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Environmental–geochemical characteristics of Cu in the soil and water in copper-rich deposit area of southeastern Hubei Province, along the middle Yangtze River, Central China

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Consider the rock–soil–water–crop as a system to study the geochemical activities and environmental pollution of copper.

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ABSTRACT

In this study, the natural Cu background concentration and Cu natural and anthropogenic contamination in soil, water and crop were investigated systematically in Huangshi area. The results show that regional geology is the dominant factor controlling the natural Cu background concentration in soil and water, and that pH is important to control the vertical distribution of Cu in soil under the same geographical and climatic conditions. The mineralization of rock bodies causes the natural Cu increase in soil and water, whereas, a large number of mining–smelting plants and chemical works are the main sources of Cu anthropogenic contamination. Cu in naturally and anthropogenically polluted soil displays differences in total and available contents, vertical distribution patterns and physico-chemical properties, the same happens in water.

1. Introduction

Soil and water are the most important factors for agriculture, and their quality has a tight relationship with the human health. Human activities with rapid industrialization and population growth influence severely the environment including soil, water and atmosphere (Phillips et al., 2001; Marchetti, 2002; Eggermont and Verschuren, 2003; Liao et al., 2005; Perrin et al., 2008). More attention and a wide range of studies have been carried out to study contamination processes of soil and water in most of the impacted world areas (Bryan and Langston, 1992; Cearreta et al., 2000; Santschi et al., 2001; Peng et al., 2005; Borrok et al., 2008; Cecchi et al., 2008).

The natural background concentration of an element is commonly defined as the natural quantity of a given element in a certain material (in absence of external pollution), and reflects the inherent characteristics of that element during existing and developing processes as well as its transformation and transferring. Background concentration is fundamental for the evaluation of soil and water pollution in various environments with different geological and geographically conditions. Therefore, in recent years, many studies have conducted to define geochemical background level to serve as a basis for legislation to assess, prevent and reduce soil contamination (Rieuwerts et al., 2000; Martínez et al., 2007).

Soil metal background concentration is determined by factors such as parent material, soil-type and its physico-chemical properties (Carral et al., 1995; Baize and Sterckeman, 2001; Cobelo-García and Prego, 2003; Fukue et al., 2006), and also by other factors such as hydrodynamic and biogeochemical processes. The difference of parent material is the primary factor inducing different background concentration; on the other hand, biological and climatic actions may lead to difference of element content in various soils originating from the same parent rock. Physico-chemical properties also affect background concentration, for instance, lower pH in acidic soil leads to desorption of element from soil particles, and makes element more active and easier to be mobile, so that the concentration of element in acidic soil is normally higher than in basic soil. The metal background concentration in natural water can be explained by the reaction of water with rock and sediment, and is

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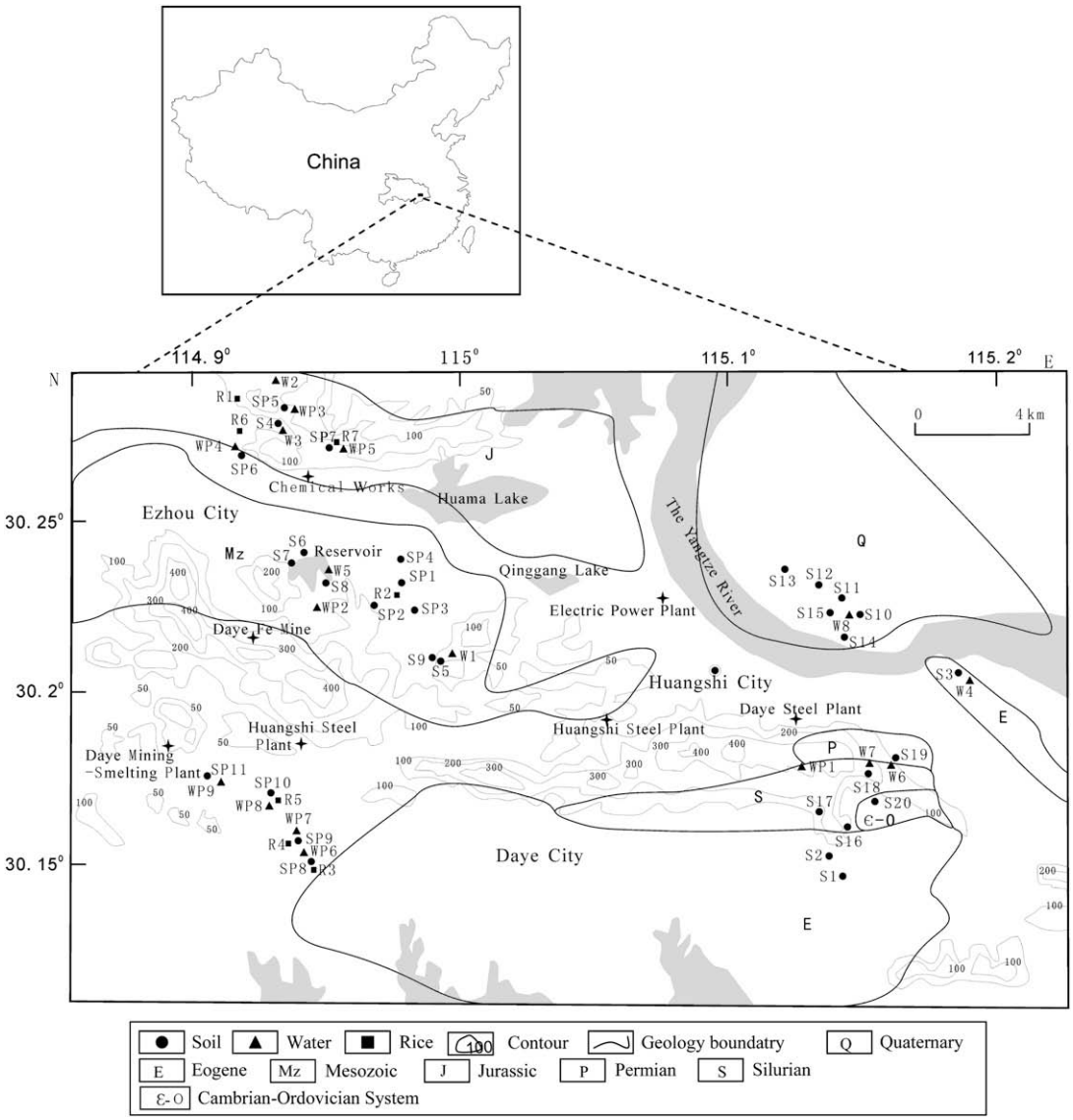

Fig. 1. The simplified geological and geomorphological map of Huangshi area and the sampling sites.

related tightly to the regional geology and soil-type. Moreover, it is controlled by other factors such as elemental characteristics, physico-chemical properties (pH, soluble inorganic/organic matter and humic matter, etc.), precipitation and runoff.

Human activities have resulted in contamination of water and soil with toxic heavy metals around the world. Especially, metals released from mining–smelting sites or chemical works disturb or severely damage the ecology (Prusty et al., 1994; Ahn et al., 2003; Garcia-Sanchez and Alvarez-Ayuso, 2003; Osher et al., 2006; Kim et al., 2007). The regions along the middle Yangtze River (southeastern Hubei Province) with a developed agriculture and a large population density are important Cu (Fe, Au and other heavy metals) mining and smelting district. The pollution arising from the development of modern industry and agriculture in recent decades has severely damaged the regional ecosystem and consequently, human health. Cu is the main mineralization element in this area and an essential micronutrient for plants and microorganisms catalyzing several key enzymatic processes. However, Cu can also become toxic to microorganisms when presents at elevated concentration (Silver, 1996; Bruins et al., 2000; Borrok et al., 2008). Therefore in this paper, the rock–soil–water–crop system, considered as a whole, was studied mainly (i) to determine natural Cu background concentration in soil and water; (ii) to estimate the recent Cu contamination in soil, water and crop and (iii) to study the mechanism and conditions of Cu distribution in the system and to assess the natural and anthropogenic impacts on the geochemical activities of Cu.

2. Materials and methods

2.1. Characteristics of the study area

The study area is centered on Huangshi city (Fig. 1) with an area of 1850 km^2 and a population of 2.5 million, and it is an important agricultural area located in the southeastern part of Hubei Province. Industries developed prosperously in this district and there are many mining and smelting plants, chemical works, electric power plants, cement factories and so on. Most of the factories built in 1950s–1960s had outdated techniques and equipments, and consumed excessive raw energy (mainly coal-burning), even weren't equipped with efficient pollutant-disposal devices. Therefore the atmosphere, soil and water were severely polluted by the large quantities of waste gases, water and residues generated and discharged in the industrial processes. The topography of Huangshi area is composed of low hilly land