ARTICLE IN PRESS

Journal of Geochemical Exploration xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Regional risk assessment of trace elements in farmland soils associated with improper e-waste recycling activities in Southern China

Wencheng Wu[a,b], Yingxin Wu[b], Jiahui Wu[b], Xiaowen Liu[b], Xianbin Chen[b], Xinde Cai[b], Shixiao Yu[a,*]

[a] School of Life Science/State Key Laboratory of Biocontrol, Sun Yat-sen University, Guangzhou 510275, PR China
[b] South China Institute of Environmental Sciences, Ministry of Environmental Protection, Guangzhou 510655, PR China

ARTICLE INFO

Keywords:
Electrical waste
Agricultural soils
Trace elements
Pollution evaluation

ABSTRACT

Trace elements contamination in soils caused by improper electrical waste (e-waste) recycling activities has attracted a lot of attention, and soaring levels of trace elements in e-waste recycling sites and the adjacent farmlands were well-recognized. However, the knowledge of pollution degree, ecological risk of trace elements in a whole e-waste recycling region was still limited. In this study, soil samples collection was conducted in a typical e-waste recycling region (approximately 30 km^2), and the concentrations of eight trace elements (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) were analyzed. Moreover, pollution index, enrichment factor, potential ecological risk, hazard quotient, and hazard index were calculated and used to assess the risk of the ecosystem and human health. The results showed that the mean concentrations of Cd, Cu, and Hg were significantly higher than their standard values of China; the excess portion was 90.2% for Cu, 87.4% for Cd, and 47.6% for Hg, indicating the regional contamination of these metals. The values of enrichment factors further demonstrated that Cd, Cu, and Hg were the most significantly enriched metals in the study area, which might be associated with e-waste activities. On the other hand, the concentrations of Cr and Ni were comparable with their background values, suggesting that they were mainly affected by soil parent materials. Health risk assessment indicated that the carcinogenic risk for the local habitants was unacceptable. Results of this study suggest that soil remediation strategies in e-waste recycling region should not only focus on the sites where e-waste recycling facilities located (i.e. hot spots), but consideration should also be given to control regional risk in farmlands.

1. Introduction

Rapid development of electronics technology industries and the upgrading of electronic products cause approximately 25 million tons of electrical-waste (e-waste) globally per year (Robinson, 2009). Most of the e-waste has been transported to developing countries in south and east of Asia (e.g., China, India, Pakistan, Bangladesh, and Vietnam). In particular, China has become the largest dumping ground for e-waste in the world due to its low labor costs and slack environmental regulations in the past decades (Hong et al., 2015). Most of the recycling processes have been carried out in small family-owned workshops in rural villages, where most of the residents are directly or indirectly involved in e-waste-related activities (Chan and Wong, 2013). These primitive family-run recycling workshops usually used crude recycling techniques, such as manual disassembling, open incineration, and strong acid dipping, which brought extensive contamination of trace elements in soil (Li et al., 2011; Liu et al., 2015; Luo et al., 2011).

As most of the e-waste recycling workshops are located near arable lands, the trace elements in soils do not only threaten local human health through soil and dust ingestion, air inhalation, and dermal absorption (Chen et al., 2015a), but also degrade the quality of soils and crops (Xu et al., 2013). Therefore, the contamination of trace elements from e-waste recycling processes has received extensive attention from scientists and the general public for the last decade, and the hotspot contamination patterns has been well recognized (Luo et al., 2011; Wu et al., 2015a). However, to the best of our knowledge, available information is limited on the distribution and environmental risk of trace elements in farmland soil at regional scale. To better understand the extent of trace elements pollution in farmland soils, we conducted researches in Longtang Town, Guangdong Province, which is one of the three largest e-waste recycling regions in China. There are about 1000 workshops and > 50,000 laborers involved in the e-waste recycling processes around one million tons of e-waste annually (Hu and Cheng, 2013). The local government has recently passed legislation to manage

* Corresponding author.
E-mail address: lssysx@mail.sysu.edu.cn (S. Yu).

https://doi.org/10.1016/j.gexplo.2018.06.009
Received 25 October 2016; Received in revised form 9 May 2018; Accepted 15 June 2018
0375-6742/

Please cite this article as: Wu, W., Journal of Geochemical Exploration (2018), https://doi.org/10.1016/j.gexplo.2018.06.009

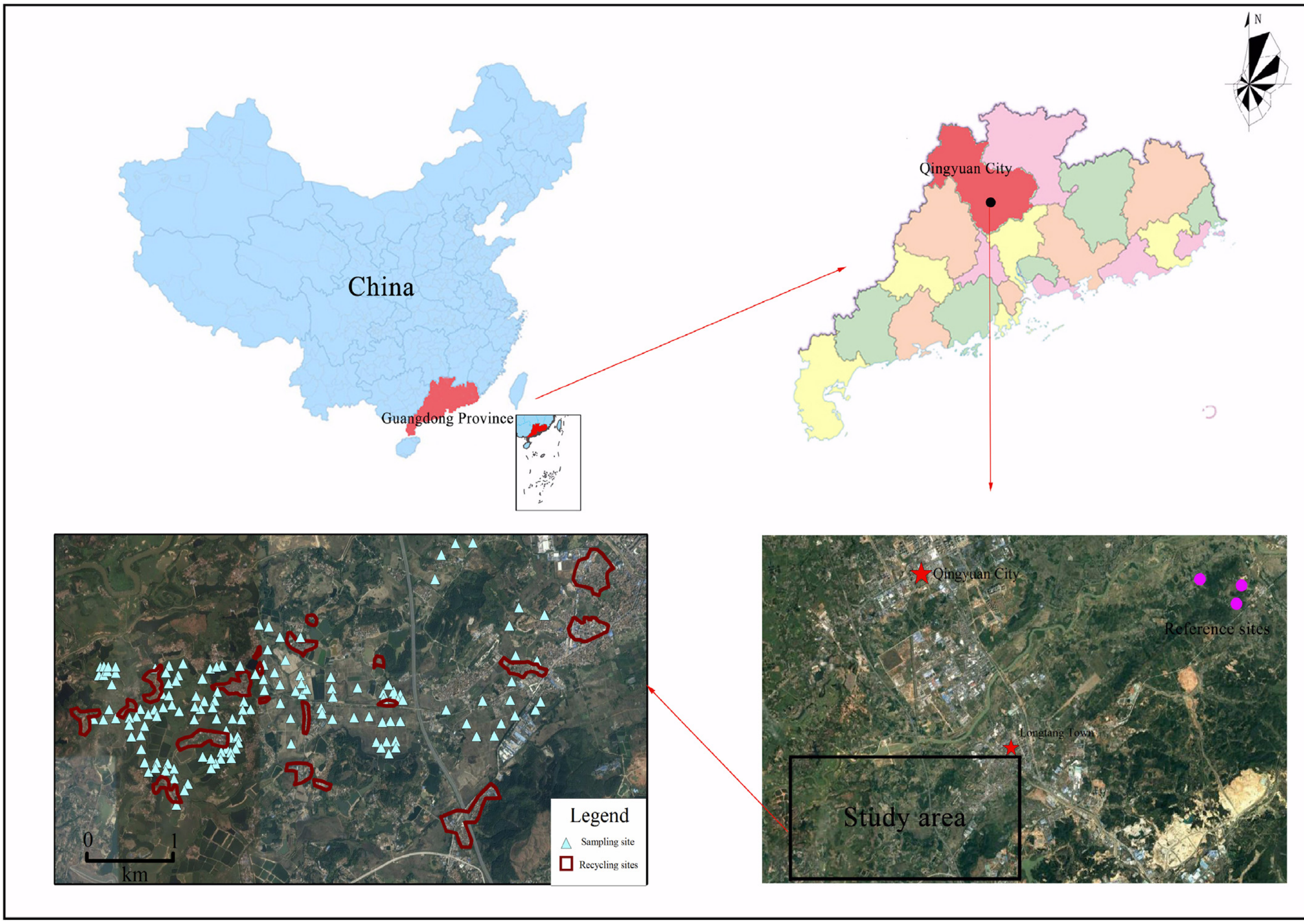

Fig. 1. Distribution of the sampling sites in the study area and the reference sites.

the uncontrolled e-waste recycling activities, and prepared for soil remediation.

The objectives of this study were: (1) to determine the concentration and pollution degree of eight trace elements (As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn) in farmland soils associated with e-waste recycling activities at a regional scale; (2) to identify the possible sources of trace elements; and (3) to evaluate the risks of trace elements for local ecosystem and habitants.

2. Materials and methods

2.1. Study area

Longtang Town is located in Guangdong Province, Southern China (Fig. 1). It has a typical subtropical monsoon climate with an annual temperature of 22.6 °C, and annual rainfall of about 1700 mm. The prevailing winds are from the southeast to northeast throughout the year.

Sample collection was conducted in an area of 30 km^2. It is also one of the earliest region involved in e-waste recycling activities, and numerous recycling workshops scattered around, dismantling the most typical types of e-waste, including electric wires, televisions, computers, and plastics, etc.

2.2. Sampling and analyses

2.2.1. Sampling

Soil samples were collected in May 2015. A total of 143 agricultural topsoil samples (0–20 cm depth) were collected in the study area (Fig. 1). In addition, three reference soil samples were collected from paddy fields 10 km away in upstream and upwind direction from the study area to eliminate any e-waste recycling effects. Each sample consisted of five subsamples collected randomly in an area of $10 \times 10\,m^2$. All samples were collected using a bamboo spade and sealed in clean polyethylene bags.

2.2.2. Analyses

The soil samples were air-dried, grounded sieved through 100-mesh (0.15 mm) sieves for further analysis. The concentrations of Cr, Cu, Ni, Pb, and Zn were determined using inductively coupled plasma-optical emission spectrophotometry (710, Agilent, USA) after acid digestion (HNO_3, HF, and $HClO_4$). The Cd concentration was measured using graphite furnace-atomic absorption spectrometry (PinAAcle 900T, Perkin Elmer, USA) due to the low concentrations in the samples. Arsenic was determined using hydride generation-atomic fluorescence spectrometry (AFS-9700, HG, China), and Hg was determined using cold vapor atomic fluorescence spectroscopy (AFS-9700, HG, China).

The quality assurance and quality control (QA/QC) procedures were conducted with standard reference materials GSS-7 (Geochemical Standard Soil). The recoveries of trace elements in GSS-7 ranged from 88% (Cd) to 112% (Pb). Duplicated samples were performed simultaneously for 20% samples, and their standard deviations were < 5%. Blank samples were also performed throughout all the experiments, and the concentrations of trace elements were not detected.