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Quantitative evaluation of carcinogenic and non-carcinogenic potential for PAHs in coastal wetland soils of China

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ABSTRACT

The levels, sources and health risks for PAHs collected at the national scale in China were discussed in the study. The total concentrations of 16 PAHs in nine coastal wetland soils ranged from 10.8 to 4870 ng g^{-1}. The sources of PAHs were apportioned by PCA, and both the carcinogenic and non-carcinogenic risks were quantitatively calculated with Monte Carlo simulation. A sensitivity analysis was performed to determine the greatest effect of input variables on the risk assessment. The results revealed that 16 PAHs mainly originated from coal combustion, natural gas combustion, diesel emission, and petrogenic source. The carcinogenic risk and non-carcinogenic risk for nine coastal wetlands were below the risk threshold value (10^{-6} for carcinogenic risk, and 1 for non-carcinogenic risk, respectively), indicating no potential adverse health effects developed. Ingestion and dermal contact were the major exposure routes for PAHs risks. Exposure duration and PAHs concentration contributed most to the total risks uncertainty. This study is the first attempt to provide information on health risk of PAHs in wetland soils from a national perspective. The findings support the feasibility of development and evaluation of an implementation strategy for PAHs risks management in coastal wetland soils.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a large group of organic chemicals with two or more condensed benzene rings. They are ubiquitously found throughout the environment (Lang et al., 2012; Zhang et al., 2012; Cobas et al., 2014). Due to their persistent nature, PAHs may remain in the environment for a long time and undergo a long-range transport. They are released into the environment mainly through anthropogenic activities, such as, power generation plants, vehicle emissions, wood and coal combustion, petroleum refining, straw and fire wood burning, oil leaks or spills (Simcik et al., 1999; Mai et al., 2003; Lang et al., 2012; Retnam et al., 2013; Sun et al., 2013; Cobas et al., 2014). Because of their bio-accumulation, carcinogenicity, toxicity, and mutagenicity, health problems such as cataracts, kidney and liver damage are considered to be closely related to the environmental PAHs, which have generated considerable interest in recent years (Wang et al., 2011; Wu et al., 2011; Retnam et al., 2013; Sun et al., 2013). Sixteen priority PAHs have been regulated by the USEPA for their potential adverse health effects (USEPA, 2003a).

The wetlands are known as one of the most productive ecosystems on the earth, as well as for maintaining coastal biological diversity (Lang et al., 2012). With the rapid industrialization, urbanization and high economic growth in recent years, pollution in wetland soils has been both serious and widespread in China. Due to their persistence and hydrophobicity, PAHs are prone to enrichment in soils and are retained for a long period of time. Therefore, soil is considered as a main reservoir for PAHs (Wang et al., 2011; Man et al., 2013). Residents may be exposed to soils PAHs via different pathways, which will cause some adverse health effects after long-term exposure. Hence, studies on health risks caused by PAHs are necessary and will be useful in providing potential strategies of human health protection.

Many studies on soil PAHs pollution in coastal wetlands of China have been performed recently (Wang et al., 2011, 2012; Lang et al., 2012; Yang et al., 2014). PAHs could be widely detected in different regions with concentrations in the range of 10.8–4870 ng g^{-1}, as regards 16 priority PAHs (Hui et al., 2009; Jiao et al., 2010). Limited studies have been carried out on the health risk assessment regarding PAHs pollution in wetland soils. Moreover, most of the previous studies mainly focused on localized wetland areas. Thus, a comprehensive nationwide health assessment for PAHs in coastal

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wetland soils is urgently needed. This study is believed to be the first attempt to calculate the health risk of soil PAHs in wetlands from a national perspective. The goals of this paper are (1) to source apportion of PAHs in wetland soils at the national scale, (2) to assess the health risks posed by soil PAHs with Monte Carlo simulations, (3) to identify critical input variables for risk evaluation.

2. Materials and methods

2.1. Sampling strategy and analysis

In the present study, nine coastal wetlands of China were selected to calculate the health risks posed by PAHs (Fig. 1). These wetlands are located in estuaries from south to north of China. Due to the geographic differences, the temperature, rainfall and plants may be different, hence, the wetlands selected maintain a high degree of representativeness. Sixteen priority PAHs including naphthalene (NaP), acenaphthene (Ace), acenaphthylene (Acy), fluorene (Fle), phenanthrene (Phe), anthracene (Ant), fluoranthene (Fla), pyrene (Pyr), benzo(a) anthracene (BaA), chrysene (Chr), benzo(b) fluoranthene (BbF), benzo(k) fluoranthene (BkF), benzo (a) pyrene (BaP), indeno(1,2,3,cd) pyrene (IND), dibenzo(a,h) anthracene (DBahA), and benzo(g,h,i) perylene (BghiP) were considered in this paper. The PAHs from Jiaozhou Bay and Liaohe estuarine wetland soils were analyzed with Agilent GC (6890-N)/ MSD (5975B). The detailed procedures were described by Lang et al. (2012) and Yang et al. (2014). The concentrations of sixteen priority PAHs in the other seven wetland soils were adapted from previous studies (Table 1).

2.2. Health risk assessment

The potential carcinogenic and non-carcinogenic risks caused by heavy metals and organic pollutants have been widely estimated in different environmental matrixes, including soils, air, drinking water, and food (Xia et al., 2010; Wu et al., 2011; Cao et al., 2014; Li et al., 2014). A probability-based approach has been successfully applied in previous studies, in order to minimize the uncertainties of risk assessment (Xia et al., 2010; Wu et al., 2011; Cao et al., 2014; Li et al., 2014; Yang et al., 2014). In the current approach, a Monte Carlo simulation with Crystal Ball software (Version 7.2) was applied. Each parameter in the proposed model was represented as a probability density function that defined both the range of values and the likelihood of the data exhibiting that value. The probability distributions of exposure parameters are presented in Table 2. The simulation was performed 50,000 times, with new values randomly selected for the parameter according to its distribution.

2.2.1. Chronic daily intake (CDI) calculation

Ingestion, inhalation and dermal contact were considered as the main exposure pathways for PAHs. To evaluate the exposure

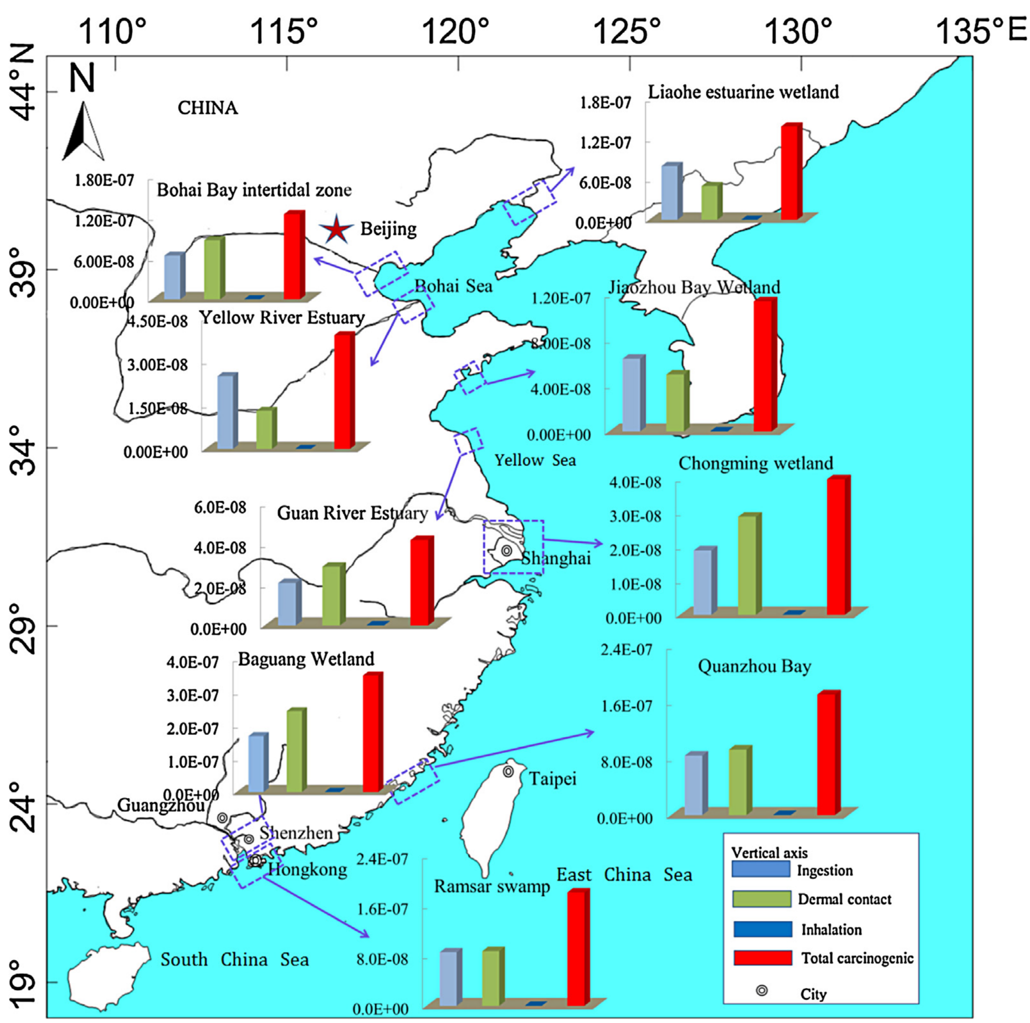

Fig. 1. The locations and carcinogenic risk of PAHs in nine coastal wetland soils of China.