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Bulk deposition of polycyclic aromatic hydrocarbons (PAHs) in an industrial site of Turkey

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Bulk deposition fluxes of PAHs were measured in an industrial area and deposition velocities of PAHs were reported.

Abstract

Ambient air and deposition samples were collected in the period of July 2004–May 2005 in an industrial district of Bursa, Turkey and analyzed for polycyclic aromatic hydrocarbon (PAH) compounds. The overall average of fourteen bulk deposition fluxes for PAHs was 3300 ± 5100 ng m^{-2} d^{-1}. PAH depositions showed a seasonal variation and they were higher in winter months. This was probably due to increases in residential heating activities and decreases in atmospheric mixing layer levels. Ambient air samples, measured with a high volume air sampler, were collected from the same site. The average total concentration including gas and particulate phase was about 300 ± 420 ng m^{-3} and it was in the range of previously reported values. Some of the ambient air and bulk deposition samples were collected simultaneously in dry periods. Both concurrently measured values were used to calculate the dry deposition velocities whose overall average value was 0.45 ± 0.35 cm s^{-1}.

Keywords: Deposition velocity; Semi-volatile organic compounds; Flux; Concentration; Bursa

1. Introduction

Polycyclic aromatic hydrocarbons (PAHs) are produced by incomplete combustion of fossil fuels, wood, organic matter and are considered as ubiquitous contaminant in the environment (Garban et al., 2002; Motelay-Massei et al., 2003; Wu et al., 2005). Main sources of PAHs are traffic, thermal power stations, residential and industrial emissions in urban areas (Odabasi et al., 1999a; Esen et al., 2006; Motelay-Massei et al., 2006).

Transport and fate of PAHs in the atmosphere partly depend on their characteristics and meteorological condition (Dickhut and Gustafson, 1995; Golomb et al., 2001; Park et al. 2001; Grynkiewicz et al., 2002; Vardar et al., 2002; Motelay-Massei et al., 2003; Vardar and Noll, 2003; Tasdemir and Esen, 2007). PAHs are semi-volatile organic compounds (SOCs) present in the atmosphere in both gaseous and particulate phases. They are subject to removal mechanisms such as oxidative and photolytic reactions, and wet and dry deposition (Dickhut and Gustafson, 1995; Hillery et al., 1998; Odabasi et al., 1999b; Garban et al., 2002; Vardar et al., 2002; Fang et al., 2004; Tasdemir and Esen, 2007). PAHs can be deposited (i) by direct impact of particles and gaseous molecules on surfaces (dry deposition) and/or (ii) by precipitation (wet deposition). Measurement of dry deposition is more uncertain. Different measurement technique of the dry deposition of SOCs have been attempted by employing surrogate and natural deposition surfaces to measure the atmospheric depositional fluxes of SOCs (Murphy, 1981; Holsen and Noll, 1992; Franz et al., 1998; Odabasi et al., 1999b; Vardar et al., 2002; Terzi and Samara, 2005; Tasdemir and Esen, 2007; Cindoruk and Tasdemir, 2007).

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Additionally, dry deposition flux of PAHs can be estimated using the dry deposition velocity (V_d, m d^{-1}) and atmospheric concentrations in accordance with $F = V_dC$ equation, where C and F refer to concentration (ng m^{-3}) and flux (ng m^{-2} d^{-1}), respectively. Therefore, dry deposition velocity is of importance in the determination of the atmospheric loadings of SOCs.

PAHs are transported in the atmosphere as gaseous and/or particulate phases and scavenged according to several processes. PAHs become associated to rain as wet deposition, they are associated with particles as dry deposition and they may be sorbed and conversely volatilized when facing large aquatic systems as air-water exchange. Bulk samplers are the sum of all of them (Ollivon et al., 2002; Gocht et al., 2007). Many resources have been launched to estimate the accumulation of persistent organic pollutants (POPs) including PAHs (OSPAR Commission, 2001; Motelay-Massei et al., 2003). For example atmospheric bulk deposition has been sampled using funnels made up of stainless steel, and borosilicate glass and dark glass bottles (Manoli et al., 2000; Garban et al., 2002; Gocht et al., 2007; Motelay-Massei et al., 2007). The bulk deposition of individual PAHs can be a function of several parameters, such as the compound's Henry's law constant and vapour pressure, the particle size distribution, the gas/particle partitioning, meteorological conditions and the size of raindrops (Sehmel, 1973; Manoli et al., 2000).

The major objectives of this paper were (i) to report the atmospheric concentrations and bulk deposition fluxes of PAHs measured in an industrial site of Bursa, Turkey, (ii) to investigate the temporal changes in the bulk deposition flux levels, and (iii) to determine the empirical dry deposition velocities of PAH compounds.

2. Materials and methods

2.1. Sampling

Twenty-five ambient air samples and 14 bulk deposition samples were collected between July 2004 and May 2005 in an organized industrial district (OID) in the city of Bursa, Turkey. A high volume air sampler (HVAS) and a bulk sampler were employed in the sampling campaigns on a ~1.5-m high platform on the roof of a 3-story building belonging to the Commerce and Industry Chamber. The sampling site was on the northwest part of Bursa (28°10′–30°00′ N, and 39°35′–40°40′ E). The site was located near to an industrial, trafficked and residential area (Fig. 1).

The ambient air samples were collected with a HVAS. Particulate phase PAHs were collected on a glass fibre filter (GFF) having a diameter of 10.2 cm. The filter was followed by a glass cartridge containing a 5 cm long polyurethane foam (PUF) plug, which was followed by a 2.5 cm thick packing of XAD-2 amberlite resin, and finally by a 2.5 cm long PUF plug to collect the gaseous phase PAHs. This type of cartridge design increases adsorption capacity and minimizes post-collection volatilization problems (Winberry et al., 1988; Odabasi et al., 1999b). Average sampling volume was 246 ± 92 m^3 and average sampling time was 22 ± 11 h (Esen et al. 2006).

Bulk deposition samples were collected with a stainless steel pot whose diameter and depth were 60.5 cm and 19 cm, respectively. Top and side views of the sampler are presented in Fig. 2. The bulk sampler was placed next to the HVAS employed in this study. The height of the building was about 10 m. There was a 20 cm long leading edge around the bulk sampler to minimize air flow disruptions caused by the shape of the collector.

2.2. Extraction and analysis

Glassware was rinsed with deionized (DI) water, methanol (MeOH), hexane (HEX) and acetone (ACE). Then, they were dried at 105 °C for about 4 h in an oven and their openings were wrapped with aluminium foil after they were removed from the oven.

A detailed discussion on sample preparation and analysis can be found elsewhere and a summary is given below (Vardar et al., 2004; Tasdemir and Esen, 2006; Esen et al., 2006). Prior to sampling, GFFs were wrapped loosely with aluminium foil and baked at 450 °C overnight. PUF cartridges and XAD-2 resin were cleaned by Soxhlet extraction with de-ionized water,

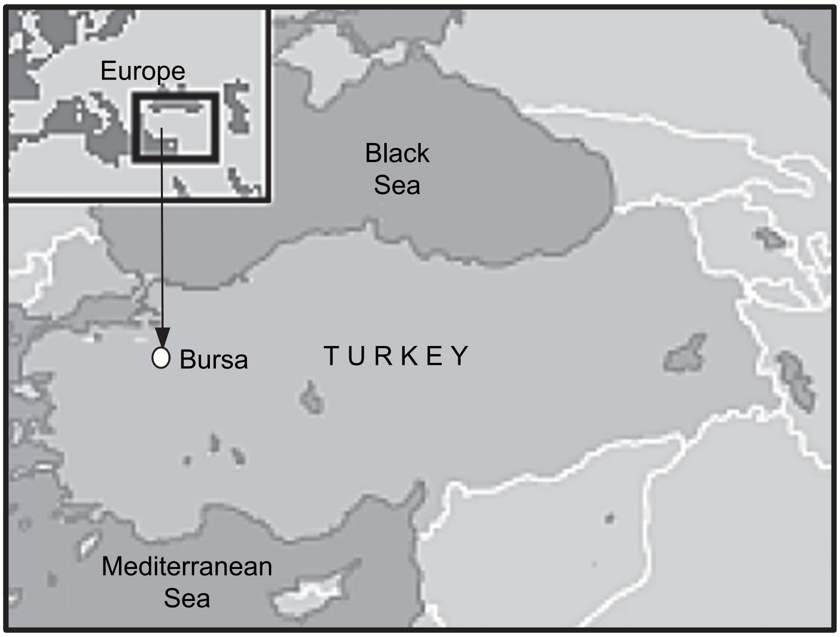

Fig. 1. The location of the sampling site.