Chapter V

Conclusions and Recommendations

5.1 Conclusions

This research succeeds in modeling of sulfur dioxide oxidation in plume using the Monte Carlo method for a single point source and flat terrain. The physico-chemical mathematical model is capable of simulating the Gaussian dispersions and chemical transformations of sulfur dioxide. The mathematical model also achieves assessment of chemical sensitivity analysis of Brimblecombe and Spedding (1974)'s reaction rate, Freiberg (1974)'s reaction rate in ammonia-rich environment and in ammonia-deficient environment and Ibusuki, Ohsawa and Takeuchi (1990)'s reaction rate in ammonia-rich environment, which effects sulfate formation by varying parameters such as atmospheric stability class, relative humidity, temperature, iron and ammonia concentrations. In this study, the measured sulfate concentration in Bang Na in 1988 by JICA (1990) was compared with the simulated sulfate concentrations calculated from Freiberg (1974)'s reaction rate and Alkezweeny and Powell (1977)'s first order reaction rate.

The conclusions of simulation results are as follows:

5.1.1 The physical and physico-chemical mathematical models hold true on the mass conservation property, that is for each cell:

$$(SO_2 + SO_4^{2-})_{in} = (SO_2 + SO_4^{2-})_{out} + (SO_2 + SO_4^{2-})_{acc} \qquad (3.19)$$

5.1.2 The physical mathematical model, using the simulated horizontal and vertical dispersion coefficients, is able to simulate the Gaussian dispersion which is close to the result from the Gaussian plume model, using Pasquill-Gifford dispersion coefficients for atmospheric stability class A, B, C and D at 1 km downwind and for atmospheric stability class C, D, E and F at 5 and 10 km downwind.

5.1.3 Comparison of yields of Brimblecombe and Spedding (1974)'s reaction rate, Freiberg (1974)'s reaction rate and Ibusuki, Ohsawa and Takeuchi (1990)'s reaction rate can be concluded that no yield occurs for Brimblecombe and Spedding (1974)'s reaction rate because this reaction rate depends much on high experimental iron concentration which cannot be found in the environment. Only at relative humidity of 99%, Freiberg (1974)'s reaction rate in both of ammonia-rich environment and ammonia-deficient environment plays a significant role in sulfate formation for every atmospheric stability class, temperature, iron concentration or ammonia concentration variations. Ibusuki et al. (1990)'s reaction rate in ammonia-rich environment does not cause significant yield for each atmospheric stability class, nor as a result of the temperature decrease or the relative humidity increase or the ammonia concentration increase or iron concentration increase because the hydrogen ion concentration, which is related to relative humidity and ammonia concentration, and the iron concentration in this rate increase with the exponent 0.5 which produce very small rate constant for any condition.

5.1.4 Relative humidity, temperature, iron and ammonia concentrations and atmospheric stability class effect yields of Freiberg (1974)'s reaction rate as follows:

5.1.4.1 The sulfate formation increases with increasing relative humidity, especially at relative humidity of 90% or higher .

5.1.4.2 The temperature increase decreases sulfur dioxide to sulfate transformation. The sensitivity of %yield to temperature depends mainly on relative humidity, meaning that there is a maximum %yield at the highest relative humidity and lowest temperature for the same atmospheric condition.

5.1.4.3 The amount of iron concentration is essential for the iron catalyzed oxidation of sulfur dioxide in solution. The higher iron concentration, the higher the sulfur dioxide oxidation in aqueous phase. In Samut Prakarn, observed iron concentration influences markedly on sulfate formation in the stable atmospheric stability at relative humidity of 99%, temperature of 20 °C and ammonia variations, particularly in ammonia-rich environment.

5.1.4.4 The amount of ammonia concentration regulates the extent of the iron-catalyzed oxidation of sulfur dioxide. The higher ammonia concentration in both ammonia-rich environment and ammonia-deficient environment, the higher increase in the acid neutralizing buffer capacity to counteract the acidity generated from the sulfur dioxide oxidation.

Most of the %yield in ammonia-rich environment is much more than that in ammonia-deficient environment because the acid neutralizing buffer capacity of the ammonia availability in the first condition is much higher than that in the latter condition. In ammonia-deficient environment, remaining ammonia concentration shows an inverse Gaussian concentration profile versus sulfate concentration and ammonia reacts with sulfate from the edge of the plume toward the center line.

5.1.4.5 Atmospheric dispersion controls sulfur dioxide concentration and sulfate formation in plume. The sulfate production is very low in the unstable and neutral atmospheric stabilities since the sulfur dioxide dispersion due to transportation with high wind velocity and diffusion by turbulent eddies and good mixing does not promote the second order sulfur dioxide oxidation rate. Vice versa, the conversion of sulfur dioxide to sulfate is very high in the stable atmosphere because the overall sulfur dioxide oxidation rate is high due to low wind velocity and poor mixing. For each atmospheric stability of any given condition, yield is rapid in early plume life and then proceeds at a slower rate and mostly tends to converge toward an asymptotic limit.

5.1.5 The measured yield is 13.67% during the dry season, where Alkezweeny and Powell (1977)'s first order reaction rate gives the yield of 4.85% at the location of Bang Na (MS1) with wind velocity of 2 m/s and Freiberg (1974)'s reaction rate in many cases provide the yields of 7.4-20.8%.

5.2 Recommendations

5.2.1 Ambient ammonia concentrations are necessary to be measured in order to simulate sulfate formation in accuracy.

5.2.2 Sulfur trioxide generated from the vanadium catalyzed oxidation of sulfur dioxide in combustion chamber of the power plant should be collected for baseline sulfate concentration estimation prior to reaction in the atmosphere.

5.2.3 Simulation of sulfur content reduction in fuel oil from 3% to 2% in order to study how reduced sulfur dioxide concentration effects sulfate formation.

5.2.4 Sampling of sulfur dioxide and sulfate concentrations as a function of distance in plume by an aircraft in order to estimate the actual transformation rate of sulfur dioxide to sulfate of the South Bangkok Power Plant plume to provide furthur understanding into actual rate of sulfate formation.