Contamination, source identification, and risk assessment of polycyclic aromatic hydrocarbons in agricultural soil of Shanghai, China

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Abstract The level, distribution, compositional pattern, and possible sources of polycyclic aromatic hydrocarbons (PAHs) in agricultural soil of Shanghai were investigated. The concentrations ranged from 140.7 to 2,370.8 μg kg⁻¹ for 21 PAHs and from 92.2 to 2,062.7 μg kg⁻¹ for 16 priority PAHs, respectively. The higher level of PAHs was mainly distributed in the south and west of Shanghai region, and the lower concentration was found in Chongming Island. Generally, the composition pattern of PAHs was characterized with high molecular weight PAHs, the seven possible carcinogenic PAHs accounted for 4.8–50.8% of the total PAHs, and fluoranthene, pyrene, and benzo[b]fluoranthene were the most dominant components in soil samples. The correlation analysis suggested that low molecular weight PAHs and high molecular weight PAHs were originated from different sources and further corroborated that total organic carbon was a key soil property affecting the fate of persistent organic pollutants in the environment. The isomer ratios and principal component analysis indicated that PAHs in the investigated areas were derived primarily from combustion of biomass, coal, and petroleum. Compared to the soil quality standards of the Netherlands, all the target PAHs (except Ant) in most samples exceeded their target values. The Nemerow composite index based on the same soil quality standard showed that 69.4% of the soil samples were heavily polluted. The total BaPₑₒₑ of ten Dutch target PAHs in 72% soil samples were higher than the reference total carcinogenic potency. Therefore, the agricultural soil in Shanghai is suffering from serious PAHs contamination.

Keywords PAHs · Surface soil · Principal component analysis · Shanghai

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are produced primarily as a result of incomplete combustion from predominantly anthropogenic sources including fossil fuel, biofuel, and vegetation fires. PAHs, as ubiquitous environmental contaminants, are receiving extensive attention...
because of their adverse effects on human health including high toxicity, mutagenicity, and carcinogenicity. Owing to meeting all the United Nations Environment Program screening criteria for persistent organic pollutants (POPs) under the Stockholm Convention: persistence, bioaccumulation, toxicity, and potential for long-range environmental transport, PAHs have been proposed as POPs candidates meriting further investigation for possible early inclusion in the Stockholm Convention on POPs (WWF 2005). A number of investigations showed that PAHs were widely present in the environmental media (Wileke 2000; Fu et al. 2003; Mielke et al. 2004; Chen et al. 2005a, b; Zohair et al. 2006; Chung et al. 2007; Jiang et al. 2009a).

Soil is the source and pool for semi-volatile organic compounds. As ubiquitous organic pollutants, it was estimated that more than 90% of the burden of surface soil PAHs residues in the UK came mainly from dry and wet atmospheric deposition (Wild and Jones 1995), and soil system contaminated by PAHs is considered to be a steady indicator of environmental pollution (Wild and Jones 1995). Accumulation of PAHs in soil may lead to further potential contamination of vegetables and food chains (Kipopoulou et al. 1999), which can cause direct or indirect human exposure. Therefore, there has been a much-growing concern about the knowledge of soil contamination with PAHs. Different levels of PAHs in soil have been reported from different regions all around the world. High levels of PAHs contamination were reported in Tianjin (Tao et al. 2004), Guanzhou (Chen et al. 2005b), and Pearl River Delta Region (Cai et al. 2007) in China, and low contamination levels were observed in unpolluted soil of Spain (Nadal et al. 2004), in agricultural soil from Poland (Maliszewska-Kordybach 1996), and in rural soil in Estonia (Trapido 1999) and Hong Kong of China (Chung et al. 2007). In China, PAHs contamination in mega-cities has roused an extensive concern for environmental scientists, and several investigations on PAHs contamination in agricultural soil have been carried out (Tao et al. 2004; Chen et al. 2005a, b; Ping et al. 2007; Cai et al. 2007.

Shanghai, located in Eastern China, has a total area of 6,340.5 km², making up 0.06% of China’s total territory. It is one of the most densely populated cites in China with heavy automobile traffics and major industrial plants. It has the largest steel works and petrochemical complex in China. Due to the rapid growth of industrial production, building activities, population, and traffic density, Shanghai is faced with serious environmental pollution problems. Recently, several studies indicated that organic pollutants, such as polychlorinated biphenyls, organochlorine pesticides, and PAHs, were widespread in various environmental media in Shanghai and its surrounding areas (Chen et al. 2004; Nakata et al. 2005; Feng et al. 2006; Liu et al. 2007, 2008; Ping et al. 2007; Jiang et al. 2009a, b). However, knowledge about the contamination of PAHs is less available in the agricultural soil of the Shanghai region. The purposes of the present study were: (1) to determine the level and distribution of PAHs contamination, (2) to elucidate potential input sources, and (3) to obtain possible carcinogenic risk of PAHs in Shanghai agricultural soil.

Materials and methods

Soil sampling and preparation

A stratified random sampling strategy was adopted to examine the PAHs contamination in agricultural areas of Shanghai and a total of 36 surface soil samples were collected in October, 2007. The sampling locations covered nine districts, including Chongming: CM1 ~ CM4, Jiading: JD1 ~ JD3, Baoshan: BS1 ~ BS3, Qingpu: QP1 ~ QP3, Songjiang: SJ1 ~ SJ6, Jinshan: JS1 ~ JS5, Fengxian: FX1 ~ FX5, Nanhui: NH1 ~ NH4, and Minhang: MH1 ~ MH3, respectively (Fig. 1). At each site, five sub-samples (at the depth of 0–15 cm in 1,000 m²) were collected and bulked together to form one composite sample. The samples were air-dried at room temperature and crushed after removing stones and residual roots to pass through a 100-mesh sieve, then stored in the refrigerator until analysis. The total organic carbon (TOC) of the soil samples was measured according to the methods described previously (Chen et al. 2005b).