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Arsenic and heavy metals in paddy soil and polished rice contaminated by mining activities in Korea

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ABSTRACT

Rice plays an essential role in Asian sustenance. Moreover, it can take up toxic elements through its roots from contaminated soils, and even its leaves and grain can absorb the elements deposited on the soil surface. Hence in 2010, forty soil and polished rice samples were collected from four representative abandoned metal mining areas in Korea and analyzed for As and heavy metals, including Cd, Cu, Pb and Zn, by atomic absorption spectrometry (AAS). Average levels of As, Cd, Cu, Pb and Zn in agricultural soil samples were 64.4, 2.31, 63.5, 146 and 393 mg kg^{-1}, respectively. In addition, the average content of As, Cd, Cu, Pb and Zn in rice grain grown on the contaminated soils evaluated was 0.247, 0.174, 4.69, 0.804 and 16.8 mg kg^{-1} (dry weight, DW), respectively. These levels are relatively higher than worldwide averages reported by various researchers. Assuming the average rice consumption of 199 g day^{-1} by overall households in Korea, the amount of daily intake of As and the heavy metals was estimated. The appraised daily intake of As and Cd from the rice grown in the study areas is up to 50% and 80% of ADI (acceptable daily intake) suggested by the FAO/WHO Joint Food Additive and Contaminants Committee, respectively. Consequently, regular rice consumption grown in soils especially in the mining areas can cause health problems for local residents.

1. Introduction

Paddy rice (*Oryza sativa L.*), especially white rice, is the staple in the diet of various people including Chinese, Japanese, Koreans and the other Asians. Rice is the most common crop grown on agricultural land in Korea, with a total production of 4.2 million tons in 2012, which is 0.6% of the total rice production of the world, which in turn is 696 million tons (Ministry of Agriculture, Food and Rural Affairs and Korea Rural Community Corporation, 2012). Household rice consumption as a staple in Korea, however, decreased year after year, for example from 374 g day^{-1} in 1970 reduced to 199 g day^{-1} in 2013 (KOSTAT, 2014). In addition, rice production also decreased from 4.9 million tons in 2002 to 4.2 million tons in 2012. In spite of decreasing production and consumption of rice in Korea, rice still plays essential role as a main meal. Rice cultivated in the polluted paddy soil area can affect health detrimentally. Hereupon, obtaining information about heavy metal concentrations in food products and its consumption as a staple are very important in assessing their human health risk (Zhuang et al., 2009).

With advent of the 20th century and its increasing in population, industrialization and urbanization, various kinds of environmental pollutants have been observed. In particular, environmental destruction through toxic elements including As, Cd, Co, Cr, Cu, Hg, Pb, Se and Zn has increased. Environmental pollutants, due to the accumulation of heavy metals on a serious level in plants, are affecting the food crop quality grown on contaminated areas (Jung, 1995). Meanwhile, absorbency of heavy metals by crop plants grown on contaminated soil can cause deleterious effects on local residents' health, and is one of the concerns in such area. Despite of the increase in population, serious environmental pollution can continuously occur. Therefore, sustainable management of the food quality and even water safety is desperately needed.

Abandoned metal mines can be a major contamination source of arsenic and heavy metals in the environment owing to previous mining activities including processing and transportation of ores, release of tailings and waste water around mines (Adriano, 1986). The disposal of mine waste often produces more environmental problems than the mining operations themselves. The pollutants maybe transferred from tailings and waste rock dump to nearby soils by acid mine drainage and/or atmospheric deposition of wind-blown dust, depending on climatic and hydraulic conditions, which determine locations of potentially contaminated areas (Chopin and Alloway, 2007a,b; Batista et al., 2007; López et al., 2008). Thus, As and heavy metals in the vicinity of mining areas are dispersed downstream and nearby agricultural soils due to heavy rainfall or strong winds, and eventually they can be accumulated into water and soil systems (Jung and Thornton, 1997). Furthermore, crop plants grown in contaminated soils contained elevated levels of As and heavy metals. Various studies have been thus undertaken regarding the accumulation and risk assessment of the elements derived from mining activities (Liu et al., 2005a, b; Wang et al., 2005;

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Yang et al., 2006; Sipter et al., 2008). Numerous researchers have focused on the assessment of potential health risks for inhabitants in the vicinity of hazardous sites like mining areas (Cui et al., 2004; Sipter et al., 2008; Zheng et al., 2007; Zhuang et al., 2009). Furthermore, several researchers have investigated trace element concentrations in rice grains from various countries including Bangladesh (Meharg and Rahman, 2003; Meharg et al., 2009), Canada (Heitkemper et al., 2001), China (Chen et al., 1999; Liu et al., 2005a,b; Yang et al., 2006; Zeng et al., 2008; Qian et al., 2010; Zhao et al., 2010), India (Roychowdhury et al., 2003; Mondal and Polya, 2008; Pal et al., 2009), Jamaica (Johann et al., 2012), Japan (Shimbo et al., 2001), Korea (Jung et al., 2005), Philippines (Zhang et al., 1998), Sweden (Jorhem et al., 2008), and the USA (Williams et al., 2005, 2007).

In spite of the large amount of rice consumption in Korea, only a few studies have been undertaken to discover element concentrations in rice through a nation-wide survey in Korea (Moon et al., 1995; Jung and Thornton, 1997; Jung et al., 2005). Therefore, the present study aimed to investigate As and heavy metal (Cd, Cu, Pb, and Zn) concentrations in paddy soils and rice grains affected from previous mining activities and assess the potential health risks of the inhabitants who consumed locally produced rice.

2. Materials and methods

Locations of the four representative abandoned metal mines selected by their extent are shown in Fig. 1, and also general information of

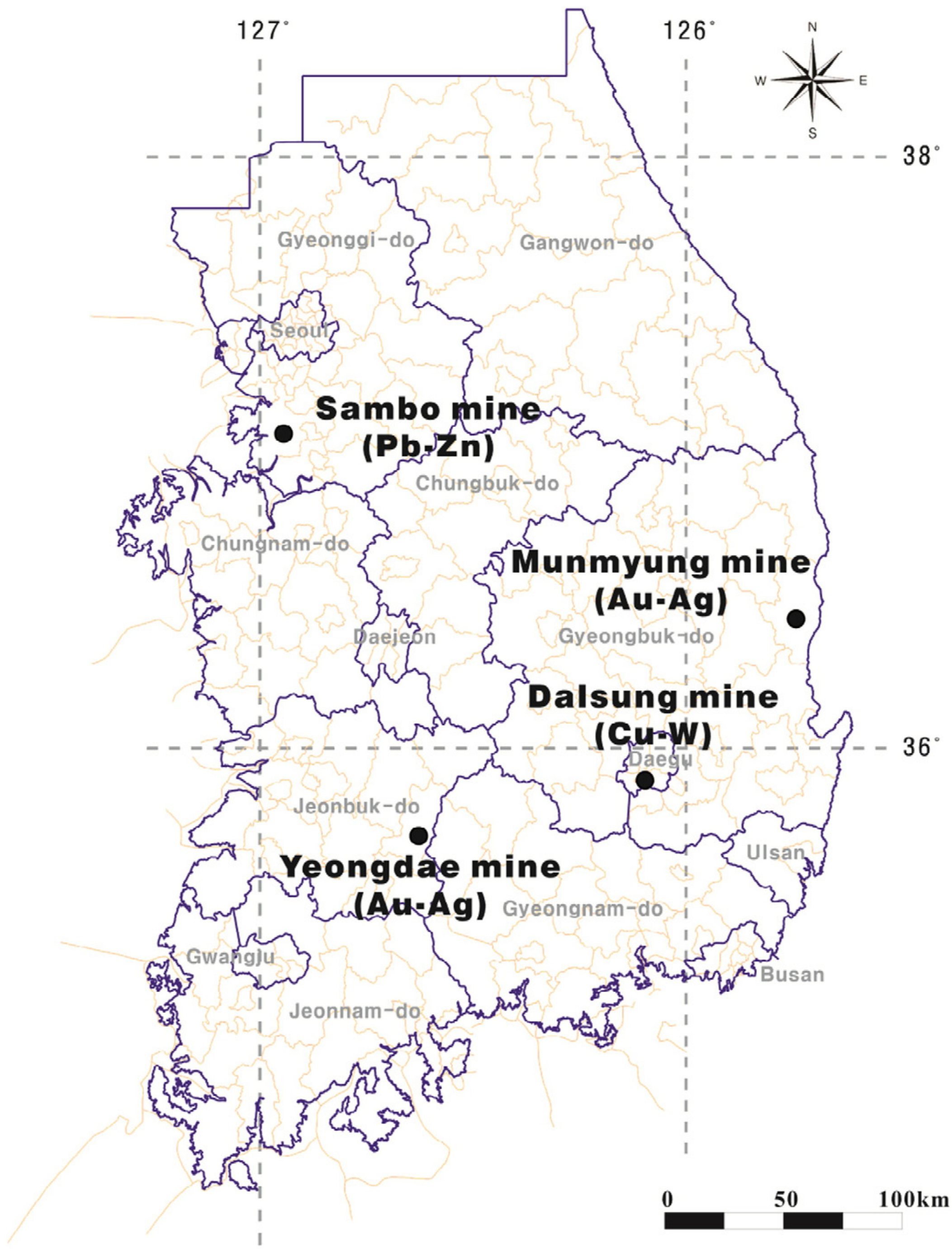

Fig. 1. Map showing the location of the four representative abandoned mines in South Korea.