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Heavy metal contamination of soil and water in the vicinity of an abandoned e-waste recycling site: Implications for dissemination of heavy metals

Qihang Wu [a,b], Jonathan Y.S. Leung [c,*], Xinhua Geng [d], Shejun Chen [e], Xuexia Huang [a], Haiyan Li [f], Zhuying Huang [a], Libin Zhu [a], Jiahao Chen [a], Yayin Lu [a]

[a] School of Environmental Science and Engineering, Guangzhou University, Guangzhou 510006, China
[b] Department of Biology and Chemistry, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong
[c] School of Earth and Environmental Sciences, The University of Adelaide, Adelaide, South Australia, 5005 Australia
[d] School of Chemistry and Chemical Engineering, Guangzhou University, Guangzhou 510006, China
[e] State Key Laboratory of Organic Geochemistry, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou 510640, China
[f] Department of Civil Engineering, Guangzhou University, Guangzhou 510006, China

HIGHLIGHTS

- Contamination of heavy metals in an abandoned e-waste recycling site is examined.
- The surface soil in the vicinity of this site is contaminated with Cd, Cu and Pb.
- The concentrations of heavy metals in soil generally decrease with depth.
- The water in the pond and stream is seriously contaminated with heavy metals.
- Results imply that the heavy metals are transported from the surface soil to ponds.

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ABSTRACT

Illegal e-waste recycling activity has caused heavy metal pollution in many developing countries, including China. In recent years, the Chinese government has strengthened enforcement to impede such activity; however, the heavy metals remaining in the abandoned e-waste recycling site can still pose ecological risk. The present study aimed to investigate the concentrations of heavy metals in soil and water in the vicinity of an abandoned e-waste recycling site in Longtang, South China. Results showed that the surface soil of the former burning and acid-leaching sites was still heavily contaminated with Cd (>0.39 mg kg^{-1}) and Cu (>1981 mg kg^{-1}), which exceeded their respective guideline levels. The concentration of heavy metals generally decreased with depth in both burning site and paddy field, which is related to the elevated pH and reduced TOM along the depth gradient. The pond water was seriously acidified and contaminated with heavy metals, while the well water was slightly contaminated since heavy metals were mostly retained in the surface soil. The use of pond water for irrigation resulted in considerable heavy metal contamination in the paddy soil. Compared with previous studies, the reduced heavy metal concentrations in the surface soil imply that heavy metals were transported to the other areas, such as pond. Therefore, immediate remediation of the contaminated soil and water is necessary to prevent dissemination of heavy metals and potential ecological disaster.

1. Introduction

Owing to the rapid development of information technology and constant upgrade of electronic products, electronic waste (e-waste) has become the fastest growing stream of municipal solid waste over the last decade (Schmidt, 2002; Ni and Zeng, 2009; Robinson, 2009). A majority of e-waste are produced by the developed countries in which the US alone generated over 9.4 million tons in 2012 (StEP: http://step-initiative.org/index.php/Overview_USA.html). To handle the e-waste, many developed countries tend to export it (ca. 50%–80%) to the developing countries (e.g., China, Bangladesh, India, Pakistan and Vietnam) for recycling and disposal in view of lower labour costs and less stringent environmental regulations (Schmidt, 2002; Ni and Zeng, 2009).

* Corresponding author. Tel.: +61 412342130.
E-mail address: jonathan_0919@hotmail.com (J.Y.S. Leung).

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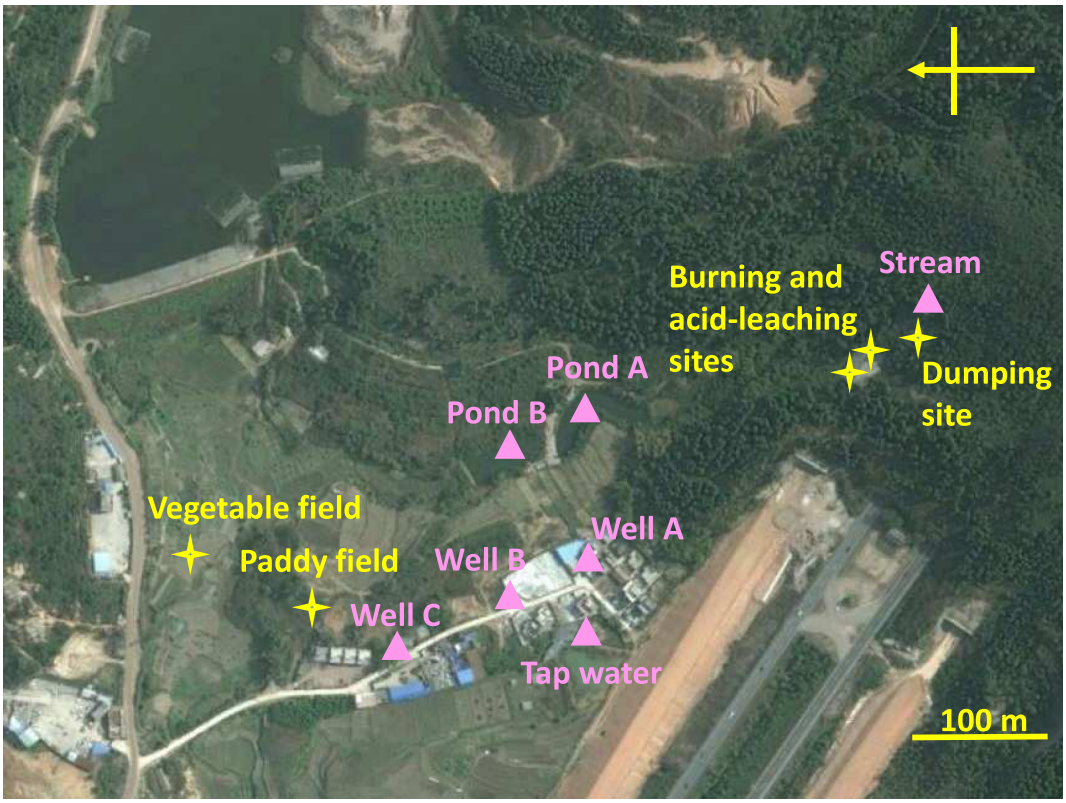

Fig. 1. The sampling map in the abandoned e-waste recycling site in Longtang, Guangdong province (Retrieved from Google Earth). + and ▲ indicate the sampling sites for soil and water samples, respectively ($n = 3$).

Nowadays, China is the largest importer and recycler of e-waste in the world, receiving over one million tons of e-waste from the US and European countries every year (Schwarzer et al., 2005; Widmer et al., 2005; Yang, 2008; Ni and Zeng, 2009). Despite the economic benefits, e-waste has caused serious environmental pollution (e.g., soil and water contamination) in China since it is often processed in backyards or workshops illegally by primitive techniques such as open burning, strong acid digestion of dismantled components to recover the precious metals and dumping of unsalvageable materials (Leung et al., 2006, 2008; Wong et al., 2007; Zhang and Min, 2009; Tang et al., 2010). Even worse, these workshops are usually located near the arable land, affecting crops and hence human health via the food chain (e.g., Fu et al., 2008; Zhang and Min, 2009; Luo et al., 2011; Zheng et al., 2013). In view of the ever-increasing domestic generation of e-waste and demand of high quality electronic products (Hicks et al., 2005; Yang, 2008), e-waste problems in China would be deteriorating. As such, the Chinese government has amended the laws, regulations and standards to reduce the number of illegal e-waste recycling workshops (reviewed in Lu et al., 2014).

It is noteworthy that none of these laws and regulations emphasise remediation of contaminated soil and water in the vicinity of e-waste recycling sites; therefore, the pollutants remaining in abandoned e-waste recycling sites can still pose hidden danger to the surrounding environments (Lopez et al., 2011; Zhang et al., 2014). Among various toxic substances in the e-waste, heavy metals are of special concern because of their toxicity, mobility and non-biodegradability. Apart from soil, water resources are very subject to heavy metal contamination. For example, heavy metals in soil can be washed away by rainfall and end up in the nearby ponds; heavy metals can contaminate groundwater via leaching especially under acidic conditions (Zheng et al., 2013; Pradhan and Kumar, 2014; Wu et al., 2014). Since the local villagers usually rely on pond water and groundwater for irrigation and drinking, respectively, the potential ecological risk of heavy metals in the vicinity of abandoned e-waste recycling sites should not be overlooked.

The present study was conducted in an abandoned e-waste recycling site in Longtang, Guangdong province, South China. Metal recycling is the major economic activity in this town where e-waste recycling activity has been conducted illegally and extensively by primitive techniques since 1991. Despite the legislation by the local government in the early 2000s, illegal e-waste recycling activity was still prevalent due to a paucity of effective enforcement. In recent years, the local government has constructed more legal e-waste disposal centres and strengthened enforcement to eradicate the illegal e-waste recycling activity, resulting in many abandoned e-waste recycling sites (personal communication with the local villagers). Apart from metal recycling, agriculture is another pivotal economic activity, but the arable lands are often located near the abandoned e-waste recycling sites. We aimed to elucidate the contamination of heavy metals in this abandoned e-waste recycling site by examining their concentrations in the surface soil, pond water, stream water and groundwater, as well as their vertical distribution in soil. In addition, pH and total organic matter (TOM) were measured because they are the most important factors governing heavy metal accumulation in soil (Covelo et al., 2007a,b; Kashem et al., 2007; Ho et al., 2012). The findings can shed light on the environmental impacts of heavy metals in abandoned e-waste recycling sites and thus can raise awareness of the local villagers and authorities concerned to take immediate action to remediate the contaminated soil and water.

2. Materials and methods

2.1. Study area and sampling method

The study area was located in an abandoned e-waste recycling site in Longtang (23°33′03″N, 113°04′31″E), which has a subtropical monsoon