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Cadmium and Lead Contents of Rice (Oryza sativa) Grown in Khuzestan, Southwest of Iran

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Abstract

Background: Lead and cadmium as two of the main industrial pollutants can cause strong negative effect on humans and animals. Rice (Oryza sativa) is a plant of the grass family, which provides the bulk of the human diet throughout Asia, i.e. feeds more than half of the world's human population. This study was conducted to determine cadmium and lead contents of cultivated rice grown in Khuzestan province.

Material and methods: In this study, 252 seed samples from Champa and Anburi rice cultivated in three areas in Khuzestan, namely, Shavur, Baghmalek, and Dasht Azadegan were collected at harvest time. The samples were digested according to the standard method of association of analytical community (AOAC). As reported in the procedure, lead and cadmium contents were measured using Graphite Furnace Atomic Absorption Spectrometry (GFAAS)

Results: The mean Pb concentrations in Anburi and Champa rice cultivated in three different regions were 0.42±0.07 and 0.44±0.05 mg Kg^{-1} which are significantly higher than the permissible average level adjusted by the Iranian Food and Drug Administration (IFDO). However, the average Cd content of Anburi and Champa rice in the regions were 0.07 ±0.008 and 0.07 ±0.006 mg kg^{-1}, respectively. The cadmium content is well below the permissible level.

Conclusion: The results indicated that the mean concentration of lead in all the samples were considerably higher than the cadmium content. This is the extent of lead contamination in this province.

Keywords: Lead, cadmium, graphite furnace atomic absorption spectrometry, heavy metals, Oryza sativa

►Please cite this paper as: Ramezani Z, Khodayar MJ, Nazari Z, Hedayatifar R, Gilani AA. Cadmium and Lead Contents of Rice (Oryza sativa) Grown in Khuzestan, Southwest of Iran. Jentashapir J Health Res 2014; 5(2):65-71

Received: 05.09.2013 **Accepted: 11.11.2013**

Introduction

Cadmium and lead are among the most well known environmental intoxicants. They do not have any essential activity in the human body. In mammals, cadmium is virtually absent at birth but develops later, especially in the liver and kidneys and can lead to health problems. The presence of cadmium in nature and its entry to the body through food causes anemia, hypertension and serious damages in kidneys, lungs, and bones (1). Recently, a research showed that there was a correlation between the consumption of rice in Sri Lanka and chronic kidney disease of uncertain aetiology (CKDu) (2). The exposure to toxic elements can be minimized by regular control of food and setting maximum permissible levels for heavy metals in these products. Accordingly, Commission Regulation (EC) No 466/2001 dated March 2001 and Polish Regulation of the Ministry of Health, January 2005, established limits for lead and cadmium in foodstuffs. The limit was between 0.01 to 1 mg mL^{-1} for both Cd and Pb (3, 4)

The metals contaminate food sources and grows and spreads in agricultural products and seafood through water, air and soil pollution (5). Heavy metals such as cadmium and lead are widely used in industry. They enter the environment through natural and anthropogenic sources. The most important anthropogenic sources of soil pollution are industrial sludge sewage discharging, super phosphate fertilizers, and the agricultural farms near lead and zinc mines or refining factories. (6, 7)

Rice (Oryza sativa) is a plant of the grass family. It provides the bulk of the human diet throughout the Asia, i.e. about half of the world's population. After maize and wheat, rice is the world's third largest crop consumed by human. The consumption rate is about tens of kilograms a year per person.

Some reports concerning heavy metal contamination on rice consumption are available. In Indonesia, 50% of the cadmium intake comes from rice (8). This is about 40 to 60% in Japan (9). Iran is also a country with a high consumption rate of rice. According to statistics, each person consumes approximately 42.5 kg yearly[7]. Therefore, this study was carried out to determine the Cd and Pb content of rice grown in Khuzestan province in southwest of Iran as one of the rice producers in the country.

Materials and methods

All chemicals used in this study were of analytical reagent grades materials prepared from Merck, Germany. Double distilled water was used throughout the study.

An Analytical Jenal 5EA graphite furnace atomic absorption spectrometer (Germany) equipped with autosampler and D_2 background correction was used throughout this study. An Iran Khodsaz muffle furnace (Iran) equipped with temperature controller was used to ash the rice samples.

Sample collection

Rice samples were collected at harvest time, in late October to early November, under the direct provision of Khuzestan Agricultural Research Center and the center of agricultural services in any of the selected city. Consequently, we selected three areas including Shavur, Baghmalek, and Dasht Azadegan and two varieties of Champa and Anburi. Generally, 42 composite rice samples in each variety, and 252 samples were collected from the selected areas. The white rice was transferred to the laboratory, a portion of the grains was cleaned, dried and ground into fine powder prior to digestion.

Sample Digestion and analysis

About 5g of the powdered white rice were carefully weighed and transferred into a cleaned crucible, then one drop of concentrated nitric acid was added, and the crucibles were placed in a muffle furnace. The furnace was programmed to reach 450±10 °C with a rate of 20 °C/min and to stay at that temperature until completely burnt (and a white residue was seen in the crucible). The residue was then dissolved in diluted nitric acid and filtered through the GF/B silica filter before turned to volume. The resulting solution was analyzed for Cd and Pb contents at 228.8 and 283.3 nm, respectively using Graphite Furnace Atomic Absorption Spectrometer. The calibration range for Pb and Cd were 10-100 and 5-50 ng mL^{-1}, respectively. The detection limit for Pb and Cd were 5 and 2 ng mL^{-1} consequently. To briefly describe the GFAAS determination protocols, using autosampler 10µl of the sample was mixed with 10µl of $NH_4H_2PO_4$ and mixture of palladium and magnesium nitrate as the matrix modifier for Pb and Cd, respectively. However, total of 25µl of each sample was injected into graphite tube of the instrument. Then, the GFAAS programs for each of these elements were run as shown in Table 1. The concentrations of samples were determined using calibration curve drawn on the same instrumental conditions. Reliability of the results was tested by spiking real samples with appropriate standards. Statistical analysis of the data including mean± SEM and analysis of variances were performed using SPSS software.

Results

The mean concentrations of lead and cadmium in the different regions on both varieties are illustrated in Table 2. All the calculated concentrations were based on dry weight. The results were the mean of three replicate of 42 collected samples. In all cases, the Pb contents were higher than the permissible level, almost twice as much. The rice cultivated in Shavur had the highest mean value for Pb and Cd in both varieties in comparison to Baghmalek and Dashte Azadegan samples. Analysis of variances (ANOVA) performed on the data obtained in the three studied cities showed significant differences in Pb and Cd content of Shavur compared to the others ($p<0.05$). The statistical analysis also indicated significant differences between Pb contents of all regions compared to permissible level adjusted by Iranian Food and Drug Organization (IFDO) that is 0.2 mg/Kg. The cadmium contents of the samples except for Shavur are well below the permissible level (0.1 mg/Kg). Shavur Cd level was near but still below the permissible level. Nevertheless, more precautions on consuming these samples should be considered. Figure 1 and 2 graphically show the percent of Cd and Pb contents of 42 analyzed samples in each region and varieties. Since no data obtained for Pb contents was below 0.2 mg Kg^{-1}, the IFDO permissible level, 0.3 mg Kg^{-1} was considered as the border line. As indicated in Figure 1, Pb contents of a few number of the samples were below 0.3 mg Kg^{-1} in Anburi rice in all the three regions but those of Champa were 100% above 0.3 mg Kg^{-1}. This means that all 42 Champa samples were intensively polluted. Cd contents of both Anburi and Champa of Dasht Azadegan and Baghmalek rice were below 0.1 mg Kg^{-1}, the permissible level, but a few of those of Shavur were above the permissible level as shown in Figure 2.

Table1. Instrumental operating conditions and heating program for the simultaneous determination of cadmium and lead by GFAAS

Step	Temperature (◦c)		Ramp (degrees/s)		Hold (s)		Argon FR (ml/min)	
	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd
Drying 1	105	105	5	5	10	10	250	
Drying 2	115	110	5	5	5	5	250	
Pyrolysis	900	800	5	5	15	10	250	
Atomization	1450	1300	1	1	5	5	0	
Cleaning	2500	2500	1·	10	3	3	250	

FR stands for flow rate. The last parameters (Argon FR) are the same for both elements.

Table 2. Mean concentration of Cd and Pb in rice cultivated in different parts of Khuzestan, Iran

Varieties	Champa		Anburi	
	Pb (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cd (mg/kg)
Shavur	0.47±0.06[a]	0.09±0.01 [a]	0.46±0.1 [a]	0.09±0.01 [a]
Baghmalek	0.43±0.05	0.06±0.003	0.40±0.06	0.06±0.005
Dasht Azadegan	0.42±0.05	0.06±0.005	0.40±0.06	0.07±0.008
Mean	0.44±0.05	0.07±0.006	0.42±0.07	0.07±0.008

[a] indicates a p value <0.05 between Shavur area and the other areas.

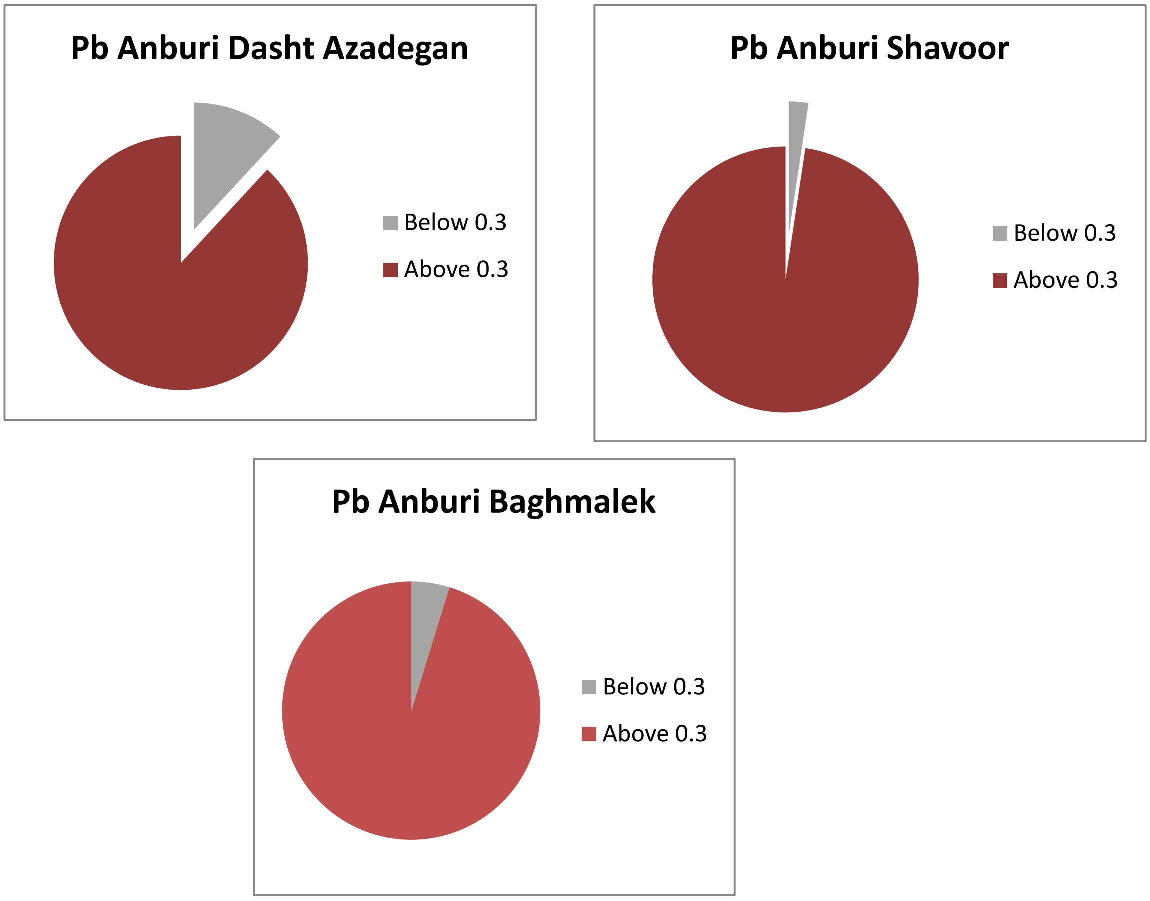

Fig 1. Data distribution around permissible value of 0.3 mg kg^{-1} Pb for 42 analyzed rice samples

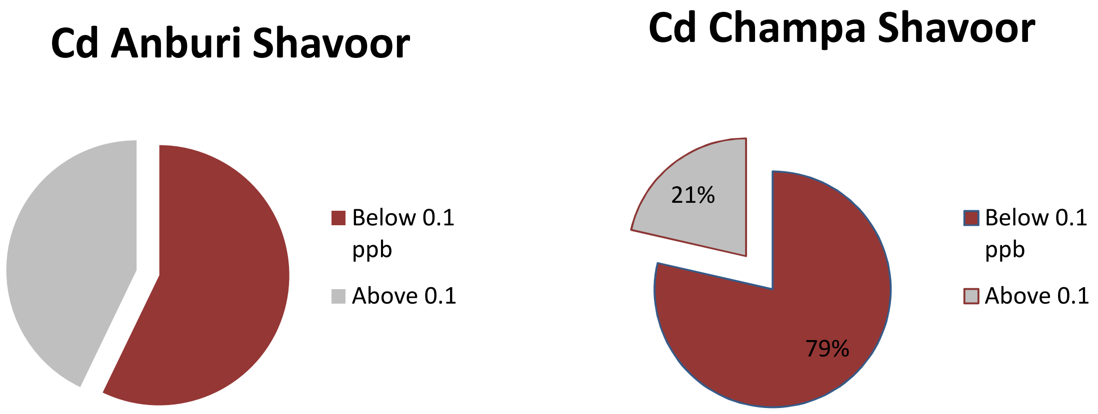

Fig 2. Data distribution around permissible value of 0.1 mg kg^{-1} Cd for 42 analyzed rice samples

Discussion

Absorption of lead through root depends on pH, kind of sediments, and the extent of soil organic contaminants. (11) Soils with permanent water residue increase the solubility of Pb (11). So the Pb content of Dasht Azadegan was more than that in Shavur region because of the soil physiological and morphological conditions. The cadmium content of rice in Shavur was higher, and further findings on 42 samples revealed that Cd value was above the permissible limits because of the extent of organophosphorus (OP) fertilizers used in rice cultivation in this region. Natural ramp and topography of the Baghmalek and also avoiding organophosphorus fertilizers in the rice cultivation caused the Cd content of Baghmalek Champa to be low.

Given the high rice consumption in the region, attentions were drawn to determine the contaminant levels. Here, we compare some research results with those obtained in this study. In a study in one of the main Iranian rice producers called Lorestan, the researcher reported the mean concentration of Pb and Cd to be 0.11 and 0.045 mg kg^{-1}, respectively[8]. Bakhtiarian et al. (7) showed that the amounts of Pb and Cd of rice in the north of Iran were 0.962 and 0.079 mg kg^{-1}, respectively. By comparing the results with the permissible level adjusted by FDA and also Iranian FDA it was found that the Cd level in rice is tolerable, and no Cd health risks following consumption of the rice are present. The amount of cadmium concentrations in this study was lower than that in Bakhtiarian et al.'s study (10), but Pb level was more than the permissible level in all of the Iranian surveys. Jahed Khaniki and Zazoli (14) showed that the highest amounts of Pb and Cd in rice in the north of Iran were 2.23 and 0.41 mg kg^{-1}. The high amount they obtained in their study indicated the extent of fertilizers used during rice growth. There are also significant amount of data available on foreign rice Pb and Cd Level. Some of them are reviewed to compare the results obtained with those of this study. In a study in Japan, it was shown that Japanese brown rice had a mean Cd content of 0.09 mg kg^{-1} (15). Shimbo et al. (16) reported the geometric mean content of Cd in rice produced in Japan in 1998 to 2000 to be 0.05 mg/kg, based on fresh weight. Kaba-Pendias (17) showed that the background levels of Cd in cereal grains exceeded the range of 0.013 to 0.22 mg/kg. In South Korea, Cd concentrations determined in rice were between 0.01 to 0.032 mg/kg with a mean of 0.021 mg/kg (18). As observed all the samples showed low Cd contamination But the Pb level is high again in overseas countries. Jung et al. [19] showed that the mean concentration of Pb in polished rice in Korea was 0.206 mg/kg. The mean Pb contents of plant foodstuffs growing in uncontaminated areas was in the range of 0.1 to 10 mg/kg [17]. Al-Saleh et al. (19) and Bennett et al. (20) reported the mean of Pb for rice samples to be 0.135 mg/kg and 0.25 mg/kg in Saudi Arabia and northern Wisconsin (USA), respectively. The average value of Pb based on fresh weight in Japanese white rice was 0.0022 mg/kg that was much lower than that of the present study.

Correia et al. (21) obtained higher Cd and lower Pb content of foodstuffs compared to our results.

Unfortunately, the amount of Pb was nearly twice as much as the upper limit approved by the Iranian FDO (9). These results are in consistent with those obtained for leafy vegetables (22, 23). It may mainly result from the air and soil pollution, topographical and physiological conditions of the regions, and uncontrolled organophosphorous fertilizers used by the farmers.

The intake of Cd and Pb is estimated by multiplication of daily consumption of rice [16, 23]. The Codex committee on food additives and contaminants of the joint FAO/WHO food standards program [24] has proposed draft levels for typical daily exposure and Provisional Tolerable Weekly Intake (PTWI) for some of the heavy metals in cereals such as rice. The Joint FAO/WHO Expert Committee on Food Additives (JCEFA) has proposed a maximum level of 0.2 mg/kg cadmium in rice but the community warned that people in the regions who eat large amount of rice with the high-contaminated level of cadmium could be significantly exposed. In addition, JCEFA has proposed a maximum level of 0.3 mg/kg lead in rice. JECFA has set the PTWI for the Cd and Pb equal to7 and 25 µg/kg of body weight, respectively. Saito (25) showed that pH is an important factor that affects the solution Pb and Cd concentration since an increase in pH causes a decrease in the solubility of the lead and cadmium compounds. However, other factors, including the ion-exchange capacity and the competitive effect of the other metallic cations on the rate of lead absorption and cadmium in the rice strongly changes the Pb and Cd adsorption in the body.

In conclusion, it can be stated that there are health problems associated with Pb in consumption of rice. In addition to rice, vegetables which are part of daily diet may also be contaminated by Pb, therefore, an accurate diet plan is recommended to minimize the health risk of Pb and Cd intake. Therefore, the periodical monitoring of the contaminants seems to be necessary in order to build and sustain a healthy community.

Acknowledgements

The authors thank the financial support of research unit of Ahvaz Jundishapur University of Medical Sciences under grant no. 605. This paper was extracted from MSc thesis of R. Hedayatifar.

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