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Potential health risk in areas with high naturally-occurring cadmium background in southwestern China

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ABSTRACT

In various parts of the world, high cadmium (Cd) concentrations in environment are not related to anthropogenic contamination but have natural origins. Less is known about health risks that arise under these conditions. This study aimed to discuss the pollution of Cd with natural sources, and to investigate the concentration of Cd in food crops and the urine of inhabitants in an area of southwestern China. The results showed that the arable soils are moderately contaminated by Cd ($I_{geo}=1.51$) relative to the local background, with a high ecological risk ($E_r=218$). The chemical fractions of Cd in soils with natural sources are probably controlled by parent materials and mostly in residual phase. The average Cd concentrations were 0.68 mg kg^{-1} (fresh weight) in local vegetables, 0.04 mg kg^{-1} in rice, and 0.14 μg L^{-1} in water. Leafy vegetable tends to accumulate more Cd than the other crops. The calculated Target Hazard Quotient (THQ) had a much higher value (4.33) for Cd, suggesting that Cd represents a significant potential risk to the local population. The urinary Cd concentrations (mean at 3.92 μg L^{-1} for male and 4.85 μg L^{-1} for female) of inhabitants in the study area were significantly higher ($p<0.05$) than those from the control area (mean at 0.8 μg L^{-1} for male and 0.42 μg L^{-1} for female). Male and female test subjects had similar urinary Cd levels ($p>0.05$), but age seemed to lead to an increase in Cd in the urine. These findings show that naturally-occurring Cd in local soils is taken up appreciably by local food crops, and that dietary exposure of Cd through vegetable ingestion is a major exposure pathway for local populations, and a potential risk to public health in the study area.

1. Introduction

Cadmium (Cd) is a non-essential trace metal that is toxic to human beings, animals and plants. Cadmium generally occurs at concentrations of about 0.2 mg kg^{-1} in the lithosphere, 0.53 mg kg^{-1} in surface soils, and less than 0.66 mg kg^{-1} (dry weight) in the plant foodstuffs (Kabata-Pendias and Pendias, 2001). However, enrichment of Cd in the environment, from natural or anthropogenic sources, or both, is a major environmental concern. The anthropogenic origins are usually from sewage irrigation, fertilizer application, mining, smelting, and fuel combustion (Nriagu and Pacyna, 1988; Baveye et al., 1999; Luo et al., 2009), whereas the natural sources of Cd in soil are mainly volcanic activity and geological weathering of the parent rocks (Nriagu, 1989; Quezada-Hinojosa et al., 2009; Liu et al., 2013).

Human exposure to Cd may cause cancer, kidney and bone damage, and hematuria (Järup and Åkesson, 2009; Satarug et al., 2010; Han et al., 2013). Since the appearance of the Itai-Itai disease in Japan in 1912, the environmental impact of Cd has been the object of significant societal concern. Numerous studies have reported Cd contamination of soils, food crops, water and sediments worldwide, leading to serious potential health risks to humans (e.g., Robson et al., 2014; Zhang et al., 2014). Cadmium in soils may transfer to crops with a high soil-to-plant transfer factor, as a result of the influence of soil characteristics (pH, SOM, etc.), and physiological plant features (size of leaf, evaporation rate, etc.). The result is that crop consumption has been regarded as the primary exposure pathway for non-smoking and non-occupationally exposed populations (Järup and Åkesson, 2009; Satarug et al., 2010).

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Whereas researchers have intensively demonstrated Cd contamination of soils and crops, with subsequent health risks in areas with anthropogenic Cd pollution, little information is available about areas where Cd occurs naturally in soils, leading to elevated Cd concentrations crops (Khan et al., 2010; Liu et al., 2013). Such areas are found in various parts of the world. For example, in the Three Gorges Region of southwestern China, the weathering of Cd-rich sedimentary rocks over many centuries has produced soils that are naturally rich in Cd (Liu et al., 2013). The main health hazard in this rural area has traditionally been associated with endemic fluorosis due to the combustion of F-rich coal (Zheng et al., 1999), but the natural enrichment of Cd in the local environment has been considered to be a hidden, yet also very problematic, concern for the local populations (Tang et al., 2009; Liu et al., 2013).

Previous studies (Tang et al., 2009; Liu et al., 2013) have demonstrated the high Cd background values and distinguished the major sources of Cd in the study area. On the basis of these results, the objectives of our research were to assess the pollution level and ecological risk of Cd in the arable soils. By combining Cd concentrations in local food crops and waters, with the statistical data of local governments and other published results, the daily intake of Cd by the residents was estimated, the exposure pathways and potential health risk were assessed. In addition, urine samples were collected in the study area to identify the Cd burden of local residents. Throughout our research, efforts have been made to describe in enough detail the methodologies adopted, so that they can be implemented in other parts of the world where high geogenic background concentrations of Cd could similarly cause health risks to local populations.

2. Materials and methods

2.1. Study area

The study area is located at Jianping (109 °55′ – 109 °58'E, 31 °01′ – 31 °03′N), a rural area in Wushan County, the Three Gorges region of southwestern China (Fig. 1). The region's subtropical continental monsoon climate is warm and humid, with an annual average precipitation of 1052 mm and a mean temperature of 18 °C. The study area is part of an extensive area of karst terrain. Severe soil erosion has occurred in the region, caused by sparse vegetation cover and sloping topography. Rock outcroppings in the study area include lithologies from the Silurian to the Permian periods, mainly composed of carbonate stones, carbonaceous mudstones, siltstones, coal seams, and a few occurrences of siliceous mudstones, siliceous limestones and sandstones (Tang et al., 2009; Liu et al., 2013). There are no industrial activities or highways in the study area. Geological weathering of the parent rocks and historical rocky coal mining and combustion were demonstrated as the major sources of Cd in local soils (Liu et al., 2013). The daily consumed food crops were locally produced, except for the staple food, rice, which was purchased from markets, since no

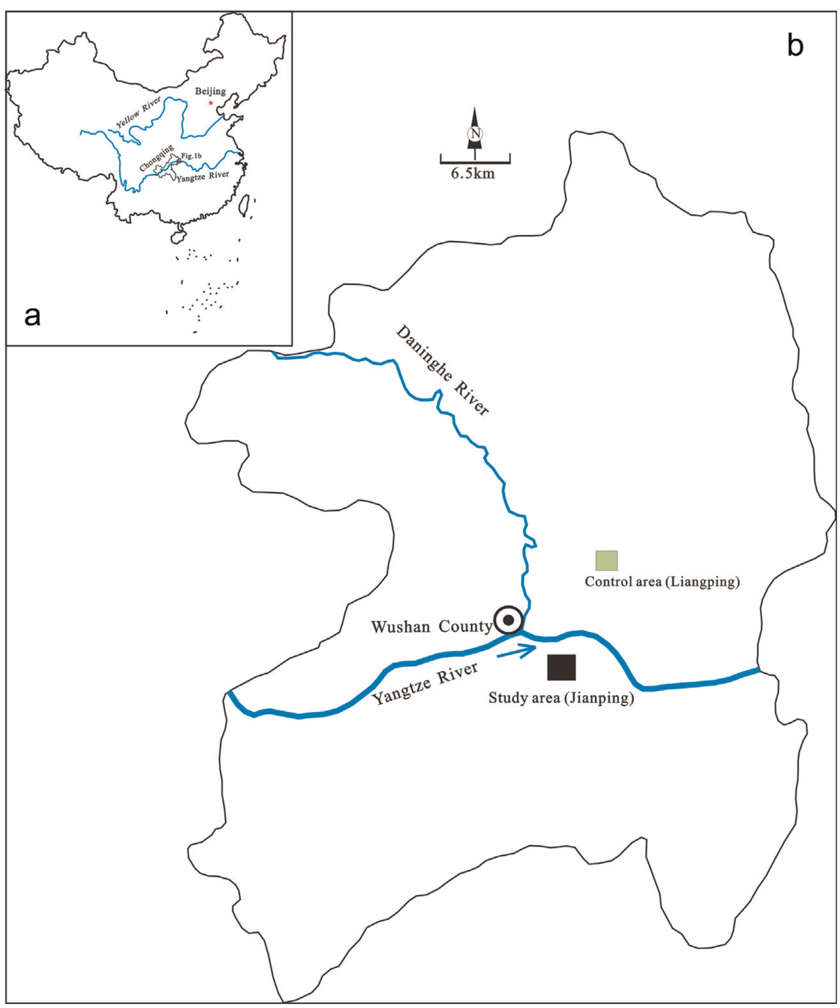

Fig. 1. Map showing the study area