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Chemical analysis and potential health risks of hookah charcoal

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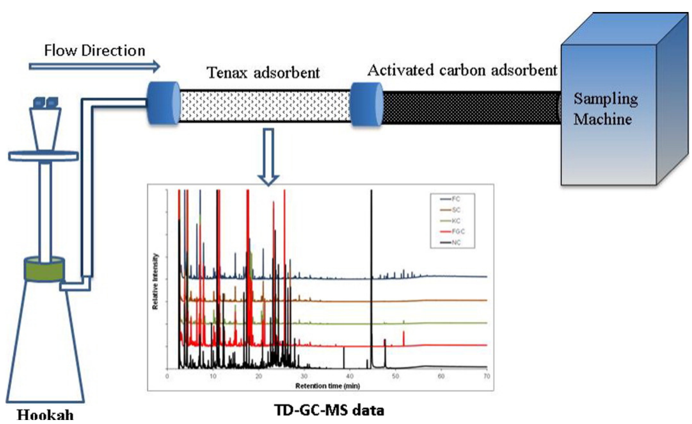
HIGHLIGHTS

- Hookah charcoals, mainly synthetic brands, contains trace/heavy metals in concentrations exceeding those in cigarettes.
- The concentration of lead in synthetic charcoal briquettes may impose adverse effects on human health.
- The amount of nitrogen in synthetic charcoal is comparable to that reported in cigarettes.
- Chemical profiling of smoke emitted from hookah charcoal reveals many compounds associated with potential health risks.

GRAPHICAL ABSTRACT



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ABSTRACT

Hookah (waterpipe) smoking is a very common practice that has spread globally. There is growing evidence on the hazardous consequences of smoking hookah, with studies indicating that its harmful effects are comparable to cigarette smoking if not worse. Charcoal is commonly used as a heating source for hookah smoke. Although charcoal briquettes are thought to be one of the major contributors to toxicity, their composition and impact on the smoke generated remains largely unidentified. This study aims to analyze the elemental composition of five different raw synthetic and natural charcoals by using Carbon-Hydrogen-Nitrogen (CHN) analysis, inductively coupled plasma (ICP), and scanning electron microscopy coupled with energy dispersive X-Ray spectrometry (SEM-EDS). Elemental analysis showed that the raw charcoals contain heavy metals such as zinc, iron, cadmium, vanadium, aluminum, lead, chromium, manganese and cobalt at concentrations similar, if not higher than, cigarettes. In addition, thermal desorption-gas chromatography–mass spectrometry (TD-GC–MS) was used to analyze the chemical composition of the smoke produced from burning the charcoal samples. The smoke emitted from charcoal was found to be the source of numerous compounds which could be hazardous to health. A total of seven carcinogens, 39 central nervous system depressants and 31 respiratory irritants were identified.

1. Introduction

Hookah, a popular form of tobacco smoking, came into existence about four centuries ago where it was commonly used by people in Asia and Africa (Goodman, 1993; Shihadeh, 2003; World Health

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Organization, 2005). Other common names for hookah are waterpipe, shisha, hubble-bubble, nargileh and argileh (Chaaya et al., 2004; Maziak et al., 2004; Mohammad et al., 2008). Hookah is normally composed of a hose attached to a vase that contains water. The tobacco, known as mouassal which is generally flavored tobacco, is placed inside a head piece that is usually heated using charcoal, resulting in the formation of smoke upon puffing (Martinasek et al., 2011; Maziak et al., 2004).

There are some similarities between the chemical composition of the smoke produced from hookah and cigarettes. Both are known to contain substances such as nicotine, tar, carbon monoxide and deleterious gases such as volatile aldehydes, ultrafine particles, and polycyclic aromatic hydrocarbons (PAHs) (Cobb et al., 2011; Eissenberg and Shihadeh, 2009; Jacob et al., 2011; Monn et al., 2007; Monzer et al., 2008; Rivero et al., 2006; Sepetdjian et al., 2010; Shihadeh, 2003; Sivaramakrishnan, 2001; World Health Organization, 2015). In fact, a single hookah session was shown to yield higher concentrations of carbon monoxide and nicotine as compared to a single cigarette (Eissenberg and Shihadeh, 2009; Jacob et al., 2011). A single hookah session was also reported to contain 20 times the amounts of PAHs as compared to cigarettes (Eissenberg and Shihadeh, 2009; Sepetdjian et al., 2008). A study conducted by Monzer et al. (2008) revealed that 90% of carbon monoxide and 95% of PAHs emitted were due to the combustion of charcoal. Similar results were obtained by Sepetdjian et al. (2010), who concluded that charcoal contains carcinogenic PAHs in significant amounts even before lighting.

Commercial charcoal briquettes used in hookah are made from a variety of raw materials and through diverse chemical processes; hence, are likely to vary in their chemical composition (Kabir et al., 2010; Sepetdjian et al., 2010). They are expected to contain trace metals such as zinc (Zn), iron (Fe), cadmium (Cd), vanadium (V), cupper (Cu), aluminum (Al), lead (Pb), chromium (Cr), arsenic (As), mercury (Hg), manganese (Mn) and cobalt (Co) (Kabir et al., 2011; Liu et al., 2008). It was shown that Fe, Zn and Pb were emitted in higher concentrations in charcoal smoke when compared to cigarettes (Kabir et al., 2011).

Many studies investigated the relationship between the chemical composition of smoke produced from hookah and the subsequent health effects (Eissenberg and Shihadeh, 2009; Monzer et al., 2008; Saleh and Shihadeh, 2008; Shihadeh, 2003; Shihadeh et al., 2015). Volatile organic compounds (VOCs) and PAHs in hookah smoke have been associated with respiratory tract irritation, headaches, nausea, liver and kidney damage and central nervous system depression (Kabir et al., 2010). High carbon monoxide levels arising from charcoal combustion are known to impair oxygen delivery to tissues and clinically presents in nonspecific neurologic symptoms (La Fauci et al., 2012). Toxicities associated with smoking hookah have been correlated with damaging effects on cardiovascular function, heart rate and blood pressure as well as detrimental effects on respiratory system function (El-Zaatari et al., 2015). Hookah smoke has also been implicated in cancer development (Aslam et al., 2014, El-Zaatari et al., 2015).

Charcoal is therefore an essential component in hookah and its contribution to the overall negative impact of hookah on health requires further studying. The differences in the raw materials of commercial charcoal briquettes may also impose varying effects (Al Rashidi et al., 2008; Monzer et al., 2008; Sepetdjian et al., 2010; Shihadeh, 2003). The objectives of this study are therefore to analyze the elemental content of raw charcoal by using carbon, hydrogen and nitrogen (CHN) elemental analysis and inductively coupled plasma (ICP) techniques. This study will also characterize the smoke generated from different brands of charcoal using thermal desorption-gas chromatography–mass spectrometry (TD-GC–MS). Lastly, possible health effects associated with the identified chemical compounds in charcoal smoke will be evaluated.

2. Materials and methods

Five charcoal samples of different brands or characteristics were used for the purpose of this study. These were chosen based on popularity. Four synthetic charcoal samples were purchased from hookah shops in Sharjah and were labelled FGC, FC, SC and KC. A natural charcoal sample of wood origin was also used for comparison and was labelled as NC. Natural charcoal is made of carbonized wood whilst synthetic charcoal is usually made of processed charcoal, of wood or coconut origin, where the processing may include grinding into powder and adding chemicals to enhance the adhesion between the powder particles and fuel to initiate the burning. It is noteworthy to mention that our chemical characterization only describes the specific charcoal batches analyzed where variations may be expected within different batches of the same brand.

2.1. CHN elemental analysis

Total carbon, hydrogen and nitrogen contents in each of the raw charcoal samples were determined using EA 3000 CHN analyzer (EuroVector, Europe) (Elsayed et al., 2014). Three replicates of each of the raw charcoal samples were analyzed.

2.2. Ash content

Three 1.0 g replicates of each of the raw charcoal samples were ashed. The samples were weighed in separate ceramic crucibles and ashed inside a furnace (Barnstead/Thermolyne Type 6000, USA) at 575 °C for 6 h (Elsayed et al., 2014). The mass of the remaining ash was weighed after cooling in a desiccator.

2.3. SEM-EDS analysis

A film of each of the raw charcoal samples was prepared on carbon film and analyzed using a scanning electron microscope (SEM, Oxford Instruments, UK) equipped with an energy dispersive X-ray spectrophotometer (EDS, Tescan Vega, Czech Republic). SEM images were obtained for each of the samples. The percent compositions of elements present on the surface of the charcoal films were determined (Elsayed et al., 2014). Three replicates of each of the raw charcoal samples were analyzed.

2.4. Microwave-assisted acid digestion and ICP analysis

Microwave acid digestion for three samples of each raw charcoal brand was conducted where 0.25 g of each of the charcoal samples was extracted using HNO_3 (9 ml) and HCl (3 ml). Multi-wave 3000 Solv microwave digester (Anton Paar, Austria) was heated to 175 °C for 10 min and kept at this temperature for 5 min. This procedure was carried out at 1000 W ramped at the rate of 10 W/min. After digestion, solutions were filtered through a 0.45 um syringe filters and samples were transferred into 50 ml volumetric flasks where the final volume was adjusted with ultra-pure water.

ICP coupled with optical emission spectrometry (OES) was used for the determination of trace metal contents in the solutions using a Liberty AX Sequential ICP-OES instrument (Varian, Australia). The heavy metals analyzed were Zn, Fe, Cd, V, Cu, Al, Pb, Cr and Mn. The selection was made on the basis of their toxicity and health risks. A multi-element stock solution, Fluka Analytical (Sigma Aldrich Chemie GmbH, Switzerland), was used for the preparation of standard solutions. Three replicates for each sample were analyzed.

2.5. Sampling of charcoal smoke and TD-GC–MS qualitative analysis

The design of the charcoal smoke sampling process is shown in Fig. 1. Prior to charcoal smoke sampling, all parts of the sampling apparatus were cleaned using methanol followed by deionized water and oven drying. A sheet of aluminum foil was wrapped around the hookah headpiece. A hand-held hole-puncher was used to perforate the aluminum sheet and ensure constant air flow through the hookah setup. For each sampling setup, two discs of charcoal were placed on top of the