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Sources identification and pollution evaluation of heavy metals in the surface sediments of Bortala River, Northwest China

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ABSTRACT

The current study focused on the Bortala River – a typical inland river located in an oasis of arid area in northwestern China. The sediment and soil samples were collected from the river and drainage basin. Results showed that: (1) the particle size of the sand fraction of the sediments was 78–697 μm, accounting for 78.82% of the total samples; the average concentrations of eight heavy metals fell within the concentration ranges recommended by the Secondary National Standard of China, while the maximum concentrations of Pb, Cd, and Hg exceeded these standards; (2) results from multivariate statistical analysis indicated that Cu, Ni, As, and Zn originated primarily from natural geological background, while Cd, Pb, Hg and Cr in the sediments originated from human activities; (3) results of the enrichment factor analysis and the geo-accumulation index evaluation showed that Cd, Hg, and Pb were present in the surface sediments of the river at low or partial serious pollution levels, while Zn, Cr, As, Ni, and Cu existed at zero or low pollution levels; (4) calculation of the potential ecological hazards index showed that among the eight tested heavy metals, Cd, Pb, Hg, and Cr were the main potential ecological risk factors, with relative contributions of 25.43%, 22.23%, 21.16%, and 14.87%, respectively; (5) the spatial distribution of the enrichment factors (EF_S), the Geo-accumulation index (I_{geo}), and the potential ecological risk coefficient (E_r^i) for eight heavy metals showed that there was a greater accumulation of heavy metals Pb, Cd, and Hg in the sediments of the central and eastern parts of the river. Results of this research can be a reference for the heavy metals pollution prevention, the harmony development of the ecology protection and the economy development of the oases of inland river basin of arid regions of China, Central Asia and also other parts of the world.

1. Introduction

Heavy metals are an important class of pollutants which can produce considerable harm to the environment when they are above certain concentrations (Varol, 2011; Gao et al., 2014; Zhang et al., 2012, 2015a,b). After heavy metals enter into a water body, they can harm aquatic organisms, and through the processes of chemical adsorption and physical precipitation, heavy metals can accumulate in the sediments of the water environment. When environment conditions such as pH, electrical conductivity (EC), oxidation reduction potential (ORP), and chemical oxygen demand (COD) change in the water or sediments, these elements can be released from the sediments and cause continual harm to the water environment (Ndimele, 2012; Li et al., 2014a; Zheng et al., 2013; Dong et al., 2014a; Fu et al., 2014). Heavy metal contents of the surface sediments are generally significantly higher compared with those in the water body, so it is very important to explore the heavy metal contents in the surface sediments as well as in the water body including rivers, lakes, and bays worldwide (Sundaray et al., 2011; Djordjević et al., 2012; Leung et al., 2014; Wang et al., 2014).

Rapid economic development and exogenous input of heavy metals from human activities are the main sources of heavy metals in the sediments of the water bodies, with the highest concentrations often measured in rivers, lakes, and the reservoirs located in the cities, and near industrial parks and towns with various human activities. Since the Industrial Revolution that began in Britain in the mid-19th century, approximately 40% of the rivers and lakes have been affected by human activities (Li et al., 2014b). Sediments are the main heavy metals accumulation places, and the heavy metals pulled into the water body of rivers, lakes and bays, eventually accumulated in the sediments (Scheibye et al.,

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2014). By statistics, about 85% of heavy metals eventually accumulated in the surface sediments (Zahra et al., 2014; Zhang et al., 2015a). In recent years, the heavy metal pollution of sediments of rivers in North America, Europe, and Asia has been widely studied, including the Mississippi River in the United States (Staley et al., 2015), the Ruhr and Rhine Rivers in Germany (Förstner and Prosi, 2013), the Mithi River in Mumbai, India (Singare et al., 2012), and the Yellow River (Ma et al., 2015) and the Yangtze river (Dong et al., 2014b) in China.

Inland rivers, such as the Tarim River in northwest China (Xiao et al., 2014), the Chari River in Africa (Moser et al., 2014), and Amu Darya and Syr Darya in central Asia (Barber et al., 2005) were formed by rain and snow runoff from inland mountains. Previous research showed that heavy metal accumulation in the inland rivers can cause continual harm to the environment due to its closure (Abuduwaili et al. 2015). The water environment of the inland rivers was very fragile, and once they suffered from heavy metals contamination, it was very difficult to remediate (Li et al., 2014b).

After the start of “The Development of the West Regions of China” in 2000, the economy of the oases in arid regions in northwestern China experienced rapid progress, as well as serious heavy metal pollution in water bodies (Zhang et al., 2012, 2013, 2015a). However, there has been limited research regarding heavy metal pollution and the potential ecological risk to the inland rivers and the rump lakes. Abuduwaili et al. (2015) found that with the economic development of the drainage basin, emissions from the petroleum chemical industry, agriculture production, and the agricultural and sideline products of the drainage basin have resulted in accumulation of the heavy metals Hg, Cd, and Cr, which were above moderate pollution levels. The high contents of these heavy metals in the river as well as in the farmland soil increased the heavy metal contents in the rump lake downstream, which reached heavy pollution levels.

The Bortala River is a typical inland river located in the Xinjiang oases of northwestern China. The river has no marine outfall and eventually flows into the rump lake, Aibi Lake (Fig. 1). Since the 1990s, the industrial structures of these regions were greatly altered with the “West to East Gas Pipeline Construction”, the Second Asia–Europe Continental Bridge Construction, the establishment of the port free trade zone of Alataw Pass, and the development of the petroleum chemical, the salt chemical, and transportation industries, and the environments of the rivers in the

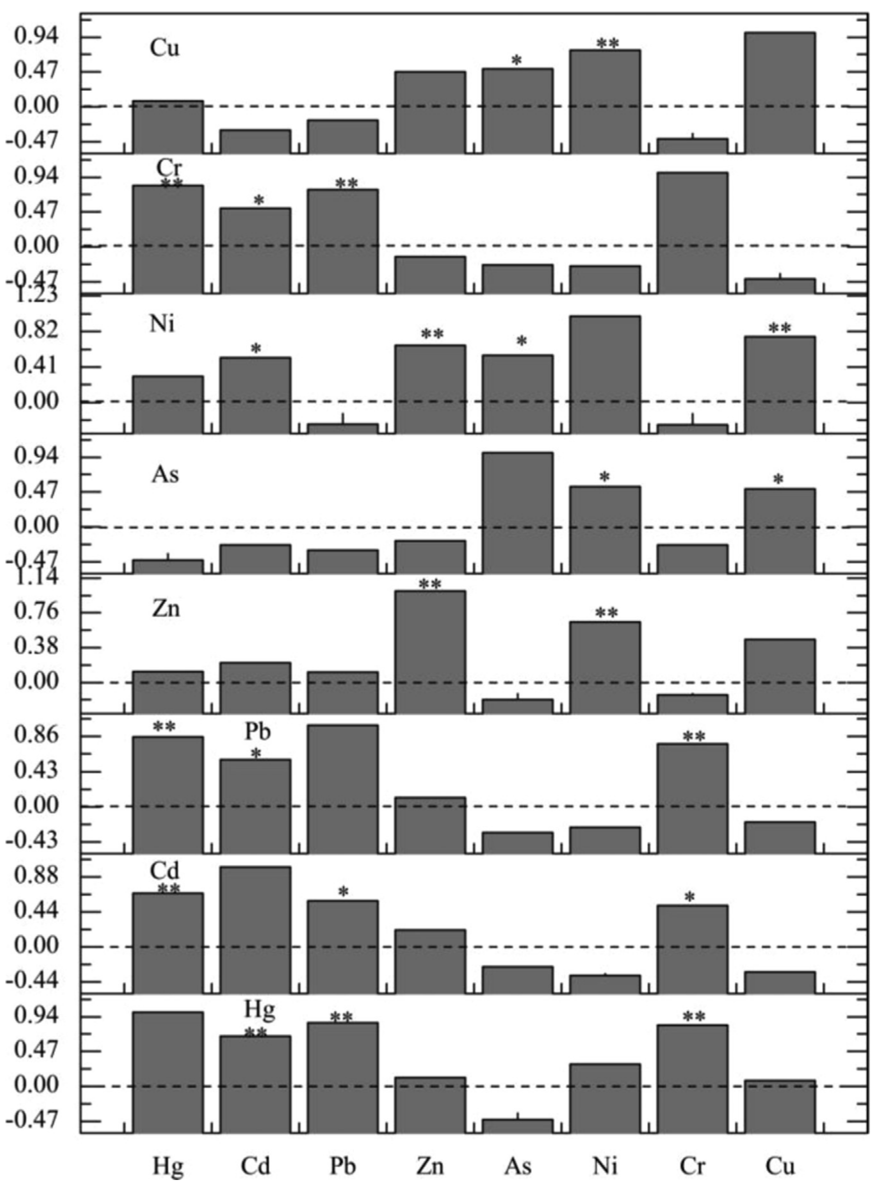

Fig. 1. Correlation coefficients of heavy metals in surface sediments of Bortala River. Note: * is significant at $p < 0.05$; ** is significant at $p < 0.01$.