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A health risk assessment of Arabian incense (Bakhour) smoke in the United Arab Emirates☆

Sarah Dalibalta *, Yehya Elsayed *, Fareedah Alqtaishat, Ioline Gomes, Nagelle Fernandes

Department of Biology, Chemistry & Environmental Sciences, American University of Sharjah, P.O. Box 26666, Sharjah, United Arab Emirates

HIGHLIGHTS

- We characterized all the chemical components emitted in Arabian incense smoke.
- Emitted smoke contains a significant number of chemical compounds.
- Investigation of compounds in smoke reveals potential carcinogens and toxicants.
- Results suggest health risks from the inhalation of Arabian incense smoke.

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ABSTRACT

Burning Arabian incense (Bakhour) is a common practice in the Middle East and Arabian Gulf. Although the incense generates large amounts of chemicals and air pollutants, little is known with regard to the nature of these chemicals and their potential health risks. The aim of this study is to provide a comprehensive characterization of the chemical constituents emitted in Bakhour smoke, and subsequently to examine the associated health implications of these components. Thermo-gravimetric analysis was used to investigate the presence and the thermal profile of volatile organic compounds in three different samples of Bakhour smoke. Thermal desorption–gas chromatography–mass spectrometry was then applied to isolate all the volatile and semi-volatile compounds present in the Bakhour smoke samples. Using a spectral library and an extensive literature search, all organic compounds detected were analyzed for potential health risks. A total of 859 compounds were emitted from burning the different Bakhour samples. The novel finding of this research shows that 42 detected compounds are suspected/known carcinogens, 20 are known to have toxic effects, and at least 200 compounds are known irritants to the eyes, skin, respiratory and digestive tracts, as reported in human and/or animal studies. Our study suggests that inhaled Bakhour smoke contains a substantial number of adverse compounds, which are known to be detrimental to human health. Moreover, the evidence presented shows that incense burning is a significant source of environmental pollution; with the potential of significant health concerns particularly with long term exposure. As the majority of the compounds detected have no reported clinical data, there is an urgent need for significant research in this field.

1. Introduction

Bakhour is the Arabic name given to scented bricks of wood that are usually burned in charcoal or incense burners to generate a rich fragrance and a thick smoke. The custom of burning incense is an age-old ritual, and has become a common cultural practice, mainly for religious ceremonies, perfuming homes, aromatherapy, and meditation (Hyams, 2004). This practice is particularly popular in the United Arab Emirates (UAE) and many other countries in the Arabian Gulf whereby Bakhour is burned not only in households, but also in public areas such as mosques and shops. A recent study showed that Bakhour incense was being burned on a weekly basis in 94% of Emirati national households in the UAE (Yeatts et al., 2012). This was further supported by another study which argued that Bakhour was one of the most common sources of indoor smoke to which individuals were frequently exposed to in the Arabian Gulf region (Wahab and Mostafa, 2007).

Arabian Bakhour is made up of a wide variety of natural substances, including aromatic woodchips from agar wood (*oud*), herbs, flowers, musk and sandalwood soaked in scented oils (Jetter et al., 2002;

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* Corresponding authors.
E-mail addresses: sdalibalta@aus.edu (S. Dalibalta), yelsayed@aus.edu (Y. Elsayed).

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Wahab and Mostafa, 2007). The incense undergoes a slow burning process with the aid of small charcoal blocks and emits a thick aromatic smoke. This smoke was shown to contain a variety of pollutants such as particulate matters (PM), polycyclic aromatic hydrocarbons (PAHs), carbon monoxide (CO), oxides of nitrogen (NOX) and isoprene (Yeatts et al., 2012; Cohen et al., 2013). Such pollutants can easily accumulate indoors, especially under inadequate ventilating conditions. In addition, most of these compounds were found to be produced in amounts that exceeded emissions from tobacco smoke, partly due to the emissions from the charcoal briquettes (Cohen et al., 2013). Indoor air quality is particularly compromised as the concentrations of indoor pollutants such as PM, NOX, in addition to sulfur dioxide (SO_2), formaldehyde (HCHO) and hydrogen sulfide (H_2S) rise. All of these pollutants have been associated with airway dysfunction, allergies, dermatological effects, asthma and neoplasm (Wahab and Mostafa, 2007; Tse et al., 2011; Chiang and Liao, 2006). A novel study on exposure to indoor air pollution from Asian incense burning also reveals higher risks of cardiovascular mortality (Pan et al., 2014).

Research has shown that particulate matters smaller than 2.5 μm ($PM_{2.5}$) can raise particular concern as air pollutants and as hazards to respiratory health (Hsueh et al., 2012). An assessment on the smoke produced from burning Bakhour in the UAE estimated that the concentration of PM was around 1.35 mg/m^3, hence in the respirable size range, with an emission rate of 5.9 mg/min, which was significantly higher than the emission rate from cigarettes (0.7–0.9 mg/min) (Cohen et al., 2013). This data indicates that PM produced from burning Bakhour can worsen respiratory diseases. *In vitro* studies on *oud* (a component of Bakhour) had shown that elements of the produced smoke lead to an up-regulated inflammatory response in human lung cells, a hallmark of asthma and other respiratory problems (Cohen et al., 2013). A community survey conducted in Oman revealed that burning Bakhour at home triggered wheezing among asthmatic children, although it could not be identified as the cause of asthma (Al-Rawas et al., 2009). Furthermore, animal studies had shown that long term exposure to incense smoke resulted in degenerative alterations to lung tissue and decreased lung weight, as well as adverse changes to the animals' metabolism (AlArifi et al., 2004; Alokail et al., 2011; Qureshi, 2013).

In addition to substantial consequences to the respiratory system, a study conducted in the UAE on 628 homes of Emirati nationals found that the burning of Bakhour on a daily basis was associated with increased headaches, difficulty concentrating and forgetfulness (Yeatts et al., 2012). Although various studies seemed to implicate potential health risks associated with the burning of Arabian Bakhour, a complete profile of the chemical composition of the emitted Bakhour smoke remains unknown. Most of the work previously reported in the literature targeted specific suspected chemical compounds for analysis. Consequently, there appeared to be an urgent need for a complete characterization of the range of compounds that might be present in Bakhour smoke.

The primary objective of this study was thus to investigate the emissions from the burning of Bakhour and to conduct a comprehensive analysis of the compounds present in its smoke. The identification of these compounds would enable us to have a better understanding of the nature of smoke that individuals are frequently exposed to, and its potential impacts on the environment and their health.

2. Materials and methods

Three different commercial Bakhour brands (named B_1, B_2, and B_3) were purchased in Sharjah, UAE. These brands were chosen based on their price and popularity among consumers. B_1 is an expensive brand, B_2 is a more popular but less expensive brand and B_3 is an inexpensive brand relative to the others. Brands B_1 and B_2, due to their cost, were expected to be made of higher quality ingredients than B_3.

2.1. Sampling methods

For each Bakhour sample, 10 g was weighed and placed in a censer. The samples were then burned with a blowtorch instead of charcoal to eliminate interferences from charcoal emissions. An inverted glass funnel was placed above the censer through which the smoke was pumped at a rate of 3 L/min for 15 min. The funnel was connected to a Tenax and carbon sorbent tubes that were placed in sequence. The smoke-sampling machine used was GilAir 5 Personal Air Sampler (Sensidyne, Florida, USA) and all sampling was performed under a fume hood to create a controlled environment. The sorbent tubes were then analyzed with a thermal analyzer (TA) and thermal desorption–gas chromatography–mass spectrometry (TD–GC–MS) (Shimadzu, Japan). The sorbent tubes of carbon and Tenax were conditioned prior to the analysis to obtain a blank and ensure that there was no contamination prior to the experiment.

2.2. Thermo-gravimetric analysis (TGA)

A TGA 4000 Instrument Thermo-Gravimetric Analyzer (Perkin Elmer, USA) was used to collect the thermal profile of the chemical compounds present in the smoke of the three Bakhour samples. For the purpose of this experiment, the Bakhour smoke was sampled on 1 g of BPL activated carbon packed in Teflon tubing. The activated carbon used (OLC 12 × 30 mesh size) was purchased from Calgon Carbon Corporation (Calgon, USA) and is known as a good adsorbent for volatile organic compounds (VOCs). The adsorbent materials were analyzed prior to and following sampling of the smoke from the three Bakhour brands (B_1, B_2, and B_3). Approximately 20 mg of the adsorbent material was used for each TGA measurement. The samples were heated at a rate of 5 °C/min from 30 °C to 500 °C, and the nitrogen flow rate was equivalent to 100 mL/min. Thermo-gravimetric (TG) and differential thermo-gravimetric (DTG) curves were obtained. TG curves provided the percentage weight loss caused by the thermal desorption from the surface as a result of heating, which might also be due to the decomposition of surface functional groups. DTG curves were obtained from TG curves, and the position of the peaks on DTG curves was correlated to the thermal stability of the adsorbed compounds and surface groups. The TG and DTG curves were corrected by the blank adsorbent.

2.3. Thermal desorption–gas chromatography–mass spectrometry (TD–GC–MS)

A QP2010 Ultra thermal desorption–gas chromatography–mass spectrometry (TD–GC–MS) (Shimadzu, Japan) was used to identify the volatile and semi-volatile organic compounds present in Bakhour smoke. Split injection mode of 30:1 was used with an injection temperature equivalent to 280 °C. The initial temperature of the oven was maintained at 40 °C for 3 min, and then increased at a rate of 5 °C/min to 300 °C where it was held constant for 15 min. The column flow was set at 41.6 ml/min. A 30-meter Rtx-5MS column (cross bond 100% dimethyl polysiloxane) (Restek, USA) was used. The gas chromatography–mass spectrometry (GC–MS) spectrums for the pure activated carbon and Tenax adsorbents tubes were obtained and used as a blank. As for the samples, three runs of analysis were conducted on each sorbent tube to ensure that all the compounds trapped were detected. The mass spectrum for each peak was processed separately to reduce background interferences and minimize any overlap between peaks. National Institute of Standards and Technology (NIST) and Wiley mass spectral libraries were used to identify the organic compounds.