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Occurrence and risk assessment of potentially toxic elements and typical organic pollutants in contaminated rural soils

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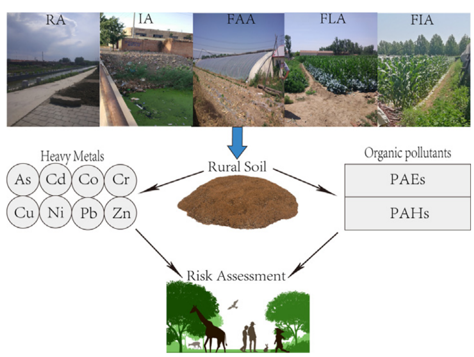
HIGHLIGHTS

- Heavy metal, PAE and PAH contents in rural soils near different pollution sources were determined.
- A health risk assessment model calculated human exposure to the pollutants.
- Different pollution sources and soil physicochemical properties affected the soil contamination profiles.
- The human health risks of As and Cr should be topics of future concern.

GRAPHICAL ABSTRACT



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ABSTRACT

The residual levels and risk assessment of several potentially toxic elements (PTEs), phthalate esters (PAEs) and polycyclic aromatic hydrocarbons (PAHs) in rural soils near different types of pollution sources in Tianjin, China, were studied. The soils were found to be polluted to different extents with PTEs, PAEs and PAHs from different pollution sources. The soil concentrations of chromium (Cr), nickel (Ni), di-*n*-butyl phthalate (DnBP), acenaphthylene (Any) and acenaphthene (Ane) were higher than their corresponding regulatory reference limits. The health risk assessment model used to calculate human exposure indicates that both non-carcinogenic and carcinogenic risks from selected pollutants were generally acceptable or close to acceptable. Different types of pollution sources and soil physicochemical properties substantially affected the soil residual concentrations of and risks from these pollutants. PTEs in soils collected from agricultural lands around industrial and residential areas and organic pollutants (PAEs and PAHs) in soils collected from agricultural areas around livestock breeding were higher than those from other types of pollution sources and merit long-term monitoring.

1. Introduction

Many toxic pollutants are introduced into and remain in soils such as metals, phthalate esters (PAEs) and polycyclic aromatic hydrocarbons (PAHs) (J. Wang et al., 2013; Islam et al., 2015; C.H. Wang et al., 2017) and excessive inputs of metals and organic pollutants may lead to

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some deterioration of soil physicochemical properties and soil biological function (Yang et al., 2006; J. Wang et al., 2015; Gulan et al., 2017). Potentially toxic pollutants such as PAEs and PAHs can be readily transferred to humans by ingestion, inhalation, or dermal absorption, accumulate in certain tissues, and subsequently affect the immune, nervous and endocrine systems and also impact cellular metabolism (Abrahams, 2002; Turkdogan et al., 2003; Kim et al., 2013).

Soil contamination with metals and organic pollutants has increased greatly in China in recent years due to rapid urbanization and industrialization (Tang et al., 2010; N. Chen et al., 2017 and W.X. Chen et al., 2017). Numerous studies report that soils in many areas have been highly polluted with metals, PAEs and PAHs and the potential threats the environment and the human food chain are growing (Cai et al., 2009; Dai and Zhang, 2010; K.R. Wang et al., 2013; Shao et al., 2015; Zeng et al., 2015). Major sources are anthropogenic exogenous inputs of metals and organic pollutants (Al-Darwish et al., 2005). For example, the total volume of untreated wastewater discharged increases annually and reached 71.6 billion tonnes in 2015 (National Bureau of Statistics, 2015) and wastewater irrigation introduces contaminants into agricultural soils. The production of plasticizers has increased rapidly from 1.25 million tonnes in 2006 to 2.20 million tonnes in 2011 and most of this has been used in the production of plastic films (Zhang et al., 2015). Increasing levels of PAEs in agricultural soils have been found because plastic films are commonly used as mulches (J. Wang et al., 2013). The primary sources of PAHs in soils include automobile fuel combustion, industrial emissions, sewage discharge and waste dumping. Wastewater irrigation has been used since the early 1960s to alleviate agricultural water shortages in arid and semiarid areas, leading to high pollution of the soils in 26.4% of sewage irrigation areas (MEP and MLS, 2014; Zeng et al., 2015). Knowledge of the pollutant status of agricultural soils is therefore urgently required.

Previous studies using risk assessments of metals and organic pollutants have focused primarily on urban areas (Peng et al., 2011; Zeng et al., 2009; Qing et al., 2015; Gulan et al., 2017), mining areas (Li et al., 2014) and some rivers and lakes (Sakan et al., 2017; Xu et al., 2017), with little study of rural areas. Pollution of rural areas where intensive crop production and livestock enterprises have developed has led to important environmental problems and threats to human health. Meng et al. (2016) reported that substantial pollution with metals such as cadmium (Cd), zinc (Zn) and mercury (Hg) has occurred in soils irrigated with untreated wastewaters in Tianjin. Zhao et al. (2018) found that di-*n*-butyl phthalate (DnBP) and di-(2-ethylhexyl) phthalate (DEHP) were the primary PAE congeners contaminating soils in the city parks of Tianjin. Tao et al. (2004) observed that agricultural soils and vegetables collected from sites located adjacent to an urban district and irrigated with wastewater for several decades are highly contaminated with PAHs. Field contamination usually involves combined pollution with metals and organic pollutants. Tang et al. (2010) reported combined pollution with metals, PAHs, and polychlorinated biphenyls (PCBs) at a new e-waste recycling city in the Taizhou area. Furthermore, metals together with organic pollutants, even at low concentrations, can represent a substantial hazard to human health and the environment because of gradual accumulation over time (Liu et al., 2017). Combined pollution with metals and organic pollutants in agricultural soils therefore merits further study.

The main objectives of this study were to investigate the residual levels of potentially toxic elements (PTEs) such as arsenic (As), Cd, chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), nickel (Ni), and Zn, and organic pollutants (PAEs and PAHs) in rural soils around different types of pollution sources in Tianjin district, to assess the risk of PTEs, PAEs and PAHs from different types of pollution source to human health and the environment, and to examine the effects of soil physicochemical properties on the residual levels of PTEs and organic pollutants in contaminated soils.

2. Materials and methods

2.1. Sample collection

A preliminary survey of contaminant levels in the surface soils (0–20 cm) in Tianjin rural areas was conducted with the aid of a global

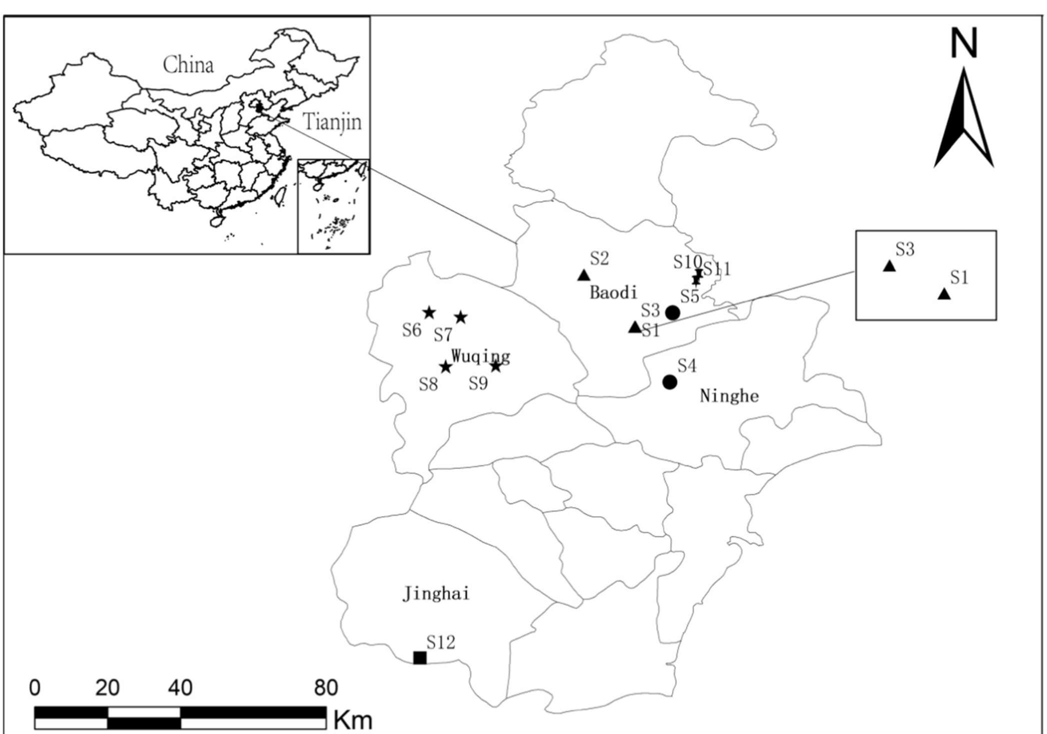

Fig. 1. Map of the study area and sampling locations; ▲, sampling sites around residential areas (RA); ●, sampling sites around industrial areas (IA); ★, sampling sites in areas with agricultural facilities (FAA); ⯆, sampling sites in agricultural lands around livestock breeding areas (FLA); ■, sampling sites in agricultural lands around industrial areas (FIA).