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Composition of carbohydrates, surfactants, major elements and anions in $PM_{2.5}$ during the 2013 Southeast Asia high pollution episode in Malaysia

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ABSTRACT

Haze episodes have become a major concern in Malaysia over the past few decades and have an increasingly important impact on the country each and every year. During haze episodes from biomass burning in Southeast Asia, particularly from Sumatra, Indonesia, particulate matter $PM_{2.5}$ is found to be one of the dangerous sources of airborne pollution and is known to seriously affect human health. This study determines the composition of carbohydrates (as levoglucosan), surfactants, major elements, and anions in $PM_{2.5}$ during a 2013 haze episode. $PM_{2.5}$ samples were collected from Universiti Kebangsaan Malaysia, Bangi, using a high volume sampler during a seven-day monitoring campaign during the peak of that year's haze episode. $PM_{2.5}$ concentrations ranged between 14.52 and 160.93 $\mu g/m^3$, exceeding the 2005 WHO air quality guidelines for $PM_{2.5}$ (25 $\mu g/m^3$ for 24-h mean). The patterns for levoglucosan, surfactants, major elements, and anionic compositions were proportional to the $PM_{2.5}$ concentrations. Changes in $PM_{2.5}$ observed on days 3 and 4 were influenced by a combination of meteorological factors, which substantiate the theory that such factors play a pivotal role in haze episodes.

Introduction

Haze episodes caused by biomass burning have become a serious issue in Malaysia over the past three decades. Anthropogenic sources, such as biomass burning and agricultural land clearing, have been determined as the main sources of these episodes (Abas, Oros, & Simoneit, 2004a, 2004b; Engling, He, Betha, & Balasubramanian, 2014; Norela, Saidah, & Mahmud, 2013). The episodes mainly occur when there is a high aerosol content in the atmosphere together with the formation of secondary aerosols that are affected by meteorological conditions (Geng, Ryu, Maskey, Jung, & Ro, 2011; Husain, Ghauri, Yang, Khan, & Rattigan, 2004; Sun, Zhuang, Tang, Wang, & An, 2006; Watson, 2002). Episodes of regional haze are problematic, because they extend across political borders. Thus, a forest fire and severe drought episode in Southeast Asia, as reported by Sun, Hong, and Wold (2010) and Mott et al. (2005), could cause problems with air pollution not only in Malaysia but also in Singapore, Brunei, the Philippines, and Thailand.

Malaysia is a tropical country which experiences uniform temperature and high humidity. However, wind flow patterns change according to various monsoons, i.e., the northeast and southwest monsoons (Malaysian Meteorological Department, 2008). Meteorological factors, such as temperature, relative humidity, rainfall, and wind direction have all been found to influence haze episodes. Haze events in Malaysia and other Southeast Asian countries usually occur during the southwest monsoon (June to September) because of the dry season (Amil, Latif, Khan, & Mohamad, 2016; Ee-Ling, Mustaffa, Amil, Khan, & Latif, 2015; Khan et al., 2016). According to Hyer and Chew (2010), during dry seasons, fires can

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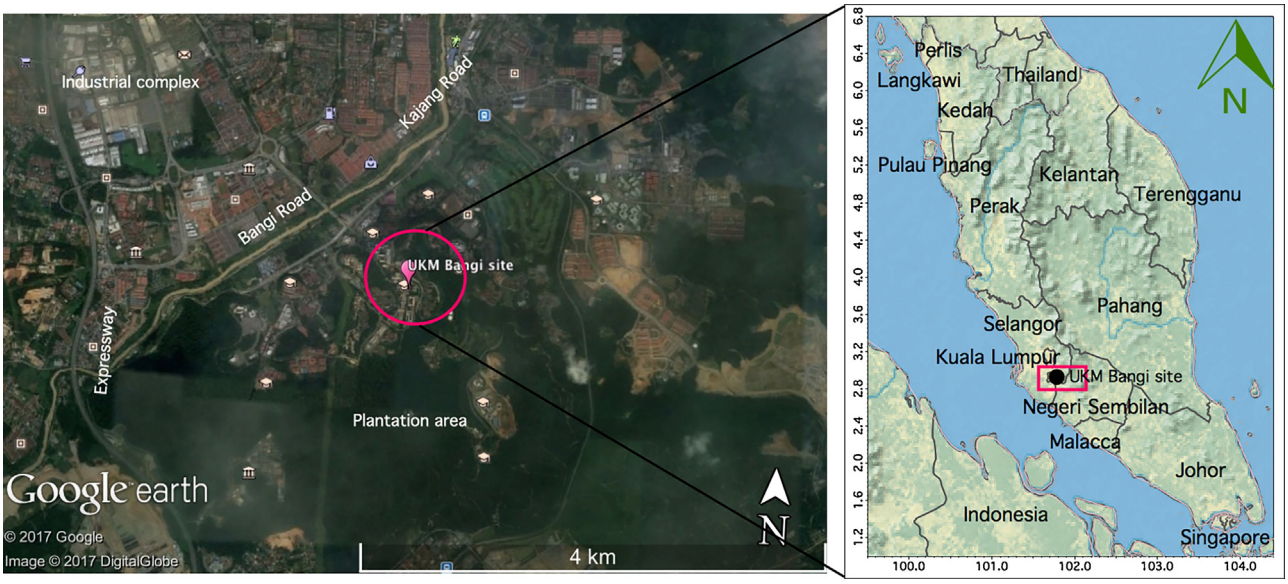

Fig. 1. Sampling location for $PM_{2.5}$.

be accidentally or intentionally started in forests and other vegetation areas, specifically in Sumatra and Kalimantan, which are two provinces in the neighboring country of Indonesia. In 1997, haze in Malaysia resulted from forest vegetation being cleared in Indonesia and consequent biomass burning products being transported over Malaysia by a southwesterly wind flow (Abas et al., 2004a, 2004b).

Biomass burning has been identified as a major source of fine suspended particulate matter ($PM_{2.5}$) (Aouizerats, Van Der Werf, Balasubramanian, & Betha, 2015; Blake, Hinwood, & Horwitz, 2009; Goldammer, Statheropoulos, & Andreae, 2008; Xu, Tai, Betha, He, & Balasubramanian, 2014). $PM_{2.5}$ can be suspended in the atmosphere for a period of several days and spread several thousand kilometers away from its source (Akagi et al., 2012; Behera et al., 2015; Warneke et al., 2009). Dispersion of $PM_{2.5}$ from biomass emissions is the dominant cause of haze episodes, which may reduce visibility and absorb radiation (Abas et al., 2004a, 2004b; Heil, Langmann, & Aldrian, 2007; McMeeking et al., 2006). Furthermore, among the major effects of haze are public health issues involving the respiratory system, namely, infections, asthma, and conjunctivitis (Akagi et al., 2012; Awang et al., 2000; Du et al., 2011; Heil et al., 2007; Rappold et al., 2011; Sahani et al., 2014). It has been reported that during haze episodes, residents in communities exposed to haze have experienced a substantial increase in short-term cardiorespiratory hospitalizations (Mott et al., 2005).

The composition of $PM_{2.5}$ during haze episode can indicate sources and impacts of that matter on both the environment and human health. Using compositions of $PM_{2.5}$, the full range of its potential sources can be identified. The toxicity of each element exposed to populations can be also used to assess human health (Amil et al., 2016; Khan et al., 2016). Levoglucosan is a specific and general indicator of biomass emissions in fine particulate matter samples (Latif et al., 2012; Simoneit et al., 1999). A study by Hoffmann, Tilgner, Iinuma, and Herrmann (2010), showed that the degradation of levoglucosan, especially in humid environments and acidic conditions, make it an effective source marker for biomass burning activities, owing to its high abundance in smoke-impacted aerosol. Being stable in the atmosphere, with no decay over 8 h exposure to sunlight (Latif et al., 2012; Puxbaum et al., 2007), levoglucosan makes a suitable molecular marker of biomass burning. Furthermore, studies of surface active agents (surfactants), an organic pollutant, have found very high concentrations during haze episodes. This may influence the solubility of materials in the atmosphere (Brimblecombe & Latif, 2004; Hanif et al., 2009; Wahid, Latif, & Suratman, 2013) and, at high concentrations, surfactants may also affect the human respiratory system (Zimmer, Baron, & Biswas, 2002). Surfactants in the atmosphere can generate more cloud water because of the reduction of surface tension in a droplet. They can behave like cloud condensation nuclei, which may influence the climate system (Ellison, Tuck, & Vaida, 1999; Latif, Anuwar, Srithawirat, Razak, & Ramli, 2011; Tabazadeh, 2005). Major elements and anions in ambient air are important indicators of various sources of particulate matter during haze episodes. According to Sunder Raman, Hopke, and Holsen (2008), particulate matter usually consists of several elements (Si, Al, Ca, Fe, Ti, V, Cr, Ni, Cu, Zn, Pb) and inorganic ions (SO_4^{2-}, NO_3^-, Na^+, NH_4^+, K^+), which may originate from a variety of sources related to anthropogenic activities.

Given the above issues, this paper presents the compositions of levoglucosan and surfactants in $PM_{2.5}$ during their peak in haze episodes in 2013. It was determined that $PM_{2.5}$ should be monitored because it is believed to pose one of the greatest health risks, because it lodges directly in into the lungs. Our study also addressed selected major elements (Ca, Mg, K, and Na), anions (F^-, Cl^-, NO_3^-, SO_4^{2-}, and PO_4^{3-}), and the influence of meteorological factors on the composition of $PM_{2.5}$. Because studies of $PM_{2.5}$ compositions during haze episodes in Southeast Asia are very limited, this research should be useful for the scientific record and may increase public awareness of haze, especially on its effect on human health and atmospheric visibility, particularly in tropical countries.

Materials and methods

Sampling location

Bangi is a suburban area about 23 km south of the city center of Malaysia's capital, Kuala Lumpur. Since the 1970s, it has grown to become a suburban area, including both residential and industrial areas. In the present study, the sampling station was atop the Biology Building at the Universiti Kebangsaan Malaysia, Bangi Campus (2°55.47′N, 101°46.39′E). This four-story building is about 20 m above ground level and was constructed in 1977. It is near to the campus's main road. Fig. 1 shows the exact sampling location.

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