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Source identification of eight heavy metals in grassland soils by multivariate analysis from the Baicheng–Songyuan area, Jilin Province, Northeast China

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HIGHLIGHTS

- Concentrations of heavy metals were measured in grassland soil in Baicheng–Songyuan area.
- Heavy metal sources were identified using multiple statistical analysis.
- The heavy metal contents were of the safety levels.
- Cd and Hg may pose more risk of contamination soil than others in term of chemical fractionation.

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ABSTRACT

The characterization of the concentration, chemical speciation and source of heavy metals in soils is an imperative for pollution monitoring and the potential risk assessment of the metals to animal and human health. A total of 154 surface horizons and 53 underlying horizons of grassland soil were collected from the Baicheng–Songyuan area in Jilin Province, Northeast China, in which the concentrations and chemical fractionations of As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn were investigated. The mean concentrations of heavy metals in grassland topsoil were 7.2, 0.072, 35, 16.7, 0.014, 15.2, 18.3 and 35 mg kg^{-1} for As, Cd, Cr, Cu, Hg, Ni, Pb and Zn, respectively, and those averaged contents were lower than their China Environmental Quality Standard values for the Soils, implying that heavy metal concentrations in the studied soils were of the safety levels. The mobility sequence of the heavy metals based on the sum of the soluble, exchangeable, carbonate-bound and humic acid-bound fractions among the seven fractions decreased in the order of Cd 50.4%) > Hg (39.8%) > Cu (26.5%) > As (19.9%) > Zn (19.1%) > Ni (15.9%) > Pb (14.1%) > Cr (4.3%), suggesting Cd and Hg may pose more potential risk of soil contamination than other metals. Multivariate statistical analysis suggested that As, Cr, Cu, Ni, Pb, Zn, Cd and Hg had the similar lithogenic sources, however, Cd and Hg were more relevant to organic matter than other heavy metals, which was confirmed by the chemical speciation analysis of the metals. The study provides a base for local authority in the studied area to monitor the long term accession of heavy metals into grassland soil.

1. Introduction

Soil pollution by heavy metals has been an issue of great interest in the past few years because the metals can impose harmful effect on soil ecosystem, agricultural production, ground water quality, food safety and human health through food chain (Kabata-Pendias, 2000; Krishna and Govil, 2005; Nagajyoti et al., 2010; Wei and Yang, 2010; Wuana and Okieimen, 2011). The pollution extent by heavy metals in soils is primarily dependency on their total contents, chemical speciation, sources, and some soil physicochemical factors affected their geochemical behaviors such as clay and major oxide contents, pH, total nitrogen (N), and total phosphorous (P). Therefore, in the monitoring and assessment of soil pollution, determination of the total contents and chemical speciation of heavy metals as well as soil physicochemical parameters are not enough, and the possible sources of heavy metals in soils should be distinguished as well (Oliva and Espinosa, 2007; Zhao et al., 2014).

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Heavy metals in soils are originated from natural and anthropogenic sources. The major natural contribution of heavy metals to soils comes from the parent materials from which the soils developed (Alloway, 1995; Blaser et al., 2000). The anthropogenic source of heavy metals in soils includes atmospheric deposition (Starr et al., 2003; Hovmand et al., 2013), fertilizers and pesticides (Nicholson et al., 2003; Nziguheba and Smolders, 2007; Montagne et al., 2007), and agricultural and industrial waste discharges (Sumner, 2000; Silveira et al., 2003; Boularbah et al., 2006; Muchuweti et al., 2006; Khan et al., 2008;Solgi et al., 2012), which has a significant contribution to the content levels of heavy elements in soils. There are many approaches for assessing the sources of heavy metal in soils, such as the enrichment factor (Tyler, 2004; Reimann and de Caritat, 2005; Saby et al., 2006; Cai et al., 2012), isotope tracer studies (Bacon et al., 1996; Erel et al., 1997), chemical speciation analysis (Singh, 1997; Narwal et al., 1999; Abollino et al., 2002; Steinnes et al., 2005; Bird et al., 2005; D'Amore et al., 2005), and multivariate analysis and geostatistical analysis (Davies, 1997; Goovaerts, 1999; Facchinelli et al., 2001; Micó et al., 2006; Lee et al., 2006; Zhang, 2006; Rodríguez Martín et al., 2006; Huang et al., 2007; Dragovic et al., 2008; Aelion et al., 2008; Davis et al., 2009; Luo et al., 2012; Sun et al., 2013). A number of studies on heavy metal pollution in soils have been carried out in the urban area because it is often assumed that the urban areas are more contaminated than rural area (Davis et al., 2009), and the rural soils may also contain a considerable amount of heavy metals from natural geologic and anthropogenic sources (Aelion et al., 2008; Davis et al., 2009; Franco-Uría et al., 2009). Understanding sources of heavy metals in surface soils from the rural area is imperative for the decision maker in China to implement the strategies for protecting the ecosystem health and food safety by reducing the entrance of the heavy metals onto the soil environment.

The Baicheng–Songyuan area in Jilin province, Northeast China, is suited at the agro-pastoral transition zones, where a plentiful of grass resources is widely distributed. In recent years, the grassland has been seriously degraded with overgrazing, plowing and salinification, so the environmental quality and ecological security in the area has been drawing much attention by the public. In order to assess the quality of grassland soil and its related compartment, an extensively eco-geochemical survey was carried out between 2007 and 2010 in the study area. The main objectives of this study are to investigate the distributions and chemical fractionations of As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn in grassland soils, to assess the factors affecting their distributions in the soils, and to define their possible sources in the soils.

2. Material and methods

2.1. Study area

The study area is located in the western Jilin Province, the western part of Songnen plain, Northeast China (Fig. 1). The area is suited at the transitional climate zone from the semi-humid to the semi-arid and arid, the agro-pastoral transitional zone in eco-environmental system as well (Zhang et al., 2003), with an annual mean temperature of about 3–5 °C, a yearly average rainfall of 400–500 mm and potential evaporation of 1600–2000 mm, respectively. Soils in the study area are mainly chestnut soil, sub-chernozem soil, chernozem soil, saline–alkali soil, meadow soil, alluvial soil, and aeolian sandy soil. The study area is covered by of 40–75% grassland vegetation. The vegetation types are mainly the drought steppe, *Stipa basicalensis* grassland, *Aneurolepilium Chinese* grassland, and forest steppe (Zhang et al., 2003), and the dominant grassland species include *Aueurolepidium chinense, Stipa baicalensis, Cleistogenes squarrosa, Puccinellia tenuiflora, Chloris virgata, Suaeda glauca, Artemisia anethifolia, Stipa grandis, Potentilla filipendula, Lespedexa davurica,* etc. (Zhang et al., 2003). The widely exposed rocks in the area are the Quaternary sediments of the alluvial, lacustrine and Aelian origins, and the Tertiary,

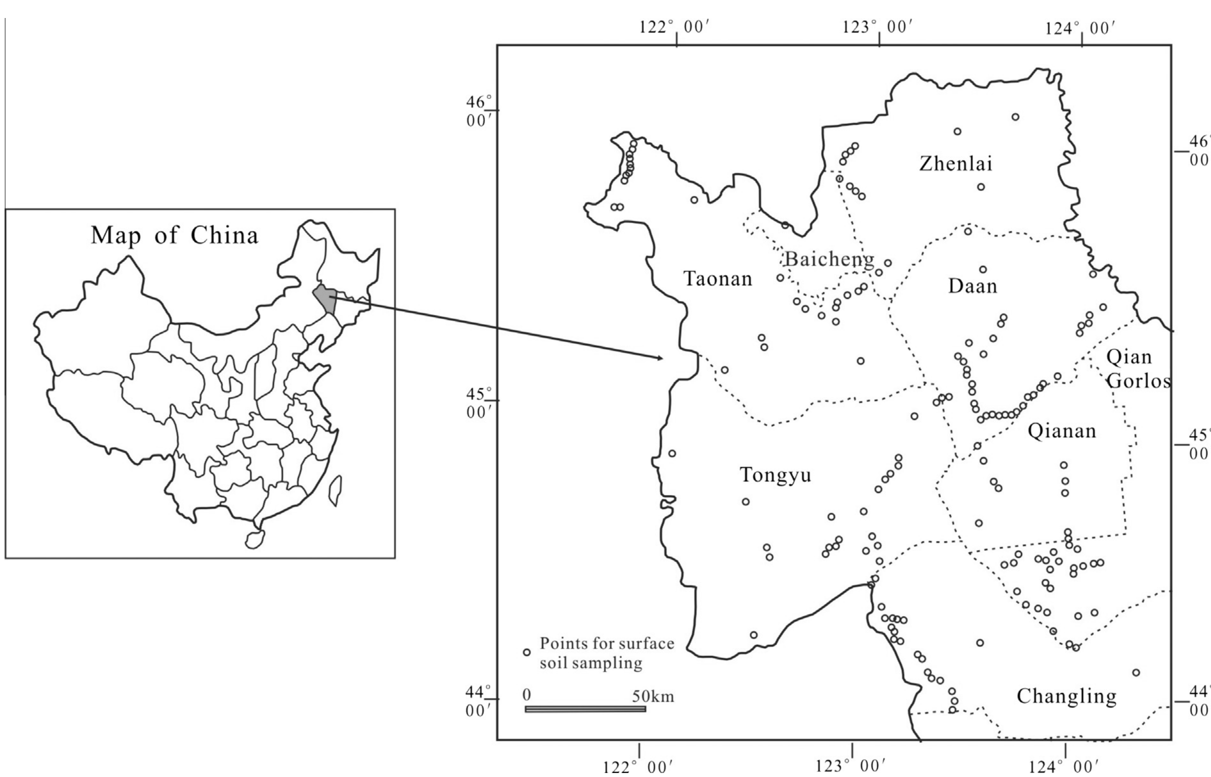

Fig. 1. Soil sampling locations of the study area.