

Assessment of Arsenic Concentrations and Estimated Daily Intake of Arsenic from Rice (*Oryza sativa*) in Ron Phibun District, Southern Thailand

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Abstract—Arsenic is a chemical element present in the environmental from both natural and human source. The accumulation of the excessive amounts of arsenic in rice can cause health problems in consumer as rice is a staple food mainly consumed in Thailand. The purpose of this study was to investigate the concentrations of arsenic in local rice grains and to assess the exposure to arsenic through local rice consumption. Rice samples were randomly collected from three sub districts of Ron Phibun district based on the rice cultivation areas. The concentrations of arsenic contaminated in rice sample cultivated in Ron Phibun district, southern Thailand, the abandoned tin mining site, were investigated using inductively coupled plasma optical emission spectrometry (ICP-OES) coupled with microwave-assisted technique under high pressure and temperature conditions. The estimated daily intake, common index for metal transfer from plant to human, was used to assess the health risk from arsenic through local rice consumption. It is found that the arsenic concentrations were in the range of 0.291-1.361 mg/kg which were lower than Thai FDA recommendation. The estimated daily intake (EDI) of arsenic by the local people ranged from 1.522 to 7.120 µg/day kg body weight. Although the estimated daily intake values of arsenic through rice consumption were lower than the standard, the potential health risk from exposure to arsenic need more attention.

Index Terms—Arsenic, estimated daily intake, heavy metal, rice.

I. INTRODUCTION

Thailand is one of the largest rice exporter in the world. Rice is the main food for domestic consumption and is one of the most important economic crop in Thailand. People can be exposed to heavy metal through the rice consumption. Ron Phibun district, Nakhon Si Thammarat province, located in southern Thailand, has a regional history of arsenic contamination. Geologically, Ron Phibun is part of the Southeast Asian Tin Belt [1]. Many research have been carried out on the assessment of potential health risks for inhabitants in the vicinity of hazardous sites through their

exposure to environmental heavy metals via consumption of farm crops [2]-[10]. Skin cancer was first reported in 1987 among other observed symptoms. Several health risk studies have been carried out in Ron Phibun [1], [11], [12]. Arsenic, the toxic heavy metal, has been identified as health risk by World Health Organization [13]. It is a chemical element presents in the environment from both natural and human sources, including erosion of arsenic-containing rocks, volcanic eruptions, contamination from mining and smelting ores, and the use of arsenic compounds as medicines, herbicides and wood preservatives. It is found in water, air, soil and foods [14]. Chronic exposure of arsenic includes dermal lesions, peripheral neuropathy, skin cancer, and peripheral vascular disease. Major dermatological signs are melano-keratosis, melanosis, spotted and diffuse keratosis, leucomelanosis, and dorsal keratosis [15]. Arsenic is taken up by plants through pathways for nutrients. Compared with other cereals, such as wheat and barley, rice has generally a much higher arsenic concentration due to rice being the only major cereal crop grown under flooded conditions. This leads to both arsenate and arsenite building up in high concentrations close to the root and have evolved efficient mechanisms of capturing them from soil solution [16].

It has been reported that the consumption of local rice grown in the arsenic contaminated soil was one of the major source of arsenic exposure to the population [17]. Several studies have reported the accumulation of arsenic in rice grains cultivated in regions with high levels of arsenic in groundwater [18]-[20].

Dietary intake is the main route of exposure to heavy metals for most people [21]. The information about heavy metal concentrations in food and the dietary intake is very important for risk assessment of human health [22]. The WHO provisional guideline value of arsenic in food is 0.02 mg/kg and a Maximum Allowable Daily Body Load (MADL) of total arsenic of 50 µg/kg bw/day was set in 1967 by the WHO. This study was aimed to investigate the concentration of arsenic in rice cultivated in the vicinity of the abandoned Tin mining site and evaluate the estimated exposure of arsenic through rice consumption.

II. MATERIALS AND METHODS

A. Study Area

Ron Phibun District, Nakhon Si Thammarat Province is located in the southern part of Thailand as depicted in Fig. 1. Ron Phibun district was selected for the study area due to the occurrence of arsenic contamination and the adverse effects

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of arsenic exposure to human health. Sample were randomly collected from three sub districts of Ron Phibun district including of Khuan Chum, Khuan Koei and Khuan Phang

selected based on the rice cultivation areas. The sampling locations were identified by Global Positioning System (GPS) receiver (see Table I).



Fig. 1. Ron Phibun district, Nakhon Si Thammarat province located in southern Thailand.

B. Sample Preparation and Analysis

A total of five rice samples were collected and gently washed with Milli-Q water to remove the dust particles. Then the samples were dried in a hot air oven to obtain the constant weight and digested with nitric acid in the Teflon microwave vessel under high pressure and temperature conditions with microwave-assisted technique according to EPA Method 3051. Rice digested solutions were filtered and analyzed for arsenic using inductively coupled plasma optical emission spectrometry (ICP-OES) according to EPA Method 6010. Precision and accuracy of analysis were ensured by blank and quality control standard in duplicate. The certified standard and a blank solution were run. Deionized water was used throughout the laboratory test. All reagents were of analytical grade. Recoveries obtained with the proposed method were over 95%.

C. Estimated Daily Intake (EDI)

The estimated daily intake, common index for metal transfer from plant to human, to obtain the estimation of dietary exposure is calculated as follows [23]:

$$EDI = \frac{C \times Cons}{Bw} \quad (1)$$

where C stand for the concentration of arsenic in rice; Cons

represents daily average consumption of rice; and Bw is the body weight. The risk characterization is based on an average adult weighting 60 kg.

III. RESULTS AND DISCUSSIONS

A. Concentrations of Arsenic in Rice Samples

Rice samples collected from three sub districts exhibits arsenic concentrations in the range of 0.291-1.361 mg/kg as shown in Table II. The highest concentration of arsenic was found in Khun Chum sub district at 1.361 $\mu\text{g/kg}$ and while others ranged from 0.291 to 0.619 $\mu\text{g/kg}$. All samples were not exceeded the maximum permitted level recommended in Thai FDA and WHO standard (2 mg/kg).

B. Estimated Daily Intake of Arsenic

A study of risk assessment of arsenic were carried out. The local people was assumed to consume the local rice. In Thailand, rice consumption per capita is 114.57 kg/yr [24]. The body weight was set to 60 kg. The provisional tolerable weekly intake (PTWI) of 15 $\mu\text{g/kg bw/week}$ (equivalent to 2.1 $\mu\text{g/kg bw/day}$) for inorganic arsenic was recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) [25]. The estimated daily intake of arsenic through rice consumption, shown in Table II, were ranged from 1.522 to 7.120 $\mu\text{g/day kg body weight}$ which are

lower than a Maximum Allowable Daily Body Load (MADL) of total arsenic of 50 µg/kg bw/day set in 1967 by the Thai FDA and WHO.

TABLE I: RICE SAMPLING SITES

Sample	Location (Sub district)	Latitude	Longitude
R1	Khuan Chum	8.18827	99.90088
R2	Khuan Koei	8.10953	99.90281
R3	Khuan Koei	8.11040	99.90137
R4	Khuan Phang	8.15155	99.94498
R5	Khuan Phang	8.15378	99.94457

TABLE II: CONCENTRATIONS OF ARSENIC IN RICE SAMPLES AND EDI

Sample	Location (Sub district)	Concentration of arsenic (µg/kg)	EDI (µg/day kg bw)
R1	Khuan Chum	1.361	7.120
R2	Khuan Koei	0.619	3.238
R3	Khuan Koei	0.538	2.815
R4	Khuan Phang	0.600	3.139
R5	Khuan Phang	0.291	1.522

The results of study showed the lower concentration of arsenic in rice samples than the Thai FDA and WHO criteria. Moreover, arsenic estimated daily intake exposed by rice consumption also showed that the arsenic daily intake in Ron Phibun district is lower than the MADL.

IV. CONCLUSIONS

Since Ron Phibun district has a long history of tin mining, therefore the large amounts of arsenic released into the environment were historically reported. Rice cultivation areas in Ron Phibun district have been transformed to other economic crop farming, i.e., rubber tree and palm, and the industrial zone, therefore, rice production are mainly for household consumption. Thus the ingestion of self-planted rice was considered to be the main exposure route of arsenic which causes the health risk for local people. Moreover, the contamination of arsenic in rice and the level of arsenic exposure to environment and the nearby agricultural area should be monitored and concerned. Long-term heavy metal through the regular consumption of rice and vegetables and the ingestion of heavy metal from water and soil in the vicinity of mining site should be further investigated. Greater attention for protective measure to avoid the potential health risk through the consumption of local crops and the ingestion of contaminated soil and water around the former mining site should also be considered, regulated and advised to the local population.

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