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Chemical composition and transportation characteristic of trace metals in suspended particulate matter collected upstream of a metropolitan drinking water source, Beijing

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ABSTRACT

The impact of mining on environment should get more attention. The Chaobai River is the major source of Miyun Reservoir, a unique surface drinking water storage for Beijing. 11 sampling sites along the Baihe and Chaohe rivers are chosen in June and September 2012 to investigate the distribution, pollution and sources of trace metals in suspended particulate matter. We analyzed 10 trace metals and Sr, as an indicated element of soil weathering. 7 samples of colloidal particles were collected and the characterization of colloids was performed using Transmission electron microscope. The results reveal that most of mean concentrations of metals in suspended particulate matter are higher than the background of Beijing soil and have no significant difference in both seasons. According to the results, a serious contamination with Cd should be discussed and addressed, especially at site B4 on Baihe River close to the gold mine. Statistical analysis suggests that Zn, Pb, Cd and Sb represent anthropogenic sources including industrial mining, atmospheric depositions and vehicle emissions; the Ni, Cu and Ba pollution may have mixed sources of anthropogenic and natural origin. The partitioning coefficient of metals shows that most metals are affected by mines, with the exception of Ni, Cr, Cu and V, which were not significantly affected by gold mine. The source of Cd included mining pollution and other serious Cd pollution sources. The colloidal particles in rivers played important role in trace metals transportation. In this study, iron oxides, organic matter and amorphous clay minerals were important in the removing and transformation of trace metals in water. In conclusion, the analysis and assessment of particulate metals would help control and reduce the pollution of trace metals in Chaobai River and Miyun Reservoir, and consequently contribute to preservation of public health.

1. Introduction

Trace metals cannot be degraded under natural conditions and trace metal contamination is one of the most ubiquitous and persistent issues in aquatic environment (Fu and Wang, 2011; Varol, 2013). Even trace levels of these metals can do harm to living organisms, including humans, the end of the biological chain (Fargussion, 1990; Blo et al., 2002). Regarding their input, anthropogenic sources, such as mining industry, waste disposal and use of fertilizers or pesticides, which have been greatly influencing the local and global geochemical cycles of trace metals (Viers et al., 2009), play more significant roles than natural sources. Some studies also found that vehicle exhaust deposit, dust particles and soil erosion in mining areas contribute significantly trace metal contamination in rivers (Velleux et al., 2006).

Trace metals do not just remain in river water, but are more likely to be scavenged or removed by the suspended solids or sediments because of adsorption, hydrolysis and co-precipitation (Santsch, 1984; Duan et al., 2007), especially the suspended particulate matter, which acts as sponges adsorbing pollutants directly from the dissolved phase as well as their suspension of sediments and playing a fundamental role in transport of metals in rivers (Hart, 1986; Bibby and Webster-Brown, 2005; Je et al., 2007; Onderka and Pekárová, 2008; Hua et al., 2011).

Suspended particulate matter is ubiquitous in environmental system and mainly consists of inorganic mineral phases and organic matter. Zhang et al. (2004) showed the organic suspended matter accounts for 30% of total suspended matter in Taihu Lake. There is a growing interest in the nature of the binding interactions about trace metals in suspended particulate matter, including those adsorbed to mineral surfaces, associated with carbonates, Fe/Mn oxides and organic matter (Viers et al., 2009; Song et al., 2010; Hua et al., 2011).

Besides that, the accumulation of trace metals in environment is of increasing concern. Some studies have demonstrated the extent of

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metal contamination in suspended solids, sediments or soils can be indicated sensitively using the geo-accumulation index (Igeo), enrichment factor (EF) and the potential ecological risk index (RI) (Qu and Kelderman, 2001; Ghrefat et al., 2011). Furthermore, multivariate statistical techniques such as correlation, principal component analysis (PCA) and cluster analysis (CA) have been frequently applied to explore the relationship between constituents, to identify the geochemical behavior and sources of trace metals (Beltrame et al., 2009; Çevik et al., 2009; Yang et al., 2009). Song et al. (2010) studied the spatial changes of As, Cd, Co, Cr, Cu, Ni, Pb and Zn in sediment and suspended solid along the Changjiang River basin. Their results showed that As and Cd had high Igeo values, and mining areas were the main contaminating sources of trace metals by using PCA analysis. Yiğiterhan et al. (2011) analyzed the elements Cu, Cr, Cd, Mo, Re, U, V, Mn, Fe, Ba, Ni, Pb, Zn, Co, Ti, Al and P in suspended matter from the Black Sea, and determined which is influenced by lithogenic input from rivers, biological and geochemical processes, and many studies have been carried out about the transport of metals (Egli et al., 2010; Marchand et al., 2011; Ingelmo et al., 2012).

The Miyun Reservoir, which is the largest reservoir located on Chaobai River, supplies the main source of drinking water for Beijing, the capital of China (Chen et al., 2011). However, numerous mines have been distributed in upper reaches of Miyun Reservoir over time, mainly for the purpose of gold and iron mining (Huang et al., 2012; Qiao et al., 2013; Zhu et al., 2013). Although most of them stopped production in recent year, the soil is still contaminated in some areas (Liao, 2007), furthermore, atmospheric depositions and vehicle emissions are also indispensable factors, all of which can become a source of pollution and have a large and lasting impact on Chaobai River and Miyun Reservoir.

Many researches have been conducted on risk assessment and source of trace metals in Miyun Reservoir and the soils around watersheds (Tian et al., 2009; Wang and Gong, 2010; Zhu et al., 2013), however no published data are available on the metal contamination in suspended particulate matter of Chaobai River. Therefore, the aim of this research is 1) to identify the concentration and distribution of trace metals in suspended particles of Chaobai River; 2) to assess contamination of trace metals in suspended particulate matter; 3) to define the sources of trace metals in suspended particulate matter. This is the first time that the data on metals in particulate matter of Chaobai River have been collected, quantified and evaluated.

2. Materials and methods

2.1. Study area

The study area is located in the northeast of Beijing, and a map showing a section of the Chaobai River is depicted in Fig. 1, The Miyun Reservoir is situated in the northern part of Beijing, between 40°31′–40°45′N and 115°56′–117°10′E with a watershed area of about 15,788 km^2, which was built in 1960 and has been used as surface drinking water storage for Beijing since 1997. The Chaobai River is the major source of Miyun Reservoir and is divided into two tributaries. The east branch is called Chaohe River including 400 km^2, and the west branch is called Baihe River about 3114 km^2. The Chaohe River originates in Fengning County of Hebei Province, runs south through Gubeikou Village into Miyun County, and then empties into the Miyun Reservoir near Xinzhuang village; The Baihe River originates in Guyuan County of Hebei Province, runs south through Chongli and Chicheng County, and flows into the Baihepu Reservoir in Yanqing County, Beijing and finally empties into the Miyun Reservoir near Zhangjiafen Village (Lu et al., 2013).

Beijing area exposed strata include Archean, the Proterozoic, Paleozoic, Mesozoic and Cenozoic. The main phase consists of Archean to amphibolite grade metamorphic rocks of the granulite facies composition, it is part of the crystalline basement of the North China platform, rich in mineral resources, iron, chromium and gold. The study area is precambrian metamorphic rocks outcrop area, however, there are many metal mines located in the catchment area around the catchment area.

2.2. Sampling and analytical methods

2.2.1. Suspended particulate matter samples

Suspended particulate matter samples were collected along the Chaobai River, taken at 11 stations, 7 in June (C1, C2, C3, B3, B5, B6

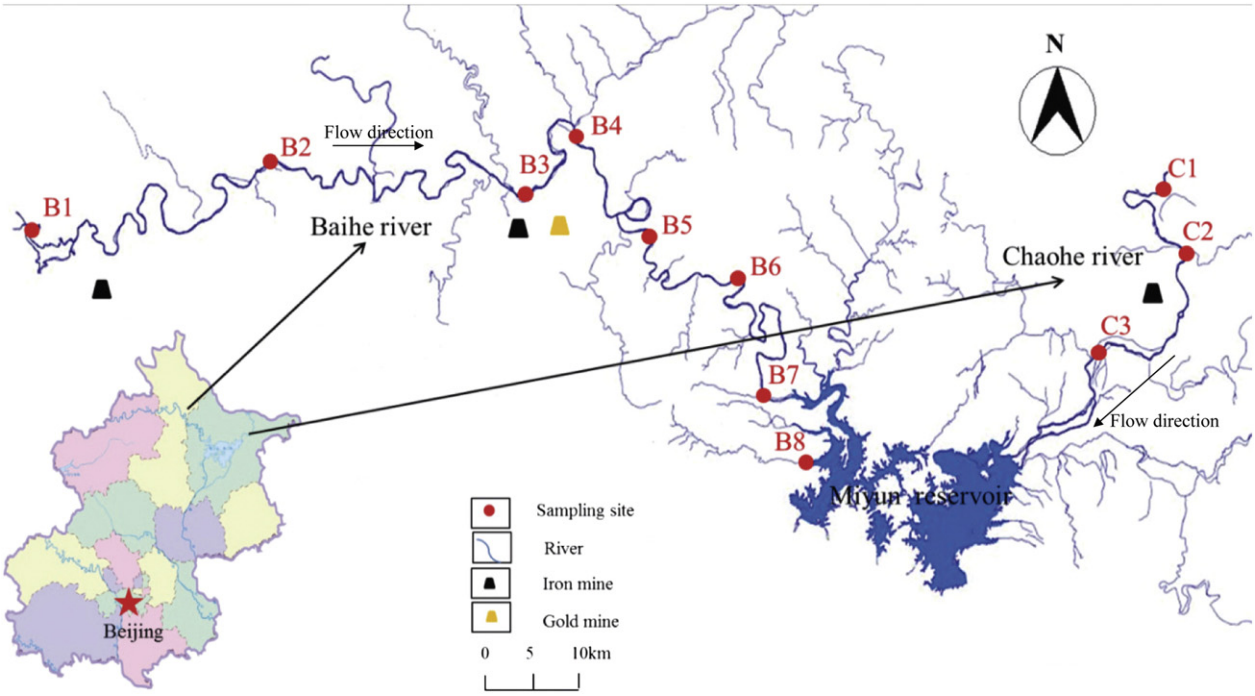

Fig. 1. Schematic map of the study area and sampling points.