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Spatial characteristics of cadmium in topsoils in a typical e-waste recycling area in southeast China and its potential threat to shallow groundwater

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HIGHLIGHTS

- We characterize the Cd_{total} in topsoils, pH and SOM in a typical e-waste recycling area.
- The relationships between Cd_{total} in topsoils, pH, and SOM were studied.
- Impact of topsoil Cd accumulation and acidification on shallow groundwater quality was evaluated.

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ABSTRACT

Informal electrical and electronic waste (e-waste) recycling often creates secondary sources of cadmium (Cd) pollution. To characterize the total Cd concentration (Cd_{total}) in topsoil and evaluate the threat of Cd in topsoils to shallow groundwater, 187 topsoil samples and 12 shallow groundwater samples were collected in a typical e-waste recycling area in southeast China. Soil organic matter content, soil pH and Cd_{total} in topsoil, pH and dissolved Cd concentration in shallow groundwater were measured. Cd_{total} in the topsoils showed an inverse distribution trend with soil pH in that high Cd concentrations (and low pH values) were found in the surrounding area of the metal recycling industrial park where there were many family-operated e-waste recycling facilities before the industrial park was established and with low concentrations (and high pH values) in other areas, and they had similar spatial correlation structures. Cd accumulation and acidification were synchronous in topsoils, and soil pH was significantly correlated with Cd_{total} in topsoils with low to moderate negative correlation coefficient ($r = -0.24$), indicating that both of them maybe correlated with informal recycling. The shallow groundwater in the surrounding area of the metal recycling industrial park was seriously contaminated by Cd, and topsoil Cd accumulation and acidification in the surrounding area of e-waste recycling sites significantly increase the risk of shallow groundwater contaminated by Cd. Action is urgently required to control Cd accumulation and acidification by improving the recycling operations of e-wastes in order to reduce the risk of Cd leaching from topsoils and shallow groundwater contamination.

1. Introduction

With the rapid development of information technology and the accelerated update and upgrade of electronic products, the elimination and recycling of electrical and electronic wastes (e-wastes) become a problem of the world currently. E-wastes not only contain recyclable resources, such as iron, aluminum, copper and precious metals, but also contain persistent organic pollutants (e.g. polycyclic aromatic hydrocarbons, polychlorinated biphenyls, polybrominated diphenyl ethers) and heavy metals (e.g. cadmium, lead, zinc, mercury). The potential economical benefit is promoting the development of e-waste disassembly industry, particularly for developing countries including China (Williams et al., 2008; Liu et al., 2009; Ni and Zeng, 2009). In China, a

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Abbreviations: E-wastes, electrical and electronic wastes; HM, heavy metal; Cd, cadmium; Cd_{total}, total Cd concentration; GPS, global positioning system; SOM, soil organic matter content; ICP-MS, inductively coupled plasma mass spectrometry; HNO_3, nitric acid; $HClO_4$, perchloric acid; $Cd_{dissolved}$, dissolved Cd concentration; RSD, relative standard deviation; ln, natural logarithmic; BV, background value; GLV, guideline value; MOH, Ministry of Health of China; NSMC, National Standardization Management Committee; SEPAC, State Environmental Protection Administration of China.

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large proportion of e-waste is transported to family-operated recycling facilities. In these recycling facilities, strong acid leaching and the open burning of dismantled components are used often to extract precious metals contained in e-wastes. These informal dismantling, recycling, and disposal practices caused severe heavy metal (HM) pollution in air, dust, soil, river water and sediment in e-waste recycling area (Deng et al., 2006; Ha et al., 2009; Zhang and Min, 2009). Informal recycling is currently the prevalent e-waste recycling practice in China, especially in some coastal regions (Liu et al., 2006; Terazono et al., 2006; Yang, 2008).

In southeast China, e-waste processing sites are usually located in fields adjacent to land used for agricultural purposes (Tang et al., 2010; Luo et al., 2011). The informal recycling process may cause serious agricultural soil contamination with HMs in the vicinity of e-waste processing sites (Wong et al., 2007; Shen et al., 2008; Zhang and Min, 2009). Agricultural soil contamination with HMs had become a serious environmental problem because it poses a serious threat to human health by entering into food chains and to environmental security by washing into surface water by rain and leaching into shallow groundwater (Shen and Chen, 2000; Romic and Romic, 2003). Cadmium (Cd) is one of the toxic HMs that was used widely in the electrical and electronic industry, and they were most widely detected in e-waste contaminated surroundings (Shen et al., 2008; Guo et al., 2009; Wang et al., 2009; Chen et al., 2010). Therefore, it is necessary to quantify the spatial characteristics of HM in agricultural soils and evaluate the threat of toxic HMs in topsoils to shallow groundwater by leaching in order to be able to formulate a policy to control or eliminate Cd pollution and ensure shallow groundwater safety.

There is a large body of literature on HM contamination in soils in the vicinity of e-waste processing site (e.g., Ha et al., 2009; Tang et al., 2010; Luo et al., 2011). However, few studies have been conducted on the threat of Cd in topsoils to shallow groundwater in the vicinity of e-waste processing sites. In this study, a typical e-waste recycling area with many family-operated recycling facilities in southeastern China was chosen as our study area. The main objectives of this study were: (1) to characterize the total Cd concentration (Cd_{total}) in topsoil in a typical e-waste recycling area; (2) to study the relationship between Cd_{total} in topsoils and pH, SOM; and (3) to evaluate the threat of Cd in topsoils to shallow groundwater.

2. Materials and methods

2.1. Descriptions of study area

The study area is part of a town in Taizhou city, Zhejiang Province, Southeast China with a total area of approximately 10 km^2. In this town, there are many family recycling facilities to process a large quantity of e-wastes from domestic supplies and developed countries from the late of 1980s. A metal recycling industrial park with a total area of 107 ha has been established in southeastern of the study area with the purpose of promoting efficient and environmentally-friendly recovery of original and imported metal scraps (Fig. 1), and most of e-waste recycling activities were carried on in the metal recycling industrial park in recent years. The study area has become an important e-waste recycling area in southeastern China.

The study area is in the northern subtropical zone of monsoonal climate with a temperate and humid climate throughout the year with four distinct seasons. The average annual temperature is 17.1 °C and the mean annual precipitation is approximately 1523 mm. Paddy fields and uplands are two major land use types of arable land in the study area. Gleysols is the major type of anthropogenic soils in the study area. According to hydrogeological data, the thickness of the porous unconfined aquifer is approximately 2–3 m, and the shallow groundwater level is approximately 0.5–2.5 m being deeper in the west and more shallow in the eastern region of the study area. The permeability of the unconfined aquifer was uneven and very low. The vertical flow is the major movement of groundwater and the velocity of horizontal flow was very low due to the small hydraulic gradient in the study area.

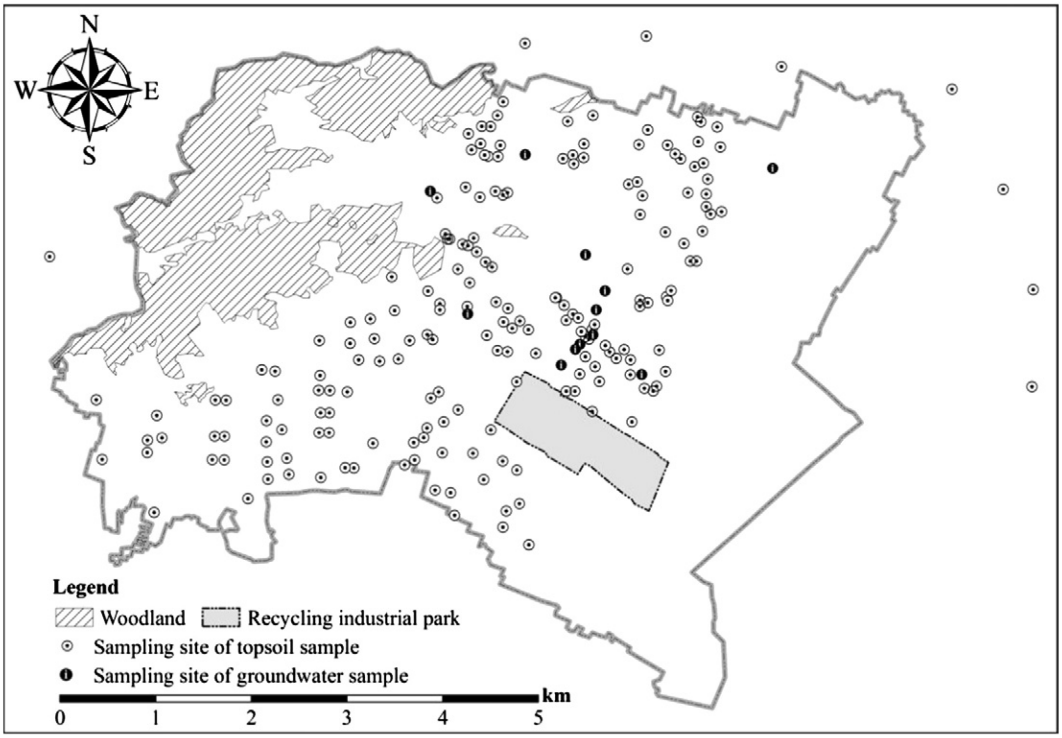

Fig. 1. The location of study area and distribution of sampling sites.