Research Article

PM_{10} Levels and Hotspots in Western Thailand in Agro-Residue Burning Season

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Abstract

Open burning of agro-residues normally generates a large amount of pollutants which may result in potential impacts on the ambient air quality and public health. A study of a correlation between PM_{10} levels in ambient air and hotspot counts in Western Thailand was conducted to investigate whether the air quality of Nakhon Pathom Province was influenced by the emission from agro-residue burning. Two high Volume Samplers for PM_{10} sampling were installed in Silpakorn University to obtain the representative PM_{10} levels in Nakhon Pathom province. The number of hotspots, as the fingerprints of open burnings, was provided by the NASA's Earth Observatory website. The hotspot counting was divided into 2 parts; (i) 5-year backward counting in the province to investigate the burning season, and (ii) counting in Nakhon Pathom province and upwind-adjacent provinces including Kanchanaburi, Ratchaburi, Pathumthani, Pranakorn Sriayudhaya and Suphanburi in a burning season. Wind directions to the sampling locations were obtained from a HYSPLIT Model. Average PM_{10} levels found in this study was 88±34 μg/m^3, which does not exceed Thailand Air Quality Standard of 120μg/m^3. The positive correlation between PM_{10} levels and hotspot counts was found at R^2=+0.81. This study indicated that air quality in Nakhon Pathom Province was affected by emissions from agro-residue burning.

Key Words: Agro-residues; Burning Season; Hotspots; PM_{10}

Introduction

Burning biomass, including living and dead vegetation, may take place intentionally (e.g. burning of vegetation for land clearing), or by natural causes. It is estimated that humans are responsible for about 90% of biomass burning with only a small percentage of natural fires contributing to the total amount of vegetation burnt (Baldini et al., 2004; NASA, 2004a). Emission from biomass burning is one of the environmental and health hazards. Humans are exposed to a large quantity of carcinogenic compounds from open burning smoke. Pollution from biomass burning emerges frequently in our daily lives, in both indoor and outdoor environment. To reduce the exposure in North America, many communities have regulations to manage domestic burning in fireplaces and wood-burning stoves to control atmospheric pollution (Andreae, 1991). For the outdoor air, biomass burning also causes multiple effects. For examples, airports like Santarém, which is in the middle of the Amazon Basin, have to be closed frequently during the burning season because of poor visibility resulting from the smoke from fires located hundreds to thousands of kilometers away from the airports. Another example was Indonesian forest fire in 1997, which caused episodic high air pollution in Kalimantan and Sumatra (Lawrence et al., 2001).

Agro-residue burning is one of the major types of intentional burning of biomass. Normally, biomass burning plays an important role in agriculture and economy (Andreae, 1991). Burning of agricultural wastes, e.g. straw and stubble from grain crops or sugar-cane fields after harvesting is a very noticeable source of air pollution in many tropical regions. Emissions from the combustion of biomass produce a large amount of particles and gaseous pollutants, which cause respiratory problems when they are inhaled (Mitra et al., 2002; NASA, 2004b). There is a significant contribution of biomass burning to the fine particulate matters (PM) pollution in the Bangkok Metropolitan Region (BMR). Source apportionment of fine and coarse fractions of PM in BMR reveals that biomass burning contributes around 30% of fine PM mass in the region (Yootong, 2003; Kim Oanh, 2006).

In Nakhon Pathom province, paddy rice is one of the major crops. Most of the crop residues are disposed of by burning. The amount of agricultural waste burnt is high each year because no regulations exist. Air pollution from biomass burning is largely overlooked. Finding the influence of agro-residue burning emission to air quality of the province is a challenge. The goal of this study is to overcome this challenge to the extent possible. Therefore, the correlation of PM10 levels and the satellite data was employed along with the trajectory modeling, which presented possible directions of the emission transport, to describe the impacts on the air quality in Western Thailand.

Materials and Methods

Determination of PM_{10}

Sampling site

Silpakorn University was selected as a sampling site because it was located moderately far (3 km) from Nakhon Pathom downtown. Moreover, the traffic in the university was considered light. Consequently, PM_{10} from vehicle travelling in the university did not interfere with the PM_{10} samples. The sampling equipment was situated on the decks of the two 3-storey buildings in the university.

Sampling and analysis methods

Glass fiber filters (GFF) (pore size 37 mm, 20x25 cm) were used for PM_{10} collection. A Five-digit balance was used to measure the particulate matter weight on the sample filters for mass analysis. The filters were prepared by keeping them in a desiccator for at least 24 hours. Filters were then pre-weighted and stored in airtight plastic bags. After sampling, filters were taken back to the lab and desiccated for at least 24 hours before post-weighing by a five-digit balance. Field blank was taken into account for PM mass. Proper flow calibration of the High Volume Sampler (1.13 m^3/min) was done for the correct fractionation of the particles below 10 μm.

The sampling period was from February 1, 2010 to March 30, 2010. The air samples were collected every 3 days in order to cover both weekdays and weekends in a dry season, which was the harvesting and burning season. During this period, many fires were set intentionally for land clearing and agro-residue removal for the upcoming growing season. Air was continuously drawn through the filters for 24 hours with desired flow from 8:00 a.m. to 8:00 a.m. on the next day. Temperature and pressure were determined. The total number of samples in this study was 20.

The levels of PM_{10} in air samples were defined as

$$PM_{10}\ (\mu g/m^3) = \frac{Weight_{post}(\mu g) - Weight_{pre}(\mu g)}{Standard\ air\ volume\ (m^3)}$$

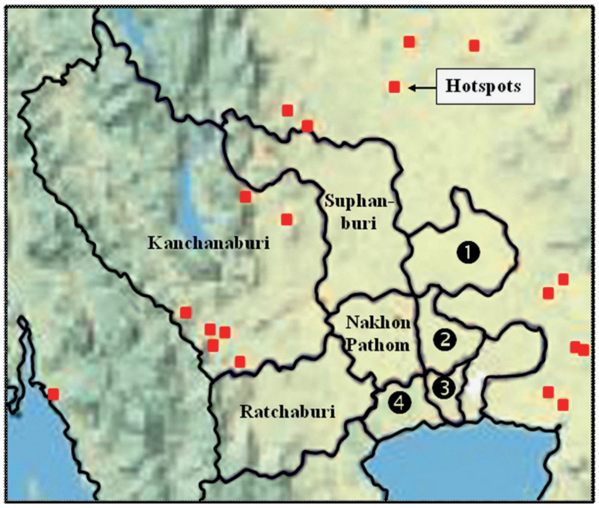
Quality assurance and quality control (QA/QC)

Sampling: High Volume Samplers were calibrated for desired flow rate before every sampling. All sample filters were kept in air-tight plastic bags to avoid contamination during the transportation. Field blanks, which were conditioned and unsampled filters, were used to determine whether similar contamination occurred during samplings by exposing to ambient air without pumping.

Analysis: Filter samples were kept in the desiccators for at least 24 hours before weighing. Three replicated measurements usually agreed within less than 0.01% of filter weight.

Determination of hotspots

During PM_{10} sampling period, the hotspots in Nakhon Pathom and the nearby provinces were extracted daily from the NASA's Earth Observatory website. The fires (hotspots) detected are updated daily on website (http://firefly.geog.umd.edu/firemap/). Figure 1 shows an example of hotspots in Thailand in March 2011. This study received the fire information (hotspots) for (i) five years backward (2005-2009) and (ii) PM_{10} sampling days. Tipayarom and Kim Oanh (2007) revealed that PM_{10} levels emitted from biomass burning showed a good correlation with hotspot counts. In this study a HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model was used to determine wind direction to Silpakorn University (sampling site) on the days of PM_{10} sampling and to identify in which provinces hotspots should be counted on each day. Figure 2 illustrates an example of wind direction to the sampling site. In this case, the number of hotspots in Nakhon Pathom and Suphanburi (located in the north of Nakhon Pathom) provinces was counted and recorded.



❶ Pranakorn Sriayudhaya
❷ Nontaburi
❸ Bangkok
❹ Samutsakon

Figure 1 Example of hotspots

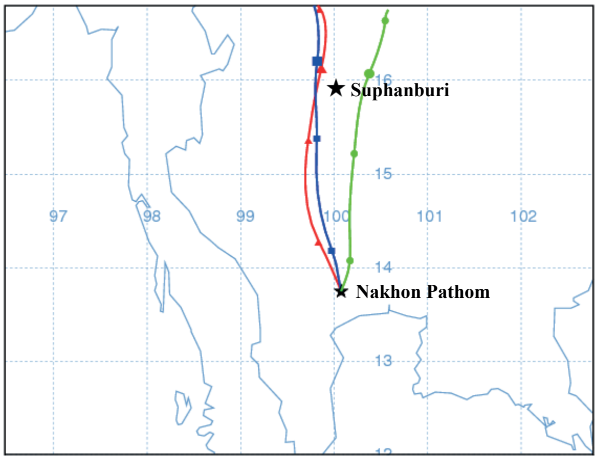


Figure 2 Example of wind direction obtained from HYSPLIT model

Data analysis

Two data sets obtained from PM_{10} samplings and hotspot countings were compared to ascertain an effect of open agro-burning in Nakhon Pathom and the nearby provinces on air quality of Nakhon Pathom Province. Correlation (R^2) was defined.

Results and Discussions

PM10 levels

In Nakhon Pathom, levels of PM_{10} were 88±34 μg/m^3. The results showed that the levels on certain days exceeded Thailand Air Quality Standard which is 120 μg/m^3. The results are illustrated in Figure 3. Comparing to Klinmalee (2008)'s study in Pathumthani Province (rice-growing province) in 2006, it was reported that PM_{10} levels in ambient air were only 47±10 μg/m^3. The PM_{10} levels in Pathumthani were lower than in Nakhon Pathom for the reason that roughly 30-40% of rice-growing farmers in Pathumthani dispose their wastes by plowing instead of burning.

Five-year backward counting of hotspots

The results from hotspot counting in 2005 - 2009 indicated that farmers typically burn their agricultural wastes during February to March each year as shown in Figure 4. Hence, the number of hotspots and PM_{10} levels were determined through

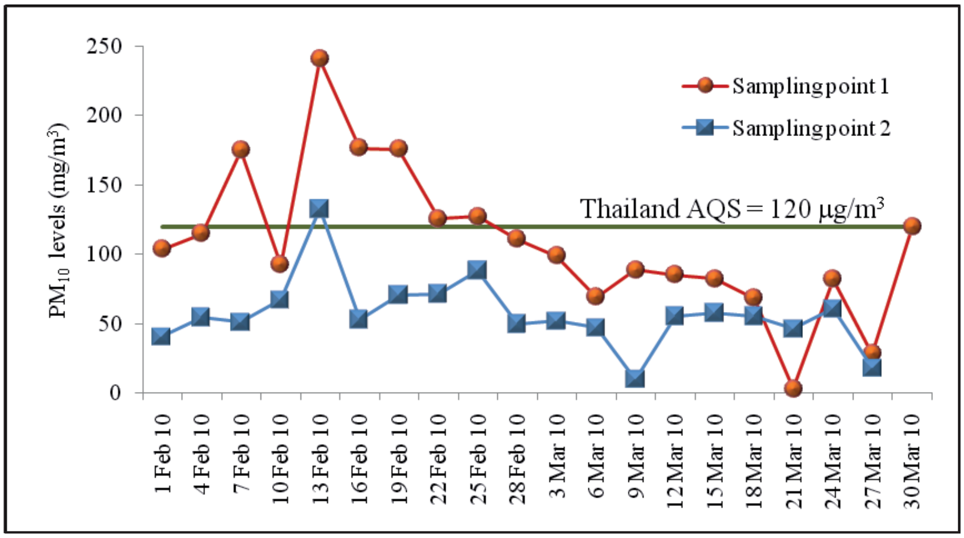


Figure 3 PM_{10} levels in Nakhon Pathom from 2 sampling points

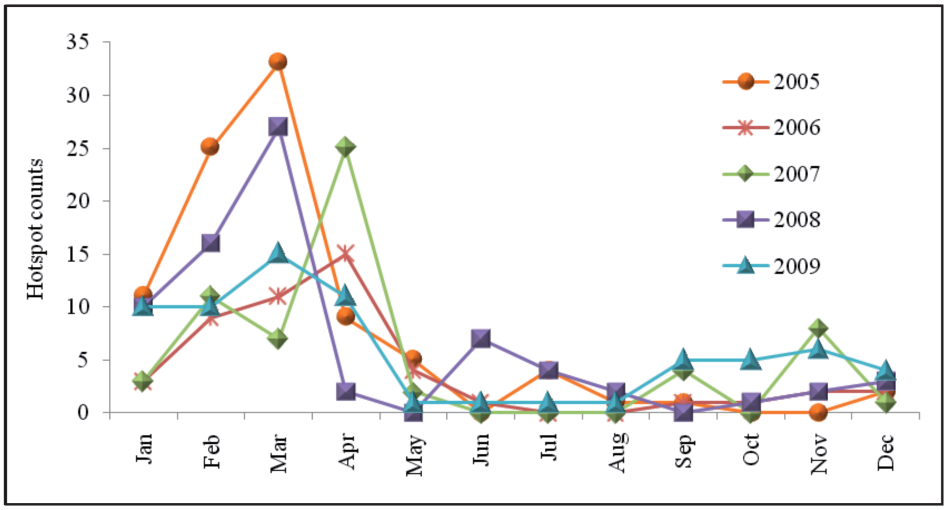


Figure 4 Five-year backward hotspot counts in Nakhon Pathom Province

that period. This finding corresponded to Klinmalee (2008)'s study that rice-growing farmers burnt their rice straw after harvesting especially in dry season (January - April). Tipayarom (2004) studied emission from open rice-straw burning in Thailand and also showed high hotspot counts during November - April. Study of Phuong (2006) regarding to impact of rice straw burning on ozone air quality in BMR also revealed the higher monthly hotspot counts in a dry season (December - April) and lower counts in a wet season (May - November). Thus, there was a large amount of smoke emitted and dispersed during that period. Similar information about burning period was also obtained from Nakhon Pathom Agricultural Extension Office (2010). Therefore, the period selected for this study was February 2010 - March 2011.

Correlation between PM_{10} levels and hotspot counts

Since PM_{10} was emitted from biomass combustion, the daily hotspot counts in the studied areas were plotted against PM_{10} levels. The results are demonstrated in Figure 5. The relationship between PM_{10} and hotspot counts was statically significant (R^2 = +0.81). Scatter plots of correlation are shown in Figure 6. However, there were some uncertainties related to hotspot counts such as cloudiness and the short duration of rice paddy burning. MODIS satellite images were available for only two times per day in Thailand.

However, the positive correlation revealed that air quality in Nakhon Pathom province had been impacted by agro-residue burning. Tipayarom and Kim Oanh (2007) studied the correlation between PM_{10} levels and hotspot counts in Pathumthani province during burning period. The results showed that hotspot counts varied in the same way as PM_{10} levels (R^2 = +0.77) corresponding to this study.

Conclusion

The integrated method in this study is unique and the study demonstrates that it can be used to primarily indentify the possible source of PM_{10} in ambient air. Reasonable correlation between MODIS hotspot counting and ground monitoring data of PM_{10} at Silpakorn University station suggests that open burning of agro-residue in Nakhon Pathom Province may affect air quality in the area.

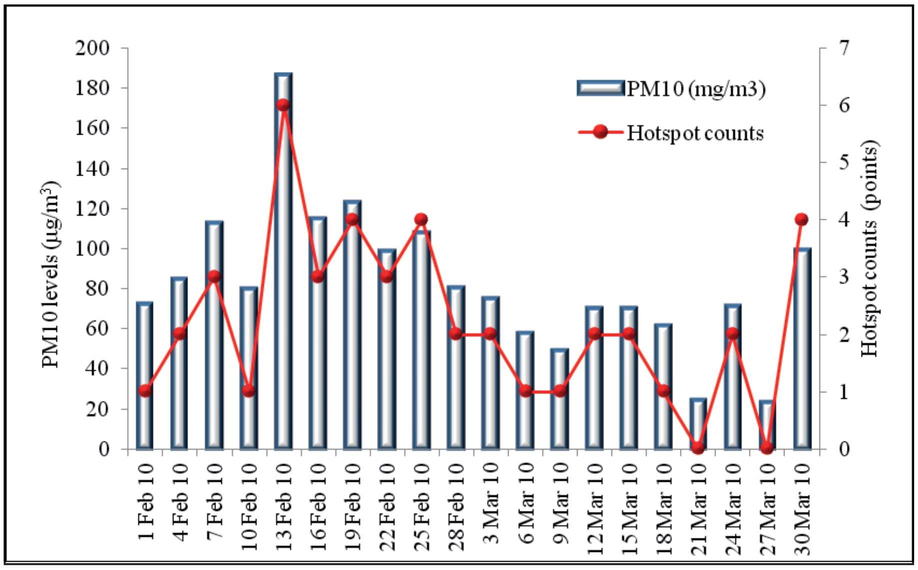


Figure 5 PM_{10} levels and hotspot counts

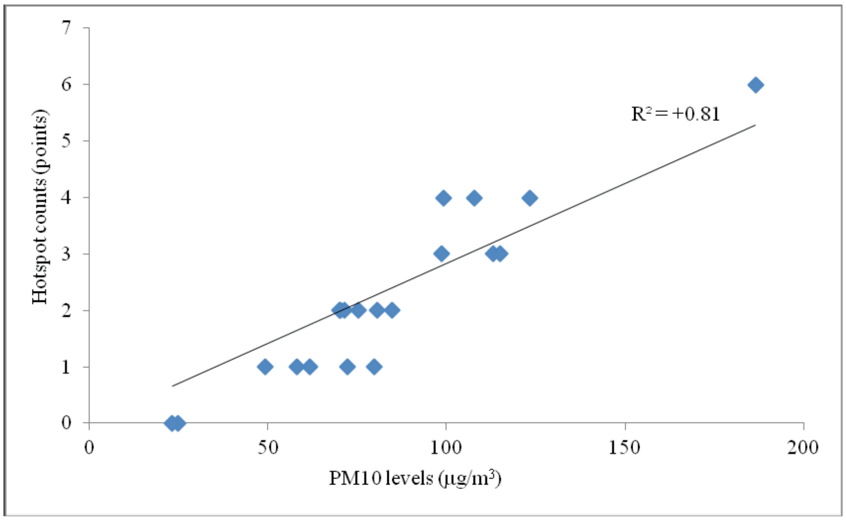


Figure 6 Correlation between PM10 levels and hotspot counts

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