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Potential Health Risk of Total Arsenic from Consumption of Farm Rice (*Oryza sativa*) from the Southern Caspian Sea Littoral and from Imported Rice in Iran

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Abstract In this study, Arsenic (As) was measured in several varieties of imported and local cultivated rice. Soil samples collected from rice farms situated in south Caspian Sea (Iran) were also studied. The mean concentration of As in imported rice, local farmed rice and soil, were determined as 0.28, 0.39 and 3.80 μg g^{-1} dry weight, respectively. Estimated daily intake of As through human consumption of imported and local produced rice was 0.77 and 1.074 μg day^{-1} kg^{-1} B.W., respectively. These values are much lower than the tolerable daily intakes estimated by JECFA. The As concentration in the soil (3.80 μg g^{-1} dry) was below acceptable limit for agricultural soil of 20.0 mg kg^{-1} as recommended by the European Community (EC). No correlation between the As concentrations in rice and soil samples was found ($p > 0.05$).

Keywords Rice · Soil · Arsenic · Iran

Arsenic (As) is a ubiquitous metalloid, derived from natural and anthropogenic sources. High exposure to inorganic As in natural environments such as water, sediment and soil have proved to be toxic for plants, animals, and humans. Accumulation of As in crops grown in polluted areas has raised concern about As ingestion through diet (Sarkar 2002). It is well-known that ingestion of contaminants in excessive amounts can have detrimental effects on health (Lowik 1996). Chronic As poisoning can cause serious health effects including cancers, melanosis, hyperkeratosis, restrictive lung disease, peripheral vascular disease, gangrene, diabetes mellitus, hypertension, and ischaemic heart disease (Das et al. 2004, Rahman 2002). According to the Codex Committee for Food Additives and Contaminants, dietary intake of heavy metals is of high public concern and needs to be monitored on a regular basis and rapidly updated to identify changes in recent dietary intake. Rice (*Oryza sativa*) is one of the main foodstuffs for the population in Iran (Samadi and Atashbozorg 2006). However, there have not been any studies conducted to estimate the content of As in rice and/or its intake by consumers in Iran.

Therefore, this study attempted to estimate the daily intake levels of As through rice consumption in Iran and to assess the potential health risk, as baseline research.

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Materials and Methods

In November 2009, samples of soil (n = 20) and local cultivated rice (n = 20) were collected from Mazandaran province on the Caspian Sea littoral, in the north of Iran. Samples of imported rice (from India, n = 15) were obtained from local markets. Each topsoil sample (0–20 cm) taken from private Iranian rice farms, was obtained by mixing at least five adjacent topsoil samples (4 corners and the centre; approximately 10 × *10 m^2). The samples of rice grain corresponding to each soil sample were bought from farmers. The soil samples were dried in a hot air oven at 60° +C for 72 h, then ground, and passed through a 2.0 mm pore-size sieve. The rice grain samples were washed thoroughly with tap water and then were rinsed with de-ionized water. Finally, they were dried

Table 1 Instrumental parameters

ICP-OES	
Power output	Of 700–1,700 W in 50 W increments
RF generator	40 MHz free-running
Nebulizer gas	High precision pressure regulator
Plasma gas	0–22.5 L min^{-1}
Auxiliary gas	0–2.25 L min^{-1}
Observation height	20 mm
Wavelength (As)	188.980 nm

at room temperature for 72 h. Portion of the soil and the rice grain samples were digested separately, following the heating block digestion procedure i.e. HNO_3+$HCLO_4$ for rice and in addition H_2SO_4 for soil samples (Rahman et al. 2007).

The As content was measured by ICP-OES Varian ES 710, Table 1 highlights some basic information about the instruments used and the operating conditions of the ICP-OES. The analytical methodologies were confirmed using standard reference materials (SRM), rice flour SRM 1568 and fly ash SRM 1633b (National Institute of Standards and Technology). The recovery of As was 93% ± 8 and 90% ± 5 for rice and ash, respectively. Detection limit of the method was 0.001 mg/kg dry weight. The SPSS version 15 for Windows was used for the statistical analysis. The test for significance of different parameters was computed by t test at $p = 0.05$ levels of significance. Pearson's correlation was carried out between the As concentration in the soil and the rice samples and between the As concentration in the soil or the rice samples with soil parameters (pH and organic carbon).

The health hazards for As in foodstuffs (e.g. rice grain for humans) depend on a number of factors, including (1) the concentration of As; (2) the present As species; and (3) how the As species are metabolized in the human body (Abedin et al. 2002). However, only the first factor was assessed in the present study.

To assess the potential health risks, the tolerable daily intake (TDI) were first calculated according to the provisional tolerable weekly intake (PTWI, given by JECFA[1]) (UNEP 1992; WHO 1993) as follows:

$$\mathrm{TDI} = \mathrm{PTWI}/7 \quad \mathrm{TDI} = 350/7 = 50\left(\mu\mathrm{g\,day^{-1}\,kg^{-1}\,bw}\right)\cdot$$

Then the estimated daily intake (EDI) of As through rice consumption by the local population was calculated as follow:

$$\mathrm{EDI} = \frac{C \times Cons}{Bw}\left(\mu\mathrm{g\,day^{-1}\,kg^{-1}\,bw}\right)$$

[1] Joint FAO/WHO Expert Committee on Food Additives.

Table 2 Arsenic concentration in samples (μg g^{-1} dry weight)

	Soil	Local rice	Imported rice
Number	20	20	15
Mean	3.802	0.390	0.280
Standard deviation	2.823	0.194	0.186
Range	0.018–8.592	0.115–0.800	*Nd—0.670

* Not detected

Table 3 Mean estimated daily intake by a 60 kg body weight person (μg day^{-1} kg^{-1} b.w)

	TDI (As) (μg day^{-1} kg^{-1} bw)	EDI	*% TDI
Local rice	50	1.074	2.148
Imported rice		0.770	1.540

* Represents EDI percentage of TDI

where C is the concentration of the As in contaminated rice, $Cons$ stands for the daily average rice consumption in the region, and Bw represents the body weight set to 60 kg in this study.

Finally, the tolerable daily intake (TDI) was compared with the estimated daily intake (EDI) to assess the potential health risks (Fu et al. 2008).

Results and Discussion

The As concentration in the imported rice, in the local most cultivated rice and the relevant soil samples were found to be 0.28, 0.39, and 3.80-μg g^{-1} dry weight, respectively. In Table 2 the number of samples, means, and standard deviations are presented.

Bhattacharya et al. (2009) reported that the As concentrations ranged from 0.05–0.58 and 0.11–9.72 mg kg^{-1} in rice and soil samples, respectively, in west Bengal (India). The As concentration in present study of the imported rice (from India) was 0.28 μg g^{-1} which is in agreement with the above-mentioned range.

There was no significant difference between the As concentrations in local and imported rice ($p > 0.05$) in Iran.

Furthermore, Table 3 shows the comparison of EDI with TDI for As. Compared with the safety standard for As set by JECFA, i.e. TDI of 50 μg/g body weight/day, the estimated As intake level in this study was 15.36% and 10.77% of TDI for local and imported rice, respectively, corresponding to the TDI standard.

Munoz et al. (2005) observed that the daily intake of As via dietary exposure were lower than the TDI given by

Table 4 Soil characteristics

Soil parameters	Values
pH	7.04–7.426
Organic matter (%)	1.534–2.245
Clay (%)	14.4–52.64
Sand (%)	28–74.48
Silt (%)	5.8–38
Texture	Clay loam

Table 5 Correlation coefficients (*r*) among arsenic concentrations in soil and rice grain and soil parameters (pH and OM)

	pH		Organic matter	
	Soil	Rice grain	Soil	Rice grain
As	−0.229	0.396	−0.314	−0.074

FAO/WHO in Chile. Lee et al. (2006) reported that the weekly intake of As via food by the Korean population was 38.5% PTWI.

Our results showed that the As concentration in the soil samples (3.80 µg g^{-1} dry weight) was below the maximum acceptable limit for agricultural soil of 20.0 mg kg^{-1} (20 µg g^{-1}) as recommended by the European Community (Bhattacharya et al. 2009).

In addition, the results showed that there was no significant correlation between the As concentrations in soil and rice grain ($r = 0.002$, $p = 0.995$) which is in good agreement with Fu et al. (2008) and Rahman et al. (2008). Zhao et al. (2009) reported that the total heavy metals concentrations alone in the soil, cannot reliably predict the availability of most heavy metals in rice.

In general, there is an increase in the As toxicity effects on plants, as the soil becomes acidic, particularly at pH below 5 (Rahman et al. 2008). Therefore, it is relevant to know about these soil properties in order to evaluate the influence of As on its accumulation in rice as well as on soil properties. Soil parameters including pH and OM are presented in Table 4. Concerning the relation between the As concentration in the soil and rice grain with soil parameters investigated, no significant correlation was observed between the As concentration in the part under study and the soil parameters (Table 5). Bhattacharya et al. (2009) reported a strong negative significant correlation between the pH of the soil and the As concentration in rice grain, which is in disagreement with this study. But Zhao et al. (2009) reported that no significant correlation between the soil pH and the As concentration in rice grain was not observed.

In this study, the As concentration of the imported and local rice as well as the soil, was determined to be lower than the maximum allowable concentration according to international standards.

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