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Characterization of fine particle emissions from incense burning

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ABSTRACT

Incense burning is an important indoor source of airborne particles. In this study, the emission factors of $PM_{2.5}$ and its chemical constituents emitted from six different brands of incense sticks were determined. Controlled experiments were conducted to measure the mass concentration of $PM_{2.5}$ and to determine its chemical composition (elemental carbon (EC), organic carbon (OC), metals, and ions). Measurements showed that the emissions vary for different brands of incense sticks, with smokeless incense sticks emitting the least amount. $PM_{2.5}$ emission factors range from 0.4 (smokeless incense stick) to 44.5 mg/g. Results also show that the amount of metals emitted is highly dependent on the quantity of metals present in the incense sticks. In addition, the information obtained from the controlled experiments is used to predict the concentration of $PM_{2.5}$ at incense smoke-influenced microenvironments, such as temples and homes, in order to assess the potential indoor exposure during the course of incense burning. Comparison with indoor air quality guidelines suggests that inhalation of incense smoke can pose adverse health impacts.

1. Introduction

Incense burning, frequently used in religious worship, is an important source of fine particulate matter smaller than 2.5 μm ($PM_{2.5}$) [2]. Emerging evidences pointed to $PM_{2.5}$ being a significant contributor to increased morbidity and mortality [14]. Indeed, indoor air quality investigations in temples have shown that incense smoke particles are hazardous to respiratory health [6]. While comprehensive research is needed to identify the exact causal factors for health effects associated with fine particles, it has been widely acknowledged that the particle size and composition largely determines the extent of health damage caused. Fine particles deposit more efficiently in the lungs and extra-pulmonary organs to react with the biological cells, possibly triggering inflammatory reactions [5]. Furthermore, these small particles have a very large surface area per unit mass, which make them an excellent carrier for harmful inorganic and organic compounds, thus increasing their toxicity.

It is therefore crucial to enhance our understanding of chemical composition of incense smoke particles. Most prior studies have concentrated on measuring polycyclic aromatic hydrocarbons (PAHs) [10,12,3,21], with only handful investigations focusing on other particulate pollutants. Hence, a comprehensive study on the detailed chemical composition of $PM_{2.5}$ emitted from incense burning is necessary.

We had previously investigated the differences in the size distribution of particle number emitted from different brands of incense sticks [16]. In this study, we report the chemical characteristics of $PM_{2.5}$, namely elemental carbon (EC), organic carbon (OC), metals (total and water-soluble), and ions as obtained from controlled experiments involving six different brands of incense sticks and also their corresponding $PM_{2.5}$ emission factors for modeling calculations.

2. Materials and methods

2.1. Experimental design

Six popular brands of incense sticks bought at local stores around Singapore were investigated in this study. All six brands are direct burning incense such that when they are lit by a flame and fanned out, the glowing ember on the incense will continue to smolder and burn away the rest of the incense. These cored sticks are formed by coating a few layers of incense powder, consisting of finely ground fragrant materials and a plant-based binder (usually makko), on a supporting material, made of either thin bamboo or wood. Brand 5 is claimed to be smokeless. Information on the six brands of incense sticks investigated in this study is given in Table 1.

Air sampling was conducted in a chamber of dimensions 1.016 m (width) × 0.660 m (depth) × 1.600 m (height) at

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