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Evaluation of heavy metal pollution and its ecological risk in one river reach of a gold mine in Inner Mongolia, Northern China

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ABSTRACT

The spatial distribution characteristics of As, Cu, Hg, Pb, Zn and pH were analyzed by measuring the contents of several heavy metals in surface and profile sediment, in one river reach of a gold mine, Inner Mongolia. The results indicated that heavy metal pollution had less and less effect on river reach with the distance from the gold mine, and the effect nearly disappeared when falling into the Zhaosu River. In vertical profile, there was a trend that the contents of heavy metals gradually decreased with the depth increasing. The river reach in the gold mine was contaminated more seriously by As and Hg, for which As contents exceeded the national soil quality standard of grade III, and the contents of Cu, Pb and Zn all didn't exceed it. The evaluation results by Hakanaon risk index method indicated that the ecological risk for Hg and As were higher, reaching up to grade C, while the risk for Cu, Pb and Zn were low. The comprehensive ecological risk of heavy metals reached up to grade III in the junction of river and valley and near the mining site, while the grades were A and B in two sampling sites of Zhaosu River. It was believed that mining activities and adsorption by clay minerals were primary controls for ecological impact of As and Hg.

1. Introduction

With the acceleration of urbanization and the development of industry, especially the mining industry, a large number of untreated municipal waste, industrial waste water and atmospheric deposition were migrated into soil, resulting in increasingly serious heavy metal pollution of soil (Diels et al., 1996; Dan, 2001; Abrusci et al., 2013). Based on the statistics, the annual mean discharge of Hg, Pb, Co, Ni and Mn are approximately 1.15 million t, 5 million t, 3.4 million t, 1 million t and 15 million t all around the world (Querol et al., 2000).

At present, the agricultural acreage under the effect of heavy metal pollution in China is nearly 20 million hm^2, accounting for one fifth of total agricultural acreage (Chen, 1998). The yield of grain polluted by heavy metals is up to 12 million t every year, and resulting annual economic loss is at least 2,000,000,000 RMB (Qu, 1989). The heavy metal pollution has a significant effect on the quality and yield of agricultural products, and harm human health through food chain, for which the typical cases include minamata disease triggered by Hg pollution and itaiitai disease caused by Cd pollution (Xu and Yang, 1995; Chapman, 1995; Conrad et al., 2007). Owing to the hidden, chronic, cumulative and irreversible characteristics of soil heavy metal pollution (Dzombak and Morel, 1987; Johnson, 1996), the treatment for which is difficult. Therefore, the treatment of soil heavy metal pollution is becoming a major concern for current environmental science.

Heavy metal ions that are adsorbed in the surface of particulate matter flow into stream through flushing and leaching, and deposit slowly with the stream flow (Dzombak and Morel, 1987; Conrad et al., 2007). The contents of heavy metals in sediments are stable (Diels et al., 1996), and long-term accumulation of which will cause sediment pollution. The determination of heavy metal concentration in sediment are representative, and sediment profile can reflect the change of era and environment for long timescale based on the change of particle size and chemical component (Hornberger et al., 1999; Du et al., 2010; Driai et al., 2015). The heavy metal pollution and its ecological remediation in mining sites is one of research hotspots in environmental science field (Li et al., 2008; Zhuang et al., 2009; Machender et al., 2010; Soriano-Disla et al., 2010), however, there has been no report about heavy

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metal pollution in stream in metal mining sites of Inner Mongolia at present.

2. Materials and methods

2.1. Study area

The study area is located in Zhaosu River catchment in Wulateqianqi, Inner Mongolia (Fig. 1). The golden mining site has an area of 1.897 km^2 and 5 industrial ore bodies, the serial number of which are 1, 3, 4, 6 and 7, respectively. Through the underground mining, annual yield of the golden mine is 60 thousand t, and the service length of the first mining section is 9.3 years. The flank shaft development system is used, which is composed of one shaft (SJ2), one return-air shaft (FJ1) and haulage roadway and air connection of each middle section. The main mining method is short-hole shrinkage, and waste lifting stope is used when ore body thickness is less than 0.8 m. The waste rock produced by mining are piled up in the waste-rock yard, the amount of which is about 16 500 m^3 during mining period. Dressing mill, industrial site, and office and living quarter were built in the mining area.

The mining area is located in the southeast of one river reach of Zhaosu River. The reach is a gully with seasonal flow, in which Quaternary sediment are distributed on the bed. In rainy season, temporary flood discharge into Zhaosu River from east to west. The Zhaosu River is perennial stream, the valley width and incision depth of which are 150–200 m and 3–5 m. The flow direction is from north to south.

2.2. Sample collection

The sampling campaign was conducted along the reach in the

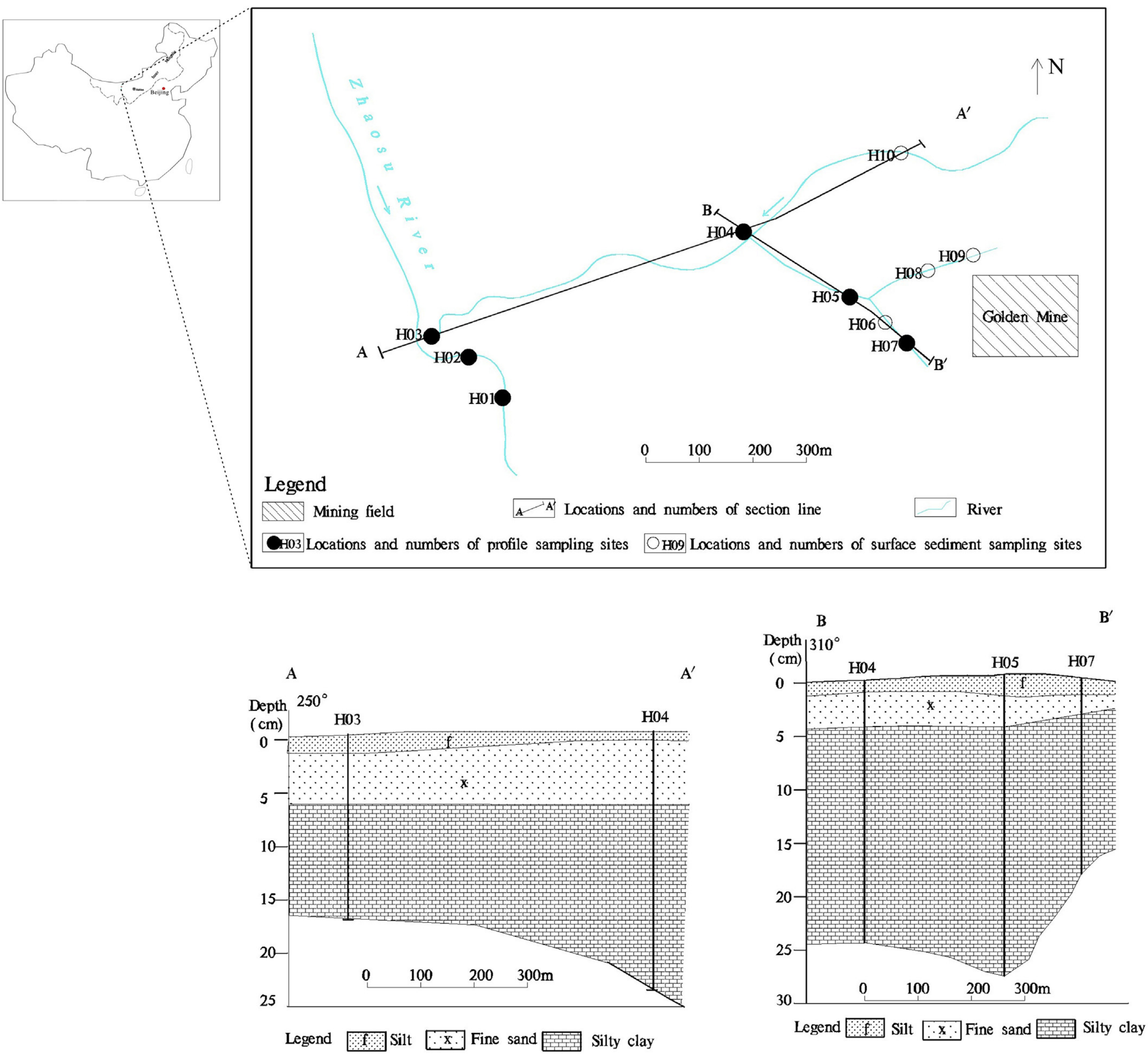

Fig. 1. Location of study area, coupled with the distribution of sampling sites. The two representative sections A-A' and B-B' were shown below.