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Baseline

Trace metals in the surface sediments of the eastern continental shelf of Hainan Island: Sources and contamination

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ABSTRACT

Major (Al) and trace metal (Cu, Pb, Zn, Cr, Ni, Cd, and As) concentrations in 29 surface sediment samples from the eastern continental shelf of Hainan Island were evaluated to determine the level of contamination. A multivariate analysis indicated that the sources of Cd, As, and Pb were primarily anthropogenic, whereas the sources of Cu, Zn, Cr, and Ni were primarily natural and/or partially anthropogenic. Enrichment factor (EF) and geoaccumulation index (I_{geo}) values were calculated to assess the anthropogenic contamination in the region. Both the EF and I_{geo} values indicated relatively elevated Cd and As concentrations. This study provides a useful aid for sustainable marine management in the region.

The anthropogenic input of metallic elements, particularly from rapid economic development in coastal areas, has caused severe environmental crises in marine ecosystems (Daskalakis and O'Connor, 1995; Zhang and Liu, 2002; Ruiz et al., 2005; Xu et al., 2014). Trace metals (e.g., Cu, Pb, Zn, Cr, Ni, Cd, and As) are of particularly high concern due to their persistence in the environment, bioaccumulation and high toxicity (Simpson and Batley, 2007; Wang and Rainbow, 2008; Cai et al., 2011; Hu et al., 2013; Wang et al., 2015). Sediments exhibit a great capacity to accumulate trace metals at even low concentrations in aquatic environments (Christophoridis et al., 2009; Hu et al., 2013). Most trace metals in the aquatic ecosystem are associated with sediments, especially bottom sediments (Kucuksezgin et al., 2008; Zahra et al., 2014). Trace metals that accumulate in sediments, which act as both final sinks for various chemical pollutants and potential secondary sources, may be released back into water columns under changing environmental conditions (Roberts, 2012; Hill et al., 2013; Wang et al., 2015). Once absorbed by aquatic organisms, trace metals may be converted to more toxic organic complexes that may not only pose a risk to aquatic organisms but may also cause long-term human health issues and may even damage the ecosystem (Wang and Rainbow, 2008; Dou et al., 2013; Wang et al., 2015). Thus, spatial surveys of metal concentrations in sediments are useful for assessing pollution in the marine environment and for providing basic information for the determination of environmental health risks (Li et al., 2012; Hu et al., 2013).

Hainan Island, located in the northern portion of the South China Sea (SCS), is the China's second largest island, with a surface area of 35.4×10^3 km^2 (Fig. 1a). The island is characterized by a seasonal and oceanic tropical climate, with annual average temperatures ranging between 22.8 °C and 25.8 °C and annual rainfall between 961 mm yr^{-1} and 2,439 mm yr^{-1} (Zhang et al., 2013). The water depth of the east coast of Hainan Island decreases sharply, with a gradient that decreases from the northwest to the southeast (Huang et al., 2013), and the isobaths and the coastline are parallel (Fig. 1b). Over the last 50–60 years, Hainan's coastal zone and its hinterland have experienced an enormous population increase concurrent with an increase in agricultural development. The agricultural area has decreased due to the booming aquacultural growth and the increasing infrastructure development for tourism (Herbeck, 2011). This style of development has been especially significant after the 1980s, when China launched economic innovation policies, and after the establishment of Hainan Province in 1988 (Zhang et al., 2013). Although previous studies have indicated that trace metals on Hainan Island have increased, the data were mainly only available at river outlets and/or estuary areas (Gan et al., 2003; Gao et al., 2011; Lin et al., 2011; Qiu et al., 2011; Xia et al., 2011; Balzer et al., 2013; Fu et al., 2013; Li et al., 2013). Hu

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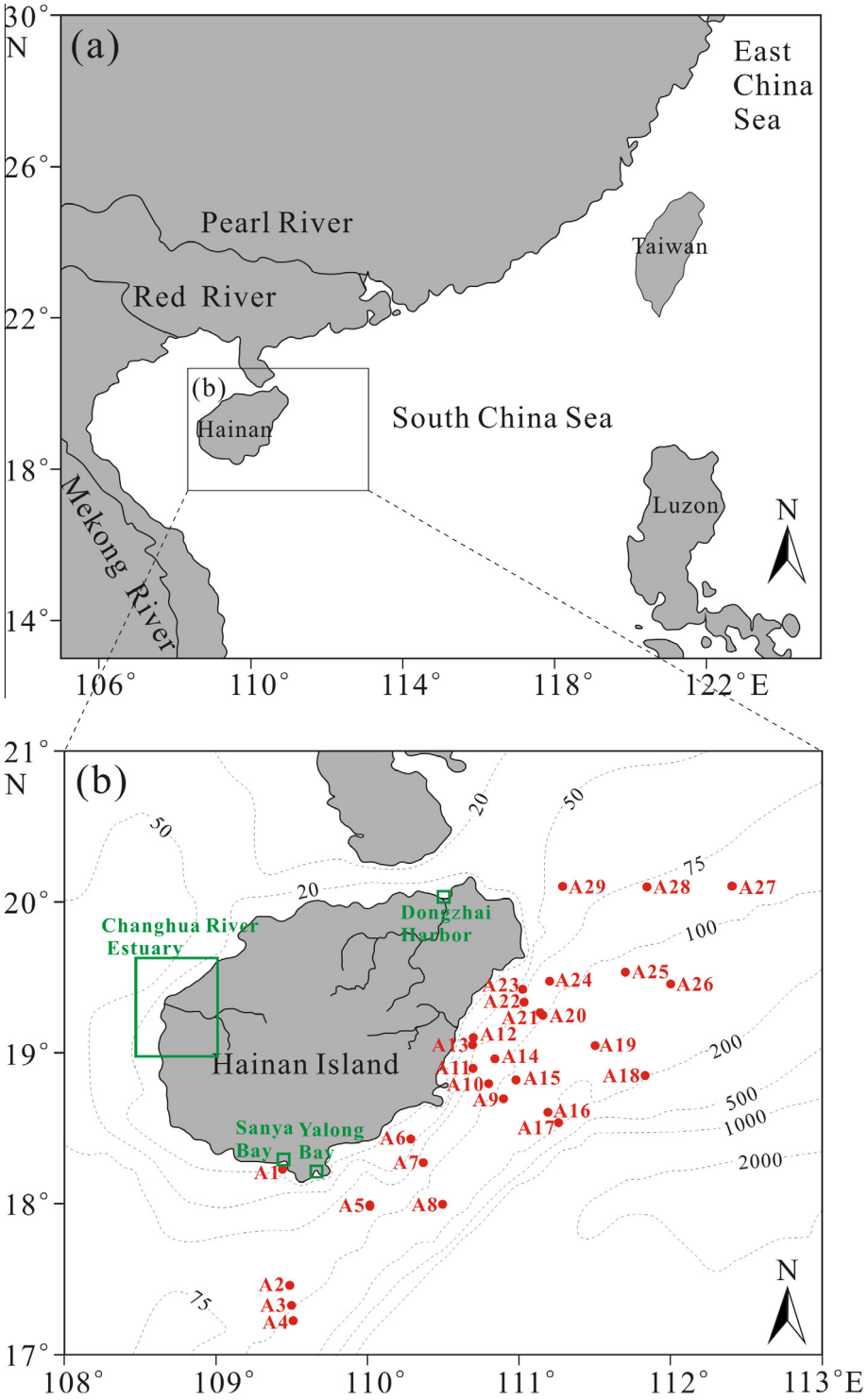

Fig. 1. (a) Geographic location of the study area, and (b) the locations of the sampling sites (red dots), Changhua River Estuary, Dongzhai Harbor, and Sanya and Yalong bays (green squares), which are mentioned in the text. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

et al. (2013) characterized the trace metal concentrations of shelf sediments on the western coast of Hainan Island (Fig. 1b). They found significant As and Pb contamination in their study area (Hu et al., 2013). However, no one has considered the quality of the sediments found on the eastern continental shelf of Hainan Island, which limits our understanding of the transport of contaminants and their potential adverse environmental impacts.

The objectives of this study were to (1) determine the concentrations of certain trace metals (Cu, Pb, Zn, Cr, Ni, Cd and As) in sediments on the eastern continental shelf of Hainan Island, (2) identify the possible sources of the trace metals with multivariate analyses, and (3) assess the metal contamination using the enrichment factor (EF) and geoaccumulation index (I_{geo}).

A total of 29 surface sediment (0–5 cm) samples were collected using a Van Veen grab sampler and a small vessel, by R/V Shiyan 3, from the South China Sea Institute of Oceanology, Chinese Academy of Sciences in 2012–2014 (Fig. 1b). All the samples were stored at 4 °C until analysis.