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Inhalation exposure and health risks for newsagents exposed to atmospheric polycyclic aromatic hydrocarbons in Tehran, Iran

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ABSTRACT

Many workers such as newsagents are exposed to polycyclic aromatic hydrocarbons (PAHs) found in urban atmosphere. The present study was designed to determine the levels of newsagents' inhalation exposure to PAHs found in ambient air of Tehran, Iran and to assess the health risks with the toxic equivalency factor (TEF) approach. Ninety personal exposure samples were collected during the summer season (representing warm period samples) and the fall season (representing cold period samples) of 2013. Sixteen priority PAHs from the United States Environmental Protection Agency (US EPA) pollutants list were selected for analysis of newsagents' personal daily exposure. Samples were analyzed by gas chromatography–mass spectrometry. The levels of benzo[*a*]pyrene (BaP) in the breathing zone air of newsagents in the summer and fall seasons were 0.122 ± 0.036 μg/m^3 and 0.361 ± 0.077 μg/m^3, respectively. The obtained benzo[*a*]pyrene equivalent BaP(eq) values of 16 USEPA PAHs were higher in the fall season than those obtained for summer season. Comparing the daily inhaled dose of PAHs in the summer and fall seasons showed that the highest daily inhaled dose (13 μg) was calculated for benzo[*a*]anthracene in the cold period (fall seasons' samples). Special attention should be paid to protect newsagents in relation to PAH exposure.

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are a group of persistent organic pollutants (POPs) which are identified as carcinogenic airborne contaminants. These are compounds composed of two or more fused aromatic rings (Maliszewska-Kordybach, 1999; Zare et al., 2012; Li et al., 2003; Zare et al., 2013). PAHs are emitted from incomplete combustion of natural organic materials such as forest fires (Li et al., 2003; Moradi Rad et al., 2015; Shahtaheri et al., 2006). However, most emissions occur from human activities such as residential heating, home cooking, manufacturing activities, and vehicle emissions (Li et al., 2003; Shahtaheri et al., 2006; Shahtaheri et al., 2007). PAHs as major pollutants in urban air have been shown to have mutagenic effects and have become a central public concern (Ćwiklak et al., 2009). International Agency for Research on Cancer (IARC) has classified BaP as carcinogenic to humans (group 1) and some PAHs as possible human carcinogens (group 2B) and probable human carcinogens (group 2A) (Li et al.,

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2003; IARC, 1987; Gatto et al., 2014; IARC, 2010). The USEPA has listed 16 PAHs in the priority pollutants list (Office of the Federal Registration, 1982). Threshold Limit Values (TLVs) for benzo[*a*]pyrene and benzo[*b*]fluoranthene have not been established by the American Conference of Governmental Industrial Hygienists (ACGIH) and it has been recommended that the level of workers' exposure to these compounds from all routes should be minimized (ACGIH, 2010). Some findings have confirmed the association between exposures to PAHs found in urban air and lung cancer (Ćwiklak et al., 2009).

The results of some studies demonstrated that many people in urban area have a probable exposure to air pollution emitted by urban traffic. Most PAHs found in the urban atmosphere are emitted into the air from incomplete combustion of fuel of heavy duty vehicles, especially diesel engines (Han and Naeher, 2006). PAHs in ambient air are presented in both gaseous and particulate phases and have a direct effect on people's health (Rezaei et al., 2015a; Rezaei et al., 2015b). More detailed information about the environmental concentration and toxicity of benzo[*a*]pyrene becomes available because researchers have drawn attention to its carcinogenic effects. The annual average recommended concentration of benzo[*a*]pyrene ranged from 1 to 10 ng/m^3 in urban air and 1 ng/m^3 for rural air (Ćwiklak et al., 2009). The health risk associated with exposure to PAHs in the outdoor environment increased with increasing urban population, increasing number of vehicles, and due to low/calm wind conditions leading to lowering the dispersion of atmospheric pollutants (Srogi, 2007).

Large number of researchers have investigated the effects of seasonal variation on concentrations of PAHs found in urban atmosphere (Srogi, 2007; Zhang and Tao, 2008; Piccardo et al., 2003; Fioretti et al., 2010). Recent evidence suggests that, the highest concentration of PAHs found in urban air was observed during the cold seasons (fall and winter) than during the warm seasons (spring and summer). A number of studies have found that, the higher level of particulates phase PAHs was observed in the winter season and the amount of gas phase PAHs was highest in the summer season. Comparing the two seasons, it can be seen that, factors such as air temperature, reduction in photolysis of pollutants and decomposition of radicals, and decreases in the deposition of particles in the wet form may increase the concentrations of PAHs in the winter season (Rezaei et al., 2015a; Srogi, 2007). Many workers such as newsagents are exposed to PAHs found in urban atmosphere (Zhang and Tao, 2008; Piccardo et al., 2003). Traffic pollution is the major sources of newsagents' exposure to PAHs. Although, the mean number of news-vendors in cities is very small in comparison with some jobs such as police and taxi drivers, newsagents are exposed to high traffic pollution levels because of working in close proximity to traffic. Piccardo et al. (2003) demonstrated that the average exposure of non-smoking newsagents to atmospheric benzo[*a*]pyrene was significantly higher in the winter season than the summer season. The level of newsagents' exposure during warm period was 35% lower than that during the cold period. Exposure to high levels of PAHs may increase the risks of adverse effects on human health. The overall PAHs inhaled dose is higher in winter compared to the summer. There are some possible reasons for the higher inhaled dose in winter than in the summer including elevated atmospheric PAHs in winter, effects of meteorological variables, and enhanced atmospheric reactivity of PAHs in the summer season (Fioretti et al., 2010).

The present study was designed to determine the levels of newsagents' inhalation exposure to PAHs found in ambient air of Tehran city in 2013 and to assess the associated health risks with the benzo[*a*]pyrene (BaP) toxic equivalents (BaP(eq)) approach.

2. Methods

A cross-sectional approach was chosen to determine the newsagents' exposure to PAHs found in the urban air of Tehran city. With regard to streets or squares with high traffic intensity, fifteen non-smoking newsagents from 22 districts of Tehran city were randomly selected. Newsstands were made from prefabricated metal sheets and glasses with an opening window at the front of structures. Samples were obtained with workers' consent. In order to determine the effects of seasonal variation on workers' exposure to PAHs, 90 personal exposure samples were collected during the summer season and fall season of 2013. PAHs sampling were repeated for 3 days in a week. Sixteen priority PAHs from the US EPA pollutants list including naphthalene (NapH), acenaphthylene (Ac), acenaphthene (Ace), fluorene (Fl), phenanthrene (Phen), anthracene (Anth), fluoranthene (F), pyrene (Py), benzo[*a*]anthracene (BaA), chrysene (Chr), benzo[*b*]fluoranthene (BbF), benzo[*k*]fluoranthene (BkF), benzo[*a*]pyrene (BaP), indeno[1,2,3-*cd*]pyrene (IcdPy), dibenzo[*a*,*h*]anthrancene (DbahA), benzo[*g*,*h*,*i*]perylene (BghiP) were selected for analysis of newsagents' personal daily exposure.

Newsagents' inhalation exposure was assessed according to a modified version of National Institute of Occupational Safety and Health (NIOSH) 5515 method using gas chromatography–mass spectrometry (GC–MS) (Agilent Technologies, Palo Alto, CA) (NIOSH, 1994; Ozcan et al., 2010). PAHs usually occur as mixtures and the compound fraction is complex. Gas chromatography with mass spectrometric detection is appropriate method for separation and detection of the individual PAH (Lee et al., 1981; Vo-Dinh, 1989).

Calibrated personal sampling pump (SKC Inc., UK) was directly connected to polytetrafluoroethylene (PTFE) filter (37 mm diameter, 2.0 μm pore size) and XAD-2 adsorbent for collecting both gas and particulate phases PAHs. The samples were collected at a flow rate of 2 l/min. All samples were stored at 4 °C prior to the start of samples analysis. Samples were extracted with methylene chloride in ultrasonic bath (30 min). Standard curves were prepared from stock solution (Sigma-Aldrich Co, UK) in acetonitrile. Samples were analyzed by GC–MS. The temperature of the GC–MS column was programmed at an initial temperature of 70 °C for 1 min, raised by 10 °C up to 300 °C. The retention time of compounds in the column was 30 min. GC–MS injector temperature was 290 °C.

The intra-assay coefficient of variation was used to determine the precision and repeatability of measurements. Recovery and desorption efficiency was performed to evaluate inter-assay accuracy of the analytical method. The retention time of PAHs compound in the column was investigated. The blank determination with 10 blank samples was used to estimate the limit of detection (LOD) and limit of quantification (LOQ) for studied PAHs (Sanagi et al., 2009).

For the estimation of daily inhalation dose of each PAH, an average respiration rate of 1.25 m^3/h and 100% of respiratory uptake were considered. In order to assess the health risk of individual PAHs, concentrations of each PAH were evaluated based on benzo[*a*]