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Distribution, sources and potential toxicological significance of polycyclic aromatic hydrocarbons (PAHs) in surface soils of the Yellow River Delta, China

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ABSTRACT

PAH concentrations of 61 surface soil samples collected from the Yellow River Delta (YRD), China were measured to determine occurrence levels, sources, and potential toxicological significance of PAHs. The total concentrations of ∑PAHs ranged from 27 to 753 ng/g d.w., with a mean of 118 ± 132 ng/g. The highest concentrations was found in the mid-southern part of the YRD (753 ng/g), which was associated with the oil exploration. The ratios indicated that the PAHs throughout the YRD were mostly of pyrogenic origin; while various sites in mid-southern part in the region were derived mainly from the petrogenic sources. Multivariate statistical analyses supported that the PAHs in surface soils of the YRD were principally from the coal and biomass combustion, petroleum spills, and/or vehicular emissions. The toxic assessment suggested that the PAHs in soils were at low potential of ecotoxicological contamination level for the YRD.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs), identified by the US Environmental Protection Agency as priority pollutants globally (Keith and Telliard, 1979; Knezovich et al., 1987), are a group of compounds which include the largest known class of chemical carcinogens and mutagens. The incomplete combustion of materials associated with high temperature industrial processes is the main anthropogenic source of PAHs. PAHs are released into the environment through wastewater effluents, coke and petroleum refining industries, accidental oil spills and leakages, aerial fallout, rainwater runoff, forest and prairie fires, vehicle traffic, and domestic heating. PAHs are the typically bioaccumulated compounds as they pass through or are sequestered by deltaic wetlands (Brož et al., 2000; Masclet et al., 1986; Poster and Baker, 1995; Simcik et al., 1996; Wolfe et al., 1994), such as the Yellow River Delta (YRD).

The YRD is an important oil industrial base in the northern part of Shandong Province, China (Fig. 1). As the 2nd largest river in China and 6th largest river in the world, the Yellow River carries a huge amount of sediments to the Bohai Sea. The YRD is the main sink of the fine-grained sediments and associated pollutants discharged from the Yellow River watershed (He et al., 2006; Li et al., 2001b). The YRD has been developed rapidly in past 40 years due to the exploitation of the Shengli Oilfield, the 2nd largest oil field in China. In addition, the YRD has become a major region for the development of agriculture and fisheries. Rapid economic growth in the YRD raises concerns of significant pollution to aquatic environment, especially to the sediments which act as a natural repository of organic pollutants (Yang et al., 2009).

There were several studies on the heavy metals, organic carbon, nitrogen, and phosphorus accumulation in the YRD, however, few studies have focused on the PAHs (Li et al., 2001a,b; Yang et al., 2009). The objectives of this research are to determine the occurrence level, composition, and sources of PAHs in surface soils at different locations within the entire YRD, and to assess potential ecotoxicological consequences on organisms in the region.

2. Material and methods

2.1. Study area

The YRD is characterized with a temperate, semi-humid continental monsoon climate. The average annual temperature is 11.7–12.6 °C and average annual precipitation is 530–630 mm

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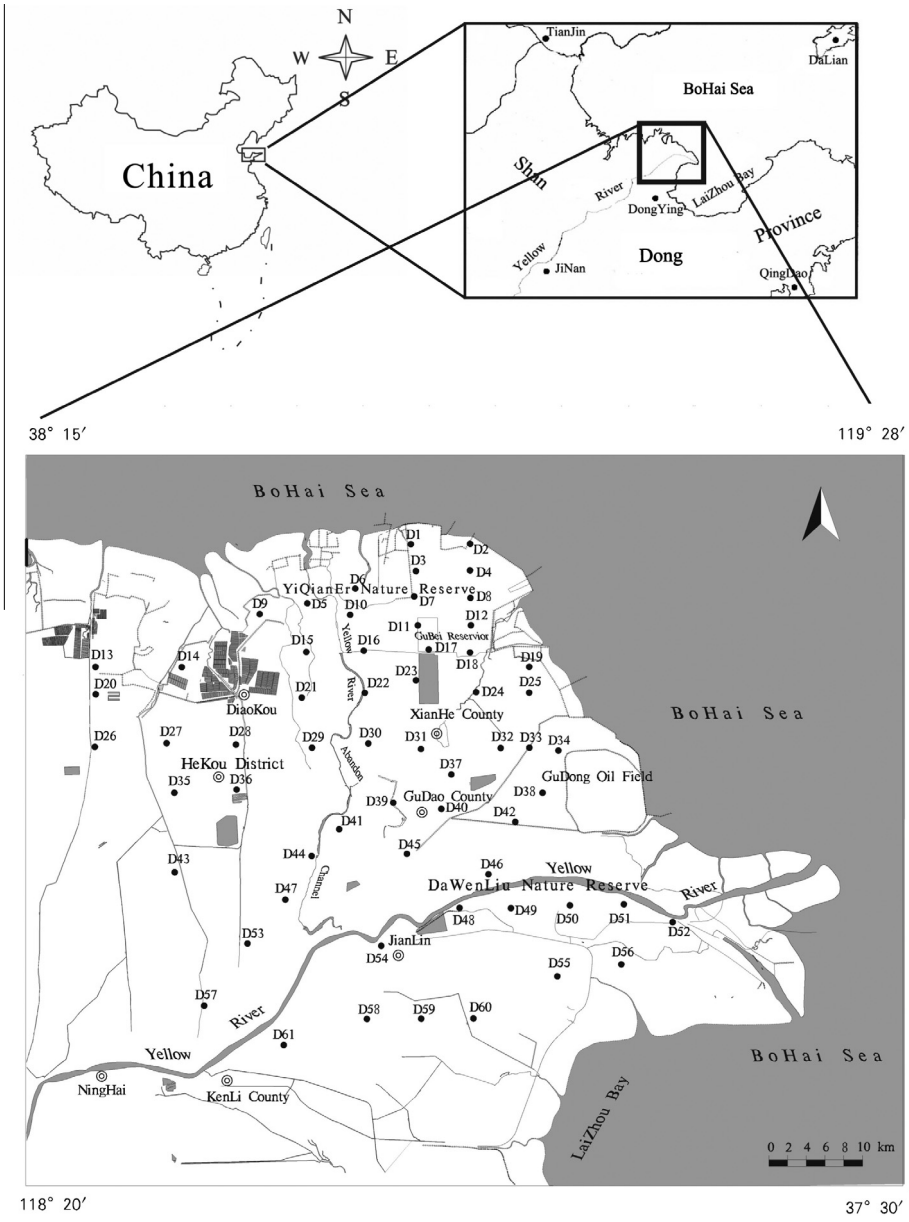

Fig. 1. Location of sampling sites.

(Yang et al., 2009). The YRD lies on the south side of the Bohai Sea, spanning from 118°07′E to 119°18′E, and from 36°55′N to 38°12′N, with an area of 6010 km^2 (Fig. 1). The YRD is the youngest, broadest, and most well-protected wetland catchment in warm temperate China, which provides critical habitat to migratory birds transiting the Western Pacific Ocean.

2.2. Sampling

Surface soils (0–5 cm) were collected every May from 2006 to 2008 by using a 10-cm-diameter wooden sampler at 61 stations within the YRD (Fig. 1). Sample locations were established as a stratified, random design to include inherent shifts in the balance of agriculture, oil and gas, and natural wetland use from the upper to lower delta. The wooden sampler was washed with deionized water between each soil sample to avoid contamination. Four soil samples were taken from each location and mixed to represent an area of approximately 9 km^2, and composited for analysis. Subsequently, samples were wrapped in aluminum foil, transported on ice from the field, and stored at −20 °C until analysis.

2.3. Analysis of total organic carbon (TOC)

The samples for TOC measurement were thawed, freeze-dried, homogenized and pulverized. TOC samples were treated with 4 N HCl to remove carbonate and subsequently rinsed with deionized water to remove the salts before drying overnight at 60 °C. The carbonate-free samples were analyzed for TOC in duplicates in a Vario EL-III Elemental Analyzer and the mean values were reported. Replicate analysis of one sample (n = 12) gave a precision of ±0.02% for TOC.

2.4. Organic analysis of PAHs

15 g of samples were transferred into a pre-cleaned cellulose extraction thimble (Advantec MFS, Inc.) for PAHs analysis and