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Assessment of heavy metal contamination, distribution and source identification in the sediments from the Zijiang River, China

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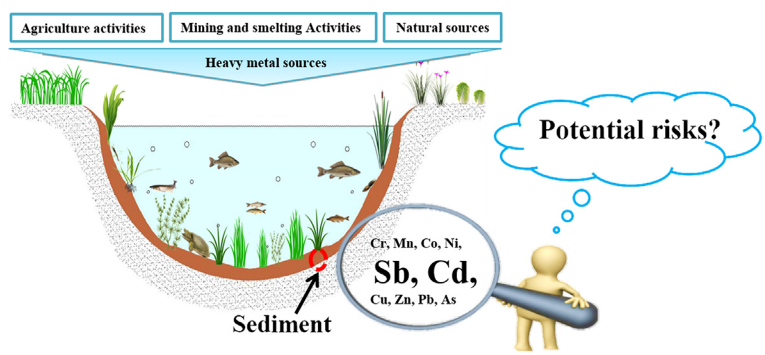
HIGHLIGHTS

- Accumulation of heavy metals was found in sediments, especially Sb and Cd.
- The downstream of Sb mining and smelting factories had serious contamination.
- Ecological risks of Sb and Cd were much higher than that of other elements.
- Sb, As, Mn, and Pb mainly derived from mining and smelting activities.
- Co, Zn, Cd, and Cu contaminants mainly derived from agricultural activities.

GRAPHICAL ABSTRACT



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ABSTRACT

In this study, the contents of 10 heavy metals (Sb, Cd, Cr, Mn, Co, Ni, Cu, Zn, As, and Pb) in 49 sediment samples from the Zijiang River were determined by using inductively coupled plasma-optical emission spectrometry. Contamination indexes including geoaccumulation index, modified degree of contamination, sediment quality guidelines, potential ecological risk index, together with potential ecological risk factor were used to assess heavy metal contamination in the sediments of the Zijiang River. Pearson's correlation analysis and principal component analysis were used to identify the sources of heavy metals. The results indicated that the mean values of heavy metals in the Zijiang River's sediments were found to be significantly higher than the corresponding background values. But when comparing with that in other rivers in the world, they were at medium levels except for Sb. Furthermore, a comparison of the heavy metal concentrations and the consensus-based sediment quality guidelines showed that the heavy metal pollutions (Cd, Cr, Ni, Cu, Zn, As, and Pb) tended to occasionally pose harmful impacts on the ecosystem. The values of contamination indexes revealed that serious heavy metal contamination and relatively high potential ecological risks were mainly existed in the downstream of antimony mining and smelting factories (S23–S49). In addition, high potential ecological risks of Sb were observed in sampling sites that were close to those factories (S23, S24, S25, and S27), and high potential ecological risks of Cd were observed in the downstream (S37–S49). Basing on the Pearson's correlation analysis and principal component analysis, three main sources were identified. Co, Zn, Cd, and Cu contaminants were mainly derived from agricultural activities; As, Sb, Mn, and Pb mainly came from mining and smelting activities; Cr and Ni were mainly from natural sources.

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1. Introduction

Heavy metal contamination in aquatic environment has received enormous attention because of its toxicity, abundance, persistence, and subsequent accumulation in aquatic habitats (Ali et al., 2016; Ke et al., 2017; Varol, 2011). Although heavy metals have low solubility, once entering in the rivers, they will be rapidly diluted and transported with hydrologic gradients for hundreds of kilometers and then absorbed and settled on the bottom sediments (Audry et al., 2004; Li et al., 2013; Resongles et al., 2014; Tam and Wong, 2000). At the same time, the heavy metals in the sediments can release into overlying waters under favorable conditions and may enter into the food chain, therefore, pose health risks to human consumers (Morina et al., 2016; Shomar, 2006; Varol, 2011; Xu et al., 2017). Thus, the sediments could act as an indicator for the pollution levels and serve as a screening tool to fingerprint both historical and recent pollution in the nearby environment (Xiao et al., 2013; Lin et al., 2008; Zahra et al., 2014).

The Zijiang River, also known as Zishui, is one of the four major water systems in Hunan Province, China. It is located in the middle of the province, with a typical subtropical monsoon climate, where the annual precipitation is between 1200 and 1800 mm, and the average annual temperature is about 20 °C. The river rises in western Shaoyang and wanders northward for 630 km to the Dongting Lake, and passes by Shaoyang, Loudi, and Yiyang in sequence. The basin which totally covers 26,738 km^2 of the Hunan Province's area, is an important industry, agriculture, and population living area. The percentages of social output in cities and prefecture are shown in Fig. S1. The basin has abundant nonferrous metal mineral resources including the superlarge antimony deposit of Xikuangshan (Wang et al., 2011) and the large antimony deposit of Zhazixi in Hunan Province. Xikuangshan is the largest antimony deposit in the world and is called as the "World Capital of Antimony". With more than one hundred years exploitation, it has caused Sb and other heavy metal pollutions in the fluvial ecosystem in the Loudi and Yiyang sections (Guo et al., 2018; Wang et al., 2011). In 2007, over 9.45×10^5 tons of wastewater, 6.72×10^5 tons of mining and smelting residues, and 1.50×10^5 tons of arsenic-alkali residues were released into the surrounding environment (Tang and Liu, 2009). To the best of our knowledge, no systematically and comprehensively investigations on the pollution levels and ecological risks of the heavy metals in the Zijiang River's sediments have been conducted so far. Additionally, Sb is a toxic element, and excess intake by humans may cause adverse health effects (Ren et al., 2014). The United States Environmental Protection Agency and the European Union have considered Sb as a priority pollutant (Filella et al., 2002). Therefore, studying the heavy metal pollutions especially for Sb pollution in the Zijiang River is very important for the ecological protection in this area.

Thus, the research was planned to conduct a scientific sampling campaign in the Zijiang River to identify the spatial distributions of heavy metals in the sediments and to reveal the pollution status using contamination indexes. Furthermore, the study aimed to assess the potential ecological risks of the aforementioned heavy metals and to discuss the possible sources based on the multivariate statistical techniques.

2. Materials and methods

2.1. Sample collection and preparation

Forty-nine samples were collected in the Zijiang River from March to April in 2017. Sampling sites are shown in Fig. 1. The samples collected from each site consisted of 4–5 sub-samples. The sediments with the depth of 0–10 cm were taken by a Petersen's grab. The locations of sampling sites were identified by a hand-held global positioning system (GPS). After collection, the sediment samples (stored in clean polyethylene zip-bags) were transferred to the laboratory immediately. A 2 mm sieve was used to remove stones and plant fragments from samples after air-dried. In the next step, the samples were ground and passed

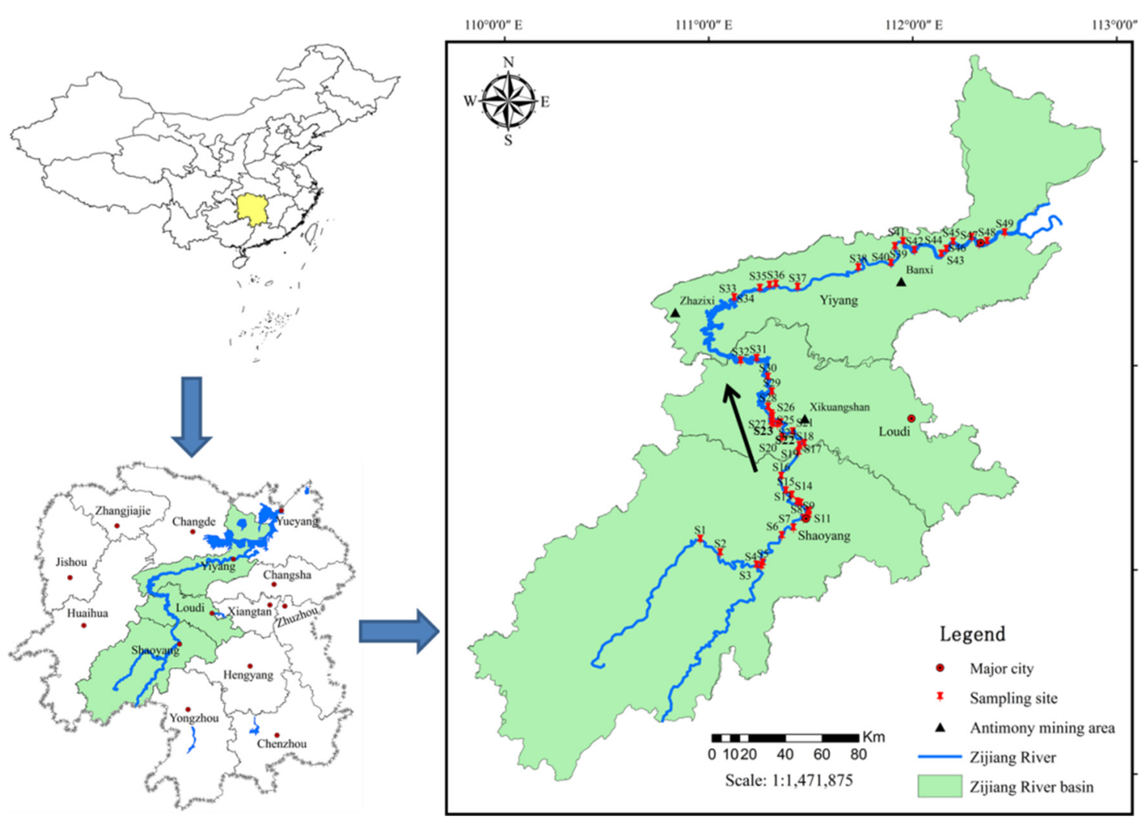

Fig. 1. The location of sampling sites along the Zijiang River.