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A case-crossover analysis of forest fire haze events and mortality in Malaysia

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HIGHLIGHTS

- We modelled association of haze events and daily mortality using a case-crossover study design.
- Days with daily PM_{10} > 100 μg/m^3 were defined as haze events.
- Haze events were significantly associated with natural and respiratory mortality at various lags.
- Immediate effects of haze were particularly seen among males.
- Children and adult females mortalities were associated with delayed effects.

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ABSTRACT

The Southeast Asian (SEA) haze events due to forest fires are recurrent and affect Malaysia, particularly the Klang Valley region. The aim of this study is to examine the risk of haze days due to biomass burning in Southeast Asia on daily mortality in the Klang Valley region between 2000 and 2007. We used a case-crossover study design to model the effect of haze based on PM_{10} concentration to the daily mortality. The time-stratified control sampling approach was used, adjusted for particulate matter (PM_{10}) concentrations, time trends and meteorological influences. Based on time series analysis of PM_{10} and backward trajectory analysis, haze days were defined when daily PM_{10} concentration exceeded 100 μg/m^3. The results showed a total of 88 haze days were identified in the Klang Valley region during the study period. A total of 126,822 cases of death were recorded for natural mortality where respiratory mortality represented 8.56% (N = 10,854). Haze events were found to be significantly associated with natural and respiratory mortality at various lags. For natural mortality, haze events at lagged 2 showed significant association with children less than 14 years old (Odd Ratio (OR) = 1.41; 95% Confidence Interval (CI) = 1.01–1.99). Respiratory mortality was significantly associated with haze events for all ages at lagged 0 (OR = 1.19; 95% CI = 1.02–1.40). Age-and-gender-specific analysis showed an incremental risk of respiratory mortality among all males and elderly males above 60 years old at lagged 0 (OR = 1.34; 95% CI = 1.09–1.64 and OR = 1.41; 95% CI = 1.09–1.84 respectively). Adult females aged 15–59 years old were

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found to be at highest risk of respiratory mortality at lagged 5 (OR = 1.66; 95% CI = 1.03–1.99). This study clearly indicates that exposure to haze events showed immediate and delayed effects on mortality.

1. Introduction

A widespread series of biomass burning from the forest fires particularly in Sumatra and Kalimantan, Indonesia caused a thick, smoky haze over a large portion of Southeast Asia, especially Indonesia, Malaysia, Singapore, Brunei and Southern Thailand (Mahmud, 2008; Pentamwa and Oanh, 2008; Permadi and Kim Oanh, 2013; Sastry, 2002). These Southeast Asian haze or air pollution episodes have become a recurring phenomenon since the 1980s, the worst one being in 1997 (Abas et al., 2004a; Afroz et al., 2003). A significant amount of particulate matter (Wei et al., 1999) from this biomass burning was transported by south-westerly winds (between June and September) to Malaysia. Heavy loads of vehicular emissions and biomass burning activities, both at a local or trans-boundary level, have in turn led to serious prolonged haze events being recorded on the Malaysian Peninsula and at Sabah and Sarawak (Abas et al., 2004b; Afroz et al., 2003).

During haze days in Southeast Asia, the concentration of particulate matter pollutants smaller than 10 microns (PM_{10}), carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone (O_3) was found to be significantly higher when compared to non-haze day concentrations (Afroz et al., 2003; Mahmud, 2008). According to the Malaysian Department of the Environment (DOE, 1997), the predominant air pollutant parameter during the worst haze episode in Southeast Asia in 1997 was PM_{10}. A haze study in Riau, Indonesia by Anwar et al. (2010) also showed a higher concentration of PM_{10} and O_3 at all stations during hazy days in 2006 compared to non-haze days. The amount of particulate matter during haze episode was dominated by organic carbon, NO_3^-, and SO_4^{2-}. Seasonal and weather conditions also played an important role in exacerbating the distribution of air pollutants during hazy condition (Dominick et al., 2012; Norela et al., 2007; Samoli et al., 2008). Source apportionment by chemical mass balance receptor modelling indicates that air pollutants can travel long distances and significantly affect the air of the downwind area (See et al., 2007).

Numerous studies have documented the acute effects of air pollution on morbidity and mortality (Lee and Schwartz, 1999; Mar et al., 2000; Schwartz, 2004; Wan Mahiyuddin et al., 2013; Yang et al., 2005). Respiratory diseases, for example, have often been linked to air pollution episodes (Aditama, 2000; Moore et al., 2006), Asian Dust Storm (ADS) (Chan and Ng, 2011; Chen et al., 2004; Lee et al., 2007, 2011), London smog, Saharan dust (Hunt et al., 2003; Mallone et al., 2011) and Southeast Asian (SEA) forest fires (Afroz et al., 2003). Recurring episodes of forest fires have become an issue of great concern due to the severe effect that they have on human health. The public health impacts from forest fire smoke were studied in association with daily $PM_{2.5}$ and the dispensation of medication and most notably had a positive association with salbutamol dispensations during days of extreme and intensified forest fire (Elliott et al., 2013). Near public places, forest fires are a particularly serious and troubling problem due to their immediate effect on mortality (Analitis et al., 2012). Emmanuel (2000) estimated that there was a 30% increase in outpatient attendance for haze-related conditions arising from forest fires, demonstrating that there should be far more concern for public health and welfare. Dennekamp and Abramson (2011) found an association between respiratory morbidity and exposure to bushfire smoke consistent with urban air pollution. Moreover, there was an association between exposure to wildfire smoke in Southern California and increased eye and respiratory symptoms, medication usage, physician visits along with visits to the emergency department (Duclos et al., 1990; Künzli et al., 2006). In Southeast Asia, the effects of the 1997 haze episode on daily natural mortality in Kuala Lumpur showed an increase in mortality among 65–74 year-old residents (Sastry, 2002). Restricted activity days during this specific haze episode also contributed to about 79.3% of the total health damage costs, while asthma attacks contributed to approximately 10.7% (Nasir et al., 2000).

The aim of this study is to adopt a case-crossover study design so as to estimate the risk of haze days on daily mortality in the Klang Valley region, which is currently the most populated urban area in Malaysia. This study will indicate the influence of haze episode from biomass burning to the human health in the Klang Valley and focus on the time period 2000 to 2007.

2. Material and methods

2.1. Study location

The Klang Valley region has been chosen as the study area for this research. The data for health and air quality were available within this area. The Klang Valley is among the most affected area during haze episode because of its location in the west coast of Peninsular Malaysia and facing the area affected by biomass burning in Sumatra, Indonesia. During the 1997 haze episode, the Klang Valley became one of the worst hit areas in Malaysia. This terrible Southeast Asian trans-boundary haze was a result of widespread forest fires in Kalimantan and Sumatra, which were in effect triggered by extremely dry weather brought about by the El Niño phenomenon (Brauer and Hisham-Hashim, 1998).

The Klang Valley region covers an area of 2832 km^2 encompasses Kuala Lumpur in the centre; the towns of Petaling Jaya, Shah Alam and Klang to the west; the town of Kuala Selangor to the northwest; the township of Gombak to the north; and the district of Hulu Langat including the town of Kajang to the south. The Klang Valley is the most developed region in Malaysia and is more prone to air pollution because of its geographical setting, development of large scale industrial and commercial activities, densely populated areas and also high vehicular traffic. Weak prevailing winds create a stable atmospheric condition which causes the pollutants to stagnate or accumulate in the air (Azmi et al., 2010).

2.2. Mortality and environmental data

The daily mortality data for the Klang Valley region from 1st January 2000 to 31st December 2007 was obtained from the Department of Statistics, Malaysia. Each mortality case consists of demographic information, including: date of death, disease diagnosis with International Classification of Disease 10th Revision (ICD10), area of residence, age and gender. In this study, mortalities from all natural causes, excluding those from accidental causes, acute and poisoning, homicide and suicide (ICD10; A00–A99) along with mortalities resulting from respiratory diseases (ICD10; J00–J99) were analysed. Both sets of mortalities were scrutinized as a total mortality, by age groups ($\leq$14 years; 15–59 years and $\geq$60 years), by gender and then combinations of age groups and gender.