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Stochastic exposure and health risk assessment of rice contamination to the heavy metals in the market of Iranshahr, Iran

Babak Djahed[a], Mahmoud Taghavi[b], Mehdi Farzadkia[c], Samira Norzaee[a,*], Mohammad Miri[d]

[a] Department of Environmental Health Engineering, Iranshahr University of Medical Sciences, Iranshahr, Iran
[b] Department of Environmental Health Engineering, Gonabad University of Medical Sciences, Gonabad, Iran
[c] Department of Environmental Health Engineering, School of Public Health, Iran University of Medical Sciences, Tehran, Iran
[d] Department of Environmental Health Engineering, School of Public Health, Sabzevar University of Medical Sciences, Sabzevar, Iran

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ABSTRACT

An investigation of some heavy metals content in rice (Oryza sativa) and associated health risks was carried out for residents of Iranshahr city, Iran. Average daily rice consumption of the citizens and most widely used rice brands in the market of Iranshahr were determined using a questionnaire. Besides, the concentration of heavy metals in the gathered rice samples was measured by inductively coupled plasma mass spectrometry (ICP-MS). Monte Carlo uncertainty simulation was utilized in conducting exposure assessment and investigating the non-carcinogenic effects of the studied elements as well as the carcinogenic effect of As. Concentrations of As, Cd, Pb, Cu, Al, and Mo were 0.369 ± 0.094, 0.0337 ± 0.039, 0.123 ± 0.14, 3.095 ± 439.42, 39.6 ± 14.73, and 1.106 ± 0.133 mg kg^{-1}, respectively. Al (0.18 ± 0.15 mg kg^{-1} d^{-1}) and Cd (0.00015 ± 0.00034 mg kg^{-1} d^{-1}) were the highest and lowest estimated daily intake, respectively. Except As (5.23 ± 4.01), the calculated hazard quotient for investigated elements showed no non-carcinogenic health risk. Besides, the simulation of the carcinogenic risk effect for As (2.37E-3) revealed that the ingestion of the studied rice brands would cause cancer risk due to lifetime consumption. Results show that consumption of rice in the Iranshahr city is a potential source of exposure to the studied elements.

1. Introduction

According to the statistics of the World Food Organization (FAO), rice (Oryza sativa) is one of the most consumed cereals among various agricultural products (Malakootian et al., 2011; Shokrzadeh et al., 2013). Rice is the staple food of more than half of the world's population (17 Asian and Pacific countries, nine countries in the South and North America, and eight countries in Africa) (Al-Saleh and Abduljabbar, 2017; Mehrnia, 2013; Sharma et al., 2018). In Iran, among the various foodstuffs, rice is one of the main components of diet (Naseri et al., 2015).

In this regard, several studies have revealed dietary intake through contaminated foods has become the main pathway of heavy metal intake by humans (Chen et al., 2018; Miri et al., 2017). Heavy metals are one of the most important contaminants of the environment as they have long biological half-lives, are non-biodegradable, and some are toxic even at very low concentrations (Ghaneian et al., 2017; Ghasemi et al., 2017; Sanchooli Moghaddam et al., 2016; Taghavi et al., 2015; Zazouli et al., 2013). Moreover, it has been illustrated that consumption of contaminated food to heavy metals causes considerable health problems (Dadar et al., 2017; Lei et al., 2015; Shahsavani et al., 2017). These elements are released into the environment from both natural and anthropogenic activities (Al-Saleh and Abduljabbar, 2017). Besides, agriculture with the irregular utilization of agrochemicals such as fertilizers and pesticides, along with mechanical cultivation, have contaminated agricultural crops to the heavy metals (Satpathy et al., 2014). Among different crops, rice can accumulate heavy metals from its environment at significant concentrations, which can lead to serious human health risks (Fang et al., 2014; Shadborestan et al., 2013). Hence, the continuous monitoring of these hazardous elements in rice is of great importance. Consequently, in many studies, contamination of this foodstuff to the heavy metals has been reported (Cao et al., 2010; Huang et al., 2013; Jorhem et al., 2008; Orisakwe et al., 2012; Rahman et al., 2014). Some studies conducted in Iran have shown the contamination of rice to be caused by some heavy metals (Naseri et al., 2015; Zazouli et al., 2006b, 2006c, 2010). In the southeast of Iran, rice is regarded as a staple food and one of the main dietary exposures to heavy metals. Inhabitants of Iranshahr (located in the southeast of Iran)

* Corresponding author.
E-mail addresses: Babak.Djahed@gmail.com (B. Djahed), taghavi66@yahoo.com (M. Taghavi), s.norzayie@gmail.com, s.norzaee@irshums.ac.ir (S. Norzaee), m_miri87@yahoo.com (M. Miri).

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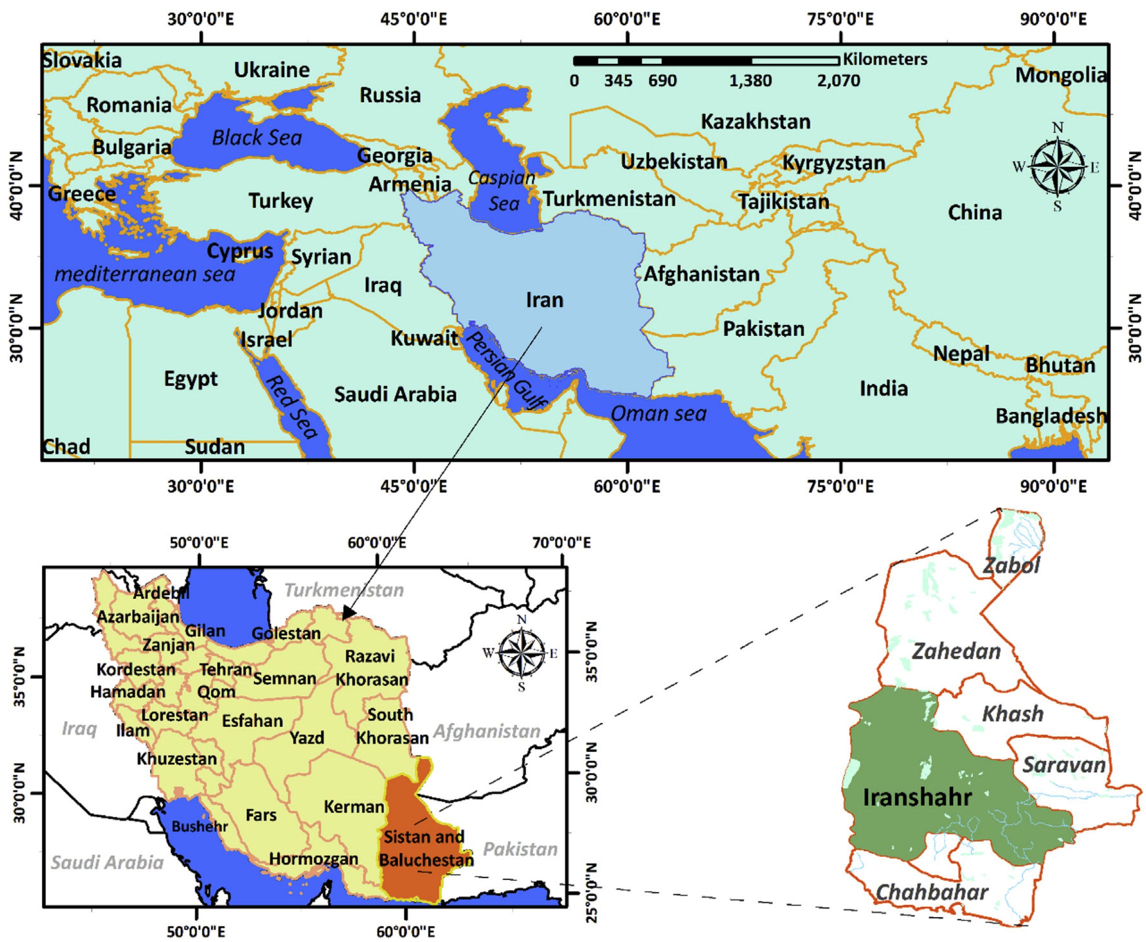

Fig. 1. Location of the sampling area, Sistan and Baluchestan province, Iran.

consume high levels of rice compared to the people living in other parts of Iran. Therefore, they may be vulnerable to the ingress of a considerable concentration of heavy metals into their body. Hence, the current study aim to measure the concentration of six heavy metals (namely Arsenic (As), Cadmium (Cd), Lead (Pb), Copper (Cu), Aluminum (Al), and Molybdenum (Mo)) in the rice available in the market of Iranshahr city, followed by determining the health risk related to consumers through an exposure assessment.

2. Materials and methods

2.1. Study site

The present study was conducted in Iranshahr city (27°12′09″ N latitude 60°41′05″ E longitude and 519 m above the sea level), located in the southeast of Iran in the Sistan and Baluchestan province (Fig. 1). The area of this city is 30,200 km^2 and it is about 1518 km from Tehran, the capital of Iran. Iranshahr has a hot desert climate with extremely hot summers and mild winters. It has a population of 131,232, the majority of which are farmers. Due to the city's geographical location, the culture of the people living in Iranshahr is close to the culture of southern Asia inhabitants.

2.2. Sampling and rice consumption rate

In order to conduct the exposure assessment and determine the highest used polished rice brands of Iranshahr, among the resident families who came to the health centers for receiving services, 258 questionnaires were distributed randomly. In the prepared questionnaire, the city inhabitants were asked about the brand of rice they generally used. In addition, they were asked how many times a day and a week their family consumed rice. After determining the 12 most widely used rice brands in the market of Iranshahr, three samples of each brand were considered. From each taken sample, 100 g was kept in polyethylene containers and then transferred to the laboratory to analyze the concentration of heavy metals.

2.3. Sample pretreatment and analysis

Rice samples were washed three times by deionized water to remove dust and impurities, and were dried in an oven for 72 h. The samples were then ground by a blender and sieved using a 1 mm-mesh sieve before digestion. After that, 0.5 g of powder sample was digested in 4 mL of HNO_3 ($\geq$69% w/w), as well as 1 mL of H_2O_2 ($\geq$30% v/v) in a microwave oven vessel (MLS 1200, Milestone, FKV, Italy). Afterward, the following heating program was used by the microwave oven: 250 W for 1 min, 0 W for 2 min, 250 W for 5 min, 400 W for 5 min, and 600 W for 5 min. The prepared sample was diluted with 25 ml Milli-Q water and analyzed using inductively coupled plasma mass spectrometry (Agilent 7500cx, Agilent Scientific Technology Ltd., USA). In order to survey the accuracy of the analytical procedures, appropriate certified reference materials (NIST-SRM-1568b) were analyzed under the same conditions as for the samples. The obtained results of average recoveries from certified reference material analysis and the determined limit of detection (LOD) for the measured elements are presented in Table 1. For more accurate results, glassware was properly cleaned by ultra-pure HNO_3 and double-distilled deionized water, and the ICP-MS was calibrated and tuned after measuring 20 samples using calibration