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Environmental evolution records reflected by radionuclides in the sediment of coastal wetlands: A case study in the Yellow River Estuary wetland

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A B S T R A C T

Vertical profiles of environmental radionuclides (^{210}Pb, ^{137}Cs, ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K) in a sediment core (Y1) of the Yellow River Estuary wetland were investigated to assess whether environmental evolutions in the coastal wetland could be recorded by the distributions of radionuclides. Based on ^{210}Pb and ^{137}Cs dating, the average sedimentation rate of core Y1 was estimated to be 1.0 cm y^{-1}. Vertical distributions of natural radionuclides (^{238}U, ^{232}Th, ^{226}Ra and ^{40}K) changed dramatically, reflecting great changes in sediment input. Concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K all had significant positive relationships with organic matter and clay content, but their distributions were determined by different factors. Factor analysis showed that ^{238}U was determined by the river sediment input while ^{226}Ra was mainly affected by the seawater erosion. Environmental changes such as river channel migrations and sediment discharge variations could always cause changes in the concentrations of radionuclides. High concentrations of ^{238}U and ^{226}Ra were consistent with high accretion rate. Frequent seawater intrusion decreased the concentration of ^{226}Ra significantly. The value of ^{238}U/^{226}Ra tended to be higher when the sedimentation rate was low and tide intrusion was frequent. In summary, environmental evolutions in the estuary coastal wetland could be recorded by the vertical profiles of natural radionuclides.

1. Introduction

Radionuclides are widespread in the earth's environment. The fate and transport of radionuclides in the environment have been extensively studied since human exposure to radiation can have detrimental health effects. (Abd El-mageed et al., 2011; El-Reefy et al., 2014; Sam et al., 1998; Shetty et al., 2006; Wang et al., 2015). However, radionuclides can also serve as effective geochemical indicators. They have been used to assess sedimentation rate (Allen et al., 1993), to trace material sources (Gulin et al., 2014; Zebracki et al., 2015), to evaluate soil erosion (Iurian et al., 2013; Martinez et al., 2009), to estimate soil heterogeneity with depth (Fujiyoshi and Sawamura, 2004), and even to reconstruct big river flood events (Yang et al., 2013). All these studies have demonstrated that variation in environmental radionuclides could reflect changes that had occurred in the soil or sediment. Few such studies have been conducted in coastal wetlands.

As typical transitional zones between the terrestrial and marine environments, estuarine coastal wetlands are very complex ecosystems which are generally known to be geochemical reactors (Cao et al., 2015). The sediment delivered by the river mostly accumulates in coastal environments and forms a delta which can be a recorder of natural and anthropogenic environmental changes (Thomas and Mead, 2009). However, a former research project concerning coastal areas has pointed out that reliable sedimentation histories were difficult to obtain using traditional methods in sandy sediment because of low radionuclide activities (Van Eaton et al., 2010). Here we conducted research in the Yellow River Estuary wetland to explore the associations between radionuclides and environmental evolutions.

The modern Yellow River Delta, located in Shandong Province, China, has developed since 1855. The Yellow River is well known for high sediment concentration and frequent channel migrations

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(Milliman and Meade, 1983). The lower reaches of the Yellow River and the delta have gone through enormous changes in recent decades (Chu et al., 2006). To control flooding and protect coastal development, extensive engineering has been implemented in the estuary areas. Due to both regional climate change and human activities such as explosive urbanization and agricultural demand for water, constructions of check dams and reservoirs as well as large-scale vegetation restoration projects, water and sediment flows to the delta have declined dramatically since the 1970s (Wang et al., 2016). In 1976, the Yellow River shifted artificially from the Diaokou course to Qingshuigou course (Pang and Si, 1979), forming a new promontory which advanced seaward quickly. Then the Yellow River shifted again at the north bank of the Qingshuigou course in 1996 (Chu et al., 2006). Since the early 1990s, the lower reaches of the Yellow River have frequently run dry (Peng and Chen, 2010). As a consequence, the government began to carry out the water-sediment regulation project in 2002 (Li, 2002). All these events brought about profound effects on the depositional environment and sedimentary process of the estuary wetland. Scientists have attempted to learn the evolution of the modern Yellow River delta through remote sensing technology (Chu et al., 2006) or sedimentary records of subaqueous delta (Wu et al., 2015). Environmental evolutions of the delta could also be recorded in the sediment of estuarine coastal wetland (Saito et al., 2000).

In this study, we collected a sediment core Y1 in the Yellow River Estuary wetland and investigated the vertical distribution of radionuclides. Our objective was to establish whether environmental changes of the estuary areas could be recorded in the wetland sediment and reflected by the activity concentration variations of radionuclides. In addition, physical-chemical parameters of the sediment were also investigated to study their influence on the migration and distribution of radionuclides.

2. Material and methods

2.1. Sample collection

The sediment core Y1 (37°46.032′N, 119°09.618′E) was located in the north shore of the Yellow River, about 500 m from the river bank (Fig. 1). The nearest coastline was several kilometers away. Only the spring tide could reach the area periodically. Vegetation, primarily *Suaeda Salsa*, was distributed uniformly around the core. The sediment samples were collected in May 2012. In order to avoid compression of the sediment, a depth profile was dug and samples were collected layer by layer. Every layer was 2 cm thick, and a total of 35 samples (70 cm long) were obtained. All the sediment samples were sealed in plastic bags and immediately transferred to the laboratory for analysis.

2.2. Analysis of physicochemical properties

The grain-size composition was measured using a Laser Particle Size Analyzer (*Cilas 940L*) after dispersion by ultrasonic apparatus. A certain amount (about 50 g) of each sample was oven-dried at 60 °C and then water content was determined using the difference in the weight before and after drying. After that, samples were sieved (<1 mm) for further analysis. The electrical conductivity (EC) was measured with a conductivity meter in a solution (soil: water, 1:5). The total organic carbon (TOC) was determined by dichromate and concentrated sulfuric acid oxidation method (Nelson and Sommers, 2013). The total nitrogen content (TN) and total phosphorus content (TP) were measured using a continuous flow analyzer (SKALAR-SAN^{++}, Breda, the Netherlands). Blank sample and standard reference material analyses were performed throughout the experiment. To evaluate the analytical precision, standard material and half of the samples were duplicated. The relative percent differences for TN and TP in duplicated samples were all <8%.

2.3. Measurement of radionuclides activity concentrations

The samples were sealed in polythene tubes, stored for three weeks before measurement to allow equilibrium between ^{226}Ra and ^{210}Pb to be established. Then the activity concentrations of radionuclides were determined by gamma-ray spectrometry using a high-purity germanium (HPGe) coaxial detector (Canberra

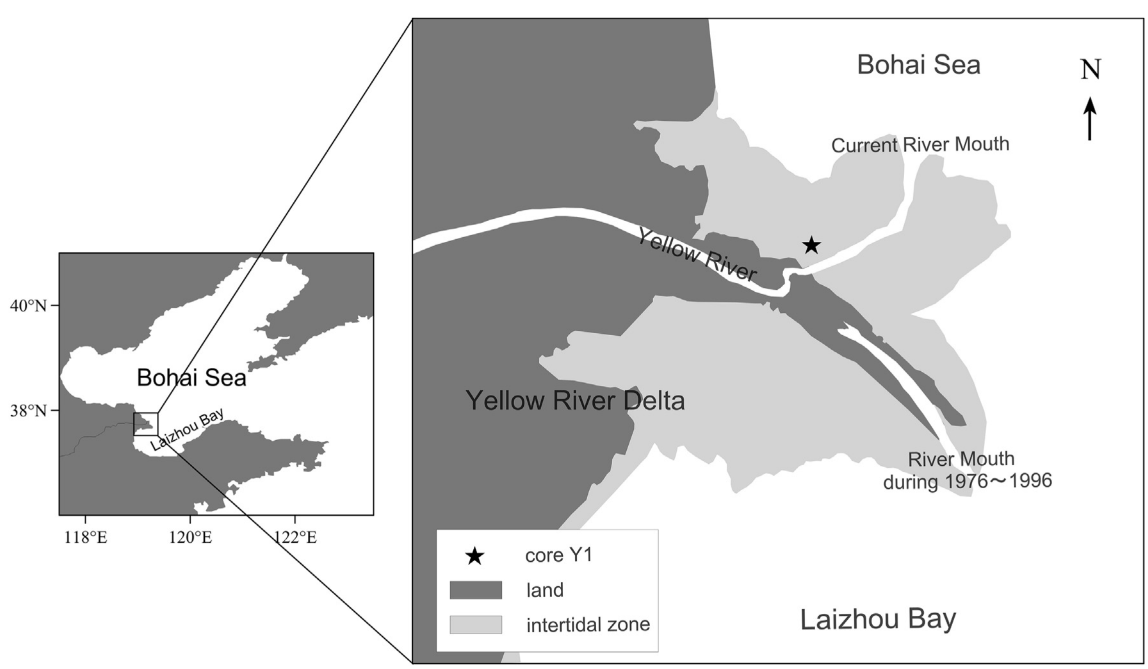

Fig. 1. Location of the sediment core in the Yellow River Estuary wetland.