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A new ecological risk assessment index for metal elements in sediments based on receptor model, speciation, and toxicity coefficient by taking the Nansihu Lake as an example

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ABSTRACT

This study focuses on the establishment of a new ecological risk assessment method called as multiparameter evaluation index (MPE) by a combination of speciation, toxicity coefficient, and receptor model of metal elements in sediments and the application of MPE in the assessment of ecological risks of Be, Sb, and Tl in the Nansihu Lake. Because of lack of toxicity coefficient values for Be, Sb, and Tl, their toxicity coefficients were calculated in this study. Speciation analysis showed that Sb had better mobility and bioavailability than Be and Tl. Source apportionment results showed that Be and Sb were mainly from human activities and introduced minerals. Tl was mainly an inherent mineral. MPE results showed that the degree of ecological risk was Be > Sb ≫ Tl. MPE could distinguish the ecological risk levels more accurately than current indices such as RI and RAC.

1. Introduction

Harmful metal elements are usually sparingly biodegradable, but they can accumulate in organisms; expand through food chains; and therefore have long-term, concealed, and hysteretic adverse effects on ecological environment and human health. Metal pollution has been a global concern since many years. The harmful metal content in water significantly increases because of industrial waste discharge, fossil fuel combustion, domestic sewage, water-borne transport, and agricultural irrigation (Prica et al., 2008; Yang et al., 2012; Zhuang et al., 2016).

Sediments are the sources and sinks of various pollutants in the water body. Various pollutants to the water body are adsorbed deposited onto the sediments; conversely, the pollutants in the sediments are released by combination reaction and redox reaction under the action of animals, plants, microbes, etc., to the water body, resulting in secondary pollution of water environment (Harter, 1968; Ciblin, 1997).

As typical harmful metal elements, Beryllium (Be), antimony (Sb), and thallium (Tl) have bioaccumulation and biomagnification effects and have been listed among 13 preferably restricted metal pollutants in water environment by U.S. Environmental Protection Agency (USEPA, 1979). Be can cause pulmonary granulomatous lesions and lung cancer; thus, it is a harmful substance that causes occupational diseases and environmental pollution (Zhang et al., 2011; Hulo et al., 2016). Sb can cause chronic obstructive lung diseases, cardiovascular diseases, cerebrovascular diseases, and apoplexia, and it is a long-spreading global pollutant (Wu et al., 2008; Zhu et al., 2010; Antoine et al., 2015; Fort et al., 2016). Tl causes cardiovascular diseases and has toxicity similar to that of As (Wappelhorst et al., 2000; Peter and Viraraghavan, 2005).

The geochemical behaviors and environmental risks of heavy metals such as As, Cd, Cr, Hg, Ni, Pb, and Zn have been studied by many researchers, but those of Be, Sb, and Tl have been studied by few researchers. Be, Sb, and Tl are typical disseminated elements in nature. Despite their broad distribution in the earth's crust, their contents are very low and they are applied not so widely as other metal elements. This may be the reason for their environmental risks not being evaluated by relevant researchers and governmental authorities.

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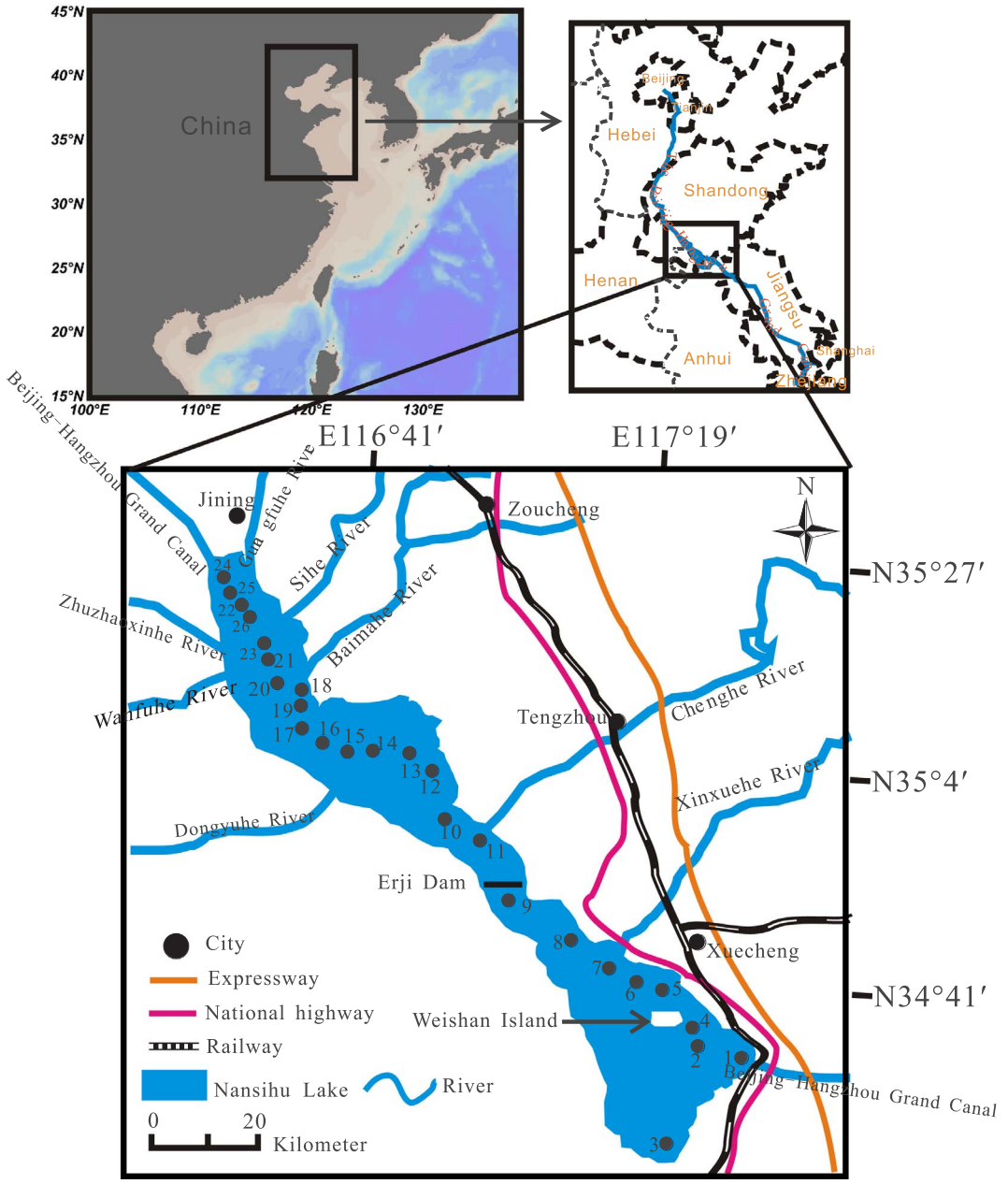

Fig. 1. Location of the sampling sites in the Nansihu Lake.

There are many methods for the assessment of pollution by metal elements in sediments. The basic principle mainly includes the following: (1) Ratio of total metal content to background value, for example, Geoaccumulation index (I_{geo}, Müller, 1969) and Enrichment factor (EF, Alexander et al., 1993); (2) speciation of metal element, for example, Risk assessment code (RAC;Perin et al., 1985); (3) Håkanson (1980) initially introduced the concept of toxicity coefficient and determined the toxicity coefficient values of several metal elements; the metal with higher toxicity coefficient has higher toxicity. Håkanson established potential ecological risk index (RI). The relationship between total metal content and background value and the toxicity of different metals were considered in this method. However, the speciation of metal elements in sediments was not considered in this method.

The receptor model for absolute principal component scores–multivariate linear regression (APCS-MLR) was proposed by Thurston and Spengler in 1985. The basic principle is that the principal component score for analysis is converted to APCS before MLR of the receptor content. The regression coefficient is used to calculate the contribution of the corresponding emission source of each component to this substance in the receptor (Thurston and Spengler, 1985).

In this paper, an ecological risk assessment index for metal elements in sediments based on the receptor model of APCS-MLR, speciation, and toxicity coefficient was established for the assessment of ecological risks of Be, Sb, and Tlin surface sediments of the Nansihu Lake as Chinese typical lake. The toxicity coefficient of Be, Sb, and Tl has not been determined. Thus, their toxicity coefficient values were calculated first according to the Håkanson calculation principle.

2. Materials and methods

2.1. Studied area and sample collection

South-to-North Water Diversion Project is a strategic infrastructure to transfer water resources across different regions and also one of the biggest water transfer projects in the world. This project covers ChangJiang River, Huaihe River, Yellow River, and Haihe River in over