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Levels and risk factors for urinary metabolites of polycyclic aromatic hydrocarbons in children living in Chongqing, China

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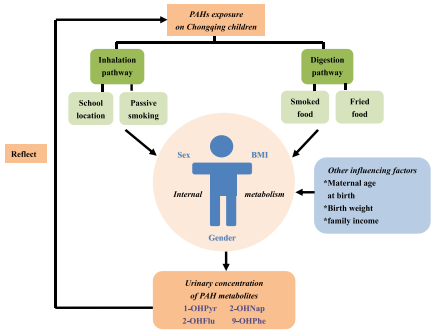
HIGHLIGHTS

- Elevated OH-PAHs were measured in 1230 children living in Chongqing, China.
- School location, diet, and SES were associated with urinary PAH metabolites in children.
- Ambient polluted air was an important PAHs exposure pathway for children.

GRAPHICAL ABSTRACT



Urinary metabolites of polycyclic aromatic hydrocarbons in children and influencing factors in Chongqing, China

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ABSTRACT

Aims: Since childhood exposure to polycyclic aromatic hydrocarbons (PAHs) have been associated with a variety of adverse health outcomes, the aims of this study were to1) document PAH exposure levels among children in Chongqing, China by measuring urinary concentrations of four PAH metabolites, 1-hydroxypyrene (1-OHPyr), 2-hydroxynaphthalene (2-OHNap), 2-hydroxyfluorine (2-OHFlu) and 9-hydroxyphenanthrene (9-OHPhe), and 2) assess the associations of urinary concentrations of these PAH metabolites with risk factors related to sources of PAHs inhalation and ingestion exposures and with personal attributes such as sex, age, and BMI.
Methods: The present study is a cross-sectional analysis using data drawn from the third follow up of a longitudinal study. Purposive sampling was used with all students in grades one to four in four schools being eligible to participate. The baseline survey included a total of 1237 students 5.8 to 12.2 years of age. At the third follow up survey, 1.5 years after the baseline survey, 1230 of the children had a physical exam and provided urine samples. Their parents completed a questionnaire including social-demographic information and possible sources of children's exposure to PAHs. Urine samples were measured for the four OH-PAHs using an HPLC-MS/MS technique. Concentrations were corrected by specific gravity. Linear regression analysis was used to investigate factors related to sources of PAHs exposure.
Results: The urinary concentrations were highest for 9-OHPhe (median at the range of 3661 ng/L), followed by 2-

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OHNap (3189 ng/L), 2-OHFlu (1116 ng/L), and 1-OHPyr (250 ng/L). In multiple linear regressions, being female ($P = 0.04$), school location near a thermal power plant ($P = 0.02$) and higher maternal age at birth ($P < 0.01$) were associated with increased concentrations of urinary 1-OHPyr; no significant associations were found for 2-OHNap; school location near a thermal power plant ($P < 0.01$) and lower family income ($P < 0.01$) were associated with increased concentrations of urinary 2-OHFlu; higher age ($P < 0.01$), school location near a thermal power plant ($P = 0.01$), frequent consumption of smoked foods ($P = 0.04$) and lower family income ($P = 0.07$) were all found to be associated with increased concentrations of 9-OHPhe.

Conclusions: Urinary concentrations of OH-PAHs, especially 9-OHPhe, were elevated in Chongqing Children compared to children in other countries. Being female, older age, school location near an industrial site, frequent consumption of smoked foods and lower family income were all associated with higher OH-PAHs concentrations. Further cohort studies are needed to confirm the associations between potential exposure sources and children's exposure to PAHs, in order to provide recommendations to reduce exposure.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a class of toxic compounds that can cause a variety of health effects. A number of these compounds have carcinogenic and mutagenic properties, as well as developmental toxicity (IARC, 2010). Humans are exposed to PAHs via inhalation of polluted air and tobacco smoke, dietary intake of smoked or grilled foods, and dermal contact with soot, tars, and polluted soils (Kamal et al., 2015).

Biological monitoring is a direct way to assess internal doses of PAHs exposure. After internal metabolism, PAHs can be enzymatically converted to hydroxylated-PAHs (OH-PAHs) that are excreted in urine. Concentrations of OH-PAHs in urine are usually related to the total amount of PAHs exposure (Gunier et al., 2006; Scherer et al., 2000). Among the many PAHs, pyrene can be absorbed through not only the respiratory tract, but also the gastrointestinal tract and skin. 1-Hydroxypyrene (1-OHPyr), one of the major urinary metabolites of pyrene, is widely used as biomarker of PAHs exposure. However, pyrene only accounts for a small fraction of the whole PAHs mixture, as concentrations of pyrene are generally far lower than those of naphthalene, fluorene and phenanthrene (Li et al., 2008; Fan et al., 2012). Hence, the determination of multiple urinary metabolites of PAHs is recommended. In this study, metabolites of four PAHs were measured including those of naphthalene, fluorene, phenanthrene, and pyrene.

The four metabolites are hydroxylated forms of the 2- to 4-ringed PAHs. In ambient air and indoor air, the concentrations of 2- to 4-ringed PAHs, which are predominantly in the gas phase, are significantly higher than those of 5-ringed or larger PAHs, which are primarily in the particulate phase. Therefore, the determination of the metabolites of 2- to 4-ringed PAHs may reflect PAHs exposure through an inhalation pathway (Liu et al., 2001). Naphthalene is in the light fraction of petroleum and its products, generally considered to be the representative substance of oil volatilization (Zhao, 2001). Mothballs also contain an abundance of naphthalene. As a 2-ring PAH which is highly volatile and mainly absorbed by inhalation, naphthalene was classified as a potential carcinogen by the International Agency for Research on Cancer (IARC) in 2002 (WHO, 2002), and has attracted global attention in recent years. Fluorine, a 3-ring PAH is a common PAH and comes from the coke oven heating and combustion. Elevated concentrations of metabolites of fluorine are widely detected in coke oven workers (Campo et al., 2008; Wang et al., 2012). As a 3-ringed PAH, phenanthrene has the same carcinogenic bay region structure as heavy-ringed PAHs (Harvey and Dunne, 1978). Combustion of coal produces large amount of phenanthrene and pyrene and relatively high concentrations of OH-phenanthrene have been found in previous studies of Chinese children (Yue, 2011; Yue et al., 2009; Fan et al., 2012).

A goal of the present study was to explore potential risk factors contributing to increased levels of PAH exposure in children living in Chongqing, the largest municipal economic center and an important communications hub at the upper reaches of the Yangtze River located in western China. The city has many heavy industrial facilities and high traffic density. Previous studies have reported higher airborne PAH concentrations in Chongqing compared with other cities in China (Guo et al., 2006; Chen et al., 2013). Inhalation and ingestion pathways are widely accepted as the two main sources of PAH exposure; and many factors related to personal attributes (such as such as sex, age, body fatness) may play important roles in the metabolism of PAHs (Dong et al., 2008; Billiard et al., 2000). Since PAHs are fat-soluble and women tend to have more body fat than men, sex and body fatness may affect the urinary concentration of PAH metabolites. However in previous studies, sex and body mass index (BMI) differences in urinary concentration of PAH metabolites have been mixed (Li et al., 2008; Thai et al., 2015; Mucha et al., 2006).

Young children are particularly susceptible to air pollution hazards compared to adults (Millman et al., 2008). It has been reported that in the same living environment, children (6–11 years old) had a mean 1-OHPyr level 30% higher than adults (Huang et al., 2006). This situation may be worse in children from low-income families since they are more likely to live close to industrial sources or heavy traffic areas (Chung et al., 1999). Because of the potential adverse effects of PAHs on children's health and development, the United States now has ongoing monitoring of urinary PAHs exposure in children through the National Health and Nutrition Examination Surveys (NHANES), while in China research and monitoring of PAHs exposure in children has been limited.

The specific aims of this study were 1) to document PAHs exposures in school-age children living in urban Chongqing by measuring urinary concentrations of four metabolites of PAHs: 1-hydroxypyrene (1-OHPyr), 2-hydroxynaphthalene (2-OHNap), 2-hydroxyfluorine (2-OHFlu) and 9-hydroxyphenanthrene (9-OHPhe) and 2) to assess the associations of risk factors related to sources of PAHs inhalation and ingestion exposures and personal attributes (i.e., sex and age) with urinary concentrations of these PAH metabolites.

2. Materials and methods

2.1. Data source

Data for these analyses are part of a larger ongoing longitudinal cohort study, designed to track the onset and process of pubertal development and assess the psychosocial and biochemical factors influencing pubertal development in children. Beginning in May 2014, the baseline survey of the cohort study was conducted using purposive sampling in schools. Jiulongpo District (JLP District) was selected as the study site as it is a district with a typical urban-rural dual economic structure in the city zone of Chongqing. Four primary schools in the JLP District were selected to represent different geographic locations. Parents of all students in grades one to four from the four primary schools were sent consent forms to sign and 1237 students returned signed consent forms to participate in the study. Two schools (school I and II) were in the same location (location A identified as a “high polluted area”)