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An exploration of spatial human health risk assessment of soil toxic metals under different land uses using sequential indicator simulation

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ABSTRACT

A modified method was proposed which integrates the spatial patterns of toxic metals simulated by sequential indicator simulation, different exposure models and local current land uses extracted by remote-sensing software into a dose-response model for human health risk assessment of toxic metals. A total of 156 soil samples with a various land uses containing farm land (F1–F25), forest land (W1–W12) and residential land (U1–U15) were collected in a grid pattern throughout Xiandao District (XDD), Hunan Province, China. The total Cr and Pb in topsoil were analyzed. Compared with Hunan soil background values, the elevated concentrations of Cr were mainly located in the east of XDD, and the elevated concentrations of Pb were scattered in the areas around F1, F6, F8, F13, F14, U5, U14, W2 and W11. For non-carcinogenic effects, the hazard index (*HI*) of Cr and Pb overall the XDD did not exceed the accepted level to adults. While to children, Cr and Pb exhibited *HI* higher than the accepted level around some areas. The assessment results indicated Cr and Pb should be regarded as the priority pollutants of concern in XDD. The first priority areas of concern were identified in region A with a high probability (>0.95) of risk in excess of the accepted level for Cr and Pb. The areas with probability of risk between 0.85 and 0.95 in region A were identified to be the secondary priority areas for Cr and Pb. The modified method was proved useful due to its improvement on previous studies and calculating a more realistic human health risk, thus reducing the probability of excessive environmental management.

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1. Introduction

At present, over half of the global population lives in urbanized areas (United Nations, 2014). Toxic metals contamination in soils has become a serious environmental problem around the world because of their potential impact to soil properties, soil biological activity and effective supply of nutrients, especially in the developing countries associated with their rapid progress of industrialization and urbanization (Guney et al., 2010; Qu et al., 2013a). In addition, soil toxic metals can be strongly enriched through the food chain or other ways, which threatens human health via direct inhalation, ingestion and dermal contact absorption (Boularbah et al., 2006; Komnitsas and Modis, 2009; Li et al., 2013; Saleem et al., 2014; Yuan et al., 2014). Therefore, to scientifically and effectively assess the potential risk of soil toxic metals to human health is of great importance to environmental management decision making.

In recent years, increasing studies have quantitatively evaluated the health risks of human exposure to soil toxic metals with single evaluation models (Lim et al., 2009; Wang et al., 2014; Cai et al., 2015; Li et al., 2015c). To preserve the spatial distribution of the risk, some studies used the geostatistical interpolation, like inverse distance weighted, kriging, or indicator kriging to evaluate the toxic metals concentrations in soils in the process of human health risk assessment (Guo et al., 2012; Li et al., 2014; Zhao et al., 2014; Xiao et al., 2015). And by comparing the calculation results with a regulatory cutoff level deemed 'safe' or 'acceptable', some studies have identified the priority pollutants/regions and provided initial risk management measures (Korre et al., 2002; Simasuwannarong and Satapanajaru, 2012; Ji et al., 2013). However, according to some researches in recent years, there are some deficiencies in the assessment process. Firstly, the smoothing effect, which results in less variation in estimated values than in

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observed values, was commonly found in the maps produced by optimal interpolation (Juang et al., 2004; Zhao et al., 2005; Modis et al., 2008; Zeng et al., 2009; Qu et al., 2013b). This problem causes large value to be underestimated and small values to be overestimated, and such effect can be transferred into the subsequent health risk assessment modeling, thereby considerably impacting on the results of the health risk assessment (Zhao et al., 2008; Qu et al., 2013a). Secondly, few studies took land use types into account in the process of health risk assessment. The pathways and receptors are different for each land use, so the land use types are in close relationship with the human health risk (Xu et al., 2008; Cheng and Nathanail, 2009; Zhao et al., 2012; Islam et al., 2015). The neglect of land use types may result in an overestimation of human health risk and consequently lead to an excessive environmental management. Finally, the risk management measures proposed in the previous studies were often inflexible and not practical. These inflexible risk management measures could neither satisfy the requirements of efficient environmental risk management in consideration of cost-benefit, nor meet the social economic demands of most developing countries like China.

To address some of these problems, a modified method is proposed which takes the spatial distribution and local uncertainty of concentrations of toxic metals into account by using SIS and incorporates different exposure models and current land use types extracted by remote-sensing software together to assess

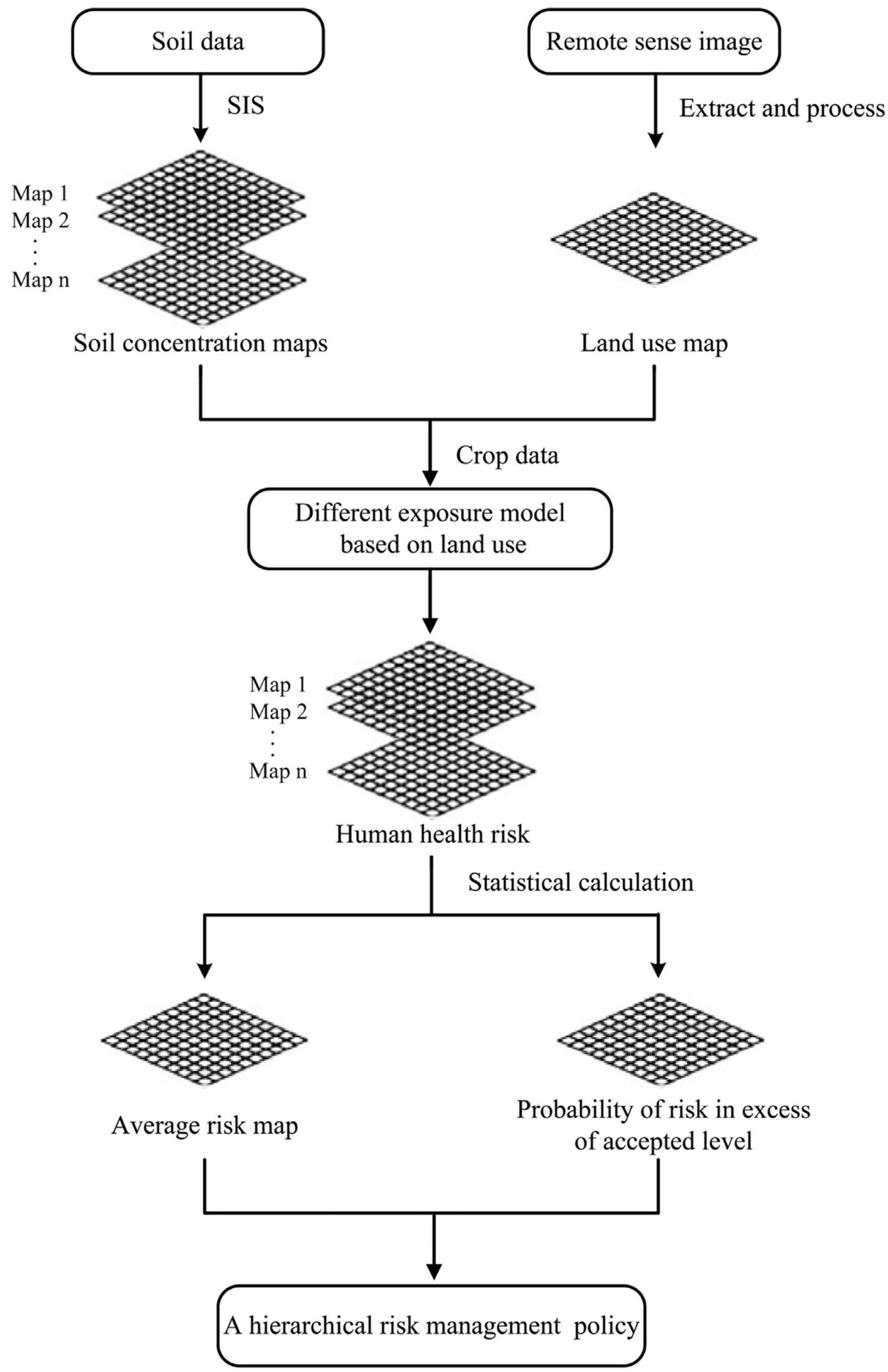

Fig. 1. Flow chart of the steps for the modified human health risk assessment of soil toxic metals under different land uses using SIS.

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