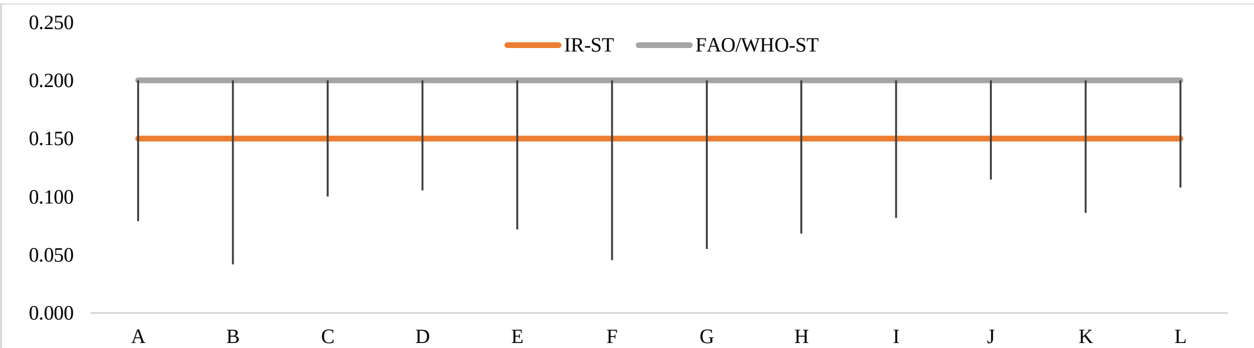

Figure 3. Arsenic levels in comparison with a limit of FAO/WHO and ISIRI.

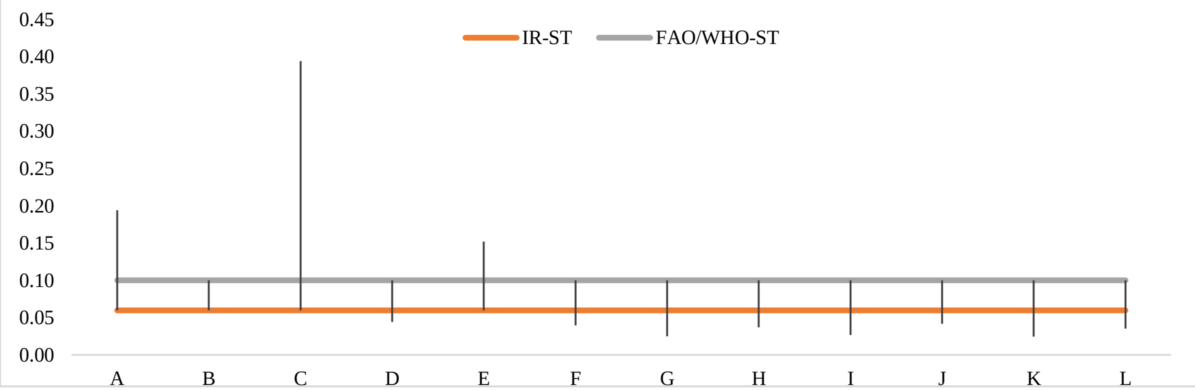

Figure 4. Cadmium levels in comparison with a limit of FAO/WHO and ISIRI.

HMs levels in imported rice brands

Mean±SD levels of Pb, As, and Cd in imported RBs were in the range of 0.086 ± 0.031, 0.085±0.021, and 0.031±0.007 mg kg^{-1}, respectively. Mean±SD levels of Pb, As, and Cd cultivated RBs were in the range of 0.06 to 0.138, 0.048 to 0.120, and 0.021 to 0.047, respectively. All imported RBs were within the range set by FAO/WHO. The highest measured levels of Pb, As, and Cd were observed in imported RBs H, J, and J, respectively, and the lowest measured levels of Pb, As, and Cd were observed in imported RBs G, G, and G, respectively. Analysis of variance showed that there was a significant difference in the amount of Pb, As, and Cd in imported rice ($p<0.05$). As can be deduced from Table 3, the mean values of these Ms in all imported RBs are below the FAO/WHO limit.

In a study in the Taiwanese market, the Cd content of rice was reported to be 0.02 mg kg^{-1}, which is consistent with our study [37]. In one study, the value of Cd in Indian rice imported to Iran in all RBs was lower than the FAO/WHO limit [38]. Other studies on imported RBs in Yazd city, Iran [25], China [20], South Korean [39], Shiraz city, Iran [31] are consistent with our results.

Estimation of weekly intake of HMs from cultivated rice consumption

To estimate the WI of HMs through rice consumption, we must obtain the mean levels of Ms in the RBs analyzed in the present study. The per capita consumption of Iranian rice is approximately 110 grams per person per day. Estimates of WI of HM in cultivated RBs were calculated and shown in Table 4.

Table 4. Lead, arsenic, and cadmium (mg kg^{-1}) levels in rice cultivated brands worldwide.

NO.	Pb	As	Cd	Region/Continent	Year	Ref
1	134.819	NM[a]	20.261	Saudi Arabia/ Asia	2001	[40]
2	0.962	NM	0.079	Gilan province, Iran/ Asia	2001	[36]
3	0.004	0.200	0.024	Sweden/ European	2008	[35]
4	ND[b]	0.940	6.095	Qaemshahr city, Iran/ Asia	2009	[41]
5	0.067±0.018	NM	0.062±0.019	Shahrekord city, Iran/ Asia	2010	[42]
6	0.320±0.090	ND	0.170±0.050	Iranian markets/ Asia	2011	[38]
7	0.073±0.035	0.070±0.010	0.045±0.025	Isfahan provinces, Iran/ Asia	2012	[43]
8	0.328	0.033	0.037	Yazd city, Iran/ Asia	2013	[25]
9	NM	NM	0.100 to 0.160	Italy/ European	2013	[34]
10	0.290±0.154	0.055±0.029	0.157±0.109	East Azarbaijan province, Iran/ Asia	2014	[26]
11	0.440±.0420	ND	0.070±0.008	Khuzestan province, Iran/ Asia	2014	[27]
12	0.040±0.030	0.035±0.009	0.009±0.013	Hormozgan Province, Iran/ Asia	2014	[44]
13	0.215±0.025	0.051±0.001	0.008±0.00	Kermanshah province, Iran/ Asia	2014	[29]
14	0.916±0.035	0.022 ± 0.027	0.057±0.014	East Azarbaijan province, Iran/ Asia	2014	[30]
15	1.280±0.710	ND	0.470±0.270	Shiraz province, Iran/ Asia	2015	[31]
16	1.430	ND	0.314	Tehran province, Iran/ Asia	2015	[32]
17	1.731±0.238	ND	0.380±0.050	Gilan province, Iran/ Asia	2016	[33]
18	NM	0.079	NM	Khuzestan province, Iran/ Asia	2016	[28]
19	0.060±0.016	0.061±0.016	0.029±0.007	Iranian markets/ Asia	2016	[45]
20	1.761± 0.427	NM	0.101±0.068	Astaneh-Ashrafieh, Iran/ Asia	2016	[46]
21	0.097±0.052	NM	0.010±0.007	Tehran city, Iran/ Asia	2017	[47]
22	0.246±0.194	0.074±0.025	0.150±0.124	our study, Iran/ Asia	2020	

[a]NM: Not Mention [b] ND: Not Detect.

As can be seen, the total mean WI of Pb, As, and Cd were 3.690, 0.949, and 1.931 mg kg^{-1}, respectively. As can be deduced from the Table 4, WI was below the PTWI limit in all cultivated RBs. Estimates of WI for Pb, As, and Cd in cultivated RBs ranged from 1.186 to 7.042, 0.537 to 1.354, and 0.513 to 5.060 µg kg^{-1}, respectively. The highest measured WI levels of Pb, As, and Cd were observed in RBs C, D, and C, respectively, and the lowest WI levels of Pb, As, and Cd were observed in RBs E, B, and F, respectively. EWI for Pb was significantly higher than other HMs. A study mentioned the WI of Cd in rice 51.620 mg kg^{-1}, which is inconsistent with our results (C and A). In a study on white and brown rice in three groups (children, adolescents, and adults), the WI of Cd in white rice for this groups 0.100, 0.250, and 0.560, respectively, and in brown rice 0.160, 0.380, and 0.820 was reported, respectively, which is consistent with our research [48]. In a study conducted on HMs in local markets of Shiraz city, Iran, WI of Cd was reported in three RBs 4.376, 3.365, and 5.300, respectively, and WI of Pb 12.256, 16.491, and 9.189, respectively, All samples were within the range specified by FAO/WHO [31]. In a study on soaked and rinsing rice, the WI of Pb, Cd, and Ar in soaked rice was reported 0.034± 0.037, 0.015±0.013, and 0.202±0.041, respectively, in rinsing rice 1.546±0.459, 0.127±0.114, and 6.220±2.668, respectively, and in rinsed three times with water 0.057±0.171, 0.027±0.013, and 0.183±0.030, respectively. Washing rice several times reduces contaminants with HMs [49]. In a study on As in Khuzestan province, Iran PTWI level was consistent with our study [28].

Estimation of weekly intake of HMs from imported rice consumption

The estimated WI of HM in imported RBs was calculated and shown in Table 5. As can be seen, the mean WI of Pb, As, and Cd are 1.107, 1.099, and 0.408 mg kg^{-1}, respectively.

Table 5. Lead, arsenic, and cadmium (mg kg^{-1}) levels in rice imported brands worldwide.

NO.	Pb	As	Cd	Region/Continent	Year	Ref
1	0.134	NM	0.020	Saudi Arabia/ Asia	2001	[40]
2	0.021	NM	0.206	South Korean/ Asia	2005	[39]
3	0. 113	NM	0.081	China/ Asia	2006	[20]
4	0.387±0.040	ND	0.0291±0.001	Iranian markets / Asia	2011	[38]
5	0.290	0.055	0.109	the south Caspian Sea, Iran/ Asia	2012	[50]
6	0.369±0.150	0.254±0.025	0.108±0.062	Isfahan provinces, Iran/ Asia	2012	[43]
7	0.254	0.087	0.043	Yazd city, Iran/ Asia	2013	[25]
8	0.096±0.017	0.060±0.030	0.032±0.012	Zahedan city, Iran/ Asia	2013	[51]
9	0.290±0.154	0.55±0.028	0.109±0.157	Tabriz, Iran/ Asia	2014	[26]
10	1.080	ND	0.069	Shiraz city, Iran/ Asia	2015	[31]
11	0.216±0.002	0.052±0.002	0.008±0.0001	Iranian markets/ Asia	2015	[52]
12	0.223 to 1.961	0.048 to 0.314	0.085 to 0.385	Torbat-Heidarieh city, Iran/ Asia	2015	[53]
13	0.330±0.250	NM	0.026±0.015	Iranian markets/ Asia	2016	[24]
14	0.054±0.016	0.055±0.012	0.031±0.008	Iranian markets/ Asia	2016	[45]

From Table 5, it can be inferred that the WI of HMs was below the PTWI limit in all imported RBs. The WI estimates for Pb, As, and Cd in imported RBs ranged from 0.521 to 1.576, 0.708 to 1.474, and 0.317 to 0.576 mg kg^{-1}, respectively. The highest measured WI levels of Pb, As, and Cd were observed in RBs B, D, and D, respectively, while the lowest WI levels of Pb, As, and Cd were observed in RBs A, A, and E, respectively. Differences in HMs levels among diverse brands are related to factors such as geographical location, grain diversity, harvest season, climate, and soil conditions. Our study showed that imported rice had lower amounts of HMs than cultivated rice and that Cd and Pb levels in cultivated RBs were slightly higher than the WHO/FAO limit while As levels were lower than this guideline.

CONCLUSIONS

As a result of this study, it was found that the mean content of Pb and Cd in cultivated RB is slightly higher than the limit set by the FAO and WHO. However, in all imported RBs, the mean content of Pb, As, and Cd is lower than the FAO/WHO limit. The EWI is lower than the PTWI for all cultivated and imported RBs. Despite this, the density of Pb and Cd in cultivated RBs was higher than the guidelines. Nevertheless, the evaluation of health effects showed that rice consumption does not pose a health or carcinogenic risk. Since rice is a staple food for Iranian people and is consumed on average once or twice a day, it is important for reputable agencies to monitor the levels of HMs in both imported and cultivated RBs. Due to the bioaccumulation of HMs, which can have adverse health effects as well as environmental effects that can cause irreversible damage to soil, water, and food cycles, it is important to be mindful of consuming foods containing HMs.

ETHICAL CONSIDERATIONS

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Conflict of interest

The authors declare that they have no conflict of interest.

Data Availability

The datasets generated during and/or analyzed during this study are available from the corresponding author on reasonable request.

Ethics approval

Not applicable.

Consent to participate

All authors have read, approved and accept responsibility for the manuscript.

Consent for publication

We consider BMC Research Notes to be an appropriate journal for the publication of this manuscript. We confirm that this manuscript has not been published before and is not under consideration for publication in another journal.

Abbreviations

HMs, Heavy metals; HM, Heavy metal; As, Arsenic; Cd, Cadmium; Pb, Lead; RBs, rice brands; PTWI, Provisional tolerable weekly intake; DIR, daily intake rate; WI, Weekly intake; EWI, Estimated weekly intake.

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