Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Linking the toxic metals to benthic community alteration: A case study of ecological status in the Bohai Bay

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ARTICLE INFO

Keywords:
Ecological significance
Sediments
Benthos
Toxic metals
Bohai Bay

ABSTRACT

Ecological effects and quality status of sediments in the Bohai Bay (North China) were studied by incorporating the traditional chemical analysis and benthic community structure. In the present study, paired sediments from 20 stations were sampled for chemical analysis and benthic assemblages. The overall results demonstrated that sediment impairment mainly appeared in the southern part of the Bay. The results obtained from the principal component analysis regarding benthic data and potential explanatory factors indicated that As, Hg and petroleum hydrocarbons (PHs) were responsible for the distribution of macrofaunal assemblages. Canonical correspondence analysis further showed As was significantly correlated to the benthic alteration, which provided evidence of ecological relevance to chemical substances of concern. Overall, this study revealed the metal contamination in the Bohai Bay was not as severe as previously regarded. Yet, further investigation is still needed considering the complexity of sediment matrices.

1. Introduction

Toxic contaminants found in only trace amounts in waters can accumulate in sediments to elevated levels (Chapman, 1989; Burton and Johnston, 2010), which raises great ecological concerns worldwide. In coastal areas of China, large quantities of pollutants are discharged into the seas with the rapid economic growth in last decades (Gao et al., 2014). Hence there is a growing interest in ecological effects of coastal sediments as well as their quality status. Toxic metals have been identified as one of the major chemical stressors in littoral ecosystems of China (He et al., 2013). Contaminated sediments can cause adverse effects on resident benthic communities. Meanwhile the benthic organisms have become reliable indicators of the sediment pollution because they are relatively sedentary (Borja et al., 2000; Ryu et al., 2011). Due to the persistence, bioaccumulation and toxicity of metals (Burton, 2010), a variety of parameters need to be integrated to determine their ecological effect in contaminated sediments. In this respect, an evaluation approach of incorporating the traditional chemical analysis and benthic community structure provides a viable solution in determining root causes of sediment degradation (Menzie et al., 1996; Chapman et al., 2002).

The Bohai Bay in northern China is surrounded by highly industrialized areas and densely populated cities, such as Tianjin Metropolis in its western coast. Due to weak water exchange and heavy waste loads, the Bohai Bay has been severely degraded since 1970s (Ye, 1991). A variety of surveys on toxic metals in this region still mainly center on chemical screening assessment relative to sediment quality guidelines (*e.g.* Feng et al., 2010). There were, however, few investigations trying to determine whether elevated contents of toxic metals could pose adverse effects on the benthic community. Benthic assemblages provide valuable ecological relevance to environmental stressors (Chapman, 2007). The biological results of benthic community and the geochemical results of sediments were rarely incorporated in previous study of Bohai Bay. For instance, responsible factors analyzed for benthic community alterations in the Bohai Bay occurred during 1980s–1990s were only limited to grain size and total organic carbon (TOC) (Zhou et al., 2007), which may inadequately account for the alterations. Preceding studies also showed benthic species diversity and richness indices in this region increased during 1980s–2000s (Zhou et al., 2012). Yet, these univariate indices of benthic assemblages were less sensitive in the detection of alterations than multivariate analysis. Therefore, further exploration is still needed in order to establish the ecological relevance of toxic metals in the Bohai Bay and determine whether immediate levels of them would result in the adverse effects on the community level.

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http://dx.doi.org/10.1016/j.marpolbul.2014.04.010
0025-326X/

In this study, the main objective is to find out the relationships between the changes in benthic community structure and toxic metals in sediments of the Bohai Bay based on multivariate statistical methods. Although the correlation of benthic community structure alteration with analyzed contaminants does not necessarily provide causality, it does assist in identifying contaminants or other stressors which are correlated with changes in benthic assemblages. In addition, we attempt to screen out sediment stations having adverse effects on ecological receptors and to identify the probability of risks, which will contribute to the optimization of the environmental management in the future. Referred by Gao and Chen (2012), there was once a plan proposed to enhance the water exchange and reduce contamination in the Bohai Bay by channeling through the Shandong peninsula to get connection with the Yellow Sea. Our study also serves as a comprehensive background investigation for this possible future engineering scheme.

2. Materials and methods

2.1. Field sampling

By utilizing 0.10 m^2 Gary-O'Hara box corer, sediment samples were collected from 20 stations located in the coastal and inner portion of the Bohai Bay in August 2010 (Fig. 1). The sediments were sampled in triplicate from the locations with the water depth ranging from 5.5 to 15.0 m. Two sediment samples were sieved through 0.5 mm mesh with site water for the benthic community study. The remained organisms on the screen mesh were preserved in 70% ethanol and stored at room temperature for further sorting. The third sediment sample was collected for chemical measurements and stored at −20 °C. The bulk samples for geochemical parameters were divided into four sub-samples for the determination of grain size, TOC, acid volatile sulfide (AVS), metals and petroleum hydrocarbons (PHs). The petroleum was determined as one of the primary contaminants due to frequent spills from oil exploration or shipping related activities in the surveyed area (Zhang et al., 2007). A series of locations including B3, B4, B7 and B8 was chosen as the reference sites for the benthic community structure analysis to reduce uncertainty (Stronkhorst et al., 2003). The reason for selecting these four stations is that they were relatively unaffected by metal contamination according to a 2009 Report on the State of the Marine Environment in North China Sea (NCSB, 2010). Generally, metal concentration in surface sediments is higher than its preindustrial level because of anthropogenic activities. Background values for metals were thus retrieved from core sediments collected in 2008 (★ in Fig. 1) rather than the sediments collected for the reference condition of benthic community, for the metal values derived from the latter sediments may underrate the contamination magnitude.

2.2. Laboratory analysis

Chemical analysis of sediments includes grain size, TOC, AVS, metals (Zn, Pb, Cd, As and Hg) and PHs. All chemical determination

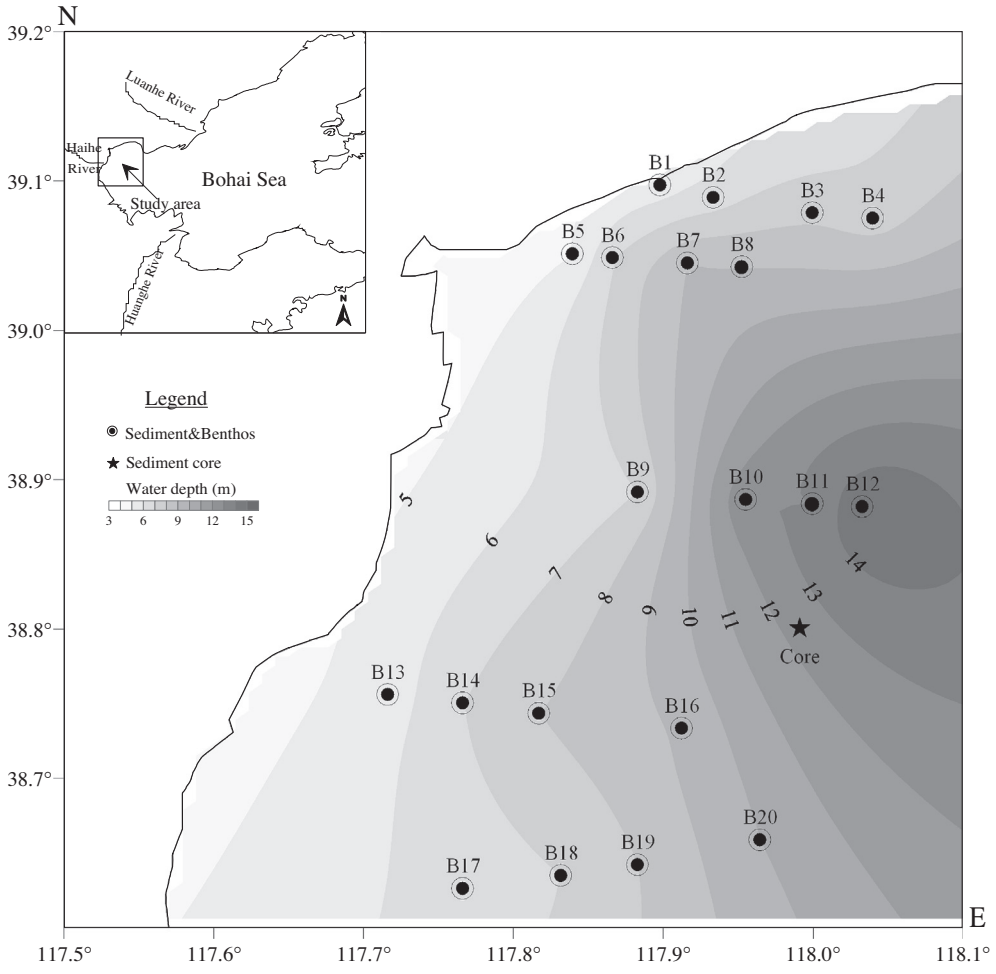

Fig. 1. The Bohai Bay and sampling stations.

Please cite this article in press as: Wu, B., et al. Linking the toxic metals to benthic community alteration: A case study of ecological status in the Bohai Bay. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.04.010