

Characterization of polycyclic aromatic hydrocarbon emission from open burning of joss paper

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Abstract

The concentration of polycyclic aromatic hydrocarbons (PAHs) in the ambient air from a massive open burning of joss paper was simultaneously measured at an open-burning site (OS) and a downwind site (DS) from 6 to 8 August 2006. A total of 16 major PAHs (particle-bound and gas-phase) concentrations were extracted by the Soxhlet analytical method and analyzed by gas chromatography. The dominant PAHs of the total mass of the organic compound at both the sampling sites were low-molecular-weight species. Further, the results showed that the start burning/end burning-dominant PAH concentration ratios at the OS and DS were 10 and 6.2, respectively. Diagnostic ratios were also used in this study to characterize and identify the PAH emission sources. The results suggest that the characterization of air pollutants emitted from open-burning joss paper lies between furnace-burning joss paper and wood combustion.

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1. Introduction

Joss paper and incense burning, due to the influence of Buddhism and Taoism, is a common and popular practice among many families and in most temples in Taiwan. During regular ritual practices, which are usually held on the 1 and 15 (or 2 and 16) of the Chinese lunar month, only a small amount of joss paper is burned in temple furnaces. However, a massive open burning of

joss paper is often observed during some of the most important festivals. According to the conclusions of several studies, incense burning is a significant source of particulate matters (PMs) (Fan and Zhang, 2001; Fang et al., 2002), metal elements (Lau and Luk, 2001; Fang et al., 2003) and polycyclic aromatic hydrocarbons (PAHs) (Lin et al., 2002; Lung and Hu, 2003; Fang et al., 2004) in ambient air. Therefore, the impact of massive open burning of joss paper on the ambient air quality is also an important issue to be investigated, particularly for the health concerns of inhabitants in a densely populated area like Taiwan.

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Several epidemiological studies have indicated consistent correlations between the exposure to ambient particulates and adverse health effects such as increased mortality, respiratory or cardiovascular diseases, respiratory symptoms and decreased lung function (Schauer et al., 2002; Zheng et al., 2002; Cincinelli et al., 2003). Dose–response functions for the relationship between PM and adverse health effects were also identified by epidemiological time-series studies (El-Fadel and Massoud, 2000). As for the emission of PAH generated by the burning of joss paper, which is one of the major pollutants affecting the public, previous investigations have revealed that the PAH level in the burned ash of joss paper is very low (Chao et al., 1997); this essentially implies that all the PAHs generated were released into the air. Therefore, the pollution of the ambient air by PAHs generated by joss paper burning requires more attention. Moreover, the emission of air pollutants from the open burning of joss papers has never been investigated. The influence of this activity, particularly its impact on human health, is not regulated by the Taiwan Environmental Protection Administration (EPA).

Previous studies on joss paper burning focused primarily on investigations of indoor/outdoor environments of temples and for the quantification of air pollutants (Yang et al., 2005). However, the emission of air pollutants from joss paper burning are as yet not well characterized, and information on the air pollutants emitted by the open burning of joss paper is unavailable. To the best of the authors' knowledge, air pollutants emitted from massive open burning of joss paper have never been investigated. Consequently, this study is the first attempt to characterize the ambient air PAH concentrations emitted during a massive joss paper open-burning event held at a suburban site. The concentrations of particulates and 16 kinds of PAHs are investigated and characterized during the burning period. The results may provide useful information for public awareness with regard to PAH emissions from the open burning of joss paper.

2. Experimental

2.1. Sampling program

Nantou Township in central Taiwan has a population of 105,356 and a surface area of 71.6021 km². It has a dense concentration of temples, 51 in all. Joss paper during burning

generates a large cloud of smoke that spreads over the surrounding areas and lasts for a few days. On 6 August 2006, a grand ceremony was held by the So-Sing Temple in Nantou Township to celebrate one of the most important festivals in Taiwan, Zhong Yuan Jie. After the celebration, about 1 ton of joss paper was burned openly on open ground near the So-Sing Temple (Fig. 1). Depending on the efficiency of the fire, the sampling was conducted for 1–3 h period (see Section 2.2) from 6 to 8 August 2006, until the concentration of pollutants in the downwind site (DS) was almost equal to that in the open-burning site (OS). The DS was determined by the wind direction relative to the open-burning site, as follows: (1) the wind direction was predominantly westerly in Nantou City during August and (2) before sampling, the wind direction was measured by an anemograph (WatchDog Model 550 weather station) and found to be westerly. Therefore, the downwind site relative to the open-burning site was to the east (Table 1). The open-burning and sampling sites of this study were located alongside an 8-m-wide-road in the open ground (Fig. 1). All the sampling heights were in the range of 1.5–1.8 m above the ground level to simulate a person's breathing zone. Except for one restaurant building, there were no structures around the sampling sites. Therefore, for safety and availability of power supply, the DS was located in the garden of the restaurant opposite the open-burning site. There are no significant industrial emissions around this suburban area but some traffic passes through it. Hence, vehicles are the major source of air pollutants when there is no joss paper burning. The traffic density at the sampling site was approximately 5–10 vehicles per hour during the sampling period. The pollutants sampled in this study included PAHs (gaseous and particulate phases), SO₂, NO_x and CO. The meteorological conditions such as temperature, relative humidity, wind velocity and wind direction were measured by an anemograph (WatchDog Model 550 weather station). The ranges of temperature, relative humidity, wind speed and atmospheric pressure during the open-burning sampling period were 28–37 °C, 24–31%, 0.1–2.9 m s⁻¹ and 1008.9–1009.5 h Pa, respectively (Table 1).

2.2. Open-burning experiments

The open-burning sampling experiments were conducted in the suburban area described previously.

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