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Assessment of selenium pollution in agricultural soils in the Xuzhou District, Northwest Jiangsu, China

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Abstract

Xuzhou City is an important base for coal production and coal-fired power. To evaluate selenium contamination in this area, we sampled agricultural soil, soil profile, irrigation water, bedrock, coal, fly ash, paddy rice, and vegetables from the north of Xuzhou City, and determined their selenium contents. The background level of selenium in the soil profile was 0.08 mg/kg. The selenium concentrations in agricultural soils and irrigation water were in the range of 0.21–4.08 mg/kg and 0.002–0.29 mg/L, respectively. Soils with high selenium content were located closely to coalmines and power plants. The average selenium concentrations in coal and coal fly ash were 5.46 and 2.81 mg/kg, respectively. In contrast, the concentrations of selenium in bedrock and in the soil profile were very low. These results imply that the high selenium level in agricultural soils is mainly caused by anthropogenic activities, rather than by parent material. The arithmetic mean of selenium concentration in paddy rice was 0.116 mg/kg, and in cabbage was 0.05 mg/kg. The selenium concentration in rice was positively correlated with total selenium concentration in soil, suggesting that selenium in soil is readily transferred into the crops. Furthermore, the estimated dietary intake (88.8 μg) of selenium from paddy rice and cabbage exceeds the recommended dietary allowance (55 μg). Therefore, there is a potential health risk from consumption of local staple food in the study area.

Key words: selenium; agricultural soils; paddy rice; Xuzhou District

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Introduction

Selenium is an essential trace element for both animal and human. It is an important component of antioxidant enzymes, which protect cells against the effects of free radicals produced during normal oxygen metabolism (Rotruer and Poue, 1993; Maleki *et al*., 2005). However, at high concentration, selenium is toxic to animal and human, as found in the Kesterson Reservoir (Ohlendorf, 1989). Selenium in soil is taken up by plants. Such contaminated plants are the main source of selenium in human food or animal fodder. The amount of selenium in plants is related to the selenium content of the soil. Selenium in livestock, therefore, results from intake of selenium-contaminated plants (Burk, 1994). Generally, selenium concentrations in soils in China are very low unless the underlying geology contains high level of selenium (Fordyce *et al*., 2000; Appleton *et al*., 2006). However, selenium may be enriched in agricultural soils due to human activities such as mining, waste irrigation, coal burning, and selenium-fertilizer application (Xu *et al*., 2005; Senesi *et al*., 1999; Diaz *et al*., 1996; Blagojevic *et al*., 1998). For instance, disposal of fossil fuel wastes and agricultural irrigation of arid, seleniferous soils at several locations in the United States have poisoned fish and wildlife, and threatened public health (Lemly, 1997). Previous studies found that the distribution of selenium in Yutangba, China was also affected by human activities (Zhu *et al*., 2008; Fang and Wu, 2004). The distribution was related to the pathways of selenium transport, including stone coal transport by local villagers, stone coal mining, and fertilizer application to improve soil. These activities caused various additions of selenium to the soil and consequently a large amount of bioavailable selenium could be released, resulting in the further accumulation of selenium in food chains to some extent. Many crops with extremely high concentrations of selenium were found at croplands nearby discarded coal spoils (Zhu *et al*., 2008; Fang and Wu, 2004). Both coal and its ash seem to be the main geochemical source of selenium in soils and plants, which might contaminate local agricultural ecosystem (Fang *et al*., 2003).

Xuzhou, the most developing industrial city in Jiangsu Province of China, has established many different industries, such as mining, metallurgy, electric power, and engineering. Nearly 90% of energy that sustains these

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industries comes from coal combustion, and this situation will last for another 50 years. Xuzhou City has exploited coal mines for over 124 years, and still has various scales of coalfields with total deposits of 3.9 billion tons. In 2006, its coal production was 259.7 million tons, and the generated electric power amounted to 7.2×10^9 kWh. The solid waste from coal-fired power plants is enriched in potentially toxic trace elements such as arsenic, mercury, selenium, and antimony. Unfortunately, the power plants in this area have only limited equipments to process such wastes. For example, the coal fly ash is simply piled in reservoirs in the open air, and effluents flow directly or indirectly into rivers. The gaseous and aerosol pollutants in the flue gases from coal combustion and the leachable constituents in coal ash also cause serious environmental pollution. Some coals have undergone diagenetic development causing the extraordinary enrichment of selenium (He *et al.*, 2002). The agricultural soil close to areas of waste production and disposal become contaminated with selenium, potentially impacting on biota (Stoewsand *et al.*, 1990; Besser *et al.*, 1996). Very little information is available on selenium accumulation in agricultural soils and crops in Xuzhou District, and the impact of selenium contamination on the ecosystem has not been fully discussed. In this study, we systemically measured selenium concentrations in power plant waste, soil, rice grains and vegetables in croplands in the Xuzhou District for the first time. The objectives of this paper is: (1) to study the spatial distribution of selenium levels in these different types of samples, (2) to identify the causes of selenium contamination, and (3) to assess the potential health risk of selenium contamination to the local residents.

1 Materials and methods

1.1 Study area

Xuzhou City lies between 33°43′N and 34°58′N latitudes and between 116°22′E and 118°40′E longitudes. It is a part of Huanghuai Plateau with altitudes varying from 20 to 50 m above sea level. The total area of the city is 11258 km^2; 47.9% of the area is under paddy rice cultivation, and 26.8% is under vegetable cultivation. Its climate is a typical warm humid monsoon with an average annual temperature of 14°C and rainfall of 900 mm. The bedrock in the study area is mainly carboniferous grey limestone, and the microlandform is mainly composed of wide diluvia plains and sporadic uplands. The main soil is a typical fluvo-aquic soil formed on the alluvium.

Three coal-fired power plants, Chacheng, Huarun, and Maocun, are located in the study area. The Maocun Power Plant has generated coal-fired power since 1930s. The Chacheng Power Plant, the largest power plant in Xuzhou City, had a capacity of 4.2×10^9 kWh in 2006. These power plants lie along the valley, and the most of surrounding lands is cropland.

1.2 Sampling and preparation

The sampling was carried out in October, 2006. Agricultural soils (70 samples) were collected from North Xuzhou City (Fig. 1). One soil sample was collected every 4 km^2. The region was divided into 2 km × 2 km plots. Within each plot, a composite of two sub-samples was taken from the upper 20 cm, which represents the ploughed layer. These sub-samples were then mixed to obtain a bulk sample that provided a representative measurement of concentrations at the site. To obtain the

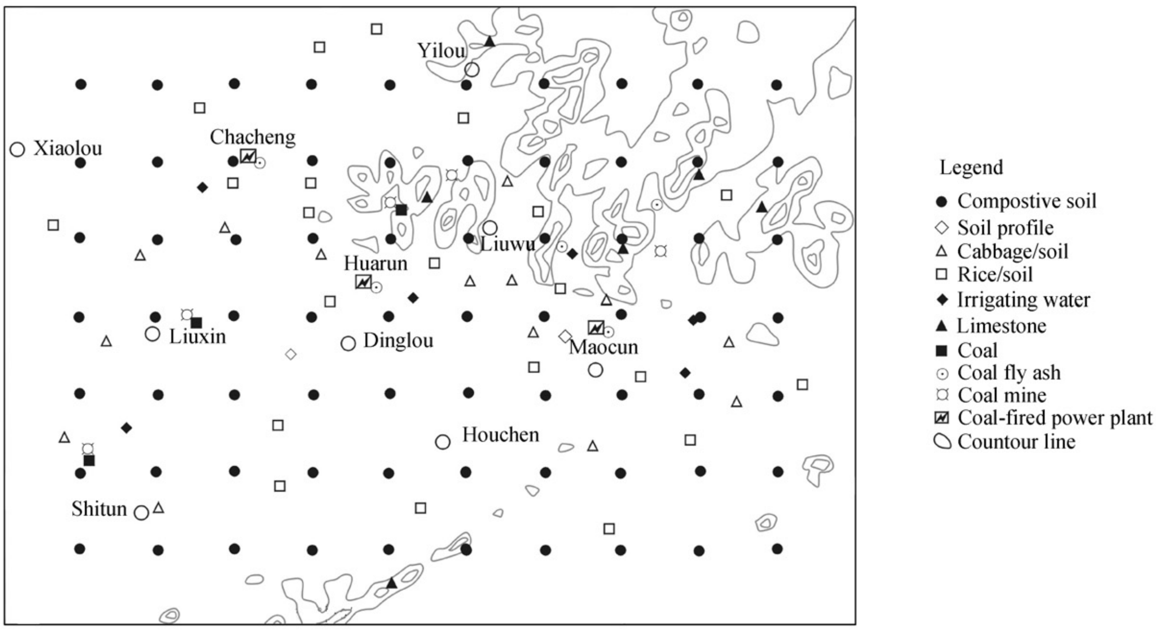

Fig. 1 Sampling locations of soils located North Xuzhou District.