Ecotoxicology and Environmental Safety 148 (2018) 644–651

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Heavy metals in soils of Hechuan County in the upper Yangtze (SW China): Comparative pollution assessment using multiple indices with high-spatial-resolution sampling

Maofei Ni[a,b], Rong Mao[a], Zhongmin Jia[c,d], Ruozhu Dong[a], Siyue Li[a,*]

[a] Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
[c] Key Laboratory of Eco-environments of the Three Gorges Reservoir Region, Ministry of Education, College of Life Science, Southwest University, Chongqing 400715, China
[d] Southeast Sichuan Geological Group, Chongqing Bureau of Geology and Minerals Exploration, Chongqing 400038, China

ARTICLE INFO

Keywords:
Heavy metals
Risk assessment
Source identification
Soil pollution
Yangtze Basin

ABSTRACT

In order to assess heavy metals (HMs) in soils of the upper Yangtze Basin, a very high-spatial-resolution sampling (582 soil samples) was conducted from Hechuan County, an important agricultural practice area in the Southwest China. Multiple indices including geoaccumulation index (I_{geo}), enrichment factor (EF), sediment pollution index (SPI) and risk index (RI), as well as multivariate statistics were employed for pollution assessment and source identification of HMs in soils. Our results demonstrated that the averages of eight HMs decreased in the following order: Zn (82.8 ± 15.9) > Cr (71.6 ± 12.2) > Ni (32.1 ± 9.89) > Pb (27.6 ± 13.8) > Cu (25.9 ± 11.8) > As (5.48 ± 3.42) > Cd (0.30 ± 0.077) > Hg (0.082 ± 0.092). Averages of HMs except Cd were lower than threshold value of Environmental Quality Standard for Soils, while 43% of total samples had Cd concentration exceeding the national standard, 1% of samples for Hg and 5% samples for Ni, moreover, Cd and Hg averages were much higher than their background levels. I_{geo} and EF indicated that their levels decreased as follows: Cd > Hg > Zn > Pb > Ni > Cu > Cr > As, with moderate enrichments of Cd and Hg. RI indicated that 61.7% of all samples showed moderate risk, while 6.5% of samples with greater than considerable risk due to human activities should be paid more attention. Multivariate analysis showed lithogenic source of Cu, Cr, Ni and Zn, while Cd and Hg were largely contributed by anthropogenic activities such as agricultural practices. Our study would be helpful for improving soil environmental quality in SW, China, as well as supplying modern approaches for other areas with soil HM pollution.

1. Introduction

Heavy metal (HM) pollution in soils poses great threat to the natural environment and human health (Chabukdhara and Nema, 2013; Wang et al., 2015b, 2016). Anthropogenic activities and lithological accumulation are both contributing to soil heavy meals (HMs), while anthropogenic inputs are more important because of urbanization and changing land use (Cai et al., 2012). The main sources of anthropogenic inputs of HMs in soils are industrial production, domestic wastes, agriculture and transportation (Muhammad et al., 2011). The environmental concerns from HM pollution in soils were mainly due to their bioaccumulation, toxicity and persistency (Saha and Panwar, 2014; Abdelhafez et al., 2015; Lao et al., 2015).

A couple of indices or models have been developed for risk assessment of soil HMs. The most widely used indices include geoaccumulation index (I_{goe}) (Martinez and Poleto, 2014), enrichment factor (EF) (Buatmenard and Chesselet, 1979) and contamination factor (CF) (State et al., 2012) that are established as single-element contamination indices. Multi-element contamination indices include sediment pollution index (SPI) (Shin and Lam, 2001), potential ecological risk index (RI) (Hakanson, 1980) and global risk index (GRI) (Zhao et al., 2012b), they assess HM pollution in soils by summarizing risk and toxicity of all analytic elements. Given specificity and internal inconsistency of the individual index, a comparable assessment of HMs in soils using various indices should be adopted for better understanding the pollution status posed by HMs. The well documented I_{geo}, EF, SPI and RI were therefore used here.

Yangtze is the third largest river in the world and originates in Qinghai Tibet Plateau. The river has multiple purposes of drinking, industry and irrigation, as well as sewage discharge and transportation

* Corresponding author.
E-mail address: syli2006@163.com (S. Li).

https://doi.org/10.1016/j.ecoenv.2017.11.009
Received 14 July 2017; Received in revised form 2 November 2017; Accepted 4 November 2017

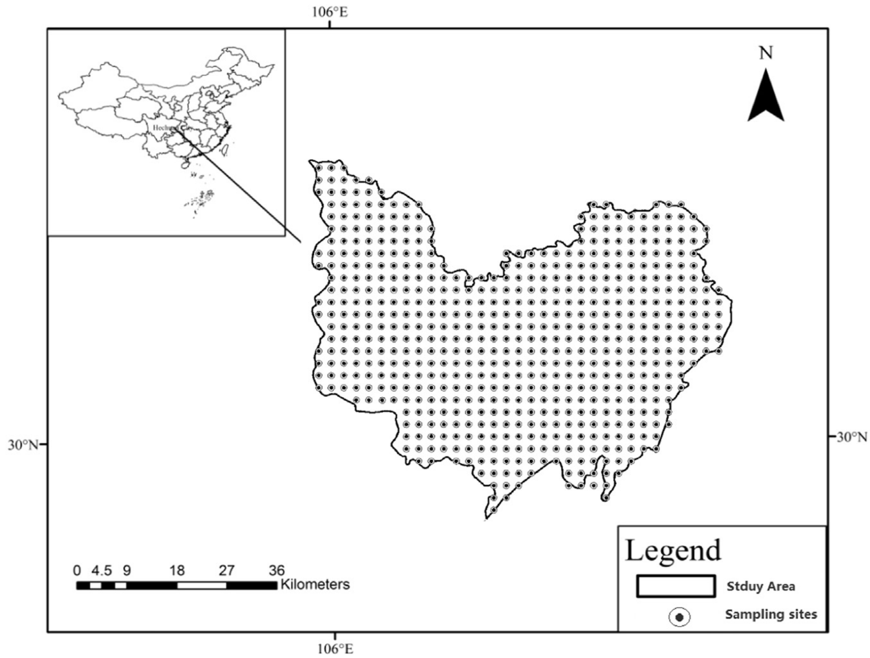

Fig. 1. Location and sampling sites of the study area.

in China. Yangtze River has been reported to be polluted by HMs because of industrial, agricultural and domestic discharges (Wu et al., 2012), which was aggravated by the occurrence of seasonal flood. Moreover, ever-increasing enrichment status of HMs in soils was also observed in the Yangtze Basin including the Three Gorges Region and its upper catchment (Hang et al., 2009; Zhao et al., 2010; Ye et al., 2011; Zhang et al., 2015). Understandably, polluted soils with HMs in the upper Yangtze Basin will discharge high loadings of metals to river systems, which will threaten the water security in the largest Yangtze particularly the Reservoir Three Gorges. However, characterization and risk assessment of soil HMs in some special regions of the upper Yangtze Basin, particularly in the agriculture-dominated area, was not well documented. Therefore, studies characterizing soil HMs in some specific area of the upper Yangtze Basin are urgent.

To better understand the pollution level, eco-risk, and potential sources of HMs in soils of the upper Yangtze Basin, a very high-spatial-resolution sampling was taken in the Hechuan County, an important agricultural practice area locating in the Southwest China (Fig. 1). Particularly, four risk assessment indices (I_{geo}, EF, RI and SPI) were applied. The original contribution includes complete assessments of priority HMs and providing urgent data for large-scale effects of soil HMs, as well as source identification for soil conservation in a fast developing area in the world. This study will provide a useful reference for soil environmental protection, and update much valuable data in soil HMs.

2. Materials and methods

2.1. Study area

The Hechuan County (E 105°58′-106°40′, N 29°51′-30°22′) is located in the southeastern part of Sichuan Basin, northwest of Chongqing in the upper Yangtze Basin. The region drains north subtropical monsoon climate with annual average temperature of 18.4 ℃, and the mean annual rainfall is 1552.7 mm. The soil types mainly include purple soil and yellow loam. Land use is dominantly controlled by agriculture (51.6%), therefore, agricultural production and transportation constitute the important anthropogenic activities. With the industrialization of the Municipality Chongqing in the upper Yangtze River Basin, the accumulation of HMs had obviously increased and soil HMs are of great concern in this region. The local government has taken a series of measures to control its HM pollution based on the results from risk assessment of eco-environment.

2.2. Sampling and analytical process

Surface soil samples (0–20 cm) were collected at intervals of 1 km^2 and the equivalent surface soil sample within a range of 4 km^2 was integrated into one surface analytical sample. The soil sample should be representative, equidistributed and reasonable. Sampling sites should avoid newly accumulated soils, garbage dump and obvious local pollution area from the main soil types or land use types. The study sample weighs in excess of 1 kg. A total of 2328 surface soil samples were taken as 582 analytical samples.

Soil samples were naturally air-dried and then passed through a 200-mesh nylon sieve after removing large debris, stones and pebbles. Each dried sample was thus obtained and preserve in the brown glass containers before analysis. The concentrations of eight HMs (i.e., Pb, Cu, Cr, Cd, As, Hg, Ni and Zn), total carbon (TC) and soil pH were analyzed by the following method in a special laboratory of ministry of land and resources of China. The TC was determined as the total evolved CO_2 by a non-dispersive infrared detector after using a solid furnace module for sample combustion at a constant temperature of 1150 °C in 100% O_2 for 180 s. Soil pH was measured by the pH meter after shaking (30 min) and standing (2 h) of the mixture of deionized water and soil (at a ratio of 1:2.5). For the HMs (Cu, Cd, As, Hg and Ni), soil samples were digested in teflon vessels by 10 mL HF and 5 mL $HClO_4$-NO_3 (1:1) for approximately 60 min. After the acids were mineralized and evaporated, 5 mL HNO_3 was added for subsequent digestion (30 min). Subsequently, the residue was filled to volume of 25 mL with ultrapure water for determination. Concentrations of Cd, Cu and Ni in the solutions were determined by inductively coupled plasma mass spectrometry (ICP-MS; Thermo X Series II, USA) or inductively coupled plasma optical emission spectrometry (ICP-OES; Thermo ICAP 6300, USA) and concentrations of As and Hg were detected by atomic fluorescence spectrometry (AFS). 5 g soil samples were obtained by using standard soil test sieve and mould pressing. Subsequently, Pb, Cr and Zn were analyzed by X-ray fluorescence spectrometry (XRF; primus II, Japan). Soils were analyzed in an authorized key lab, where best methods for different HMs were adopted.