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Indoor Air Quality of PM2.5 in Classrooms of Science Building, Udon Thani Rajabhat University, Thailand

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Abstract

This work investigates for indoor air quality particulate matter 2.5 microns (PM2.5) in classrooms of Science building at the Faculty of Science, Udon Thani Rajabhat University, Thailand. The study was determined from selected five classrooms and monitored by a dust track meter during the summer (April-May 2019) and rainy season (June–July 2019). PM2.5 concentrations in summer were found between 53.1±11.10 μg/m^3, which over the maximum acceptable value PM2.5 for indoor air quality in office buildings (8 hours) by the Ministry of Public Health, Thailand (35 μg/m^3), while in the rainy found only 25.6±4.99 μg/m^3. This indicated summer was also possibly related to the thermal inversion phenomena, which often occurs in high and low temperatures between indoor and outdoor sites. The results showed the average PM2.5 concentration in laboratory rooms (43.2±9.36 μg/m^3) was higher than that of the lecture rooms (32.71 μg/m^3). This is because the activity of class occurred during the laboratory lesson time. Additionally, the outdoor source caused by air pollution from sugar cane combustion near Udon Thani University can be generated the high PM2.5 (Average 91.70±21.62 μg/m^3). As because of this, PM2.5 generated by particles of these activities was the critical environmental problems in the Udon Thani city. The results show that new data in Udon Thani university for the air quality (PM2.5) based on concentrations from indoor air in classroom, including caused of PM2.5 pollution is emitted from outdoor pollution sources. It is well known that air pollution constitutes the most pressing environmental health risk and environmental problems. Therefore, the data of this study to benefit for the local government and environmental organizations to reduce or prevent the concentrations of many pollutants are influenced by local in Udon Thani city.

Keywords : Indoor Air Quality; PM2.5; Air Pollution Monitoring; Classroom; Udon Thani

Introduction

Particulate matter 2.5 micron (PM2.5) is a major air pollution problem that can be contributed to the toxic and biological pathogen city [1]. PM2.5 can cause harm to the human respiratory system and deposits in alveolar regions [2]. The component of PM2.5 is well known generated by combustion during the waste combustion or using fireplaces [3, 4]. On the other hand, PM2.5 from outdoor sources originated mainly from internal combustion engine exhaust soot [5]. Thailand is the world's 4th largest sugarcane producer and the 2nd largest sugar exporter, while Udon Thani province is the major producer for a big sugar exporter in Thailand [6]. Udon Thani is located at the northeast of Thailand and serves as a centre of transportation and economic, especially the sugar industry [7]. Sugar cane is essential raw material for sugar industries, so it is important for problems effect of the environment [8]. The percentages of burned sugarcane in the production found higher and mainly caused by air pollution in the forms of smoke, toxic gas, dust, and particles in the air [9].

At present, the sugarcane industry's trend to expand every year, sugarcane farmers grow more sugarcane and harvest manually in most areas. For convenience, sugar cane farmers choose to burn sugarcane before harvesting, this burning prior to harvesting causes air pollution [10]. As because of this, PM2.5 generated by particles from the sugar cane burning is one of the most critical environmental problems in the Udon Thani city. The agricultural biomass burning is the major source of outdoor air pollution in Udon Thani province which is seasonal from January to April in every year. The situation could be worse in the future unless proper measures are undertaken. More recently, PM2.5 is well known negative health effects on humans and can lead to long-term and short-term health problems [11]. Specially, students in universities always spend more time in classrooms which can increase their inhaled doses of indoor air pollution [12, 13]. This is mostly air pollution, contaminated in the classrooms of the university such as allergens, particles, volatile organic compounds [14]. Moreover, a high concentration of PM2.5 in indoor air may cause acute or chronic health effects, and even cause premature deaths in the elderly people and people with asthma [15, 16]. Thus, the indoor air quality of PM2.5 should be studies became an important research topic for public health. Furthermore, the World Health Organization (WHO) also reports published the limit on indoor air pollution level of PM2.5 including the particularly in relation of classrooms in schools or universities is still limited [11, 17].

Therefore, the aim of this work was investigated the indoor air quality of PM2.5 in the university classrooms during lessons. The objective was to determine the concentration of PM2.5 including the temperature, and relative humidity was studied in five classrooms, which is located on the 6th floor of the Science building, Faculty of Science, Udon Thani Rajabhat University. Experimental method investigated during in the summer (April-May 2019) and rainy season (June-July 2019). The concentrations of particulate matter were determined by a DustTrak™ aerosol meter with using a light scattering principle. This method is wildly used for indoor air quality monitoring in office buildings following the methods reported in previous works [3, 4]. The level of PM2.5 concentration between different seasons and various floors of Science building was determined and compared. Finally, the obtained monitoring of indoor air quality PM2.5 including the maximum, minimum, and average PM2.5 concentrations in classrooms of the Udon Thani University was promoted to improve this situation or environment management in the future.

Methodology

Area sites

This work was studied in five classrooms by the purposive sampling of Science building (ScB) of the faculty of Science, Udon Thani Rajabhat University (Sam Phrao campus), where is in Udon Thani province. Udon Thani Rajabhat University has two main campuses, and the faculty of Science is in Sam Phrao campus (N 17.450816, E 102.936165). More information, the faculty of Science has four buildings, namely ScB1, ScB2, ScB3 and ScB4. The selected building on this work was selected from ScB1 (6^{th} floors). The indoor air quality of PM2.5 was carried out in the summer (April to May 2019) and rainy season (June to July 2019) to compare. The average data of indoor temperature, and relative humidity was also carried out.

Classroom sampling sites

The classrooms of Science building 1 (ScB1) in this work were divided by lecture room and laboratory room types. To compare the high PM2.5 concentrations during the activity in each classroom, the lecture room was studied for no class activity or movement, while in the laboratory room studied for class activities and movement. Indoor air quality data were collected from the ScB1 building (6^{th} floors). The classroom sampling was selected from each floor by the randomly sampling from 80% of the total floors of the building [18]. Therefore, the five selected classrooms were collected from 1^{st} - 5^{th} floor. For the limitations of monitoring instruments and class activity, this work monitored indoor air for PM2.5 concentrations in the selected five classrooms for once a week of one classroom and per one month. The five of selected classrooms from ScB1 were namely $ScB1_1$, $ScB1_2$, $ScB1_3$, $ScB1_4$ and $ScB1_5$ following the classroom from 1^{st} floor, 2^{nd} floor, 3^{rd} floor, 4^{th} floor and 5^{th} floor, respectively, as shown in **Figure 1**.

The period time in this work was investigated on a working day with 8 hours (08.00 a.m. to 16.00 p.m.) to compare with the maximum acceptable value for indoor air quality in office buildings that PM2.5 must not exceed 35 μg/m^3. All the lecture room type ($ScB1_1$ and $ScB1_2$) had a same capacity of 40 persons and a volume of 192 m^3, while all the laboratory room type ($ScB1_3$, $ScB1_4$ and $ScB1_5$) had a same capacity of 60 persons and a volume of 384 m^3. All classrooms were equipped with the standard school tables, chairs, fans, and a blackboard with chalk at the front. In addition, the selected classrooms of ScB1 building were naturally ventilated by opening windows all time in the lecture with the class activity. All classrooms in this studied had no air conditioning and open all windows during the monitoring time.

Sampling of PM2.5 by a DustTrak meter

PM2.5 was determined by a DustTrak meter with a model 1103 (TSI Incorporated, USA). PM2.5 was monitored and measured by a DustTrak meter with flow rate 3±0.01 L/min based on of a light scattering method. The particle of PM2.5 concentrations was measured with a real-time in each classroom and obtained with a 1-minute time resolution. The instrument was calibrated daily to a zero filter that used to zero setting as a unit and ensure for accuracy of reading. The DustTrak meter was placed in a middle back corner of the classroom about 1.0 m above the floor, which corresponds to the breathing zone of the sitting student, as illustrated in **Figure 2**. To study indoor air quality that influenced by and therefore related to outdoor air quality, the PM2.5 concentration was also measured. The DustTrak meter was placed in a front of ScB1 building about 1.5 m above the floor and 1.0 m from the roadside, which corresponds to the ambient air monitoring.

Figure 1 The selecting classrooms of Science building (ScB1) with each floor

Figure 2 The sampling of PM2.5 by a DustTrak meter in classrooms

Results and Discussion

Temperature and relative humidity in classrooms

A monitoring of indoor air quality PM2.5 from the selected five classrooms in the Science building (ScB1), Faculty of Science, and Udon Thani Rajabhat University was investigated the temperature (T) and the relative humidity (RH) as shown in **Table 1**.

A summary detailed of temperature and relative humidity in the classrooms from April to July 2019 is divided into summer and rainy seasons as shown in Table 1. Thailand is a most of the rains in the June to September that considered as the rainy season, while January to early May is considered as summer of the year. The average of temperature and relative humidity in the selected five classrooms were 30.96±2.63℃, RH=72.0±8.6%, respectively. Obviously, the average temperature in

classrooms in summer found 33.06±2.12°C, while in rainy found 28.85±0.48°C. For the average relative humidity was also the same trend, it was found 64.1±4.4% in summer, while in rainy found 79.8±1.2%. It was observed that the temperature and relative humidity in summer were higher than that of in rainy. As the results, it was considered to discuss for the factors of dust re-suspension in the next discussion.

Table 1 Temperature and relative humidity values of the selected five classrooms in winter and rainy season

Floor of building	Name	Room type	Summer (2019)				Rainy season (2019)			
			April		May		June		July	
			T (^{o}C)	RH (%)	T (^{o}C)	RH (%)	T (^{o}C)	RH (%)	T (^{o}C)	RH (%)
1	$ScB1_1$	Lecture	35.5	61	31.5	68	29.5	81	29.0	80
2	$ScB1_2$	Lecture	34.7	60	30.7	69	29.0	80	28.3	81
3	$ScB1_3$	Laboratory	35.0	59	30.5	69	28.7	82	28.0	78
4	$ScB1_4$	Laboratory	35.0	60	31.0	67	29.0	79	28.5	79
5	$ScB1_5$	Laboratory	35.0	60	31.7	68	29.5	79	29.0	79
Average of month			35.04	60.0	31.08	68.2	29.14	80.2	28.56	79.4
Average of season			T = 33.06±2.12°C, RH = 64.1±4.4%				T = 28.85±0.48°C RH = 79.8±1.2%			
Average of classrooms			30.96±2.63°C, RH=72.0±8.6%							

PM2.5 levels in classrooms

The average PM2.5 concentrations obtained from a real-time monitoring of 8 h from the selected five classrooms. In the summer, it was found that the average PM2.5 concentration were 53.1±11.10 μg/m^3, while in the rainy season only 25.6±4.99 μg/m^3. For comparison of month, the results showed the average of PM2.5 concentrations in ranged from 63.0, 40.8, 26.6 and 24.6 μg/m^3 in April, May, June, and July (2019), respectively. When comparing the different type room with the same students (40 persons), it was differences for observed for the average of PM2.5. The PM2.5 concentration in a laboratory room type (43.2±9.36 μg/m^3) was higher compared with a lecture room type (32.71 μg/m^3). This result indicated that the concentration of PM2.5 was increased in summer season, especially in April 2019 (63.0±10.60 μg/m^3) that observed in the highest temperature (35.04°C). The higher PM2.5 concentrations in summer were also possibly related to the thermal inversion phenomena, which frequently occurred in high and low temperature. The maximum acceptable value for the indoor air PM2.5 in office buildings is limited in 8h at 35 μg/m^3 [18]. As the results, the average PM2.5 concentration in this work (April to July 2019, monitored 8h per day) was found 38.75±12.81 μg/m^3 that over limited of the maximum acceptable value for the indoor air PM2.5 in office buildings. A high PM2.5 concentration was found during class activities from the laboratory room type and ground floor of building that should be focus. Therefore, it should be beware and continue monitored to find environmental management in this situation.

Generally, a high PM2.5 level was found in the classrooms indicating the particles related to major PM2.5 indoor sources such as blackboard dust and organic matter of students as well as the re-suspension phenomena of particles. However, many previous reports [12, 17] .were found the outdoor sources also main factor to increase the level of PM2.5 in the classroom, such as the vehicle's combustion, the burning industries or the product burning from agriculture. Udon Thani province is the major producer for a big sugar cane exporter and sugar cane burning process was mainly caused to the air, hence, it is important for problems effect of the environment. Especially for sugarcane farmers in Sam Phrao in Udon Thani province, their mostly burned the sugarcane in December to April in every year and it obtained to the toxic gas, dust, and particles that caused to problem of air pollution. The biomass activities from the burning sites related to the university was found in the working time of day (07.00 a.m.-17.00 p.m.). The approximately size of burning was 2500 rai. As because of this, PM2.5 generated by particles from the sugar cane burning is one of the most critical environmental problems in the classroom of Udon Thani Rajabhat University.

According to Table 2, the average of PM2.5 in summer generated from outdoor source was found at 129.2±17.26 μg/m^3, while in rainy was found at 54.2±10.23 μg/m^3. Obviously, these results could be explained that in the summer (April to May 2019) showed the higher PM2.5 more than in the rain (April to May 2019) as shown in Figure 3. Moreover, April 2019 was observed the highest PM2.5 concentration (63.0μg/m^3) that caused from outdoor sources (159.8μg/m^3) by sugar cane burning and the high temperature (35.04°C). In the rainy season, it has the rain effect that can be reduced the particle in the ambient air from the outdoor source. This is the effect of the low PM2.5 concentration in June and July 2019. Additionally, the higher levels of particle concentration found in summer were in accordance with the corresponding to previous studies [14, 15].

Table 2 Summary of the average PM2.5 concentrations in selected five classrooms

Floor of building	Classroom	Description	Room area (m^2)	PM2.5 concentrations (μg/m^3)							
				Summer (2019)				Rainy (2019)			
				April		May		June		July	
				Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor	Indoor	Outdoor
1	$ScB1_1$	Lecture	192	55	126	37	88	24	50	22	44
2	$ScB1_2$	Lecture	192	48	110	33	70	20	46	18	43
3	$ScB1_3$	Laboratory	384	82	227	59	127	34	81	32	70
4	$ScB1_4$	Laboratory	384	62	155	39	117	27	53	26	48
5	$ScB1_5$	Laboratory	384	68	181	36	91	28	58	25	49
Average of month				63.0	159.8	40.8	98.6	26.6	57.6	24.6	50.8
Average of season				Indoor air 53.1±11.10 μg/m^3				Indoor air 25.6±4.99 μg/m^3			
				Outdoor air 129.2±17.26 μg/m^3				Outdoor air 54.2±10.23 μg/m^3			
Average of indoor air pollution				38.75±12.81 μg/m^3							
Average of outdoor air pollution				91.70±21.62 μg/m^3							

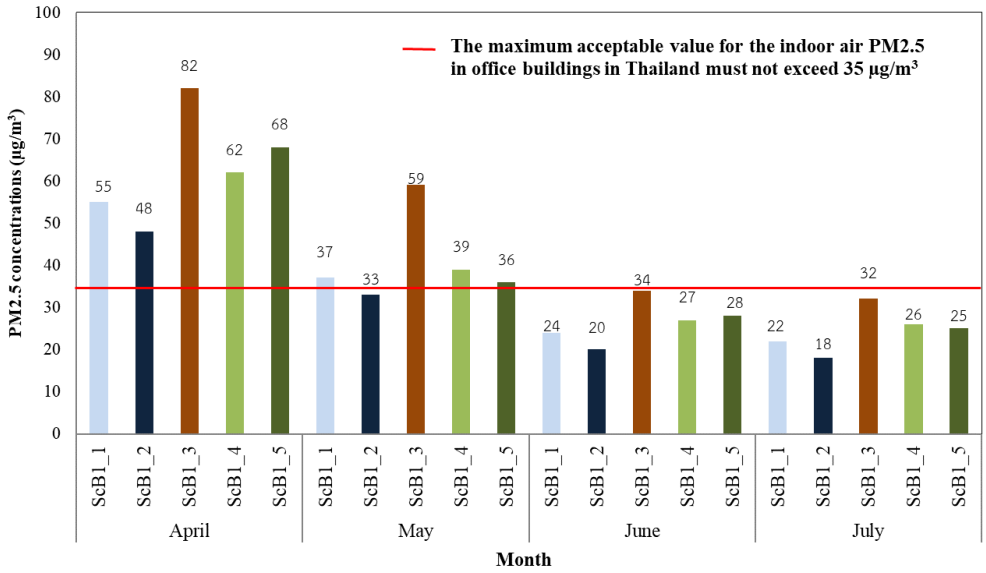

Figure 3 The concentration of PM2.5 from five classrooms for each month

The indoor air quality of PM2.5 concentration measured from five classrooms was focused within each class of the month. Considering for each month, the result indicated the PM2.5 concentrations from a laboratory room ($ScB1_3$, $ScB1_4$ and $ScB1_5$) was higher more than a lecture room ($ScB1_1$ and $ScB1_2$). The high PM2.5 concentrations were found during the activity class in each day, while in the lecture room no class activity or movement. Thus, the PM2.5 concentrations from a lecture room were observed less. This is because of a major classroom activity occurred, rather than during class time when the student was seated at their tables. Moreover, a high concentration of PM2.5 was also detected in the higher floor more than that of the first floor. This is because during break time, students were movement for going in and out of the classrooms. Furthermore, it was obvious that the average PM2.5 concentration was higher in the front of classrooms than in the rear of the classrooms that caused by a fine particle from backboard. These indicated that one possible reason for PM2.5 pollution in the classroom was the re-suspension of settled particles due to the class activity of the student movement. More understandingly, this study found the indoor particle number concentrations at classrooms were related to the high activity times, and higher in summer than in rainy, according to the previous studies [4, 12]. The maximum PM2.5 concentration was observed after studying after 1 h in the morning and afternoon, while the minimum PM2.5 also observed in lunchtime and after studied over 3 h, as illustrated in **Figure 4**. It is difficult to make a direct comparison, because of different sampling time and measuring instrument used between studies.

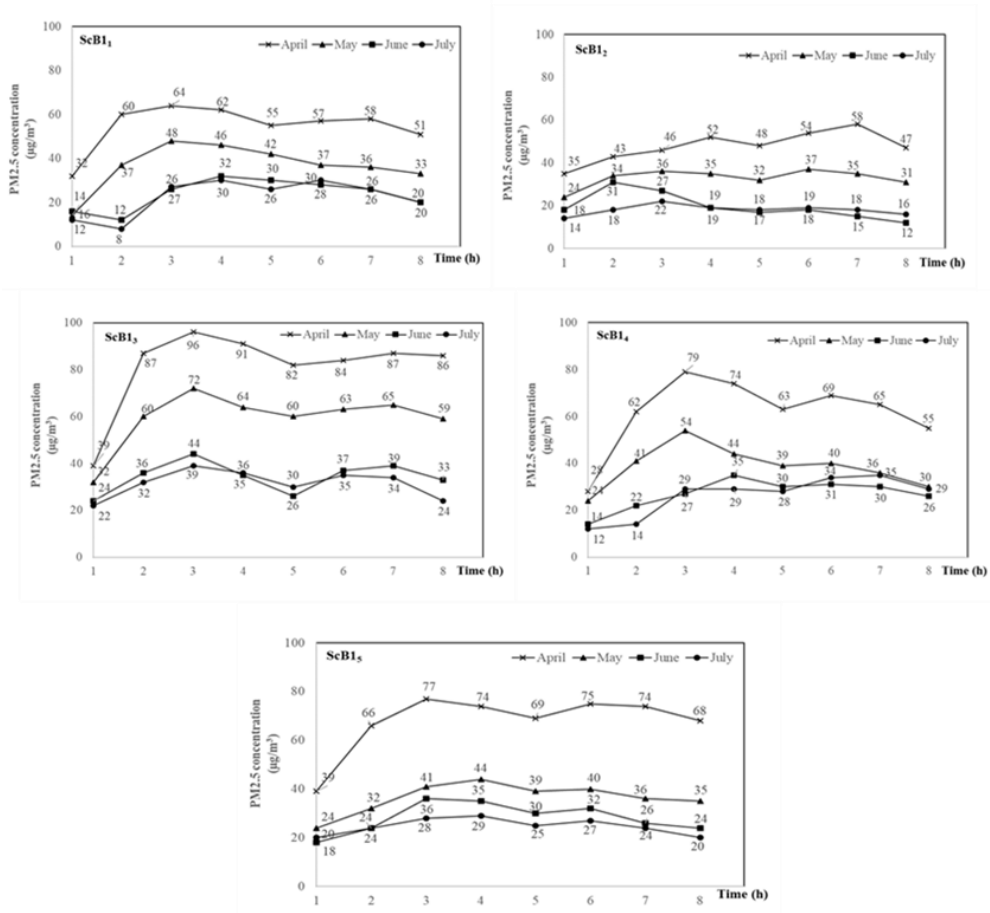

Figure 4 A real-time 8h for PM2.5 concentration monitored from each classroom

Conclusion

The study was determined from five classrooms within each level of the Science building. In summer found the higher PM2.5 concentration more than that of in rainy. This is because the activities from class, sugar cane burning pollution from the outside and meteorological in high temperature. During the rain, the windows were closed during class studied to prevent rain and dust from entering classrooms. In the summer, the windows were open most of the time, in this case the high indoor particular matter levels observed in our study could be explained by infiltration from the outdoor environment and the movement of student studied in classrooms. It can be indicated that distribution of PM2.5 concentration was increased in summer season. Moreover, a high concentration of PM2.5 from difference five classrooms was dependent on class activity occurred, rather than during class time when the student was seated at their tables. A laboratory room found PM2.5 concentration higher that of a lecture room. This is because during break time, students were movement for going in and out of the classrooms, and recreational activities inside the building with different floor. The results in this study show that air quality of PM2.5 based on

concentrations of the indoor air in classrooms at Faculty of Science, Udon Thani Rajbhat University, including how much of each pollutant is emitted from various pollution sources. It could be observed that outdoor air pollution is the one of the health and environmental problems. The results showed the concentrations of PM2.5 pollutants are influenced by local. Therefore, the indoor air quality in this work is influenced by and therefore related to outdoor air quality. In addition, the data of this study the new data of air pollution in Udon Thani province including outdoor air pollution impact to health student that could be benefit for the local government and environmental organizations to enforce to reduce or prevent the concentrations of many pollutants are influenced by local in Udon Thani city.

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