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Cadmium and Lead Contents in Rice (*Oryza sativa*) in the North of Iran

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ABSTRACT

This study was carried out to determine the Cd and Pb contents in *Oryza sativa* rice in the north of Iran. Sixty samples were collected from four areas of Qaemshahr region in north of Iran (Mazandaran province) at harvesting of rice in field. In laboratory, grains of rice were milled and were digested by acid digestion method and then were analyzed for Cadmium and lead by atomic absorption spectrophotometry. The results showed that average concentrations of Cd and Pb in rice were 0.41 ± 0.17 and 2.23 ± 18 mg kg^{-1} dry weight, respectively. Notably the Cd and Pb contents in the rice samples were found to be upper than the FAO/WHO Guidelines. To assess the safety of dietary of intake, weekly intake of Cd and Pb by rice was calculated based on daily consumption of rice. The results indicated that weekly intake of Cd and Pb from rice was upper than the maximum weekly intake recommended by WHO/FAO.

Key Words: Cadmium; Lead; Rice; Iran; Heavy metals; Dietary intake

INTRODUCTION

Heavy metals such as Cadmium and lead are widely used in industry. They enter to the environment from natural and anthropogenic sources. The most important anthropogenic sources of soil pollution to metals are industrial sludge sewage discharging, applying super phosphate fertilizers, burying the non-ferrous wastes in land and closing the agricultural fields to lead and Zinc mines or refining factories (Rowland *et al*., 1997). These metals contaminate food source and accumulate in both agricultural products and seafood through water, air and soil pollution (Lin *et al*., 2004). Cadmium (Cd) and lead (Pb) are two of the most well-known environmental intoxicants to humans. Cadmium is one of the elements that have no constructive purpose in the human body. In mammals, Cadmium is virtually absent at birth and accumulates with time, especially in the liver and kidneys that can lead to health problems. Its presence in nature and entrance to human's food chain, causes anemia, hypertension and the serious damage in kidneys, lungs, bones (Moffat & Whittle, 1999; Mahindru, 2004). It is also known that people, especially those who take rice as staple food for daily energy, are inevitably exposed to significant amounts of heavy metals including cadmium and lead via rice. Rice cropped even from non-polluted areas may be contaminated because of fertilizers that are used in farm, having Cd and Pb (Watanabe *et al*., 1996).

Tarrom rice is a variety of *Oryza sativa* and it is cultured in the north of Iran. Some chemical fertilizer is used on land or farm to make rice plant grow better. Chemical fertilizers such as super phosphate have Cd and Pb and they can be the major source of cadmium uptake in rice. It was identified as the major source of cadmium intake among of Itai-Itai disease endemic in Jinzu river basin in Japan in the mid 20th century (Shimbo *et al*., 2001). Some researches state to approximately 50% of the daily intake of Indonesian comes from rice and 40 to 60% for the Japanese (Rivai *et al*., 1990). Cd can contaminate food sources and accumulate in both agricultural products and sea food through water, air and soil pollution if waste discharge not properly treated. For example, Cadmium polluted rice in Taiwan Country resulted from the illegal discharge of waste-waters from chemical plants and metal recycling factories (Lin *et al*., 2004). Moreover, Cd and Pb can enter the food chain from aquatic and agricultural ecosystems and threaten human health indirectly (Watanabe *et al*., 1989). It is known that Cd content is much higher in rice bran than in polished rice grains (which essentially consist of albumen) (Zhang *et al*., 1998).

The objective of this study was to investigate and monitor Cd and Pb contents of raw rice (var: Tarrom) in Qaemshahr region in Mazandaran province in the north of Iran and also based on the data obtained, weekly Cadmium intake from rice were calculated.

MATERIALS AND METHODS

Sixty rice samples were collected from four major rice production areas in Qaemshahr region in Mazandaran province and 15 samples were taken from each. In the first step, samples were collected in rice farms when farmers harvested their crops. A portion of rice grains was collected and cleaned for determination of Cd and Pb, in raw rice. 2 g of rice were taken and weighed. They were dried at 105°C for 48 h. Then, the samples were digested by a nitric-perchloric acid digestion method based on ASTM standards (A.S.T.M., 2000).

Each rice sample was refluxed in a premixed solution of concentrated nitric and perchloric (70%) acids (3:1) at the rate of 20 mL per gram of sample. 2.5 mL of sulfuric acid (spg. 1.84) was added per gram of sample. Then, the mixture was swirled and allowed to stand for 30 min. Then the beaker was covered with an acid-washed watch glass, placed it on a hot plate and gradually the temperature increased until the mixture was boiling. The boiling was continued until evaporation occurred and perchloric fumes were evolved. Heating was terminated when about less than 3 mL of a clear liquid was obtained. Afterwards, deionized water was added to bring the digest to 25 mL. The digested solution was analyzed for Cd and Pb, contents by flame atomic absorption spectrometer (Chemtech, Eng & Alpha-4). All of samples were digested as duplicate. Each sample was analyzed two or three times.

Concentrations of Cd and Pb in rice were expressed in terms of mg kg^{-1} on a dry weight basis. Data analysis was done by SPSS program. Analysis of variance (ANOVA) followed by multiple comparison (Scheffe) was employed to detect significances between or among samples. Weekly or daily Cadmium intake from rice was calculated by Cadmium and lead contents in rice multiplied to weekly and daily rice consumption (Nogawa & Ishizaki, 1979; Rivai *et al*., 1990).

RESULTS

The results of cadmium and lead contents in 60 samples of raw rice from four areas are shown in Table I and II, respectively. Results indicated that the mean value of Cd concentration in rice was 0.41 mg kg^{-1} on dry wt. basis and the range was 0.13–0.81 µg kg^{-1} dry wt. The food sanitary standard of Cd in rice on FAO/WHO Codex is 0.2 µg kg^{-1} and also the mean value of Pb concentration in rice was 2.23 mg kg^{-1} on dry wt basis and the range was 1.6–2.6 µg kg^{-1} dry wt. The food sanitary standard of Cd in rice on FAO/WHO Codex is 0.3 µg kg^{-1}. Therefore, the average content of Cd and Pb, in Iranian rice is over the maximum permitted level for rice compared with FAO/WHO Codex. The results revealed that less than 12% of rice samples had Cd content below 0.2 mg kg^{-1} and also the amount of Cd content in 88% samples was above 0.2 µg kg^{-1} levels but the amount of Pb content in 100% samples was above the maximum permitted level. The weekly intake of Cd and Pb from rice in this study was 7.89 and 42.23 µg kg^{-1} body weight/week, respectively that was more than of total dietary Cd and Pb intake (Table III). ANOVA showed that there was a significant difference in Cd contents in rice ($P < 0.003$), while there wasn't a significant difference in Pb contents in rice ($P > 0.05$).

Table I. Cadmium contents in collected rice from various areas in Qaemshahr

Sampling area	Sample number	Mean (mg/kg dry wt)	Standard Deviation	Minimum (mg/kg dry wt)	Maximum (mg/kg dry wt)
1	15	0.54	0.19	0.15	0.81
2	15	0.35	0.13	0.12	0.56
3	15	0.37	0.15	0.13	0.63
4	15	0.37	0.16	0.16	0.63
Total	60	0.41	0.17	0.12	0.81

Table II. Lead contents in collected rice from various areas in Qaemshahr

Sampling area	Sample number	Mean (mg/kg dry wt)	Standard Deviation	Minimum (mg/kg dry wt)	Maximum (mg/kg dry wt)
1	15	2.26	0.18	1.9	2.6
2	15	2.2	0.17	1.7	2.5
3	15	2.2	0.19	1.8	2.4
4	15	2.27	0.11	1.6	2.4
Total	60	2.23	0.17	1.6	2.6

DISCUSSION

As shown in Table I, the present study showed that average content of Cd in raw rice produced in north of Iran was approximately 0.41 mg kg^{-1} dry wt with significant variation depending on the areas. Table IV presents the values of Cd reported in literature (Watanabe *et al*., 1996). The mean Cadmium content values in rice reported in literature are 50 ng g^{-1} dry wt for Japan in 1998-2000 (Shimbo *et al*., 2001), 0.01 mg kg^{-1} dry wt to Taiwan in 2004. The Pb content in rice samples from various countries ranged from 1.6 to 58.3 ng g^{-1} and the average content was 15.7 ng g^{-1} (Lin *et al*., 2004). Comparing the results in Table I and II with Cd and Pb content of rice from other countries, it appears that the obtained values were upper Cd and Pb content in Iranian rice.

When the present observation is compared with the values reported in previous studies in Iranian rice, it appears that there have been changes in Cd contents and may have been increased gradually. The average Cd contents in the rice samples of this survey were lower than a similar survey done in years 1993 and 1998.

Afshar *et al*. (1995) determined Cd content in Amol rice (a variety of Iranian rice) found that the mean Cd concentration in Amol rice was 0.09 mg kg^{-1}. The previous studies have shown that averaged Cd content in raw rice produced in north of Iran was 0.34 mg kg^{-1} and the range was 0.25-0.45 mg kg^{-1}; also it showed that Cd content of soil was increasing gradually from 33 mg kg^{-1} in 1998 to 34 mg kg^{-1} in 1999 (Khani & Malekoti, 2000; Khani & Malekoti, 2000). Hence, there has been a gradual increase in

Table III. Intake of Cadmium and lead via rice [(weekly dietary intake of Cd by eating rice) (µg/ kg body weight/week)]

	Item	Average	Ranges
	Daily Rice Consumption (g/day)	165	158-178
Cadmium	Content (µg/g)	0.41	0.12- 081
	Weekly intake (µg/kg body weight/week)	7.89	2.21-16.82
	Provincial tolerable weekly intake (µg/kg body weight/week)	7	-
Lead	Content (µg /g)	2.23	1.6-2.6
	Weekly intake (µg/kg body weight/week)	42.23	29.49-53.99
	Provincial tolerable weekly intake (µg/kg body weight/week)	25	-

Table IV. Cadmium contents in rice from various area reported in Literature

Areas	Mean (ng g^{-1})
Australia	2.67
China	15.54
Taiwan	39.55
Indonesia	21.77
Japan	55.70
Korea	15.7
Thailand	15.04
Malaysia	27.74
Philippines	20.14
Vietnam	18.5
Canada	29.02
Columbia	133.20
Finland	25.8
France	17.41
Italy	33.92
South Africa	15.82
Spain	0.85
USA	7.43

the Cd contents in Iran rice. At this moment, it seems to pose a great threat with increase in rice consumption. Watanabe *et al*. (1996) showed that there was a substantial difference in Cd contents among in consumed in various areas in Asia and elsewhere. In sum investigation of Cd content of rice from different countries revealed a range from 0.0008 to 0.13 mg kg^{-1} with the average of 0.03 mg kg^{-1}. Shimbo *et al*. (2001) showed that Pb contents in raw rice were 2.2 ng g^{-1}. Some researcher stated that the reasons for higher Cd contents in rice is complex, whereas Cd in rice grains uptake from soil and rice harvested from paddy fields of rice in Cd trends to contain Cd at a high level (Nogawa & Ishizaki, 1979; Watanabe *et al*., 1996). Absorption of Cd from soil to the rice grain extensively modified by the redox potential of the soil, which affects solubility of metals, is known to increase with a decrease in soil pH and hence plant metal uptake is higher in acidic soils than in calcareous paddy soils (Valdares *et al*., 1983; Watanabe *et al*., 1996). Metal uptake due to soil pH under the present state is limited in both soils, but any reduction in soil pH in these farms can raise metal availability and metal uptake by plants, which also could increase health risk. It is also known that there is a linear relationship between metal availability and organic matter content (Basta & Tabatabai, 1992).

The intake of Cd and Pb was estimated by multiplication of daily consumption with Cd and Pb contents in rice (Zhang, *et al*., 1998; Shimbo *et al*., 2001). The Codex committee on food additives and contaminants of the joint FAO/WHO food standards program, has proposed draft levels for typical daily exposure and theoretical tolerable weekly intake (PTWI) for some of 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^{-1} Cd in rice but the community warned that people who eat a lot of rice from regions containing the higher levels of Cadmium could be significantly exposed. And also JCEFA has proposed a maximum level of 0.3 mg kg^{-1} lead in rice. JECFA has set the Provisional Tolerable Weekly Intake (PTWI) for the Cd and lead equal to 7 and 25 µg kg^{-1} of body weight, respectively (W.H.O, 2004). According to the published papers, daily consumption of rice in Asia countries ranges from 158-178 g/person-day and the average is 165 g/person-day, and the average body weight is 60 kg/person (Nogawa & Ishizaki, 1979; Rivai *et al*., 1990). The weekly intake of Cd and Pb from rice in this study was 7.89 and 42.23 µg kg^{-1} body weight/week, respectively that was more than of total dietary Cd and Pb intake. Table III reveals that weekly Cd and Pb intake from rice was above the maximum weekly intake recommended by WHO/FAO. Furthermore, we should not overlook other foods that contain Cd and Pb such as fish, wheat and vegetable consumption by community, the situation could worsen in the future. Table III shows that the Cd and Pb intake via rice is the highest in this study compared to the studies in other countries. This high value is due to the fact that the large amount of fertilizer used in rice fields and these fertilizers had high values of Cd. As discussed, Iranian weekly Cd and Pb intake from rice was above the maximum weekly intake recommended but these values for Cd are 7-32% in Japanese (Shimbo *et al*., 2001) and Taiwan people intake is 3% of total diet (Lin *et al*., 2004). Approximately 50% of the Cd daily intake of Indonesian comes from rice (Rivai *et al*., 1990). Thus, health risk of Cd and Pb intake is high in Iran and also this risk will increase with consumption of vegetable, fish etc in the future. Periodical monitoring of rate of contamination and consumption is necessary to assess the overall exposure level in Community. Also, it is recommended to treat and remediate the polluted soils and environment by preventing of using more fertilizer for reduction in health risks.

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