Journal of Geochemical Exploration 155 (2015) 26–32

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

Historical record of trace elements input and risk in the shallow freshwater lake, North China

Fan Gao [a], Wei Guo [b,*], Jingxian Wang [a], Xu Zhao [c]

[a] Beijing Key Laboratory of New Technology in Agricultural Application, Department of Resources and Environment, Beijing University of Agriculture, Beijing 102206, China
[b] School of Environmental and Chemical Engineering, North China Electric Power University, Beijing 102206, China
[c] School of Nature Conservation, Beijing Forestry University, Beijing 100083, China

ARTICLE INFO

Article history:
Received 17 July 2014
Accepted 1 April 2015
Available online 14 May 2015

Keywords:
Trace metals
^{210}Pb
Enrichment factor
Ecological risk

ABSTRACT

Approximately 80-year input of trace elements (Cr, Cu, Mn, Ni, Zn, Fe, and P) based on ^{210}Pb analysis in sediment cores was studied to assess the contamination status of these elements in the Baiyangdian Lake in China. The pollution concentration and enrichment factor, geoaccumulation index, and ecological risk index of these metals indicate that the degree of pollution and risk of these metals in the lake is higher in the upper layers (0–5 cm) and in recent years (1997–2012), but still at a moderate level. Among these metals, Cr and Ni may cause slight adverse biological effects in the area. Although the study indicated that the lake was not significantly affected by anthropogenic activities, a good logarithmic relationship ($R^2 \geq 0.85$) between the ecological risk index and gross domestic product per capita in Baoding City, China, during 1943–2012 confirmed the effect of increasing human activity on the lake. The correlation and principal component analyses indicated that Cr, Zn, Mn, and Fe mainly originated from natural input with weathering and erosion of rocks and soil parent materials; however, Cu, Ni, total organic carbon, and P mainly originated from anthropogenic activities such as agriculture, industry, and sewage effluents.

1. Introduction

Lakes are important freshwater resources and ecosystems in the earth and play important roles in the region's water supply, climate regulation, flood control, and biodiversity preservation. However, rapidly growing anthropogenic activities such as city construction, industrial and agricultural development, and exploitation of mineral resources have inevitably affected freshwater lakes (Hansen, 2012; Schindler and Smol, 2006; Yasuda et al., 2000). Some water environmental and ecological problems such as drawdown, eutrophication, and aquatic ecosystem degradation emerged endlessly, particularly in developing countries experiencing rapid growth (Guo et al., 2011; Qiao et al., 2006; Thevenon et al., 2013; Zan et al., 2012). Therefore, it is necessary to consider the state of the regional environment not only current, but also prior to the recent economic development for better protecting these vulnerable freshwater ecosystems.

Since the industrial revolution, the anthropogenic release of trace elements into the environment has changed their biogeochemical cycles (Romano et al., 2012). Furthermore, high recent fluxes may have led to accumulation in freshwater and biota, thus affecting both animals and humans beings (UNEP, 2011). For example, P is the key limiting factor for eutrophication (Sondergaard and Jeppesen, 2007), and higher levels of Cu, Cr, and Ni are toxic to enzymatic systems as well as liver, skin, bones, and teeth (USG, 2011). These elements enter freshwater lakes due to industrialization, agriculture, urban sewages, roadways, and basin erosion (Razo et al., 2004; Yang and Rose, 2005) and finally deposit in the sediment (Bacardit et al., 2012). Therefore, the vertical distributions of the major elements and trace elements in freshwater lake sediments can provide historical environmental information and serve as a baseline for future investigations (Conaway et al., 2012; Ma et al., 2013; Ra et al., 2011; Routh et al., 2007). Thus, it is important to understand the sources and influences for the trace elements in the sediments of freshwater lakes. In particular, it is important to understand the effect of anthropogenic activities on heavy metal accumulation because these activities have accelerated the geochemical cycles and increased the delivery of these elements to the lakes.

In this study, a typical freshwater lake, the Baiyangdian Lake in North China, was selected to study the pollutant characteristics and history in similar aquatic environments. For the first time, we studied the distribution and variation of trace elements including Cu, Mn, Fe, Zn, Ni, Cr, and P in an age-dated sediment core in the lake. The enrichment factor (*EF*), the geoaccumulation index (I_{geo}), and ecological risk index (*RI*) were used to assess the degree and risk of these elements. Moreover, the relationship between pollution and economic growth was also analyzed. The possible geochemical sources of the elements were evaluated by

* Corresponding author. Tel./fax: +86 10 61773936.
E-mail address: gwfybj@ncepu.edu.cn (W. Guo).

http://dx.doi.org/10.1016/j.gexplo.2015.04.002
0375-6742/

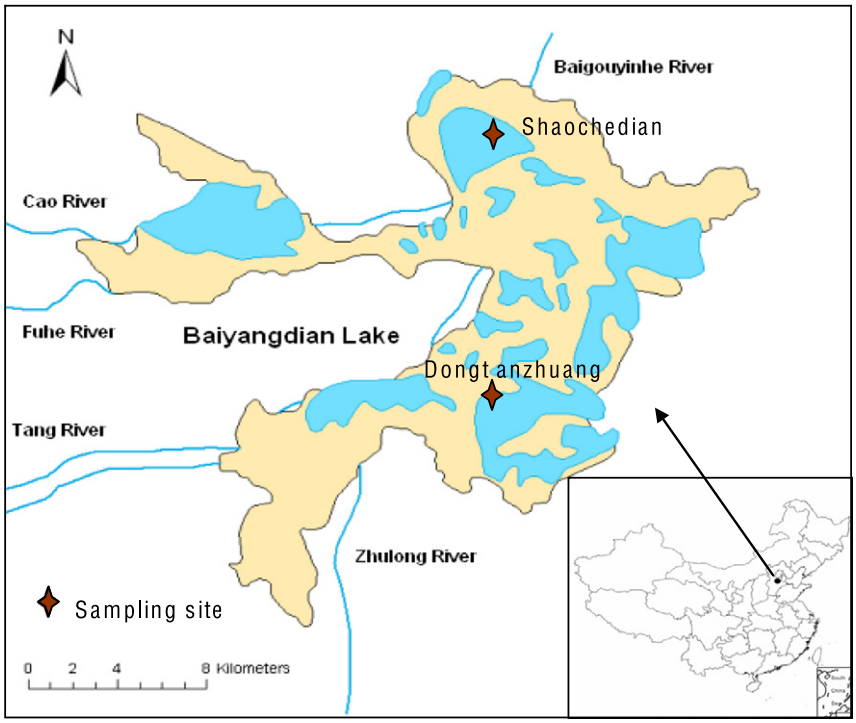

Fig. 1. Map of the study area and location of the sampling site.

correlation and principal component analyses. This study aims to provide an effective reference for the environmental protection of similar freshwater lakes.

2. Materials and methods

2.1. Study site and sampling

This study was performed at the Baiyangdian Lake, a shallow freshwater lake, 362.8 km^2 surface area within a catchment area of 31,200 km^2, located at the central part of the Hebei Province, China (115°38′–116°07′ east; 38°43′–39°02′ north) (Fig. 1). The Baiyangdian Lake is the largest freshwater resource in northern China and plays important roles in determining the region's water supply, agriculture and aquaculture, climate regulation, and flood control (Guo et al., 2011). Most parts of the lake are not more than two meters in depth. The catchment has a total population of ~2.04 million. In fact, the original lake area was 561.1 km^2, and the water quality was excellent before the 1950s. With increasing human activities in the watershed, the lake area decreased to 362.8 km^2, and the water quality suffered deterioration problems such as eutrophication (Cui et al., 1999).

The study was carried out in the autumn of 2012 in the Baiyangdian Lake (Fig. 1). Sediment cores about 25-cm-long were collected using a Beeker 04.23 core sampler (100 cm length × 57 mm i.d.; Eijkelkamp Co., Giesbeek, The Netherlands) from two sites at the Baiyangdian Lake. Site Shaochedian (SCD) located near the point source input district which was directly affected by an important polluted tributary, the Baigouyinhe River. Site Dongtianzhuang (DTZ) located near the southern of the lake, representing the agricultural region along the lake. The core sediments were sliced into 1-cm-thick sections. Next, each section

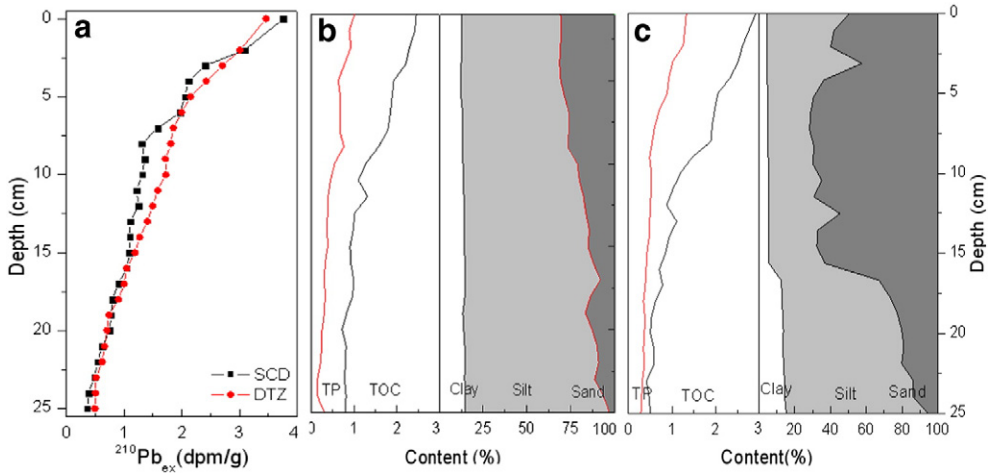

Fig. 2. Age–depth profiles of excess ^{210}Pb ($^{210}Pb_{ex}$), grain size, total organic carbon (TOC), and total P (TP) in sediment cores. a: ^{210}Pb dating; b: TP, TOC and grain size distribution in the Dongtianzhuang (DTZ) core; c: TP, TOC and grain size distribution in the Shaochedian (SCD) core; dpm/g: decays per minute per gram.