

Conference Paper

Particulate Matter and Subjective Respiratory Health Effect Measurements in Palembang during Forest Fire Episode in October 2015

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Abstract

Particulate matter is a mixture of solid particles and liquid droplets that can gather in the atmosphere. Wild land fires are uncontrollable land fires that consume combustible plants and emit significant amounts of carbon dioxide, methane, non-methane volatile organic compounds, nitrogen oxides, and particulates. This research was conducted to measure the fine particulate matter (PM_{2.5}) pollution during October 2015 that was caused by a September forest fire in Palembang, one of the cities most affected by wildfires in Indonesia. Sampling was based on the United States Environmental Protection Agency (US EPA) IP 10-A Method updated by SKC Ltd and was conducted every day for a week for six hours each day, divided into morning and evening sequences. Coarse and fine particles were filtered using a Sioutas Impactor and a Leland Legacy personal pump with a flow rate of 9 L/min. Quartz fiber filters were placed in every stage of the impactor to collect the particles. Particulate matter (PM) concentration was measured using the gravimetric method. The weighing was done using a Mettler Toledo MX5 microbalance. Questionnaires were used to gather information on health problems from 63 adults and 54 children from Palembang. The mean concentrations of coarse and fine particulate matter (PM₁₀ and PM_{2.5}) in Palembang during the measurement periods were determined to be 818.78 µg/m³ and 672.99 µg/m³ respectively. The peak measurements for the 24-hour mean concentrations of PM₁₀ and PM_{2.5} on October 21, 2015 were 1,369.34 µg/m³ and 1,246.92 µg/m³ respectively. Both PM groups exceeded the 24-hour standards for PM₁₀ and PM_{2.5} concentrations outlined in the WHO Air Quality Guidelines and the US EPA National Ambient Air Quality Standards. Based on the results of the questionnaires, more than two-thirds of both children and adults experienced sneezing, nasal congestion, influenza, and dry cough during the forest fire episode. In conclusion, the particle pollution in Palembang city that was caused by the forest fire was hazardous to human health, and further research is needed to explore the health effects resulting from forest fire pollution that may affect Palembang's citizens.

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Received: 21 January 2018

Accepted: 8 April 2018

Published: 17 May 2018

Publishing services provided by
Knowledge E

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Selection and Peer-review
under the responsibility of the
2nd International Meeting of
Public Health 2016 Conference
Committee.

 OPEN ACCESS

Keywords: PM_{2.5}, forest fire, Palembang, respiratory effect.

1. INTRODUCTION

Solid particles and liquid droplets smaller than 2.5 μm suspended in the air are known as fine particulate matter ($\text{PM}_{2.5}$) [19]. Fine particulate matter is formed by primary and secondary processes. The primary process of fine particulate matter formation involves the condensation of high-temperature vapor during combustion, while the secondary process involves nucleation, gas condensation onto existing particles, and gas absorption into liquid droplets [8]. An uncontrollable fire that consumes dried vegetation, or a wildfire, emits an abundance of complex gasses and aerosol mixtures into the air [17]. Carbon dioxide, methane, non-methane volatile organic compounds, nitrogen oxides, and aerosol are major pollutants from wildfires [17].

Wild land fires have occurred annually at several locations in Indonesia since 1997 [1]. The ability of fine particles to travel up to a thousand kilometers makes wildfire pollution a regional problem that affects neighboring countries [17]. It is estimated that 339,000 death shave occurred globally every year because of wild land fire smoke, while the highest proportion of deaths occurs in Southeast Asia with 110,000 deaths per year (Johnston et. al, 2010). Exposure to fine particles from wildfires is also associated with an increase in heart attack risk outside of hospitals, while coarse particulate matter (PM_{10}) from wildfires is associated with an increase in respiratory disease, chronic obstructive pulmonary disease, and adult asthma [11]. This research aimed to measure the $\text{PM}_{2.5}$ pollution and subjective respiratory health effects from September to October 2015 that were caused by a September forest fire in Palembang, one of the most affected cities in Indonesia.

2. METHODS

Fine particles and subjective respiratory health effect data were collected in the Sukabangun district of Palembang city, located in the middle of the South Sumatra province. Palembang is located between $-2^{\circ}52'S$ and $-3^{\circ}5'S$ latitude and $104^{\circ}37'E$ and $104^{\circ}52'E$ longitude and situated five meters above sea level. South Sumatra has an abundance of fire hot spots, with up to 239 spots during 2015.

2.1. Particulate Matter Measurement

$\text{PM}_{2.5}$ was collected according to the US EPA IP 10-A Method updated by SKC [13]. A Sioutas Cascade Impactor was used to collect and separate coarse and fine particles

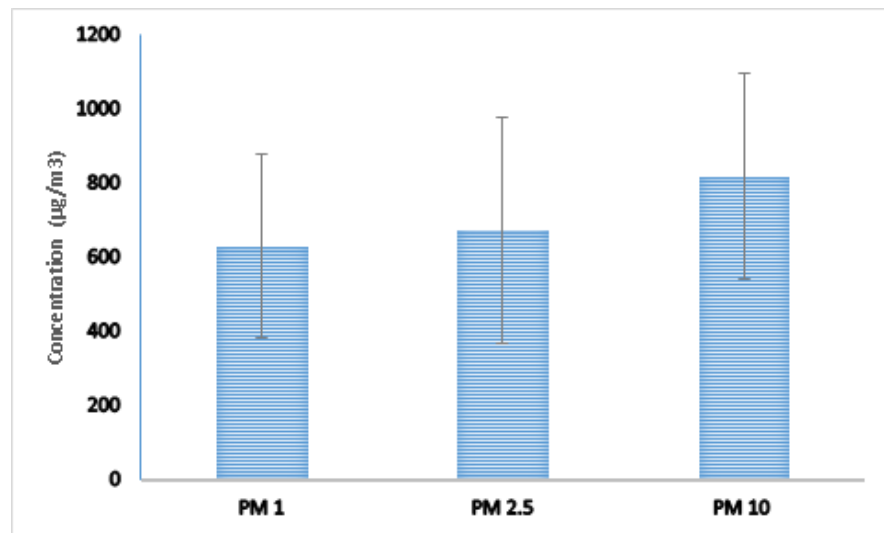


Figure 1: Particulate matter mean concentrations at the Sukabangun district in Palembang city during the smoke period, October 2015.

according to their size. The impactor was filled with five quartz fiber filters and attached to a Leland Legacy personal pump running at 9L/min. The PM measurement apparatus was located indoors in two different locations. Sampling was conducted from October 15 to 21, 2015, for six hours each day, divided into morning and evening periods of three hours each. The particulate matter concentration was measured by the gravimetric method using a microbalance.

2.2. Subjective Respiratory Health Effect Measurements

Subjective respiratory health effects were measured using a questionnaire adapted from the American Thoracic Society. The chosen respondents were 63 adults and 54 children from the Sukabangun district. The questionnaire was used to measure acute respiratory and other health problems from two weeks after and one year prior to the fire.

Figure ?? illustrates the particulate matter concentrations in the Sukabangun district in Palembang city during the smoke period. Ultrafine (PM_1), fine ($PM_{2.5}$), and coarse (PM_{10}) particles were collected in two different locations in the Sukabangun district for seven consecutive days. The 24-hour mean concentrations of PM_1 , $PM_{2.5}$, and PM_{10} were $632.13 \pm 247.71 \mu\text{g}/\text{m}^3$, $672.6 \pm 305.55 \mu\text{g}/\text{m}^3$, and $818.78 \pm 279.6 \mu\text{g}/\text{m}^3$ respectively. Both $PM_{2.5}$ and PM_{10} concentrations exceeded both US EPA National Ambient Air Quality Standards and WHO Air Quality Guidelines [18, 21].

3. Subjective Respiratory Health Effects

Data were collected from 63 adults between 18 and 68 years old, at a 23:40 male to female ratio. These data were collected in October during the same period as the particulate matter measurements. Based on respondent opinions, the smoke period started in early September and lasted up to the time the interview was conducted. Sneezing two weeks before the start of the smoke period was reported by 83% of respondents, while 60% also stated that they had experienced nasal congestion and dry cough, and 63% indicated that they had experienced influenza during the same time frame. Regarding non-respiratory effects, 58.73% and 65.08% of adults suffered from red and itchy eyes during the smoke period.

Similar results were collected from 54 children in the same area and at the same time. Sneezing and nasal congestion affected 83% and 61% of these children respectively, while 67% suffered from both influenza and dry cough. Non-respiratory effects showed small differences from the adult group; 46% of the children suffered from itchy eyes, and 41% of the children experienced fever during the forest fire period.

4. DISCUSSION

The mean concentration of PM_{10} found in this study is three times the normal monthly mean concentration in Palembang as measured by "Badan Meteorologi, Klimatologi dan Geofisika" (BMKG) (the Indonesian Agency for Meteorology, Climatology, and Geophysics) [2]. September and October have the highest PM_{10} concentration levels during 2015, reaching 304.43 and 349.74 $\mu\text{g}/\text{m}^3$ respectively. This trend is similar to that of the year before, in which September, October, and November had the highest PM_{10} concentration levels, peaking in October at 292.37 $\mu\text{g}/\text{m}^3$. A wild land fire that occurred in South Sumatra during that period was the main cause of this increase.

Several studies show that forest fires, bush fires, and other types of wild land fires are responsible for high concentrations of PM. During a forest fire period, PM_{10} and $PM_{2.5}$ concentrations in Sobreiras were respectively halved and doubled when compared to their mean concentrations at another time [14]. Also due to forest fires, PM_{10} concentrations in California, British Columbia, and Athens peaked at 200, 248.4, and 96 $\mu\text{g}/\text{m}^3$ respectively [3, 6, 20]. Measurements taken by firefighters during forest fire periods in Australia also show remarkable levels of respirable particles, with the highest recorded concentration from 11 samples being 3,800 $\mu\text{g}/\text{m}^3$ [12].

Particulate matter in all size categories is notorious for its adverse effects on human health. A study on particles released from wild land fires in Alaska shows that coarse and ultrafine particles contain abundant levels of carbon and OH radicals respectively [9]. This study shows that all sizes of particles can cause DNA damage. Another study on seasonal forest firefighters found that acute exposure to forest fire emissions can induce inflammation within the lungs and initiate a systemic inflammatory response [15]. Forest fire smoke has also been associated with an increased number of respiratory complaints in Kelowna, British Columbia [10]. In children's health, wildfire exposure has been associated with the development of eye and respiratory symptoms and an increase in medication use and physician visits [5]. Increased concentrations of PM_{10} have also been associated with increased hospital admissions in British Columbia, Canada and Victoria, Australia [4, 16].

5. CONCLUSION

The mean concentrations of PM_{10} and $PM_{2.5}$ in Palembang during the measurement periods were $818.78 \mu\text{g}/\text{m}^3$ and $672.99 \mu\text{g}/\text{m}^3$ respectively. The peak levels for the 24-hour mean concentrations of PM_{10} and $PM_{2.5}$ on October 21, 2015 were $1,369.34 \mu\text{g}/\text{m}^3$ and $1,246.92 \mu\text{g}/\text{m}^3$ respectively. Both PM groups exceeded the WHO Air Quality Guidelines and US EPA National Ambient Air Quality Standards 24-hour standards for PM_{10} and $PM_{2.5}$ concentrations [18, 21]. Based on the results of the questionnaires, more than two-thirds of both children and adults experienced sneezing, nasal congestion, influenza, and dry cough during the forest fire episode. The particle pollution in Palembang city that was caused by the forest fire was hazardous to human health, and further research is needed to elaborate on the health effects resulting from forest fire pollution that may affect Palembang's citizens.

ACKNOWLEDGEMENTS

We gratefully acknowledge that this study was funded by the Directorate of Research and Community Services of Universitas Indonesia.

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