Air Quality Monitoring around the Developed Area of Chulalongkorn University in Kaeng Khoi District, Saraburi Province

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Abstract

The construction project for the developed area in Kaeng Khoi district, Saraburi Province, Thailand, drafted by Chulalongkorn University has raised various concerns over environmental impacts, particularly relating to public health and air quality. In order to investigate impacts of this project, air quality sampling was conducted in Tan Diew sub-district, Huai Haeng sub-district, Cham Pak Paew sub-district and some surrounding sites of Chulalongkorn developed area by gravimetric method using a high volume air sampling machine. Two types of particulate matter including total suspended particulate matter (TSP) and particulate matter < 10 μm (PM_{10}) were continuously monitored during all 3 seasons for a study period of 3 years in order to compare the effect of seasonal variation on the amount of particulate matter generated in each study area, to study the correlation between TSP and PM_{10}, and finally to identify other causal factors related to particulate levels. Results from this study indicated that TSP and PM_{10} both reached the highest in winter followed by summer and appeared to be at the lowest level during the rainy season. In addition, causal factors such as wind direction and human activities also influenced particulate levels in each study area.

Keywords: Total suspended particulate (TSP); particulate matter (PM_{10}); seasonal variation; air quality

Introduction

Urban expansion has driven a major boom in construction of basic infrastructure to serve a growing population. Chulalongkorn University has also prepared for the construction project of new educational centers in 3 sub-districts of Kaeng Khoi district, Saraburi province, which are Tan Diew, Huai Haeng and Cham Pak Paew sub-district. However,

concerns of inevitable impacts on air quality and public health affected by this construction project have been subsequently raised. Infrastructure construction can be considered as a source of various pollutants and also its impact on nearby communities also need to be considered. Therefore, the assessment of environmental impact during project construction and operation is necessary especially, the start-up phase for construction. The majority of particulate matters especially TSP and PM_{10} found within the project boundary as a result of construction have been studied by many researchers [2, 3]. Moreover, impacts of both particulate matters could further exacerbate the situation as a result of other human activities such as open-paddy field burning, chemical spraying, and transportation. Furthermore, natural factors such as seasonal variation and weather conditions may further elevate levels of airborne particulates [1], especially total suspended particulates (TSP) and particulate matter <10 μm (PM_{10}). Pengchai et al. (2008) [6] found that construction sites in Chiang Mai have higher level of TSP and PM_{10} than other area resulting from vehicle operation, cement mixing, and transporttation. Muangjai (2010) [5] also reported that construction areas in Chiang Mai province have a high level of TSP and PM_{10} in winter season (November to February) to decrease in summer (March to April) and the rainy season (May to October), respectively. This is due to slight wind and stable atmosphere in winter season. Human health can be adversely affected by exposure to these particulates since they can accumulate in the human body and subsequently cause respiratory disorder to people who live nearby the construction project [4].

It is to say that air quality is an important environmental issue because the particulate matter can cause respiratory diseases and also acute disorder to frequently-exposed persons. It is confirmed by Chang et al. (2005) [7] that workers who are always expose to TSP and PM_{10} have a symptom of respiratory disorder by 3.68 times more than unexposed workers. Maddison (2005) [8] also found that mortality rate of the TSP and PM_{10} on fre-

quently-exposed persons is higher than unexposed workers at about 1.86 fold. Therefore, it is necessary to continuously monitor air quality and particulate concentration, especially around the construction project of Chulalongkorn University in Kaeng Khoi district, Saraburi province. For this reason, this study emphasized to investigate particulate concentrations, most notably TSP and PM_{10} around the project area during 2011-2013 in order to identify their impacts, to understand the relationship between TSP and PM_{10}, and finally to find out emission sources of particulate matters.

Methodology and apparatus
1) Methodology

Four sites surrounding the construction project in Kaeng Khoi district, Saraburi province were selected for this study which include 1) Tan Diew sub-district 2) Huai Haeng sub-district 3) Cham Pak Paew sub-district and 4) the construction area of Chulalongkorn university in Ban Wang Pae, Cham Pak Paew sub-district (Figure 1). Air quality sampling by gravimetric method using a high volume air sampling machine was conducted continuously in all selected sites with 3 duplicates in each site. In order to identify different types of particulate matter from air sampling, a glass fiber air filter was used for TSP and a quartz fiber air filter was used for PM_{10}. Air samples had been collected continuously for 3 years between 2011 and 2013 taking into account the timeline of this construction project in order to cover all construction phases and all 3 different seasons (winter, summer and rainy season). Each air filter was used for 24 hours continuous air sampling; then replaced with a new filter. After the sampling was completed, the air filters were 24 hour-dried in a desiccator. Subsequently, the concentration of TSP and PM_{10} were analyzed by following the air sampling equation for Gravimetric Method. Results obtained from air sample analysis were compared to the standard levels of air quality for TSP and PM_{10} set by the Pollution Control Department of Thailand which is at 0.33 mg/m^3 for TSP and 0.12 mg/m^3 for PM_{10}, respectively [9].

2) Statistical analysis

In order to investigate air quality during the construction project, results of TSP and PM_{10} were statistically analyzed by a non-parametric test using the Statistical Package for the Social Science (SPSS) version 17 employing the following methods;

• Comparing the effect of seasonal variation on TSP and PM_{10} generated in each study area by conducting Chi-Square tests.

• Investigating the relationship between TSP and PM_{10} in each selected site by calculating Correlation Coefficients.

• Analyzing the correlation of TSP and PM_{10} with the number of respiratory disorder patients in Kaeng Khoi hospital by calculating Correlation Coefficients.
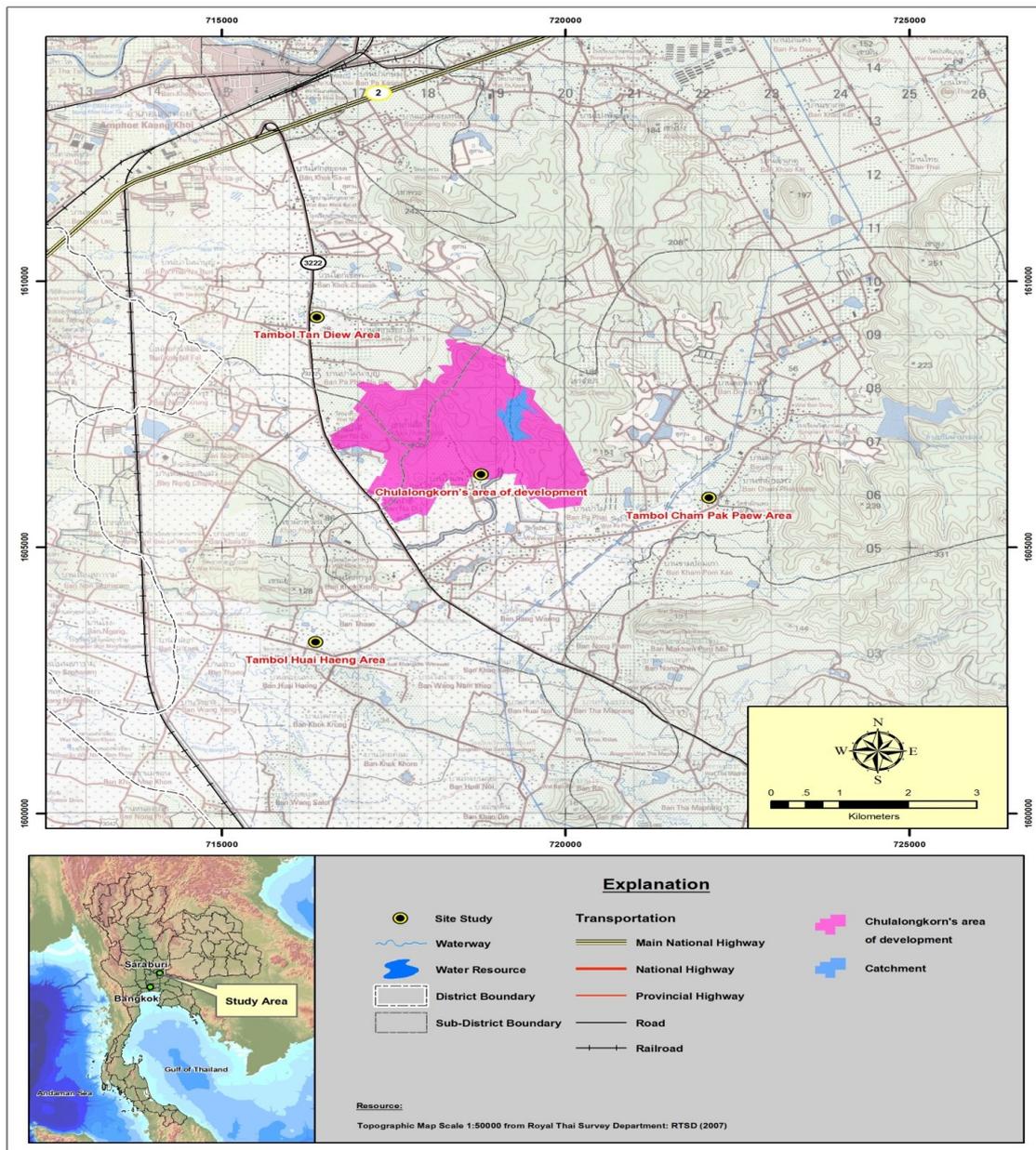
Figure 1 Site sampling areas

Results and discussion

Results from air quality monitoring around the construction project for the developed area of Chu-

lalongkorn University in Kaeng Khoi district, Saraburi province can be summed up as followings:

1) The concentration of TSP and PM$_{10}$ in the different study areas of Kaeng Khoi district, Saraburi province

After air sampling was completed, TSP and PM$_{10}$ contained in air filter samples were analyzed. The results clearly indicate that TSP concentrations in filters collected from Tan Diew sub-district, Huai Haeng sub-district, Cham Pak Paew sub-district and the construction area of Chulalongkorn University in Ban Wang Pae, Cham Pak Paew sub-district were all lower than 0.33 mg/m^3, the standard TSP level in ambient air set by the Pollution Control Department of Thailand during every season along the study years of 2011-2013 (Table 1). For PM$_{10}$ concentrations, as presented in Table 2, the results show that PM$_{10}$ in Huai Haeng sub-district and Cham Pak Paew sub-district during the entire study period was within the acceptable level of 0.12 mg/m^3 for PM$_{10}$ in ambient air. However, in the winter of 2011, it appeared that PM$_{10}$ in the area of Tan Diew sub-district and the construction project in Ban Wang Pae exceeded the standard PM$_{10}$ level. The average PM$_{10}$ level in Tan Diew sub-district was at 0.1283 mg/m^3 which is 1.06 fold higher than the standard. This might be a result of open-paddy field burning by local farmers during that period [10]. However, it later decreased to be within the standard level in 2012-2013 because plough up and over method for rice straw was used in that area instead of rice field burning. This is also in accordance to Pimonsri et al. (2008) [11] who found that open burning would generate PM$_{10}$ and other air pollutants about 2.1 fold higher than the pollutants generated from plough up and over method for corn cultivation. The average level of PM$_{10}$ in the construction area of Chulalongkorn University in Ban Wang Pae was found to be at 0.1722 mg/m^3 in 2011 which is 1.43 fold higher than the standard resulting from various construction activities during the start-up period of the project in 2011. However, Chulalongkorn University created a mitigation plan to alleviate such higher level of PM$_{10}$ in that period. Consequently, PM$_{10}$ in the construction area subsequently decreased to be within the standard level in 2012 – 2013 [12].

2) Effects of seasonal variation on TSP and PM10 generated in each study area

In order to investigate the effect of seasonal variation, TSP and PM10 levels in each season (winter, summer and rainy season) from different study areas are compared in this part. Both TSP and PM$_{10}$ levels in Tan Diew sub-district, Huai Haeng sub-district, Cham Pak Paew sub-district and around the construction project of Chulalongkorn University in Ban Wang Pae (Figure 2 and 3) were at the highest level in winter, then decreased in summer and followed by rainy season accordingly. In addition, statistical analysis clearly revealed that TSP was significantly higher at $P<0.05$ in winter as compared to the other seasons. Also, the data of PM$_{10}$ was in the same direction as TSP. Puangthongthub et al. (2007) [13] suggested that the higher level of TSP observed in the winter might be the result of low moisture and high pressure which has subsequently made a long period suspension of TSP in ambient air. However, a significantly high TSP at $P<0.05$ was observed at Huai Haeng sub-district during the rainy season rather than the summer of 2011. This is because rain storms bring particulate matter from the hills to this area. Moreover, other related factors such as incomplete combustion of open field burning in a high humidity atmosphere during the rainy season could be a source of high particulate matter. Pimonsri (2010) [14] also stated that wildfires occurred during a high moisture atmosphere, such as in the rainy season, would create more particulate matter; about 1.5 fold than complete combustion occurred in winter due to the product from complete combustion being in the form of gases rather than particulates. The PM$_{10}$ concentration of the construction project in Ban Wang Pae also appeared to be above the acceptable level in the winter of 2011. This was resulting from activities of local farmers who normally burn rice straw in a paddy field after harvesting [12].
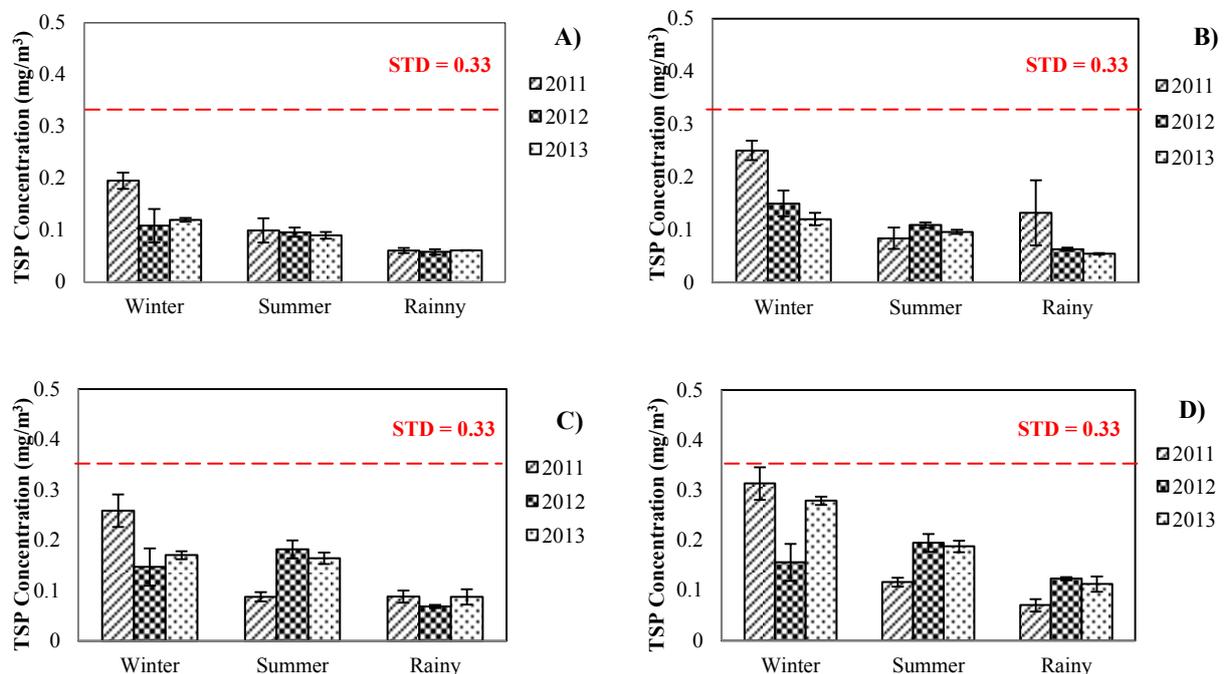
Table 1 Data of TSP in study areas

TSP (mg/m³)

Year	Season	Tan Diew sub-district					Huai Haeng sub-district					Cham Pak Paew sub-district					Chulalongkorn construction area in Ban Wang Pae				
		Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd
2011	Winter	0.1774	0.2052	0.1955	0.204	0.0157	0.2372	0.2635	0.2504	0.2504	0.0186	0.2295	0.2934	0.2585	0.2526	0.0324	0.271	0.3965	0.3135	0.2731	0.0719
	Summer	0.0384	0.1227	0.0996	0.0997	0.0232	0.0694	0.1069	0.0837	0.0749	0.0203	0.0797	0.0973	0.0874	0.0853	0.009	0.1035	0.1296	0.1166	0.1166	0.0185
	Rainy	0.0233	0.0254	0.061	0.061	0.0049	0.084	0.2018	0.1319	0.11	0.0619	0.0739	0.0958	0.088	0.0943	0.0122	0.0626	0.0814	0.0703	0.0669	0.0099
2012	Winter	0.043	0.0758	0.1088	0.1072	0.0324	0.1264	0.1752	0.1497	0.1476	0.0245	0.1048	0.176	0.1467	0.1592	0.0372	0.1186	0.2211	0.156	0.1284	0.0566
	Summer	0.0405	0.0546	0.0963	0.0912	0.0089	0.1051	0.1145	0.1085	0.106	0.0052	0.1623	0.1971	0.1819	0.1862	0.0178	0.1903	0.2006	0.1948	0.1934	0.0053
	Rainy	0.0279	0.03	0.0582	0.0577	0.0052	0.0611	0.0664	0.063	0.0614	0.003	0.0644	0.0705	0.068	0.0691	0.0032	0.1219	0.125	0.1234	0.1233	0.0016
2013	Winter	0.0437	0.0608	0.1201	0.1222	0.0037	0.1087	0.1325	0.12	0.1188	0.0119	0.1611	0.1768	0.17	0.172	0.008	0.2686	0.2853	0.2789	0.2828	0.009
	Summer	0.0379	0.0432	0.0901	0.0928	0.0065	0.0915	0.0992	0.0957	0.0965	0.0039	0.1548	0.177	0.164	0.1602	0.0116	0.1838	0.1933	0.188	0.1868	0.0049
	Rainy	0.0294	0.0359	0.0612	0.0613	0.0002	0.0523	0.0554	0.0542	0.0549	0.0017	0.0701	0.0996	0.087	0.0913	0.0152	0.0989	0.1259	0.1125	0.1127	0.0135

Table 2 Data of PM₁₀ in study

PM_{10} (mg/m³)

Year	Season	Tan Diew sub-district					Huai Haeng sub-district					Cham Pak Paew sub-district					Chulalongkorn construction area in Ban Wang Pae				
		Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd	Min	Max	Average	Median	Sd
2011	Winter	0.0889	0.1585	0.1283	0.1375	0.0357	0.0864	0.1262	0.1083	0.1122	0.0202	0.084	0.1201	0.1011	0.0993	0.0181	0.1407	0.1912	0.1722	0.1848	0.0275
	Summer	0.0384	0.0494	0.0437	0.0433	0.0055	0.0368	0.0589	0.0468	0.0447	0.0112	0.038	0.0414	0.0394	0.0387	0.0018	0.0449	0.0512	0.0473	0.0458	0.0034
	Rainy	0.0233	0.0254	0.0244	0.0244	0.0015	0.0251	0.034	0.0295	0.0293	0.0045	0.0272	0.0444	0.0338	0.0299	0.0093	0.0286	0.0438	0.0358	0.0349	0.0076
2012	Winter	0.043	0.0758	0.0579	0.055	0.0166	0.0596	0.0916	0.0774	0.0811	0.0163	0.0653	0.0822	0.0754	0.0787	0.0089	0.0492	0.0672	0.0582	0.0582	0.009
	Summer	0.0405	0.0546	0.049	0.0518	0.0075	0.0481	0.0564	0.0515	0.0499	0.0044	0.0547	0.0569	0.0558	0.0559	0.0011	0.0523	0.0555	0.0535	0.0526	0.0018
	Rainy	0.0279	0.03	0.0287	0.0281	0.0012	0.0283	0.0349	0.0317	0.0318	0.0033	0.0342	0.0368	0.0353	0.035	0.0013	0.0364	0.0429	0.0393	0.0386	0.0033
2013	Winter	0.0437	0.0608	0.053	0.0546	0.0087	0.0589	0.0686	0.0633	0.0623	0.0049	0.0688	0.0762	0.0714	0.0691	0.0042	0.0599	0.067	0.0641	0.0655	0.0037
	Summer	0.0379	0.0432	0.0405	0.0404	0.0027	0.0535	0.0576	0.0552	0.0545	0.0021	0.0585	0.0614	0.0602	0.0607	0.0015	0.061	0.0619	0.0614	0.0613	0.0005
	Rainy	0.0294	0.0359	0.0336	0.0355	0.0036	0.0373	0.048	0.043	0.0437	0.0054	0.0423	0.0481	0.0453	0.0455	0.0029	0.0406	0.0503	0.0454	0.0454	0.0049

Overall, it can be concluded that seasonal variation directly affects the distribution of particulates in ambient air of the study areas in Kaeng Khoi district. Pimonsri (2009) [15] also stated that this variable affects the behavior of particulate matter. Her study in Chiang Mai province confirmed that concentrations of TSP and PM_{10} in winter were 1.25 fold higher than summer and 2.3 fold higher than rainy season. Similar to the winter in Saraburi province, the winter in the northern Thailand also has a characteristic of low air pressure coupled with a high dryness which is an important combination that affects the concentration of generated particulates. Regarding the rainy season which has a characteristic of an unstable air pressure the level of particulates can decrease by many related factors such as rain storms or strong winds. This is also supported by Viroj (2008) [16] who studied the effect of seasonal variation on the concentration of air pollutants in Mae Hong Son province. He/She found that TSP and PM_{10} levels in winter were higher than in summer and rainy season. Moreover, open field burning which is normally done in winter led to higher detected levels of air pollutants in winter rather than other seasons.

Figure 2 Air qualities within areas of study (TSP)
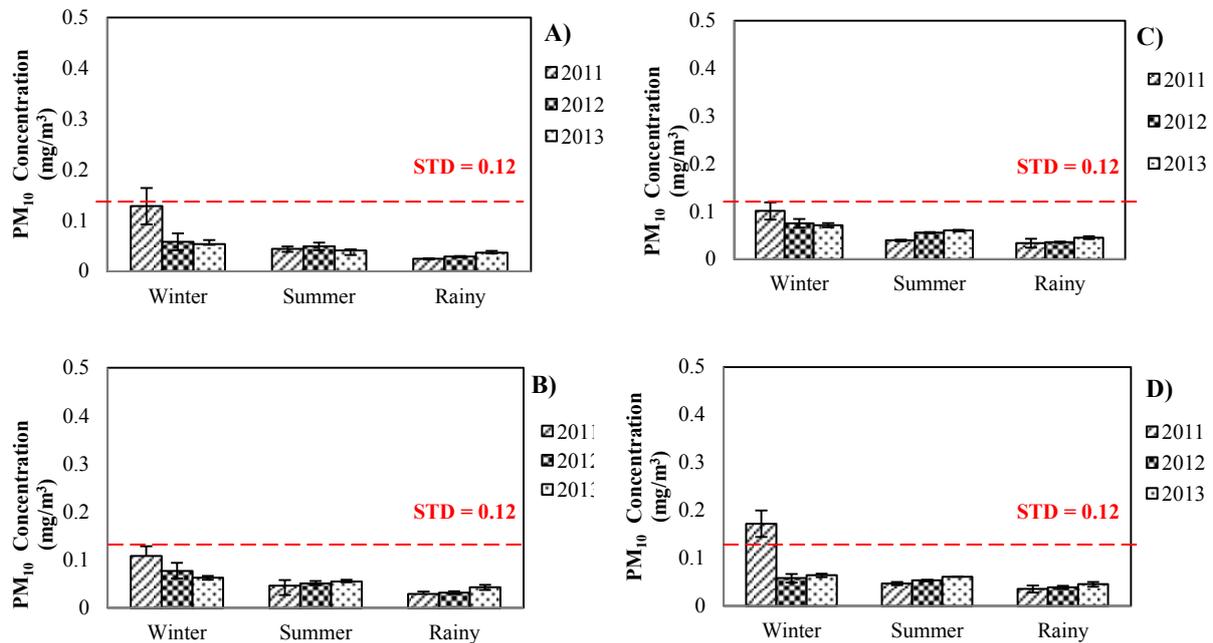A) Tan Diew sub-district B) Huai Haeng sub-district
C) Cham Pak Paew sub-district and D) Chulalongkorn construction area in Ban Wang Pae

In addition, there are many other factors such as activities of local people and wind characteristics that can directly affect the concentration and distribution of particulate matter in the construction area of Chulalongkorn University [17]. Results from the study show that the level of air pollution is mostly affected by human activities [19] such as construction, the operation of machines, transportation, field burning, and also chemical fertilization. After the particulate matter has been generated, it will spread out from the source by natural factors, especially wind. Also, the direction and velocity of wind has an impact on pollution distribution in the construction area. Karim et al. (2009) [20] confirmed that wind is a key factor that can disperse and reduce the concentration of air pollutions. Wind characteristics can be different in each area. Therefore, to identify the impact, specific information is required such as local wind direction, monsoon dynamics, etc. Moreover, other natural factors including temperature and

air pressure can also reduce the particulate concentration. For, instance, rain can decrease particulate level in ambient air as it allows particulates to dissolve into rain drops then fall out to ground level by gravimetric method.


Figure 3 Air qualities within area of study (PM_{10})
A) Tan Diew sub-district B) Huai Haeng sub-district
C) Cham Pak Paew sub-district and D) Chulalongkorn construction area in Ban Wang Pae
Note: STD means stantard level of TSP and PM_{10}

3) The relationship between TSP and PM_{10} in the study areas of Kaeng Khoi district, Saraburi province

Statistical results showing the relationship between TSP and PM_{10} is illustrated in Figure 4. It was found that at the significance level of $P<0.05$, the correlation coefficient of determination (R^2) equals to 0.63 which indicates that TSP and PM_{10} have a positive collation. This implies that if the concentration of TSP increases, the PM_{10} level will also increase. Considering Table 1 during 2011-2013 at every single sampling point, it obviously shows that if TSP is high, PM_{10} in that area will also be high. Pimonsri (2010) [14] studied the changing of parti-culate levels in the north of Thailand and found that high PM_{10} levels are associated with high TSP levels as well as high levels of other air pollutions.
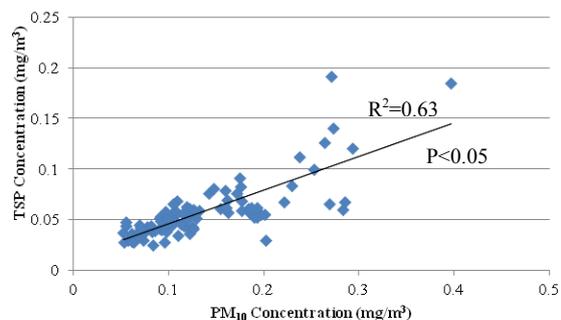
Figure 4 Relation of TSP and PM_{10} concentration

4) Potential sources of particulate matter in each sampling site in Kaeng Khoi district, Saraburi province.

The PM_{10}/TSP ratio in Table 3 represents the concentration of particulate matter in the study areas. It was found that the PM_{10}/TSP ratio in the area of Cham Pak Paew sub-district is similar to the ratio in the construction area of Chulalongkorn Univer-sity in Ban Wang Pae. This implies that

construction activities in the area of the university's project can subsequently affect particulate levels as detected in Cham Pak Paew sub-district. This is due to wind flows from the construction area of the university toward Cham Pak Peaw sub-district [22]. In addi-tion, it was found that the calculated PM_{10}/TSP ratios of these areas are less than 0.5 which means that the majority of particulate matter generated in these two areas is Total Suspended Particulate (TSP); not particulate matter <10µm (PM_{10}). It can be implied that the potential source of parti-culate found in Cham Pak Paew sub-district and the construction area of Chulalongkorn Univer-sity in Ban Wang Pae are from various activities related to the land development project of the Uni-versity such as transportation and construction. These activities generate higher TSP levels compared to PM_{10}. In contrast, the result shows that Tan Diew sub-district and Huai Haeng sub-district had a PM_{10}/ TSP ratio more than 0.5 indicating that both areas had a higher level of PM_{10} than TSP. Agricultural activities in these two sub-districts cause the rela-tively high PM_{10} levels, mostly as a result of in-complete combus- tion of paddy field burning, trash burning and spraying of chemical fertilizer. Cicero-Fernández et al. (1993) [23] studied the con-centration of TSP, PM_{10} as well as PM_{10}/TSP ratio within metropolitan and rural areas of Mexico and found that PM_{10}/TSP ratio varied according to sea-sons because of uncontrolled natural factors such as wind, rain, temperature and humidity as well as human activities such as construction and transport-tation. Moreover, they found that PM_{10}/TSP ratios in metropolitan areas were low because of construc-tion and transportation while in rural areas the ratios were high due to agricultural activities, open field burning and trash burning.

Table 3 PM_{10}/TSP Ratio

Year	Season	PM₁₀/TSP Ratio			
		Tan Diew sub-district	Huai Haeng sub-district	Cham Pak Paew sub-district	Chulalongkorn construction area in Ban Wang Pae
	Winter	0.6563	0.4325	0.3911	0.5493
2011	Summer	0.4388	0.5591	0.4508	0.4057
	Rainy	0.4000	0.2237	0.3841	0.5092
	Winter	0.5322	0.5170	0.5140	0.3731
2012	Summer	0.5088	0.4747	0.3068	0.2746
	Rainy	0.4931	0.5032	0.5191	0.3185
	Winter	0.4413	0.5275	0.4200	0.2298
2013	Summer	0.4495	0.5768	0.3671	0.3266
	Rainy	0.5490	0.7934	0.5207	0.4036

Note: PM_{10}/TSP Ratio > 0.5 means PM_{10} > TSP
    : PM_{10}/TSP Ratio < 0.5 means PM_{10} < TSP

5) Correlation of TSP, PM_{10} and the number of respiratory disorder patients in Kaeng Khoi district, Saraburi province

From the literature review, it was found that particulates in ambient air would affect the respi-ratory system of humans since they easily get into the respiratory system by inhaling, accumulate and then cause illnesses. Aran (2010) [24] affirmed that particulate matter is one of the important air pol-lutants because of its small size of particles and long

periods of suspension in the atmosphere. Consequently, humans are easily exposed. After exposure to particulate matter, some people can develop allergic symptoms immediately. In addition, particulates can subsequently cause chronic diseases to the respiratory system for frequently-exposed workers by 2.1 fold higher than other factors [24]. However, results from this study indicate a non-significant relation between TSP concentration and the number of patients who have respiratory disorder symptoms in Kaeng Khoi district ($P > 0.05$). This can be explained and supported by Agapol's et al. (2009) [25] work who found that TSP can reach the ground level faster than PM_{10} because of its higher weight. Therefore, TSP less affects human respiratory system as compared to a very small particulate matter which can suspend in ambient air for a very long period. It is obvious that particulates which can cause respiratory disorder in humans are very small particulates with a dimension of less than 10 μm (PM_{10}). Because of the very small size of PM_{10} as compared to TSP, it therefore easily passes through the respiratory mechanics. Many researchers also pointed out a same pattern of very small and respirable PM_{10} pariculates irritating human respiratory systems. Wiwanitkit (2008) [19] studied the impact of particulates on human health during the critical situation of a smog problem in 2007 and found that the number of patients is significantly related to PM_{10} concentration. The higher the PM_{10} concentration, the more respiratory patients in the hospital. Nantawan et al. [26] also suggested that the reduction plan of PM_{10} level in Bangkok from 60 to 50 μg/m^3 can save medical costs of about 8.7- 44.3 billion baht. However, it is unfortunate that various activities in construction areas generate more PM_{10} than TSP which is the opposite situation compared to normal areas. For this reason, the number of respiratory disorder patients from construction areas was found to be 1.43 fold higher than other areas.

The relation between PM_{10} and the number of respiratory patients in Kaeng Khoi hospital is pre-sented in Figure 5. It shows that the correlation coef-ficient (R^2) is at 0.746. Such a positive value indi-cates that the concentration of PM_{10} in the study area is related to the number of patients in the hospital. There-fore, it can be implied that if PM_{10} level is reduced, the number of hospital patients should decreased. It is interesting that the highest PM_{10} level was found in the whole year of 2011. Therefore, it is not surprising that the number of respiratory patients was higher in 2011 than other years. Aran [24] mentioned that high concentration of particulates lead to a higher severity of respiratory disorder symptoms for frequently ex-posed persons. Consequently, mitigation measures for particulate reduction such as reducing field burning, rice straw burning, and using chemical fertilizer should be established in order to reduce the concentration of particulates in ambient air and also to eliminate respi-ratory disorder problems in the long run.
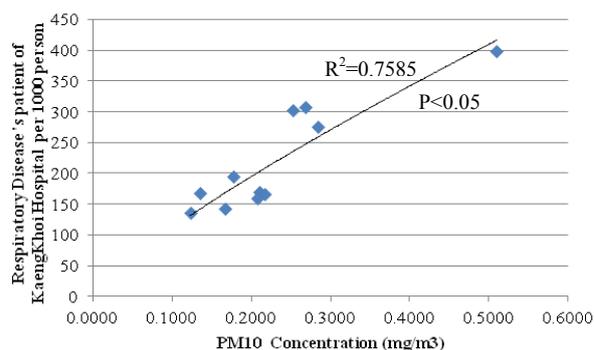
Figure 5 Relation of PM_{10} and patient in Kaeng Khoi Hospital

Conclusion

The Chulalongkorn Development Project starting in 2011 led to many construction activities especially the construction of infrastructure systems, road and buildings in the study areas. The concentration of TSP and PM_{10} levels in the study areas, their correlation as well as the effect of seasonal variation were investigated. Both types of particulates were continuously monitored starting from the beginning of the project in 2011 until the completion in 2013. Overall, it can be summarized that a positive relation between the concentration of TSP and PM_{10} was observed in this study. This obser-

vation means that a high level of TSP will also result in a high level of PM_{10}. In addition, the results indicate that the highest level of TSP and PM_{10} occurred in winter due to dry weather conditions, low air pres-sure, and stable and weak winds. However, the level of both TSP and PM_{10} subsequently decreased in summer and the rainy season. Furthermore, human activities such as paddy field burning, trash burning, spraying of chemical fertilizer, machine operations, factory operations as well as infrastructure construction are major sources of TSP and PM_{10}. A continuous decrease of both TSP and PM_{10} from 2011 to 2013 was also observed. This indicates that human activities directly affect the concentration of overall particulates in the study areas. Therefore, it can be implied that lowering of construction activities can reduce particulate concentration. The results from this study also indicate a positive relation between particulate concentrations and the number of respiratory disorder patients in Kaeng Khoi hospital. Consequently, particulate concentrations should be further monitored in order to design and implement proper mitigation plans and to subsequently eliminate respiratory disorder problems.

Acknowledgement

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