Application of ISC-AERMOD program for Evaluation of Air Pollutants Dispersion in Siriraj Hospital

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Abstract

The dispersion of air pollutants emitted from the boiler stack located at Siriraj Hospital was predicted by using ISC-AERMOD View program. In this research, the types of air pollutants including carbon monoxide (CO), nitrogen dioxide (NO_2) and sulfur dioxide (SO_2) were indicated because of their adverse effect on human health. The CO, NO_2 and SO_2 concentrations in the atmosphere and from the mobile sources surrounding Siriraj Hospital were determined and used as the background concentrations for evaluating the values of their maximum concentrations in order to compare to the ambient air quality standard in Thailand. The results showed that the maximum background concentrations of SO_2 for 24 hr and yearly, CO for 1 hr and 8 hr, and NO_2 for1 hr were 0.011 ppm, 0.011 ppm, 2.196 ppm, 2.134 ppm, and 0.015 ppm, respectively. The predicted results revealed that the dispersion of SO_2 and NO_2 was approximately 285 m from the boiler stack through the eastern part of the boiler while the CO dispersion was about 137 m from the boiler stack to the eastern part or the Chlermprakiet Building area. Also, the predicted maximum concentrations of SO_2 for 24 hr and yearly, CO for 1 hr and 8 hr, and NO_2 for1 hr were 0.010 ppm, 0.005 ppm, 0.0001 ppm, 0.00002 ppm, and 0.0097 ppm, respectively. Therefore, the maximum concentrations resulting from the background and predicted maximum concentrations for SO_2 at 24 hr and yearly, for CO at 1 hr and 8 hr and for NO_2 at 1 hr were 0.021 ppm, 0.016 ppm, 2.1962 ppm, 2.1345 ppm and 0.024 ppm, respectively. These concentrations were less than the concentrations in the ambient air quality standards. As a result, SO_2, CO and NO_2 emitted from the boiler stack at Siriraj Hospital might be slightly affected and less harmful to the hospital workers. However, to confirm the adverse effect on the hospital workers the risk assessment of air pollutants should be determined.

Keywords: ISC-AERMOD View program, Siriraj Hospital, Air Pollutant Dispersion.

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Introduction

Since some air pollutants are very harmful to humans, animals and plants, their emission rates have been considerably concerned in the environment. Siriraj hospital located on Phan nok road, Siriraj subdistrict, Bangkok noi district, Bangkok, has 12,000 staffs working for 72 buildings on the area of 230,000 m^2. Several hazardous chemicals and some drugs for patient treatment, several sterilized medical tools were used in the hospital and the laboratory for several experiments. Also, the residue oil used as fuel in the steam boiler is mainly resulted in releasing of several air pollutants such as CO, SO_2 and NO_2. The other types of air pollutants such as formaldehyde and glutaraldehyde are from the pathology laboratory, and the sterilized medical tools, respectively. However, these air pollutants are low amount releasing to the environment. The major air pollutants are mainly from the used oil in the boilers. Therefore, this research is intended to assess the dispersion of these major air pollutants exposed to the environment by using ISC-AERMOD View program in terms of the concentration prediction at different places and the background concentrations from the atmosphere and the mobile sources surrounding Siriraj hospital.

The main objectives of this study were:

1. to identify the types of air pollutants released from Siriraj Hospital.

2. to determine the directions and concentrations of each air pollutant for the average 1-hour, 8-hour and 24-hour simulation by using ISC-AERMOD program.

Research Methodologies

Data Collection

The relevant information needed to run ISC AERMOD View program was collected including the air pollutants from the combustion of fuel oil - boiler that occur every day in Siriraj Hospital. The US.EPA method 6, US.EPA method 7 and TELEGAN combustion analyzer model Sprint V1 is the methods for determining the concentrations of air pollutants such as SO_2, NO_2 and CO in terms of ppm. These SO_2, CO and NO_2 concentrations can be converted to the unit of mg/m3 following equation 1 and 2.

$$Cp = \frac{Csp \times P(atm) \times T(s)}{T(atm) \times P(s)} \quad (1)$$

$$Cm = \frac{Cstp \times MW}{24.45} \quad (2)$$

Where, Cp is the sampling site concentration in ppm, Cstp is the concentration at STP in ppm, Cm is the concentration in mg/m^3, P(atm) is the atmosphere pressure in mmHg, P(S) is the sampling site pressure in mmHg, T(atm) is the ambient temperature in ^oK, and T(s) is the sampling site temperature in ^oK

$$\text{Emission Rate} = Cm \times V \times A \quad (3)$$

Where, Cm is the concentration of pollutants in mg/m^3, V isvelocity in m/s and A is inside diameter in meter.

Also, the other input data for ISC-AERMOD View program included emission velocity, emission temperature, stack height and stack internal diameter. The data for velocity used in this research are from the flow rate of dry air inside stack equation (Equation 4).

$$Q_{sd} = 3600(1 - B_{ws}) \times V_s \times A \times \left(\frac{T_{std}}{T_{s(avg)}} \right) \left(\frac{P_s}{P_{std}} \right) \quad (4)$$

Where, Q_{sd} is the flow rate of dry air inside stack (for this study got from combustion equation) in m^3/hour, BWS is moisture in air (%), VS is velocity in side stack in m/s, A is cross-section area of stack inside diameter in meter, Tstd is 25°C + 273 = 298°K, Ts(avg) is the absolute temperature in °K, PS is the absolute temperature (P_{bar} + P_g) in mmHg, P_g is the static pressure inside stack in mmHg, P_{bar} is the atmospheric pressure in mmHg and Pstd is 760 mmHg.

In this research the building downwash was studied by collecting the specific content of area such as building dimensions which affect the air pollution dispersion and by using BPIP View program to create the file used in ISC-AERMOD View. A Siriraj Hospital map in terms of DFX format is used for input in ISC-AERMOD View and used for expressing the contour result.

Meteorological Data Preparation

The meteorological data used in this research including the hourly surface air data and upper air data were prepared for AERMET program. AERMET program is the meteorological preprocessor used for the organization of the available meteorological data into a suitable format for the ISC- AERMOD View program (Lakes Environmental Consultants Inc, 2003). The hourly surface data in a period of one year (from 1 January to 31 December 2007) were prepared from the observation stations of Pollution Control Department (Intrapitak Station), as well as the ceiling height and mixing height from Thai Meteorology Department. The surface air data in terms of SAMSON format and preprocessor by Rammet View program are also prepared. The upper air data used in AERMET program was received from one year period (from 1 January to 31 December 2007) from website of University of Wyoming, and prepared in terms of FSL format. The AERMET program was conducted to get 2 files including Surface file and Profile file for ISC-AERMOD View program.

Determination of Air Pollutants for Stack Boiler

ISC-AERMOD View is a user-friendly interface for four U.S. EPA air dispersion models: ISCST3, AERMOD, ISC-PRIME and AERMOD-PRIME. This interface was specially developed for Microsoft Windows and operated on Windows 95, Windows 98, and Windows NT. The meteorological information from AERMET program, source information from 2.1, Building downwash information and area map were added to ISC-AERMOD View modeling to simulate the dispersion of the air pollutants released from stack boiler in a period of one year (from 1 January 2007 to 31 December 2007). Each pollutants from ISC-AERMOD stimulation was compare to the average concentration of the ambient air standard of Thailand including SO_2 in 24 hours, SO_2 annual, CO in 8 hour, CO in 1 hour and NO_2 in 1 hour. The execution of ISC-AERMOD View program can be shown as figure 1.

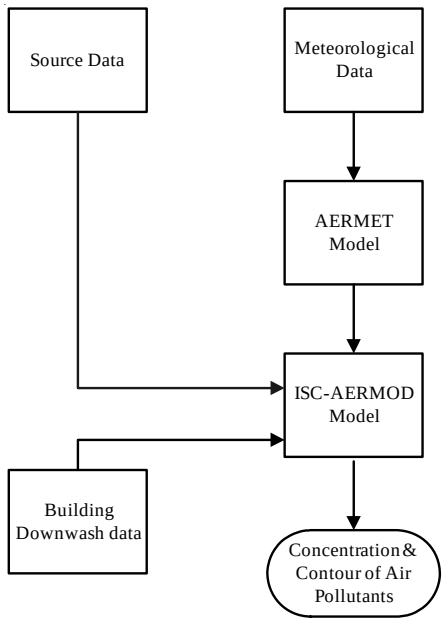

Figure 1. Process of the ISC-AERMOD View Program Stimulation.

In addition, the assumed conditions such as variety of stack heights and layout of buildings were compared to the actual conditions.

Determination of Background Concentrations

The background concentrations were used from two sources. The first source is the concentration in the atmosphere from hourly air quality data in one year period (from 1 January 2007 to 31 December 2007) receiving from the observation station of Pollution Control Department nearly Siriraj Hospital (Intrapitak Station). The second source is the local concentration from Siriraj Hospital, by counting the vehicles on the roads including Arunamarin, Phan nok, rail road, internal main A and internal main B in 24 hours periods. Then, the types of vehicles are separated as motorcycles, gasoline engine, diesel engine and large diesel engine with the average velocity of each type of vehicles. The emission rate is determined by equation 3 and 4;

$$\text{CEF} = N \times EF \quad (5)$$

$$\text{Emission Rate} = CEF \times V \quad (6)$$

Where CEF is the composite emission factor in g/km , N is a number of vehicles in 1 hour, and EF is emission factor in g/km, V is average velocity in km/hour.

The emission rate calculated from equation 4 was added to the ISC-AERMOD View program selected by the line source while the meteorology date available for 1 year were applied for determining the local concentration. Then, the atmospheric concentration was added the local concentration to get the background concentration emission of air pollutants. Only NO_X is required to change from NO_X to NO_2 by the ratio (NO_2/NO_X) of 0.75 (US.EPA, 1996a) (Sukanda,2006).

Air Quality Impact Assessment

The background concentrations and the concentrations of air pollutants from the stack boilers were compared to the ambient air quality standards of Thailand in order to determine the air quality impacts at Siriraj Hospital.

Result and Discussion

The results of this study are described following this section.

Air Pollutants Measurement

The measurement of air pollutants from the stack boiler at 2 places of Siriraj Hospital indicated that SO_2, CO and NO_2 concentrations at Syamindry building were approximately 73.40 ppm, 34 ppm and 22 ppm, respectively and their concentrations at Laundry division were 872 ppm, 6 ppm and 245 ppm, respectively. Following the equation 1, 2 and 3 the emission rate of each pollutant was determined and shown in table 1.

Table 1. The emission rate of SO_2, CO and NO_2

Pollutants	Syamindry (g/s)	Laundry (g/s)
SO2	0.020	1.230
CO	0.004	0.004
NO2	0.001	0.262

The important parameters used for ISC-AERMOD View program were expressed in table 2.

Table 2. The source parameters.

Parameters	Syamindry Building	Laundry Division
Velocity (m/s)	0.63	1.38
Temperature (^{o}K)	459	408
Stack Height (m)	65	25
Internal Diameter (m)	0.4	0.60

Meteorological Data

The meteorological data at Siriraj Hospital including the average velocity of 1.61 m/s in one year period are shown as figure 2.

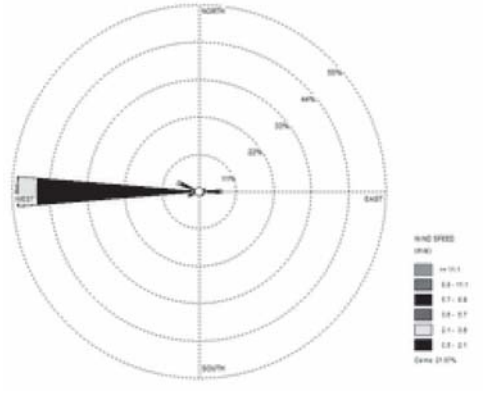

Figure 2. Typical of Average Velocity in a period of 1year.

From figure 2 the wind direction often flows from the western to the eastern at Siriraj hospital. The average velocity in each season is equal to 1.66 m/s, 1.64 m/s and 1.50 m/s, respectively.

Actual Condition Result

The results of this research for three air pollutants emitted from the stack showed that the annual maximum concentration of SO_2 for exhausted air was about 0.0103 ppm and 0.005 ppm, respectively. SO_2 was dispersed from the western to the eastern of the hospital area (Arunamrin road side to Chaophraya river side), and the distance from the Syamindry Stack and from the Laundry stack to the concentration maximum location (Medical Technical Building) was 134 m and 250 m, respectively. The following figure showed the typical dispersion of 24 hour SO_2 from the stack boiler at Siriraj Hospital.

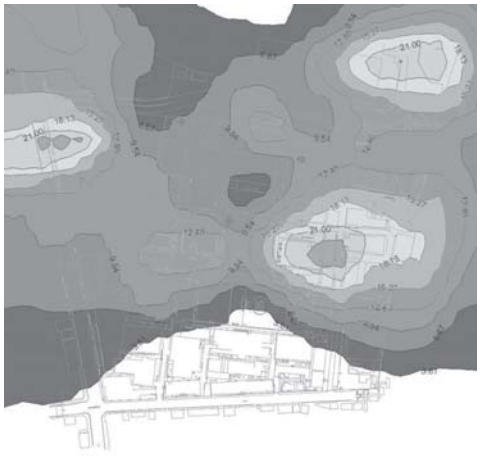

Figure 3. Typical Dispersion of 24 hour SO_2 in Hospital.

The maximum concentration of CO emitted from the stack for1 hour and 8 hours was 0.000357 and 0.000325 ppm respectively. For 1 hour the dispersion was moved from the western part to the

eastern part of the hospital (Arunamrin road side to Chaophraya river side), and the distance from Syamindry Stack and from Laundry stack to the maximum concentration location (72 years Building) was 137 m and 265 m, respectively. The following figure showed the typical dispersion of 1 hour CO from the stack boiler at Siriraj Hospital.

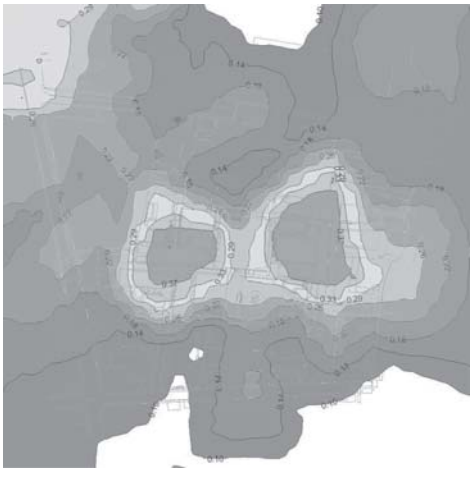

Figure 4. Typical Dispersion of 1 hour CO in Siriraj Hospital.

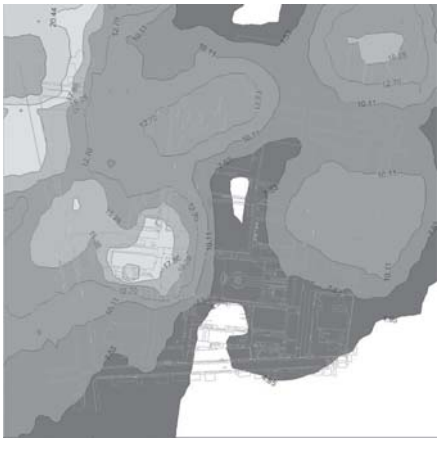

Figure 5. Typical Dispersion of 1 hour NO_2 in Siriraj Hospital.

The maximum concentration of NO_2 in 1 hour that emitted from stack was 0.010 ppm and dispersed from the northwest to the southwest (Chaophraya river side to Arunamarin road side), and the distance from the Syamindry Stack and from the Laundry stack to the maximum concentration location (Praob Building) was 148 m and 230 m, respectively. The following figure showed the typical dispersion of NO_2 from the stack boilers at Siriraj Hospital.

The annual concentrations of SO_2, CO and NO_2 were 4.86E-03, 9.71E-05 and 1.35E-03 ppm, respectively. These three pollutants were dispersed from the western to the eastern (Arunamrin road side to Chaophraya river side). Considering from the contour of each stack point, the annual concentration of SO_2 from Laundry Division was 4.86E-03 ppm and the distance to the location maximum concentration was (SiME Building) about 285 meters. The annual concentration of SO_2 from Syamindry building was 3.5E-03 ppm and the distance to the location maximum concentration (Chlermprakiet Building) was 117 meters. The following figure showed the typical dispersion of SO_2 at Siriraj Hospital.

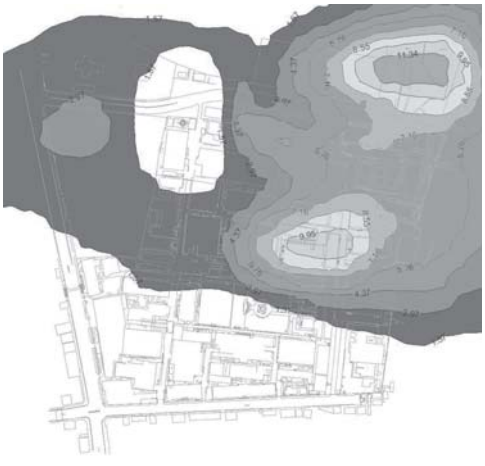

Figure 6. Typical Dispersion of SO_2 in Siriraj Hospital.

The annual concentration of CO from Syamindry Building was 9.71E-05 ppm and the distance from the boiler stack to the maximum concentration location (Chlermprakiet Building) was 73 meters. The annual concentration of CO from Laundry Division was 3.17E-05 ppm and the distance from the stack to the maximum concentration location (SiME Building) was 284 meters. The following figure showed the typical dispersion of CO at Siriraj Hospital.

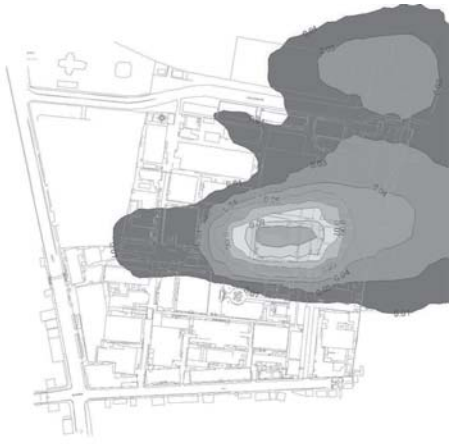

Figure 7. Typical Dispersion of CO in Siriraj Hospital.

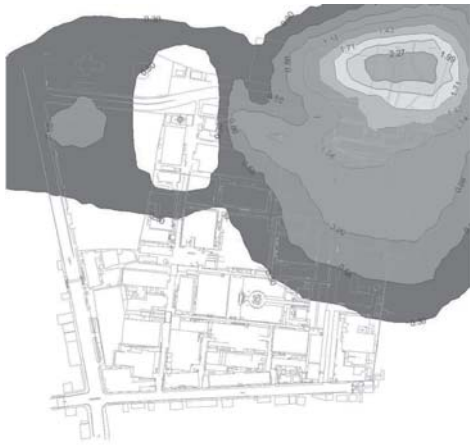

Figure 8. Typical Dispersion of NO_2 in Siriraj Hospital.

The annual concentration of NO_2 from both stacks was 1.35E-03 ppm and the distance from the stack to the maximum concentration location (SiME Building) was 285 m and 293 m for Laundry Division and for Syamindry Building. The following figure showed the typical dispersion of NO_2 at Siriraj Hospital.

Background Concentration Result

The hourly air quality information obtained from Intrapitak station showed that SO_2, CO and NO_2 were 0.011, 1.8 and 0.050 ppm, respectively for the percentile of 90. The daily number of vehicles on 5 roads that is Arunamarin, Phannok, Rail road, internal main A and internal main B were 62,112; 29,178; 17,960; 12,087; and 7,008 vehicles, respectively. The average velocity of vehicles on each road was 30.25, 22.50, 32.50, 17 and 20 kilometer per hour, respectively.

From the number of vehicles, the composite emission factors in each road are shown in table 3.

Table 3. The composite emission factor from motor vehicle.

Road	SO_2 (g/km)	CO (g/km)	NO_X (g/km)
1[a]	0.027	24.052	1.812
2[b]	0.029	32.985	1.305
3[c]	0.006	19.303	1.448
4[d]	0.028	29.653	1.297
5[e]	0.030	31.101	1.393

The results of the emission rates added to ISC-AERMOD program are expressed in table 4.

Table 4. The emission rate from motor vehicle.

Road	SO_2 (g/s)	CO (g/s)	NO_X (g/s)
1[a]	2.3×10^{-4}	0.202	0.0152
2[b]	1.6×10^{-4}	0.185	0.0073
3[c]	5.4×10^{-5}	0.174	0.0130
4[d]	1.3×10^{-4}	0.138	0.0060
5[e]	1.7×10^{-4}	0.171	0.0076

Note: table 3 and 4: a = Arunamarin road, b = Phannok road, c = Rail road, d = Internal main A, e = Internal main B

The information from table 4 was added to the ISC-AERMOD program and executed by selecting the line source and the meteorological data for one year period. It was found that the average concentrations of daily SO_2, annual SO_2, hourly CO, 8 hour CO and hourly NO_2 were 3.0E-05 ppm, 1.87E-05 ppm, 0.396 ppm, 0.334 ppm and 9.55E-03 ppm, respectively. The results from the addition in the atmospheric concentration were 11.03E-03 ppm, 11.01E -03 ppm, 2.196 ppm, 2.134 ppm and 14.554E-03 ppm, respectively. The distance for the maximum average concentration from Siriraj junction was 184 m (24-hour and annual SO_2), 309 m (1-hour and 8-hour CO) and 40 m (1-hour NO_2) respectively. These positions are shown in figure 9.

Actual Concentration Results and Air Quality Impact Assessment

The actual concentrations for each location at Siriraj Hospital were shown in table 6.

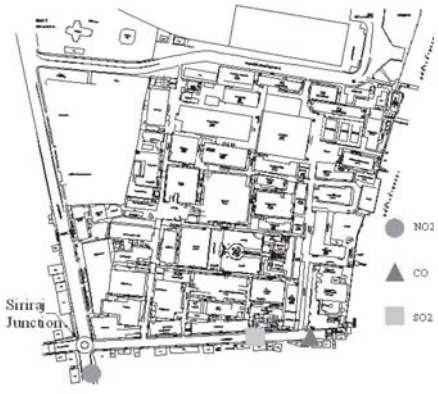

Figure 9. The maximum points of three pollutants from background source.

Table 6. The actual concentration in Siriraj Hospital

Pollutants	Background (ppm)	Stacks (ppm)	Actual (ppm)
24 hr SO_2	11.01E-03	10.21E-03	21.22E-03
Annual SO_2	11.00E-03	4.87E-03	15.87E-03
1 hr CO	2.1961	10.0E-05	2.1962
8 hr CO	2.1344	2.0E-05	2.1345
1 hr NO_2	14.45E-03	9.76E-03	24.21E-03

These concentrations were compared with the ambient air quality standard of Thailand as expressing in table 7. It was found that the concentrations of air polluants obtained from the model and background concentrations are less than the ambient air quality standard. However, these three air pollutants might be slightly affected to the hospital staffs. It is recommended to determine risk assessment for these air pollutants.

Varied Stacks and Building Condition

The results of the first test by varying the stack height from 10 to 40 meter at Laundry stack (25 meters) and fixing the Syamindry stack (65 meters) are shown as figure 9.

Table 7. Average pollutant concentrations and ambient air standards of Thailand (ppm).

Pollutants	Condition	Result	Standard
SO2	24 hr	21.22E-03	0.30
	Annual	15.87E-03	0.12
CO	1 hr	2.1962	30
	8 hr	2.1345	9
NO2	1 hr	24.21E-03	0.17

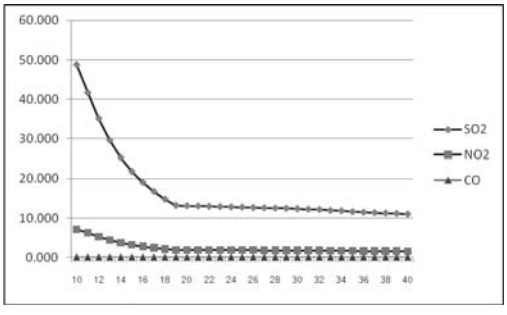

Figure 10. The graph from concentrations by varied stack height (10 - 40 meters).

It was found that the concentrations of SO_2 and NO_2 decreased as the height increase except for CO. Also, when the stack height was about 25 m, the concentrations of SO_2 and NO_2 were slightly decreased. The concentration of CO was almost constant at each height of the stack. However, the stack height of the Syamindry source is varied from 55 to 75 meters. It was found that there was no difference between these heights.

The results of the second test that was varied the building height surrounding the stacks by adding or reducing the building height to 10 m are shown as Figure 10. The annual concentrations of three air pollutants were found no difference. However, for 1 hour concentration it was found that there was difference when the building height was varied.

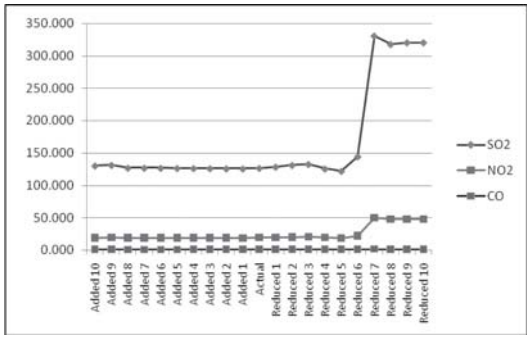

Figure 11. The graph from concentrations by varied building height (up and down 10 meters).

Figure 10 showed that the concentration at each building height for three air pollutants did not change as the building height was reduced while the SO_2 and NO_2 concentrations were dramatically increased at the building height of 7 meters. This result indicated that at this building height may affect the change of air pollutant concentrations.

Conclusions

The SO_2, NO_2 and CO from the boiler stack were found dispersion from the western to the eastern following the prediction by the ISC-AERMOD program. The maximum concentrations of these pollutants were found at SiME building located on the eastern part of the hospital. The addition of the background concentrations resulted in the change of the maximum concentration location. The concentration of SO_2 from the stacks was higher than the background concentration while the concentration of NO_2 has no difference. In contrast, the CO concentration from the stack was less than the background concentration. This result may occur from the variation of the stack height and the building height. However, the results of stack height and building height variation have slightly affected the air pollutants concentrations.

Limitations and Recommendations

The concentrations of air pollutants from the boiler stacks in this study were based upon measurement in 2007 and velocity was calculated from the exhausted air flow rate and combustion equation (not actual), the concentrations of the air pollutants obtained from ISC-AERMOD View program could be some error. Therefore, the measurement of every parameter from stacks boiler should be determined for further study.

The further study should be determination of the concentrations of air pollutants in the ambient air around Siriraj Hospital area for comparison of the concentrations obtained from ISC-AERMOD View program prediction.

The further research should be determined the air pollutants from the stack by using CALPUFF modeling system and local concentration form mobile source by use about a program evaluate the air pollution from traffic such as CALINE4.

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