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Accumulation status, sources and phytoavailability of metals in greenhouse vegetable production systems in Beijing, China

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ABSTRACT

The accumulation status, sources and phytoavailability of selected metals in greenhouse vegetable production systems in peri-urban areas of Beijing were investigated. The mean concentrations of As, Cd, Cr, Hg and Pb in greenhouse soils were 8.44, 0.25, 69.0, 0.09 and 22.0 mg kg^{-1}, dw, respectively. According to principal component analysis, As, Cd, Cr and Hg are mainly from anthropogenic source, but Pb is likely from natural source. Metal concentrations in all vegetable samples were decreased in the order of Cr > As > Pb > Cd > Hg. Compared with root and fruit vegetables, leaf vegetables had relatively high concentrations and transfer factors of heavy metals, except for Cd. By including soil pH, OM and greenhouse soil metals, 10 empirical models were derived using stepwise multiple linear regression analysis to predict heavy metal concentrations in the edible parts of different vegetables. Among the different vegetable groups, the highest intakes of metals occurred through consumption of leaf vegetables for the two age groups, except for Cd. The HI value of the studied metals were all below 1, indicating that consumption of vegetables grown in greenhouse soils was of low risk to consumers in our study area.

1. Introduction

Because of the growing demand for vegetables and the economic benefits of intensifying vegetable production, greenhouse vegetable production (GVP) has expanded rapidly in China. Given a shortage of land resources and convenient transportation, increasing numbers of greenhouses have been built in the peri-urban areas of big cities such as Beijing (Shen et al., 2010; Yang et al., 2013). The GVP cultivation area increased from 16,690 ha in 2004 to 38,763 ha in 2013 in Beijing (BSBC, 2014). Greenhouse vegetable production in the peri-urban areas of the city was affected not only by agricultural activity, but also by the processes of urbanization and industrialization.

Compared with conventional vegetable cultivation, GVP provides continuous production year-round with high-intensity use of agricultural materials and energy (Holvoet et al., 2015). Greenhouse vegetable production allows the provision of sufficient quantities of vegetables, even during off-season months. However, the unique requirements of GVP such as high chemical input, high temperatures, and high cropping indexes may cause irreversible environmental problems (Chen et al., 2013; Zhu et al., 2011). Accumulations of metals in GVP systems have become a common problem. For example, Hu et al. (2014a) found high concentrations of trace elements in soils in a highly intensive vegetable planting region.

Vegetables are extremely important for the health of human beings because vegetables contain essential components of protein, vitamins, iron, calcium and other nutrients (Yang et al., 2011). They can also absorb nonessential elements, such as metals, over a wide range of concentrations (Liu et al., 2013). The security of greenhouse vegetables should be a high priority because they have become a significant part of the human diet. An assessment of the migration of metals from soils to the edible parts of vegetables and the subsequent health risk in GVP systems is necessary and urgent (Chen et al., 2014a).

During the past three decades, the concentration and accumulation of metals in soils in Beijing has been studied, including surveys of the background concentrations of soil heavy metals, heavy metal contamination in agricultural soils (not including

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greenhouse soils) and soil pollution levels in Beijing's urban parks (Chen et al., 2005, 2004; Lu et al., 2012). However, few studies have focused on metal accumulation in greenhouse soils, especially the metals concentrations in greenhouse vegetables and their potential human health risk. According to statistic data, one third vegetable in Bejing was from these GVP systems (BSBC, 2014). The results of our research will provide preliminary data for developing appropriate strategies of controlling heavy metals in this agricultural system and further facilitating sustainable GVP in Beijing.

Therefore, the objectives of this research were to (i) investigate the present accumulation status of Cd, As, Cr, Hg and Pb in soil and edible parts of vegetables in GVP systems, (ii) identify the sources of metals in GVP systems by principal component analysis, (iii) compare phytoavailability of five metals in different vegetables with soil parameters, and (iv) assess potential health risks through greenhouse vegetable consumption. The results of our study will better guide vegetable production, fertilizer use and rational soil use in GVP systems.

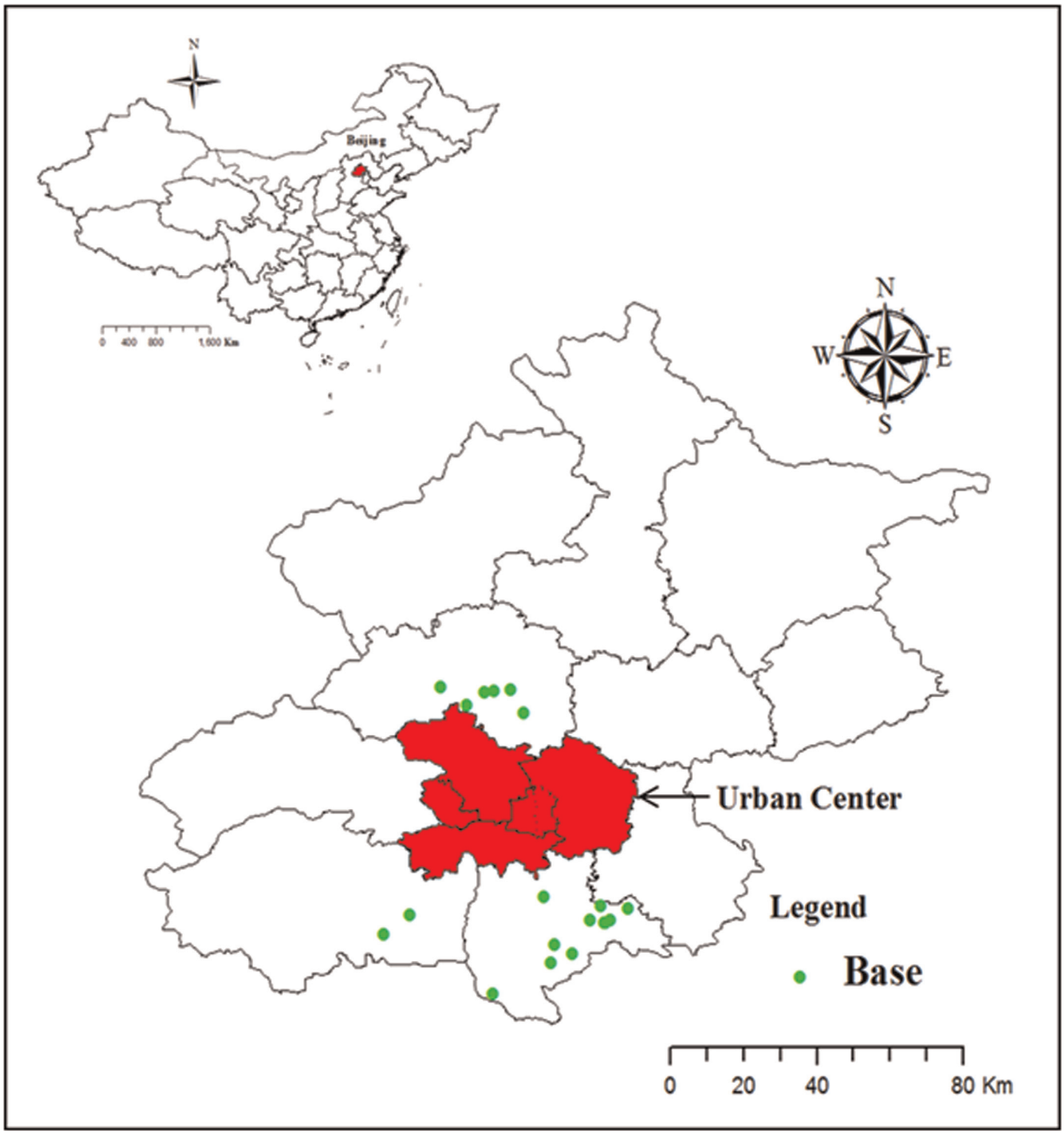

Fig. 1. The site of 19 greenhouse vegetable production bases in the Beijing.