Spatial distribution and human contamination quantification of trace metals and phosphorus in the sediments of Chaohu Lake, a eutrophic shallow lake, China

Enfeng Liu · Ji Shen · Xiangdong Yang · Enlou Zhang

Received: 1 July 2010 / Accepted: 26 April 2011 / Published online: 15 May 2011
© Springer Science+Business Media B.V. 2011

Abstract Distinguishing and quantifying anthropogenic trace metals and phosphorus accumulated in sediment is important for the protection of our aquatic ecosystems. Here, anthropogenic proportion and potential sources of trace metals and phosphorus in surface sediments of Chaohu Lake were evaluated based on the exhaustive geochemical data. The analysis shows that concentrations of major and trace metals, and phosphorus, displayed significant spatial diversity and almost all elements were over the pre-industrial background value, which should be related to the variations of sediment composition partially. Therefore, conservative element normalization was introduced and calculated enrichment factors (EFs) of the elements were referenced highlighting the human contamination. EFs of the major and trace metals, except Zn, Pb, and Cu, were all nearly 1.0, indicating the detrital origin. The EFs of Zn, Pb, Cu and phosphorus were 1.0–10.4, 1.0–3.8, 1.0–4.9, and 1.0–7.6, respectively, showing moderate to significant contamination. Higher EFs of Zn, Pb and Cu occurred in the mouth areas of Nanfei River and Zhegao River, and they decreased to the lake center in the northwest and northeast lake areas, respectively. We deduced that anthropogenic Zn, Pb, and Cu were mainly from urban and industrial point sources and the non-point sources of atmospheric deposition contributed little to their contamination. The EFs of phosphorus showed similar spatial degradation with that of Zn, Pb, and Cu. Moreover, higher EFs (>1) of phosphorus also occurred in other areas adjacent to the river mouths besides Nanfei River and Zhegao River. This indicated that the non-point agricultural source may also be responsible for the contamination of phosphorus in Chaohu Lake in addition to the urban sewage sources. Anthropogenic phosphorus was mainly concentrated in the speciation of NaOH-P, which had higher potential biological effects than the detrital proportion. Concentrations of Zn, Pb and Cu surpassed the threshold effect concentrations (TEC) of consensus-based sediment quality guidelines of freshwater ecosystems, especially in the contaminated northwest area of Chaohu Lake. This highlighted the contributions of anthropogenic contamination to the elevated potential biological effects of trace metals. Though there had been no obvious human contamination of Cr and Ni in Chaohu Lake, concentrations were all over the TECs, which may be due to higher background
levels in the parent materials of soils and bedrocks in Chaohu Lake catchment.

**Keywords** Sediments · Trace metals · Phosphorus · Human contamination · Source · Chaohu Lake

**Introduction**

Urbanization, agricultural, and industrial activities have largely contributed to contamination of aquatic ecosystems (Smith et al. 1999; Bennett et al. 2001; Wang et al. 2004; Battarbee 2005). Trace metals are regarded as a serious contaminant in aquatic ecosystems since they do not degrade, but accumulate in sediment. Anthropogenic trace metals are mainly combining with hydrated oxides of iron and manganese, sulfide, organic compound in sediment, which possess higher eco-toxicity than that of natural origins (Murray et al. 1999; Cuong and Obbard 2006; Simpson and Batley 2007). For a better assessment of sediment quality, it is essential to distinguish the proportions of trace metals related to natural processes and to anthropogenic input. However, due to variations in sediment composition, such as grain-size distribution and mineralogy, it could create anomalously high or low trace metals concentrations (Liaghati et al. 2003; Chen et al. 2004; Reimann and de Caritat 2005; Murray et al. 1999). Therefore, to quantify human contamination of trace metals, the variations in sediment composition should be compensated.

As another contaminant of concern, net storage of phosphorus in terrestrial and freshwater ecosystems increased at least 75% greater than pre-industrial levels globally (Bennett et al. 2001). A major proportion of anthropogenic phosphorus stored in the sediment by biogeochemical processes, and the internal phosphorus release had been one of the main sources of eutrophication besides external input (Søndergaard et al. 2003; Nixdorf and Deneke 2004). Phosphorus and metals in the sediment was mainly from weathering and erosion of geological formations in pre-anthropogenic periods and the concentration of which was also dominated by sediment composition (Dean 2002; Sun et al. 2010). In this sense, the influence of sediment composition variations should also be considered for the quantification of phosphorus human contamination though this was seldom done in previous studies.

Sewage discharge, industrial, and agricultural activities are the main anthropogenic sources for trace metals and phosphorus, which are usually introduced into the lake via the inflow rivers. Furthermore, atmospheric deposition was also documented to be the important anthropogenic source of trace metals especially in the remote aquatic ecosystem (Outridge et al. 2002; Yang and Rose 2005; Kamenov et al. 2009). The sedimentary records also indicated atmospheric deposition may be a significant source of anthropogenic trace metals in Taihu Lake catchment (Rose et al. 2004), which was a typical industrial area in the middle-lower reaches of Yangtze River watershed. However, seldom further sedimentary research has been performed proving the atmospheric inputs of trace metals in other regions of the middle-lower reaches of Yangtze River watershed.

As one of the degraded lakes in the middle-lower reaches of Yangtze River watershed, Chaohu Lake has undergone major changes in eutrophication in recent decades (Zhang et al. 1997; Shang and Shang 2007). It has also suffered from trace metal contamination in some lake areas (Tang et al. 2010; Zheng et al. 2010). However, due to a dearth of information on background levels and the lacks of sediment normalization procedures, little knowledge on quantification of trace metals and phosphorus contamination is available. In the present work, concentrations of major and trace metals, phosphorus and chemical speciations in surface sediments of Chaohu Lake was determined. The specific objectives of this study were to determine the spatial variation of phosphorus and trace metals in surface sediments of Chaohu Lake, quantify the anthropogenic proportion and determine potential sources.

**Site description**

The middle-lower reaches of Yangtze River watershed is the most populated and economically developed region of China (Fig. 1). It covers an