การเปลี่ยนแปลงตามพื้นที่และเวลาของความเข้มข้น PM_{10} บริเวณแหล่งอุตสาหกรรมผลิตภัณฑ์จากแร่ในจังหวัดสระบุรี

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บทคัดย่อ

ข้อมูลตรวจวัดความเข้มข้นของฝุ่นที่มีขนาดเล็กกว่า 10 ไมครอน (PM_{10}) ในบรรยากาศ จากสถานีตรวจวัดในจังหวัดสระบุรี ระหว่างปี 2544-2548 ได้นำมาวิเคราะห์เพื่อทราบการเปลี่ยนแปลงตามพื้นที่และเวลา ผลการศึกษาพบว่าตำบลหน้าพระลานและบริเวณใกล้เคียงซึ่งเป็นแหล่งอุตสาหกรรมผลิตภัณฑ์จากแร่ในจังหวัดสระบุรีเป็นบริเวณที่มีปัญหาฝุ่นอย่างมาก ระหว่างปี 2544-2548 ความเข้มข้น PM_{10} ที่สถานีตรวจวัดหน้าพระลานเกินมาตรฐานรายปี (50 ไมโครกรัม/ม.^{3}) ทุกปี ระดับความเข้มข้น PM_{10} มีการเปลี่ยนแปลงตามพื้นที่สูง ทั้งนี้เนื่องจากสภาพอากาศของพื้นที่มีความเร็วลมต่ำและฝุ่นขนาดใหญ่ที่ปลดปล่อยมาจากโรงโม่หินและฝุ่นที่ฟุ้งกระจายจากถนน นอกจากนี้ผลการศึกษาพบว่าแหล่งกำเนิดในท้องถิ่นเป็นแหล่งปลดปล่อยหลักของ PM_{10} ในบรรยากาศบริเวณหน้าพระลาน จากข้อมูลความเข้มข้น PM_{10} เฉลี่ยรายเดือนพบว่ามีการเปลี่ยนแปลงตามฤดูกาลสูง โดยความเข้มข้น PM_{10} เฉลี่ยรายปีในฤดูหนาว ฤดูร้อน และฤดูฝน มีค่าเท่ากับ 102.3±66.0 80.3±44.8 และ 86.8±38.7 ไมโครกรัม/ม.^{3} ตามลำดับ ความเข้มข้น PM_{10} ที่สูงกว่าในฤดูหนาวเนื่องจากมีปริมาณฝน ความเร็วลม และอุณหภูมิที่ต่ำกว่า การเปลี่ยนแปลงภายในวันของความเข้มข้น PM_{10} มีลักษณะความเข้มข้นสูงสุดสองเวลา ได้แก่เวลาประมาณ 9.00-11.00 นาฬิกา และ 19.00-21.00 นาฬิกา ซึ่งสัมพันธ์กับช่วงเวลาที่มีปริมาณการปลดปล่อยฝุ่นจากแหล่งกำเนิดสูงและสภาพบรรยากาศที่เหมาะกับการสะสมของมลพิษ (ความเร็วลมต่ำและความสูงของชั้นผสมต่ำ) นอกจากนี้ยังพบอีกว่าการเปลี่ยนแปลงภายในวันในแต่ละฤดูกาลมีลักษณะที่แตกต่างกัน โดยฤดูหนาวจะมีการเปลี่ยนแปลงมาก ส่วนฤดูร้อนจะมีการเปลี่ยนแปลงน้อย

คำสำคัญ : PM_{10} / การเปลี่ยนแปลงตามพื้นที่ / การเปลี่ยนแปลงตามเวลา / สระบุรี / อุตสาหกรรมผลิตภัณฑ์จากแร่

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Spatial and Temporal Variations of PM_{10} Concentrations over a Mineral Products Industrial Area in Saraburi

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Abstract

The observational data set of ambient PM_{10} concentrations from monitoring stations in Saraburi during 2001 to 2005 was analyzed to investigate the spatial and temporal variations. The result shows that Nah Phra Laan sub-district and its vicinity, mineral products industrial area in Saraburi, is very serious area for particulate problem. During 2001-2005, the PM_{10} concentrations at Nah Phra Laan site exceeded annual standard of 50 µg/m^3 every year. PM_{10} levels show strong spatial variation that can be attributed to low wind speed and coarse particulate matters emitted from crushed stone plants and re-suspended dust from roads. The result reveals that local sources are main contributors of PM_{10} in Nah Phra Laan's atmosphere. Monthly average PM_{10} concentrations show strong seasonal variation. Annual average PM_{10} concentrations in winter, summer, and rainy season were 102.3±66.0, 80.3±44.8, and 86.8±38.7 µg/m^3, respectively. Higher PM_{10} concentration in winter is due to less precipitation, weaker wind speed, and lower temperature. The diurnal variations of PM_{10} concentrations characterize by two peaks at around 9.00-11.00 AM and 7.00-9.00 PM that are associated with high emission rate and accumulated condition (low wind speed and short mixing height). The difference of diurnal variations in each season is found with the high variation in winter and the low variation in summer.

Keywords : PM_{10} / Spatial Variation / Temporal Variation / Saraburi / Mineral Products Industry

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1. Introduction

Saraburi province is an important limestone resource of Thailand. Several crushed stone plants and cement plants are located in this area, especially in Nah Phra Laan sub-district in Saraburi province. The crushed stone plants, cement plants and related activities such as transportation are significant sources of particulate matter (PM). The people in Nah Phra Laan and surrounding have been facing an air quality problem for a long time. Based on the PM_{10} annual NAAQS of 50 μg/m^3, during 2001-2005 the concentrations of particulate matter with an aerodynamic diameter less than 10 μm (PM_{10}) exceeded the standard every year. Moreover, during 2004-2005, PM_{10} concentrations exceeded the PM_{10} 24-hr NAAQS of 120 μg/m^3 more than 100 days in each year. The particulate matters can cause of several problems. Adverse human health effects related to PM were revealed such as reduced lung capacity, increased mortality [1-2]. In 2003, Epidemiological studies found that the respiratory illness of the pupils in the Nah Phra Laan school was greater than that in the area without mineral products industry [3]. During 1995-1997, the cost of medical care for the respiratory illness of labor population living in Nah Phra Laan and surrounding was 4.7 times of the cost in other area in Saraburi [4]. The mean pulmonary function parameter values of worker in stone crushing unit were significantly lower than the values of healthy males in the South Indian [5]. In addition, particle pollutants cause aesthetic problems and reduce visibility [6-7], which usually appear in Nah Phra Laan.

The development of effective pollution abatement measures requires a through understanding of the variations of ambient PM_{10} concentrations. However, most PM_{10} studies have been conducted in developed countries, with only a small number of studies conducted in Asia [8]. Previous study of PM_{10} distributions in Thailand found that PM_{10} levels vary considerably across the country. High concentrations are found in the central areas, while low concentrations are observed in the south of Thailand. PM_{10} levels in central and northern Thailand show high in the winter and low in the summer. Higher PM_{10} levels are observed in early morning [9]. The characteristic of PM_{10} concentrations in Saraburi is dominated by emissions from the mineral products industries and related activities in mountainous area. Although several control measures have been taken to reduce ambient concentration, PM_{10} concentrations are still high and regularly exceed the NAAQS. Therefore, it is necessary to understand the characteristic of PM_{10} concentrations in this area for effective air quality management. The objective of this study is to investigate spatial and temporal variations of PM_{10} concentrations in a mineral products industrial area in Saraburi by analyzing the observed data.

2. Methodology

2.1 The study area

Saraburi is located in the central part of Thailand. Around 40% of Saraburi is mountain and plateau (Fig.1). The elevation of this area is ranging between 100-500 m above mean sea level (MSL) except the highest elevation of mountain in south-east of Saraburi is about 1,000 m MSL. The surrounding area in the South and West of Saraburi is plain. Nah Phra Laan is located in mountainous area. There are many hills, which are sources of limestone. Due to complex terrain, meteorological condition in this area is influenced by the interactions between the synoptic-scale forcing and local-scale forcing.

In Thailand, there are three seasons. The rainy season usually starts in mid-May and ends in mid-October. The rainy season is under the influence of the Southwest monsoon, which brings warm and moist air from the Indian Ocean causing rain and high humidity. The Northeast monsoon brings cold and dry air from Mongolia and China in winter (mid-October to mid-February). Summer is in the transition period between the Southwest and the Northeast monsoons that normally starts in mid-February and ends in mid-May [10].

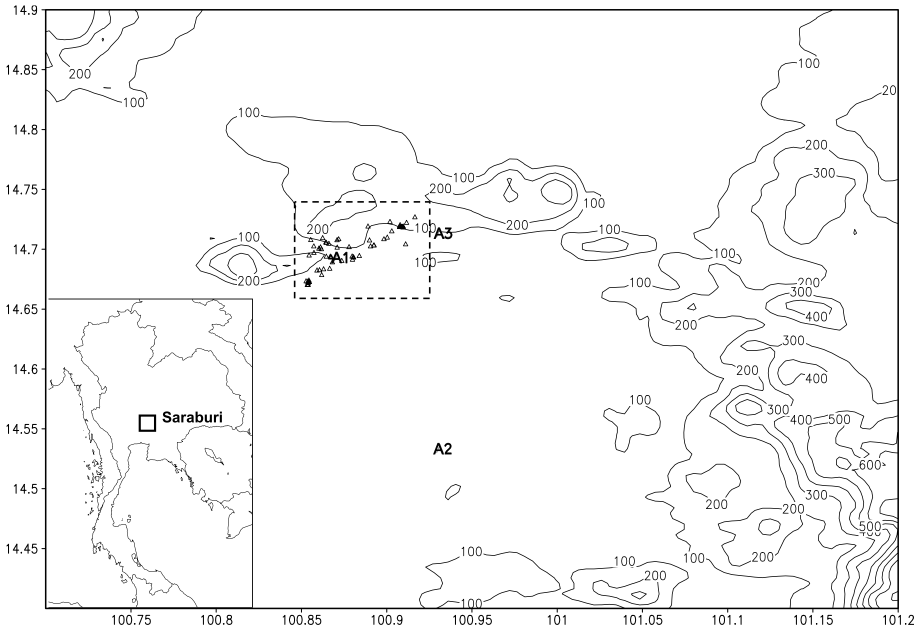

Fig. 1 Topography of Saraburi with 100 m contour intervals, air quality monitoring stations in Saraburi (A1 - Nah Phra Lann station, A2 - Urban station, A3 - Ban Nhong Chan mobile station) and triangles in the dotted rectangular are the location of mineral industrial emission sources in Nah Phra Laan and its vicinity

2.2 Data and instrumentation

A monitoring dataset was analyzed to know PM_{10} variations in Saraburi. The analysis focused on polluted area in the Nah Phra Laan. The present study covers the five-year period of 2001-2005. A monitoring dataset of hourly pollutant and meteorological measurements was obtained from Pollution Control Department. There are two air quality monitoring stations in Saraburi. The first monitoring station is located in urban and is far about 20 m from the low traffic road. The second monitoring station is located in the Nah Phra Laan school, about 20 km north of the urban station. This station is located in a mineral products industrial and high traffic area that is approximately 5 m far from the main arterial route. During May 2005 to April 2006, there was mobile station located in Ban Nhong Chan (BNC) school, where was about 7 km from the Nah Phra Laan station (Fig. 1). Urban station use the Beta-attenuation method to measure PM_{10} concentrations, whereas BNC site uses Tapered Element Oscillating Micro-balance (TEOM). Nah Phra Laan station used the Beta-attenuation method from January 2001 to July 2005, after that TEOM was applied. Sampling heights are about 3 m above ground level (AGL) except that wind is measured at about 10 m AGL. Pollutant and meteorological parameters are recorded automatically as mean hourly values. In addition, during 3-9 August 2005, PM_{10} concentrations were measured 4 points around the Nah Phra Laan using high volume air sampling system.

The original dataset of hourly measurements was aggregated to obtain the daily average, monthly average and yearly average. The observed dataset was analyzed to know yearly, seasonal, diurnal variations of PM_{10} concentrations in Saraburi and primary factors affecting the variations. The emissions and meteorological conditions related to PM_{10} concentrations were considered. Atmospheric stability was also applied in this analysis. Atmospheric stability class was classified by criteria of Pasquill stability classes as shown in Table 1.

Table 1 Pasquill stability categories [6].

Surface wind speed (m/s)	Daytime solar radiation (W/m^2)		
	Strong >590	**Moderate 290-590**	**Weak <290**
< 2	A	A-B	B
2-3	A-B	B	C
3-5	B	B-C	C
5-6	C	C-D	D
> 6	C	D	D

A- Very unstable, B- Moderately unstable, C- Slightly unstable, D- Neutral, E- Slightly stable, F- Moderately stable, E- Very stable

3. Results and discussion

3.1 Spatial variation

Annual average PM_{10} concentrations at the Nah Phra Laan and urban monitoring stations are shown in Fig. 2. During 2001 to 2005, it was found that the annual average PM_{10} concentrations at the Nah Phra Laan exceeded the annual PM_{10} NAAQS every year. The annual average PM_{10} concentrations at the Nah Phra Laan during 2001 to 2005 were 86, 84, 63, 107, and 108 µg/m^3. In the other hand, the PM_{10} concentrations at the urban never exceeded the standard. The annual average PM_{10} concentrations at the urban during 2001 to 2005 were 39, 38, 40, 42, and 31 µg/m^3. The maximum daily average of PM_{10} concentrations at the Nah Phra Laan were about 3 times the daily PM_{10} standard. The annual average PM_{10} concentrations at the Nah Phra Laan were 1.6-3.5 times of the concentration at the urban, where is far from the Nah Phra Laan about 20 km.

During the field campaign, May 2005 to April 2006, there was an additional PM_{10} measurement at the BNC in Nah Phra Laan sub-district (Fig. 1). In this period, the highest annual average PM_{10}

concentration was found at the Nah Phra Laan site, which was located in dense mineral products in dustrial area and near the highway. The annual average PM_{10} concentration was more than twice the annual PM_{10} NAAQS. On contrary, the annual average PM_{10} concentrations at the urban and the BNC did not exceed the standard. The high spatial variation of PM_{10} concentrations was found. The variation of annual average PM_{10} concentrations between the Nah Phra Laan and the BNC was three-fold over the distance of about 7 km. Furthermore, the variation between the Nah Phra Laan and the urban was five-fold over the distance of about 20 km. Astonishingly, the low PM_{10} concentrations were found at the BNC site, where was at a few kilometers east of large sources in the Nah Phra Laan. The maximum daily average PM_{10} concentration at the BNC was 111 µg/m^3 that was lower than the daily PM_{10} NAAQS of 120 µg/m^3 and the mean daily PM_{10} concentration was 43±18 µg/m^3, while PM_{10} concentration at the Nah Phra Laan site exceeded the daily PM_{10} NAAQS at 45% and the mean daily PM_{10} concentration was 123±55 mg/m^3. Low PM_{10} concentrations at the BNC reflect the low effect of local sources. The reason is the BNC site located mostly upwind of the Nah Phra Laan sources. The wind directions from emission sources in the Nah Phra Laan to the BNC station were between 225° and 315°, which were less than 20% during the field campaign period. Moreover, the low correlation of PM_{10} concentrations between the Nah Phra Laan site and the BNC site was found. The correlation coefficient (r) of daily average PM_{10} concentrations between the BNC site and the Nah Phra Laan site was 0.65, whereas there was more correlation of PM_{10} concentrations between the BNC site and the urban site with correlation coefficient of 0.79 was seen. High correlation indicates that similar emission sources and regionally prevailing meteorological conditions control the variability of daily PM_{10} levels over the area [11].

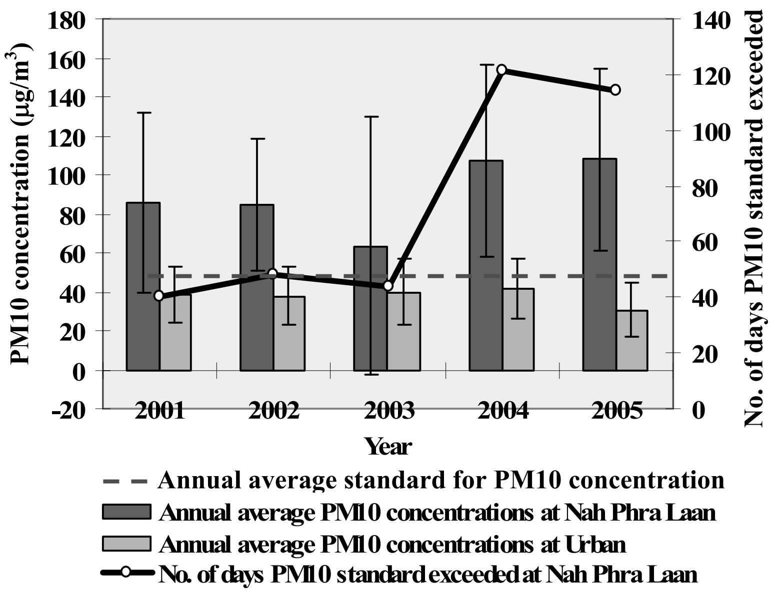

Fig. 2 Yearly data of PM_{10} concentrations at the Nah Phra Laan station and Urban station during 2001-2005

Strong spatial variations and low correlation of PM_{10} concentrations at the Nah Phra Laan and the other area imply that particulate matters emitted from significant sources in the Nah Phra Laan disperse short distance. This can be attributed to the high proportion of coarse particles emitted from sources and low wind speed. In the Nah Phra Laan, the size distribution of dust from equipment in crushed stone plant was investigated, and it was found that PM_{10} was about 20% of TSP. $PM_{2.5}$ was less than 2% of TSP [12]. The study of dust emissions from unpaved surfaces in Taiwan show that the fractions of PM_{10} and $PM_{2.5}$ in the TSP resuspended from the unpaved roads are 20.6±12.9% and 2.3±1.2%, respectively [13]. In the period of 2001 to 2005, daily average wind speed was 0.88 m/s and maximum daily average wind speed was 1.98 m/s. Since the wind is light making weak drag force, it could not take the particulate matter for a long distance. Analysis of PM_{10}, it shows that most of particulate matters emitted from main sources in the Nah Phra Laan and its vicinity impact on source region and surrounding area. This is corresponded with the measurements of field campaign during 3-9 August 2005 [14]. PM_{10} concentrations were high only at the Nah Phra Laan stations in densely industrial area, but low PM_{10} concentrations were found at the sites where are located outside the Nah Phra Laan (Fig. 3). Spatial analysis found that the air pollution associated with particulate matter was

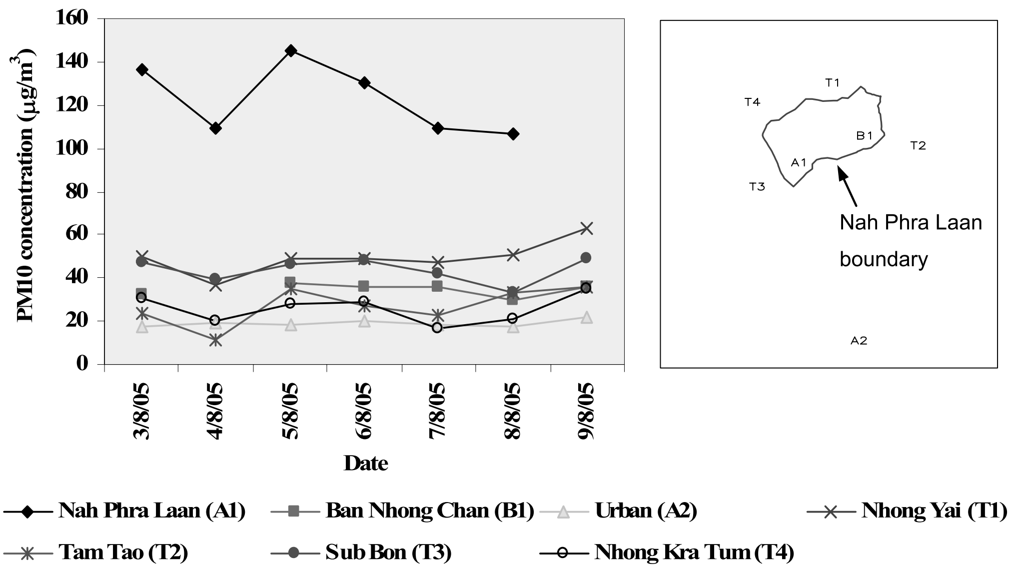

Fig. 3 Time series of daily average PM_{10} concentrations in Saraburi during 3-9 August 2005, Monitoring station in Saraburi (A1, A2, B1, T1-T4)

serious only in the Nah Phra Laan. The following investigation will be focused on the Nah Phra Laan area.

3.2 Temporal variations

Fig. 2 shows the annual average PM_{10} concentrations at the Nah Phra Laan, which varied from year to year during 2001 to 2005. In the last two years, 2004-2005, annual average PM_{10} concentrations increased moderately, but it decreased obviously in 2003. During 2001-2003, the PM_{10} concentrations exceeded the daily PM_{10} standard less than 50 days/year, but during 2004-2005, the PM_{10} concentrations exceeded the standard more than 100 days/year. The increasing of PM_{10} concentrations might be caused by the increasing of emissions of crushed stone plants and the transportation. The emissions from transportation of four main roads in the Nah Phra Laan from 2001 to 2005 were 807, 884, 1019, 1098, and 978 ton/year, respectively (The calculation use the number of total vehicles of each year and use road surface silt loading and average weight of vehicles in 2005). Lime stone productions in Saraburi during year 2001-2005 were 44, 54, 54, 68, and 66 million ton/year, respectively (Department of Primary Industries and Mines 2007). Although emission rate tended to increase, annual average PM_{10} concentration in 2003 decreased.

Meteorological parameters also influence the ambient concentrations. The measurement analysis shows that the significant parameter affecting annual average PM_{10} concentration was precipitation hours (precipitation hour is defined as an hour in which there is precipitation at least 0.1 mm.), which increased sharply in 2003. The variation from year to year of total yearly precipitation hours was high. The total yearly precipitation hours were 337, 356, 418, 278, and 292 hours during 2001 to 2005 (Fig. 4(a)). High inverse correlation between annual average PM_{10} concentrations and total yearly precipitation hours was found ($r = -0.988$). Precipitation was a significant factor, which affected the annual average PM_{10} concentrations. However, annual average PM_{10} concentrations did not correspond to the amount of total yearly precipitations, which were 461, 574, 549, 1,078, and 1,210 mm from 2001 to 2005 (Fig. 4(b)). Therefore, PM_{10} concentration was more influenced by the frequency of precipitation than the amount of precipitation. High effect of the frequency of rainfalls on PM_{10} level was found in another study [15]. That is why annual PM_{10} concentration was decreased obviously in 2003. However, the analysis based on 5 year dataset is a short period. It should be further investigated.

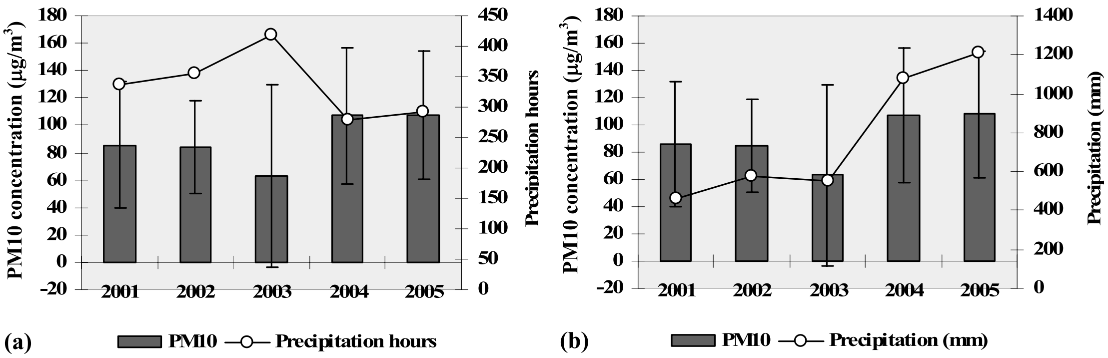

Fig. 4 Yearly variations of annual average PM_{10} concentrations and (a) precipitation hour, (b) precipitation (mm) at the Nah Phra Laan station during 2001-2005

3.2.1 Seasonal variations

PM_{10} levels in Saraburi exhibit seasonal variation as shown in Fig. 5. There is a regular pattern of the PM_{10} concentrations in urban area that PM_{10} concentrations are low during rainy season and high during winter, while seasonal variation of PM_{10} concentration at the Nah Phra Laan did not show obviously the same pattern. This may be related to the variations of local emissions and short-term weather conditions. Nevertheless, there are some similar variation, that is to say, there are increasing PM_{10} concentrations during winter and decreasing PM_{10} concentrations during summer. The statistical data of PM_{10} concentrations in season blocks at the Nah Phra Laan site during 2001-2005 are summarized in Table 2. The result shows that the highest PM_{10} problems occurred in winter. During winter 2001-2005, daily average PM_{10} concentration was 102.3 µg/m^3 and exceeded the daily NAAQS by 33%. While PM_{10} levels in summer and rainy season were nearly the same. The concentrations were 80.3 and 86.8 µg/m^3 respectively. Both seasons are also serious particulate problems with the number of PM_{10} exceedance days by 16% and 18% in summer and in rainy season respectively. It is surprising that there were high PM_{10} problems in the wet season. There will be an analysis in this point later in this paper.

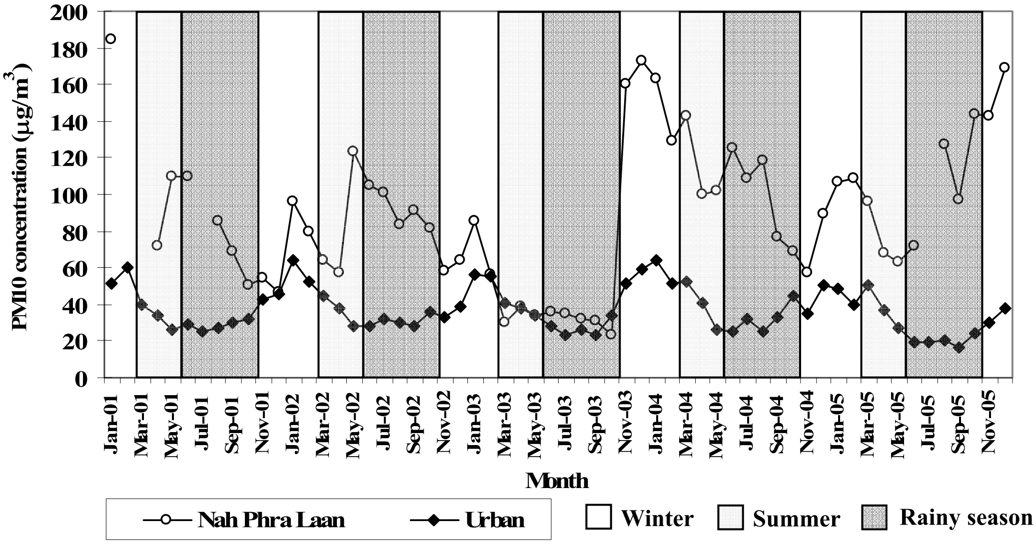

Fig. 5 Monthly average PM_{10} concentrations at monitoring stations in Saraburi, 2001-2005

Table 2 Summary statistics for PM_{10} concentrations at the Nah Phra Laan monitoring station during 2001-2005

	No. of data	Mean	Standard Deviation	No. of PM_{10} exceedance days
Total	1531	90.7	52.0	359 (23%)
Winter	535	102.3	66.0	178 (33%)
Summer	371	80.3	44.8	59 (16%)
Rainy season	625	86.8	38.7	114 (18%)

The main factors affecting the variation of ambient concentration are emissions and meteorological conditions. Emission rates in the Nah Phra Laan are fluctuant due to the variation of activity rates. For example, the total number of vehicle during 4-10 May 2005 was more than that during 5-10 August 2005, about 20% (32,410 vehicles during 4-10 May 2005, 26,384 vehicles during 5-10 August 2005). However, according to limitation of emission data, this study emphasized on meteorological parameters related to PM_{10} concentrations. The seasonal patterns of PM_{10} concentrations, precipitation hours, temperature, and stability conditions at the Nah Phra Laan during 2001-2005 can be seen from the monthly averages as presented in Fig. 6.

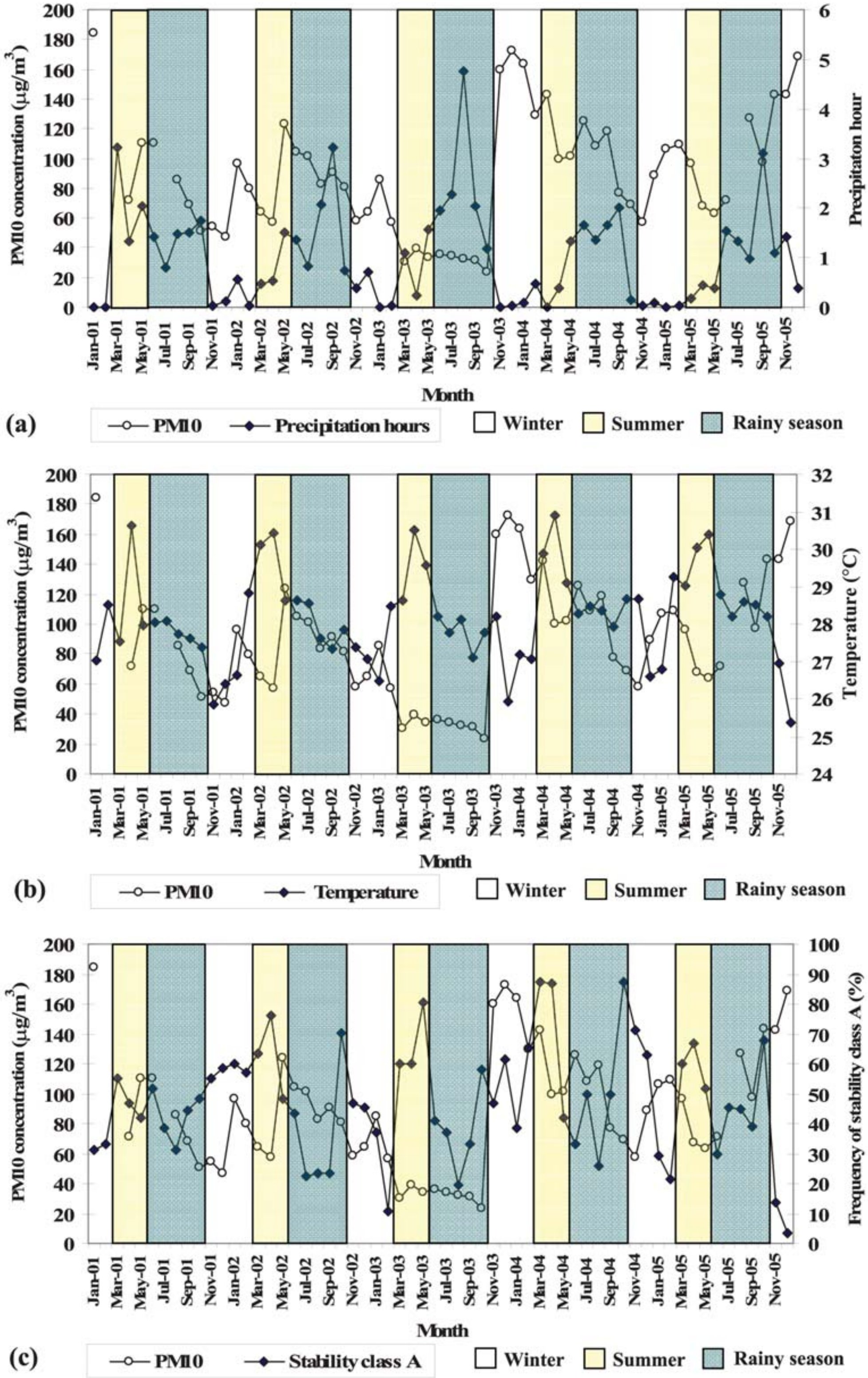

Fig. 6 Variation of monthly average PM_{10} concentrations and (a) precipitation hours, (b) temperature and (c) frequency of stability class A (at midday) at the Nah Phra Laan monitoring station, 2001-2005

Fig. 6(a) shows the variation of monthly average PM_{10} concentrations and precipitation hours at the Nah Phra Laan. Normally the PM_{10} concentrations were high in winter according to less precipitation, and low in rainy season due to wet deposition. In addition, precipitation enhances humidity, which reduces emission from the largest source of resuspended road dust (47% of total emission for emission inventory in 2005). The statistical data in Fig. 7 shows the relationship between the daily average PM_{10} concentrations and precipitations at the Nah Phra Laan in the period of 2001-2005. It shows that the daily average PM_{10} concentrations decreased while the precipitation hours increased. Moreover, the inverse correlation between PM_{10} concentrations and the amount of precipitation in working hours was evidenced. However, the relationship between daily average PM_{10} concentrations and the amount of precipitations in the whole day did not appear. This is may be due to more influence of wet deposition during high emission in working period that the large numbers of particulate matters are emitted to atmosphere because of working time of crushed stone plant and high traffic volume period. This is the other evidence showing that there is more influence of the frequency of precipitation on PM_{10} concentration than that of the amount of precipitation. Therefore, the relationship between PM_{10} levels and precipitation hours was studied in the next study, diurnal variation.

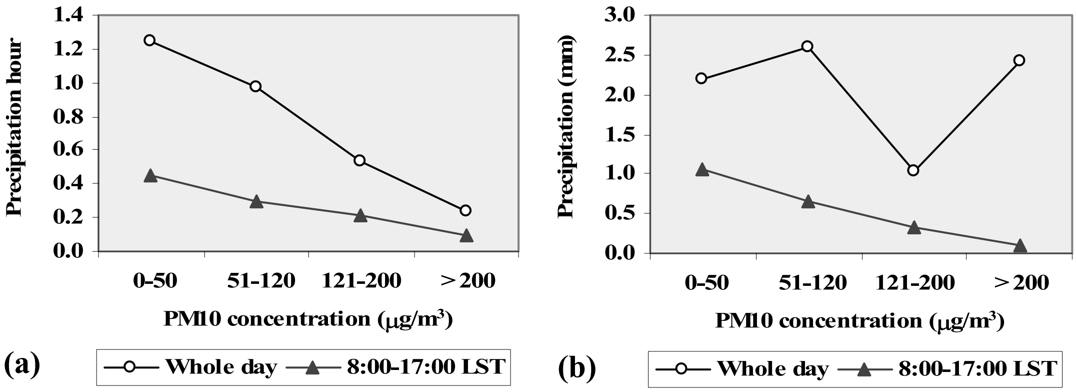

Fig. 7 Daily average PM_{10} concentrations and (a) average precipitation hour and (b) amount of precipitation (mm) at Nah Phra Laan monitoring station, 2001-2005

The relationship between monthly average PM_{10} concentrations and temperature can be seen in Fig. 6(b). Generally, the results show that high PM_{10} concentrations appeared with low temperature in winter, whereas low PM_{10} concentrations were noted with high temperature in summer. Statistical data during 2001 to 2005 at the Nah Phra Laan show that daily average PM_{10} concentration in winter was 102.3±66.0 mg/m^3 with daily average temperature at 27.1±1.7°C, while in summer daily average PM_{10} concentration was 80.3±44.8 μg/m^3 with daily average temperature 29.6±1.6°C. Normally, pollutants are more diluted by turbulent diffusion under higher temperature conditions. Temperature can be an indicator of many processes for example, a low mixing height that it confines dispersion of pollutant can be easily formed in winter nights with low temperature [16]. Estimate mid-day mixing heights in Chiang Mai, province in northern part of Thailand, during February and March were 900 m, while from April to October they were about 1,400 m [17].

Furthermore, the ambient concentrations related to the atmospheric stability conditions were investigated. The atmospheric stability is the most important parameter affecting dilution of air pollutions [18]. Atmospheric stability classes were classified by the criteria of Pasquill stability classes [6]. Fig. 6(c) shows monthly average PM10 concentrations and frequency of very unstable (stability class A) at midday. Generally, the result shows inverse correlation between PM_{10} concentrations and the frequency of very unstable. Low PM_{10} concentrations appeared in summer under high frequency of very unstable that pollutants dilute well, while lower frequency of very unstable occurred in winter and rainy season. Statistical data during 2001 to 2005 at the Nah Phra Laan show the frequency of very unstable of 64 %, 46 %, and 39 % during summer, winter and rainy season respectively. This result reveals the reason of high PM_{10} concentrations in rainy season that were associated with less frequency of very unstable condition.

3.2.2 Diurnal variations

Fig. 8(a) shows the diurnal variations of hourly average PM_{10} concentrations at Nah Phra Laan in winter, summer and rainy season during 2001-2005. The diurnal variations of PM_{10} concentrations characterize by two peaks at about 9-11 AM and 7-9 PM. From 4-8 AM, emission rate increased due to increasing in transportation and the high particulate matters were emitted from crushed stone plants during 8 AM – 5 PM as shown in Fig. 9. The particulate matters were accumulated in atmosphere causing elevated PM_{10} concentrations from around 6-11 AM until reached its peak around 9-11 AM that was saturated point. Although emission rate was still high after 11 AM, but the PM_{10} concentrations decreased due to the convective condition, which the pollutants dispersed quickly in this condition within the mixed layer [19]. Generally, the mixing height increases through the day and becomes maximum in the late afternoon and then decreases rapidly in nighttime [20]. The annual average mixing heights in Bangkok (about 100 km south of Saraburi) in 2003 reported by Thai Meteorological Department were 824, 925, 1,244, 1,225 and 675 m at 7 AM, 10 AM, 1 PM, 4 PM and 7 PM respectively. Due to quick decreasing of mixing heights in evening, PM_{10} concentrations increased from evening and were peak at about 7-9 PM. After that, the PM_{10} concentrations fell down because of low emission rate.

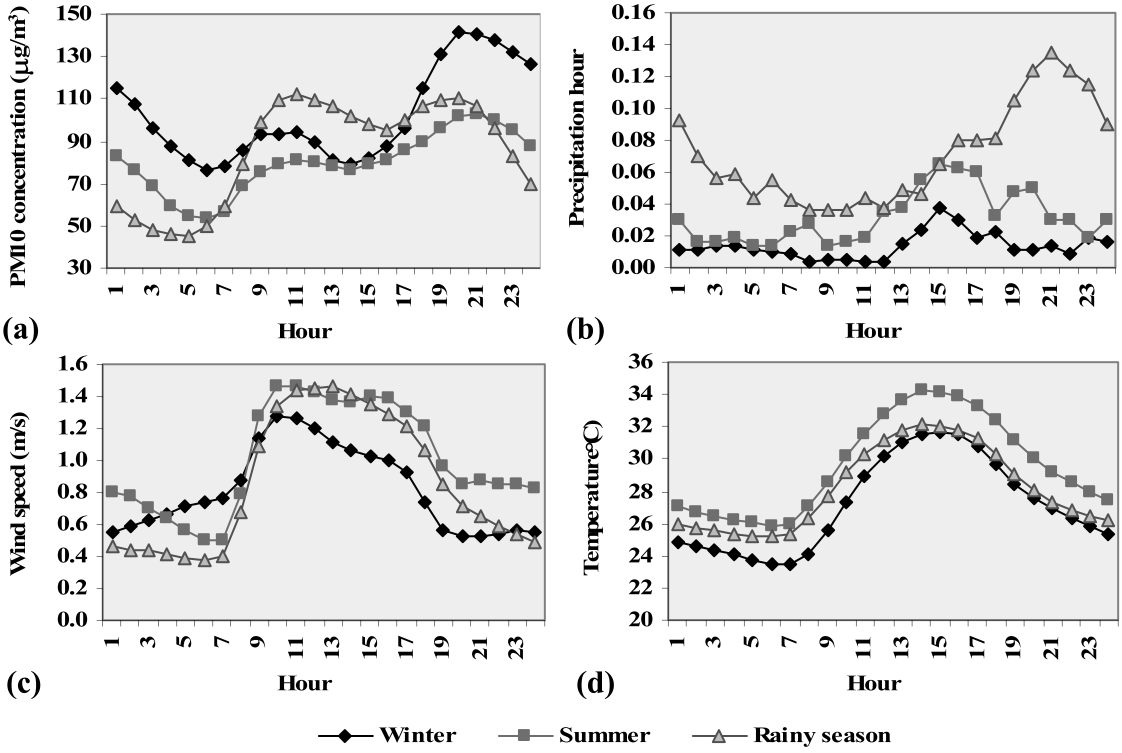

Fig. 8 Hourly averages of (a) PM_{10} concentrations, (b) precipitation hours, (c) wind speeds, and (d) temperatures at the Nah Phra Laan monitoring station during 2001-2005

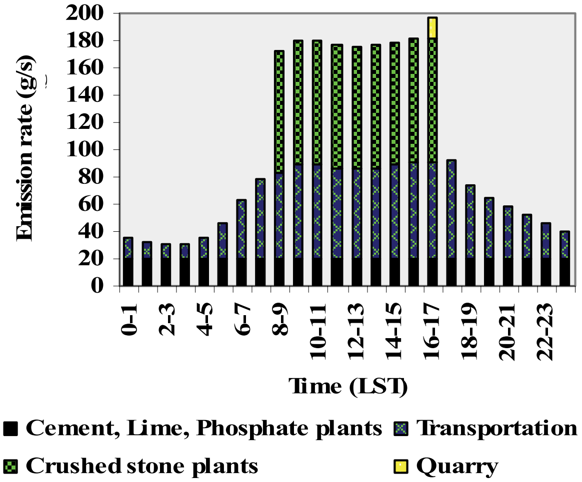

Fig. 9 Diurnal variations in PM_{10} emission from sources in Nah Phra Laan and its vicinity in workday (Monday-Saturday)

There are different diurnal variations for different seasons as shown in Fig. 8(a). In winter and summer, the highest peak of hourly average PM_{10} concentrations occurred about 8-9 PM and this peak was higher than the first peak in the morning, especially in winter. However, in rainy season the both peaks were nearly same level. This may be resulting from high precipitation in the evening in rainy season, which it can be seen in Fig. 8(b). In addition, the hourly average PM_{10} concentrations during 0-6 AM were low corresponding with high hourly average precipitation hours in this period. The highest hourly average PM_{10} concentration at 8 PM was revealed in winter, which it can be explained by low wind speed, precipitation and temperature (Fig. 8(b-d). In summer, low PM_{10} concentrations and low diurnal variation were found due to high wind speed and temperature causing good dispersion (Fig. 8(c) and 8(d)). Moreover, in evening hourly average PM_{10} concentrations were not too high due to the rain in some day in summer as shown Fig. 8(b).

4. Conclusions

According to the acquired data of hourly PM_{10} concentrations and meteorological parameters from air quality monitoring stations in Saraburi during 2001-2005, a serious particulate problem is in Nah Phra Laan, mineral products industrial area. This area appeared strong spatial variation of particulate matters. The strong spatial variation can be explained by low wind speed and coarse particles emitted mainly from crushed stone plants and resuspended dust from roads that they lead to a short lifetime in the atmosphere. Moreover, it was found that most of particulate matters emitted from sources in Nah Phra Laan and its vicinity impact on local area.

For seasonal variation, the highest PM_{10} problems occurred in winter associated with low precipitation, wind speed and temperature. Whereas, the lowest PM_{10} problems appeared in summer due to good dispersion condition that wind speeds and temperatures are high. The diurnal variations of PM_{10} concentrations occurred two peaks. The first peak was at about 9-11 AM and the highest peak was at about 7-9 PM resulting from weak wind speed and short mixing height. The diurnal variations in each season are different. Obvious highest peak of PM_{10} concentration in evening was found in winter. While, in rainy season PM_{10} concentrations were high in daytime and low in nighttime. During summer, diurnal variation was low.

Air quality management for particulate problem in Saraburi should focus to control emission sources in Nah Phra Laan and its vicinity. According to the particulate problems existing in every season and different PM_{10} distributions in each season, control measures should consider every season that the contribution of particulate matter from each source to ambient concentration might be different.

Measurement analysis can give the information of typical temporal and spatial variations of PM_{10} concentrations at the Nah Phra Laan site. However, only a point measurement can not show the dispersion of PM_{10} and explain fully understanding atmospheric process related to ambient conentrations. Thus, the integration of observations from field campaigns with results from air quality model over the same domain of time and space should be applied.

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