American Journal of Environmental Sciences 7 (5): 415-422, 2011
ISSN 1553-345X

Annual Concentration Report and Emission Sources Analysis of the Air Pollutants Measured by the Air Quality Monitoring Station

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Abstract: Problem statement: Air Quality Monitoring (AQM) station at Kasetsart University, Si Racha Campus, Thailand, was routinely monitor the annual concentrations and analysis the emission sources of the air pollutants in the area since 2007. The level of concentration CO, SO_2, NO_x and O_3 were measured. PM_{10} concentration was measured by mean of TOEM method. The PM_{10} and TSP (manifold) filters were collected for the measurement of heavy metals adsorbed in the particulate by ICP-AES techniques. Scanning Electron Microscopic (SEM) and Energy Dispersive Spectrometric (EDS) techniques were used to identify the morphologies and elemental compositions of particulate matters from the PM_{10} and TSP filters. **Approach:** The annual concentrations of all pollutants were almost real-time reported from July 2007-2008. The O_3 concentrations are higher than the standard level (100 ppb) in July 2007 and April 2008 with the value of 109 and 114 ppb, respectively. Average PM_{10} concentrations are higher than the standard level (120 $\mu g.m^{-3}$) in November 2007, January 2008 and March 2008 with the value of129, 123 and 125 $\mu g.m^{-3}$, respectively. Strong correlations between NO_2 with O_3 and between NO_2 with PM_{10}were found. **Results:** These results showed that NO_2 was the precursor of the photochemical reaction and generate O_3. NO_2concentrations are found to be corresponding with both O_3 and PM_{10}. The directions of O_3 emission sources were the southwest, south and southeast due to wind direction, whereas the PM_{10} are originated from the northwest. The microscopic structures of TSP provided various shapes and dimensions from 0.1 to greater than 100 μm, while the microstructures of PM_{10} presented the needle-like and spherical shape. SEM-EDS analysis was able to detect some element (C, O, F, Na, Al, Si and K), while the ICP-AES showed that there were other heavy metals present in the filter sample (Ni, Cu, Zn, Pb and Se). **Conclusion:** Among the amounts of selected heavy metals, Zn is the most probable among all metals with the value of 1.3891±1.6198 $\mu g .g^{-1}.m^{-3}$ in TSP. Amounts of heavy metals inPM_{10}, Cu is dominated with 0.5374±0.8084 $\mu g .g^{-1}.m^{-3}$, the others were almost in the same levels and much lower than in TSP. Correlation coefficient between each metal can be estimate the emission source of their particulate matter together with the wind speed and wind direction.

Keywords: Air quality monitoring, Si Racha, heavy metal, Scanning Electron Microscopic (SEM), heavy metals, emission sources, spherical shape, wind direction, elemental compositions

INTRODUCTION

Air Quality Monitoring (AQM) station at the Kasetsart University, Si Racha campus, Chonburi, Thailand was established since 2007. AQM station plays an important role in monitoring the situation of air pollution around industrial areas such as Si Racha and LaemChabung industrial estate, where the Si RachaTown

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Municipal and LaemChabung City Municipal have received the complaining about the air pollution more than 100 times since 2006 (OSOS, 2009).

Air pollution is the serious problems around the world, especially in less-industrialized countries where the early stages of industrial growth are often pursued without much investment in environmental protection, leading to heavy air pollution in urban areas (Florig *et al*., 2002). In many developing countries including Thailand one factor related to atmospheric pollution originated from urban contribution where is directly resulted of uncontrolled emission from motor vehicular and other anthropogenic activities (Kim and Hopke, 2008).

Si Racha Metropolitan Area (SRMA), Chonburi province is located at the east of Thailand. The major sources of air particulate include transportation, stationary fuel combustion, processes and agricultural waste and others. From Si Racha Public Health records, population in Si Racha got sick in the respiratory syndrome 21cases (diseases of respiratory system). The numbers of patients were 46163, 56593, 65139, 59030 and 58016 in the year of 2005, 2006, 2007, 2008 and 2009, respectively Report Sheet 504.

Up to now, the concentration levels of air pollutants in the area are routinely monitored by the Pollution Control Department (PCD) Ministry of Natural Resources and Environment. Air quality was monitored using a standard method for ambient air pollution. Although 53 AQM stations are distributed aroundthe whole country, only 4 stations are located in the industrial area, Chonburi province. The results of pollutant annual concentration from PCD are very close to the limit level of the (Notification of National Environmental Board No. 28, B.E. 2007, Table 1) (CD, 2010). These levels may cause high risk on population health in the area. Particularly, particulate matters can cause coughing, wheezing and overall decreased lung function in children and adult (Zanobetti *et al*., 2000; Limbach *et al*., 2005).

Table 1: Standard level concentrations of each pollutant (DEQM, 2007)

Pollutants	Average	Standard
	1 h	Not exceed 30 ppm. (34.2 mg.m^{-3})
Carbon monoxide (CO)	8 h	Not exceed 9 ppm. (10.26 mg.m^{-3})
Nitrogen dioxide (NO_2)	1 h	Not exceed 0.17 ppm. (0.32 mg.m^{-3})
Ozone (O_3)		
	1 h	Not Exceed 0.10 ppm. (0.20 mg.m^{-3})
	8 h	Not Exceed 0.07 ppm. (0.14 mg.m^{-3})
Sulfur dioxide (SO_2)		
	1 year	Not exceed 0.04 ppm. (0.10 mg.m^{-3})
	24 h	Not exceed 0.12 ppm.(0.30 mg.m^{-3})
	1 h	Not exceed 0.3 ppm.(780 μg.m^{-3})
Lead (Pb)	1 month	Not exceed 1.5 μg.m^{-3}
Particulate matter	24 h	Not exceed 0.12 mg.m^{-3} (120 μg.m^{-3})
(< 10 μ)(PM_{10})	1 year	Not exceed 0.05 mg.m^{-3}
Particulate matter	24 h	Not exceed 0.33 mg.m^{-3}
(< 100 μ)	1 year	Not exceed 0.10 mg.m^{-3}

However, it is very important to characterize airborne particulate matters especially morphology, chemical compositions and their origins in relation to health and environmental impact (Baulig *et al*., 2004; Areekijseree *et al*., 2009). It is very important to measure not only the levels of fine particles in and around major cities and industrial area but also to identify the sources of these particles.

The aims of this research are: (1) To quantify the average concentrations of CO, SO_2, NO_x, O_3, $PM_{10}$and TSP in ambient air around Si Racha area. (2) To measure the heavy metal accumulated in the particulate matter, elemental composition and microstructure of PM_{10} and TSP (3) To identify the possible emission sources of the air pollutants with the meteorological data. Identifying the source of airborne particles and their composition, physical and chemical properties will help to provide a clear connection to their impact on the environment and the human health (Brook *et al*., 2004).

MATERIAL AND METHODS

Sampling location: The Si Racha Metropolitan Area has a surface area of approximately 616.4 km^2 and about 228,717inhabitants. The atmospheric aerosol has been studied since 2006 (Pollution Control Department (PCD). There are basically three seasons in SRMA: a rainy (June to August), a winter and dry (November to February) and a summer (March to May) season. The air quality monitoring is located in Kasetsart University Si Racha Campus (13°07´15.42´´N, 100°55´09.28´´E) where is about 15 m closed to Sukumvit Road (Fig. 1a-c). The station unit is situated within an urban commercial/residential and industrial area.

Sampling technique: Tempered Element Oscillating Microbalance (Model TEOM 1400ab Ambient Particulate Monitor) has been used as a standard method for continuous of PM monitoring in the AQM station. The 1400ab series TEOM (Thermo Scientific) is equivalent to US EPA method (US EPA equivalency designation number EQPM-1090-079) which provides an almost real-time PM_{10} masses from a 16.67, lmin^{-1}air flow (1.002 m^3 h^{-1}). Atmospheric air was pump though the sampling head with the flow rate of 16.67 lmin^{-1} and then divided into filter flow (3 lmin^{-1}) and auxiliary flow (13.67 lmin^{-1}).

Another pollutant such as CO, SO_2, NO_x and O_3 were also measured and real-time reported. Their technique, range, accuracy and their low limit detection are shown in Table 2.

(a) (b) (c)

Fig. 1: The location of the sampling site (a) Chonburi province (b) Kasetsart University Si Racha Campus and (c) the Air quality monitoring station.

Table 2: Pollutants, techniques, range, accuracy and low detection limit (TEOM 1400ab data sheet)

Pollutants analyzer	Technique	Range	Accuracy (%)	Low limit detection
SO_2	UV Fluorescence	0-500 ppb to 0-20 ppm	1	0.5 ppb
$NO-NO_2-NO_x$	Chemiluminescence	0-500 ppb to 0-20 ppm	1	0.5 ppb
CO	Non-dispersive infrared detection	0-50 ppm to 0-200 ppm	1	0.05 ppm
O_3	UV absorption	0-500 ppb to 0-10 ppm	1	0.5 ppb

In order to measure the concentration of TSP, Teflon fiber filters were accurately pre-weighted with analytical balance (Metler Toledo AG 204±0.0001 g). Sample filters were collected from stack filter unit twicea month as located in the manifold tube with a flow rate of ≅1L min^{-1}. Meteorological data (temperature, wind speed and wind direction, dew point used to compute relative humidity data) have been provided by the facilities in the AQM station.

Chemical compositions of heavy metals analysis in particulate matters: Teflon fiber filters and a 16 mm PTFE-coated glass fiber filter (PM_{10}) were collected (twice a month) to measure the heavy metals accumulated in the particulate matter. Heavy metals adsorbed on particulate matters were determined by digesting the filter paper with 20 mL deionizer water (purified by Millipore Simplicity 185) in Sonorec ultrasonic bath (Super RK 514 BH). The extract solutions were analyzed by injection to inductively coupled plasma atomic emission spectrometry (ICP-AES, Jobin Yvon JY2000) via nebilizingsystem (Khaenamkaew *et al*., 2010). The instrument was well calibrated with standard reference material (SpexCertiprep) of heavy metals.

Morphology and elemental composition analysis: The shape and physical structure of particles in the filter samples were observed using a Scanning Electron Microscope equipped with Energy Dispersive Spectrometer (Phillips: XL30 and EDAX). The filter samples were cut onto the area of 0.5×0.5 cm^2. Gold and carbon were coated on the filter samples with a Pirani501 device for the SEM and ED's analysis, respectively. Analytical conditions were fit to 15 kV accelerating voltage and 100s of effective counting time.

Besides ED's analysis, the electron beam was spot over the selected area. Elements with atomic numberless than 11 cannot be determined due to insufficient accuracy and presence of carbon in the substrate. The morphologies and spotted elemental compositions of the reference samples were shown in Fig. 7 and 8.

RESULTS AND DISCUSSION

Average concentrations of pollutants from AQM: The average concentrations of pollutants measured by AQM from July, 2007-2008 are provided in Table 3. Average concentration of ozone is higher than the standard level (100 ppb) in July 2007 and April2008 (Table 3).

O_3 concentration and their possible source: Ozone is a molecule made up of three oxygen atoms (O_3), Avery reactive gasandeven at low concentrations it is irritating and toxic.

When ozone is present at ground level and in the troposphere (10-18 km above earth's surface), it is considered as a pollutant and a greenhouse gas (Mason *et al*., 2001).

The ozone concentrations are higher than the limit level in July 2007 and April 2008. Moreover, the concentrations of ozone were found relatively high in December 2007-March 2008. In this period, wind roses are indicated the ozone comes from the southwest, south and southeast direction (Fig. 2 and 3) Southern of the AQM station are the petrochemical industry and the sea side area. Ozone is readily formed in the atmosphere by the reaction of Volatile Organic Compounds (VOCs) and NO_x in the presence of heat and sunlight, which are most abundant in the summer (Mason *et al*., 2001; Crutzen and Lelieveld, 2001).

Table 3: Air quality and PM_{10}concentration from AQM

Month	Average	CO (1 h)	NO_2 (1 h)	SO_2 (1 h)	O_3 (1 h)	PM_{10} (24 h)	TSP (24h)
Jul-07	Min	0.23	3.9	0.3	0.6	18	54.40
	Max	1.43	64.0	76.3	109.0	64	
Aug-07	Min	0.27	1.9	0.4	0.1	27	43.10
	Max	3.08	52.6	55.8	7.3	50	
Sep-07	Min	0.78	0.0	0.0	0.1	22	41.30
	Max	2.54	37.5	91.3	20.3	76	
Oct-07	Min	0.74	0.3	2.2	0.4	24	7.40
	Max	2.48	42.2	41.7	47.7	114	
Nov-07	Min	0.73	1.3	2.3	1.1	24	9.30
	Max	2.49	56.0	10.2	47.0	129	
Dec-07	Min	0.44	1.7	2.5	0.9	30	9.00
	Max	2.31	66.7	39.4	91.5	101	
Jan-08	Min	0.55	0.0	2.6	1.8	37	13.80
	Max	2.76	80.3	84.2	96.7	123	
Feb-08	Min	0.68	0.0	0.8	0.4	24	151.00
	Max	2.47	67.2	62.9	90.2	100	
Mar-08	Min	0.72	0.0	0.8	0.0	29	9.70
	Max	2.14	73.3	81.3	95.8	125	
Apr-08	Min	0.40	0.0	0.2	1.3	18	55.10
	Max	1.70	40.1	41.7	114.3	56	
May-08	Min	0.46	0.6	0.8	0.4	21	8.50
	Max	1.56	33.7	49.2	37.8	61	
Jun-08	Min	0.38	0.4	0.7	0.5	26	4.70
	Max	2.27	47.3	58.1	47.5	53	
Jul-08	Min	0.00	0.2	0.8	0.0	23	54.40
	Max	1.52	22.7	61.2	21.7	46	
PCD Standard unit		30 ppm	170 ppb	300 ppb	100 ppb	120 μgm^{-3}	330μgm^{-3}

Wind rose	Average (%)
North (N)	6.51
Northeast (NE)	4.45
East (E)	2.40
Southeast (SE)	17.47
South (S)	13.01
Southwest (SW)	16.78
West (W)	8.90
Northwest (NW)	8.56
Calm	20.50

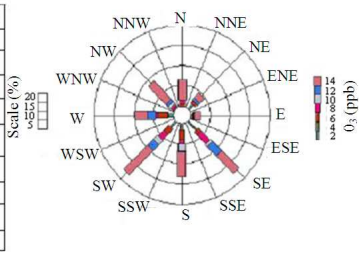

Fig. 2: The monthly pollution rose: O_3 max = 109 ppb in July 2007

Wind rose	Average (%)
North (N)	2.34
Northeast (NE)	6.44
East (E)	5.71
Southeast (SE)	27.23
South (S)	16.98
Southwest (SW)	23.43
West (W)	3.51
Northwest (NW)	4.54
Calm	8.70

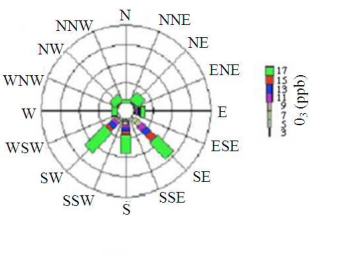

Fig. 3: The monthly pollution rose: O_3 max = 114.3 ppb in April 2008

VOCs are emitted from variety of sources, including motor vehicles, chemical plants, refineries, factories and natural (biogenic) sources (Florig *et al*., 2002). Nitrogen oxides (a precursor to ozone) are emitted from motor vehicles, power plants and other sources of combustion, as well as natural sources including lightning and biological processes in soil (CEPA, 2011). Figure 2 are also shown the concentration level of NO_2. Although the levels are lower than standard values (170 ppb, as seen in Table 1), but the concentration are relatively high in December 2007, January 2008, February 2008 and March 2008.

Figure 2 and 3 are the wind roses of the ozone sources. In July 2007 and April 2008, the wind direction came from the southwest, south and southeast.

These result indicated that ozone possibly come from the sea spray, petrochemical industry and other factories in southern of AQM station.

PM_{10} concentration and their possible source: Particulate matter is the generic term for a broad class of chemically and physically diverse substances that exist as discrete particles (liquid droplets or solids) over a wide range of sizes. The concentration of TSPand PM_{10} are shown in Table 3. The concentrations of PM_{10} are higher than the limit of standard level (120$\mu g.m^{-3}$, Table 1) in November 2007, January 2008 and March 2008 with the value of 129, 123 and 125$\mu g.m^{-3}$, respectively.

Particulate matter may be emitted directly or formed in the atmosphere by transformations of gaseous emissions such as sulfur oxides, nitrogen oxides and VOCs. The chemical and physical properties of particulate matters are greatly varied with time, location, meteorology and source category, thus complicating to assessment of health and welfare

effects (Paoletti *et al*., 2002). However, the wind roses of the PM_{10} can be also measure and carefully considered. Figure 4-6 show the wind speed and wind direction of the PM_{10} during the level are exceed than those standard level. November 2007 and January 2008 wind direction came from the northeast and the results indicated that PM_{10} possibly come from the industry estate area. While March 2008 wind direction came from the southwest direction that is transportation activity. The possible sources of particulate matter collected from this site are: commercial and residential heating, road transportation, petrochemical industry and industrial estate area. There is also a possibility that some of these airborne particulates may have migrated to this region from elsewhere (Paoletti *et al*., 2002).

Morphologies and elemental compositions: The surface texture of PM_{10} and TSP filter sample were illustrated in Fig. 7 and 8, respectively. The elemental compositions of selected PM_{10} and TSP were given in Table 4. Both images provided spherical particles with 10 μm-diameters in TSP and less than 10 μm for PM_{10}.

In agreement with the results from SEMobservations and EDS analysis (Table 4), it could be concluded that soil and rock dust represented a large proportion of particles adsorbed onto the glass and quartz filters (Han *et al*., 2009). Particles from anthropogenic sources and the marine environment were also found in filter samples (Khaenamkaew *et al*., 2010).

Chemical compositions of heavy metals in particulate matters: The amounts of selected heavy metals which were calculated in terms of mass of metals per mass of particle per unit air volume ($\mu g g^{-1} m^{-3}$). Among all metals, zinc was the most probable among all metals with the value of 1.3891 ± 1.6198 $\mu g g^{-1} m^{-3}$ in TSP. The weighted mean concentrations were 0.4200 ± 0.4381, 0.4293 ± 0.5276, 1.3891 ± 1.6198, 0.6577 ± 0.8702 and 0.7069 ± 0.7186 $\mu g g^{-1} m^{-3}$ for Ni, Cu, Zn, Pb and Se, respectively. Amounts of heavy metals in PM_{10}, Cu was dominated with 0.5374 ± 0.8084 $\mu g g^{-1} m^{-3}$, the others were almost in the same levels and much lower than in TSP (Table 5). However, all of heavy metals are not exceeding than the national standard level (13 mg $g^{-1} m^{-3}$) (PCD).

Correlation between amounts of PM_{10} and various kinds of pollutants: As mentioned in the previous paragraph, O_3 and NO_2 show strong correlation. It is confirmed that theNO_2 is the precursor of O_3 (19). Beside O_3 and NO_2, the strong correlation between PM_{10} and NO_2 is shown in Table 6. It is possible that the NO_2 is a precursor of PM_{10}. NO_2 and other chemical substances can form to be aerosol or particle-bound to water and show a particulate property.

Wind rose	Average (%)
North (N)	19.77
Northeast (NE)	62.87
East (E)	5.69
Southeast (SE)	0.57
South (S)	0.28
Southwest (SW)	0.00
West (W)	0.28
Northwest (NW)	1.28
Calm	7.00

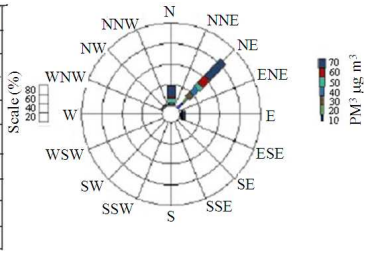

Fig. 4: The monthly pollution rose: PM_{10} max = 129 μg m^{-3} in November 2007

Wind rose	Average (%)
North (N)	2.45
Northeast (NE)	8.72
East (E)	4.09
Southeast (SE)	22.89
South (S)	17.85
Southwest (SW)	29.16
West (W)	2.72
Northwest (NW)	2.59
Calm	8.00

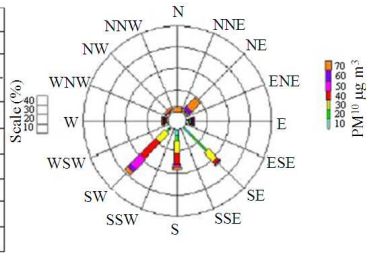

Fig. 5: The monthly pollution rose: PM_{10} max = 123 μg m^{-3} in January 2008

Wind rose	Average (%)
North (N)	2.45
Northeast (NE)	8.72
East (E)	4.09
Southeast (SE)	22.89
South (S)	17.85
Southwest (SW)	29.16
West (W)	2.72
Northwest (NW)	2.59
Calm	8.00

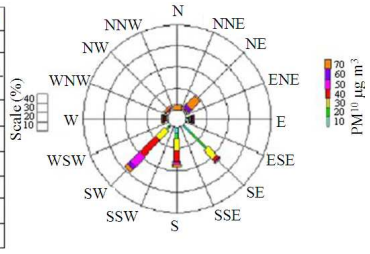

Fig. 6: The monthly pollution rose: PM_{10} max = 125 μg m^{-3} in March 2008

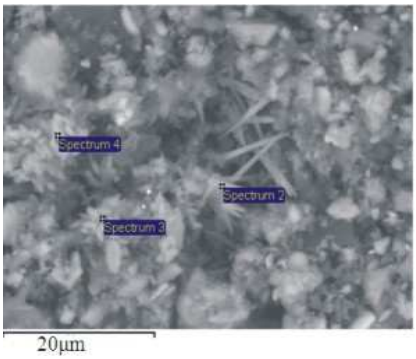

Fig. 7: SEM Micrograph of PM_{10} sample collected from AQM

Table 4: Elemental composition of PM_{10} (spectrum 1, 2 and 3) and TSP (EDS spot)

PM_{10} Spectrum 2		PM_{10} Spectrum 3		PM_{10} Spectrum 4 TSP (xEDS spot)			
Elem	Wt (%)	Elem	Wt (%)	Elem	Wt (%)	Elem	Wt (%)
C	19.71	C	22.54	C	28.34	C	38.60
O	34.50	O	38.91	O	24.09	O	29.24
Na	0.52	Na	0.71	Na	0.82	Na	2.02
Al	1.89	Al	6.03	Al	3.61	Al	3.98
Si	5.76	Si	19.20	Si	12.68	Si	8.99
S	15.03	S	2.10	S	2.97	S	5.00
Cl	0.98	Cl	0.72	Cl	1.23	Cl	-
K	1.61	K	7.25	K	1.87	K	1.80
Ca	18.46	Ca	1.34	Ca	2.21	Ca	1.49
		Fe	1.21	Mn	1.12	Mn	-
				Fe	18.80	Fe	4.12
				Zn	1.44	F	3.58
				Mg	0.80	Mg	1.18

Table 5: Amounts of heavy metals in PM_{10} and TSP

			Concentration of heavy Metals ($\mu g g^{-1} m^3$)				
PM	Collecting time	PM Weight (mg)	Ni	Cu	Zn	Pb	Se
PM_{10}	July 07	0.0739	0.2032	1.7345	0.6318	0.2422	0.3900
PM_{10}	October 07	0.0313	0.1874	0.3195	1.0121	0.1082	2.3122
PM_{10}	March 08	0.0778	0.1310	0.0587	0.2242	0.0000	1.0915
PM_{10}	June 08	0.0764	0.0728	0.0367	0.1859	0.0542	0.2627
Geometric mean		0.0648	0.1486	0.5374	0.5135	0.1011	1.0141
Standard deviations		0.0224	0.0593	0.8084	0.3889	0.1039	0.9390
TSP	July 07	0.0544	0.0773	0.2677	0.3268	0.1290	0.1280
TSP	August 07	0.0431	0.1350	0.1346	0.3761	0.3396	0.4523
TSP	September 07	0.0413	0.0509	0.1952	0.1027	0.3765	0.4837
TSP	October 07	0.0074	0.6303	0.5803	4.7325	2.6281	1.4313
TSP	November 07	0.0093	0.5615	0.2098	0.5518	1.6675	2.0320
TSP	December 07	0.0090	1.3053	1.9758	1.7891	0.8250	0.2861
TSP	January 08	0.0138	0.2313	0.3292	1.6080	0.2110	0.7866
TSP	February 08	0.1510	0.0253	0.0202	0.0869	0.0325	0.0494
TSP	March 08	0.0097	0.3852	0.3035	1.2991	1.6832	0.0000
TSP	April 08	0.0551	0.1047	0.0670	0.4250	0.0000	0.0000
TSP	May 08	0.0085	0.3218	0.3281	0.8191	0.0000	1.8210
TSP	June 08	0.0047	1.2116	0.7402	4.5523	0.0000	1.0124
Geometric mean		0.0339	0.4200	0.4293	1.3891	0.6577	0.7069
Standard deviations		0.0417	0.4381	0.5276	1.6198	0.8702	0.7186

Table 6: The Pearson correlation between amounts of PM_{10} and various kinds of air pollutants

	CO	NO_2	SO_2	O_3	PM_{10}
CO	1.000				
NO_2	0.400	1.000			
SO_2	0.008	0.219	1.000		
O_3	-0.276	0.635	0.107	1.000	
PM_{10}	0.421	0.649	-0.109	0.348	1.000

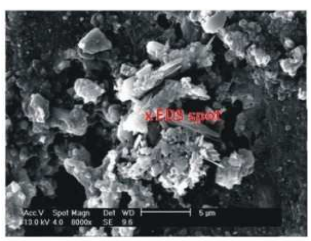

Fig. 8: SEM Micrograph of TSP sample collected from AQM

Table 7: The Pearson correlation between amounts of PM10 and various kinds of heavy metal

	PM_{10}	Ni	Cu	Zn	Pb	Se
PM_{10}	1.00000					
Ni	-0.59416	1.00000				
Cu	-0.24860	0.62924*	1.00000			
Zn	-0.55211	0.71750	0.31973	1.00000		
Pb	-0.46336	0.34170	0.13280	0.47461	1.00000	
Se	-0.44293	0.17076	-0.09310	0.25729	0.19705	1.00000

Table 8: The Pearson correlation between amounts of TSP and various kinds of heavy metal

	TSP	Ni	Cu	Zn	Pb	Se
TSP	1.00000					
Ni	-0.55904	1.00000				
Cu	-0.42099	0.84587*	1.00000			
Zn	-0.50004	0.69258*	0.42457	1.00000		
Pb	-0.41115	0.26892	0.16861	0.42615	1.00000	
Se	-0.51828	0.27292	-0.00553	0.33227	0.33825	1.00000

*: Correlation is significant at the 0.01 level (2-tailed); **: Correlation is significant at the 0.05 level (2-tailed)

It is the secondary form of particulate matter namely artifact particulate matter (Turpin *et al*., 2000). Artifacts in the measurement of particle mass concentrations also arise from the adsorption of semi-volatile organic gases onto or from collected particulate matter and filter media (Tsai and Huang, 1995) and the neutralization of acid or basic gases on either filter media, or collected particulate matter (Turpin *et al*., 2000). Table 6 The Pearson correlation between amounts of PM_{10} and various kinds of air pollutants

As Ni is strongly correlated with Cu (Table 7 and 8), it may be assumed that they originated from the same source. For the TSP, the strong correlation coefficient between Cu, Ni and Zn (Table 8) suggest be the same origin of these elements (Spotar and Sorokin, 2010). It could be assumed that Cu, Ni and Zn partially originated from same origin due to the correlation.

CONCLUSION

The annual concentrations of O_3 are higher than the limit of standard level in July 2007 and April 2008.The PM_{10} concentrations are higher those level in November 2007, January 2008 and March 2008. Emission sources of the O_3 possibly estimate from the wind speed and wind direction. The result indicated that O_3 came from the southwest, south and southeast direction where the petrochemical and others industries. PM_{10} came are also analyzed, the possible sources of PM_{10} are the industry estate and the transportation activities in SukumvitRoad. Strong correlations between NO_2 with O_3 and between NO_2 with PM_{10} were found. These results show that NO_2 is the precursor of the photochemical reaction and generate O_3. Among the amounts of selected heavy metals, Zn was the most probable among all metals with the value of 1.3891±1.6198 $\mu g g^{-1}.m^{-3}$ in TSP. Amounts of heavy metals in PM_{10}, Cu was dominated with 0.5374±0.8084 $\mu g.g^{-1} m^{-3}$, the others were almost in the same levels and much lower than in TSP. The microscopic structures of TSP provided various shapes and dimensions from 0.1 to greater than 100 μm, while the microstructures of PM_{10} presented the needle-like and spherical shape. SEM-EDS analysis was able to detect some element (C, O, F, Na, Al, Si and K), while the ICP-AES showed that there were other heavy metals present in the filter sample (Ni, Cu, Zn, Pb and Se).Correlation coefficient between each metal can be estimate the emission source of their particulate matter together with the wind speed and wind direction.

ACKNOWLEDGEMENT

The researchers would grateful to thank Assoc. Prof. Dr. Nipon Tangkananuruk for his suggestions. TheAQM station received the maintenance budget from Faculty of Resources and Environment. This research project was financially supported by the Kasetsart University Research and Development Institute (KURDI: Code No. RM 24.53) and partially supported by Kasetsart University, Si Racha Campus.

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