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Heavy metals in Australian grown and imported rice and vegetables on sale in Australia: Health hazard

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ABSTRACT

Dietary exposure to heavy metals is a matter of concern for human health risk through the consumption of rice, vegetables and other major foodstuffs. In the present study, we investigated concentrations of cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb), and zinc (Zn) in Australian grown and imported rice and vegetables on sale in Australia. The mean concentrations of Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn in Australian grown rice were 7.5 $\mu g\ kg^{-1}$, 21 $\mu g\ kg^{-1}$, 144 $\mu g\ kg^{-1}$, 2.9 $mg\ kg^{-1}$, 24.4 $mg\ kg^{-1}$, 166 $\mu g\ kg^{-1}$, 375 $\mu g\ kg^{-1}$, and 17.1 $mg\ kg^{-1}$ dry weight (d. wt.), respectively. Except Cd, heavy metal concentrations in Australian grown rice were higher than Bangladeshi rice on sale in Australia. However, the concentrations of Cd, Cr, Cu, and Ni in Indian rice on sale in Australia were higher than Australian grown rice. The concentrations of Cu and Ni in Vietnamese rice, and that of Cd, Cr, Cu, Ni, and Pb in Thai rice on sale in Australia were also higher than Australian grown rice. Heavy metal concentrations in Pakistani rice on sale in Australia were substantially lower than that in Australian grown rice. In Australian grown rice varieties, the concentrations of heavy metals were considerably higher in brown rice varieties than white rice varieties, indicating Australian brown rice as a potential source of dietary heavy metals for Australian consumers. The mean concentrations of heavy metals in Australian grown and Bangladeshi vegetables on sale in Australia were also determined. Some of the Australian grown and Bangladeshi vegetables contained heavy metals higher than Australian standard maximum limits indicating them as potential sources of dietary heavy metals for Australian consumers. Further investigation is required to estimate health risks of heavy metals from rice and vegetables consumption for Australian consumers.

1. Introduction

In addition to their essentiality for plant growth and/or human nutrition, some micronutrient elements, for example copper (Cu), chromium (Cr), molybdenum (Mo), nickel (Ni), selenium (Se) and zinc (Zn), may be toxic to both animals and humans at high concentrations (McLaughlin et al., 1999). Other trace elements, for example arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb), may also inadvertently enter the food chain and pose health risks to humans and animals. Therefore, the implications associated with metal contamination in food are of great concern, particularly in agricultural products such as rice and vegetables. Several studies have indicated that rice and vegetables, particularly leafy crops, grown in heavy metals contaminated soils have higher concentrations of heavy metals than those grown in uncontaminated soils (Al-Saleh and Shinwari, 2001; Fu et al., 2008; Guttormsen et al., 1995; Sharma et al., 2007). A major pathway of soil contamination is through atmospheric deposition of heavy metals from point sources such as metaliferous mining, smelting and industrial activities. Other non-point sources of contamination affecting predominantly agricultural soils include inputs such as fertilisers, pesticides, sewage sludge, organic manures and composts (Singh, 2001). Additionally, foliar uptake of atmospheric heavy metals emissions has also been identified as an important pathway of heavy metal contamination in vegetable crops (Salim et al., 1993, 1992).

Rice is the major staple food in many countries, particularly in Asian countries like Bangladesh, India, Thailand, China and

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Vietnam where soil and groundwater pollution with high level of As and heavy metals have been reported (Roychowdhury et al., 2003). Increased levels of As and heavy metals in agricultural soils and its uptake in rice, vegetables and other food crops has become a real health issue in this region (Meharg and Rahman, 2003; Williams et al., 2006). While a significant number of studies have focused on As in Bangladeshi and Indian rice and vegetables (Alam et al., 2003; Das et al., 2004; Karim et al., 2008; Smith et al., 2006; Rahman and Hasegawa, 2011), studies on other heavy metals in these foods are limited (Alam et al., 2003; Rahman et al., 2012a). A recent study by Rahman et al. (2012a) demonstrated that home-grown Bangladeshi vegetables from As-contaminated area are likely to be important sources of As and heavy metals for humans. Some vegetables such as bottle ground leaf, taro, and elephant foot had higher concentrations of Pb compared to Cd, and other leafy and root vegetables contained higher concentrations of Zn and Cu (Alam et al., 2003). In addition to Asian countries, As and heavy metal contamination in agricultural soils and their uptake in food crops such as rice and vegetables has also been found in Australia (Jinadasa et al., 1997; Kachenko and Singh, 2004; Kachenko and Singh, 2006; Smith et al., 2003; Tam et al., 2004). However, the health risks of heavy metals to the Australian consumers from local and imported foods on sale in Australia are yet to be fully determined. In addition, knowledge on concentrations of heavy metals in foods is essential to determine the environmental impact in agricultural food crops.

Some heavy metals are important nutrients for plants and animals, but they can be toxic to them at high concentrations. Copper is an essential nutrient for human health but long-term exposure to elevated levels of Cu can cause irritation of the nose, mouth, and eyes as well as headaches, stomach aches, dizziness, and acute gastrointestinal effects such as vomiting and diarrhoea (Rahman et al., 2012a). Inhaled Ni compounds are carcinogenic to humans although there is a lack of evidence of a carcinogenic risk of Ni from oral exposure to human (WHO, 2008; Rahman et al., 2012a). Manganese is an essential nutrient and excessive exposure to Mn has been associated with adverse health effects including neurotoxicity (Wasserman et al., 2006). Food is the main source of daily exposure to Cd, and this element may cause increased risk of tubular dysfunction (WHO, 2008). Lead can cause a variety of health problems. A prolonged period of Pb exposure causes kidney issues or high blood pressure in adults and delays in physical and mental development in children (Rahman et al., 2012a). Zinc is essential for all living organisms (Frisbie et al., 2009).

Foods and water are the two major sources of heavy metal exposure in many developing countries (WHO, 2008). The most significant concern related to human health risks from heavy metal toxicity is world-wide food chain transfer with the expansion of the global food trade, as millions more people are exposed to the increased concentrations of elements in imported food in situations where local contamination of heavy metals does not occur. Australia is a multicultural country with a significant number of immigrants from a range of countries including throughout Asia. Rice is the staple food for a large number of Asian people living in Australia. Asian immigrants living in Australia also have strong preferences for food items including vegetables which are imported from Asian countries notably Bangladesh, West Bengal (India), China, Cambodia, and Vietnam. Since high concentrations of As and heavy metals in foods from these countries has been reported (Alam et al., 2003; Fangmin et al., 2006; Fu et al., 2008; Karim et al., 2008; Sharma et al., 2007; Zhuang et al., 2009), foods on sale in Australia imported from these countries could be an important source of dietary heavy metals for Australian consumers, particularly the Asian immigrant who regularly consume these foods. The objective of the present study was to determine the concentrations of heavy metals in Australian grown rice and vegetables and those imported from Asian countries and on sale in Australia to establish whether Australian consumers are likely to be at risk of heavy metals exposure via ingestion of these foodstuffs.

2. Materials and methods

2.1. Sample collection and preparation

Fifty one rice samples of different origin (Bangladesh, Canada, India, Italy, Pakistan, Thailand, and Vietnam) were purchased from Asian shops in Sydney, Australia during the month of January 2012. Twenty three vegetable samples (frozen) of Bangladesh origin were purchased from Bangladeshi shops in Sydney, Australia during the month of November 2007. In order to compare heavy metal concentrations in Australian grown and imported rice and vegetables on sale in Australia, Australian grown rice (21 samples) and vegetable (40 samples) were also collected from supermarkets in Sydney and Adelaide, Australia. The details (country of origin, varieties and sample number for rice, and country of origin, English and scientific names, sample number for vegetables) are given in Supplementary information Tables 2–3 for rice and Supplementary information Tables 4–5 for vegetables used in this study. The collected samples were stored at 4 °C prior to further processing. After allowing the vegetable samples to equilibrate to room temperature for several hours, the samples were cut into pieces with stainless steel knife. All samples were washed with tap water (three times) followed by ultrapure (18 MΩ cm) water (twice). The samples were then dried in the open air for 24 h and in an oven at 65 °C for 48 h. Then the samples were homogenized by grinding with a glass mortar.

Concentrated nitric acid (70 percent, analytical grade obtained from Mallinckrodt Chemicals, USA) was used for the digestions of all samples as per the procedure of Rahman et al. (2009). Following digestion, tubes were removed and after cooling the samples were diluted to 20 mL with ultrapure (18 MΩ cm) water. Prior to analysis, all rice samples were filtered through 0.45 μm filter paper (Whatman 41) while vegetable samples were filtered through a 0.45 μm filter (Millex, Millipore). Elemental concentrations in rice and vegetables were determined on a dry weight (d. wt.) basis. We did not analyse Co for vegetables.

2.2. Sample analysis

An Agilent 7500ce (Agilent Technologies, Tokyo, Japan) inductively coupled plasma mass spectrometry (ICP-MS) was used for the determination of heavy metals in rice and vegetables samples. The instrumental detection limits (dl) for Cd, Co, Cr, Cu, Mn, Ni, Pb, and Zn were 0.03, 0.01, 0.03, 0.02, 0.01, 0.10, 0.05 and 0.01 $\mu g\,L^{-1}$ in solution matrix, respectively.

2.3. Analysis of standard reference materials (SRMs)

Rice flour (SRM 1568a) from the National Institute of Standard and Technology (NIST), USA and citrus leaves (NCS ZC73018) from China National Analysis Centre, China, were used as standard reference materials (SRMs). The analytical results of heavy metals in SRMs indicate that the observed values are very close (recovery 88–107 percent) to the certified values (see SI Table 1). A reagent blank and a SRM were included with each batch of sample analysis in order to check the precision of the method.

3. Results and discussion

3.1. Heavy metals in rice and vegetables

The mean and range of heavy metal concentrations in imported and Australian grown rice and vegetables are presented in Supplementary information (SI) Table 2-5. A comparison of heavy metal concentrations in rice and vegetables of different origin reported in the previous studies and observed in the present study is presented in Table 1.

3.1.1. Cadmium

Cadmium is a metallic element that occurs naturally at low levels in the environment. Food, rather than air or water, represents the major source of cadmium exposure (FSANZ, 2003). The highest Cd concentration in rice on sale in Australia was found in Bangladeshi rice (mean: 73 $\mu g\,kg^{-1}$, range: 69–77 $\mu g\,kg^{-1}$, $n=6$)