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Characteristics of carbonaceous aerosols emitted from peatland fire in Riau, Sumatra, Indonesia

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HIGHLIGHTS

- $PM_{2.5}$ aerosols emitted from peatland fire in Indonesia were characterized.
- $PM_{2.5}$ aerosols emitted from peatland fire were primarily composed of OC.
- We found some source indicators that were inherent in peatland fire.

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ABSTRACT

Biomass burning is a significant source of fine particulate matter ($PM_{2.5}$). Forest, bush, and peat fires in Kalimantan and Sumatra, Indonesia are major sources of transboundary haze pollution in Southeast Asia. However, limited data exist regarding the chemical characteristics of aerosols at sources. We conducted intensive field studies in Riau Province, Sumatra, Indonesia, during the peatland fire and non-burning seasons in 2012. We characterized $PM_{2.5}$ carbonaceous aerosols emitted from peatland fire based on ground-based source-dominated sampling. $PM_{2.5}$ aerosols were collected with two mini-volume samplers using Teflon and quartz fiber filters. Background aerosols were also sampled during the transition period between the non-burning and fire seasons. We analyzed the carbonaceous content (organic carbon (OC) and elemental carbon (EC)) by a thermal optical reflectance utilizing the IMPROVE_A protocol and the major organic components of the aerosols by a gas chromatography/mass spectrometry. $PM_{2.5}$ aerosols emitted from peatland fire were observed in high concentrations of 7120 ± 3620 μg m^{-3} and were primarily composed of OC (71.0 ± 5.11% of $PM_{2.5}$ mass). Levoglucosan exhibited the highest total ion current and was present at concentrations of 464 ± 183 μg m^{-3}. The OC/EC ratios (36.4 ± 9.08), abundances of eight thermally-derived carbon fractions, OC/Levoglucosan ratios (10.6 ± 1.96), and Levoglucosan/Mannosan ratios (10.6 ± 2.03) represent a signature profile that is inherent in peatland fire. These data will be useful in identifying contributions from single or multiple species in atmospheric aerosol samples collected from peatland fires.

1. Introduction

Peatland is organic soil that has formed for over thousands of years from decomposed vegetation and other life forms, and peat deposits can extend up to 7 m in thickness (Wulandari, 2002). In Southeast Asia, smoke originating from peatland fires in Kalimantan and Sumatra in Indonesia is a major cause of transboundary haze pollution.

In general, approximately 80–90% of the smoke particles produced by biomass burning is in the $PM_{2.5}$ size range, and these particles are primarily composed of organic carbon, which constitutes 50–60% of the total particle mass (Phuleria et al., 2005; Reid et al., 2005). $PM_{2.5}$ aerosols present a high risk of deposition in the alveoli of lungs and are associated with a greater general health risk than coarse aerosols (Federal Register, 2006; Lippmann, 1998).

According to version 3 of the Global Fire Emissions Database (GFED), average $PM_{2.5}$ emissions from fire (including deforestation, savanna, forest, agricultural waste, and peat fires) from 1997 to 2010 in Indonesia are 2.9 Tg $year^{-1}$, accounting for 9.2% of global fire $PM_{2.5}$ emissions and 62% of Southeast Asian fire emissions. In

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Indonesia, peatland fire is a dominant source of $PM_{2.5}$ emissions, accounting for 55% of all fire sources. Thus, it is a significant emission source of $PM_{2.5}$ aerosols in Indonesia.

Many peatland fires occur on Sumatra and Kalimantan islands during the dry season, emitting gases and smoke aerosols that cause atmospheric pollution (haze) and adversely affect the health of people living in surrounding areas. For example, an unprecedented Indonesian fire episode occurred in 1997–1998 due to the El Niño–Southern Oscillation (ENSO) event at that time. Extensive forest fires, including peatland fires, resulted in the development of a smog blanket that covered an immense area of 4 million km^2 in Southeast Asia. This smog affected the livelihoods and health of 75 million people in six countries and completely toppled their lives. Moreover, the smog resulted in the closure of airports; it was cited as the possible cause of an air crash near Medan, Sumatra, and a tanker collision in the Straits of Malacca (Stolle and Tomich, 1999). Air pollution attained previously unknown levels in East Kalimantan, Singapore, and Kuala Lumpur, with daily average particulate matter reaching extremely hazardous levels (4000 μg m^{-3}; Heil et al., 1998). Although ENSO events considerably contribute to the occurrence of Indonesian fires, pollution from smoke haze is a recurrent problem in Indonesia and neighboring countries, even in non-ENSO years (Tacconi, 2003).

Riau Province in Sumatra is one of the primary hotspots for peatland fire during the dry season, and the smoke aerosols generated there cause haze in Riau and in neighboring countries such as Malaysia and Singapore (Harahap, 2012; Hong, 2012). However, limited data exist regarding the chemical characteristics of these smoke aerosols (Othman and Latif, 2013; See et al., 2007) and the effects of aerosols from peatland fires on the atmospheric environment and human health. To investigate these effects, the chemical characterization of fresh smoke aerosols from peatland fire is necessary. In this study, the carbonaceous species of $PM_{2.5}$ aerosols emitted from peatland fire were characterized by directly sampling $PM_{2.5}$ aerosols at fire hotspots in Riau Province. Moreover, we determined source indicators of carbonaceous species of smoke from peatland fires for source apportionment. These data can help in identifying single or multiple species in atmospheric aerosol samples that contribute to peatland fires.

2. Materials and methods

2.1. Sampling locations

The sampling locations in this study are illustrated in Fig. 1. The burning site and background site were located at Sepahat Village and Sukajadi Village, respectively, in Bengkalis Regency, Riau Province. The burning site was surrounded by peatland and forest, and the background site was located ~50 km away from the burning site and housing estates. Bengkalis Regency lies on the east coast of Sumatra Island and consists of several islands. This district covers an area of 1,204,423 km^2, in which nearly 85% of the land exhibits low topography and is covered with tropical forests, with an average elevation of only 2.0–6.1 m above sea level. Most of the soils are organosols or peat soils; that is, they contain abundant organic substances. The temperature in a Bengkalis is strongly influenced by the tropical marine climate and is typically 26–32 °C. The rainy season generally lasts from September to January, with an average rainfall of 809–4078 mm $year^{-1}$, and the dry season usually spans February to August. Fig. 2 illustrates monthly hotspot counts in Riau in 2011 and 2012 based on Indofire datasets, confirming that many hotspots are detected in the area during the dry season.

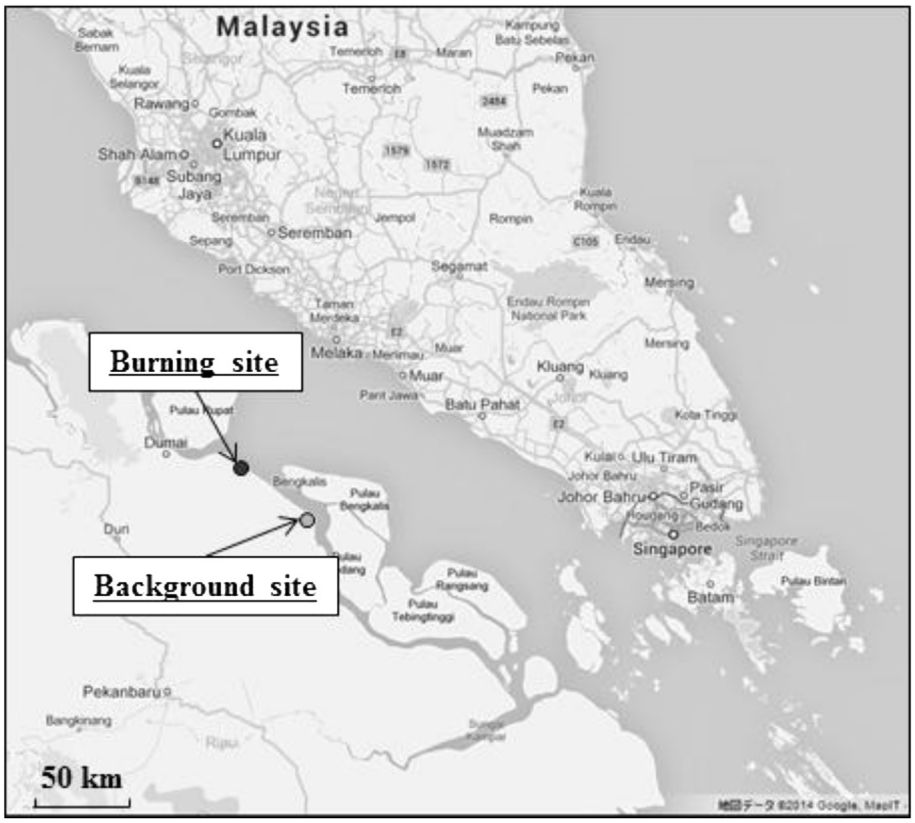

Fig. 1. Map of Bengkalis showing the sampling sites.