Chapter V

Discussion

5.1 Site to site comparison

To make comparison between Ban Tha Si and Ban Sob Pat, the correlation coefficient is taken to analyze the relationship of each parameters. The intersite correlation coefficients for air quality variables is showed in table 5-1.

Table 5-1 Intersite correlation coefficients(ρ) for air quality variables (n = 30)

Variables	correlation coefficient
SO_4^{2-}	0.50
H^+	0.50
NH_3	0.27
Fe	0.27
Mn	0.25
SO_2	0.09

From table 5-1, it can be summarized that SO_4^{2-} and H^+ have no difference values between 2 sites ($\rho = 0.50$), and indicated more stronger correlation than SO_2 which did not have statistically significant correlation between 2 sites. Average SO_2 concentrations during the sampling period (January 8-23, 1996) elucidated the obvious difference of SO_2 between Ban Sob Pat and Ban Tha Si for the same investigated time (Appendix B). For example, the highest peak for Ban Tha Si occurred during daytime in January 13,1996 was 135.37 ppb while SO_2 concentration at Ban Sob Pat was only 4.63 ppb, and when SO_2 at Ban Sob Pat had the highest value (95.25 ppb), the concentration at Ban Tha Si was 24.37 neq/m^3 in daytime period in January 16,1996. The average values of SO_2 for both sites also showed that Ban Tha Si had higher concentration than Ban Sob Pat (Ban Tha Si = 15.45 ; Ban Sob Pat = 5.73 ppb) as summarized in table 5-2 and figure 5-1 which showed the average values of each variables for both sites comparison. In addition with the mean ratio of SO_2 which was 2.70 indicated the difference between 2 areas. These may be caused by the pattern of the winds during the studied period which can be seen that there were a lot of calm presence in wind vane at both upper wind and lower wind measurement. Nevertheless, the major wind direction which can be observed during daytime in upper wind level were from south (S) to southwestern (SW) and the lower wind blew from northeast (NE) to southeastern (SE). It can be summarize by using the SO_2 data which indicated that Ban Tha Si always had more higher concentrations than Ban Sob Pat, especially during daytime period. By considering that the higher concentration, the more dispersion, it can be concluded that the upper wind which blew from the south would be the major wind direction in these areas more important than the lower wind.

Table 5-2 Average values of measured variables comparison between 2 sites (n = 30)

variables	Ban Tha Si			Ban Sob Pat			Ratio
	Min.	Mean	Max.	Min.	Mean	Max.	mean#
SO_4^{2-}	47.71	483.8±358.85	1756.67	36.88	452.76±389.75	1747.29	1.07
H^+	5.71	144.6±122.11	431.67	17.41	115.56±96.26	333.58	1.25
NH_3	11.93	125.99±81.71	344.05	19.89	126.25±80.19	311.81	1.00
Fe	0.42	2.24±1.22	5.12	1.00	3.44±1.15	5.88	0.65
Mn	0.02	0.08±0.04	0.16	0.03	0.18±0.09	0.39	0.44
SO_2	1.44	15.45±26.91	135.37	1.63	5.73±16.65	95.25	2.70

Remark: The ratio mean is the fraction of average value at Ban Tha Si per average value at ban Sob Pat.

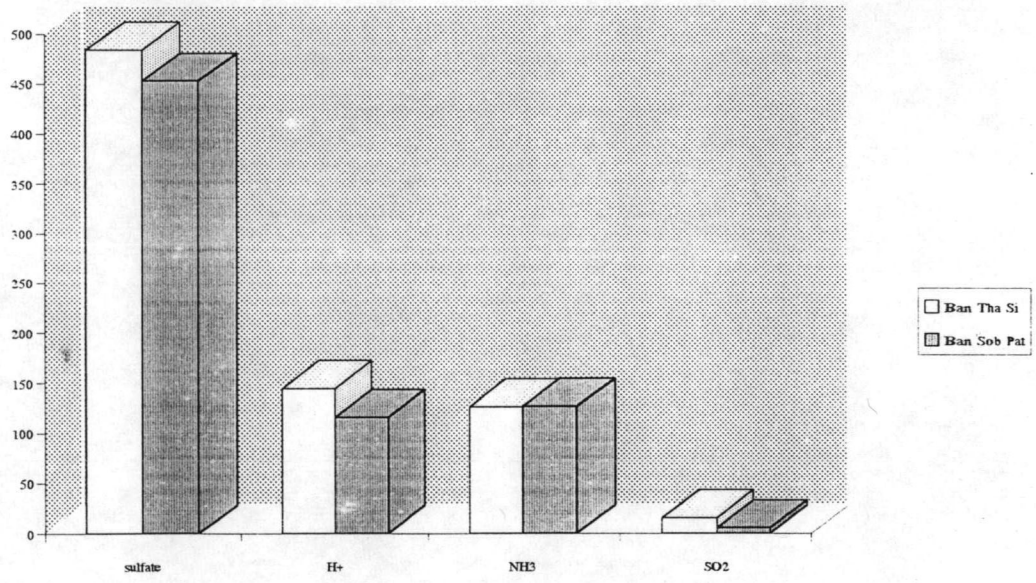

Figure 5-1 Average values for SO_4^{2-}, H^+, NH_3 and SO_2 for both sites

Correlation coefficient was taken for evaluation SO_4^{2-} relationship indicated the resemblance of 2 sites. The sulfate variations of both sites during the sampling periods as shown in figure 5-2 which also showed that there was little difference between SO_4^{2-} at both sites. Nevertheless, it can be considered from average values of SO_4^{2-} that Ban Tha Si had higher concentrations than Ban Sob Pat. (average value of Ban Tha Si = 483.82 neq/m^3 and Ban Sob Pat = 452.76 neq/m^3)

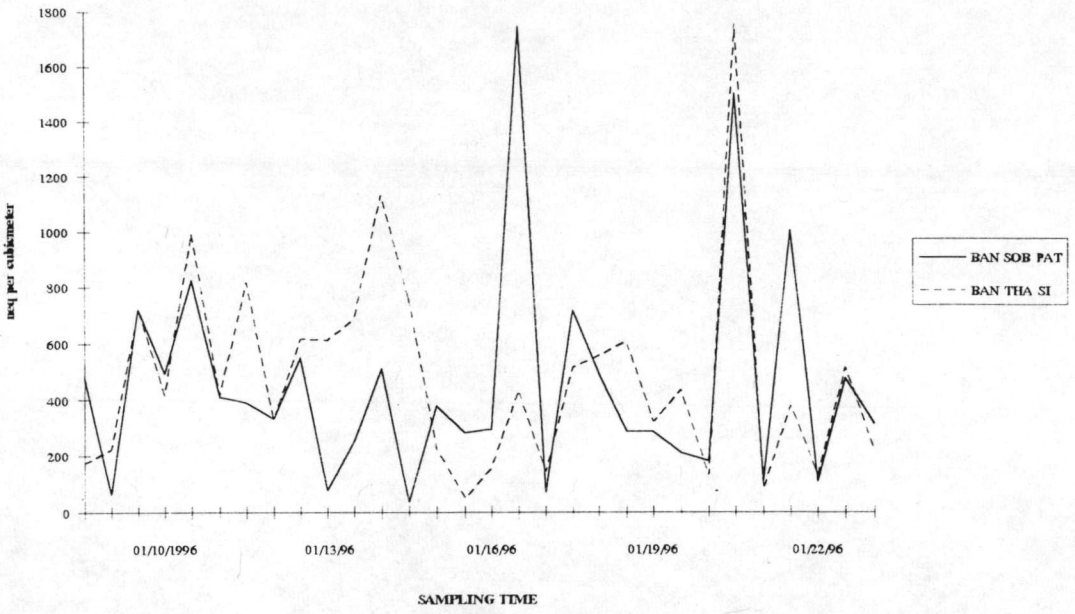

Figure 5-2 Sulfate aerosol concentrations at Ban Tha Si and Ban Sob Pat

H^+ had the same values of correlation coefficient with SO_4^{2-} ($\rho = 0.50$). It can be considered that both acidic species always had the similar pattern which indicated the irreversible characteristics as shown in figure 4-3, but when considered the average values and the ratio mean of H^+, founded that H^+ at ban Tha Si had more higher values than Ban Sob Pat as indicated in table 5-2. Nevertheless the standard deviation of H^+ at Ban Sob pat was less than Ban tha Si which can be summarized that there was no difference between both sites.

Correlations of NH_3, Fe and Mn were weakly correlated between two site, too. Although there had few difference concentration of Fe and Mn between 2 sites, the average values showed that Ban Sob Pat have more Fe and Mn than Ban Tha Si while NH_3 had similar values between both sites.

5.2 Day to night comparison

A comparison was made between daytime (09.00-17.00) and nighttime period (17.00-09.00) with the purpose to evaluate the persistence of reactive air pollutant species such as aerosol acidity, O_3 and relative meteorological conditions such as solar radiation, wind speed and wind directions. Daytime values of acidity, sulfate and ammonia were frequently more lower than those of the following nighttime except daytime ammonia concentrations at Ban Sob Pat which was found more higher values than nighttime (table 5-3). The ratio mean of acidic species which summarized in table 5-3 indicated that average daytime values of the NH_3 were equal nighttime values multiple by 0.5.

Table 5-3 Daytime (09.00-17.00) and nighttime (17.00-09.00) values of each variables

variables	site @	daytime			nighttime			ratio mean
		Min.	Mean	Max.	Min.	Mean	Max.	
SO_4^{2-}	1	61.46	272.56±144.90	508.96	36.88	591.16±351.70	1747.29	0.43
	2	78.90	296.15±154.90	1135.21	47.71	588.17±351.70	1756.67	0.54
NH_3	1	29.34	122.77±79.10	311.81	19.89	116.49±63.60	116.49	1.04
	2	34.58	82.54±40.90	150.76	11.93	166.88±72.10	344.05	0.50
H^+	1	17.41	62.77±48.80	202.78	18.61	159.88±92.40	333.58	0.46
	2	17.32	78.86±61.60	431.67	5.71	189.78±105.40	378.10	0.52
SO_2	1	2.25	9.47±22.94	95.25	1.63	1.99±0.28	2.69	4.76
	2	3.40	27.73±34.68	135.37	1.44	3.98±2.22	7.94	6.97
O_3		8.50	12.41±2.21	16.88	4.63	5.75±1.06	8.50	2.16
solar radiation		347.25	415.42±31.58	471.29	14.64	18.02±1.78	20.96	23.05

Remark: @ 1 = Ban Sob Pat
2 = Ban Tha Si

The resemblance situations which peaks occur at nighttime were also seen by Pierson *et al.*(1980b) and Keeler (1987) for the study at two elevated sites (>1,000 ft) in western, Pennsylvania. These were described that there were caused by the high relative humidities that existed at nighttime which caused the local nighttime conversion of SO_2 to SO_4^{2-} more relatively important than daytime conversion (photochemical processes). The study by US.EPA. (1994) during December,1993 to March,1994 at Ban Sob Moh located in the vicinity of Mae Moh Power Plant areas also indicated that nighttime SO_4^{2-} concentrations were higher than those daytime concentrations. Consequently, from this study and the study by US.EPA.(1994) which were conducted, and the diurnal patterns were investigated in the vicinity of Mae Moh Power Plant areas can be summarized that there were the higher sulfate concentrations occurring during nighttime than daytime period.

While data on boundary layer stability are not available, nocturnal temperature inversions close to the ground are common wintertime occurrences. By squelching dispersion, these would be expected to promote greater availability of these acidic species near the Power Plant in nighttime period. In addition, the pattern of the winds in nighttime periods were calm, so dispersion of air pollutants cannot be well when compare with daytime dispersion.

Average daytime SO_2 concentrations were predictably higher than those for nighttime on virtually all dates, similarly with O_3 concentrations which were higher values in daytime than nighttime period. The decrease of SO_2 concentrations during nighttime period can be explained by the constructed tall stacks (150 m above ground level). The stack height can prevent the occurrence of fumigation and downwash that when there were surface inversion occurring in the evening and in the morning, air pollution emitted at the high level couldnot reach the ground during this time, so SO_2 concentrations which were measured by the ground level monitoring stations detected less SO_2 values than those in daytime including with the higher wind speed which

supported the atmospheric turbulence during daytime period also caused the more dispersion than those during nighttime period. The decreasing were also caused by the burning of oil instead of coal (Appendix E). Solar radiation values were also the same patterns with SO_2 and O_3. Average daytime value was 415.21 w/m^2 while it was 18.02 w/m^2 at nighttime period. The comparison of day and nighttime average values for each variables was shown in figure 5-3.

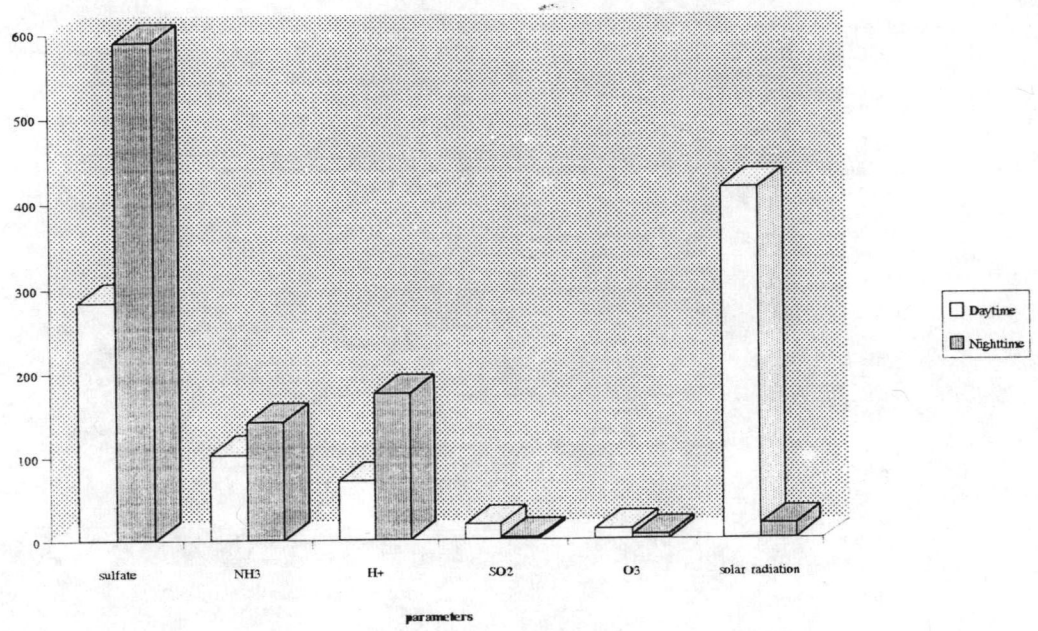

Figure 5-3 Daytime and nighttime average values for each parameters

5.3 Relationship for air quality variables

The relationship for air quality variables at each site was indicated by using correlation coefficient as shown in table 5-4. Although, sulfate and its acidity concentrations were strongly correlated for both sites, there were negative relation pattern for SO_4^{2-} with SO_2, Fe and Mn. It can be concluded that there were weakly versible correlated for these variables which indicated the more SO_4^{2-}, the less SO_2, Fe and Mn in these areas.

Table 5-4 Correlation coefficient for air quality variables at each site (all sample)

Variables	Ban Tha Si	Ban Sob Pat
SO_4^{2-} - H^+	0.7208	0.7093
SO_4^{2-} - NH_3	0.4714	0.2265
H^+ - NH_3	0.0938	0.1976
SO_4^{2-} - Fe	-0.1711	-0.2962
SO_4^{2-} - Mn	-0.2253	0.0049
SO_4^{2-} - SO_2	-0.0223	-0.0875

Table5-5 indicated the correlation coefficient of each parameters which are expected to affect sulfate concentrations. There is strong correlation between solar radiation and ozone, and between Fe and Mn. The negative correlation of SO_4^{2-} with each parameters indicated the more sulfate, the less the others, but it cannot found the conclusion for the obvious relationship of each parameters since these study is not performed in the laboratory scale and the multiple regression analysis does not indicate the relative significance for each parameters as indicated in appendix F.

Table 5-5 Correlation coefficients between sulfate and another factors

	SO_4^{2-}	Fe	Mn	SO_2	O_3	Solar radiation
SO_4^{2-}	1.00	-0.23	-0.07	-0.04	-0.38	-0.38
Fe		1.00	0.77	-0.01	0.41	0.38
Mn			1.00	-0.15	0.17	0.11
SO_2				1.00	0.23	0.21
O_3					1.00	0.86
Solar radiation						1.00

The actual factor contributed in SO_4^{2-} formation would be SO_2 concentrations directly emitted from the source. In this study, it was found that there were difference in SO_2 concentrations between both sites and both daytime and nighttime periods. This variation is caused by the dispersion of SO_2 emitted from the stacks of the Power Plant depended on the meteorological conditions which brought the opportunities to investigate more SO_4^{2-} concentration at Ban Tha Si than Ban Sob Pat and higher values during daytime period than those during nighttime although there were a little difference of diurnal variations in exhaust SO_2 gas from the Power Plant. It can be summarized that SO_2 concentration was the major factor which affected the quantity of SO_4^{2-} concentration in these areas while meteorological conditions performed as the most related factors which affected to the concentration of SO_2 at ground level and quantity of the detected SO_4^{2-} by contribution in dispersion of SO_2 from its source.

The transformation of SO_2 to SO_4^{2-} in the vicinity of Mae Moh Power Plant can be described by considering processes of the formation of SO_4^{2-}. Since there are two pathways of SO_4^{2-} formation, one is the gas phase mechanisms, and the other is the aqueous phase mechanisms. From the study, it can be summarized that the more possible conversion processes in these areas during the period of study is the oxidation of SO_2 in the aqueous phase due to the investigation of higher SO_4^{2-} concentrations in nighttime period than those in daytime period, and the sampling sites which located in the vicinity of Mae Moh Power Plant according to these reactions do not require a long time nor long distance. In addition to the presence of more Fe and Mn which are known as the catalysts in these processes high enough to accelerate the formation of SO_4^{2-}. These reactions do not require sunlight nor warm temperatures, and their conversions can be very fast which caused the local reactions while the gas phase or photochemical processes require long reaction times and therefore long distance transport before substantial amounts of acid sulfate are formed. Consequently, the aqueous phase reaction which Fe and Mn perform as the catalysts will lead to the

production of acid sulfates in the vicinity of Mae Moh Power Plant while in the farther areas, the photochemical processes will be the dominant processes of SO_4^{2-} formation. These nonphotochemical processes are also supported by high humidities since Mae Moh Power Plant is located in tropical zone and the stagnation of wind during the wintertime influencing to the dispersion of air pollutants cause the opportunities in the occurring of SO_4^{2-} in the vicinity of its source.

Therefore, it can be summarized that Mae Moh Power Plant areas have the potential in the transformation of SO_2 to SO_4^{2-} due to the feasible of the catalysts, and the meteorological conditions which also support the occurrence of these processes, particularly during nighttime and wintertime which the high quantities of SO_4^{2-} can be detected in the vicinity of these Power Plant areas. The knowledge of the potential of the formation of SO_4^{2-} in these areas will be useful in considering the damage and exposure effects which affect to man and environment in these areas not only the effects from SO_2 but also the effects from another sulfur-containing compounds.

5.4 Exposure of acid aerosol

Aerosol acidity are evaluated in terms of the H^+/SO_4^{2-} equivalent ratio. These values range from 1, for pure H_2SO_4, to 0, for the fully neutralized aerosol $(NH_4)_2SO_4$. Figure 5-4 shows the acid aerosol phase diagram obtaining from the relationship of sulfate and its acidity (H^+). The fraction of H^+ and SO_4^{2-} which is called acidic fractions or aerosol acidity in these study were about 0.09-0.49 and 0.07-0.50 for Ban Tha Si and Ban Sob Pat, respectively. There did not have acid aerosol in sulfuric (H_2SO_4) phase, i.e. $H^+/SO_4^{2-} \leq 1$, found in these episode. Almost of acid aerosol (92.7%) were found in partially neutralized acid phase or $(NH_4)_3H(SO_4)_2$, i.e. $H^+/SO_4^{2-} = 0.1\text{-}0.5$, and few of neutralized acid phase or $(NH_4)_2SO_4$ about 8.3% were found during these episode and it was only one time which acid aerosol was found in bisulfate phase ($(NH_4)HSO_4$).

The relevant research for acid aerosol was conducted by US. EPA. during 1993-1994 (US.EPA.,1994) which determined the sulfur dioxide, acidic species and acid sulfate concentrations in community near Mae Moh Power Plant. The study also indicated the aerosol acidity in terms of acid aerosol phase. The concentration indicated that average acidity of these aerosol were partially neutralized acid aerosols, but there were significant of bisulfate and the neutralized acid phase in these study.

Pollution Control Department (PCD) investigated the acid aerosol and other acidic species in December, 1994. Sampling were conducted at Ban Sob Pat, Ban Tha Si and Ban Huay Pang (reference site). Results of the study was taken for evaluating the aerosol acidity for the purpose to compare with both studies which is described above. A clear difference between sites emerges in the phase diagram for aerosol acidity which was an apparent hierarchy among site (Ban Sob Pat>Ban Tha Si>Ban Huay Pang). The aerosol acidity comparison for all of these three studies which taken places in the vicinity of Mae Moh Power Plant is summarized in table 5-6.

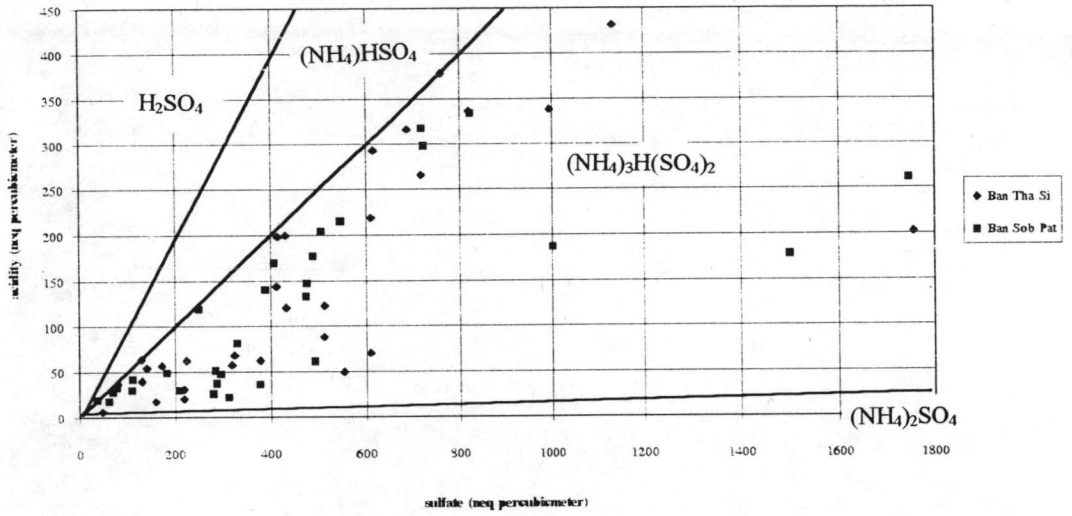

Figure 5-4 Acid Aerosol Phase Diagram

Table 5-6 Acid aerosol phase comparison

study period	percent of acid aerosol phase			
	H_2SO_4	$(NH_4)HSO_4$	$(NH_4)_3H(SO_4)_2$	$(NH_4)_2SO_4$
Jan08-23/96 (a)	-	1.67	91.67	6.67
Dec15/93-Apr/94 (b)	-	12.08	80.22	7.69
Dec08-27/94 (c)	-	32.14	57.14	10.75
Huay Pang (d)	6.25	6.25	56.25	31.25

Remark: (a) This study was conducted at Ban Sob Pat and Ban Tha Si during January 08-23/1996 (n=60).
(b) US. EPA worked at Ban Hua Sua, Ban Sob Pat and Ban Tha Si during December 15/1993 to April/1994 (n=91).
(c) PCD. worked at Ban Sob Pat & Ban Tha Si during December 08-27/1994 (n=56).
(d) Reference sites in PCD.'s investigation (n=16)

The occurring of SO_4^{2-} in Mae Moh Power Plant areas which were usually investigated in the formed of ammonium salts (NH_4HSO_4 and $(NH_4)_3H(SO_4)_2$) demonstrated the potentiality of neutralization in these areas. Since the ambient measurements of ammonia gas in these study suggested that the ammonia concentration were found to be higher during nighttime than those during daytime periods, these caused no relative difference in the forms of SO_4^{2-} between daytime and nighttime periods although there were higher quantities of SO_4^{2-} and its acidity (H^+)

during nighttime than daytime periods. Approximately 92% of SO_4^{2-} in these study were found in partially neutralized acid phase ($(NH_4)_3H(SO_4)_2$) which indicated the decreasing of direct damage and harmfulness affecting by the acid aerosols in Mae Moh Power Plant areas. It can be summarized that these areas have the high opportunity in the transformation of SO_2 to SO_4^{2-}, but the acid sulfate usually occurred in the forms of ammonium salts which its acidity are decreased by the neutralization process by abundant ammonia found in these areas.

There are many possible health effects associated with acid aerosols, both with acute and chronic exposures, but the available animal and controlled human data to assess concentration-response relationships are limited, particularly for assessing health risk at ambient exposures. While the controlled studies provide the best quantitative data at this time, very few of the studies have examined concentrations that approach known peak ambient level, and too few concentration-response or concentration time studies have been performed. However, chronic studies of ambient acid levels using sensitive measurement techniques have not been performed. Thus the no measurable effect level is not adequately defined for risk assessment purposes. At present, epidermiology provides no clear quantitative relationships because of a lack of sufficient ambient acid measurements by which to define exposure-response effects levels.

In conclusion, the available information derived from animal and controlled human studies clearly indicates that exposure to acid aerosols at high enough concentrations can produce health effects of concern, particularly in sensitive subgroups of the population and after chronic exposure. The bulk of these studies, however, have examined H_2SO_4 exposures. Data for other acid species and mixtures are extremely limited. The effects seen range from mild and transient changes, such as small, reversible functional effects that may have acute or chronic health consequences, such as persistently altered clearance and structural changes that may be suggestive of chronic lung disease. In addition, there are some notable consistencies in the health effects information across various studies and disciplines. However, there are significant limitations in the available data to assess the health risk of current ambient exposures. The available animal and controlled human exposure studies provide good quantitative information on a range of possible health effects, but most of these studies have examined H_2SO_4 levels well above known peak ambient concentrations and hence provide limited information for possible ambient exposures. Several relevant epidemiological studies indicate effects consistent with those observed in the controlled studies but lack direct or concurrent acid exposure data, substantially limiting their usefulness for quantitative assessment of health of current ambient exposures. The few epidemiological studies that do have direct acid measurements generally recorded low acid levels or, where acid levels were elevated, ozone was also elevated and the contribution of the acid component for affecting pulmonary function is not clear, and cannot be taken to summarized for this study which acid levels and ozone concentration were not simultaneously elevated (Raizenne *et al.*, 1987, 1989) . Finally, there are several factors that may significantly influence the concentration-response relationships that are not completely understood.