Bull Environ Contam Toxicol (2010) 84:285–288
DOI 10.1007/s00128-009-9928-9

Cadmium Content of Commercial and Contaminated Rice, *Oryza sativa*, in Thailand and Potential Health Implications

R. Zwicker · A. Promsawad · B. M. Zwicker · S. Laoharojanaphand

Received: 30 July 2009 / Accepted: 17 December 2009 / Published online: 29 December 2009

Abstract Thailand is the number one global exporter and among the top five producers of rice in the world. A significant increase in anthropogenic contamination in agricultural soils over the past few decades has lead to concerns with cadmium and its uptake in rice. The cadmium levels in Thai rice from different sources/areas were determined and used to estimate the potential health risks to consumers. The cadmium concentration in the commercial rice samples ranged from below the detection limit to 0.016 mg/kg. The cadmium concentrations in the contaminated rice samples ranged from a low of 0.007 mg/kg to a high of 0.579 mg/kg. Five of the calculated values exceed the proposed PTWI, with one value almost three times higher and two values almost double. The three highly elevated values are certainly a concern from a health standpoint. Ultimately, action is required to address the health implications resulting from the cadmium contamination in agricultural soils used for rice production in a few select areas of Thailand. Overall, this study indicates that the vast majority of rice produced, consumed and exported by Thailand is safe pertaining to cadmium content.

R. Zwicker · S. Laoharojanaphand
Ministry of Science and Technology, Thailand Institute of Nuclear Technology (Public Organization), 16 Vibhavadi Rangsit Rd., Bangkok, Chatuchak 10900, Thailand

A. Promsawad
Department of Chemistry, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand

R. Zwicker (✉) · B. M. Zwicker
SLOWPOKE-2 Facility, Department of Chemistry, Dalhousie University, Halifax, NS B3H 4J3, Canada
e-mail: pl378712@dal.ca

Keywords Cadmium · Thailand · Rice · Weekly intake

Thailand is the number one global exporter and among the top five producers of rice in the world (USDA 2008). This rice is of high quality, which ordinarily is in constant demand internationally. It remains the primary food source for Thailand, particularly in rural areas. Although agriculture is no longer the predominant source of national income, it is an economic and employment stabilizer during financially difficult periods. Plainly stated, rice is extremely important to the country of Thailand and its citizens. In the past few decades, Thailand has experienced a period of economic growth resulting in additional industrialization and urbanization. Leading to a significant increase in anthropogenic contamination in associated agricultural soils, many used for rice production. One of the main concerns with this contamination is the heavy metal cadmium and its uptake in rice.

Power stations, metalworking industries, incineration of wastes, combustion of fossil fuels and fertilizers are the principal sources of cadmium discharge into the environment (Nriagu and Pacyna 1988). The culmination of the cadmium discharge is soil contamination through emissions and wastewater. If the contaminated soils are agricultural in nature, then cadmium transfer into feed crops, such as rice is a concern. Concern of cadmium in rice has caught significant attention in parts of the world where rice is the major food staple, like Japan as well as other Asian countries. Cadmium is not an essential element for plants or animals; conversely, it is toxic at elevated concentrations. Once ingested or absorbed by humans, it has a long biological half-life and causes numerous health concerns. The purpose of this study was to determine cadmium levels in Thai rice from different sources/areas, with some areas contaminated through industrial activity. If determined cadmium levels in rice are elevated, then to estimate the potential health risks to consumers.

Materials and Methods

Two or three random samples of eight different commercial varieties of rice purchased from markets in Bangkok and eleven collected directly from rice plants in the field from known contaminated areas were analyzed for cadmium. The resulting 50 samples in total covered most varieties of rice consumed and included many of the known contaminated rice producing areas in Thailand.

The determination of cadmium in rice samples was based on the method developed by Bedregal and Montoya (2002) with several modifications. Briefly stated, rice samples were ground into flour and then 1 g. was accurately weighed and sealed in a polyethylene bag, which had been pre-cleaned with 5% nitric acid. Cadmium standards (ICP-AES standard solutions from SCP Science) were prepared by spotting a cadmium solution containing 0.5 μg on filter paper, which were also sealed in pre-cleaned polyethylene bags. The samples and standards were then irradiated in the Thai Research Reactor-1/Modification 1 (TRR-1/M1) at the Thailand Institute of Nuclear Technology with a neutron flux of 5.8×10^{11} cm^{-2} s^{-1} for 3 days.

After 3 days of decay, the samples were digested as previously described (Promsawad et al. 2008). The cadmium chloride complex solution was then passed through an ion exchange column packed with BIO-RAD, AG1x8, 100–200 mesh (chloride form) resin, which had been preconditioned with 10 ml. of 2 M HCl. The cadmium was absorbed onto the resin and then eluted from the column using 10 ml. of 8-M NH_3, resulting in a chemical yield of 95 % (Promsawad et al. 2008).

Immediately following collection of the cadmium from the column, the solution was placed on an ORTEC HpGe gamma-ray spectrometry (FWHM of 1.77 keV at 1.33 MeV, ^{60}Co, rel. eff. 20% and a peak-to-Compton ratio of 53:1) for a counting period of 3 h. The prepared cadmium standards were also given 3-days decay and counted for 3-h. The Maestro-32 (ver.5.10 A65-B32) for Windows 95/98NT (Perkin-Elmer Instruments) software was used for photopeak quantification.

All reagents used were analytical grade or better and the water used was of high-purity throughout. Two certified reference materials were analyzed (Table 1), one in duplicate and the other five-fold to insure analytical accuracy and precision of the method. The RNAA method eliminates the possibility of sample contamination during digestion and separation while results of uncontaminated rice samples suggest contamination was not a concern. The statistical variability between duplicate or triplicate analysis of samples indicates adequate sample homogeneity. The recovery rates for cadmium in Bovine Liver (SRM 1577b) were 92% and 84% for Oyster Tissue (SRM 1566b) The detection limit for the method was determined using the following formula: $DL = 2.71 + 3.29[B(1 + n/2n)]^{1/2}$ (Gilmore and Hamingway 1995). The estimated weekly intake (WI) of cadmium through rice consumption was calculated using WI = [(daily rice consumption) × 7 × (cadmium concentration in rice, μg/kg)]/average body weight, kg (Simmons et al. 2005). These estimated values were evaluated using limits determined by international agencies regarding health and long-term exposure to cadmium.

Results and Discussion

Cadmium concentrations determined in the commercial and contaminated rice samples are provided in Table 2. The cadmium concentration in the commercial rice samples ranged from below the detection limit (DL) to 0.016 mg/kg. Most samples are below the method detection limit of 0.006 mg/kg. All the commercial rice samples are well below the limit proposed by the Codex Committee on Food Additives and Contaminants (CCFAC) of 0.4 mg/kg for polished rice (ALINORM 2006). However, upon examination of the cadmium concentrations found in the contaminated rice samples, one exceeds the limit and several are very close to the limit. The contaminated samples ranged from a low of 0.007 mg/kg to a high of 0.579 mg/kg.

The cadmium concentrations found in the commercial rice from Thailand in this study are lower or in agreement

Table 1 Concentration of cadmium in certified reference materials

CRM	Mean ± SD[a] (mg/kg)	No. of replicates (n)	Certified value (mg/kg)
NIST SRM 1577b (Bovine liver)	0.46 ± 0.01	5	0.50
NIST SRM 1566b (Oyster tissue)	2.35 ± 0.03	2	2.8

[a] *SD* standard deviation

Table 2 Cadmium concentration in Thai rice from commercial and contaminated sources

Commercial rice		Rice from contaminated locations	
Rice sample	Mean Cd conc. (mg/kg)	Rice sample	Mean Cd conc. (mg/kg)
Leb nok rice	0.0065	No. 1	0.2700
Cho long rice	<DL[a]	No. 2	0.0376
Boton rice	<DL	No. 3	0.3048
Chiang rai sticky rice	0.0160	No. 4	0.3607
Man pu jasmine rice	<DL	No. 5	0.5789
Keaw ngue sticky rice	<DL	No. 6	0.3434
Patumthani 1 jasmine rice	<DL	No. 7	0.1949
Jasmine rice	<DL	No. 8	0.1293
		No. 9	0.1517
		No. 10	0.0074
		No. 11	0.0851

[a] *DL* detection limit

with those from previously published values. Jorhem et al. (2008) found mean values ranging from 0.010 to 0.025 mg/kg cadmium in Thai commercial rice. Other studies found mean cadmium in Thai rice values of 0.05 mg/kg (Zarcinas et al. 2004); 0.011–0.022 mg/kg (Rivai et al. 1990).

The cadmium concentrations in the contaminated rice samples ranged from a low of 0.007 mg/kg to a high of 0.579 mg/kg. In general, they were lower than other published values for cadmium in contaminated rice originating from Thailand and China. Simmons et al. (2005, 2008) completed two studies from an area contaminated by a nearby mining operation in Thailand, where rice samples contained 0.02–7.75 mg/kg of cadmium. Two studies from contaminated sites in China revealed elevated cadmium levels in rice ranging from 0.21 to 2.4 mg/kg (Dong et al. 2001; Nordberg and ChinaCad Group 2003). Despite being lower, cadmium concentrations in contaminated rice samples from this study may constitute a health risk to the consumer.

Therefore, health concerns from the cadmium contaminated rice samples were evaluated by calculating the estimated weekly intake (WI) for consumers of this rice. The quantity for daily rice consumption was estimated to be 0.3 kg (Kosulwat 2002) for a 60 kg adult. The results of these calculations are illustrated in Fig. 1. The provisional tolerable weekly intake (PTWI) proposed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) of 7 μg Cd per kg body weight per week (JECFA 2005) was used as the guideline to evaluate the estimated WI values. Five of the calculated values exceed the proposed PTWI, with one value almost three times higher and two values almost double. These three values are certainly a

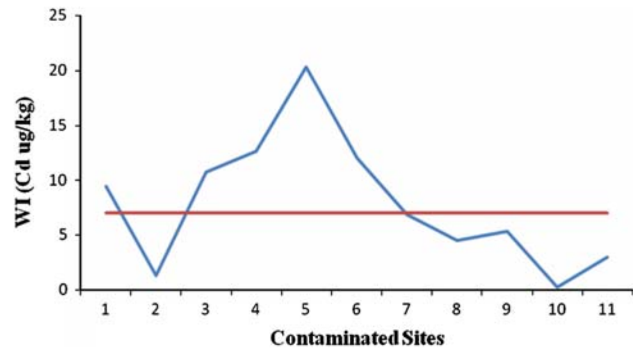

Fig. 1 Weekly intake of cadmium from contaminated rice

concern from a health standpoint. Long-term consumers would be at risk of suffering some or all of the consequences of excessive cadmium exposure. Such as "itai-itai disease", permanent damage to organs like the kidney and liver, as well as, the possibility of inhibiting calcium absorption by the body (Friberg et al. 1992). The health related effects of cadmium exposure have been and continue to be studied currently.

The primary despair with this situation in Thailand is the lack of governmental regulation and monitoring of contaminated agricultural areas used for rice production. Without such regulations, there is a distinct possibility that the consumption of rice contaminated with unacceptable levels of cadmium is occurring. Over the long-term, this will lead to increased health problems in the contaminated areas.

Regulations and monitoring of rice could prevent health concerns in the future and possibly insight into environmental contamination. Although there are numerous factors involved in the uptake of cadmium by rice from contaminated soils, there are numerous publications indicating a relationship between elevated cadmium levels in soil and the rice derived from this soil (Sun et al. 2008; Zarcinas et al. 2004). Monitoring cadmium in rice could provide insight into soil contamination problems. Ultimately, action is required to address the health implications resulting from the cadmium contamination in agricultural soils used for rice production in a few select areas of Thailand.

Overall, this study indicates that the vast majority of rice produced, consumed and exported by Thailand is safe; well below the guidelines for cadmium in rice set by such international agencies as Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO). The only real concern is rice produced in highly contaminated areas.

Acknowledgments We thank Arporn Busamongkol and Wuttichai Chantarachot for their assistance in sample collection and preparation.

References

ALINORM 06/29/41 (2006) Joint FAO/WHO Food Standards Programme 29th Session. Geneva, Switzerland

Bedregal PS, Montoya EH (2002) Determination of cadmium using radiochemical neutron activation analysis. J Radioanal Nucl Chem 254:363–364

Dong WQY, Cui Y, Liu X (2001) Instances of soil and crop heavy metal contamination in China. Soil Sediment Contam 10:497–510

Friberg L, Elinder CG, Kjellstrom T (1992) Environmental health criteria 134. Cadmium. WHO, Geneva

Gilmore G, Hamingway DJ (1995) Practical gamma-ray spectrometry. Wiley, Chrichester

JECFA (2005) Report of the 64th meeting of the JECFA Rome, 8–17 Feb 2005

Jorhem L, Astrand C, Sundstrom B, Baxter M, Stokes P, Lewis J, Grawe KP (2008) Elements in rice from the Swedish market: 1. Cadmium, lead and arsenic (total and inorganic). Food Addit Contam 25:284–292

Kosulwat V (2002) The nutrition and health transition in Thailand. Public Health Nutr 5:183–189

Nordberg G, ChinaCad Group (2003) Cadmium and human health: a perspective based on recent studies in China. J Trace Elem Exp Med 16:307–319

Nriagu JO, Pacyna JM (1988) Quantitative assessment of worldwide contamination of air, water and soils by trace metals. Nature 333:134–139

Promsawad A, Kongsakphaisal A, Laoharojanaphand S (2008) Determination of cadmium in rice by radiochemical neutron activation analysis. KMITL Sci J 8:12–17

Rivai IF, Koyama H, Suzuki S (1990) Cadmium content in rice and its daily intake in various countries. Bull Environ Contam Toxicol 44:910–916

Simmons RW, Pongsakul P, Saiyasitpanich D, Klinphoklap S (2005) Elevated levels of cadmium and zinc in paddy soils and elevated levels of cadmium in rice grain downstream of a zinc mineralized area in Thailand: implications for public health. Environ Geochem Health 27:501–511

Simmons RW, Noble AD, Pongsakul P, Sukreeyapongse O, Chinabut N (2008) Analysis of field-moist Cd contaminated paddy soils during rice grain fill allows reliable prediction of grain Cd levels. Plant Soil 302:125–137

Sun H, Li L, Qiao F, Liang S (2008) Availability of lead and cadmium in farmland soil and its distribution in individual plants of dry-seeded rice. Commun Soil Sci Plant Anal 39:450–460

United States Department of Agriculture (2008) Grain: world markets and trade, circular series FG 11-08

Zarcinas BA, Pongsakul P, McLaughlin MJ, Cozens G (2004) Heavy metals in soils and crops in southeast Asia. 2. Thailand. Environ Geochem Health 26:359–371