Continental Shelf Research 90 (2014) 163–169

Contents lists available at ScienceDirect

Continental Shelf Research

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

Enrichment of heavy metals in the inner shelf mud of the East China Sea and its indication to human activity

Bin Chen [a], Dejiang Fan [a,*], Weiran Li [a], Liang Wang [a], Xilin Zhang [a], Ming Liu [a], Zhigang Guo [b]

[a] Key Lab of Submarine Geosciences and Technology of the Ministry of Education, Ocean University of China, 238 Songling Road, Qingdao 266100, China
[b] Department of Environmental Science and Engineering, Fudan University, Shanghai 200082, China

ARTICLE INFO

Article history:
Received 11 October 2013
Received in revised form
18 April 2014
Accepted 20 April 2014
Available online 6 May 2014

Keywords:
Heavy metal
High-resolution sedimentary record
East China Sea
Yangtze River
Human activities

ABSTRACT

The Yangtze River Basin, which has a population of 0.4 billion and an economic output accounting for 50% of China's Gross Domestic Product (GDP), is one of the most developed regions in China. With dramatic developments in the economy, large quantities of pollutants have entered the Yangtze River and have eventually been discharged into the East China Sea (ECS), and then most of them were preserved in the inner shelf coastal mud areas of the ECS. The inner shelf costal mud areas of the ECS, with sedimentation rate ranging from 0.8 cm/a to 1.2 cm/a, are an ideal place to obtain the high-resolution heavy metal record. In this work, two sediment cores collected in the inner shelf of the coastal mud areas of the ECS in 2009 were used to reconstruct historical records of anthropogenic heavy metal input from the Yangtze River Basin. The temporal distribution of enrichment factors (EFs) is in good accordance with social development of Yangtze River Basin. Before the 1930s, the EFs of Pb and Zn are considered as the background level of study area, according to the agricultural country of China in that time. The much higher EFs of Pb and Zn from the 1930s to 1980s were associated with significant improvement of industry of the Yangtze River Basin. After 1983, the dramatical incensement of EFs of Pb and Zn responded to the remarkable economic development of the Yangtze River Basin. Of particular interest, the construction of the Three Gorges Dam (TGD) in 2003 possibly induced a significant increase in the heavy metal levels in the coastal ECS, and the ban on leaded gasoline in China induced a remarkable decrease in Pb levels. Although heavy metal levels have increased since the 1930s, the coastal mud area of the ECS remains under low ecological risk.

1. Introduction

Heavy metal contamination is an essential indicator of environmental health. Heavy metals are released into marine environments by natural or anthropogenic processes. The principal natural processes include weathering processes, volcanic eruptions, forest fires, and other natural events. Human activities, such as iron and steel smelting, fossil fuel burning, and non-ferrous metal smelting, can produce large quantities of heavy metals that are delivered to hydrosphere or the atmosphere. The levels of anthropogenic heavy metals in the environment have increased dramatically since the Industrial Revolution (Nriagu, 1979; Lima et al., 2005; Lee et al., 2008; Thevenon et al., 2011). A significant portion of these metals is discharged into the sea through river discharge and atmospheric deposition, where they are preserved in estuaries and continental shelves (IP et al., 2004; Zourarah et al., 2007; Shi et al., 2010; Xia et al., 2011; Elbaz-Poulichet et al., 2011; Morelli et al., 2012).

The Yangtze River Basin is one of the most developed regions in China, providing 42% of China's GDP and housing 400 million inhabitants (Yang et al., 2006). It is also the earliest industrialized region in China (Yang et al., 2006; Guo et al., 2007). With the rapid economic development and industrialization in recent decades, huge amounts of anthropogenic heavy metals have been delivered into the ECS from the Yangtze River (Lin et al., 2002; NBO, 2003–2009). For example, fifteen thousand tons of heavy metals were discharged into the ECS from the Yangtze River in 2002, and this value reached 22.6 thousand tons in 2008 (Lin et al., 2002; NBO, 2003–2009). Meanwhile, with rapidly increasing energy demands, a number of huge dams have been built in the upper and middle reaches of the Yangtze River. Among them, the Three Gorges Dam (TGD) is the largest and has stored water since 2003. These dams have resulted in a significant decrease in the sediment discharge from the Yangtze River into the ECS (Yang et al., 2006; CWRC, 2002–2009). Heavy metals prefer to deposit in the subaqueous delta and the adjacent inner shelf coastal mud areas of the ECS (Lin et al., 2002; Guo et al., 2007; Hao et al., 2008). The inner shelf coastal mud area of the ECS has high sedimentary rates ranging from 1.0 cm/a to 5.0 cm/a (Huh and Su, 1999; Liu et al., 2009), making it an excellent area for constructing a high-resolution record of the levels of sedimentary heavy metals.

* Corresponding author. Tel.: +86 532 66781956; fax: +86 532 66782062.
E-mail address: djfan@ouc.edu.cn (D. Fan).

http://dx.doi.org/10.1016/j.csr.2014.04.016
0278-4343/

Recently, several studies of the heavy metal levels in the Yangtze River Estuary mud area have been reported, revealing a prominent increase in heavy metal concentrations over the last 60 years (Chen et al., 2004; Liu and Fan, 2010). Compared with the Yangtze River Estuary mud area, the inner shelf mud area has a higher content of fine sediment fractions (< 4 μm), which tend to absorb heavy metals (Che et al., 2003; Guo et al., 2003; Chen et al., 2004). This difference in sediment properties implies that the coastal mud area could be more sensitive than the estuary to heavy metal deposition. However, there are few high-resolution records of the heavy metal content in this area. More importantly, the TGD, the largest dam in the world, has been used since 2003. The effect of the construction of the TGD on the environment is poorly understood. Dong et al. (2009) reported that the concentrations of heavy metals in the surface sediments in the Yangtze River estuary and its adjacent area increased shortly after 2003, whereas the heavy metal levels on this episode have not changed.

Our study is based on two gravity sediment cores collected in the inner shelf coastal mud area of the ECS in 2009. The primary purpose of this study was to construct a high-resolution record of the heavy metals in the inner shelf coastal mud area over the last hundred years to explore the relationship between the heavy metal levels and anthropogenic activity in the basin with an emphasis on the influence of the TGD on the heavy metal levels in the coastal ECS.

2. Materials and methods

2.1. Sampling

Sediment cores C0702 (122.453°E, 29.209°N), C0803 (121.656°E, 27.636°N) (Fig. 1) were obtained in April 2009 from the coastal mud area using a gravity corer deployed on the R/V Dong Fang Hong 2 of the Ocean University of China (OUC). Sediment cores were kept in the pre-cleaned plastic tubes and they were sealed tightly by plastic cap. Then they were kept in the laboratory of the ship until they were moved to the land-based lab. The lengths of cores C0702 and C0803 were 179 cm and 189 cm, respectively. Core C0702 was sub-sampled in 1 cm intervals from the top to 120 cm and in 2 cm intervals below 120 cm. Core C0803 was sub-sampled in 1 cm intervals above 100 cm and in 2 cm intervals below 100 cm.

2.2. Grain size analysis

The grain sizes of the sediments in the two cores were determined using a laser particle size analyzer (Mastersizer 2000, Malvern Instruments, Ltd., UK) at the Key Lab of Submarine Geosciences and Technology, Ministry of Education, OUC. There were few shells appeared in the two cores. The shells were picked up before grain size analyzing with the laser particle size analyzer. Approximately 0.5 g of a pre-homogenized sediment sample was pretreated using 10 ml of a 30% H_2O_2 solution to oxidize any organic matter, and then the sample was dispersed and homogenized using an ultra-sonicator for 30 s for subsequent grain size analysis. The grain size fractions < 4 μm represent clay, the fractions 4–63 μm in size represent silt, and those > 63 μm in size represent sand. The measurement error was within 3%.

2.3. Element analysis

The concentrations of the elements in cores C0702 and C0803 were measured by a desktop X-ray fluorescence (XRF) system (Spectr, Germany) at the laboratory of the College of Marine Geosciences, OUC. The analysis and quality control methods used were according to Liu and Fan (2010). The method can

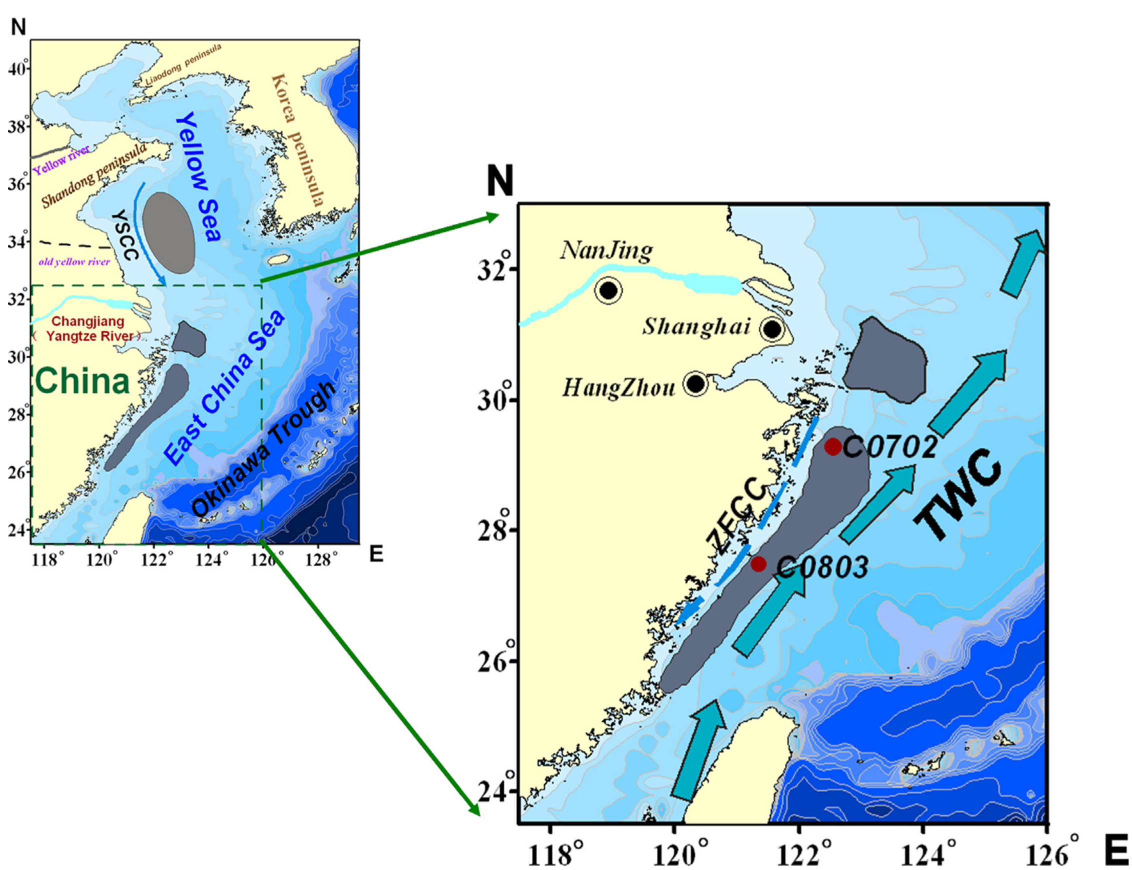

Fig. 1. Sampling sites of sediment cores C0702 and C0803. (Circulation system and mud areas (dark areas) are after Guo et al. (2007). YSCC: Yellow Sea Coastal Current; TWC: Taiwan Warm Current; ZFCC: Zhejiang Fujian Coastal Current.)