CHAPTER 4

RESULTS AND DISCUSSION

4.1 Time Trends of The Five Pollutants

Fig. 4.1 indicates daily concentrations of NO_2, CO, PM_{10}, SO_2 and O_3 from January 1997 to December 1998 for the Dindang site. There are some points missing in these plots due to malfunctioning of measuring instruments. Averages, standard deviations, ranges, and Thai national ambient air quality standard (TNAAQS 1995) for all five pollutants are given in Table 4.1.

Table 4.1 Descriptive statistics of five air quality parameters at Dindang site.

Value	NO_2 (ppb)	CO (ppm)	PM_{10} (mg/m^3)	SO_2 (ppb)	O_3 (ppb)
Average	45.4	3.0	119.9	15.5	4.7
Standard deviation	15.0	1.1	40.2	6.0	2.8
Range	24.1 - 83.1	1.4 -5.7	55.8 - 219.1	5.3 - 32.5	0.7 - 14.3
Thai national ambient air quality standard TNAAQS (1995)	170 (1-hr)	30 (1-hr)	120 (24-hr)	300 (24-hr)	100 (1hr)

Three air pollutants; NO_2, CO, and PM_{10} exhibited similar trends. High values were seen from January 1997 to the end of April 1997 and from September 1997 to the end of January 1998. Lower values around 30 ppb, 2 ppm, and 75 $\mu g/m^3$ for NO_2, CO, and PM_{10}, respectively, during May 1997 to August 1997 and during February 1998 to July 1998 were very visible. However, low concentrations of SO_2 and O_3 were also observed from May 1997 to September 1997.

The averages of almost all air pollutants (Table 4.1) were well below Thai national ambient air quality standards except for PM_{10}. The mean concentrations of NO_2, CO, PM_{10}, SO_2, and O_3 were 45.4 ppb, 3.0 ppm, 119.9 mg/m^3, 15.5 ppb, and 4.7 ppb, respectively. However, fluctuation of some pollutant concentrations such as NO_2, CO, and PM_{10}, also indicated potential periods where air quality were more degraded than other periods of time and may be attributed to certain factors such as seasons, transportation activities, or presence of construction sites nearby.

4.2 Correlation Analysis

Table 4.2 shows the correlation among each pair of variables. From this result, NO_2, CO, and PM_{10} were highly correlated to each other and may be an indication of emission from the same source. Such high correlations were presented by correlation coefficients of greater than 0.7. Sulfur dioxide exhibited moderate relationship with NO_2, CO, and PM_{10} whereas O_3 did not correlate to the rest.

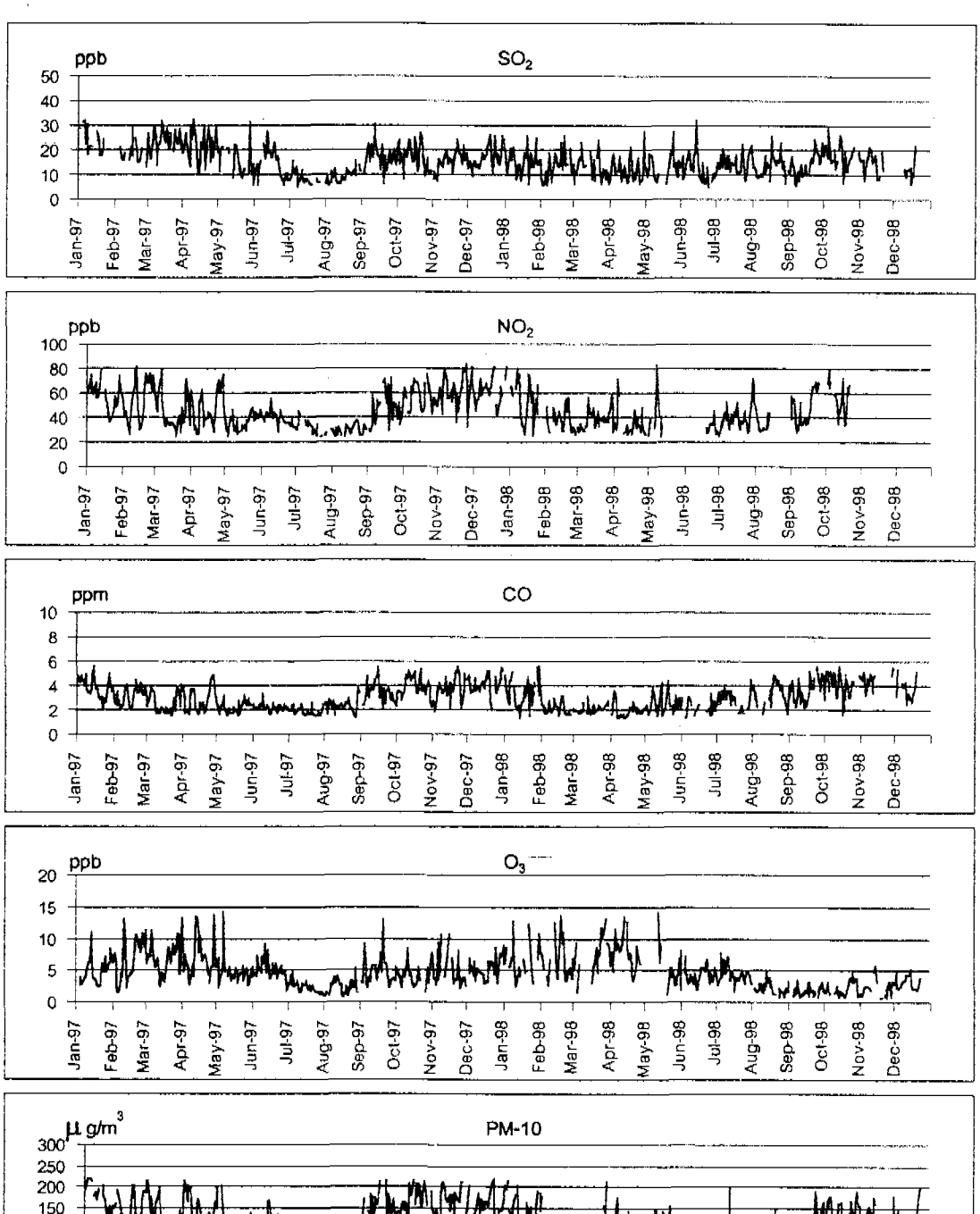

Fig. 4.1 Time series Plots of SO_2, NO_2, CO, O_3 and PM_{10} concentration from January 1, 1997 – December 31, 1998 for the Dindang site

Table 4.2 correlation among the five pollutants

	NO_2	CO	PM_{10}	SO_2	O_3
NO_2	1.000	0.848	0.804	0.447	0.090
CO	0.848	1.000	0.772	0.426	-0.059
PM_{10}	0.804	0.772	1.000	0.503	0.080
SO_2	0.447	0.426	0.503	1.000	0.151
O_3	0.090	-0.059	0.080	0.151	1.000

4.3 Results of Factor Analysis

Three factors were retained for the Dindang site. The unrotated factors, varimax-rotated factor loadings, and eigenvalues are given in Table 4.3. Factors one, two, and three accounted for 51.39, 21.04, and 20.36 % of the total variance, respectively. All three factors accounted for 92.79% of the total variance in the data set.

The first factor was identified as motor vehicles since factor loadings were high on NO_2, CO, and PM_{10} variables. These three pollutants are mainly associated with emissions from transportation sources (JICA 1996; Kleeman et. al. 1999).

The fact that this sampling site was influenced by transportation source can be shown by the 24-hr plots of NO_2, CO, and PM_{10} in Fig. 4.2. There were two peaks in these plots that correspond to rush hour periods from 6 to 10 a.m. and from 5 to 9 p.m. in Bangkok. This finding confirms that air quality for this site was impacted by motor vehicle emission.

The second factor was high in SO_2 (rotated loading on SO_2 = 0.96). Thus, this factor could be a representation of power plants, industrial combustion, or vehicular emissions of diesel engine. However, the 24-hr plot of SO_2, again, exhibited two peaks during the Bangkok rush hours. This may indicate association of SO_2 in factor two with diesel fuel used in transportation sector.

The third factor was dominated by the factor loading of ozone (rotated loading on O_3 = 0.99). Ozone is a secondary air pollutant that is formed in atmosphere from reactions between NO_x and hydrocarbon compounds with a catalyst of sunlight radiation. It may be possible that the primary compounds required for the formation of ozone are supplied by vehicle exhausts. Peak ozone concentrations was observed from 1 p.m. until 5 p.m. in the ozone 24-hr plot (Fig. 4.2).

All three factors derived from factor analysis seem to indicate the importance of vehicular source. Different loading characteristics of each factor may result from different types of combustion techniques and fuel used for a variety of vehicles as well as different pathways for pollutant formation in atmosphere.

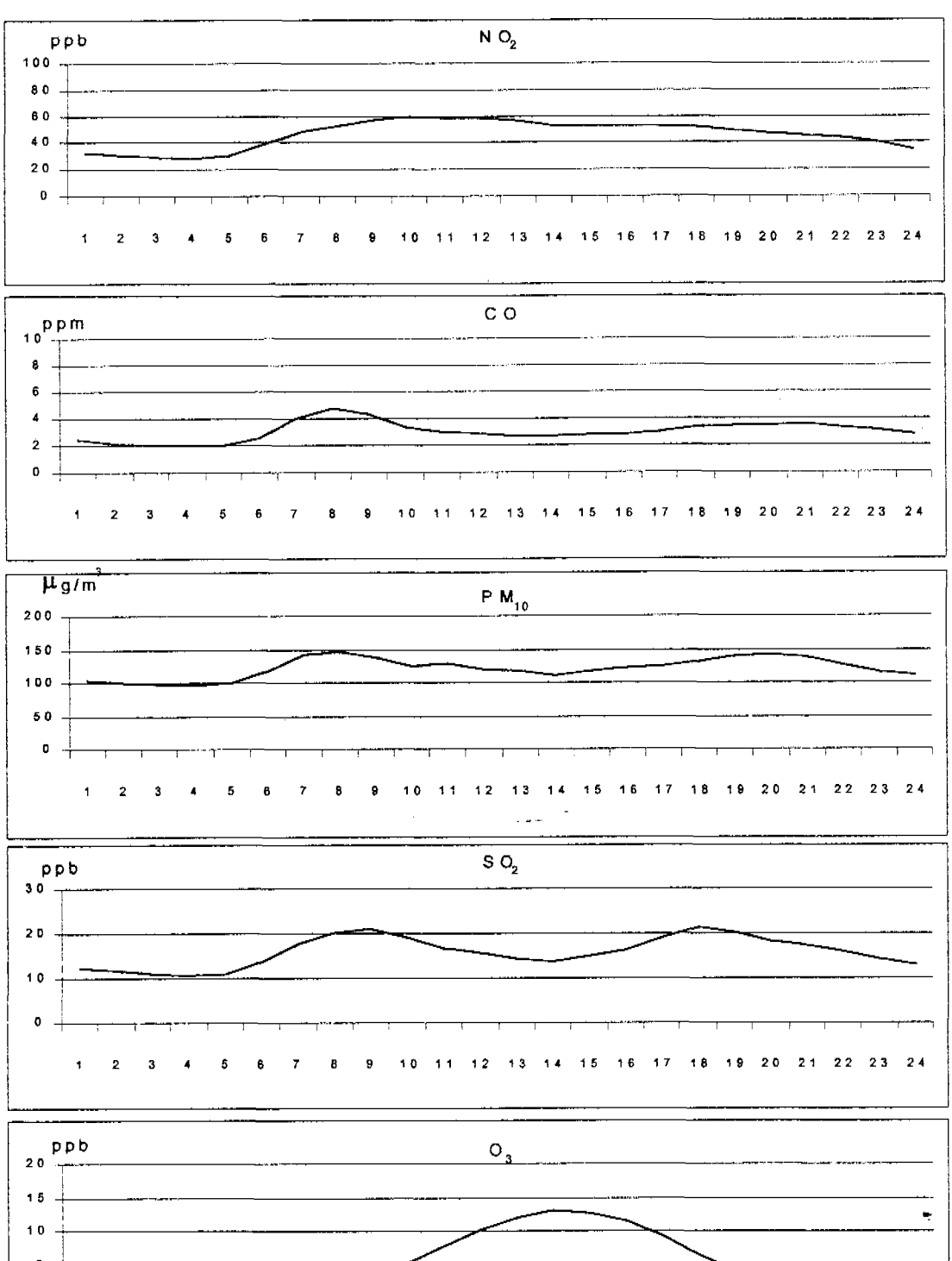

Fig. 4.2 The 24-hr concentration plots of NO_2, CO, PM_{10}, SO_2, and O_3 for the Dindaeng site during a period of 730 days

Table 4.3 Unrotated and rotated factor loading of Dindang site.

	Factor 1		Factor 2		Factor 3	
	unrotated	rotated	unrotated	rotated	unrotated	rotated
NO_2	0.93	0.93	-0.05	0.17	0.22	0.08
CO	0.91	0.93	-0.22	0.17	0.16	-0.10
PM_{10}	0.91	0.87	-0.03	0.28	0.10	0.06
SO_2	0.65	0.29	0.27	0.95	-0.71	0.08
O_3	0.10	0.01	0.96	0.07	0.25	0.99
Eigenvalue	2.57		1.05		1.02	
Percent variance	51.39		21.04		20.36	

4.4 Results of Decomposition Technique

Fig. 4.3 A, B, and C show the mean values of cyclic indices for hourly, daily, and monthly intervals, respectively. Associated statistical results such as mean, standard deviation (SD), coefficient of variation (CV), range, minimum and maximum value are also given in Table 4.4 and Table 4.5, respectively. The figures demonstrate the cyclical pattern of PM_{10} level in Dindang district. From these results, indices of the hourly and monthly cyclics indicate higher influences of hours in day and months in year to PM_{10} levels than the daily cyclic which is almost a flat line. This indicates that days in week is a less influencing factor than others for the PM_{10} level. For hourly and monthly indices, the Fig. 4.3A and C show the obvious variation in these indices. Hourly indices (Fig. 4.3A) are high during rush hours which obviously indicate relationship between the number of vehicles during rush hour and concentration levels of PM_{10}. The accumulation of vehicles in rush hour periods lead to accumulation of PM_{10} simultaneously. From 7 to 9 am and from 7 to 9 pm are the critical time periods one should be concerned for controlling of the PM_{10} level.

Monthly indices are also the vital factor and seems to be the most important factor as indicated by magnitude of its values and variation in Table 4.4. High values of monthly indices occured from October to January which represent the cold season. If we compare monthly cyclic index with wind speed (Fig. 4.4), we found that wind speed was consistently high in the range of 1.5-2.0 m/s during the months of May 1997 to September 1997 and during the months of February 1998 to July 1998. Strong rainy wind during the first period may be responsible for low values of monthly cyclic indices of PM_{10} concentrations in that time through the mechanisms of dilution by wind as well as washing out by rain water. High velocity wind during summer times (February to April, 1998) depressed the concentration of PM_{10}. In fact, wind speed is usually high in summer for Thailand compared to other seasons.

Table 4.4 Statistical results of daily cyclic index

DAY	MEAN	SD	CV	MIN	MAX
MON	0.967	0.063	0.065	0.876	1.049
TUE	1.026	0.027	0.026	0.979	1.057
WED	1.036	0.046	0.044	0.970	1.130
THU	1.007	0.029	0.028	0.961	1.074
FRI	0.984	0.040	0.040	0.926	1.043
SAT	1.015	0.029	0.029	0.980	1.077
SUN	0.966	0.091	0.094	0.851	1.143

Table 4.5 Statistical results of monthly cyclic index

MONTH	MEAN	SD	CV	MIN	MAX
JAN	1.33	0.09	0.07	1.18	1.49
FEB	0.71	0.11	0.16	0.54	0.87
MAR	0.67	0.07	0.10	0.54	0.78
APR	0.83	0.11	0.13	0.60	0.97
MAY	0.93	0.14	0.15	0.73	1.16
JUN	0.79	0.11	0.14	0.58	0.96
JUL	0.60	0.13	0.22	0.48	0.93
AUG	0.71	0.07	0.10	0.58	0.84
SEP	1.26	0.12	0.09	1.13	1.47
OCT	1.35	0.15	0.11	1.16	1.59
NOV	1.40	0.16	0.11	1.16	1.59
DEC	1.41	0.11	0.08	1.13	1.53

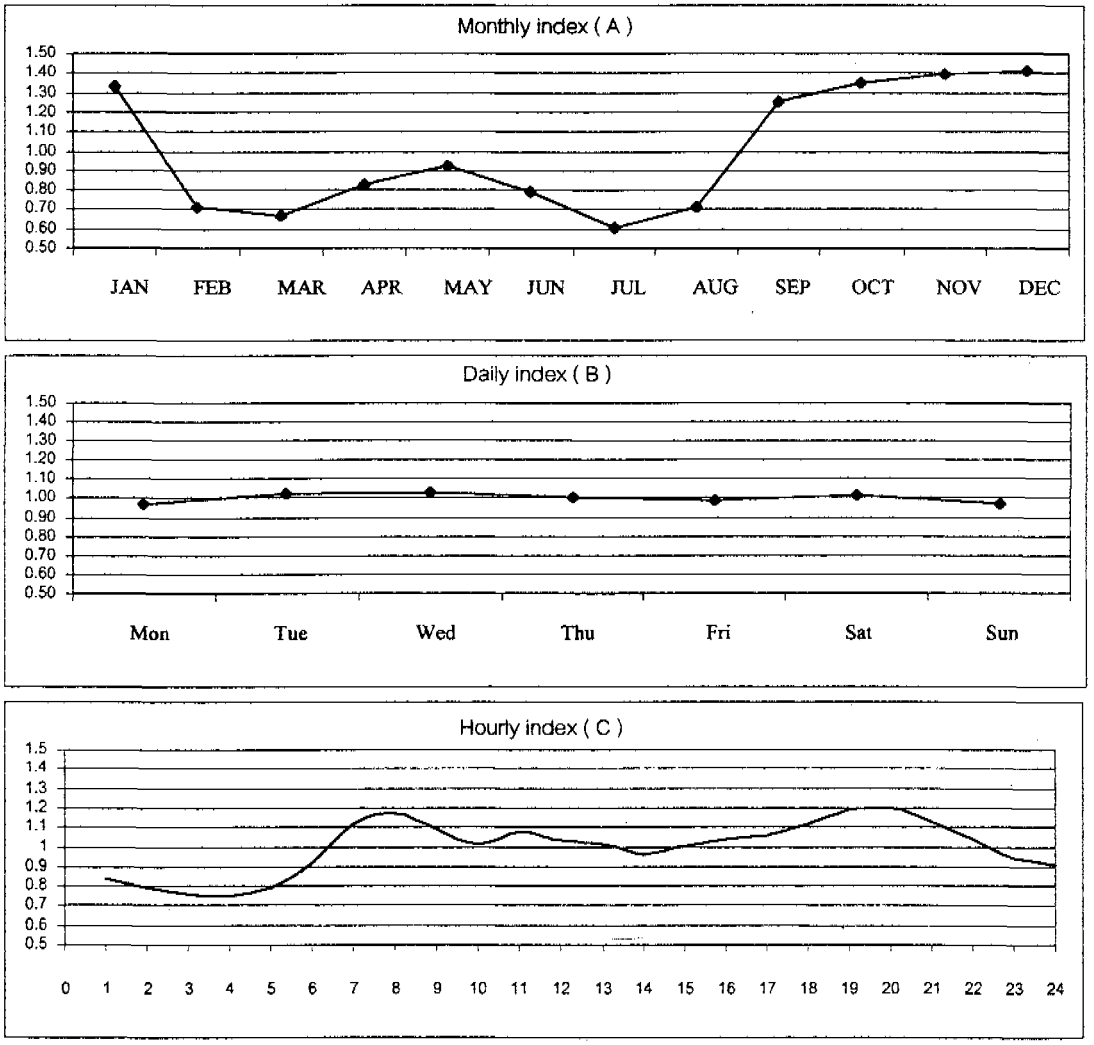

Fig. 4.3 A, B and C Graph of hourly, daily, and month cyclic index

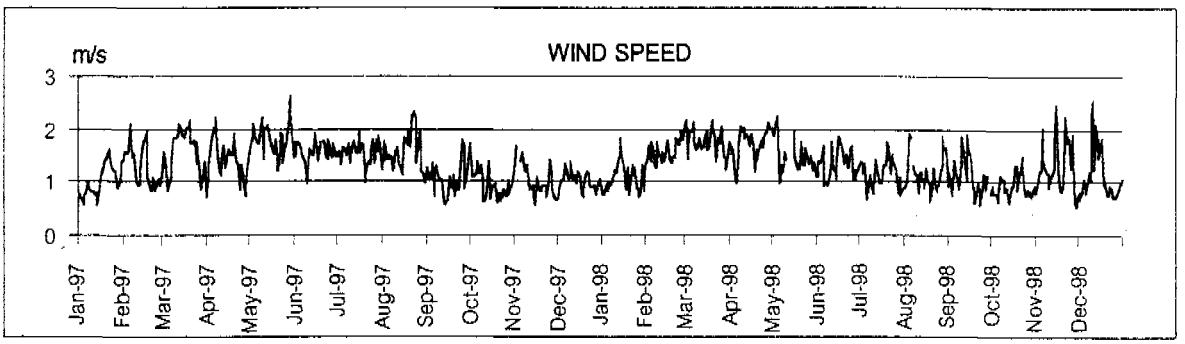

Fig. 4.4 Wind speed Plot of Dindang site from January 1, 1997 – December 31, 1998