4.1.2 Analysis of the Monitoring Data

(1) Outline of Pollutant Concentration

The Data and the measurement periods included in this analysis are as follows. Detailed analyses were mainly made with the data of the fixed stations.

	Fixed Stations		
S-1	City Hall	March, 1992	→ February, 1993
S-2	UPM	March, 1992	→ February, 1993
S-3	Petaling Jaya	March, 1992	→ February, 1993
S-4	Shah Alam	March, 1992	→ February, 1993
S-5	Klang	July, 1992	→ February, 1993
	Mobile Stations		
M-1	City Hall	March, 1992	→ April, 1992
		September, 1992	→ November, 1992
M-2	Gombak	March, 1992	→ April, 1992
M-3	Bangi	April, 1992	→ May, 1992
M-4	Rawang	April, 1992	→ May, 1992
M-5	Dengkil	June, 1992	→ July, 1992
M-6	Jl.Kuching	July, 1992	→ August, 1992
M-7	Federal Expressway	August, 1992	→ September, 1992
M-8	Sungai Besi	August, 1992	→ September, 1992
M-9	Kuang	September, 1992	→ November, 1992
M-10	Sepang	November, 1992	→ December, 1992
M-11	Ulu Klang	November, 1992	→ December, 1992
M-12	UTM	January, 1993	→ February, 1993
M-13	Kapar	January, 1993	→ February, 1993

Averages of major pollutants throughout the measurement periods are summarized in Table 4.1.3.

Stations which have shown the highest concetntration of each pollutant are as follows;

	Fixed Station	Mobile Station
SPM	Shah Alam	Jl.Kuching
SO_2	Petaling Jaya	Sungai Besi
NO_2	City Hall	Sungai Besi
NO_x	City Hall	Federal Expressway
CO	Petaling Jaya	City Hall (M)
O_3	Klang	Sungai Besi
NMHC	Petaling Jaya	City Hall

Compliance with the guidelines at fixed stations can be observed in Table 4.1.4, in which TSP and PM10 concentrations are estimated by the following equations.

C(TSP) = 1.21 x C(SPM)	C(TSP)	: Concentration of TSP
	C(PM10)	: Concentration of PM10
C(PM10) = 0.82 x C(SPM)	C(SPM)	: Concentration of SPM

The delivery of the equations is described in Section 4.3.

Remarkables in Table 4.1.4 are;

- A maximum value and an annual average of PM10 at Shah Alam exceeds the guidelines.
- SO_2 and NO_2 guidelines are satisfied at all fixed stations, but hourly values of SO_2 and NO_2 at City Hall, Petaling Jaya, and Shah Alam reach more than 100 ppb.
- Maximum values of CO eight hour averages exceed the guideline at City Hall and Petaling Jaya.
- Hourly values of O_3 at all stations and eight hour averages of O_3 except UMP exceed the guidelines more than once.

Although the data at the mobile stations are insufficient for accurate evaluation, the hourly maximum value of SO_2 at Bangi, Dengkil, Sungai Besi, and Jl.Kuching, exceeded the guideline. The hourly maximum values of NO_2 at Jl.Kuching and City Hall (M) exceeded 130 ppb.

Health implications of these pollutants are described in Section 2.3.3.

Cumulative distribution graphs of the pollutants at the fixed stations are included in Section 2.1 of the Supporting Report. The same graphs at the mobile stations are included in Section D of the Data Book. Most of hourly and daily values show linear fit on lognormal distribution scale at least in the middle ranges such as from 50% to 93.3%.

Table 4.1.3 (1) Average Concentrations of SPM, SO_2, NO_2 and NOx (Mar. 1992 ~ Feb. 1993)

	Monitoring Sites	SPM (μg/m³)	SO_2 (ppb)	NO_2 (ppb)	NOx (ppb)
Fixed Station	City Hall	50.7 (6432)	10.4 (3264)	21.7 (6590)	103.3 (6590)
	UPM	24.1 (7114)	8.0 (7363)	8.6 (6005)	18.1 (6005)
	Petaling Jaya	58.8 (7554)	13.3 (8410)	19.3 (8099)	49.4 (8099)
	Shah Alam	67.6 (8227)	7.7 (7990)	15.2 (7832)	31.4 (7832)
	Klang	60.8 (3222)	8.5 (2070)	11.4 (3701)	26.6 (3701)
Mobile Station	City Hall(M)	86.3 (2510)	10.1 (2379)	30.0 (2537)	126.0 (2537)
	Gombak	65.0 (1157)	5.8 (1040)	11.4 (1161)	24.7 (1161)
	Bangi	66.7 (849)	12.4 (790)	9.4 (857)	20.8 (857)
	Dengkil	57.8 (1223)	5.2 (1142)	3.6 (1235)	12.2 (1235)
	Jl.Kuching	92.1 (902)	8.0 (966)	33.1 (971)	103.2 (971)
	Federal Expressway	87.2 (804)	12.1 (801)	32.2 (808)	131.6 (808)
	Sungai Besi	83.3 (935)	13.7 (888)	33.5 (901)	118.2 (901)
	Kuang	47.7 (1126)	4.2 (1139)	7.6 (1134)	23.3 (1134)
	Sepang	33.8 (550)	3.0 (471)	7.8 (597)	23.2 (597)
	Ulu Klang	30.6 (847)	3.2 (838)	9.2 (856)	22.7 (856)
	UTM	47.2 (894)	2.9 (902)	14.4 (903)	40.0 (903)
	Kapar	52.1 (938)	8.3 (637)	5.3 (948)	19.7 (948)

Note : Number of sample data in parentheses.
Monitoring periods are in Page 4-3.

Table 4.1.3 (2) Average Concentrations of CO, O_3 and NMHC (Mar. 1992 ~ Feb. 1993)

	Monitoring Sites	CO (ppm)	O_3 (ppb)	NMHC (10ppbC)
Fixed Station	City Hall	2.73 (6880)	9.5 (6344)	—
	UPM	—	10.0 (7196)	—
	Petaling Jaya	2.84 (8384)	9.7 (8126)	79.1 (7546)
	Shah Alam	0.70 (7405)	10.9 (8017)	22.5 (7804)
	Klang	—	12.4 (3679)	—
Mobile Station	City Hall (M)	3.74 (2537)	10.4 (2536)	145.5 (1959)
	Gombak	0.63 (1161)	17.7 (1161)	27.1 (1162)
	Bangi	0.30 (855)	18.3 (857)	119.7 (519)
	Dengkil	0.39 (1242)	13.6 (1234)	140.3 (107)
	Jl. Kuching	2.06 (543)	8.7 (971)	89.6 (401)
	Federal Expressway	2.10 (808)	11.0 (808)	91.7 (811)
	Sungai Besi	2.91 (899)	26.2 (901)	124.9 (905)
	Kuang	—	17.9 (1134)	46.6 (788)
	Sepang	0.64 (602)	12.5 (597)	38.2 (466)
	Ulu Klang	0.40 (287)	16.8 (857)	79.5 (854)
	UTM	1.31 (902)	18.3 (903)	137.0 (892)
	Kapar	0.23 (949)	20.0 (948)	71.8 (834)

Note : Number of sample data in parentheses.
Monitoring periods are in Page 4-3.

Table 4.1.4 (1) Compliance with Guidelines on TSP, PM10, and SO_2 (Mar. 1992 ~ Feb. 1993)

Items		TSP		PM10		SO_2	
Guidelines		Yearly 90	Daily 260	Yearly 50	Daily 150	Daily 40	Hourly 130
Unit		(μg/m3)		(μg/m3)		(ppb)	
City Hall	Avg.	61.3		41.5			
	Max.		112.5		76.3	33.5	106
	99%		106.3		72.1	30.5	43
	98%		104.1		70.6	27.3	35
	95%		92.7		62.8	23.9	25
	No.	6432	267	6432	267	114	3264
UPM	Avg.	29.2		19.8			
	Max.		66.3		44.9	31.4	60
	99%		58.0		39.3	17.5	27
	98%		54.6		37.0	14.8	21
	95%		45.7		31.0	13.3	16
	No.	7114	293	7114	293	297	7363
Petaling Jaya	Avg.	71.1		48.2			
	Max.		165.4		112.1	29.5	111
	99%		144.1		97.7	24.9	44
	98%		136.8		92.7	23.9	37
	95%		120.5		81.7	22.1	29
	No.	7554	314	7554	314	351	8410
Shah Alam	Avg.	81.7		55.4 X			
	Max.		253.1		171.6 X	20.1	103
	99%		179.5		121.6	18.0	43
	98%		164.7		111.6	17.0	34
	95%		137.2		93.0	15.6	24
	No.	8227	342	8227	342	333	7990
Klang	Avg.	73.6		49.9			
	Max.		187.8		127.3	22.8	95
	99%		168.1		113.9	18.2	42
	98%		162.3		110.0	15.1	30
	95%		152.6		103.4	13.6	21
	No.	3222	130	3222	130	83	2070

Abbreviations Avg. : Average value X: Exceed
Max. : Maximum value
No. : Number of Data

Table 4.1.4 (2) Compliance with Guidelines on CO, NO_2, and O_3

Items		CO		NO_2	O_3	
Guidelines		8 Hours 9	Hourly 30	Hourly 170	8 Hours 60	Hourly 100
Unit		(ppm)		(ppb)	(ppb)	
City Hall	Avg.					
	Max.	10.53 X	15.4	121	118.7 X	267 X
	99%	6.65	9.1	61	59.4	86
	98%	5.86	8.2	53	50.8	70
	95%	5.09	6.6	45	37.3	46
	No.	6871	6880	6590	6244	6344
UPM	Avg.					
	Max.			73	55.8	106 X
	99%			28	39.6	53
	98%			24	36.0	45
	95%			19	29.6	36
	No.			6005	7159	7196
Petaling Jaya	Avg.					
	Max.	10.15 X	15.7	108	80.1 X	128 X
	99%	6.96	8.6	56	54.4	81
	98%	6.30	7.7	51	47.0	66
	95%	5.49	6.3	42	36.6	47
	No.	8397	8384	8099	8129	8126
Shah Alam	Avg.					
	Max.	3.55	5.2	168	93.9 X	158 X
	99%	2.30	3.0	60	64.5 X	88
	98%	1.99	2.6	45	53.8	68
	95%	1.60	2.0	34	39.9	48
	No.	7419	7405	7832	7995	8017
Klang	Avg.					
	Max.			72	68.9 X	132 X
	99%			30	50.9	70
	98%			27	46.3	59
	95%			23	36.9	45
	No.			3701	3641	3679

Abbreviations Avg. : Average value
Max. : Maximum value
No. : Number of Data

X: Exceed

(2) Diurnal Change of Pollutant Concentration

There are typically three main patterns on diurnal changes of pollutant concentrations.

The first one is a 'two peak pattern' with a sharp peak in the morning and a moderate peak in the evening through the night. Most of diurnal changes of CO and Nitrogen Oxides exhibit the two peak patterns and some diurnal changes of SPM and Hydrocarbons also exhibit the two peak patterns. Diurnal changes of Nitrogen Oxides and CO at City Hall are shown in Fig. 4.1.2 and Fig. 4.1.3 respectively. Diurnal changes of Hydrocarbons at Petaling Jaya are shown in Fig. 4.1.4. This two peak pattern is an indication of the influence by motor vehicles.

The second one is a 'single minimum pattern' with the minimum occuring during the daytime. Some monitoring stations exhibit diurnal changes of SPM showing this pattern. It is to be noted that SPM concentration rises up in the evening through the night and the concentration does not decrease till the morning. Diurnal change of SPM at Shah Alam is shown in Fig. 4.1.5.

The third one is a 'single peak pattern' with the peak in the afternoon. O_3 diurnal changes at all stations show this pattern. This pattern closely follows the daily cycle of insolation. Diurnal changes of O_3 at Shah Alam are shown in Fig. 4.1.6.

Diurnal changes of SO_2 at Petaling Jaya are shown in Fig. 4.1.7, which have the insignificant single peak or two peaks pattern.

The remainders of diurnal changes at the fixed stations are included in Section 2.1 of the Supporting Report. Diurnal changes at the mobile stations are included in Section E of the Data Book.

Weekly changes of the pollutants at the fixed stations are included in Section 2.1 of the Supporting Report and the ones at the mobile stations are in Section F of the Data Book .

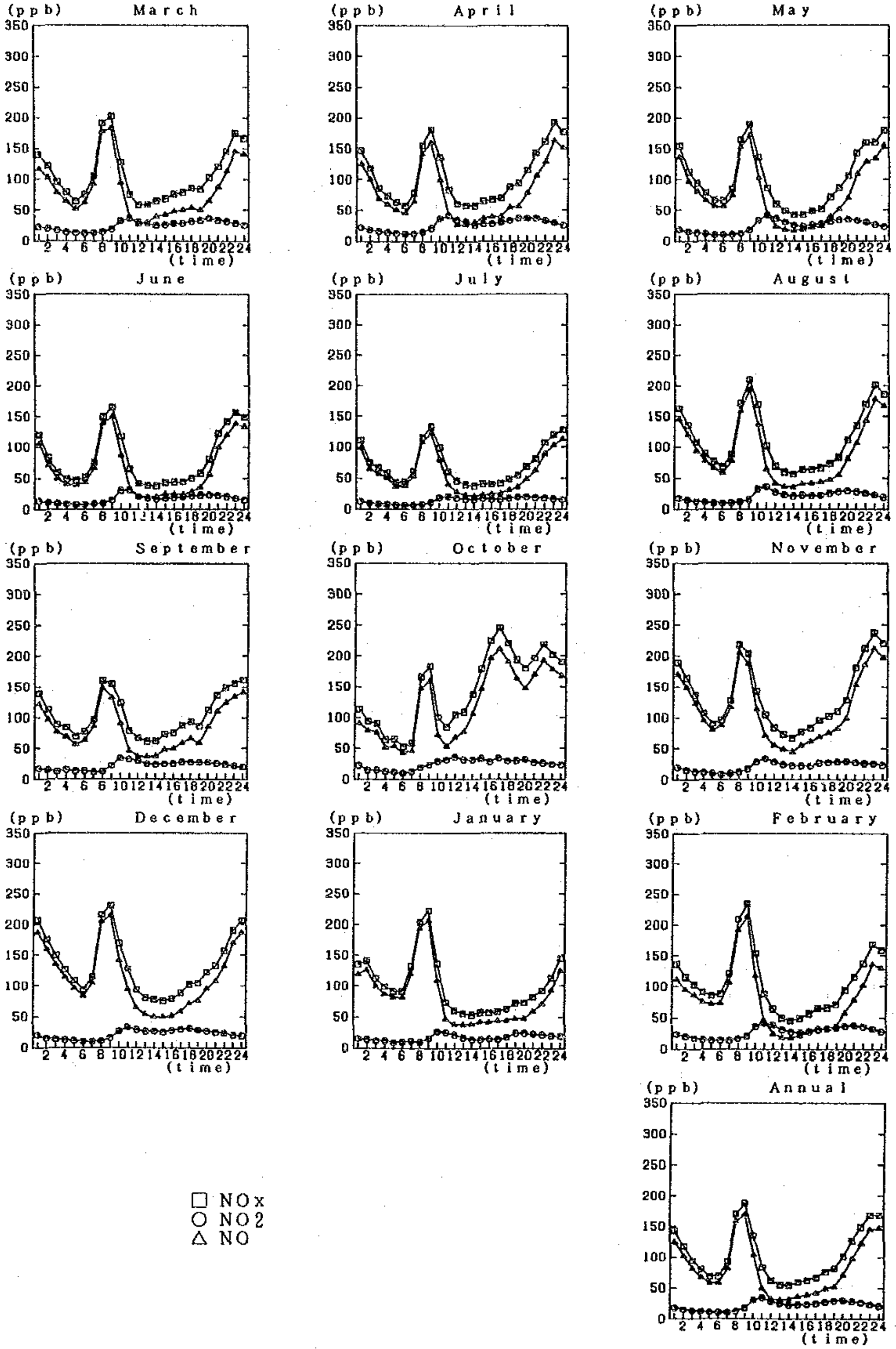


Fig. 4.1.2 Diurnal Change of Nitrogen Oxides at City Hall (Mar. 1992 ~ Feb. 1993)

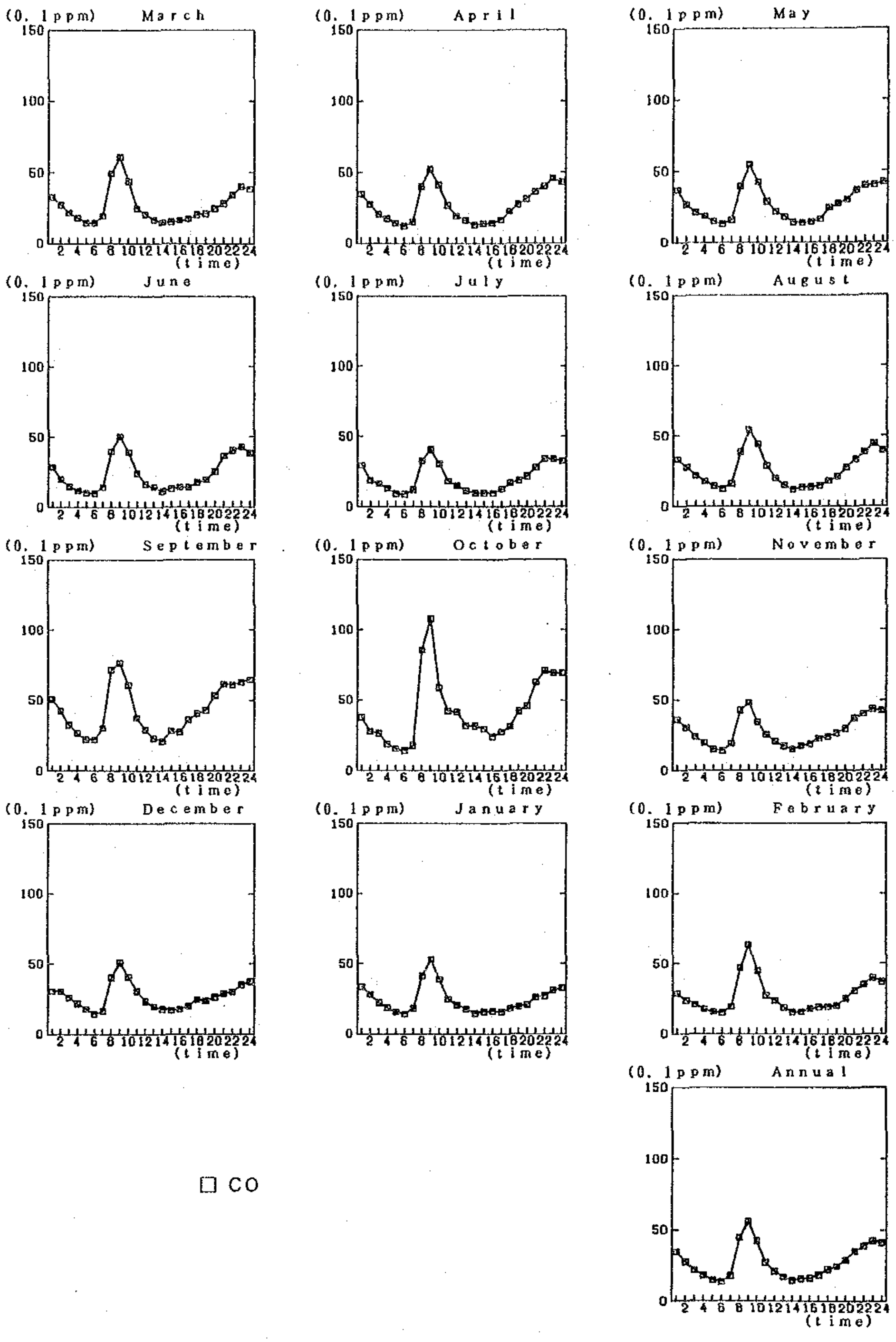


Fig. 4.1.3 Diurnal Change of CO at City Hall
(Mar. 1992 ~ Feb. 1993)

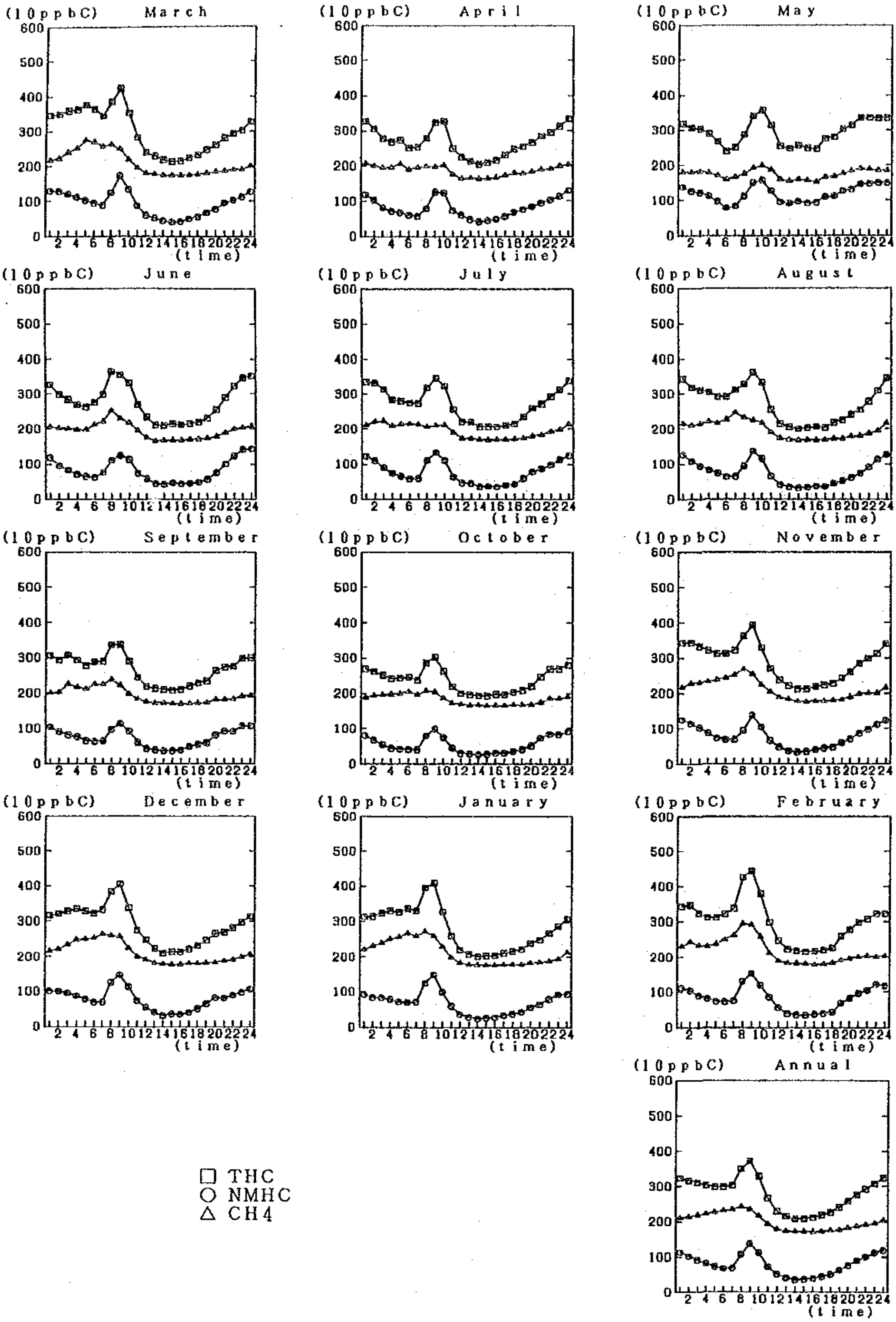


Fig. 4.1.4 Diurnal Change of Hydrocarbons at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

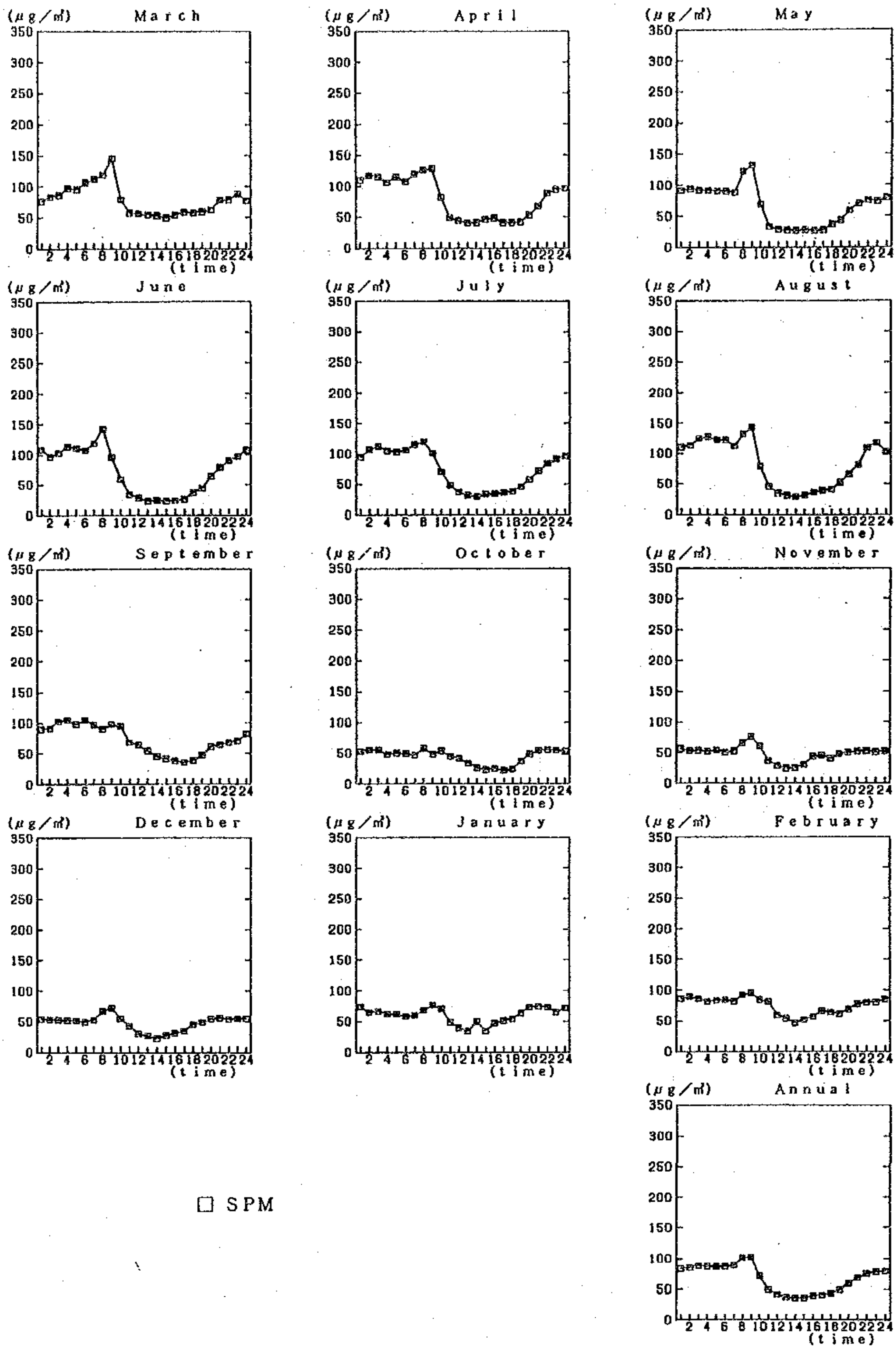


Fig. 4.1.5 Diurnal Change of SPM at Shah Alam (Mar. 1992 ~ Feb. 1993)

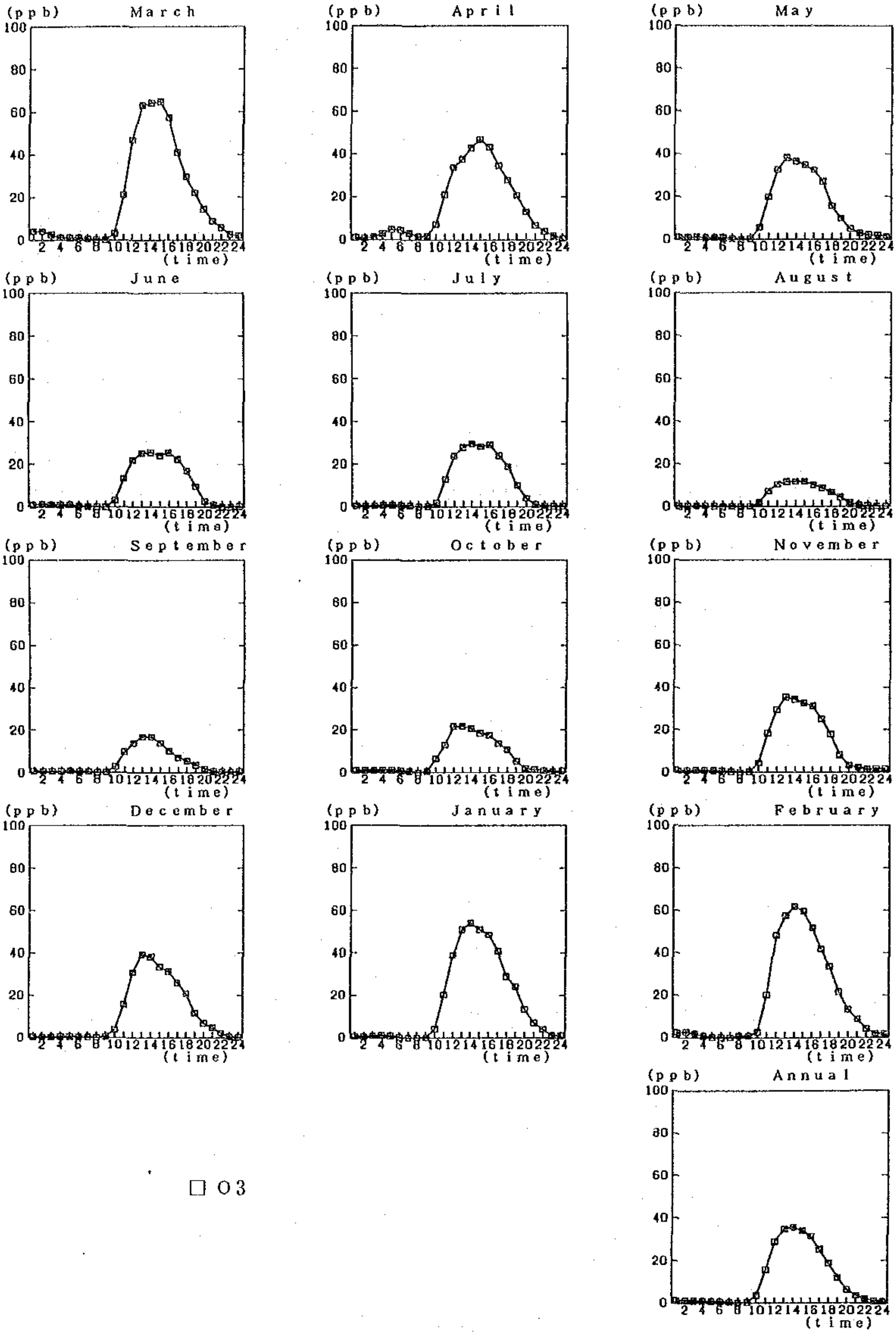


Fig. 4.1.6 Diurnal Change of O3 at Shah Alam (Mar. 1992 ~ Feb. 1993)

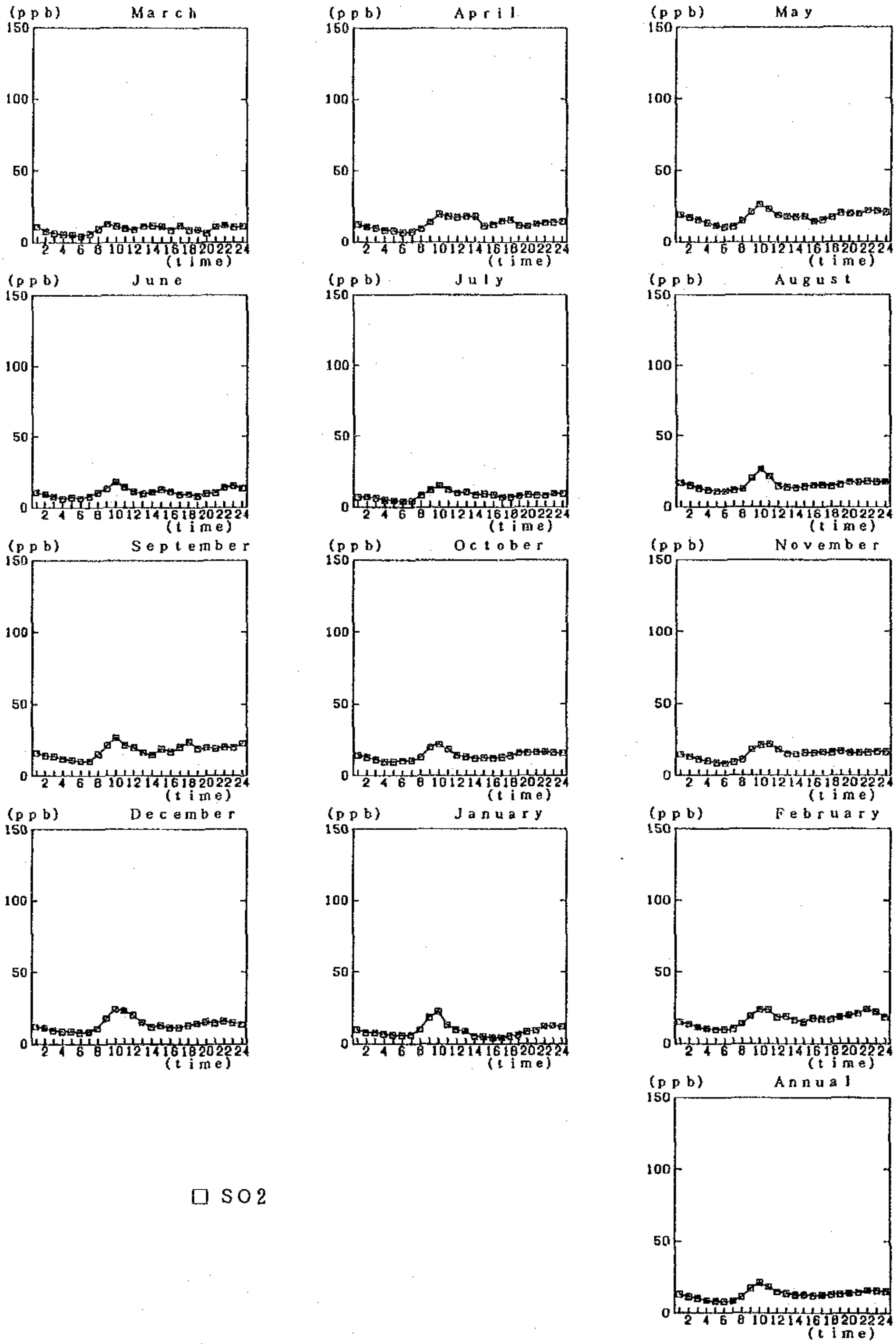


Fig. 4.1.7 Diurnal Change of SO_2 at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

(3) Monthly Change of Pollutant Concentration

Monthly changes of SPM, SO_2, CO, Nitrogen Oxides, O_3, and Hydrocarbons are shown in Fig. 4.1.8 through Fig. 4.1.13.

They did not show any clear seasonal pattern.

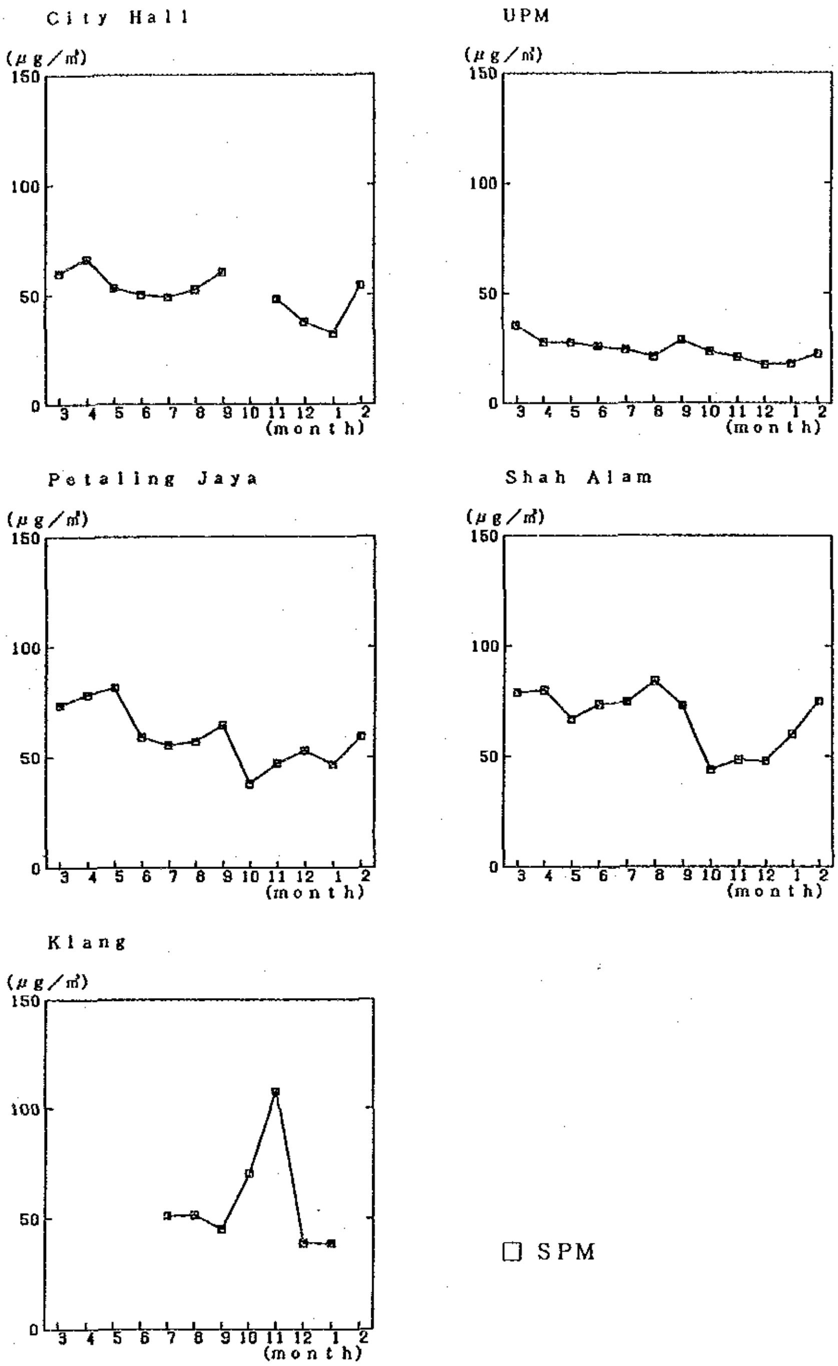


Fig. 4.1.8 Monthly Change of SPM at Fixed Stations (Mar. 1992 ~ Feb. 1993)

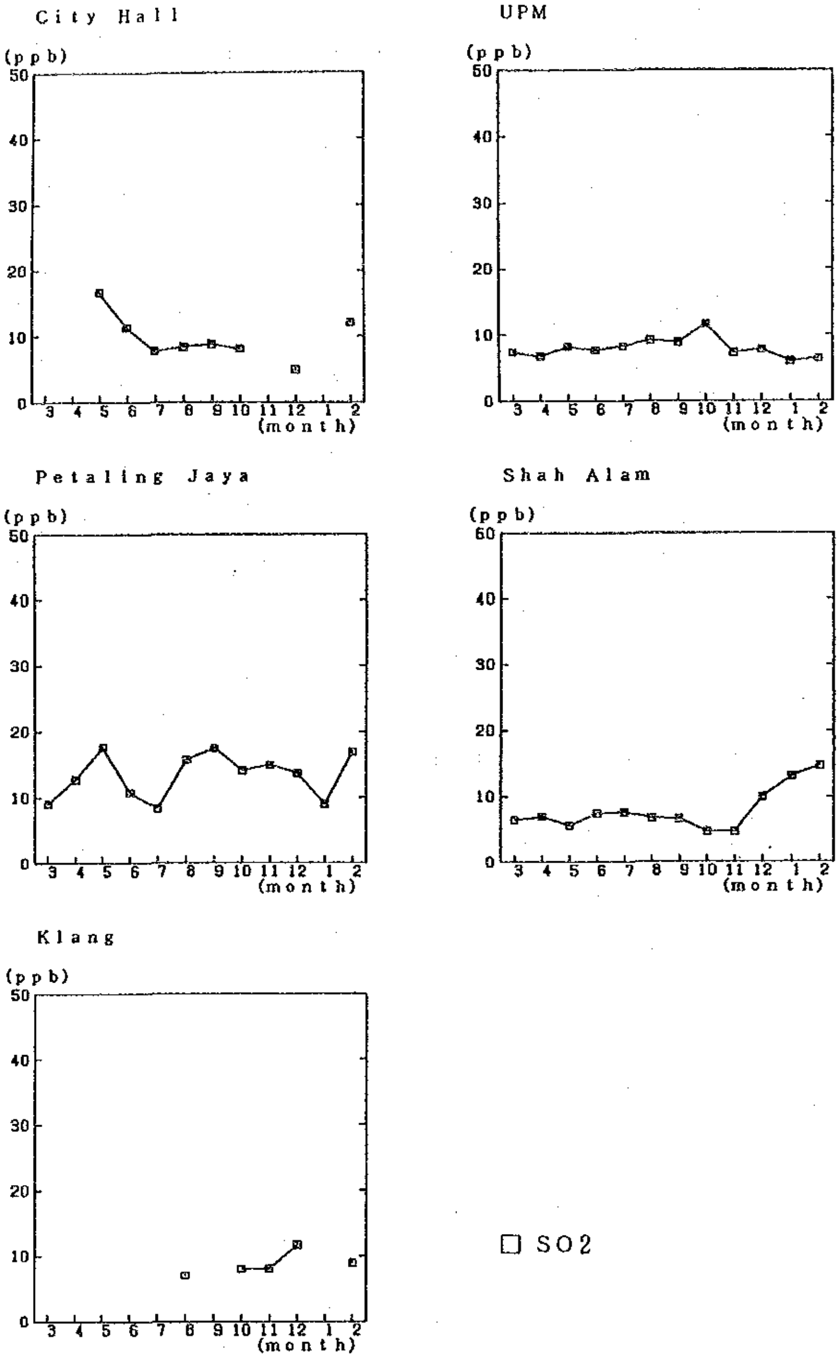


Fig. 4.1.9 Monthly Change of SO_2 at Fixed Stations (Mar. 1992 ~ Feb. 1993)

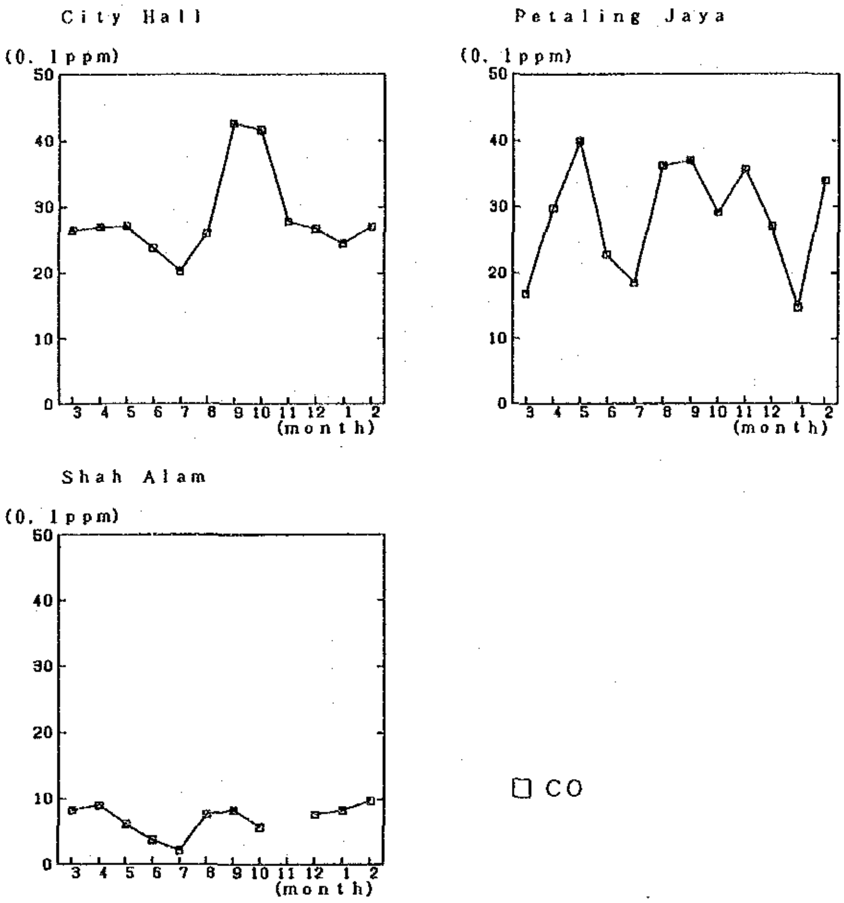


Fig. 4.1.10 Monthly Change of CO at Fixed Stations (Mar. 1992 ~ Feb. 1993)

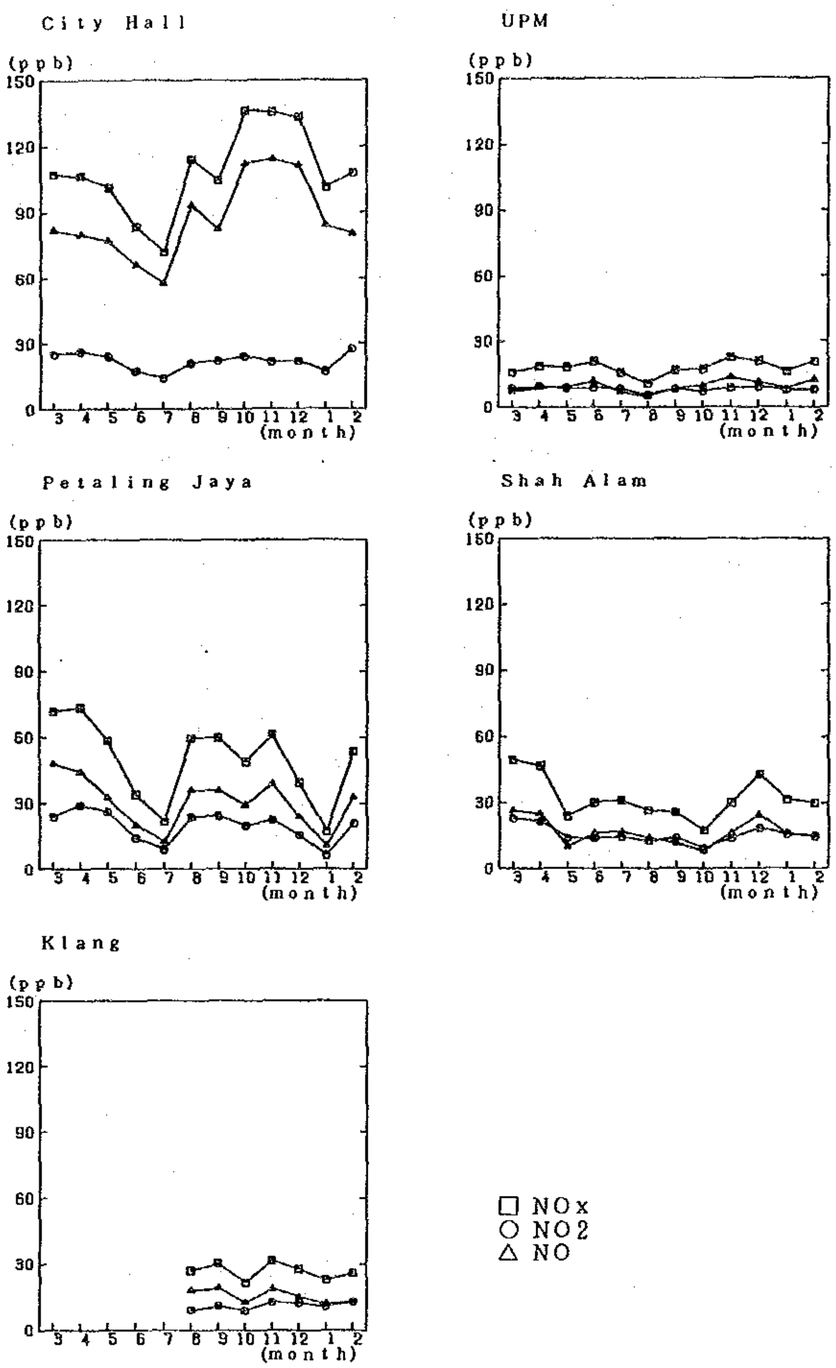


Fig. 4.1.11 Monthly Change of Nitrogen Oxides at Fixed Stations (Mar. 1992 ~ Feb. 1993)

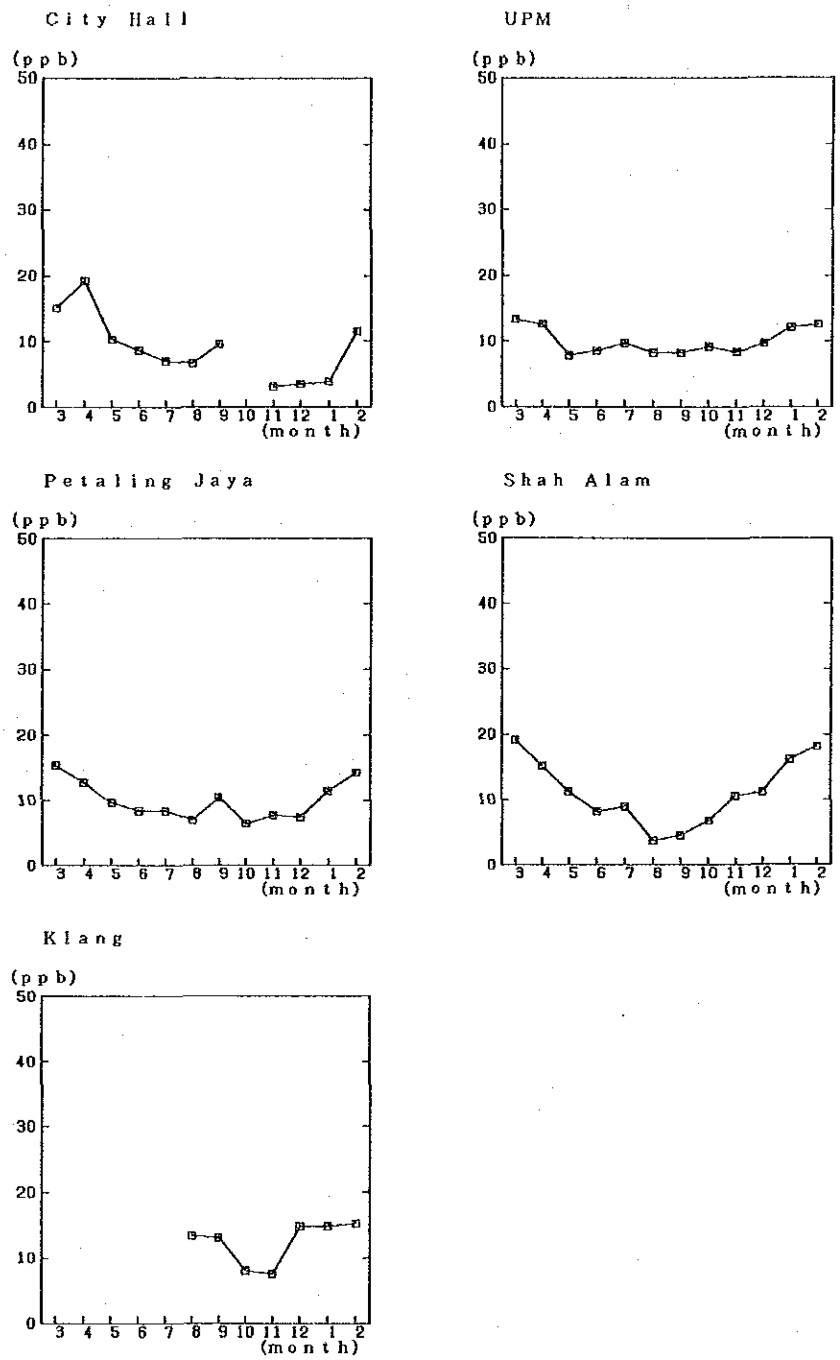


Fig. 4.1.12 Monthly Change of O3 at Fixed Stations (Mar. 1992 ~ Feb. 1993)

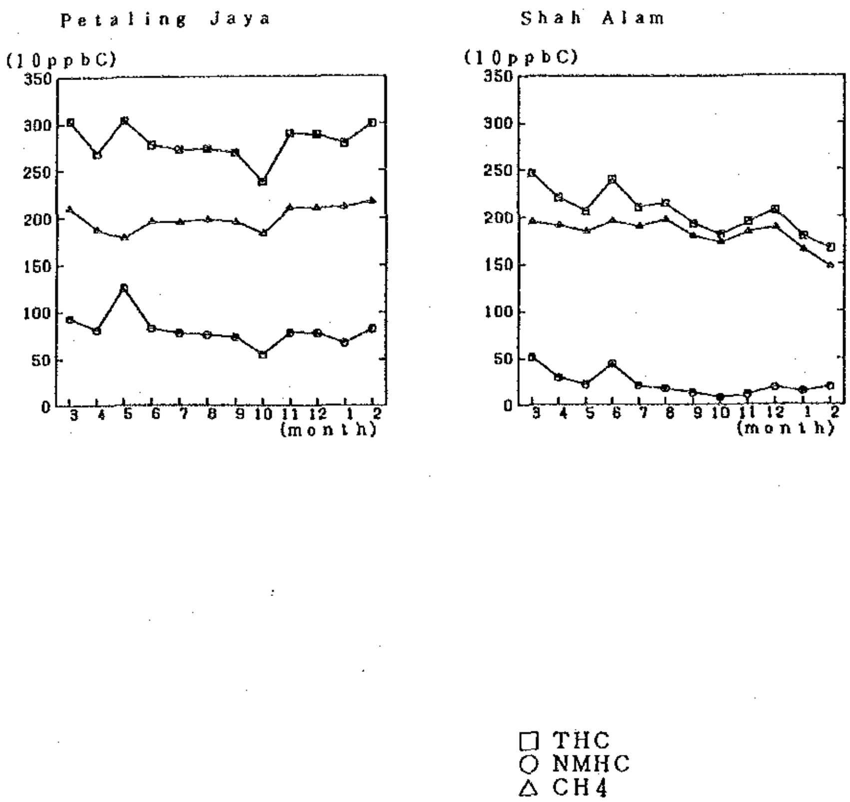


Fig. 4.1.13 Monthly Change of Hydrocarbons at Fixed Stations (Mar. 1992 ~ Feb. 1993)

(4) Relationship of Air Pollutant Concentration to Meteorological Parameters

To analyze the relationships between the pollutant concentrations and the meteorological parameters, the concentrations of the pollutants were averaged by ranks of the meteorological parameters, such as wind direction, wind speed, stability index, and rainfall amount. The pollutants analyzed are SPM, SO_2, CO, Nitrogen Oxides, O_3, and Hydrocarbons.

In summary, the following characteristics are highlighted.

O_3 concentrations at all stations show high values in the SW through WNW wind directions (Fig. 4.1.14). The increase of O3 concentration around 2:00 p.m. coincides with sea breeze.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show decrease of concentrations with increase of wind speed. Relationships of CO concentration to wind speed are shown in Fig. 4.1.15.

Generally, the concentration of pollutant should decrease with increase of wind speed because of dilution. However, O_3 concentrations increase with increase of wind speed (Fig. 4.1.16). The increase of O_3 concentration coincides with sea breeze and the sea breeze is relatively strong.

SPM, CO, nitrogen oxides, and hydrocarbons almost show high values with strong stable condition. SPM concentration by stability index at Shah Alam is shown in Fig. 4.1.17. If the atmospheric condition is stable, the emission source around the ground level would strongly affect the pollutant concentration.

O_3 concentrations decrease from unstable condition to stable condition. O_3 concentration for different stability index at Shah Alam is shown in Fig. 4.1.18. Generally, O_3 concentrations are high around 2:00 p.m. when incoming solar radiation is strong that contributes towards the unstable atmospheric condition.

SPM concentrations show a decreasing trend with increase in rainfall amount. The relationship between SPM concentration and rainfall amount at Petaling Jaya is shown in Fig. 4.1.19. The wash out effect on particulate matters seems large. However, gaseous pollutants such as SO_2 do not show any clear effect by rainfall.

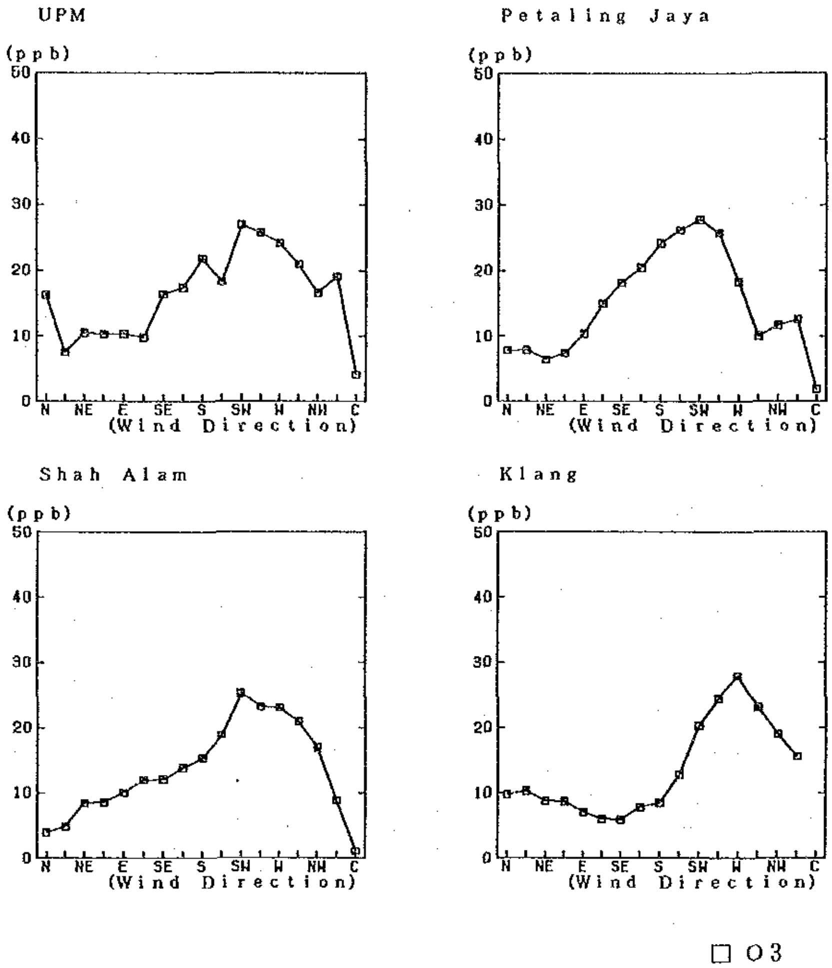
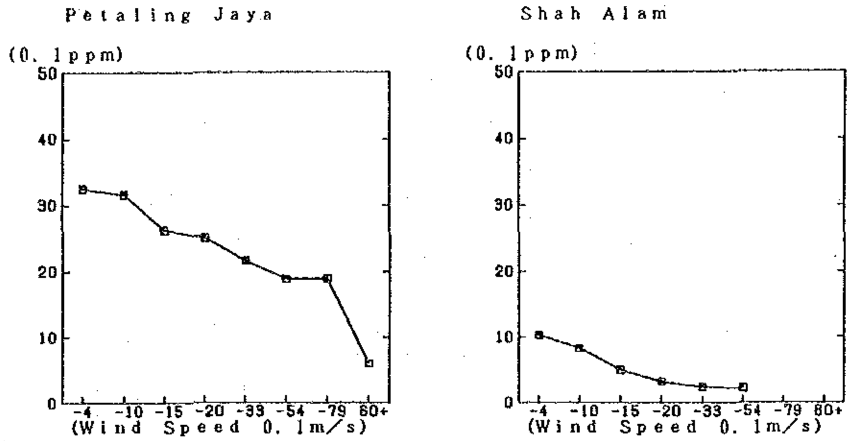


Fig. 4.1.14 O_3 Concentration by Wind Direction (Mar. 1992 ~ Feb. 1993)



□ CO

Fig. 4.1.15 CO Concentration by Wind Speed (Mar. 1992 ~ Feb. 1993)

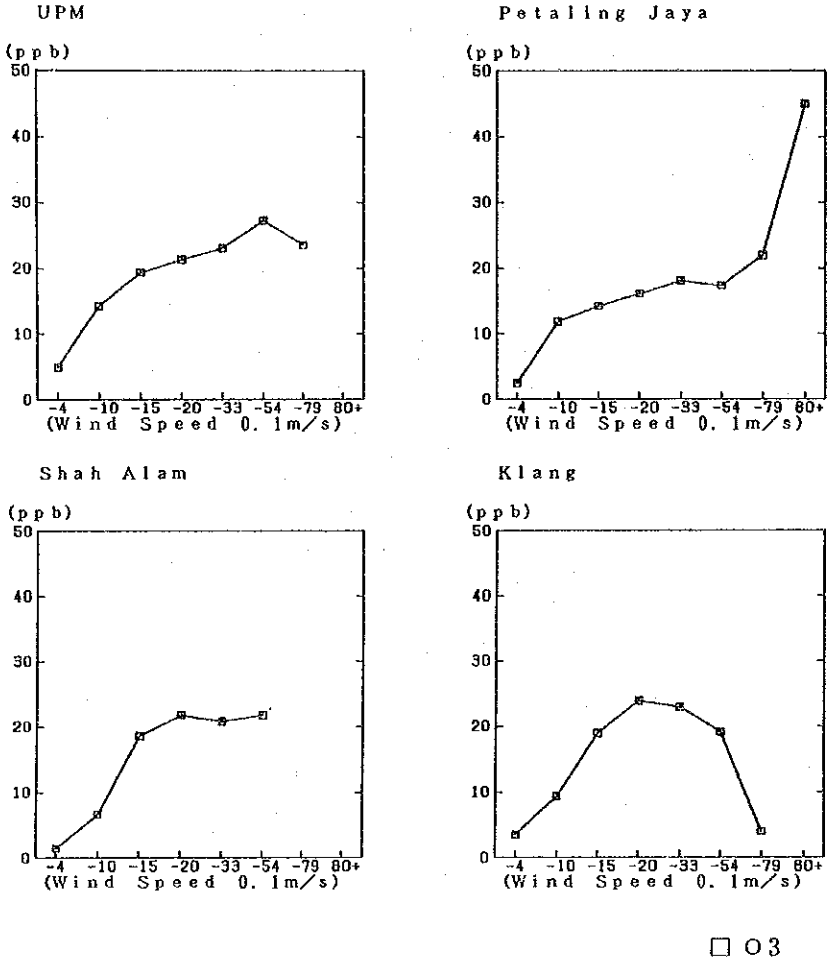


Fig. 4.1.16 O3 Concentration by Wind Speed (Mar. 1992 ~ Feb. 1993)

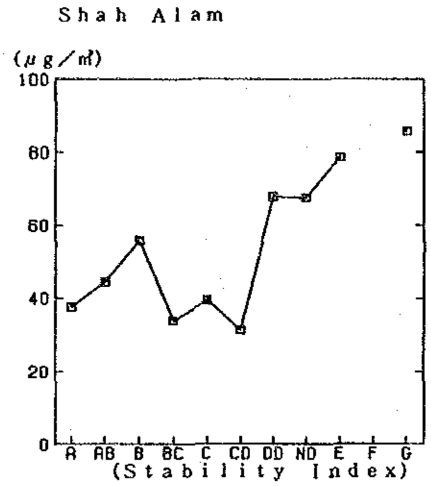


Fig. 4.1.17 SPM Concentration by Stability Index at Shah Alam (Mar. 1992 ~ Feb. 1993)

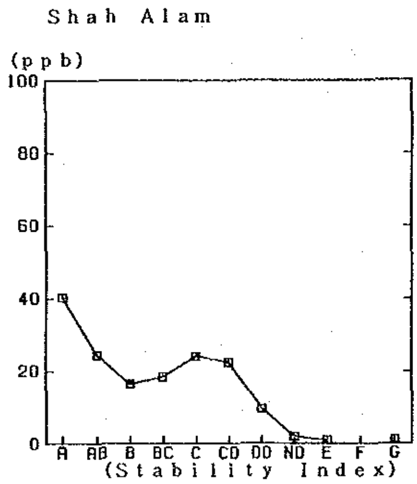


Fig. 4.1.18 O_3 Concentration by Stability Index at Shah Alam (Mar. 1992 ~ Feb. 1993)

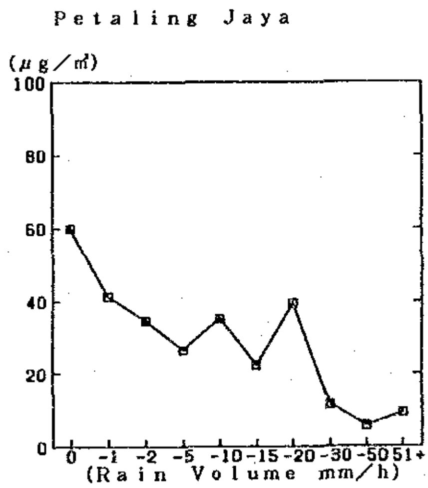


Fig. 4.1.19 SPM Concentration by Rainfall Amount at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

(5) Analysis of High SPM Concentration

To investigate the causes of high SPM concentration, the following methods were adopted.

a) Correlation analysis of SPM concentrations with the meteorological parameters and some pollutants.

Meteorological parameters: Wind speed, Solar radiation, Temperature, Rainfall amount, Relative humidity

Pollutants: SO_2, NO_2, NO_x

Statistical values: Daily average (equal to or more than 18 data in a day) or hourly value

b) Selection of high SPM concentration days

The days with daily average more than 120 $\mu g/m^3$ were defined as high concentration days taking into consideration the guideline value for PM10 (150 $\mu g/m^3$).

c) Comparison between the high concentration days and the remaining days defined as the low concentration days.

Items of the comparison are the following.

- Diurnal change of SPM
- Wind rose
- Diurnal change of meteorological parameters
  (Wind speed, Solar radiation, Temperature, Rainfall amount, Relative humidity)
- Diurnal change of some other pollutants (SO_2, NO_2, NO_x)

By the correlation analysis, the following features were found.

SPM and wind speed are negatively correlated to some extent at Shah Alam and Klang. SPM and temperature are correlated to some extent at UPM. Among SO_2, NO_x, and NO_2, NO_2 shows the highest correlation with SPM. The scatter diagrams of SPM with NO_2 at the fixed stations are shown in Fig. 4.1.20. Scatter diagrams of SPM with the other items are shown in Section 2.1 of the Supporting Report.

Selected days with high SPM concentrations are shown in Table 4.1.5.

Table 4.1.5 High SPM Concentration Days

Month	Number of Days	Stations
March, 1992	4	Petaling Jaya, Shah Alam
April, 1992	5	Petaling Jaya, Shah Alam
May, 1992	2	Petaling Jaya
June, 1992	0	
July, 1992	1	Shah Alam
August, 1992	4	Shah Alam
September, 1992	3	Shah Alam, Klang
October, 1992	2	Klang
November, 1992	7	Klang
December, 1992	0	
January, 1993	0	
February, 1993	0	

By comparison between the high SPM days and the low SPM days, the following features were found.

Diurnal changes of SPM during the high SPM days and low SPM days are shown in Fig. 4.1.21. The differences between the high SPM days and low SPM days are large at Shah Alam and Klang during the morning.

Wind roses during the high SPM days and low SPM days are shown in Fig. 4.1.22. The frequencies of calm are lower during the high SPM days at most of the stations.

Diurnal change of net radiation at Petaling Jaya is shown in Fig. 4.1.23. The net radiation values during the high SPM days are lower in the afternoon.

Diurnal changes of NO_2 during the high SPM days and low SPM days are shown in Fig. 4.1.24. NO_2 concentrations during the high SPM days are also higher.

Diurnal changes of the other meteorological parameters and pollutant concentrations are shown in Section 2.1 of the Supporting Report.

Y－axis：SPM
(Daily Data)
X－axis：NO2
(Daily Data)

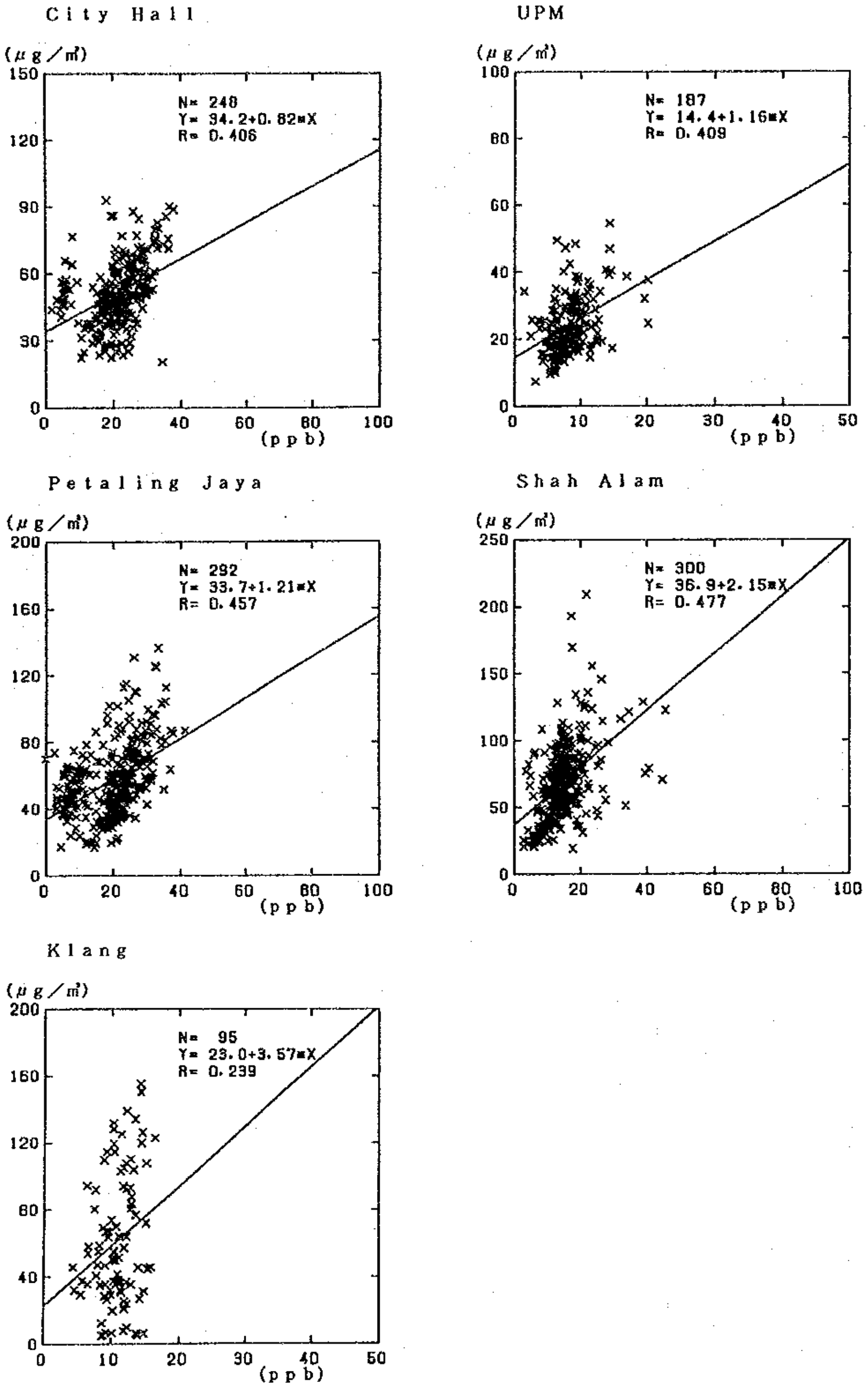


Fig. 4.1.20 Scatter Diagram of SPM with NO_2
(Mar. 1992 ~ Feb. 1993)

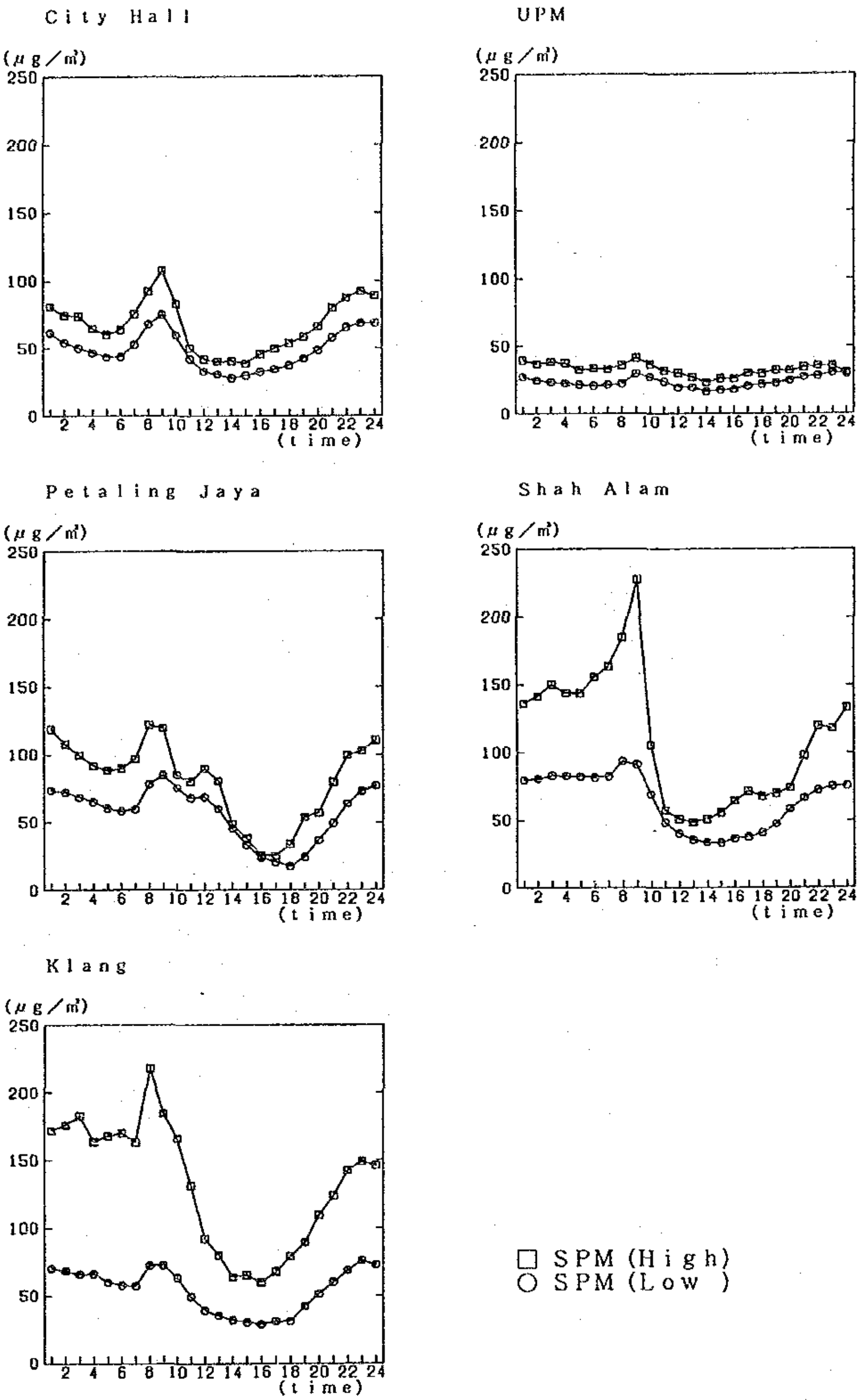


Fig. 4.1.21 Diurnal Change of SPM during High SPM Days and Low SPM Days (Mar. 1992 ~ Feb. 1993)

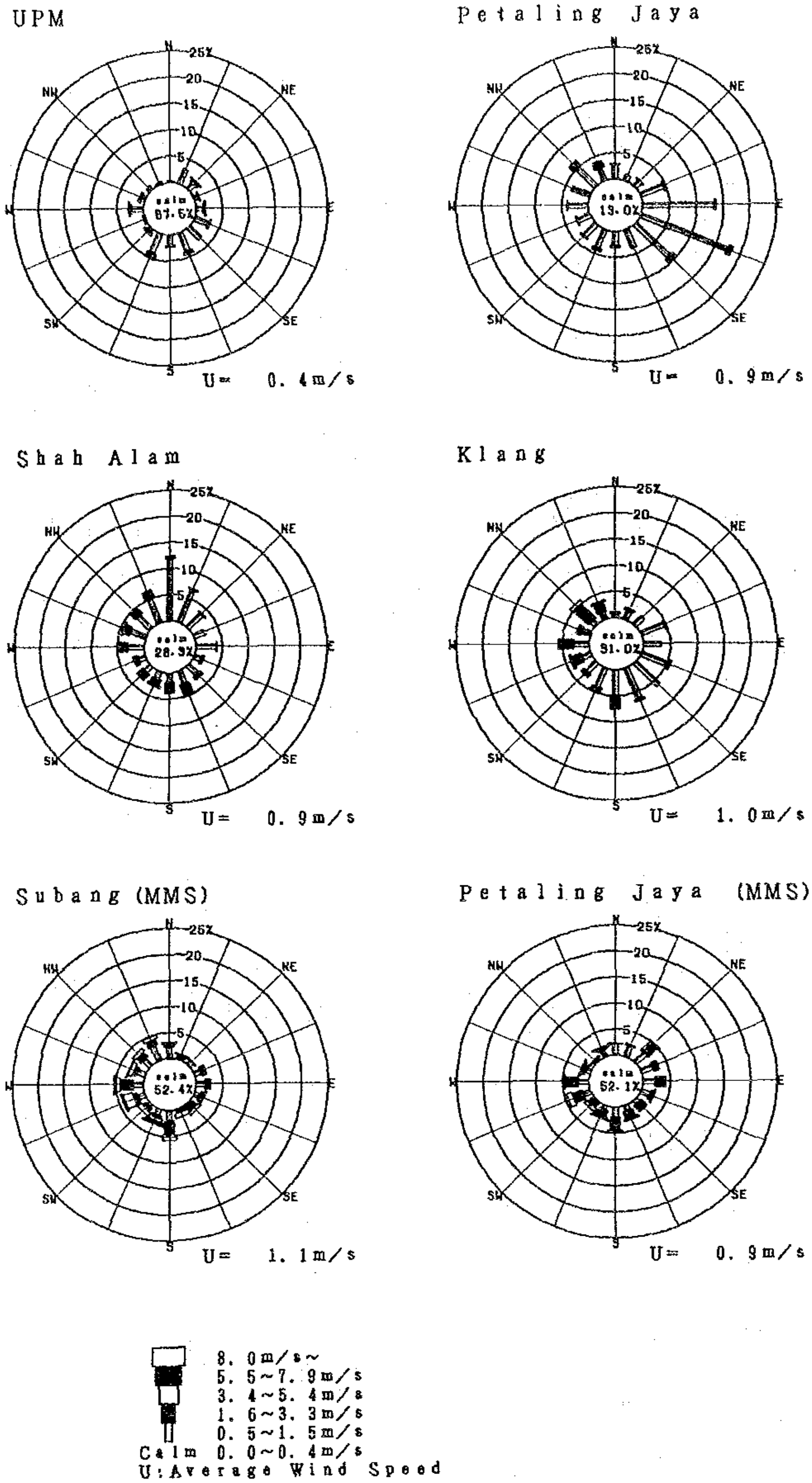


Fig. 4.1.22 (1) Wind Rose during High SPM Days
(Mar. 1992 ~ Feb. 1993)

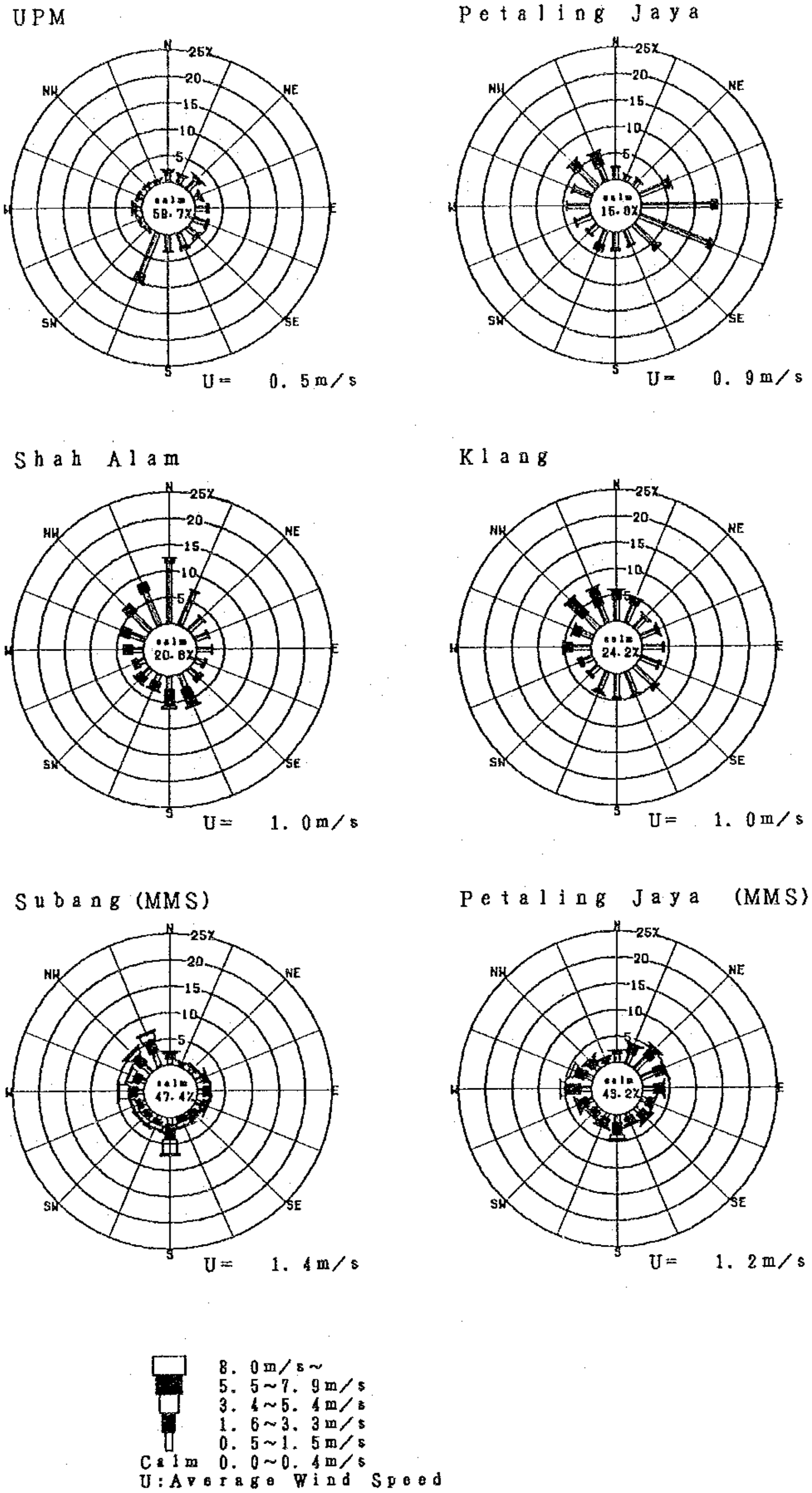


Fig. 4.1.22 (2) Wind Rose during Low SPM Days
(Mar. 1992 ~ Feb. 1993)

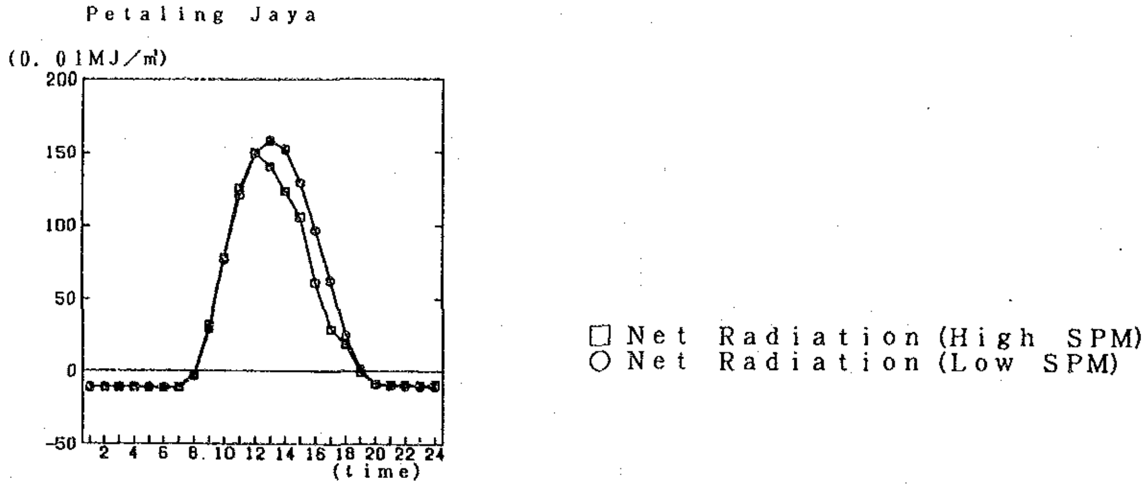


Fig. 4.1.23 Diurnal Change of Net Radiation during High SPM Days and Low SPM Days at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

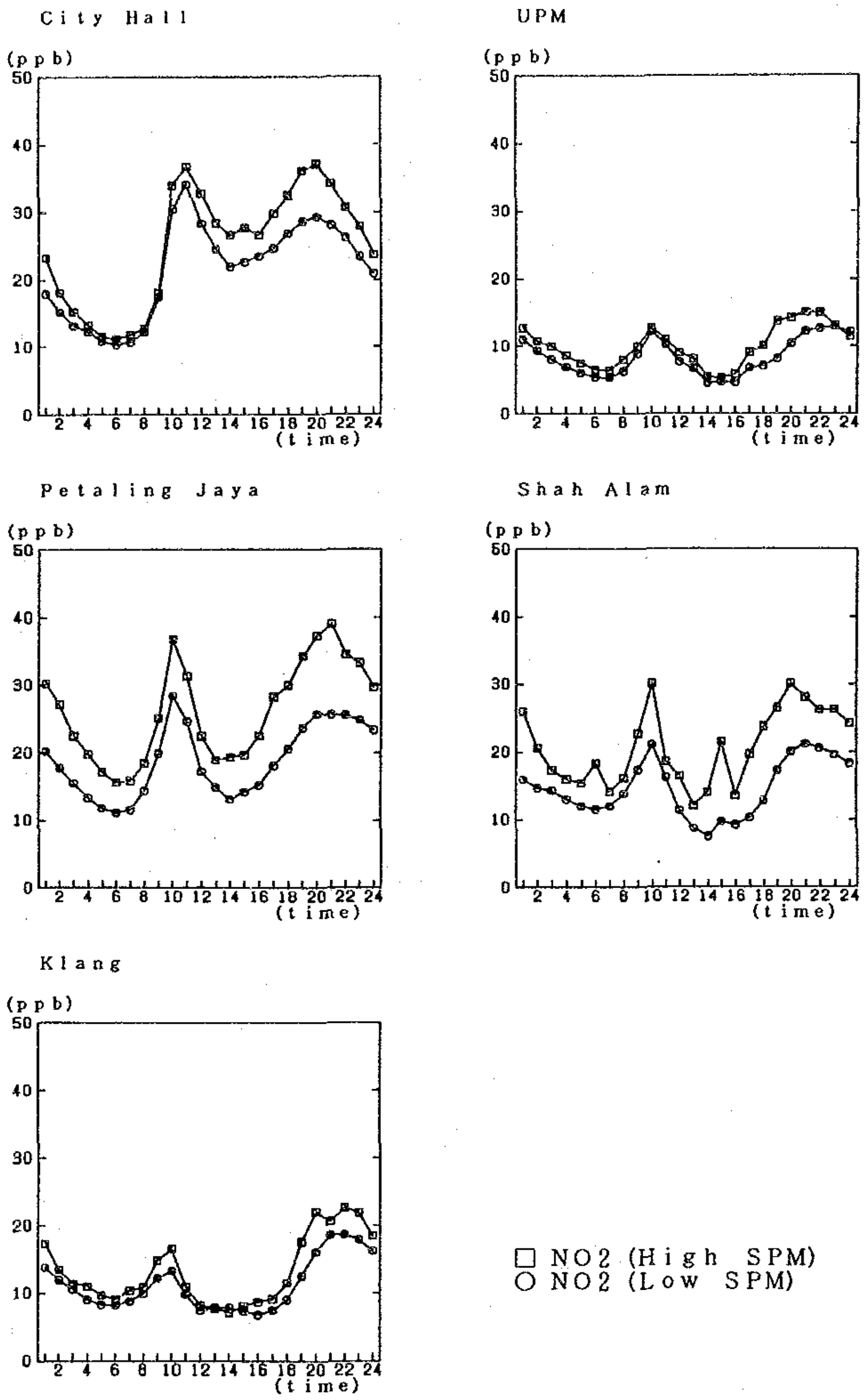


Fig. 4.1.24 Diurnal Change of NO2 during High SPM Days and Low SPM Days (Mar. 1992 ~ Feb. 1993)

(6) Analysis of High O3 Concentration

To investigate the causes of high O_3 concentration, the same methods used for the high SPM concentration were adopted.

a) Correlation analysis of O_3 concentrations with the meteorological parameters and some pollutants.

Meteorological parameters: Wind speed, Solar adiation, Temperature, Rainfall amount, Relative humidity

Pollutants: NMHC, NO_2

Statistical values: Two sets of combinations as follows.

O_3: Hourly values
Meteorological parameters: Hourly values
Pollutant: Hourly values

O_3: Daily maximum
Meteorological parameters: Morning averages
Pollutants: Morning maximum
Here, the 'Morning' is defined as the interval from 7 to 12.

b) Selection of high O_3 concentration days

The days with maximum O_3 concentration more than 100 ppb are defined as the high concentration days taking into consideration the guideline value for O_3.

c) Comparison between the high concentration days and the remaining days defined as the low concentration days.

Items of the comparison are the following.

- Diurnal change of O_3
- Wind rose
- Diurnal change of meteorological parameters
  (Wind speed, Solar radiation, Temperature, Rainfall amount, Relative humidity)
- Diurnal change of some other pollutants (NMHC,NO_2)

By the correlation analysis, the following features were found.

O_3 with solar radiation and temperature are correlated and O_3 with relative humidity is negatively correlated.

The scatter diagram of O_3 with solar radiation is shown in Fig. 4.1.25. The scatter diagram of O_3 with temperature is shown in Fig. 4.1.26. The scatter diagram of O_3 with relative humidity is shown in Fig. 4.1.27. Scatter diagrams of O_3 with the other items are shown in Section 2.1 of the Supporting Report.

Y－axis：O3
(Hourly Data)
X－axis：Solar Radiation
(Hourly Data)

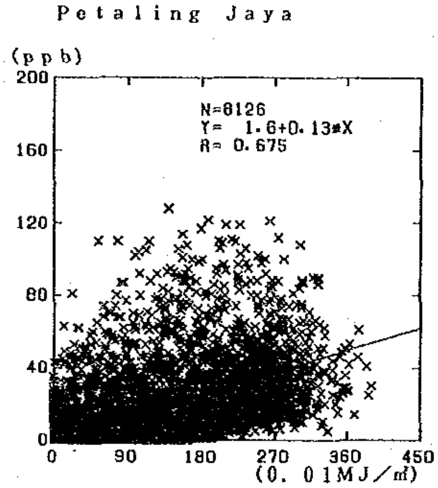


Fig. 4.1.25 Scatter Diagram of O3 with Solar Radiation
(Mar. 1992 ~ Feb. 1993)

Y－axis：O3
(Hourly Data)
X－axis：Relative Humidity
(Hourly Data)

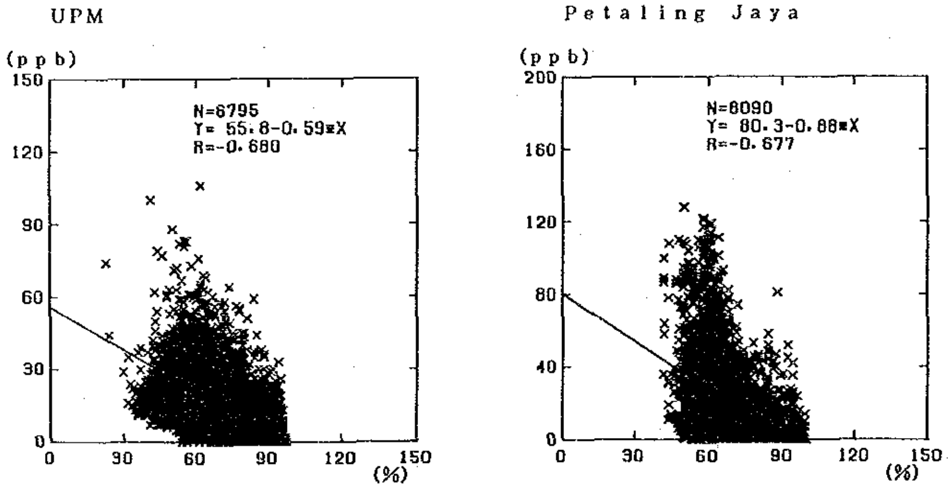


Fig. 4.1.26 Scatter Diagram of O3 with Relative Humidity
(Mar. 1992 ~ Feb. 1993)

Y−axis：O3
(Hourly Data)
X−axis：Temperature
(Hourly Data)

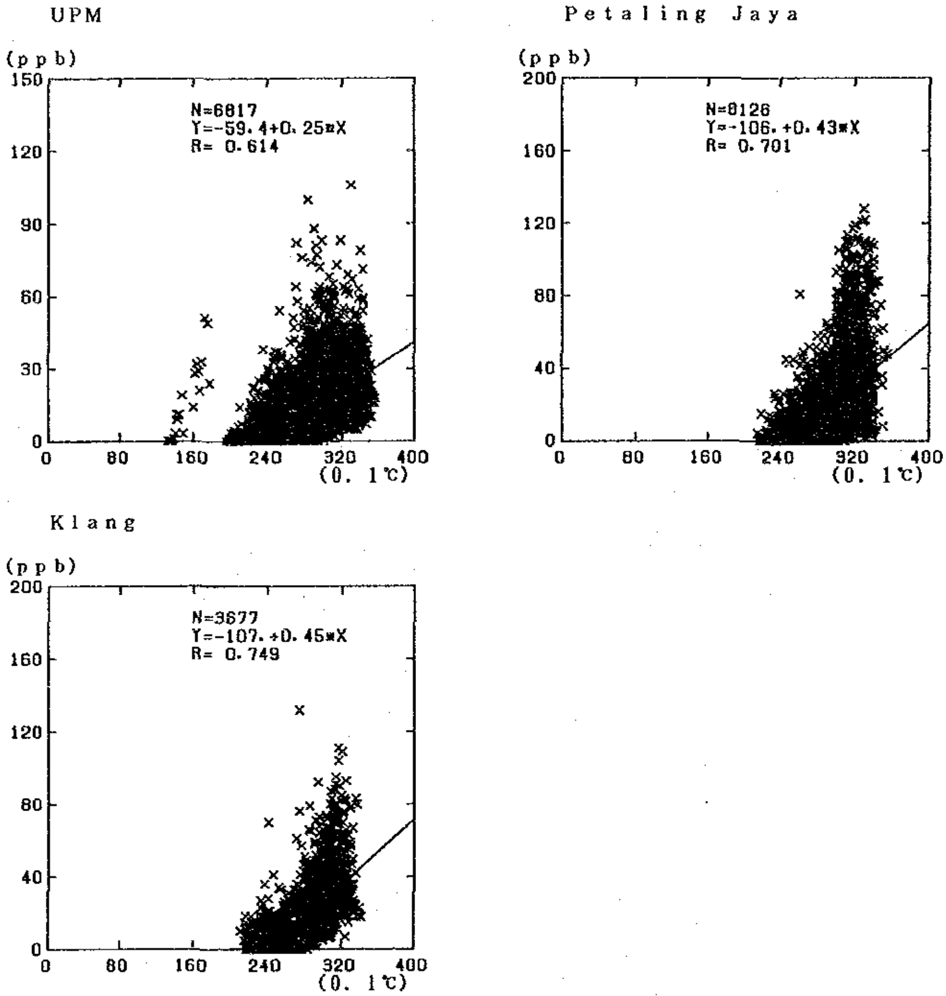


Fig. 4.1.27 Scatter Diagram of O3 with Temperature
(Mar. 1992 ~ Feb. 1993)

Selected days with high O_3 concentrations are shown in Table 4.1.6.

Table 4.1.6 High O_3 Concentration Days

Month	Number of Days	Stations
March, 1992	15	City Hall, Petaling Jaya, Shah Alam
April, 1992	8	City Hall, Petaling Jaya, Shah Alam
May, 1992	2	City Hall, Petaling Jaya
June, 1992	1	UPM
July, 1992	1	Petaling Jaya, Shah Alam
August, 1992	0	
September, 1992	4	City Hall, Petaling Jaya
October, 1992	0	
November, 1992	2	Petaling Jaya, Shah Alam, Klang
December, 1992	0	
January, 1993	6	Petaling Jaya, Shah Alam, Klang
February, 1993	10	City Hall, Petaling Jaya, Shah Alam

By comparison between the high O_3 days and the low O_3 days, the following features were found.

Diurnal changes of O_3 during the high O_3 days and low O_3 days are shown in Fig. 4.1.28. The differences between the high O_3 days and low O_3 days are large at City Hall, Petaling Jaya, and Shah Alam.

Wind roses during the high O_3 days and low O_3 days are shown in Fig. 4.1.29. Wind is relatively weak during the high O_3 days.

Diurnal change of net radiation during the high O_3 days and low O_3 days at Petaling Jaya is shown in Fig. 4.1.30. Net radiation during the high O_3 days is higher than the one during the low O_3 days.

Diurnal change of relative humidity during the high O_3 days and low O_3 days is shown in Fig. 4.1.31. Relative humidity in the daytime during the high O_3 days is lower than the one during the low O_3 days.

Diurnal changes of NO_2 during the high O_3 days and low O_3 days are shown in Fig. 4.1.32. NO_2 concentrations during the high O_3 days at all stations are higher than the ones during the low O_3 days. The differences are large at City Hall, Petaling Jaya, and Shah Alam.

Diurnal changes of NMHC during the high O_3 days and low O_3 days are shown in Fig. 4.1.33. NMHC concentration during the high O_3 days is higher than the one during the low O_3 days.

The remaining figures as wind roses and diurnal changes are shown in Section 2.1 of the Supporting Report.

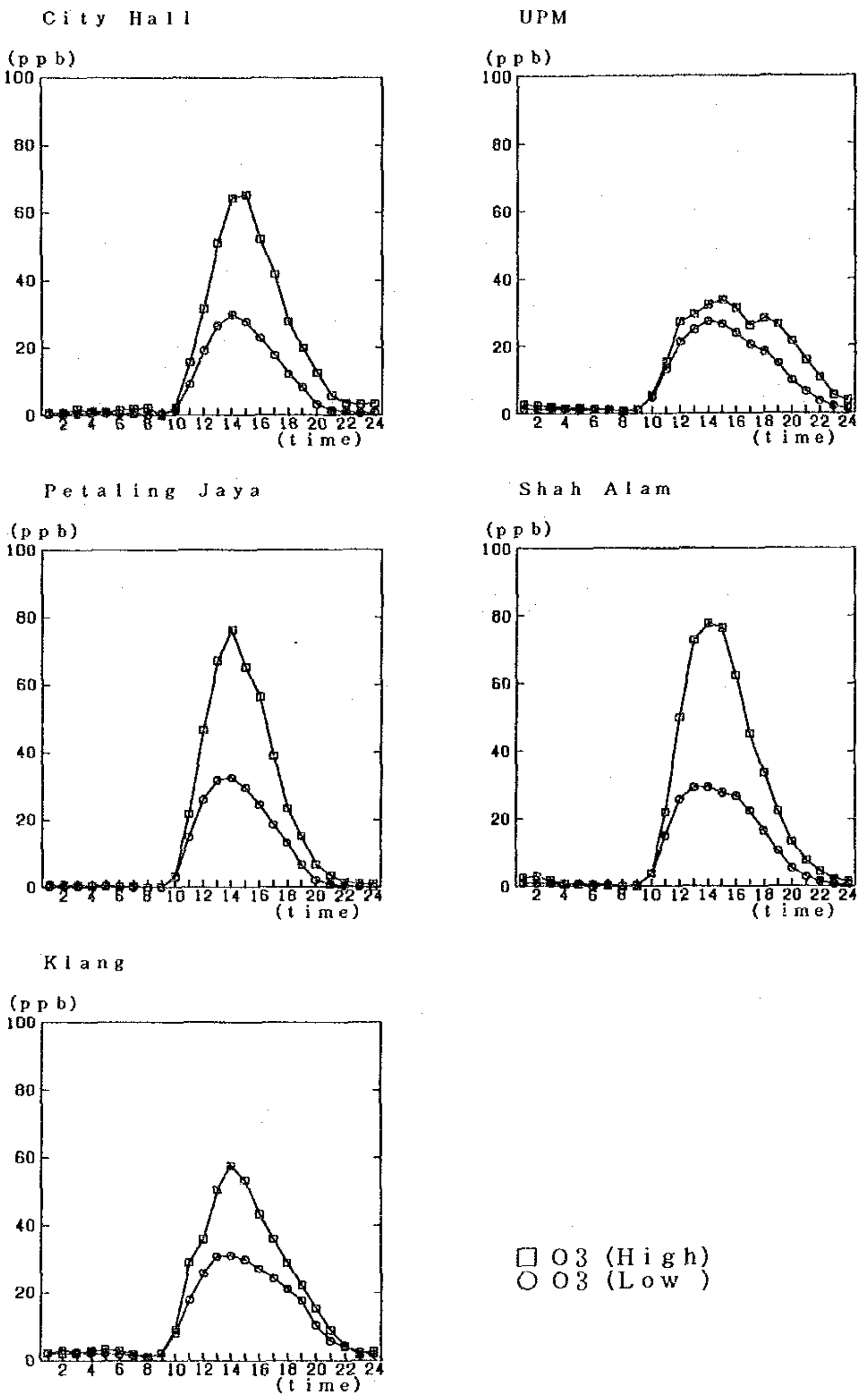


Fig. 4.1.28 Diurnal Change of O3 during High O3 Days and Low O3 Days (Mar. 1992 ~ Feb. 1993)

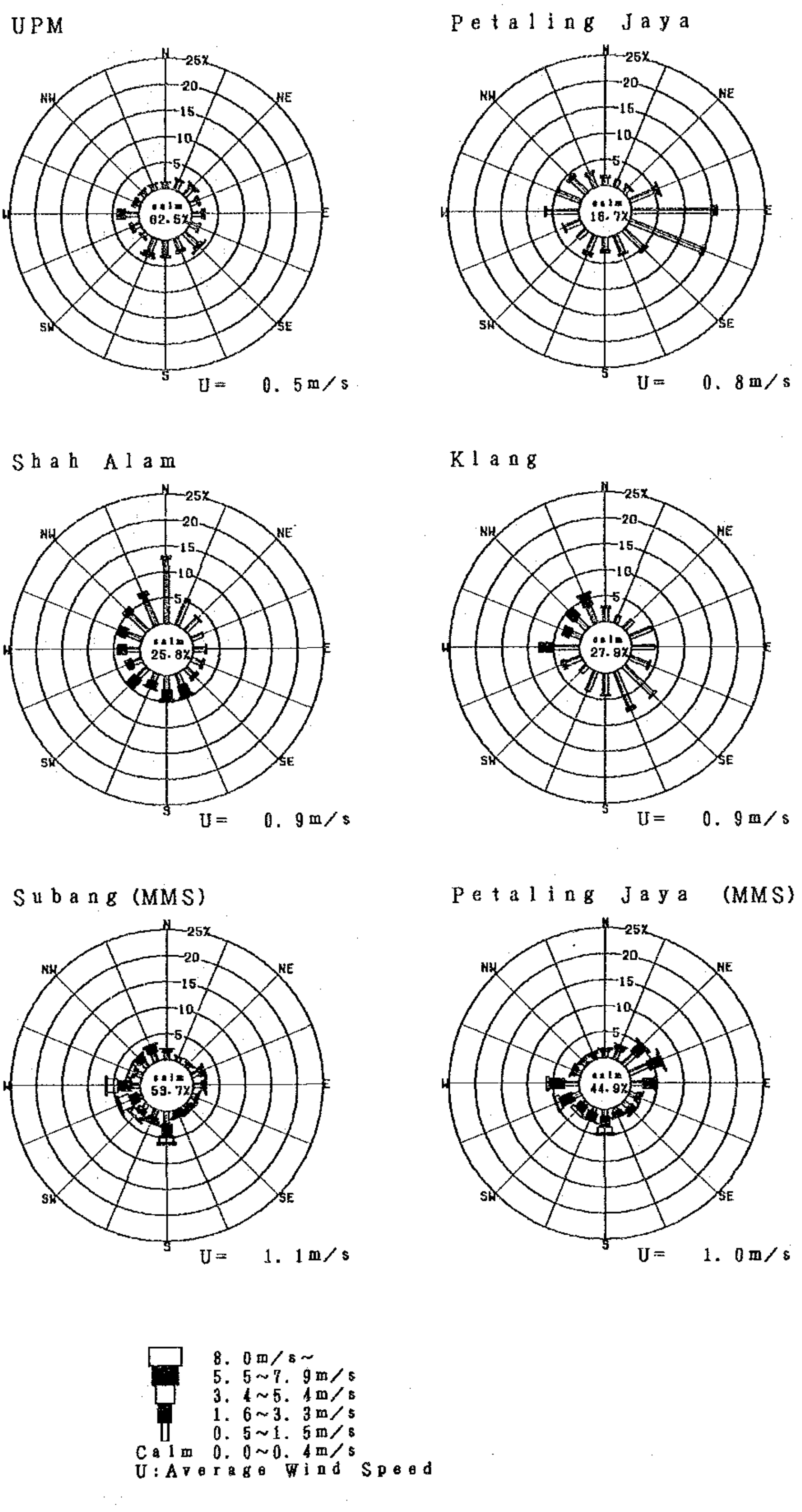


Fig. 4.1.29 (1) Wind Rose during High O_3 Days (Mar. 1992 ~ Feb. 1993)

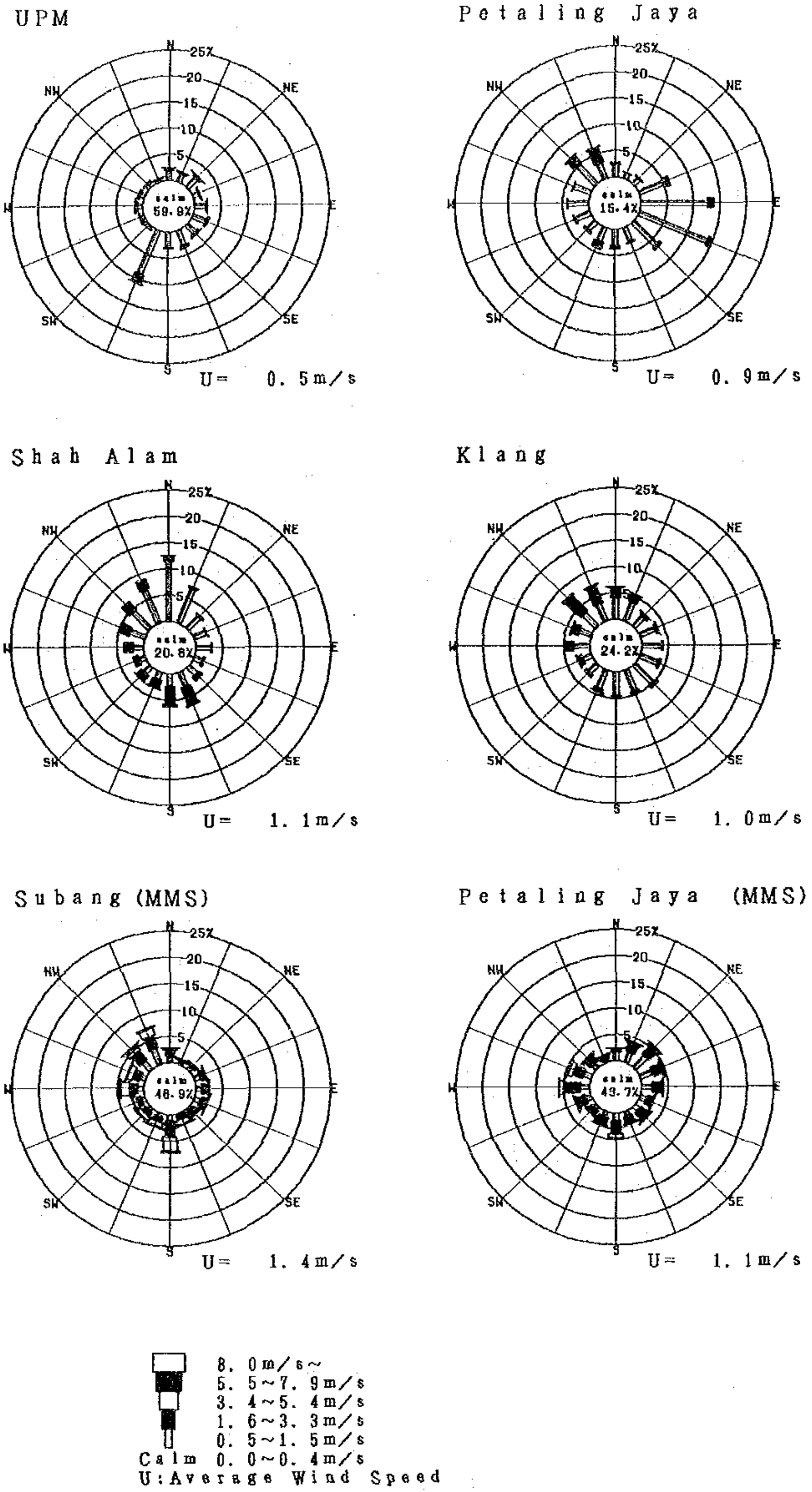


Fig. 4.1.29 (2) Wind Rose during Low O_3 Days
(Mar. 1992 ~ Feb. 1993)

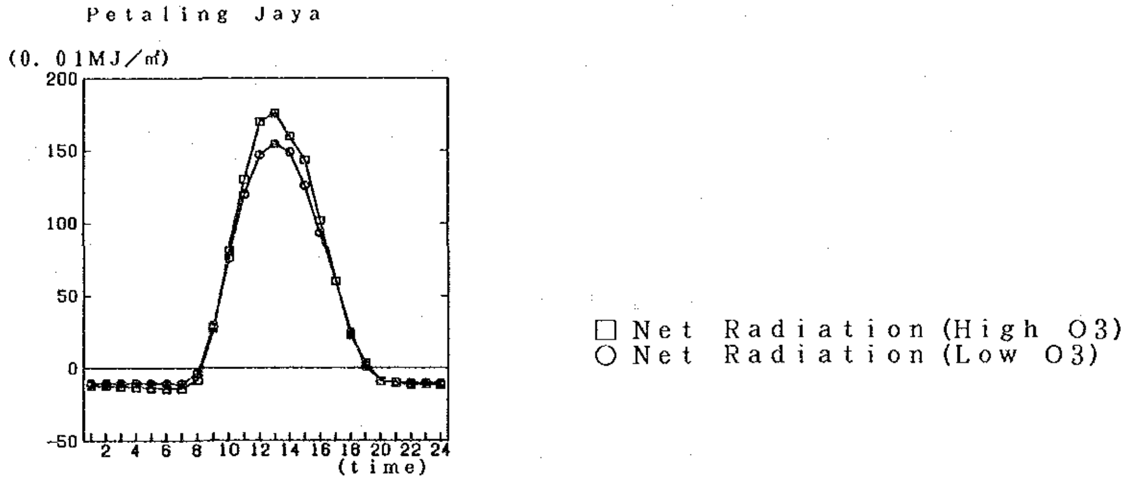


Fig. 4.1.30 Diurnal Change of Net Radiation during High O3 Days and Low O3 Days at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

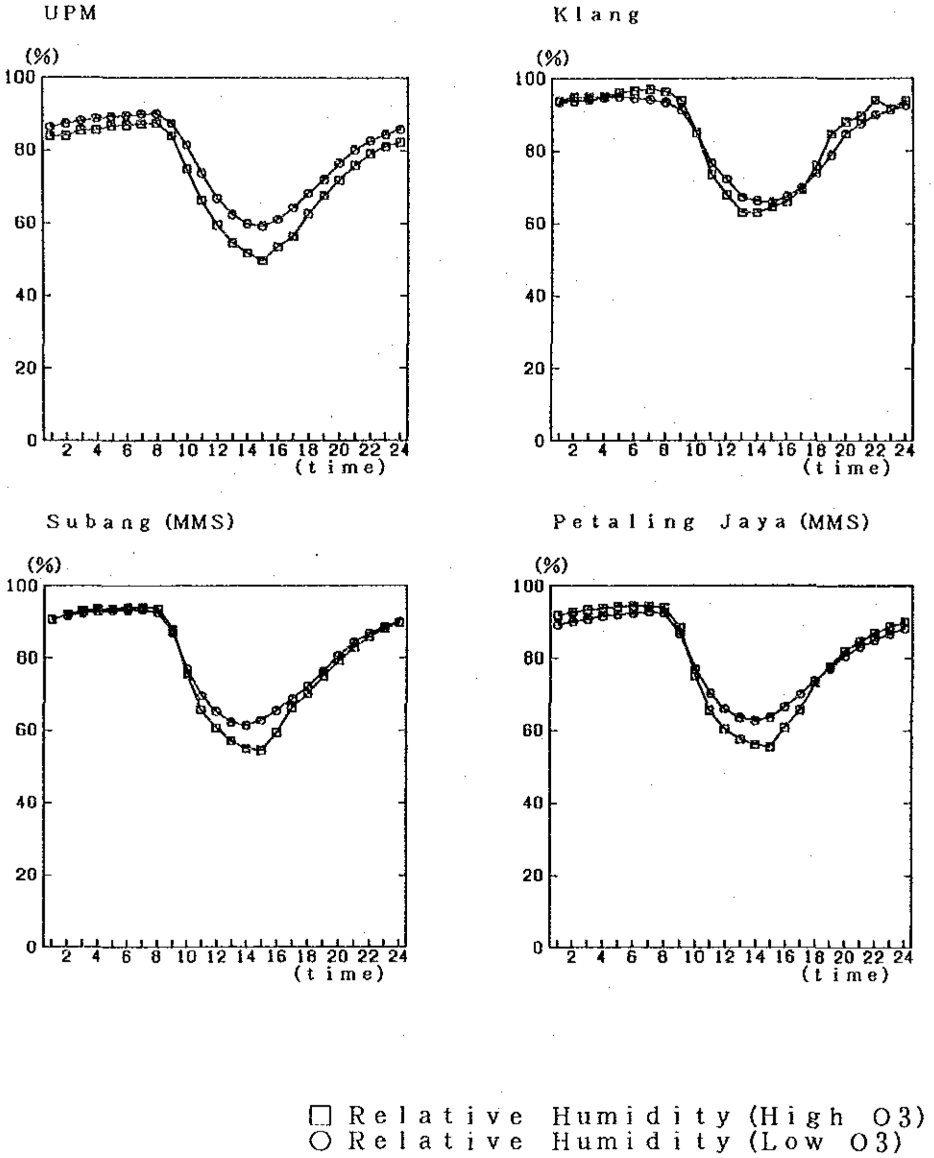


Fig. 4.1.31 Diurnal Change of Relative Humidity during High O_3 Days and Low O_3 Days (Mar. 1992 ~ Feb. 1993)

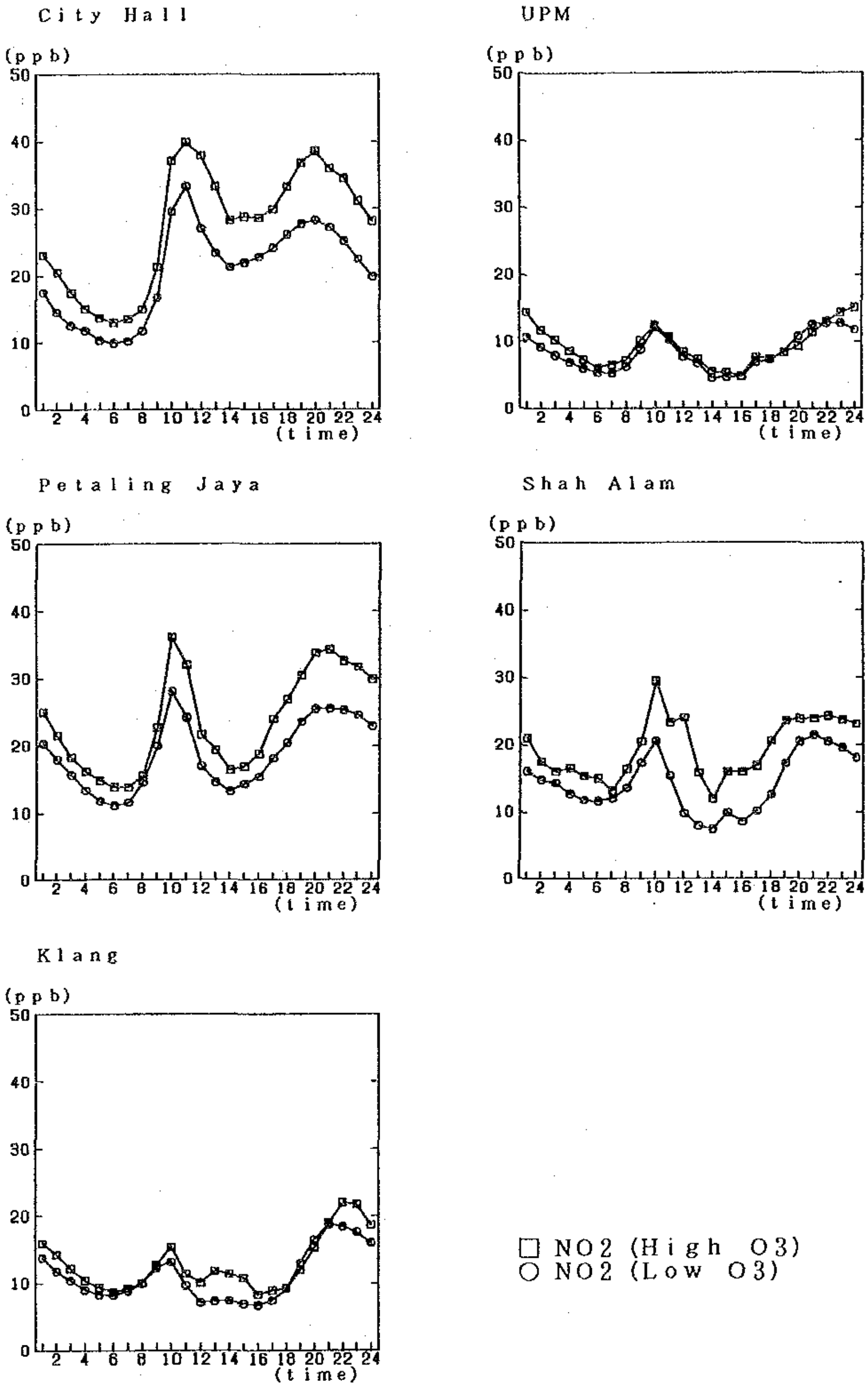


Fig. 4.1.32 Diurnal Change of NO_2 during High O_3 Days and Low O_3 Days (Mar. 1992 ~ Feb. 1993)

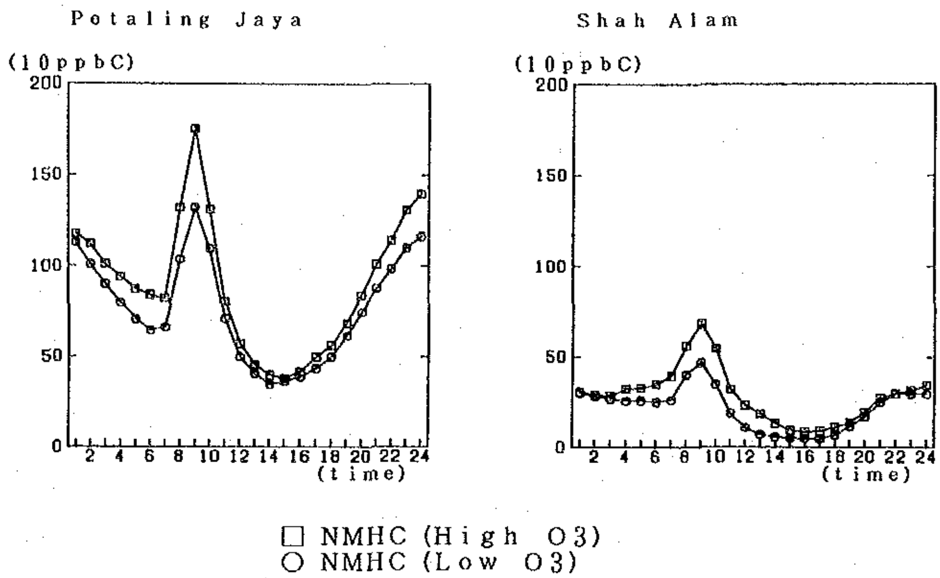


Fig. 4.1.33 Diurnal Change of NMHC during High O_3 Days and Low O_3 Days
(Mar. 1992 ~ Feb. 1993)

4.2 Simplified Measurement

4.2.1 Simplified Measurement over a Wide Area

(1) Outline of Measurement

To examine spatial distribution of $SO_3(SO_2)$, NO_2, and NOx concentration in Kelang Valley Region, the shelters for simplified measurement were installed at 50 points shown in Fig. 4.2.1.

Outline of the measurement is summarized in Table 4.2.1.

Table 4.2.1 Outline of Simplified Measurement in Wide Area

Item	Method	Period
SO_3	PbO_2 Method	1. February - March, 1992 2. March - April, 1992
NO_2, NOx	PTIO Method (YOKOHAMA-KOKEN-Method)	3. July - August, 1992 4. October - November, 1992 Exposure period: about 30 days / one period

Note: Measurement and chemical analysis method

PbO_2 method: A cylinder coated with lead dioxide paste is exposed to the ambient air for about a month. After exposure, the sample is analyzed by absorptiometry method.

PTIO method: A sampler with an absorbent filter containing PTIO and TEA reagent is exposed to the ambient air for about a month. After exposure, the sample is analyzed by absorptiometry method.

PTIO : 2-phenyl-4,4,5,5-tetramethylimidazoline-3-oxide-1-oxyl

TEA : Triethanolamine

(2) Data Analysis

To survey the spatial distribution of the pollutants, contour figures were produced.

At first, the concentration values at each grid point with 2000 meters X-span and 2000 meters Y-span were calculated. The calculation was made using the weighted averaging methods with $1/R^2$ weight. R is a distance from a grid point to a station. For the calculation at a grid point, the closest station and the second closer station were used. Then, contour lines were drawn for each period and each pollutant.

NO_2 distribution in the first period is shown in Fig. 4.2.2. Areas of high concentration with more than 20 ppb appear in Kuala Lumpur through

Petaling Jaya and Shah Alam through Klang. Areas of high concentration with more than 20 ppb mainly appear in Kuala Lumpur during the second through fourth period. During the second period, areas of high concentration also appear in Gombak.

NOx distribution in the fourth period is shown in Fig. 4.2.3. A high concentration center with more than 100 ppb appears in the middle eastern part of Kuala Lumpur. Centers of high concentration appear in Kuala Lumpur during the second through fourth period, but the area sizes of the high concentration centers are smaller during the first and the second period.

SO_3 distribution for the second period is shown in Fig. 4.2.4. Area of high concentration with more than 300 (0.001 $mg/day/100cm^2$ Pb) appears in the north part of Kuala Lumpur.

Area of high concentration with more than 300 appears in Gombak during the first period.

SO_3 concentration is converted to SO_2 concentration using the following equation.

SO_2 (ppm) = SO_3 ($mg/day/100cm^2$ PbO2) x 0.04

So 0.44 $mg/day/100cm^2$ PbO_2, the maximum value of SO_3 during these periods is converted to 17.6 ppb. The 300 contours in the figure corresponds to 12 ppb.

The contour maps not shown in this section are included in Section 2.2 of the Supporting Report.

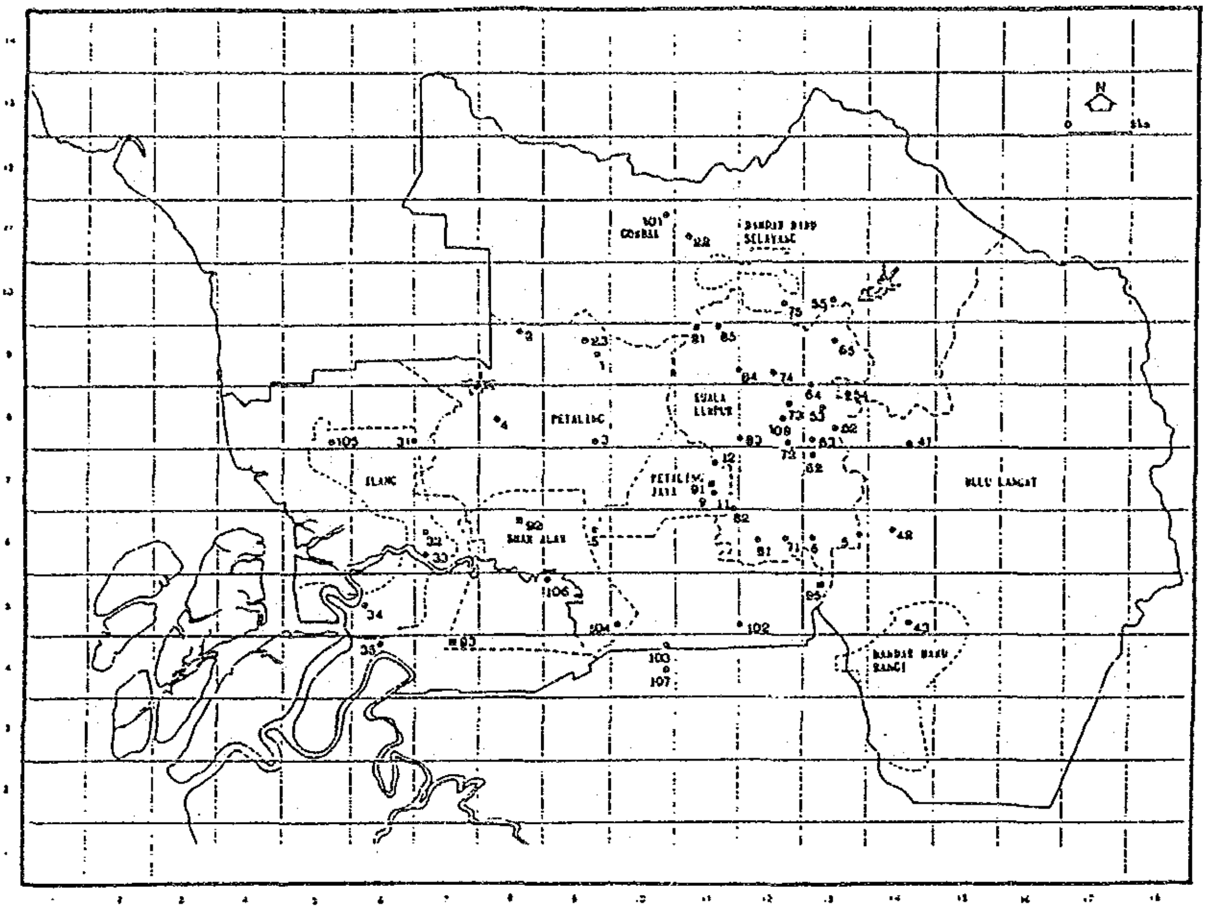


Fig. 4.2.1 Locations of Simplified Measurement Points in Wide Area

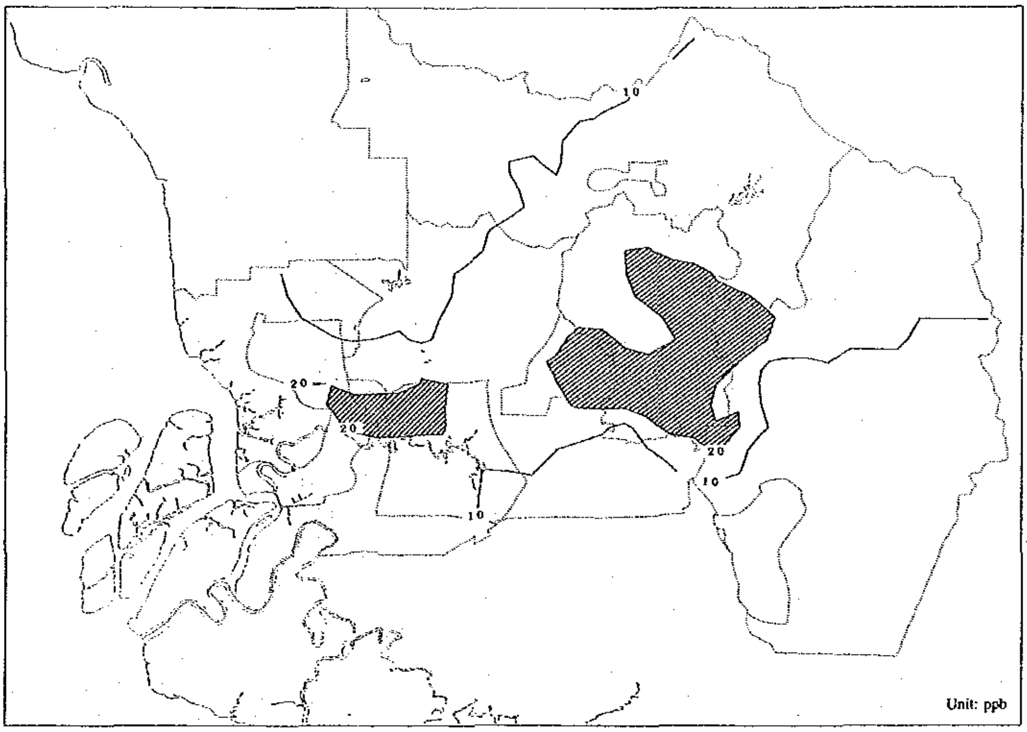


Fig. 4.2.2 Contour Map of NO2 by Simplified Measurement in Wide Area (Feb. ~ Mar. 1992)

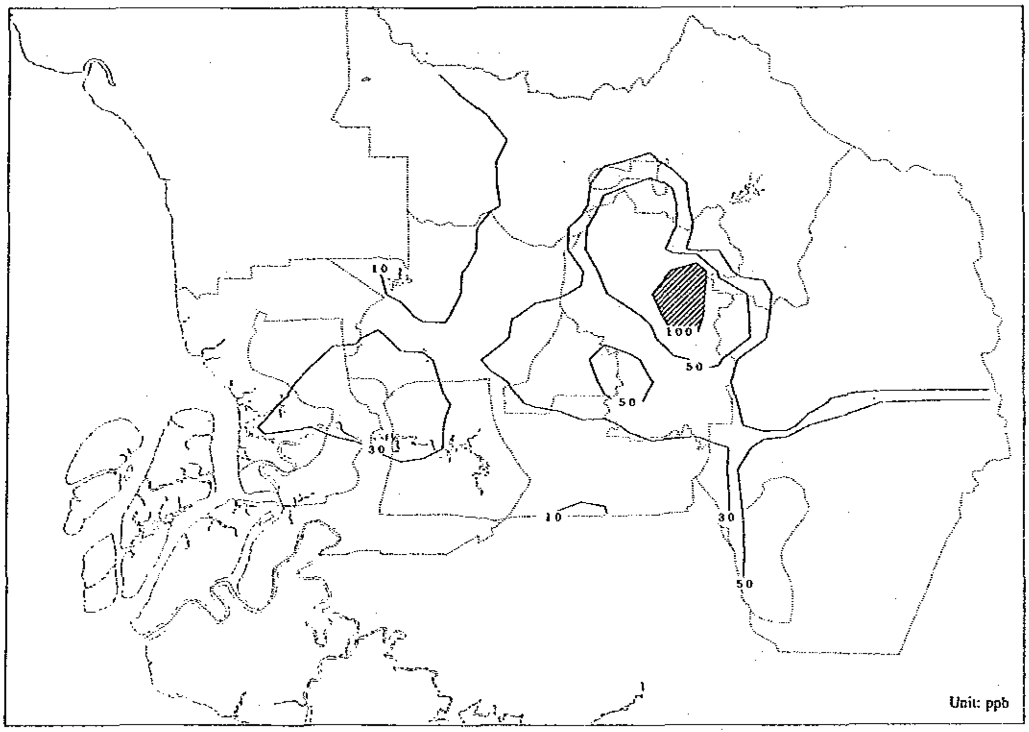


Fig. 4.2.3 Contour Map of NOx by Simplified Measurement in Wide Area (Oct. ~ Nov. 1992)

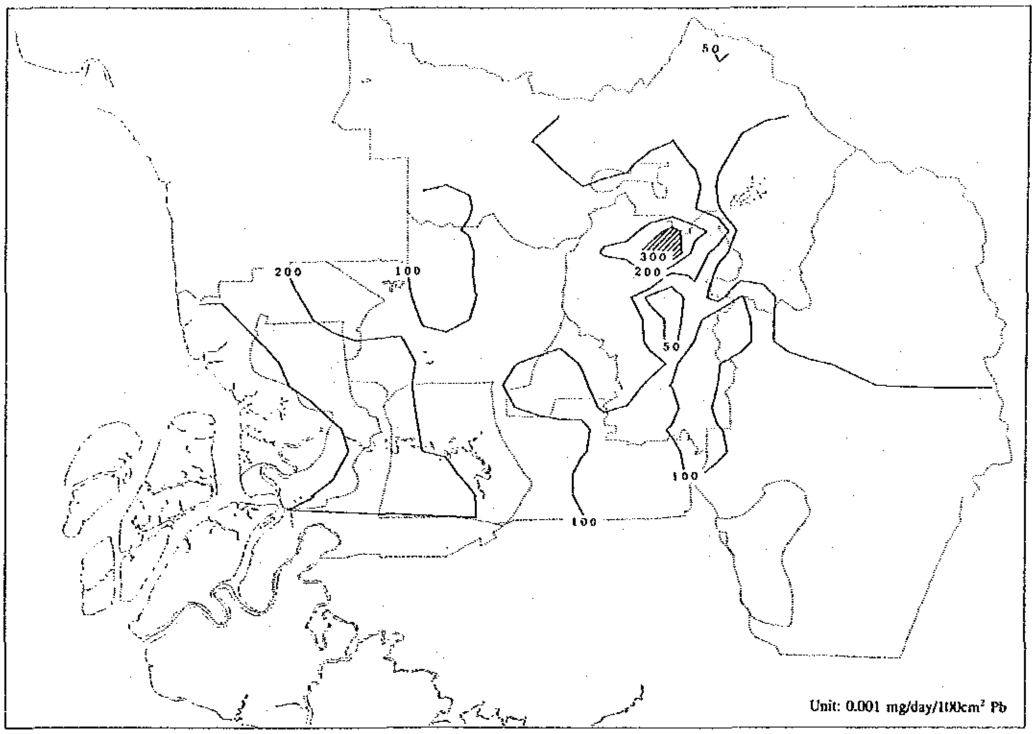


Fig. 4.2.4 Contour Map of SO_3 by Simplified Measurement in Wide Area (Mar. ~ Apr. 1992)

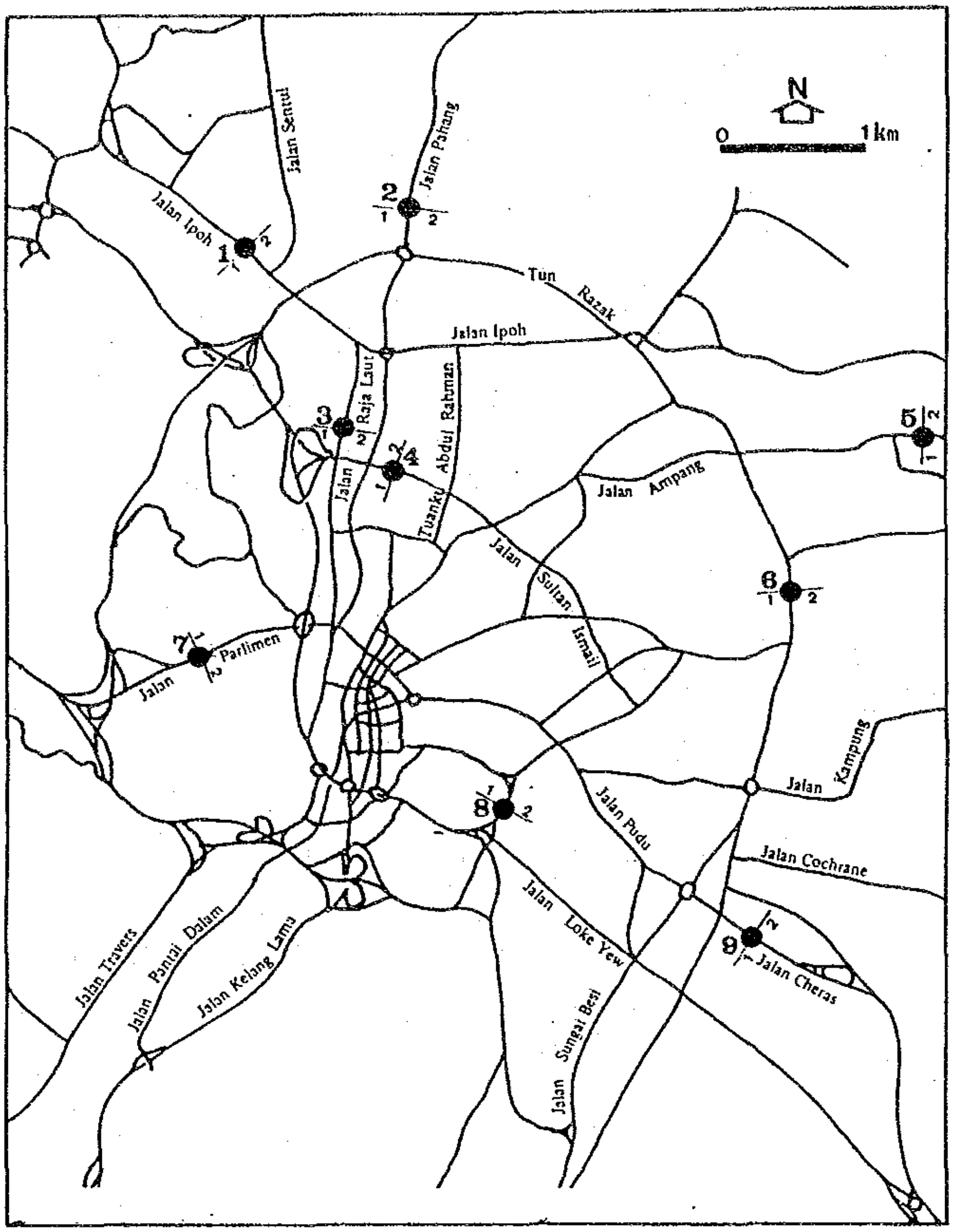
4.2.2 Simplified Measurement around Roads

(1) Outline of Measurement

To investigate the profile of air pollutants around roads, CO concentrations were measured with detector tubes at the points shown in Fig. 4.2.5. The points were placed in a line vertical to each of the road.

The measurements were conducted for four periods at each point.

First	:	5/Mar/1992	-	7/Mar/1992
Second	:	24/Apr/1992	-	27/Apr/1992
Third	:	11/Aug/1992	-	13/Aug/1992
Fourth	:	2/Nov/1992	-	4/Nov/1992



Legend

Observation Point

No.	MAIN ROAD	Survey Road 1	Survey Road 2
1	Jl. Ipoh	Jl. Kolam Air	Small road near by G.S.
2	Jl. Pahang	Jl. Pahang Barat	Jl. Titiwangsa III
3	Jl. Raja Laut	Jl. Tiong Nam	Jl. Sri Amar
4	Jl. Sultan Ismail	Parking near by Jl. TAR	Parking near by Jl. TAR
5	Jl. Ampang	Jl. Palas	Jl. Ritchie
6	Jl. Tun Razak	Jl. Eaton	Jl. Langgak Golf
7	Jl. Parlimen	Jl. Cenderawasih	Jl. Sultan Salahuddin
8	Jl. Hang Tuah	Road to School	Jl. Kenanga
9	Jl. Cheras	Road to Dewan Bandaraya	Jl. Timun

Fig. 4.2.5 Locations of Simplified Measurement Points around Roads

(2) Data Analysis

The results of the measurements are summarized in Table 4.2.2. And CO profiles around the roads are shown in Fig. 4.2.6 through Fig. 4.2.9.

Concentration decrease with distances from the road.

Table 4.2.2 Measurement Result of CO by Detector Tube

unit : ppm

No	Point	Time	Period	Road-1					Road-2				
				Distant (m)					Distance (m)				
				0	10	20	40	100	0	10	20	40	100
1	Jl. Ipoh	1	7/ 3/92'	9	5	5	4	1	3	2	2	1	1
		2	25/ 4/92'	8	2	3	2	3	4	2	2	2	1
		3	13/ 8/92'	9	2	1	1	1	5	1	1	1	1
		4	3/11/92'	5	2	1	2	1	9	5	3	4	1
2	Jl. Pahang	1	5/ 3/92'	5	4	3	1	1	5	1	2	1	2
		2	25/ 3/92'	11	4	5	7	4	5	3	3	2	3
		3	12/ 8/92'	11	6	7	4	3	6	1	2	2	2
		4	4/11/92'	10	3	3	2	2	5	3	2	2	1
3	Jl. Raja Laut	1	5/ 3/92'	5	2	2	3	2	8	5	5	4	4
		2	27/ 4/92'	8	4	3	1	2	8	6	5	4	4
		3	12/ 8/92'	7	5	5	4	3	11	4	6	5	5
		4	3/11/92'	10	3	3	3	3	10	6	4	6	5
4	Jl. Sultan Ismail	1	5/ 3/92'	7	3	3	3	1	5	1	1	1	1
		2	25/ 4/92'	11	4	3	3	2	8	1	1	1	1
		3	12/ 8/92'	5	1	5	2	4	9	3	3	2	1
		4	3/11/92'	7	4	4	3	2	13	5	5	4	1
5	Jl. Ampang	1	7/ 3/92'	10	4	3	2	1	8	4	2	3	2
		2	24/ 4/92'	6	3	2	1	1	4	3	2	3	2
		3	11/ 8/92'	8	3	2	2	2	7	3	3	3	2
		4	2/11/92'	7	4	2	1	1	7	4	4	2	1
6	Jl. Tun Razak	1	6/ 3/92'	5	1	2	1	1	11	3	4	1	1
		2	24/ 4/92'	10	4	3	3	3	10	4	4	3	2
		3	11/ 8/92'	6	2	3	2	2	13	4	4	4	2
		4	2/11/92'	11	5	5	2	1	13	5	3	2	1
7	Jl. Parlimen	1	6/ 3/92'	2	2	3	2	1	2	1	1	1	0
		2	27/ 4/92'	14	7	5	3	2	4	3	2	1	1
		3	11/ 8/92'	14	9	5	5	5	4	3	1	1	1
		4	4/11/92'	5	6	3	4	3	6	1	1	1	1
8	Jl. Hong Tuah	1	6/ 3/92'	2	1	2	1	1	4	2	4	2	3
		2	27/ 4/92'	8	6	4	3	2	9	7	5	4	3
		3	13/ 8/92'	11	6	3	4	4	10	9	6	6	8
		4	4/11/92'	3	1	2	4	1	5	3	1	1	3
9	Jl. Cheras	1	6/ 3/92'	6	4	2	4	3	6	2	4	2	2
		2	24/ 4/92'	3	2	2	1	2	8	3	4	3	2
		3	11/ 8/92'	3	2	3	3	2	9	3	3	2	1
		4	2/11/92'	4	3	3	2	2	5	3	2	1	1

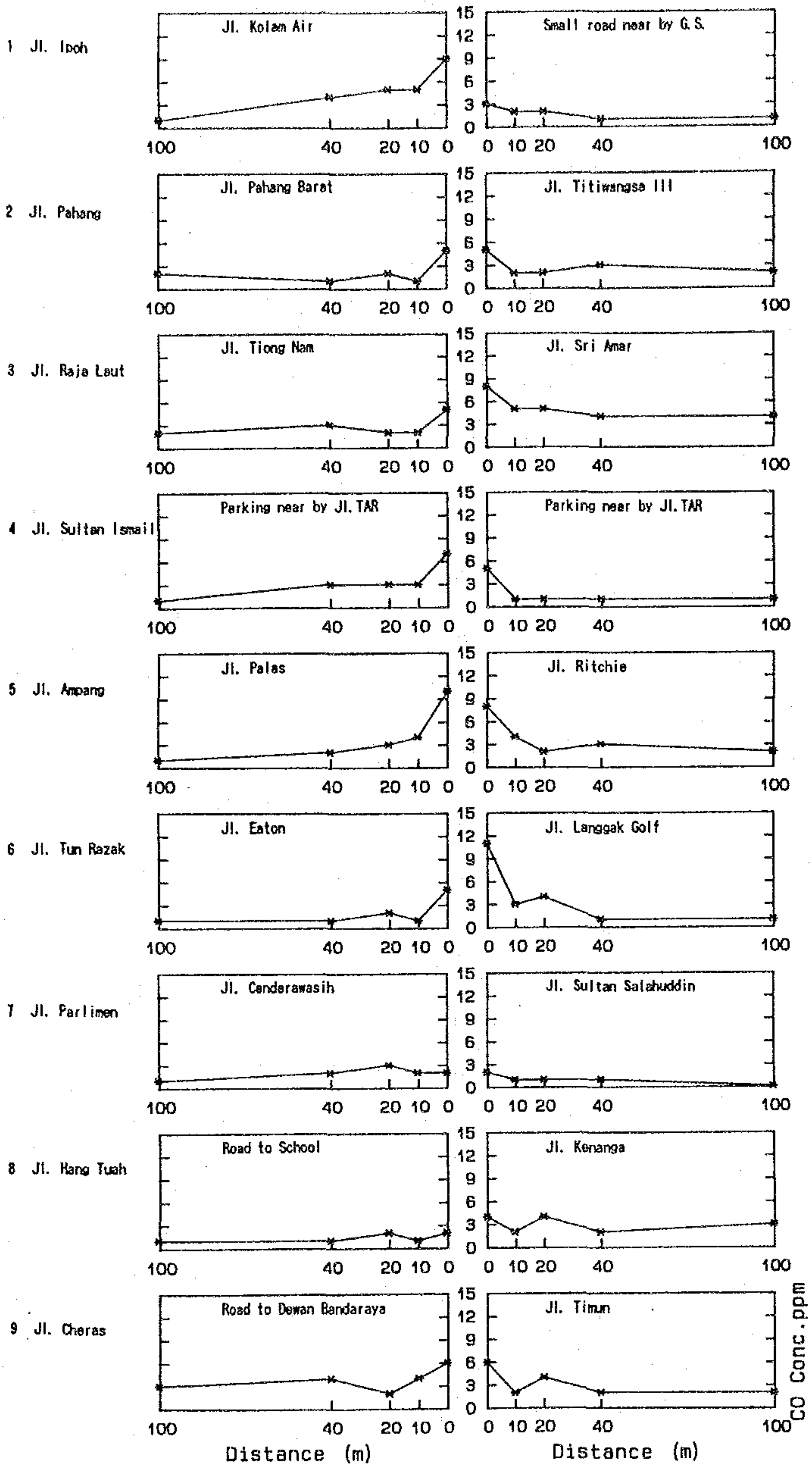


Fig. 4.2.6 CO Profile by Detector Tube of the First Period (5th ~ 7th/Mar./1992)

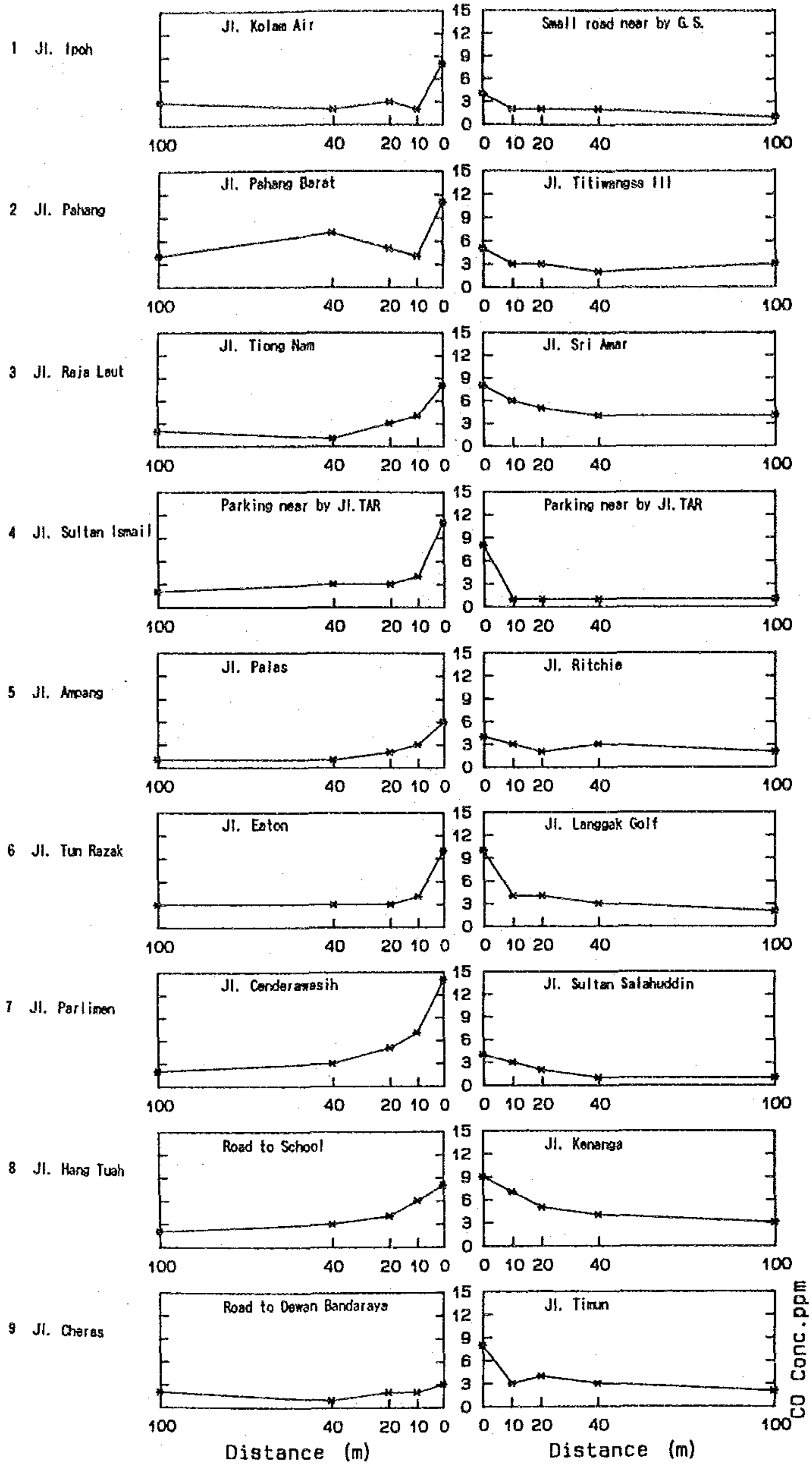


Fig. 4.2.7 CO Profile by Detector Tube of the Second Period (24th ~ 27th/Apr./1992)

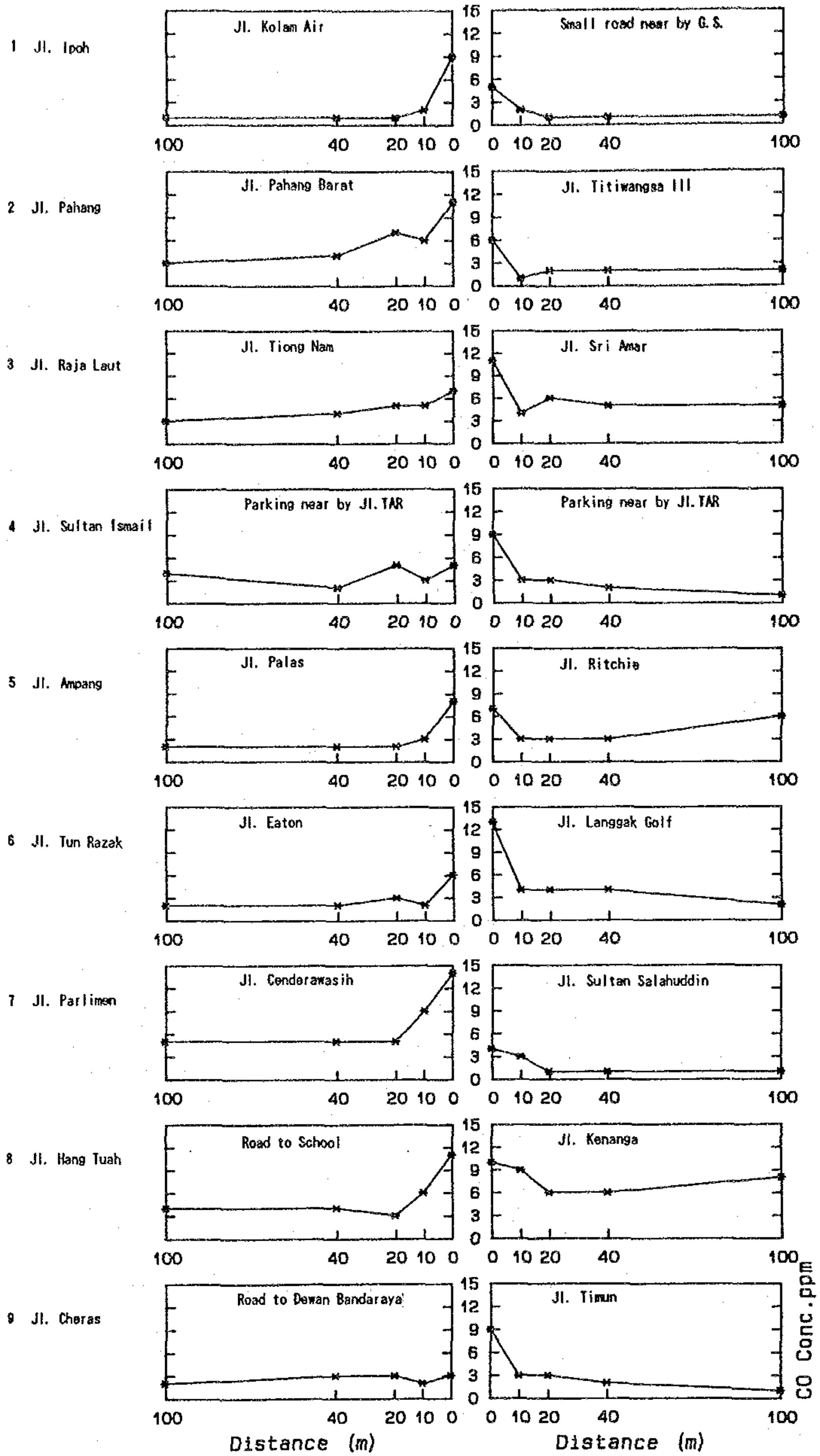


Fig. 4.2.8 CO Profile by Detector Tube of the Third Period (11th ~ 13th/Aug./1992)

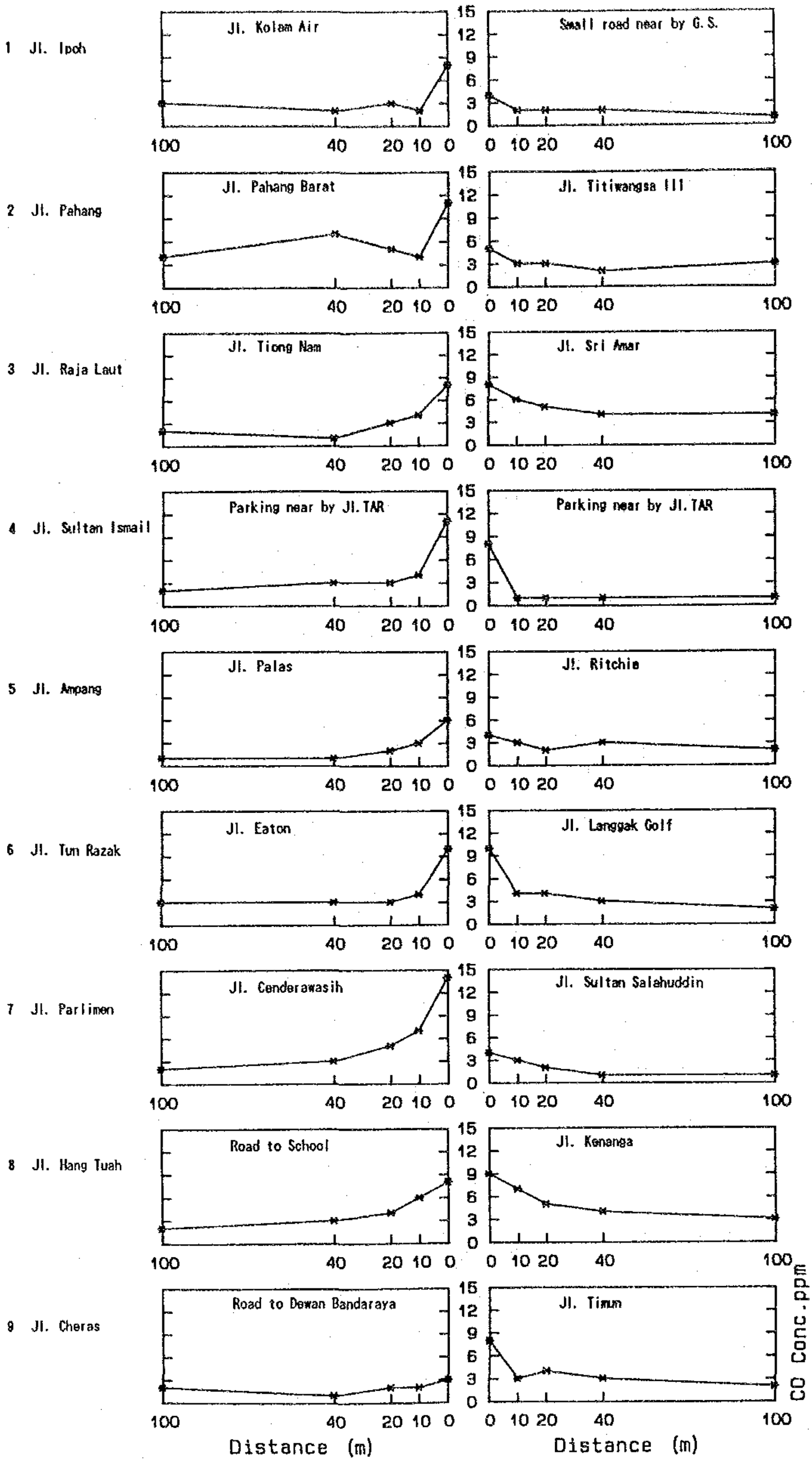


Fig. 4.2.9 CO Profile by Detector Tube of the Fourth Period (2nd ~ 4th/Nov./1992)

4.3 Analysis of Other Related Data

(1) Summary of Reports and Research Papers

Some reports and papers related to the ambient air quality in Kelang Valley Region were provided by DOE, MMS, and UPM.

As mentioned in some reports (#3001, #3012), information relating to air pollution issues in Kelang Valley Region or Malaysia was very limited in the past years.

TSP and PM10 were observed accurately by some agencies such as DOE, UPM, MMS, UTM and others, but data on gaseous pollutants as SO_2, NOx, CO, and O_3 were very limited and where they existed, the records were not continuous.

However, with the installation of three micro-computer system for air monitoring units in 1984, more accurate and continuous measurement of air pollutants including gaseous ones started.

The existing information that have been observed in the study area are listed below (#3001).

- TSP concentration measured at Petaling Jaya in 1986 satisfied the annual guideline (90 $\mu g/m^3$) and the daily guideline (260 $\mu g/m^3$).

- Though it was said that more investigations were requested, TSP concentration values at Rawang, Klang, and Shah Alam in 1986 exceeded the guidelines to some extent.

- PM10 concentration values at Petaling Jaya in 1986 exceeded the guideline for daily value, but the values in 1987, and 1988 satisfied the guidelines.

- SO_2 concentration values at City Hall in 1986 satisfied the guidelines for hourly value (130 ppb) and the 99 percentile value was 25 ppb.

- SO_2 concentration values at Kapar and Meru near fire power plant satisfied the guideline and the 99 percentile values were 56 ppb and 36 ppb for each station.

- NO_2 concentration values at City Hall station in 1986 satisfied the guideline for hourly value (170 ppb) and the 99 percentile value was about 38 ppb.

- O_3 concentration values at City Hall in 1986 sometimes exceeded the guideline and the 99 percentile value was about 97 ppb.

On the basis of the above, the concentration levels of each pollutant was summarized as below;

- TSP and PM10 concentration values sometimes probably exceeded the guidelines, but the exceeding was likely to occur mainly at non-residential sites.

- SO_2 concentration values were likely to be satisfied at all residential and commercial sites.

- NO_2 was likely to be satisfied at all residential sites, but higher values were probably measured at some commercial sites.

- O_3 concentration data were limited, but they indicated high level concentration even at the city sites.

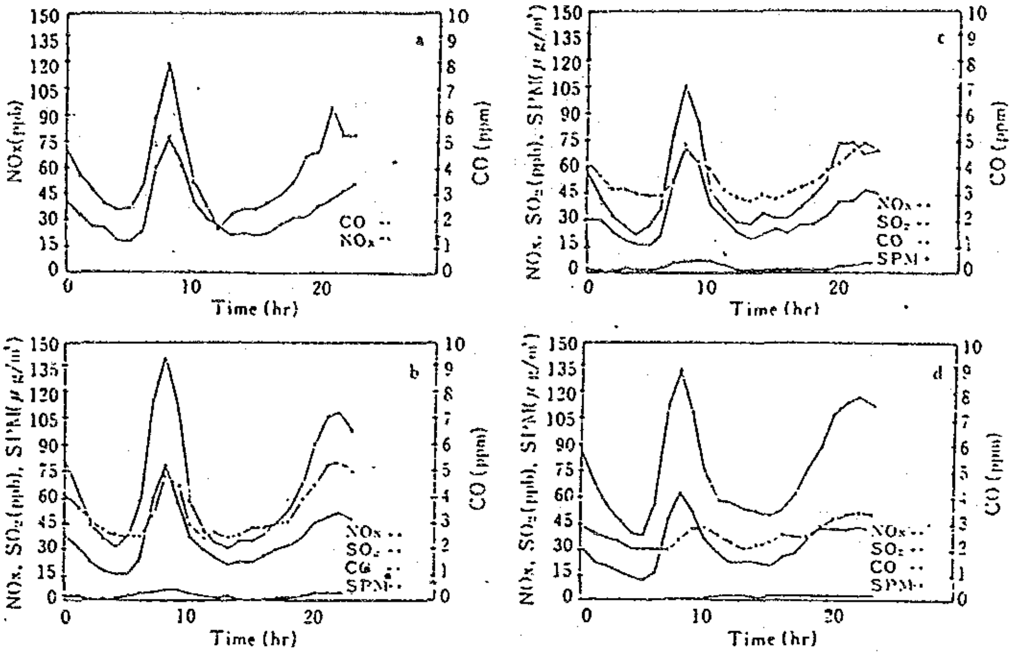
- CO concentration data were limited, but higher level than the guideline probably occur red at least in commercial area.

On the basis of more recent data of TSP concentration in 1989, annual mean values of heavy traffic sites exceeded the guideline at 6 out of 7 sites (#8004). Annual mean values at industrial sites exceeded the guideline at 5 out of 9 sites and the values at commercial sites exceeded the guideline at 1 out of 5 sites. In this case, the site at which the values exceeded the guideline was Shah Alam (SIRIM).

Figs. 4.3.1(1) and (2) show diurnal changes of SO_2, CO, NOx, and O_3 in Kuala Lumpur (#3021). Graph (a) shows the result in December in 1984 through March in 1985, graph (b) shows the one in April through May in 1985, graph (c) shows the one in June through September in 1985, and graph (d) shows the one in October through November in 1985.

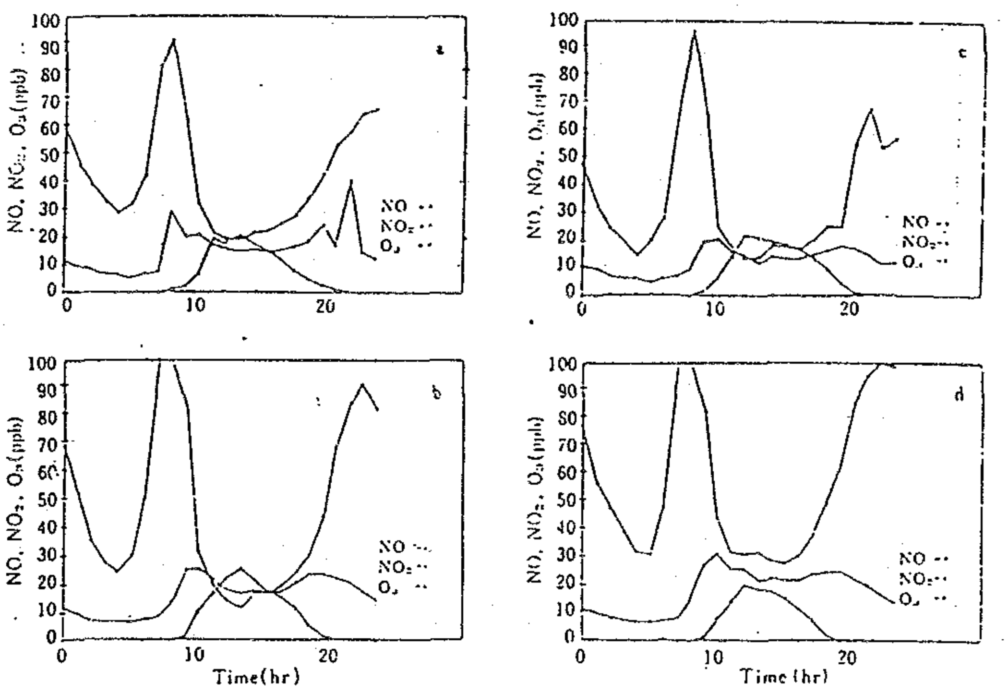
Data of SPM, CO and NOx have two distinct peaks, one in the morning and another in the evening. These are indications of the influence by motor vehicles. As to meteorological parameters, diurnal changes of mixing height and wind speed are related to the air pollution. As to diurnal change pattern of NOx and O_3, it is indicated that the peak is first reached by NO, followed by NO2 and finally by O_3.

Fig. 4.3.2 shows seasonal change patterns of SPM, CO, NOx, and O_3 (#3012). TSP was measured at MMS (Petaling Jaya) and O_3 values were the monthly averages of daily maximum. SPM, and TSP show peaks in June during the dry period, and the strong surface inversions are likely to have contributed to the peak.



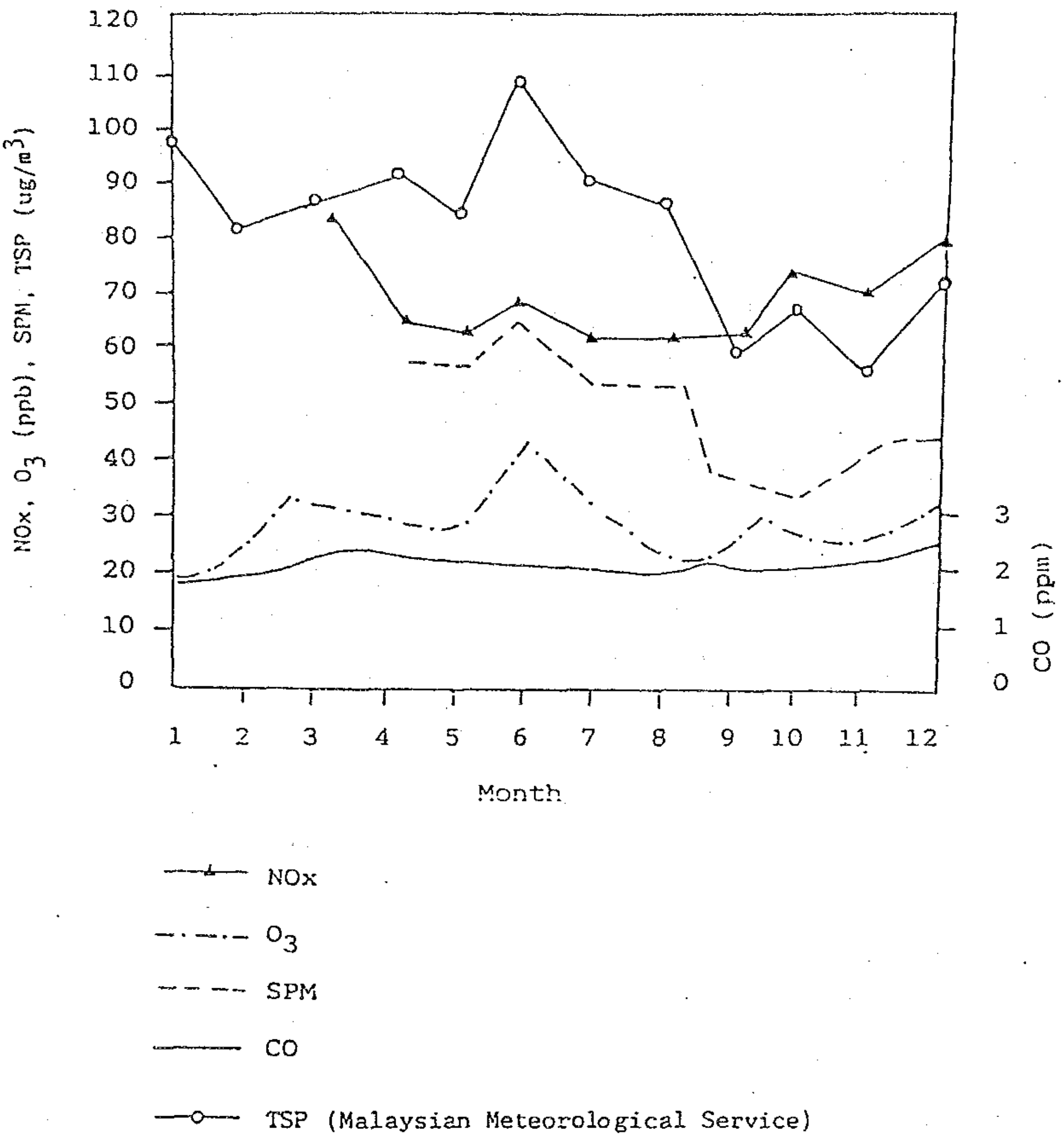
(a: Dec. 1984 ~ May 1985, b: Apr. ~ May 1985,
c: Jun. ~ Sep. 1985, d: Oct. ~ Nov. 1985)

Fig. 4.3.1(1) Diurnal Variation in NOx, SOx, SPM and CO in Kuala Lumpur



(a: Dec. 1984 ~ May 1985, b: Apr. ~ May 1985,
c: Jun. ~ Sep. 1985, d: Oct. ~ Nov. 1985)

Fig. 4.3.1(2) Diurnal Variation in NO, NO2 and O3 in Kuala Lumpur



(Source : Azman et.al., 1988)

Fig. 4.3.2 Average Monthly Concentration of NOx, CO and SPM and Monthly Average of Daily Maximum Value of O3 in Kuala Lumpur(1985)

(2) Analysis of TSP and PM10 Data

TSP data in 1977 through 1992 and PM10 data in 1990 through 1992 were provided by MMS. TSP and PM10 were observed at Petaling Jaya by high volume sampling for 24 hours.

Monthly changes of TSP in 1977 through 1992 and PM10 in 1990 through 1992 are shown in Fig. 4.3.3. High TSP concentrations were observed in the following months.

- January and April of 1979
- September through December of 1982
- August of 1990
- September and October of 1991

PM10 concentrations in August of 1990 and October of 1991 were also high.

To obtain the conversion factors from SPM concentration to TSP and PM10 concentrations, correlation analysis was conducted. Daily averages of the monitoring SPM concentrations were calculated during the corresponding period to TSP and PM10 observation in 1992. Then linear regression lines were determined under the condition that TSP or PM10 is fixed at zero when SPM value takes zero value.

Scatter diagrams of SPM with TSP or PM10 are shown in Fig. 4.3.4. The equations for conversion from SPM to TSP or PM10 are as follows.

C(TSP) = 1.21 x C(SPM)

C(PM10) = 0.82 x C(SPM) Unit: $\mu g/m^3$

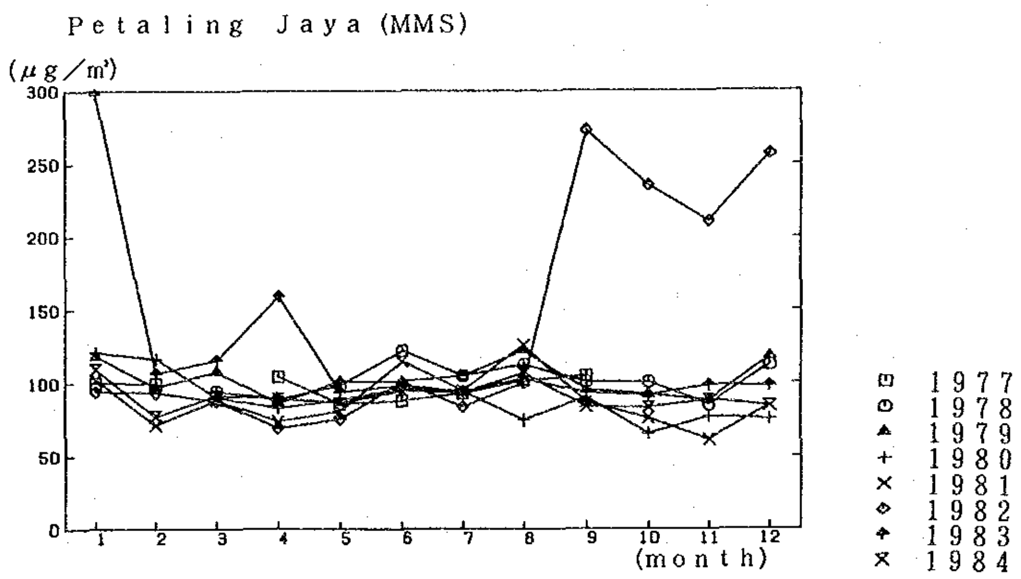


Fig. 4.3.3(1) Monthly Change of TSP at Petaling Jaya in 1977 through 1984

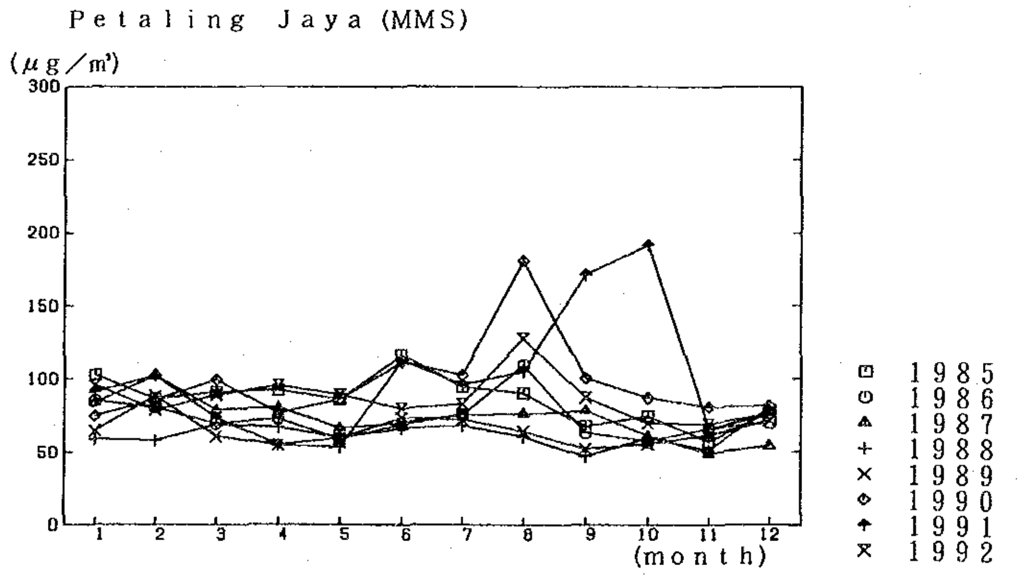


Fig. 4.3.3(2) Monthly Change of TSP at Petaling Jaya in 1985 through 1992

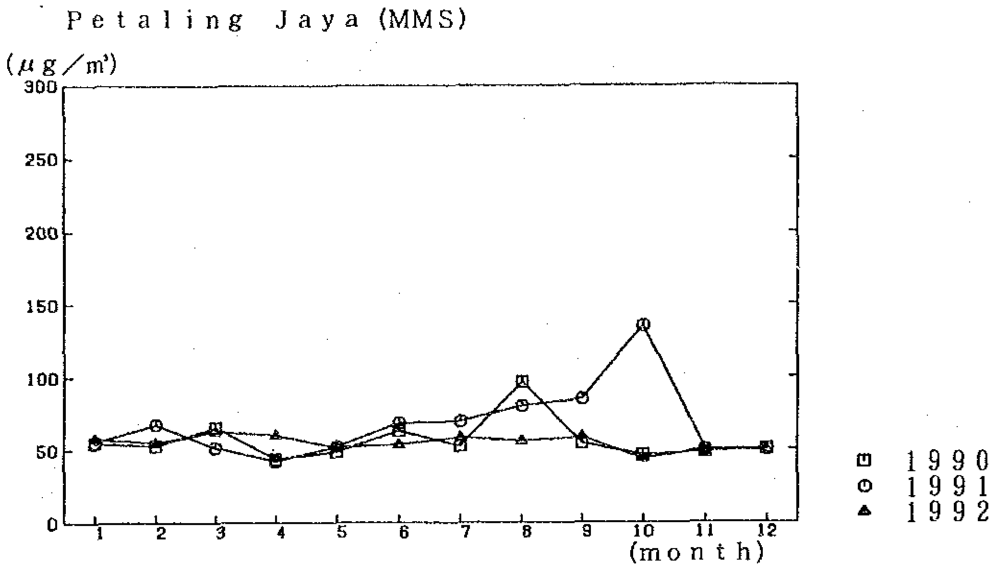


Fig. 4.3.3(3) Monthly Change of PM10 at Petaling Jaya in 1990 through 1992

1992 Feb. ~1992 Dec.

ALL

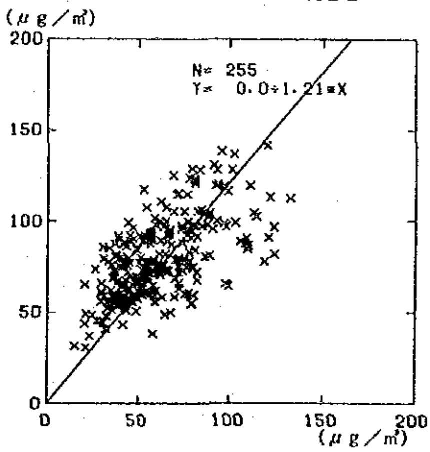


Fig. 4.3.4(1) Scatter Diagram of TSP with SPM at Petaling Jaya

1992 Feb. ~1992 Dec.

ALL

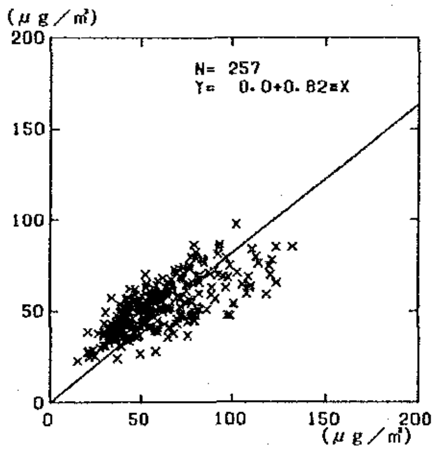


Fig. 4.3.4(2) Scatter Diagram of PM10 with SPM at Petaling Jaya

(3) Analysis of Existing Data at UPM

Some meteorological parameters and pollutants were measured in October of 1991 through February of 1992 and Haze episode occurred in October of 1991. The existing data and the monitoring data in March through September were put together to make an annual data.

At first, compliance with the guidelines during this period is shown in Table 4.3.1. SPM concentration is converted to TSP concentration or PM10 concentration for comparison with guidelines. Certainly TSP or PM10 concentration increases, but only maximum value of PM10 daily averages exceeded the guideline.

Table 4.3.1 Compliance with Guidelines at UPM

Items		TSP		PM10		SO2	
Unit		(μg/m3)		(μg/m3)		(ppb)	
Guidelines		Yearly 90	Daily 260	Yearly 50	Daily 150	Daily 40	Hourly 130
UPM	Avg.	36.1		24.5			
	Max.		249.2		168.9 X	14.8	89
	99%		189.7		128.6	13.9	21
	98%		135.0		91.5	12.9	18
	95%		66.3		44.9	12.3	1
	No.	7193	296	7193	296	325	7850

Items		NO2	O3	
Unit		(ppb)	(ppb)	
Guidelines		Hourly 170	8 Hours 60	Hourly 100
City Hall	Avg.			
	Max.	73	57.8	106 X
	99%	30	41.4	55
	98%	25	37.5	47
	95%	21	31.6	38
	No.	7119	7300	7331

Then the same methods described in section 4.2.1 were adopted to investigate the cause of high SPM concentration. The methods are as follows.

a) Correlation analysis

As statistical values, daily averages were used.

b) Selection of high SPM concentration days

c) Comparison between the high SPM days and the low SPM days

By the correlation analysis, SPM shows negative correlation with wind speed to some extent. SPM with temperature shows correlation to some extent. SPM with SO_2 or NO_2 shows correlation to some extent. The scatter diagrams are shown in Section 2.3 of the Supporting Report.

The days in October of 1991 were defined as the high SPM concentration days. The remaining days were the low SPM days.

Wind roses during the high SPM days and low SPM days are shown in Fig. 4.3.5. Wind speeds during the high SPM days are smaller than the ones during the low SPM days.

Diurnal changes of SPM, SO_2, NO_2, and NOx during the high SPM days and the low SPM days are shown in Fig. 4.3.6 through Fig. 4.3.9. SPM concentrations during the high SPM days are about two or three times of the ones during the low SPM days. However, SO_2, NO_2, and NOx show no clear difference between the high SPM days and low SPM days.

Diurnal changes of wind speed, relative humidity, temperature, and rainfall amount during the high SPM days and low SPM days are shown in Fig. 4.3.10 through Fig. 4.3.13. Relative humidity during the high SPM days is higher than the one during the low SPM days throughout a day.

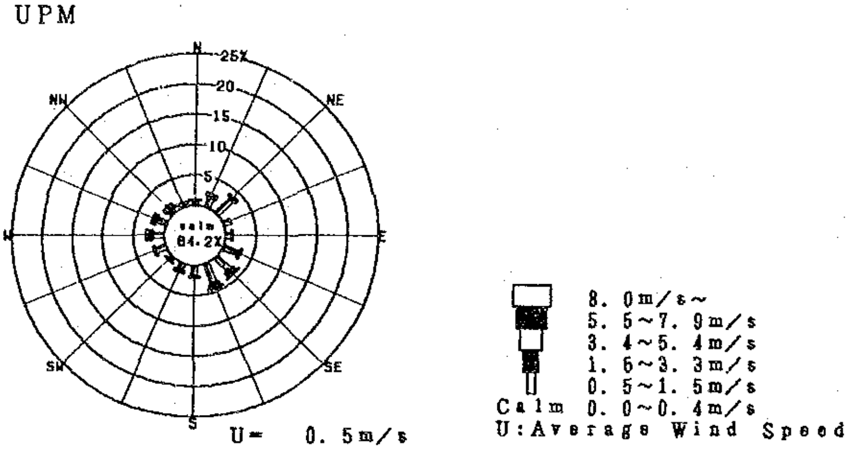


Fig. 4.3.5 (1) Wind Rose of High SPM Days at UPM

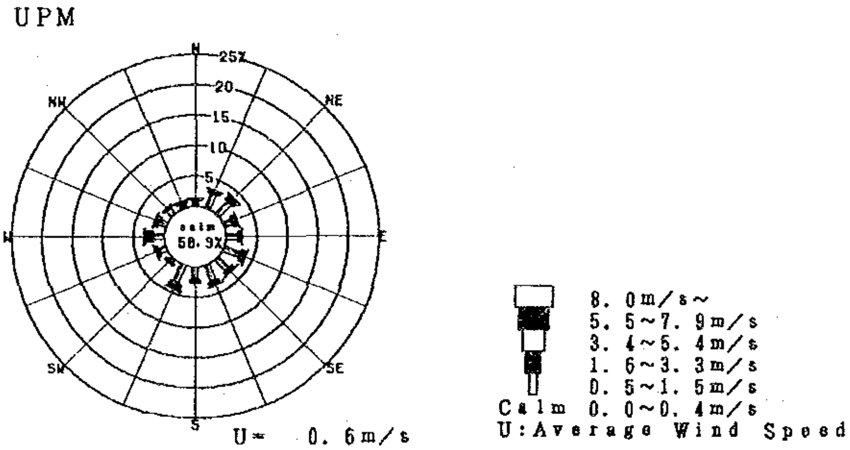


Fig. 4.3.5 (2) Wind Rose of Low SPM Days at UPM

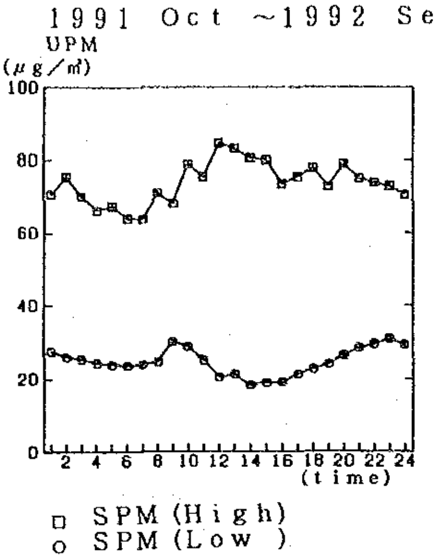


Fig. 4.3.6 Diurnal Change of SPM during High SPM Days and Low SPM Days at UPM

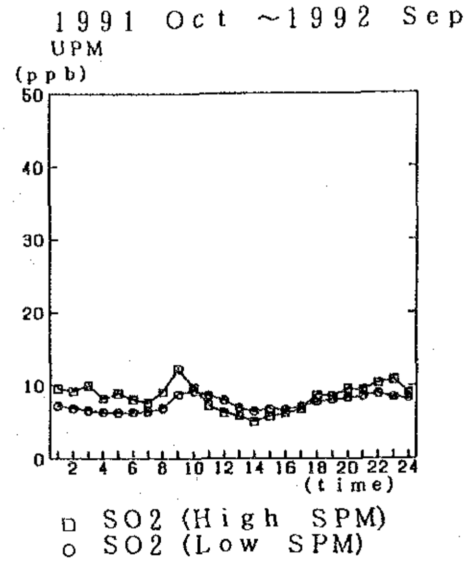


Fig. 4.3.7 Diurnal Change of SO_2 during High SPM Days and Low SPM Days at UPM

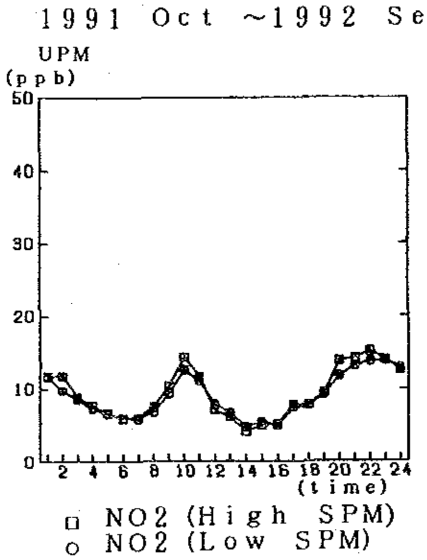


Fig. 4.3.8 Diurnal Change of NO_2 during High SPM Days and Low SPM Days at UPM

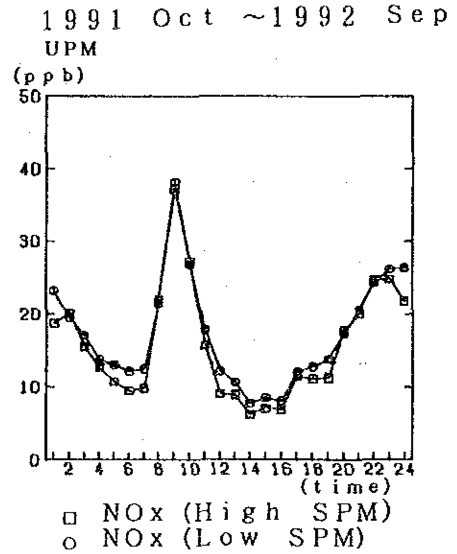


Fig. 4.3.9 Diurnal Change of NO_x during High SPM Days and Low SPM Days at UPM

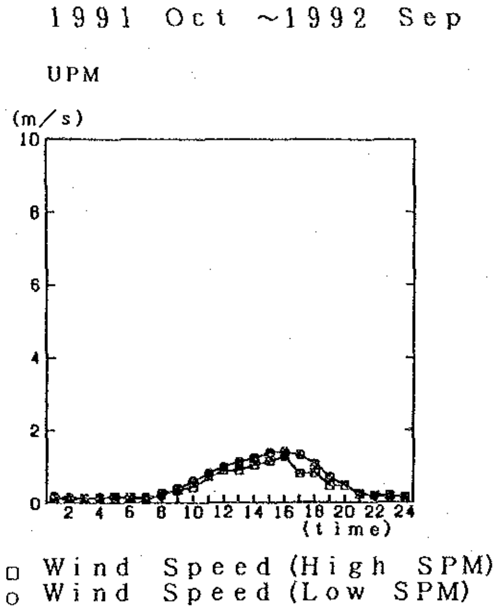


Fig. 4.3.10 Diurnal Change of Wind Speed during High SPM Days and Low SPM Days at UPM

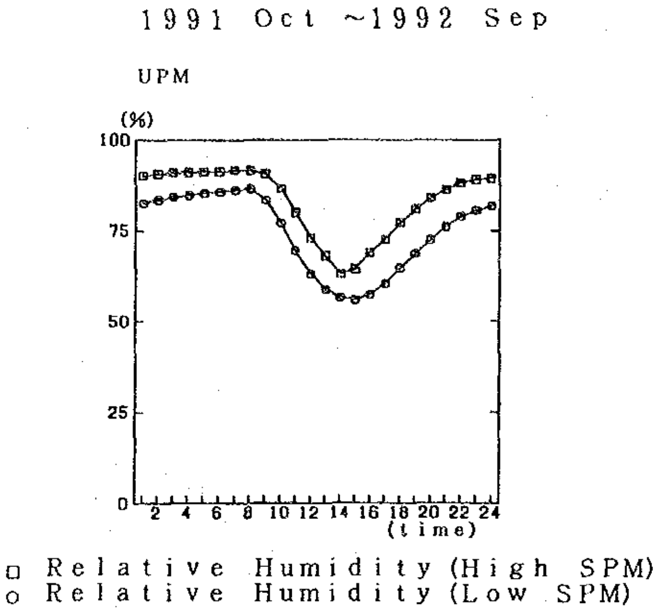


Fig. 4.3.11 Diurnal Change of Relative Humidity during High SPM Days and Low SPM Days at UPM

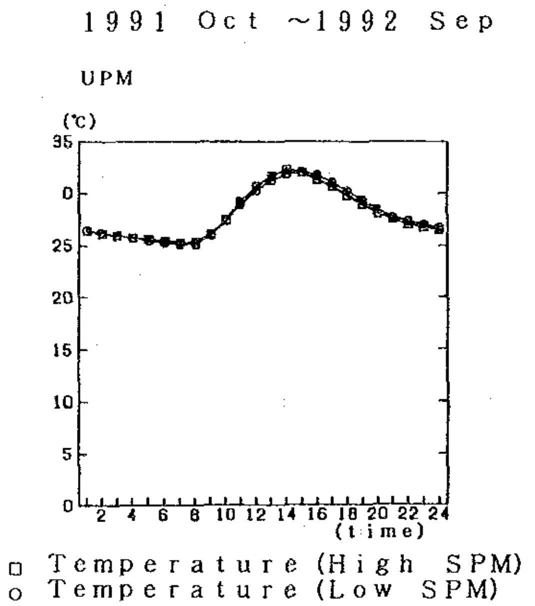


Fig. 4.3.12 Diurnal Change of Temperature during High SPM Days and Low SPM Days at UPM

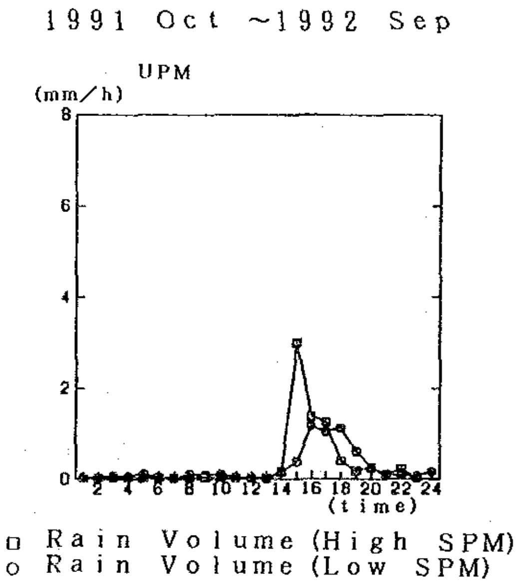


Fig. 4.3.13 Diurnal Change of Rainfall Amount during High SPM Days and Low SPM Days at UPM

4.4 Summary

The characteristics of ambient air quality in Kelang Valley Region as a result of this study is summarized as follows.

Based on the analysis of data from the fixed stations, the status of air pollution in the Kelang Valley Region in 1992 is relatively serious in comparison with the guidelines. Annual average and daily average of PM10 at Shah Alam exceeded the guideline and annual averages of PM10 at Klang and Petaling Jaya were around the guideline level. CO at City Hall and Petaling Jaya exceeded the guideline for 8 hours. O_3 at the all fixed stations exceeded the guideline. The guidelines for SO_2 and NO_2 were satisfied at all the fixed station, but hourly values of SO_2 and NO_2 at City Hall, Petaling Jaya, and Shah Alam exceeded 100 ppb.

Annual average of the each pollutant is the highest at City Hall, Petaling Jaya, or Shah Alam among the fixed stations. The areas around these stations are highly polluted.

Most of diurnal changes of CO and Nitrogen Oxides show the 'two peak pattern'. Diurnal changes of SPM and Hydrocarbons at some stations show the 'two peak pattern'. This 'two peak pattern' is mainly due to the influence of motor vehicles. Diurnal changes of SPM at Shah Alam and some other stations show the 'single minimum pattern'. Diurnal changes of O_3 at all stations show the 'single peak pattern' and this pattern is mainly influenced by the temporal pattern of incoming solar radiation.

The relationship between pollutant concentrations and meteorological parameters reveals the followings.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show a decrease of concentration with increase of wind speed, but O_3 shows the reverse relationships to wind speed.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show high values with strong stable condition, but O_3 concentrations decrease from unstable condition to stable condition.

SPM concentrations show decrease with increase of rainfall amount.

Analysis of SPM concentration shows that SPM concentration is related to low wind speed and high temperature to some extent. NO_2 concentrations are also higher during the high SPM days, but no significant change in NO_2 concentration happened during the haze period in October of 1991.

Analysis of high O_3 concentrations shows that the high O_3 concentration is related to strong solar radiation and high temperature to some extent. NMHC and NO_2 concentrations are also higher during the high O_3 days.

Simplified measurement over a wide area shows the spatial distribution of the pollutants in Kelang Valley Region. Areas of high NO_2 concentration mainly occur in Kuala Lumpur and sometimes in Klang and Gombak districts. Areas of high SO_3 concentration occur in Kuala Lumpur.

Simplified measurement across roads shows the CO profiles.

The results indicate that, air pollution in Kelang Valley Region is relatively serious in 1992 judged from the monitoring data. Moreover, the meteorological conditions such as weak wind, strong solar radiation, and high temperature in the Region have potential to worsen the ambient air quality. Furthermore, the diurnal changes of some pollutants show the influence by motor vehicle even in 1992. Efforts to improve and maintain ambient air quality should be strengthened.

CHAPTER 5 PRESENT STATE OF AIR POLLUTION SOURCES

CHAPTER 5 PRESENT STATE OF AIR POLLUTION SOURCES

Investigation of pollution sources is one of the most important tasks in air pollution control planning. Primary purpose of the source investigation in the Study was to estimate quantities of air pollutant emissions to prepare a "source model" as an essential part of the air quality simulation model described in Chapter 6.

The targeted sources and pollutants are shown in Table 5.1.1. Households include hotels, restaurants and so on. Pollutant emissions unlisted in the Table such as open burning activities, earthworks and nature, were not estimated in the Study. The estimated pollutant emissions are only those emitted from stacks of factories and establishments, ships and households, from tail pipes of motor vehicles and from engines of airplanes. Pollution sources used for air dispersion simulation are factories and establishments, motor vehicles, airplanes and ships. The simulated pollutants are SO_2, NOx and CO.

Table 5.1.1 Targeted Pollution Sources and Pollutants

Pollution Sources	Pollutants					Source Model
	SOx	NOx	PM (Dust)	CO	HC	
Factories and Establishments	O	O	O			O
Motor Vehicles	O	O	O	O	O	O
Airplanes	O	O	O			O
Ships	O	O	O			O
Households*		O	O			

* Households include hotels, restaurants and so on.

This chapter describes results of the investigation and presents the estimated amount of pollutant emissions from pollution sources in Kelang Valley Region.

The source model for CO, SO_2 and NOx is developed from not only the regional emission quantity but detailed information on each source such as specific location of the source, height and diameter of stacks, seasonal and time-zonal variation of emissions, etc. The investigation was made source by source for factories and establishments, road by road for motor vehicles in major roads, and on the unit area basis for minor roads, and also for airplanes and ships. However, because of various constraints on the investigation including the limited period, it was not possible to cover all the sources in the Region. So, the estimation of pollutant amounts in the Study will give a value for regional total quantity of pollutant emissions lower than the actual value. The contribution to simulated concentration by the sources which were not used for air quality simulation is generally expressed as the background concentration of the pollutant.

5.1 Factories and Establishments

As for stationary sources, current air pollution sources were studied on factories selected from a factory list compiled by DOE, depending on the industry type, facility type and size, fuel type, and so on.

Questionnaire survey was conducted on study items such as facility type, size, fuel consumption, condition of facility operation, pollution control etc. As the number of recovered questionnaires was less than 150, the data from DOE's factory inventory were used too. The questionnaire formats used are shown in Sections 3.1.1 and 3.1.2 in the Supporting Report.

5.1.1 Air Pollution Facilities and Fuel Consumption

(1) Number of Factories Surveyed

172 factories in total were surveyed in the Study. Outline of the factories is shown in Table 5.1.2.

This Table classifies factories by industry type; 55 % of surveyed factories belong to industries of food and kindred products, lumber and wood products, rubber products, and metal products.

Two thermal power stations and one cement factory are considered large-scale factories among those surveyed.

Table 5.1.2 Number of Factories Surveyed by Industry Type

Code	Industry	Number	(%)
101	Food and kindred products	24	14.0
102	Drink feed	1	0.6
103	Tobaccos	1	0.6
104	Textiles	3	1.7
105	Apparel and related products	2	1.2
107	Footgear products	1	0.6
108	Lumber and wood products	15	8.7
109	Furniture and fixtures	1	0.6
110	Pulp, paper and allied products	7	4.1
111	Publishing, printing and allied industries	2	1.2
112	Chemical and allied products	8	4.7
113	Palm oil mill	7	4.1
116	Rubber products	23	13.4
117	Plastic products	4	2.3
118	Ceramic, stone and clay products	2	1.2
119	Glass products	2	1.2
120	Non-ferrous metals and products	2	1.2
121	Iron and steel	6	3.5
122	Fabricated metal products	1	0.6
123	Metal products	15	8.7
124	General machinery and equipment	1	0.6
125	Electrical machinery, equipment and supplies	7	4.1
126	Transportation	1	0.6
128	Other manufacturing industries	24	14.0
129	Electricity supply	2	1.2
131	Hospital	1	0.6
135	Quarry	5	2.9
136	Other establishments	4	2.3
	Total	172	100.0

(2) Type of Pollution Facilities

Table 5.1.3 shows type of pollution facilities.

Total number of pollution facilities in 172 factories is 248. The number of boilers is the highest of these and accounts for 78 % of the total. Other notable facilities are metal heating furnaces, dryers, incinerators etc.

Table 5.1.3 Number of Facilities by Industry Type and Facility Type

Industry Code & Industry Type \ Facility Code		0101	0102	0103	0202	0502	0506	0601	0606	0607	0611	0613	0615	0821	0901	0915	1001	1004	1102	1104	1106	1204	1301	1303	1304	0002	0005	0006	0008	Total	(%)
101	Food and kindred products		16	15														3			2									36	14.5
102	Drink feed		1																											1	0.4
103	Tobaccos			1																										1	0.4
104	Textiles		2	1																										3	1.2
105	Apparel and related products		2																											2	0.8
107	Footgear products			1																										1	0.4
108	Lumber and wood products		11	10																				1						22	8.9
109	Furniture and fixtures		1																											1	0.4
110	Pulp, paper and allied products		4	5																										9	3.6
111	Publishing, printing and allied industries		3																											3	1.2
112	Chemical and allied products		7	1													1		1											10	4.0
113	Palm oil mill		12	2										2										2						18	7.3
116	Rubber products		10	16				1																1						28	11.3
117	Plastic products		2	2																										4	1.6
118	Ceramic, stone and clay products														1					3										4	1.6
119	Glass products			1												1												1		3	1.2
120	Non-ferrous metals and products												3																	3	1.2
121	Iron and steel		5	3								1										2							1	12	4.8
122	Fabricated metal products		1																											1	0.4
123	Metal products		9	6			1			3	1										2								1	23	9.3
124	General machinery and equipment		1																											1	0.4
125	Electrical machinery, equipment and supplies		3	7	1	1																								12	4.8
126	Transportation		1																											1	0.4
128	Other manufacturing industries		18	4																	1			1	1		1			26	10.5
129	Electricity supply	4																								6				10	4.0
131	Hospital			1																										1	0.4
135	Quarry		1							1																			5	7	2.8
136	Other establishments		2	1					1														1							5	2.0
	TOTAL	4	112	77	1	1	1	1	1	4	1	1	3	2	1	1	1	3	1	3	5	2	1	5	1	6	1	1	7	248	100.0
	(%)	1.6	45.2	31.0	0.4	0.4	0.4	0.4	0.4	1.6	0.4	0.4	1.2	0.8	0.4	0.4	0.4	1.2	0.4	1.2	2.0	2.0	0.4	2.0	0.4	2.4	0.4	0.4	2.8	100.0	

Classification of Facility

Code	Facility	Process	Code	Facility	Process
0101	Boiler	for electric power	1001	Reacting furnace	for inorganic chemical products
0102		for heating	1004	Direct heating furnace	for food stuff
0103		exclusive of 0101 and 0102	1102	Drying over kiln (drier)	for raw materials of cement
0202	Gas furnace		1104		for mold
0502	Melting furnace	for refining of alminium	1106		exclusive of 1102, 1104 and those for aggregates, detergent, and raw materials for brick
0506	Metal melting furnace	for casting exclusive of alminium, iron and steel			
0601	Heating furnace (reheating furnace) for rolling of metal	for iron and steel, continuous type	1204	Electric furnace	for steel, arc furnace
0606		batch type exclusive of those for alminium, iron and steel	1301	Incinerator	for domestic waste, continuous type
0607	Metal heat treating furnace	for iron and steel, continuous type	1303		for industrial waste, continuous type
0611		for iron and steel, batch type	1304		for industrial waste, batch type
0613	Metal forge furnace	for iron and steel, continuous type	0002	Gas turbine	
0615		for alminium, continuous type	0005	Baby cupola	exclusive of those for refining cast steel and platinum
0821	Combustion furnace		0006	Glass annealing furnace	
0901	Cement kiln	dry and suspension preheater type	0008	Other furnace	exclusive of the above furnaces
0915	Glass melting furnace	tank furnace			

(3) Stack Height

For stack heights shown in Table 5.1.4, most of the stacks are as low as or less than 50 m with the exception of thermal power stations with 7 stacks higher than 100 m.

The stack height is decided according to the British standard (#4020) which regulates stack height by sulphur content in fuels.

Table 5.1.4 Stacks Classified by Height

Height (m)	Number	(%)
<10	9	3.7
10≤ <20	41	16.8
20≤ <30	105	43.0
30≤ <40	64	26.2
40≤ <50	16	6.6
50≤ <60	1	0.4
60≤ <70	0	0.0
70≤ <80	1	0.4
80≤ <90	0	0.0
90≤ <100	0	0.0
100≤	7	2.9
Total	244	100.0

* Inclusive of 10 stacks of power stations

(4) Fuel Type and Consumption

Main fuels used in Kelang Valley Region are heavy fuel oil, light fuel oil as liquid fuel, and wood waste, palm waste and coal as solid fuel. Coal is used at thermal power stations and a cement factory.

Tables 5.1.5 (1) and 5.1.5 (2) show the coverage rate of fuel consumption in the Study. From the standpoint of the fuel consumption, the factories targeted in the Study are considered to cover most of the main factories in KVR.

Fuel consumption by industry type and fuel type is shown in Table 5.1.6.

Fuel consumption by facility type and fuel type is shown in Tables 5.1.7 (1) and (2). Fuel used for boilers is mainly heavy fuel oil, while most of the factories with other facilities use light fuel oil. Industry type of factories using fuel oil is considered mainly metal product industry using metal heating furnace.

Table 5.1.5 (1) Coverage Rate of Fuel Consumption by General Factories

Fuel Type	Consumption surveyed	Consumption in Kelang Valley Region	Coverage(%)
HFO	9,068.5 kl/y		
MFO	50,906.7 kl/y		
LFO	287,837.7 kl/y		
IFO	88,929.1 kl/y		
Other Liquid Fuel	18,908.0 kl/y		
Total of Liquid Fuel	455,650.0 kl/y	453,000.0 kl/y *	100.6
LPG	85,236.0 kl/y	85,000.0 kl/y *	100.3
Palm Waste	187,200.0 t/y	187,200.0 t/y **	100.0
Coal	88,460.0 t/y	90,760.0 t/y **	97.5
Wood	307,197.9 t/y	328,448.0 t/y **	93.5
Electricity	291,375.0 1000kw/y	291,375.0 1000kw/y	100.0

* PETRONAS (1990)
** DOE (1992)

Table 5.1.5 (2) Coverage Rate of Fuel Consumption by Power Stations

Fuel Type	Consumption surveyed	Consumption in Kelang Valley Region	Coverage(%)
MFO	258,750.0 kl/y	261,473.6 kl/y *	99.0
NG	1,861,109.0 1000M3N/y	1,861,109.0 1000M3N/y *	100.0
Coal	806,400.0 t/y	806,400.0 t/y *	100.0

* TENAGA Nasional Bhd (1992)

Table 5.1.6 Number of Facilities Surveyed and Annual Fuel Consumption by Industry Type (1992)

Industry Code & Industry Type		Number of Facilities	Liquid Fuel (kl/y)	Solid Fuel (ton/y)	N.Gas (1000M3N)	LPG (kl/y)	Electricity (1000kw/y)
101	Food and kindred products	36	69,041.2			835.6	
102	Drink feed	1	3,713.7				
103	Tobaccos	1				568.9	
104	Textiles	3	1,791.7				
105	Apparel and related products	2	1,002.7	5,616.0			
107	Footgear products	1	1,570.4				
108	Lumber and wood products	22		301,581.9			
109	Furniture and fixtures	1	173.1				
110	Pulp, paper and allied products	9	16,936.6				
111	Publishing, printing and allied industries	3	7,379.6				
112	Chemical and allied products	10	10,838.0			133.3	
113	Palm oil mill	18	33,772.6	187,200.0			
116	Rubber products	28	21,095.9	208.8			
117	Plastic products	4	4,300.1				
118	Ceramic, stone and clay products	4		88,460.0		46,113.0	
119	Glass products	3	20,460.0				
120	Non-ferrous metals and products	3	2,552.5				
121	Iron and steel	12	10,431.9			3,386.7	291,375.0
122	Fabricated metal products	1	1,249.9				
123	Metal products	23	12,961.4			2,206.7	
124	General machinery and equipment	1				161.3	
125	Electrical machinery, equipment and supplies	12	2,086.7			31,360.0	
126	Transportation	1	126.0				
128	Other manufacturing industries	26	16,231.6			471.1	
129	Electricity supply	10	258,750.0	806,400.0	1,861,109.0		
131	Hospital	1	2,205.7				
135	Quarry	7	67,676.9				
136	Other establishments	5	148,053.4	648.0			
	TOTAL	248	714,401.7	1,390,114.7	1,861,109.0	85,236.5	291,375.0

Table 5.1.7 (1) Annual Fuel Consumption by Facility Type (general factories) in 1992

Fuel / Facility Code & Facility	Number of Facilities	HFO (kl/y)	MFO (kl/y)	LFO (kl/y)	IFO (kl/y)	LPG (kl/y)	Other Liquid Fuel (t/y)	Coal (t/y)	Palm Waste (t/y)	Other Wood (t/y)	General Waste(t/y)	Industrial Waste(t/y)	Electricity (1000kw/y)
0102 Boiler	112	1,200.5	14,904.1	45,318.7	49,436.5	11,034.7			99,360.0	158,776.6			
0103 〃	77	7,868.0	32,342.9	13,096.5	23,238.0	16,995.5	18,908.0			147,950.4			
0202 Gas furnace	1					4,593.3							
0502 Melting furnace	1					2,240.0							
0506 Metal melting furnace	1			118.6									
0601 Heating furnace (reheating furnace) for rolling of metal	1			566.3									
0606 〃	1			145,294.1									
0607 Metal heat treating furnace	4			14,157.2									
0611 〃	1			598.6									
0613 Metal forge furnace	1			1,016.5									
0615 〃	3			2,552.5									
0821 Combustion furnace	2		2,871.5										
0901 Cement kiln (dry and suspension preheater type)	1							88,460.0					
0915 Glass melting furnace	1				14,218.1								
1001 Reacting furnace	1		788.2										
1004 Direct heating furnace	3			2,470.6									
1102 Drying over Kiln (drier)	1			2,541.2									
1104 〃	3					46,113.0							
1106 〃	5			355.8	1,909.9	933.3							
1204 Electric furnace	2												291,375.0
1301 Incinerator	1										648.0		
1303 〃	5			214.5					87,840.0	470.9		208.8	
1304 〃	1			616.8									
0005 Baby cupola	1			405.7									
0006 Glass annealing furnace	1			5,632.9									
0008 Other furnace	7			52,882.6	127.3	3,386.7							
TOTAL	238	9,068.5	50,906.8	287,838.9	88,929.7	85,236.5	18,908.0	88,460.0	187,200.0	307,197.9	648.0	208.8	291,375.0

Table 5.1.7 (2) Annual Fuel Consumption by Facility Type (2 power stations) in 1992

Fuel / Facility Code & Facility	Number of Facilities	MFO (kl/y)	Coal (t/y)	Natural Gas (1000M3N/y)
0101 Boiler	4	258,750.0	806,400.0	275,111.9
0002 Gas turbine	6			1,585,998.0
TOTAL	10	258,750.0	806,400.0	1,861,109.9

5.1.2 Flue Gas Measurement

(1) Measuring Method

A total number of 36 flue gas measurements were conducted on SOx, NOx, Dust, and O_2.

The measurement item and method are as following.

SOx: JIS K 0103 (Methods for determination of Sulphur in Flue Gas)
JIS B 7981 (Continuous Analyzers for Sulphur Dioxide in Flue Gas)

NOx: JIS K 0104 (Methods for Determination of Oxides of Nitrogen in Flue Gas)
JIS B 7982 (Continuous Analyzer for Oxides of Nitrogen in Flue Gas)

Dust: JIS Z 8808 (Methods of Measuring Dust Concentration in Flue Gas)

O_2: JIS B 7983 (Continuous Analyzers for Oxygen in Flue Gas)

(2) Measurement Result

Measurement result is shown in Table 5.1.8. As seen in this Table, O_2 concentration is high regardless of fuel type or facility type. It suggests combustion control is not satisfactory enough.

Summary of SOx, NOx, Dust and O_2 concentration is shown in Table 5.1.9. Figures in the Table are those actually measured. They would be higher if converted following to the Malaysian standard, CO_2 12%.

Table 5.1.8 Result of Factory Flue Gas Measurement

Industry	Facility	Dust Collector	Flue Gas Quantity	Concentration				Fuel and Sulfur Content (%)	Fuel Consumption
				Dust	SO_2	NOx	O_2		
			m^3_N/Hr. (Dry)	g/m^3_N	ppm	ppm	%		
Saw Mill	Steam Boiler	—	11,600	0.24	0	79	12.8	Wood Chip —	
Foundry	Electric Furnace	Bag Filter	4,100	< 0.011	0	0	21.0	Electricity —	
Foundry	Lead melting Furnace	Bag Filter and Water Scrubber	17,800	< 0.008	550	16	20.4	Diesel Oil —	110 ~ 135 ℓ/h
Fatty acid	Steam Boiler	—	23,800	0.38	31	84	16.1	Palm Waste —	8.1ton/h
Electricity supply	Steam Boiler (No.1)	—	820,000	0.53	1,700	315	3.5	Heavy Oil 2.9%	63ton/h
Fire Bricks	Heating Boiler	Cyclone	14,900	0.12	0	8	19.3	Medium Oil 1.0%	400 ℓ/h
Palm Oil	Steam Boiler		12,500	0.50	0	115	13.4	Palm Fiber —	
Palm Oil	Steam Boiler		41,000	2.3	57	185	12.8	Palm Fiber —	
Plywood	Boiler		20,700	0.40	56	42	17.2	Saw Dust —	
Plywood	Steam Boiler		31,600	0.28	0	88	14.3	Saw Dust —	
Saw Mill	Boiler		3,600	0.062	0	41	18.9	Saw Dust —	
Cotton Towel	Boiler		—	—	0	27	19.0	Solid Fuel —	
Palm Oil	Boiler		25,100	0.29	0	53	18.7	Palm Fiber —	
Saw Mill	Boiler	—	6,000	0.39	0	33	18.4	Saw Dust —	2,722kg/h
Wood Base	Boiler		15,400	0.37	0	45	18.0	Saw Dust —	
Wood Base	Boiler	—	3,400	0.28	0	35	18.2	Saw Dust —	540kg/h
Foundry	Furnace		22,600	0.008	0	3	20.9	Diesel Oil —	
Wood Base	Boiler	Multi Cyclone	3,200	0.065	31	11	18.7	Saw Dust —	1,340kg/h
Wood Base	Boiler		14,000	0.11	0	34	18.4	Saw Dust —	
Chemical	Mixer		5,200	< 0.016	53	0	21.2	— —	
Kiln Dry	Boiler		6,600	0.38	0	54	18.2	Saw Dust —	
Wood Base	Boiler		14,100	0.35	0	0	— (17.0)	Saw Dust —	
Wood Base	Boiler		14,200	0.42	0	0	— (17.0)	Saw Dust —	
Wood Base	Boiler	Multi-cone Dust Collector	7,800	0.001	0	76	— (16.4)	Saw Dust —	8.5~10.5 ton/day
Kiln Dry	Boiler		9,600	0.24	0	84	— (12.4)	Saw Dust —	
Wood Base	Boiler		7,400	0.28	0	28	— (13.0)	Saw Dust —	
Timber	Boiler	Cyclone	7,500	0.29	0	29	19.5	Wood Chip Saw Dust < 0.1	6 ton/day
KIENING	Boiler	Cyclone	40,000	0.69	14	125	15.3	Wood Chip Saw Dust —	4 ton/h
Rubber	Dryer	Water Scrubber	34,800	—	0	5	20.8	Diesel Oil < 3.5	3188 ℓ/day
Foundry	Electric Furnace	Bag Filter	238,000	0.043	0	11	20.0	Electricity —	—
Cement	Limestone Grinding Mill	Electric Precipitator	220,000	0.11	0	320	9.0	H.F.O & Coal (<3.0) (<0.5)	H.F.O 30 ton/day Coal 300 ton/day
Rockwool Manufacture	Melting Furnace	Bag Filter	13,600	—	158	68	13.7	Coke	400 kg/h
Rubber	Dryer	Water Scrubber	6,600	0.008	0	40	18.5	Diesel Oil	100 ℓ/h
Electricity Supply	Steam Boiler (No.3)		707,000	0.028	432	415	8.0	Coal	
Premix & Quarry	Premix		30,300	0.10	81	12	15.1		
Electricity Supply	Steam Boiler (No.2)	—	593,000	—	—	173	9.0	N.Gas	

Table 5.1.9 Summarized Concentration of Dust, SO_2, NOx, and O_2

Measuring Item	Concentration of emitted pollutant		
		Boiler	Furnace
Dust (g/m^3N)	< 0.53	0.24 ~ 0.53	< 0.011
SO_2 (ppm)	0 ~ 1,790	0 ~ 1,790	0 ~ 550
NOx (ppm)	0 ~ 315	79 ~ 315	0 ~ 15
O_2 (%)	3.5 ~ 20.4	3.5 ~ 16.1	20.4 ~ 21.0

5.1.3 Fuel Analysis

Fuel samples from factories were collected at the on-site survey while those from vehicles were collected at petrol stations in KL. These 53 samples, 44 of which are from factories and 9 of which are for vehicles were analyzed as in Table 5.1.10.

Types of factory fuels are classified into four; HFO, MFO, LFO, and IFO, and types of vehicle fuels into three; Diesel, Unleaded and Leaded petrols.

Sulphur contents of HFO, MFO, and IFO exceeded 2% while those of LFO varied depending on samples. Sulphur in Palm and Wood exceeded 0.2% in most samples. It suggests notable amount of SOx is emitted from boilers using palm waste. On the other hand, sulphur contents of petrol are relatively low.

Table 5.1.10 Result of Fuel Analysis

	Fuel	S (%)	C (%)	H (%)	N (%)	W (%)	A (%)	H.V (kcal/kg)	D (g/ml)	Pb (g/l)
1	HFO *	2.67	84.78	10.79	0.98					
2	″	2.63							0.97	
3	″	2.22	78.47	10.62	0.23			10350	0.95	
4	MFO **	2.22	82.41	10.85	0.27			10276	0.97	
5	″	2.26						10190	0.97	
6	″	2.35						10337	0.95	
7	″	2.06								
8	″	2.53								
9	″	2.30	84.63	11.31	1.02			10290	0.95	
10	″	2.57								
11	″	2.62								
12	″	2.52								
13	″	2.37								
14	″	2.58								
15	″	2.65								
16	″	2.45								
17	″	2.41								
18	LFO ***	0.00								
19	″	0.44								
20	″	0.27								
21	″	0.49								
22	″	0.42								
23	″	0.15								
24	″	0.20								
25	″	0.33	85.66	12.03						
26	″	0.20	85.39	11.23						
27	″	0.41	85.48	11.19						
28	IFO ****	2.23	78.63	11.90	0.50			10306	0.95	
29	″	2.37								
30	″	2.72	79.71	11.18	1.27			10891	0.94	
31	″	2.33								
32	″	2.25						10248	0.96	
33	″	2.21								
34	″	2.36						10338	0.93	
35	Coal	0.60	58.92	5.45	1.41	4.38	9.86	6902		
36	″	1.02	62.21	4.70	1.21	10.55	9.6	6019		
37	Palm *****	0.22	42.02	5.54	0.86	28.14	7.37	4442		
38	″	0.15				6.38	5.08			
39	″	0.06	47.60	6.09	1.12					
40	Wood	0.20	47.16	5.28	0.18	9.02	0.07			
41	″	0.60						4258		
42	″	0.34						4269		
43	″	0.23						4204		
44	″	0.01	49.82	6.40	0.15					
45	Diesel	0.26							0.85	
46	″	0.57							0.86	
47	″	Nil						10290	0.84	
48	″	0.25						10877	0.84	
49	″	0.21								
50	Unleaded	0.00							0.79	0.003
51	″	0.01							0.77	
52	Leaded	0.07							0.78	0.15
53	″	0.00							0.76	0.14

* HFO: Heavy Fuel Oil
** MFO: Middle Fuel Oil
*** LFO: Light Fuel Oil
**** IFO: Industrial Fuel Oil
***** Palm: Palm Waste

5.1.4 Emission Factor

Emission factors were selected from the results of flue gas measurements and the existing data in U.S.A. and Japan (Table 5.1.11). Method for determining emission factors from the flue gas measurements is shown in Section 3.1.3 in the Supporting Report.

The emission factor is expressed as kg/kl for liquid fuel and kg/ton for solid fuel in this report.

Table 5.1.11 Emission Factor by Facility Type and Fuel Type

Facility		Fuel Type	NOx	Ref	DUST	Ref
0101	Boiler	(12)MFO	7.34kg/kl		6.01kg/kl	
		(20)Coal	8.86kg/t	J	0.29kg/t	
		(28)NG	5.84kg/10^3m^3	J	0.2kg/10^3m^3	
0102		(11)HFO	1.74kg/kl		12.74kg/kl	
		(12)MFO	1.74kg/kl		12.74kg/kl	
		(13)LFO	1.74kg/kl		12.74kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
		(22A)Palm Waste	3.93kg/t		14.88kg/t	
		(22C)Wood	2.19kg/t		6.95kg/t	
		(29)LPG	2.10kg/kl	J	0.20kg/kl	E
0103		(11)HFO	1.74kg/kl		12.74kg/kl	
		(12)MFO	1.74kg/kl		12.74kg/kl	
		(13)LFO	1.74kg/kl		12.74kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
		(19)Other L.F.	1.74kg/kl		12.74kg/kl	
		(22C)Wood	2.19kg/t		6.95kg/t	
		(29)LPG	2.10kg/kl	J	0.20kg/kl	E
0202	Gas furnace	(29)LPG	1.35kg/kl	E	0.20kg/kl	E
0502	Melting furnace	(29)LPG	1.35kg/kl	E	0.20kg/kl	E
0506	Metal melting furnace	(13)LFO	2.99kg/kl	J	0.59kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0601	Heating furnace	(13)LFO	3.45kg/kl	J	1.26kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0606		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0607	Metal heating furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0611		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0613	Metal forge furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0615		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0821	Combustion furnace	(12)MFO	2.02kg/kl	J	1.53kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0901	Cement kiln	(20)Coal	7.90kg/t		0.54kg/t	
0915	Glass melting furnace	(12)MFO	1.93kg/kl	J	0.18kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
1001	Reacting furnace	(12)MFO	2.80kg/kl	J	0.59kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1004	Direct heating furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1102	Drying over kiln (drier)	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1104		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
1106	Dryer	(12)MFO	5.46kg/kl	J	0.30kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	5.46kg/kl		0.30kg/kl	
		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
1204	Electric furnace	(37)Electricity			0.03kg/10^3kw	
1301	Incinerator	(38)G.Waste	0.95kg/t	J	5.46kg/t	J
1303		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(22A)Palm Waste	3.23kg/t		10.68kg/t	
		(22C)Wood	1.54kg/t	J	2.27kg/t	J
		(39)I.Waste	2.59kg/t	J	3.08kg/t	J
1304		(12)MFO	0.38kg/kl		2.08kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(39)I.Waste	2.59kg/kl	J	3.08kg/kl	J
0002	Gas turbine	(28)N.Gas	1.35kg/10^3m^3N	J	0.08kg/10^3m^3N	E
0005	Baby cupola	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(21)Coke	0.06kg/t	J	8.32kg/t	J
0006	Glass annealing furnace	(12)MFO	4.33kg/kl	J	0.38kg/kl	J
		(13)LFO	4.33kg/kl	J	0.38kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0008	Quarry	(16B)IFO	5.46kg/kl		0.30kg/kl	
		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
		Primary Crushing	-		0.25kg/T	E
		Secondary 〃 & Screening	-		0.75kg/t	E
		Screening, Conveying, Handing	-		1.00kg/t	E

Note 1; Reference; E:EPA, J:Japan Environment Agency,
blank:factors obtained from measurement results

Note 2; Emission factors for boilers, incinerators were calculated from the flue gas measurement results.

5.1.5 Air Pollution Load

Air pollutant emissions from factories were estimated with the emission factors shown in Table 5.1.10. As the result, pollutant emission in 1992 is 9,000 tons/yr for dust, 30,600 tons/yr for SOx, and 15,800 tons/yr for NOx, as broken down by industry type in Table 5.1.12.

Food and related product industry, palm oil mills, and power stations emit pollutants highly. Especially emissions from thermal power stations account for 22% of the Dust emission, 64% of the SOx emission, and 81% of the NOx emission. Emissions from factories other than power stations accounts for 78% of the Dust emission and 36% of SOx emission. Emissions from nitric acid plants or scrap melting furnaces are not efficiently controlled. Yellow or black smoke is being observed from their premises. Also a large amount of Dust is being emitted from some furnaces for palm waste burning because of the low-temperature combustion.

Pollutant emissions by the facility type are shown in Table 5.1.13. Boilers produce prominently high amounts of pollutants because heavy fuel oil and solid fuel are used. Very small number of precipitators are equipped as a means of dust control. Besides, their efficiency is not high.

Emissions by district are given in Table 5.1.14. As thermal power stations are located in Klang district, Klang has as high as 54% of Dust emission, 74% of SOx emission, and 86% of NOx emission in the KVR. Emission in districts other than Klang are all from general factories. Emissions from general factories are high in Petaling, and Klang. These districts emit 65% of Dust emission (7,033 tons/yr), 78% of SOx emission (11,047 tons/yr) and 53% of NOx emission (2,979 tons/yr), respectively of each pollutant tons from all surveyed general factories.

Table 5.1.12 Air Pollutant Emission by Industry Type (1992)

Industry Code	Industry Type	Pollutant Amount (ton/y)		
		SOx	NOx	Dust
101	Food and kindred products	2,357.04	127.59	642.22
102	Drink feed	167.23	6.46	47.31
103	Tobaccos	0.00	1.19	0.11
104	Textiles	67.14	3.09	18.62
105	Apparel and related products	62.56	14.04	51.81
107	Footgear products	8.81	2.73	20.01
108	Lumber and wood products	934.90	660.16	2,093.79
109	Furniture and fixtures	0.97	0.30	2.21
110	Pulp, paper and allied products	755.36	29.40	204.57
111	Publishing, printing and allied industries	41.40	12.25	3.62
112	Chemical and allied products	391.64	19.75	95.04
113	Palm oil mill	1,909.37	733.77	2,814.68
116	Rubber products	855.92	38.08	241.94
117	Plastic products	24.12	7.40	42.61
118	Ceramic, stone and clay products	0.00	761.09	56.99
119	Glass products	927.09	50.19	191.04
120	Non-ferrous metals and products	14.32	4.24	1.25
121	Iron and steel	243.70	22.27	72.90
122	Fabricated metal products	56.28	2.17	15.92
123	Metal products	365.07	26.66	94.27
124	General machinery and equipment	0.00	0.34	0.03
125	Electrical machinery, equipment and supplies	93.97	64.41	32.86
126	Transportation	5.67	0.22	1.61
128	Other manufacturing industries	443.30	28.57	120.43
129	Electricity supply	19,522.07	12,791.67	1,968.62
131	Hospital	12.37	3.84	28.10
135	Quarry	428.60	112.44	48.37
136	Other establishments	880.25	246.48	91.52
	TOTAL	30,569.15	15,770.80	9,002.45

Table 5.1.13 (1) Air Pollutant Emission by Facility Type (1992) (general factories)

Equipment Code & Equipment	Pollutant Amount (ton/y)		
	SOx	NOx	Dust
0102 Boiler	4,015.54	951.15	3,519.81
0103 〃	4,355.36	525.50	2,203.83
0202 Gas furnace	0.00	6.12	0.91
0502 Melting furnace	0.00	3.02	0.45
0506 Metal melting furnace	0.67	0.35	0.07
0601 Heating furnace (reheating furnace) for rolling of metal	3.18	1.95	0.71
0606 〃	815.10	241.19	71.19
0607 Metal heat treating furnace	79.42	23.50	6.94
0611 〃	3.36	0.99	0.29
0613 Metal forge furnace	5.70	1.69	0.50
0615 〃	14.32	4.24	1.25
0821 Combustion furnace	133.42	5.80	4.39
0901 Cement kiln (dry and suspension preheater type)	0.00	698.83	47.77
0915 Glass melting furnace	867.19	24.74	181.14
1001 Reacting furnace	36.62	2.21	0.47
1004 Direct heating furnace	13.86	4.10	1.21
1102 Drying over Kiln (drier)	14.26	4.22	1.25
1104 〃	0.00	62.25	9.22
1106 〃	88.00	12.28	0.93
1204 Electric furnace	0.00	0.00	8.74
1301 Incinerator	0.00	0.62	3.54
1303 〃	261.35	285.34	939.95
1304 〃	3.46	1.02	0.30
0005 Baby cupola	2.28	0.57	0.17
0006 Glass annealing furnace	31.60	24.39	2.14
0008 Other furnace	302.40	93.05	26.63
TOTAL	11,047.09	2,979.12	7,033.80

Table 5.1.13 (2) Air Pollutant Emission by Facility Type (1992) (2 power stations)

Equipment Code & Equipment	Pollutant Amount (ton/y)		
	SOx	NOx	Dust
0101 Boiler	19,522.07	10,650.57	1,843.97
0002 Gas turbine	0.00	2,141.10	124.66
TOTAL	19,522.07	12,791.67	1,968.63

Table 5.1.14 Pollutant Emission by District (Factories) (1992)

		SOx	NOx	Dust
1. Hulu Langat		1,184	575	1,924
2. Gombak		556	720	198
3. Kuala Lumpur		641	102	346
4. Petaling		5,558	765	1,698
5. Klang	Factory	3,108	818	2,867
	Power St.	19,522	12,791	1,969
Total		30,569	15,771	9,002

Unit : ton/y

5.2 Motor Vehicles

5.2.1 Result of Traffic Volume Survey

Traffic volume survey was conducted at 50 points on major roads (40) and minor roads (10) in Kelang Valley Region. Survey points were selected after examination of road network of the study area. Table 5.2.1 shows names of survey points and Fig. 5.2.1 shows their location. Motor vehicles were classified into 9 types as shown in Table 5.2.2.

Table 5.2.2 Classification of Motor Vehicles

No.	Vehicle Type
1	Motorcycle
2	Motor Car
3	Van
4	Taxi
5	Mini Bus
6	Medium/Large Bus
7	Small Truck
8	Medium/Large Truck
9	Lorry/Trailer

The following characteristics were observed on the traffic in the study area from the result of the survey. The results of the traffic volume survey are shown in Section 3.2.1 in the Supporting Report.

(1) Traffic Volume

Twenty-four (24) hour survey was conducted at ten (10) points out of those on major roads. The remaining forty (40) points were surveyed for sixteen (16) hours.

Figs. 5.2.2 (1) and (2) show the distribution of weekday traffic volume in the study area.

Concerning the daily traffic volume (24 hours), the heaviest traffic was observed at the survey point No.31 (Federal Route 2) with approximately 386,000 vehicles/day and this was followed by No.10 (Jln. Sultan Hishamuddin) with approximately 166,000 vehicles/day.

The traffic volume of Middle Ring Road (Nos.26, 23, 22 and 11) and roads (Nos.16, 20 and 10) which run north and south inside the Ring Road is around 100,000 vehicles. Furthermore, it was observed that as many as 50,000 vehicles run on the other roads inside the Ring Road.

Traffic is heavy on the trunk roads (Nos.3, 28, 24 and 5) which spread radially from the center of the Kuala Lumpur city to the north, east and west, as well as on the Ring Road which connects above mentioned radial roads. Remarkable in the traffic flow between Kuala Lumpur city and the provinces was that the traffic on the Federal Route 2 (No.31) between Petaling Jaya and KL was by far the heaviest with around 350,000 vehicles. It suggests a strong relation between both areas.

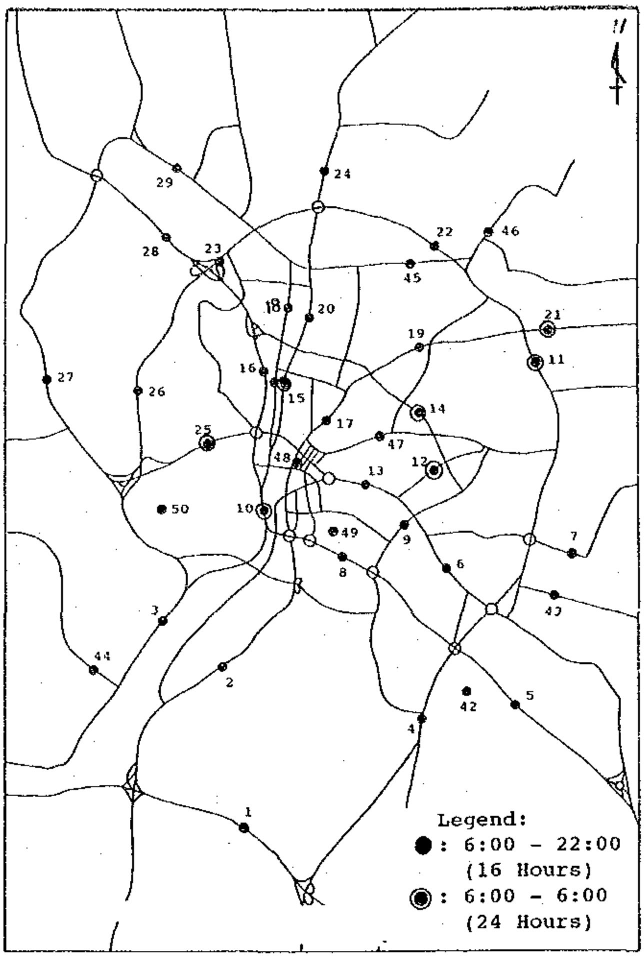
The difference of traffic volume between Sunday and weekday is shown by the ratio of weekday traffic volume to Sunday traffic volume in Table 5.2.3. It presents that Sunday traffic volume is about 20 percent less than weekday's one.

Ten daily traffic survey on ten points are insufficient to analyze. However, 50 survey points' data of 16 hour (6:00 - 22:00) traffic volume which covers major daily activity of vehicles can be used to investigate a distribution of daily traffic volume in the study area.

Table 5.2.1 Station of Traffic Volume Survey

No.	Survey Station	Type	Hour
1	Federal Route 2 (west of Jln Pantai Dalam)	M	16
2	Jln Syed Putra (Wisma Belia)	M	16
3	Jln Bangsar (KTM Quarters)	M	16
4	KL-Seremban Exp. (Lpg. Ter. Lama)	M	16
5	Jln Loke Yew (Taman Maharja)	M	16
6	Jln Pudu (Tan Chong)	M	16
7	Jln Kampong Pandang (east of roundabout)	M	16
8	Jln Maharajalela (Stadium)	M	16
9	Jln Hang Tuah (Pudu Prison)	M	16
10	Jln Sultan Hishamuddin (Masjid Negara)	M	24
11	Jln Tun Razak (north of Jln U Thant)	M	24
12	Jln Bukit Bintang (BB PLAza)	M	24
13	Jln Pudu (Magnum Finance)	M	16
14	Jln Sultan Ismail (Wisma SPK)	M	24
15	Jln T.A.Rahman (north of Jln Selat)	M	24
16	Jln Kucing (Arch)	M	16
17	Jln Ampang (AIA)	M	16
18	Jln Templer (east of Jln Selangor)	S	16
19	Jln Ampang (Wisma Angkasa)	M	16
20	Jln T.A.Rahman (Hankyu Jaya)	M	16
21	Jln Ampang (French Embassy)	M	24
22	Jln Tun Razak (Bernama)	M	16
23	Jln Tun Razak (PWTC)	M	16
24	Jln Pahang (Tawakal)	M	16
25	Jln Parlimen (Padang Merbuk)	M	24
26	Jln Sultan Salahuddin	M	16
27	Jln Duta (Semantan-NKVE)	M	16
28	Jln Kucing (south of Jln Duta)	M	16
29	Jln Ipoh (HKSB)	M	16
30	PJ Highway	M	16
31	Federal Route 2 (Kota Darul Ehsan)	M	24
32	Federal Route 1 (north of Jln Kepong)	M	16
33	Jln Semantan (Jln D Bakar-Jln S17)	M	16
34	KL-Seremban Exp. (FR2-Jln Kucai Lama)	M	24
35	Federal Route 2	M	16
36	Federal Route 1 (KL-Sel border)	M	16
37	State Road (KL-Sel border)	M	16
38	Federal Route 2 (east of NKS Bypass)	M	24
39	Federal Route 5 (south of Jln Kim Chuan)	M	16
40	Jln Pelabuhan Utara (south of bridge)	M	16
41	Federal Route 2 (Carlsberg)	M	16
42	Jln Chan Sow Lin	S	16
43	Jln Cochrane	S	16
44	Jln Maarof (just north of Jln Bangsar int.)	S	16
45	Jln Raja Muda	S	16
46	Jln Semarak (Wisma Keramat)	S	16
47	Jln Raja Chulan (Plaza See Hoy Chan)	S	16
48	Jln Hang Kasturi	S	16
49	Jln Stadium	S	16
50	Jln Kebun Bunga	S	16

Note 1. Survey Type M : Major Road, S : Minor Road



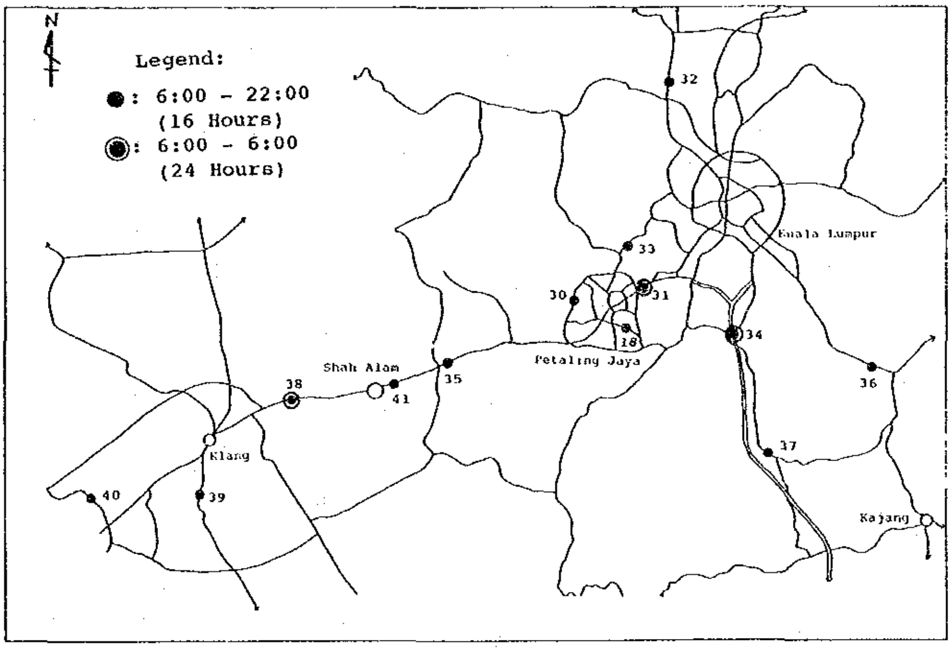


Fig. 5.2.1 Location Map of Traffic Volume Survey Point in Kelang Valley Region

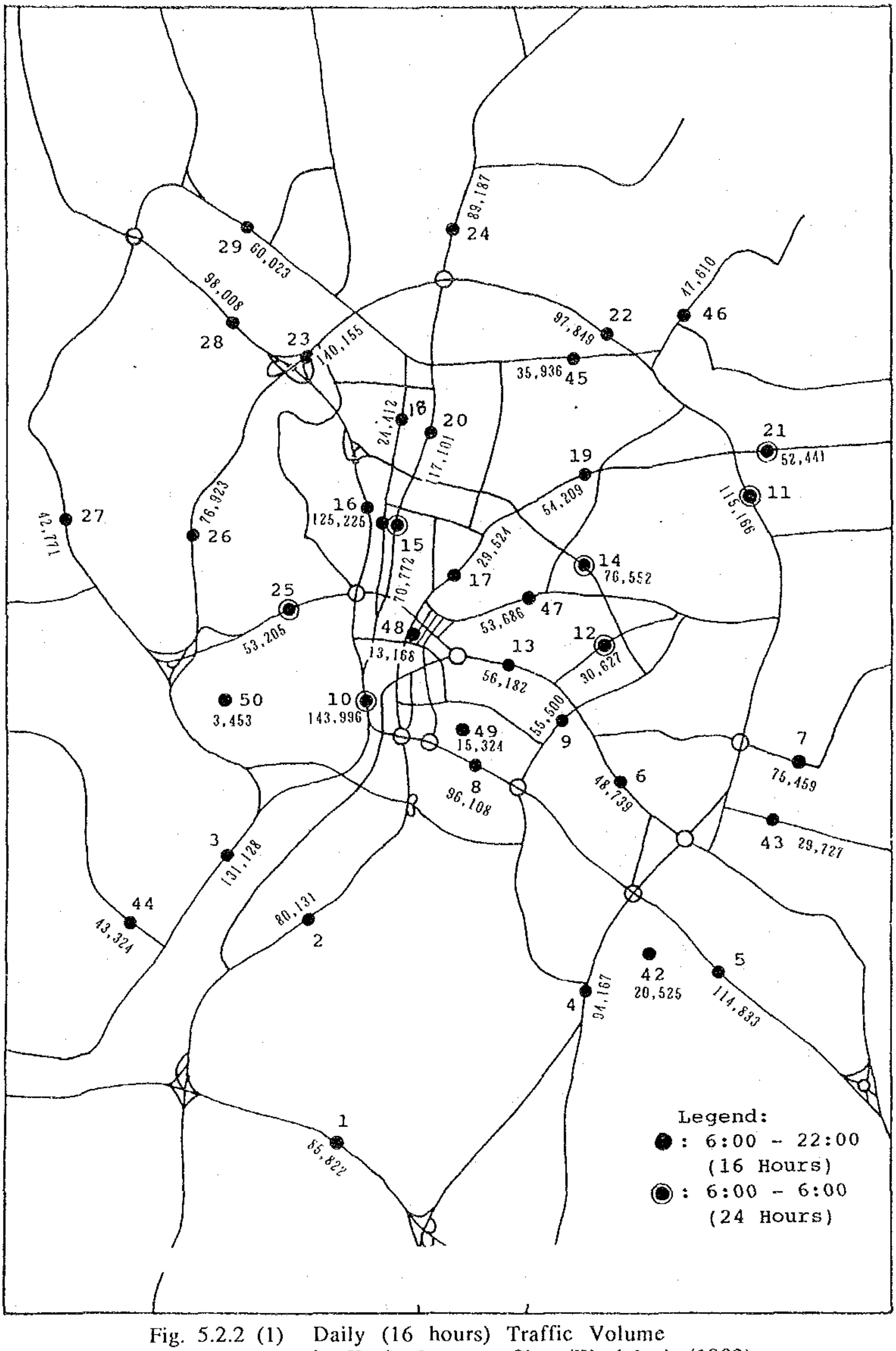


Fig. 5.2.2 (1) Daily (16 hours) Traffic Volume in Kuala Lumpur City (Weekday) (1992)

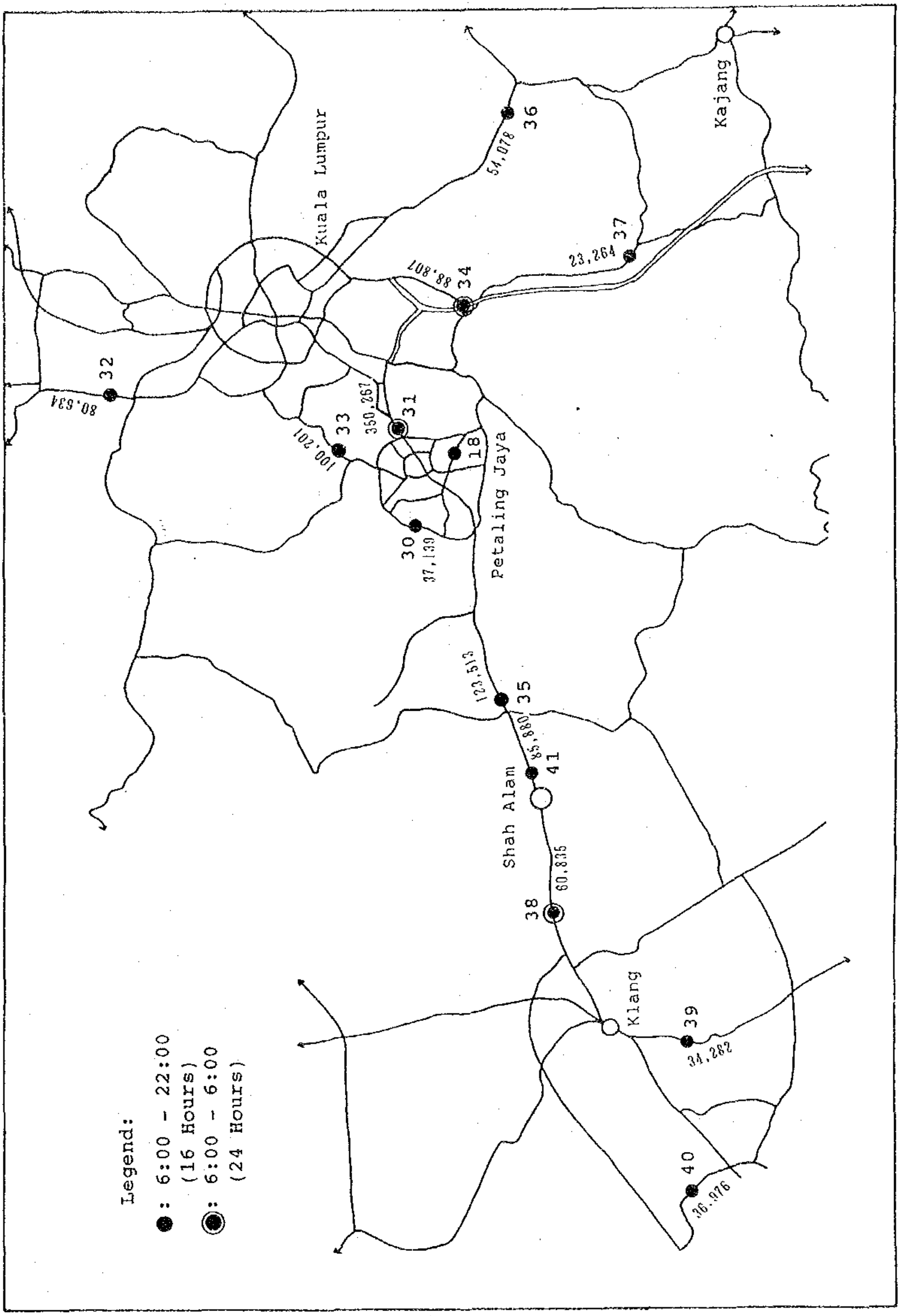


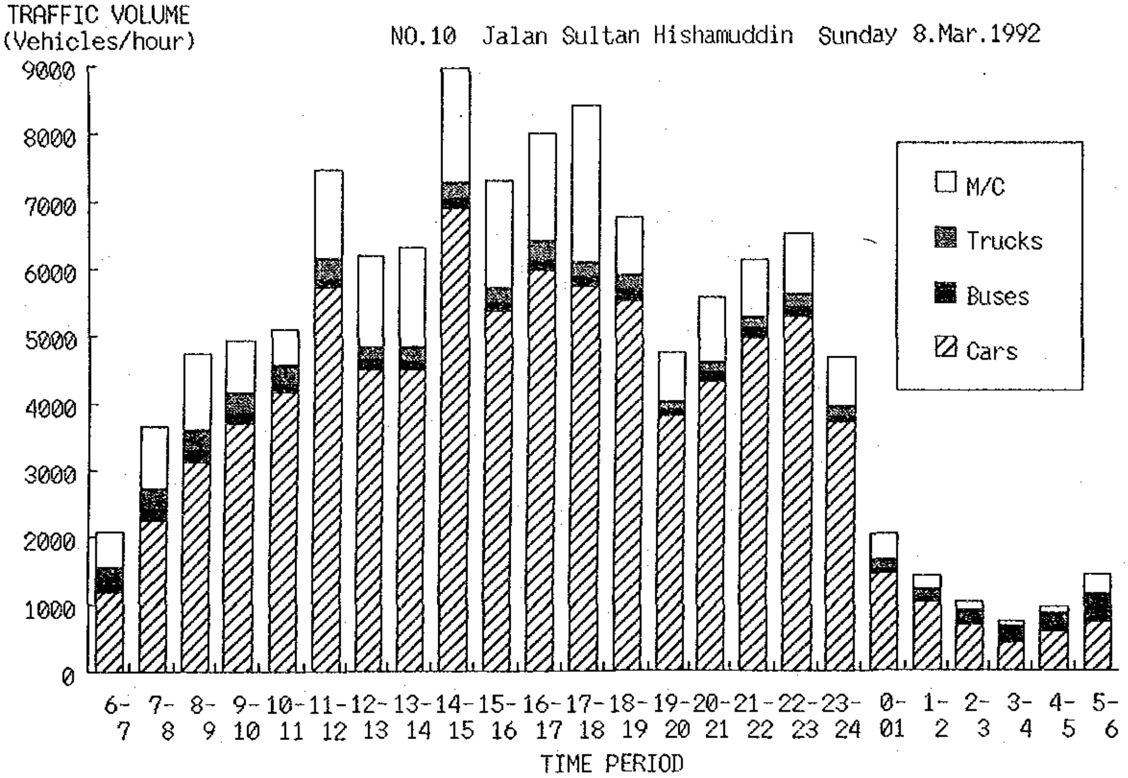
Fig. 5.2.2 (2) Daily (16 hours) Traffic Volume
Outside Kuala Lumpur City (Weekday) (1992)

Table 5.2.3 Summary of Traffic Volume (1992)

Station No.	Survey on weekday		Survey on Sunday			
	Traffic volume (16h)	Traffic volume (24h)	Traffic volume (16h)	Ratio (To Weekday)	Traffic volume (24h)	Ratio (To Weekday)
1	85,822		59,076	0.69		
2	80,131		133,316	1.66		
3	131,128		59,282	0.45		
4	94,167		91,528	0.97		
5	114,833		103,005	0.90		
6	48,739		34,127	0.70		
7	75,459		56,594	0.75		
8	96,108		77,031	0.80		
9	55,500		52,384	0.94		
10	143,996	166,066	96,745	0.67	115,642	0.70
11	115,166	131,662	88,170	0.77	102,102	0.78
12	30,627	38,615	26,688	0.87	31,893	0.83
13	56,182		45,411	0.81		
14	76,552	85,426	42,505	0.56	50,031	0.59
15	70,772	81,521	45,641	0.64	52,855	0.65
16	125,225		96,202	0.77		
17	29,524		16,478	0.56		
18	24,412		21,729	0.89		
19	54,209		24,725	0.46		
20	117,101		83,320	0.71		
21	52,441	62,419	44,206	0.84	54,140	0.87
22	97,849		70,210	0.72		
23	140,155		115,430	0.82		
24	89,187		113,134	1.27		
25	53,205	55,995	19,227	0.36	21,820	0.39
26	76,923		99,982	1.30		
27	42,771		25,515	0.60		
28	98,008		112,016	1.14		
29	60,023		54,887	0.91		
30	37,139		29,832	0.80		
31	350,267	386,476	184,633	0.53	215,853	0.56
32	80,634		82,432	1.02		
33	100,201		94,613	0.94		
34	88,807	98,336	91,660	1.03	106,382	1.08
35	123,513		71,970	0.58		
36	54,078		55,079	1.02		
37	23,264		20,400	0.88		
38	60,835	68,865	50,850	0.84	59,428	0.86
39	34,282		39,553	1.15		
40	36,976		15,519	0.42		
41	85,880		85,663	1.00		
42	20,525		11,585	0.56		
43	29,727		13,408	0.45		
44	43,324		32,563	0.75		
45	35,936		26,593	0.74		
46	47,610		28,388	0.60		
47	53,686		19,727	0.37		
48	13,168		7,852	0.60		
49	15,324		6,817	0.44		
50	3,453		3,966	1.15		
Average	73,497	117,538	57,633	0.788	81,015	0.729

(2) Pattern of Hourly Traffic Volume Fluctuation

With regard to the pattern of hourly traffic volume fluctuation, the patterns of representative traffic survey points are shown in Fig. 5.2.3. The Sunday pattern is basically similar in each Sunday and also the weekday pattern is similar in each weekday. The pattern of weekday has two peaks which correspond to the "rush hours" caused by commuters, one in the morning and another in the evening, while Sunday pattern has one peak centered at daytime. Both patterns are obviously different each other depending on human activity.



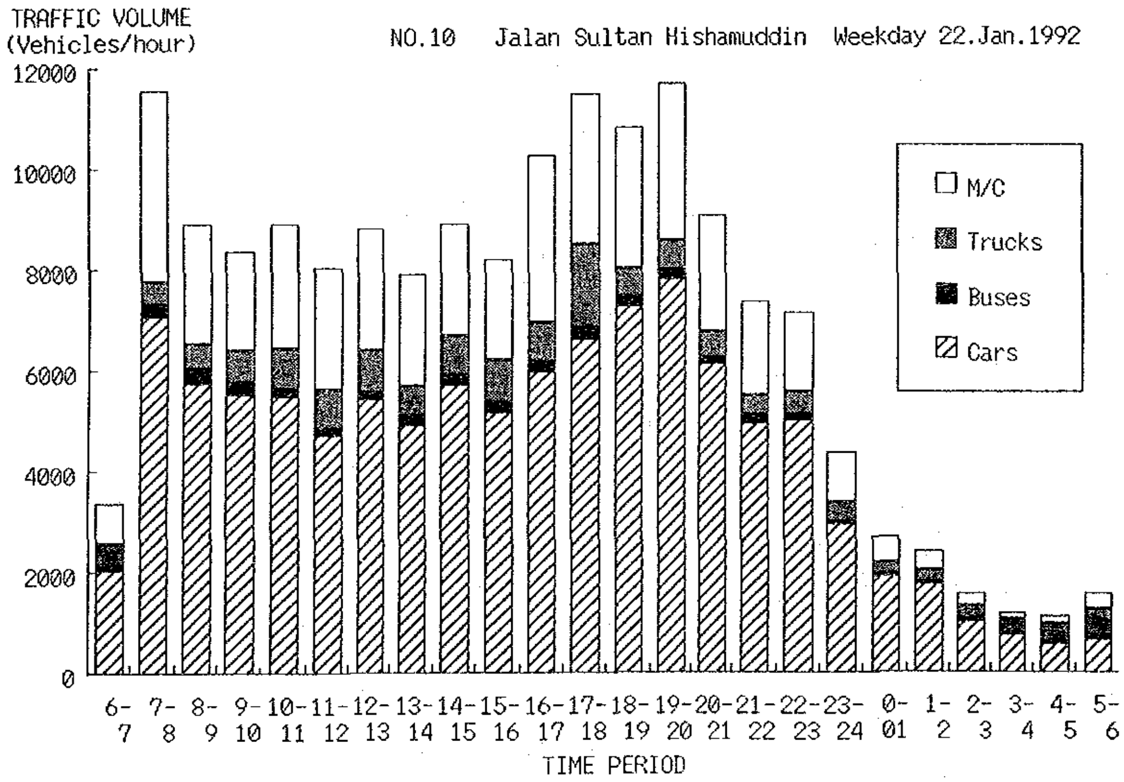
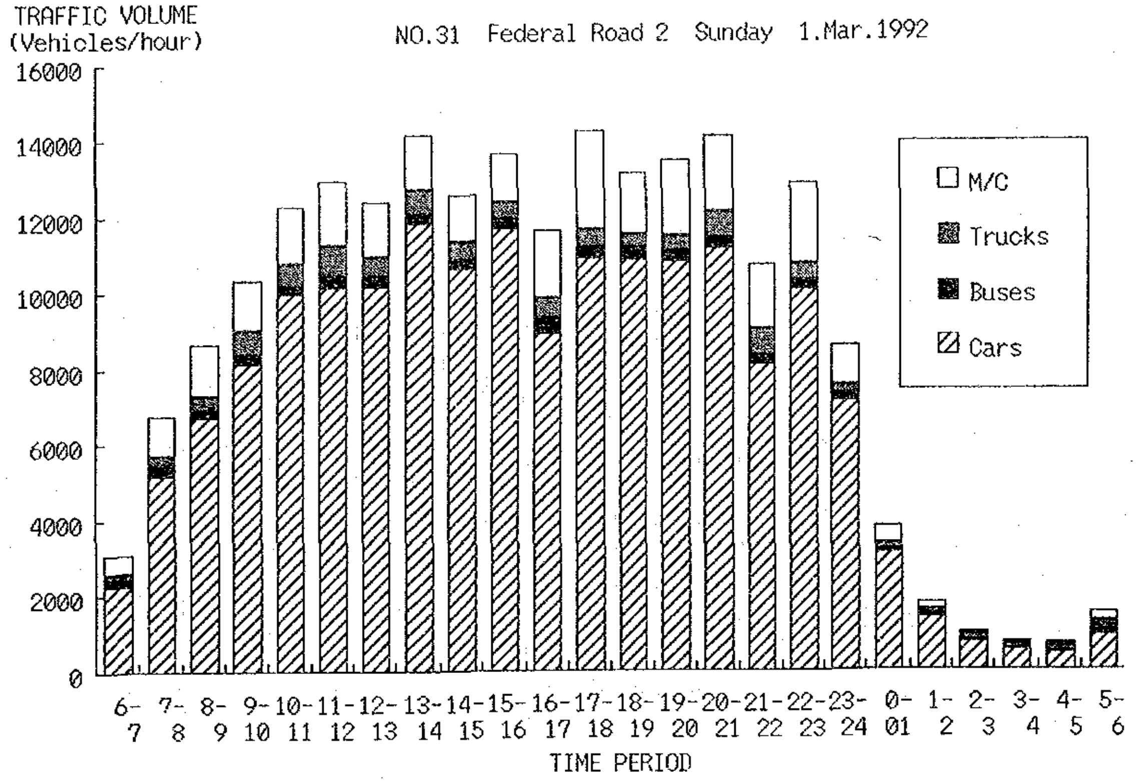


Fig. 5.2.3 (1) Hourly Traffic Volume Fluctuation (No.10)



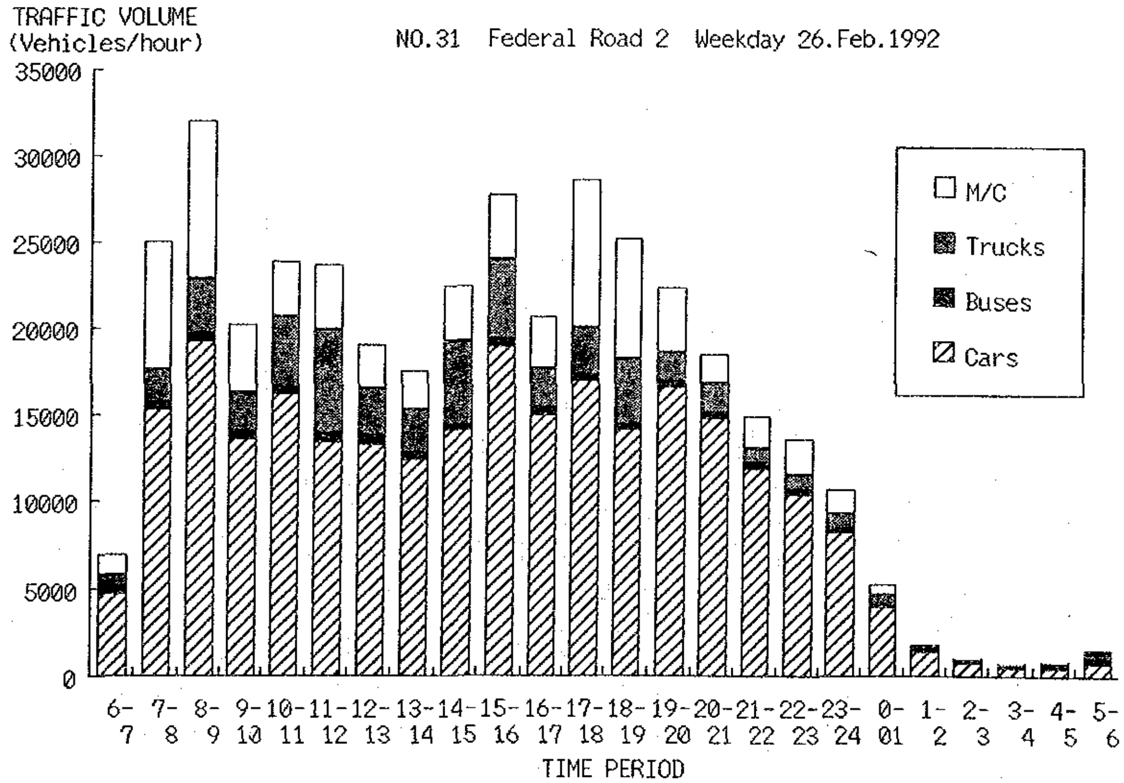
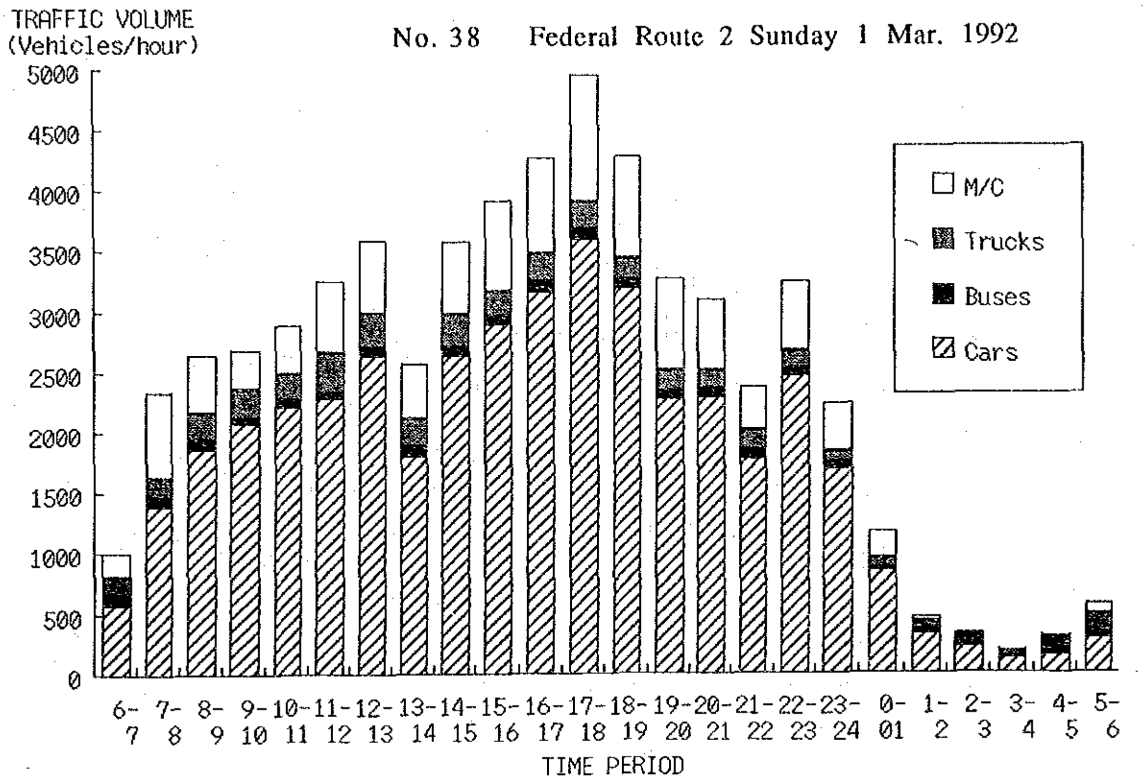


Fig. 5.2.3 (2) Hourly Traffic Volume Fluctuation (No.31)



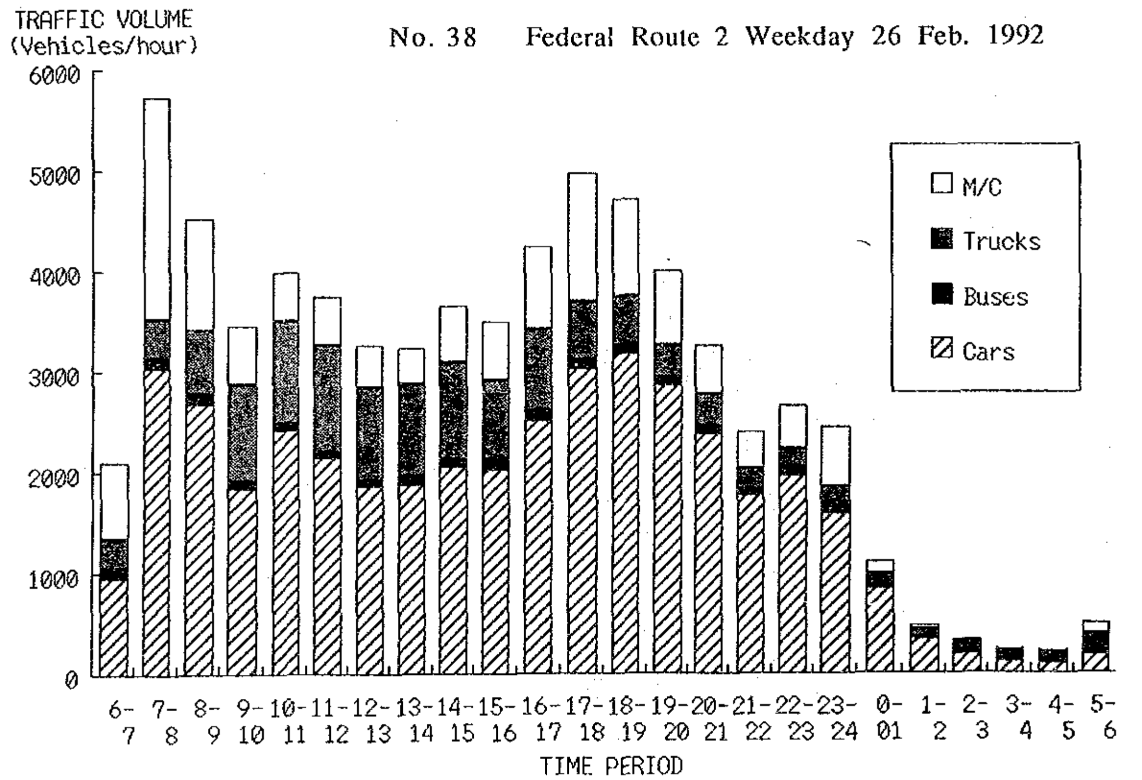


Fig. 5.2.3 (3) Hourly Traffic Volume Fluctuation (No.38)

(3) Vehicle Type and Traffic Volume

Although nine vehicle types: motor car, van, taxi, mini bus, medium/large bus, small truck, medium/large truck, lorry/trailer and motorcycle were actually surveyed, they were classified into four vehicle types.

Cars : motor car, van, taxi
Buses : mini bus, medium/large bus
Trucks : small truck, medium/large truck, lorry/trailer
Motorcycle :

Table 5.2.4 shows traffic volume of all survey points according to this classification. Fig. 5.2.4 illustrates the ratio of traffic volume of each type to daily traffic volume. According to the figure, the ratio of "motorcycles" is quite high: 8-15% on weekday, 20-30% on Sunday. The ratio of "trucks" is 10-18% on weekday and less than half of weekday on Sunday.

Since the vehicle type ratio is changeable point by point because of their social conditions, it is better to know a general tendency of the ratio rather than individual ratios. Table 5.2.5 shows average ratio of vehicle type which is calculated from all survey points' data.

Table 5.2.5 Ratio of Vehicle Type to Daily Traffic Volume on the Average (1992)

Vehicle type	Sunday (%)	Weekday (%)
Cars	68.0	73.1
Buses	2.4	2.8
Trucks	3.8	8.8
Motorcycle	25.8	15.3

Table 5.2.4 Daily Traffic Volume According to Classified Vehicle Types (1992)

Station No.	Survey on Sunday									Survey on Weekday								
	Total traffic volume	Cars		Buses		Trucks		Motor cycle		Total traffic volume	Cars		Buses		Trucks		Motor cycle	
		Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)		Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)	Traffic volume	Ratio (to Total)
1	64,428	48,699	0.756	484	0.008	3,614	0.056	11,631	0.181	80,470	62,733	0.780	398	0.005	11,060	0.137	6,279	0.078
2	136,622	118,739	0.869	3,204	0.023	9,629	0.070	5,050	0.037	76,823	59,053	0.769	4,895	0.064	11,131	0.145	1,744	0.023
3	81,225	36,081	0.444	1,620	0.020	1,656	0.020	41,868	0.515	108,465	78,944	0.728	3,468	0.032	6,848	0.063	19,205	0.177
4	95,600	72,109	0.754	1,018	0.011	4,804	0.050	17,669	0.185	90,090	67,505	0.749	894	0.010	8,094	0.090	13,597	0.151
5	112,224	77,531	0.691	350	0.003	3,714	0.033	30,629	0.273	105,614	76,339	0.723	604	0.006	7,261	0.069	21,410	0.203
6	38,415	23,136	0.602	4,656	0.121	420	0.011	10,203	0.266	44,455	30,203	0.679	7,169	0.161	1,168	0.026	5,915	0.133
7	64,133	42,675	0.665	915	0.014	1,520	0.024	19,023	0.297	67,920	51,850	0.763	1,313	0.019	3,273	0.043	11,484	0.169
8	82,703	57,951	0.701	318	0.004	3,534	0.043	20,900	0.253	90,436	62,358	0.690	616	0.007	12,234	0.135	15,228	0.168
9	59,133	43,104	0.729	554	0.009	1,014	0.017	14,461	0.245	48,751	39,486	0.810	501	0.010	1,052	0.022	7,712	0.158
*10	137,059	86,062	0.628	2,140	0.016	5,448	0.040	43,409	0.317	144,649	105,679	0.731	3,122	0.022	13,856	0.096	21,992	0.152
*11	114,076	77,722	0.681	516	0.005	3,814	0.033	32,024	0.281	119,684	91,721	0.766	919	0.008	6,998	0.058	20,046	0.167
*12	35,773	26,392	0.738	179	0.005	468	0.013	8,734	0.244	34,735	28,756	0.828	223	0.006	902	0.026	4,854	0.140
13	50,984	31,771	0.623	4,555	0.089	823	0.016	13,835	0.271	50,609	34,057	0.673	6,744	0.133	1,546	0.031	8,262	0.163
14	62,215	40,857	0.657	1,038	0.017	774	0.012	19,546	0.314	73,242	62,292	0.850	1,318	0.018	2,270	0.031	7,362	0.101
15	61,686	29,466	0.478	5,657	0.092	697	0.011	25,866	0.419	72,690	47,921	0.659	6,408	0.088	1,326	0.018	17,035	0.234
16	105,426	71,125	0.675	1,052	0.010	5,587	0.053	27,662	0.262	116,001	83,243	0.718	1,440	0.012	12,880	0.111	18,438	0.159
17	21,562	9,265	0.430	3,864	0.179	196	0.009	8,237	0.382	24,440	16,126	0.660	4,462	0.183	699	0.527	3,153	0.129
18	22,895	16,988	0.742	300	0.013	669	0.029	4,938	0.216	23,246	17,516	0.754	413	0.018	1,545	0.030	3,772	0.162
19	32,776	17,332	0.529	1,549	0.047	469	0.014	13,426	0.410	46,158	37,182	0.806	1,787	0.039	1,814	0.033	5,375	0.116
20	93,460	49,540	0.530	10,155	0.109	1,820	0.019	31,945	0.342	98,101	64,850	0.661	5,504	0.056	5,972	0.018	21,775	0.222
*21	58,740	38,498	0.655	2,243	0.038	2,730	0.046	15,269	0.260	64,206	41,505	0.646	8,830	0.138	3,202	0.093	10,669	0.166
22	81,726	53,067	0.649	204	0.002	1,918	0.023	26,537	0.325	88,413	66,870	0.756	2,443	0.028	4,079	0.036	15,021	0.170
23	127,244	88,120	0.693	592	0.005	4,079	0.032	34,453	0.271	127,482	97,645	0.766	37	0.000	7,161	0.025	22,639	0.178
24	112,092	78,393	0.699	5,927	0.053	3,323	0.030	24,449	0.218	90,229	58,022	0.643	2,968	0.033	3,748	0.045	25,491	0.283
*25	29,563	18,270	0.618	514	0.017	295	0.010	10,484	0.355	48,252	39,381	0.816	3,437	0.071	2,893	0.148	2,741	0.057
26	95,602	75,830	0.793	912	0.010	6,908	0.072	11,952	0.125	81,293	58,621	0.721	334	0.004	6,016	0.046	16,322	0.201
27	30,804	20,870	0.678	137	0.004	1,210	0.039	8,587	0.279	37,482	30,241	0.807	237	0.006	3,706	0.072	3,298	0.088
28	113,300	85,628	0.756	1,283	0.011	5,767	0.051	20,622	0.182	96,724	64,354	0.665	891	0.009	12,141	0.062	19,338	0.200
29	60,345	38,130	0.632	4,431	0.073	1,947	0.032	15,837	0.262	54,565	36,755	0.674	3,672	0.067	3,759	0.068	10,379	0.190
30	31,561	25,721	0.815	31	0.001	380	0.012	5,429	0.172	35,410	30,458	0.860	82	0.002	1,170	0.033	3,700	0.104
*31	257,634	172,348	0.669	4,446	0.017	9,820	0.038	71,020	0.276	344,695	260,000	0.754	5,903	0.017	49,553	0.144	29,239	0.085
32	82,486	59,398	0.720	1,956	0.024	5,226	0.063	15,906	0.193	80,580	52,178	0.648	2,414	0.030	10,136	0.126	15,852	0.197
33	102,154	82,585	0.808	687	0.007	2,493	0.024	16,389	0.160	92,660	80,249	0.866	669	0.007	2,894	0.031	8,848	0.095
*34	110,898	84,251	0.760	1,607	0.014	5,560	0.050	19,480	0.176	93,820	63,363	0.675	1,118	0.012	14,375	0.153	14,964	0.159
35	84,389	55,690	0.660	1,600	0.019	3,617	0.043	23,482	0.278	111,094	80,629	0.726	2,099	0.019	17,303	0.156	11,063	0.100
36	56,263	40,321	0.717	583	0.010	2,507	0.045	12,852	0.228	52,894	34,537	0.653	815	0.015	5,874	0.111	11,668	0.221
37	21,203	15,023	0.709	335	0.016	1,077	0.051	4,768	0.225	22,470	14,021	0.624	341	0.015	4,143	0.184	3,965	0.176
*38	62,002	43,046	0.693	1,213	0.020	4,250	0.068	13,583	0.219	66,201	42,150	0.637	1,405	0.040	11,727	0.337	10,919	0.165
39	39,027	26,091	0.669	931	0.024	3,774	0.097	8,231	0.211	34,808	20,491	0.736	510	0.018	5,050	0.181	8,757	0.252
40	24,670	6,333	0.257	250	0.010	1,329	0.054	16,758	0.679	27,825	13,662	0.491	513	0.018	6,043	0.217	7,607	0.273
41	87,439	68,069	0.778	1,395	0.016	3,770	0.043	14,205	0.162	84,104	58,518	0.696	1,528	0.018	11,629	0.138	12,429	0.148
42	14,750	6,676	0.453	504	0.034	876	0.059	6,694	0.454	17,360	10,180	0.586	643	0.037	3,008	0.173	3,529	0.203
43	16,431	9,319	0.567	333	0.020	323	0.020	6,456	0.393	26,704	21,110	0.791	568	0.021	1,593	0.060	3,433	0.129
44	35,854	28,104	0.784	93	0.003	706	0.020	6,951	0.194	40,033	34,599	0.864	296	0.007	1,478	0.037	3,660	0.091
45	29,386	17,241	0.587	1,183	0.040	389	0.013	10,573	0.360	33,143	23,031	0.695	1,590	0.048	742	0.022	7,780	0.235
46	35,900	17,690	0.493	727	0.020	450	0.013	17,033	0.474	40,098	28,446	0.709	955	0.024	1,176	0.029	9,521	0.237
47	29,520	16,506	0.559	876	0.030	375	0.013	11,763	0.398	43,893	40,010	0.912	1,274	0.029	639	0.015	1,970	0.045
48	10,732	5,105	0.476	1,161	0.108	100	0.009	4,366	0.407	10,288	7,468	0.726	967	0.094	367	0.036	1,486	0.144
49	9,765	4,871	0.499	42	0.004	788	0.081	4,064	0.416	12,376	10,810	0.873	85	0.007	365	0.029	1,116	0.090
50	3,975	3,476	0.874	6	0.002	59	0.015	434	0.109	3,444	2,935	0.852	5	0.002	78	0.023	425	0.123

* Bold number : 24 hours observation point

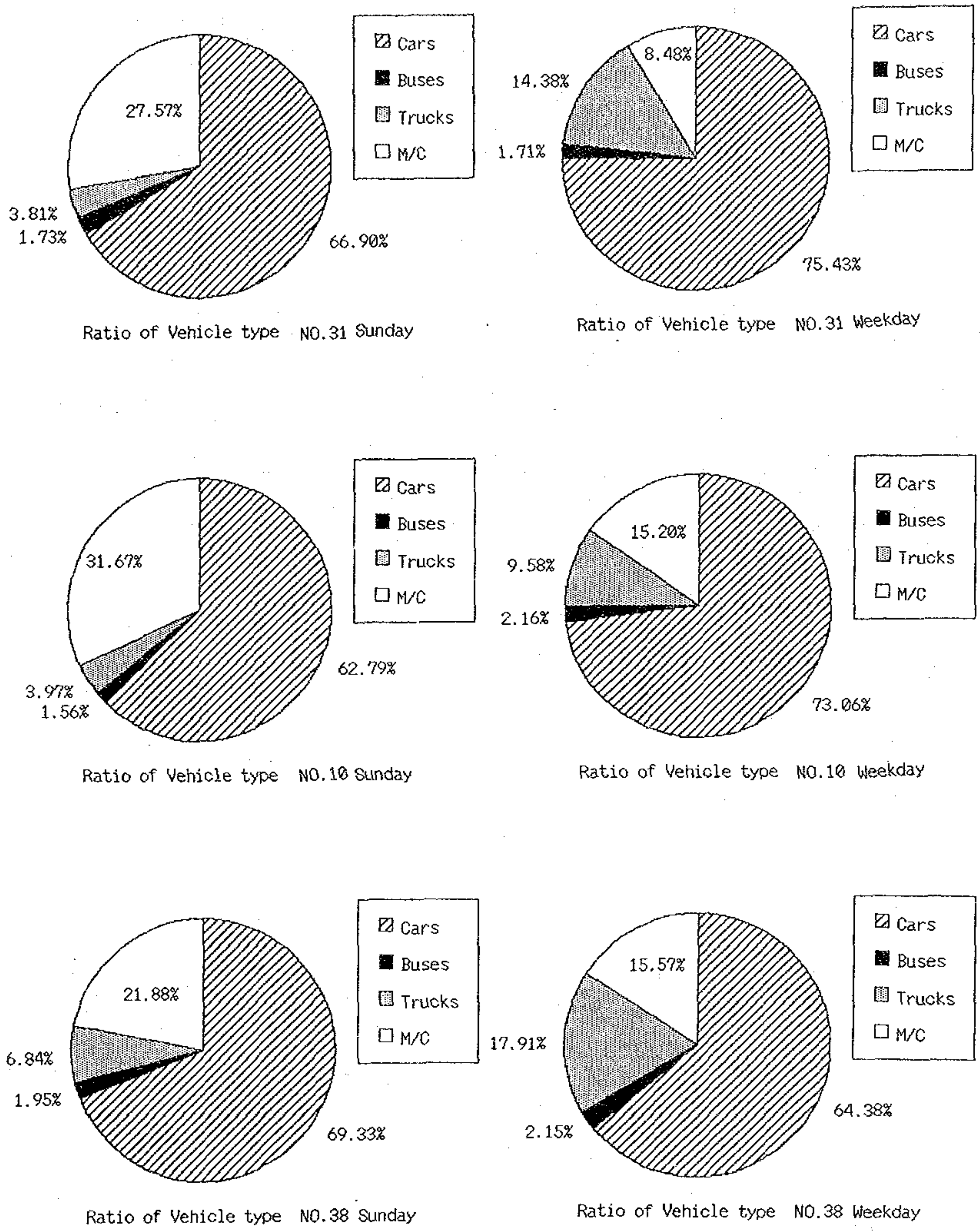


Fig. 5.2.4 Vehicle Type Ratio of Representative Survey Points (1992)

5.2.2 Traffic Volume in Kelang Valley Region

Roads in KVR are classified into major roads and minor roads in the Study. Major roads are those with heavy traffic volume, which emit much pollutants. Minor roads have less traffic and emit less pollutants.

(1) Traffic Volume on Major Roads

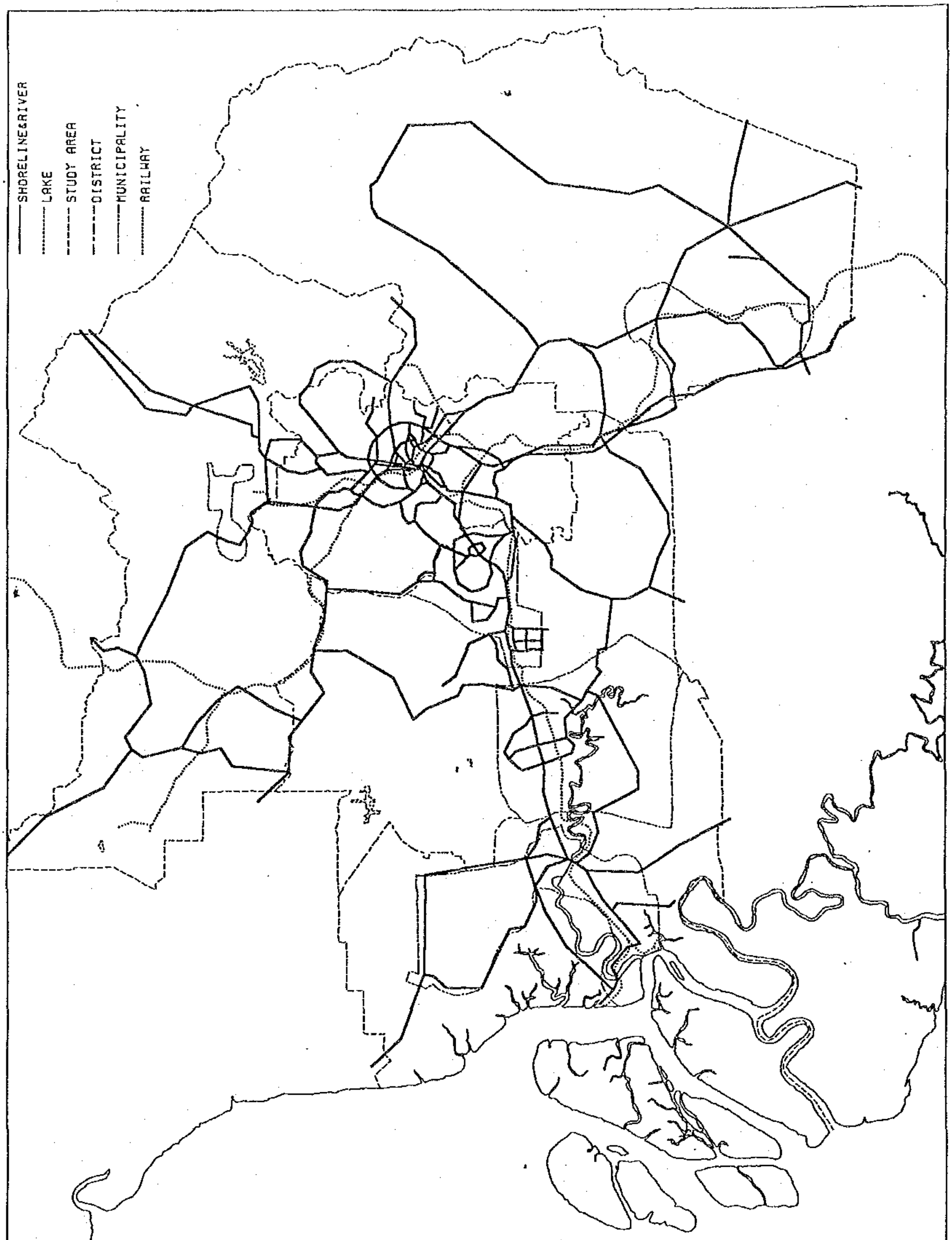
1) Traffic Volume

Traffic volume on major roads was based on data from the traffic volume survey conducted in this study and the existing data. The latter includes data from JKR (1990) (Section 3.2.6 in the Supporting Report) and KVTS (#6007) (1985). After necessary processes such as correction of traffic volume by difference in surveyed years, estimation of nighttime traffic volume for each type of vehicle and by time-zone, current major road traffic volumes were estimated.

2) Major Road Network

Fig. 5.2.5 shows the current major road network. The total length of the major roads is 731.9 km.

Fig. 5.2.5 Current Major Road Network (1992)



(2) Traffic Volume on Minor Roads

1) Traffic Volume

As for traffic volume on minor roads (roads other than major roads), daily traffic volume during weekdays was estimated based on the origin/destination (OD) Table for KVR in 2005 (#6008). In this table, KVR is divided into 129 zones (C-zones). The OD Table for the year 1992 was derived from the OD Table for the year 2005, and growth rate of trip numbers from 1992 to 2005. Based on the traffic volume data obtained in this study, one full day traffic volume for 4 different vehicle types in each C-zone was divided into those for 9 vehicle types and 24 time-zones. The traffic zones and number of vehicle trips in each zone are shown in Section 3.2.5 in the Supporting Report.

2) Trip Length

Average trip length of vehicles for minor roads originating from a C-zone was assumed to be the radius of a circle which area is equal to that of the zone.

3) Total Distance Travelled in Mesh

Total distance travelled (vehicle numbers x km) in each mesh (1km square) was estimated from C-zone distance travelled. The following shows the procedure.

a) C-zone distance travelled is a product of the average trip length (the radius of the C-zone circle) times numbers of vehicle in the C-zone.

b) As for a mesh which is in more than two C-zones, the largest C-zone is considered to correspond to the mesh.

c) Distance travelled for each type of vehicle and each time-zone is apportioned to the corresponding meshes evenly.

5.2.3 Travel Speed

Travel speed survey was conducted for 5 routes of major roads as shown in Table 5.2.6 to grasp driving state of vehicles in Kelang Valley Region. Figs 5.2.6 (1) and 5.2.6 (2) show routes for travel speed survey. Detailed results of the travel speed survey are shown in Section 3.2.2 in the Supporting Report.

Table 5.2.6 Routes for Travel Seed Survey

No.	Road Name	Survey Section	Length (km)
1	Federal Highway 2	Batu Tiga - Jln S. Hishamuddin	19.00
2	KL - Seremban Expressway	Kajang Toll Plaza - Jln Kucing	23.20
3	Jln Pahang/Jln Genting Klang	Taman Bunga Raya - Jln S. Hishamuddin	9.00
4	Inner Ring Road	Jln Syed Putra Cross. (Start and End)	8.15
5	Middle Ring Road	Jln Sungai Besi Cross. (Start and End)	17.15

(1) Zones and Travel Speed

Average travel speed by route and direction during weekdays and holidays is shown in Table 5.2.7. Average travel speed is higher during holidays.

In order to clarify relations between zones and average travel speed, average travel speed of both directions was calculated for 4 zones, namely Zone 1: inside Inner Ring Road, Zone 2: between Inner Ring Road and Middle Ring Road, Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya (Urban Area), and Zone 4: Kelang Valley Region (outside of Kuala Lumpur) and Petaling Jaya (Suburban area), as shown in Tables 5.2.8 (1) and 5.2.8 (2).

Table 5.2.7 Average Travel Speed (1992)

(Unit: km/hour)

Survey Route	Direction	Weekday			Holiday		
		Morning Peak	Off Peak	Evening Peak	Morning Peak	Off Peak	Evening Peak
No.1 (19.00 Km) Federal Highway	To KL	21.2	40.3	26.4	59.6	44.8	47.4
	To Shah alam	29.3	42.9	19.4	58.8	46.7	46.3
N.2 (23.20 Km) KL-Seremban Exp.	To KL	34.0	44.8	32.6	55.1	45.4	45.2
	To Seremban	48.8	46.9	39.7	54.9	49.9	50.1
No.3 (9.00 Km) Jln Pahang	To KL	14.4	24.5	24.6	41.1	33.2	32.1
	To T.B. Raya	33.7	35.8	20.2	46.1	30.9	28.3
No.4 (8.15 Km) Inner Ring Road	Anti-clock	25.7	24.1	12.1	24.3	19.0	13.6
	Clockwise	20.7	11.7	9.8	22.6	16.9	18.1
No.5 (17.15 Km) Middle Ring Road	Anti-clock	32.1	15.1	26.7	42.7	43.2	47.7
	Clockwise	31.9	35.2	28.2	46.2	38.3	38.9

Note Morning peak : from 07:00 to 09:59
Off peak : from 10:00 to 15:59
Evening peak : from 16:00 to 20:00

Table 5.2.8 (1) Average Travel Speed by Road (Weekdays) (1992)

(Unit: km/h)

No.	Road Name	Zone	Morning peak	Off peak	Evening Peak
1	Federal Highway 2	2	10.1	13.9	8.1
		3	22.6	44.1	24.7
		4	34.7	47.8	23.6
2	KL-Seremban Exp.	1	18.8	22.1	14.8
		2	27.8	21.8	19.8
		3	40.7	51.7	30.7
		4	51.5	63.6	55.4
3	Jln Pahang	1	23.2	24.8	16.4
		2	30.2	28.4	24.2
		3	17.6	31.4	25.2

Note Zone 1: Area inside Inner Ring Road
Zone 2: Area between Inner Ring Road and Middle Ring Road
Zone 3: Area outside Middle Ring Road and Petaling Jaya (urban area)
Zone 4: Area outside of Kuala Lumpur and Petaling Jaya (suburban area)

Table 5.2.8 (2) Average Travel Speed by Road (Holidays) (1992)

(Unit: km/h)

No.	Road Name	Zone	Morning peak	Off peak	Evening Peak
1	Federal Highway 2	2	22.2	22.9	19.0
		3	62.9	50.4	49.9
		4	65.3	44.4	50.4
2	KL-Seremban Exp.	1	36.3	23.7	24.2
		2	31.8	26.5	33.2
		3	61.9	56.8	58.2
		4	64.5	60.5	56.3
3	Jln Pahang	1	38.4	29.1	26.2
		2	42.8	35.2	31.7
		3	45.8	32.1	31.1

Note Zone 1: Area inside Inner Ring Road
Zone 2: Area between Inner Ring Road and Middle Ring Road
Zone 3: Area outside Middle Ring Road and Petaling Jaya
Zone 4: Area outside of Kuala Lumpur and Petaling Jaya

As seen in the above tables, the average Travel speed is generally higher in outer zones on both weekdays and holidays. During weekdays, the average travel speed is at the lowest in Morning Peak and Evening Peak. During holidays, the average travel speed is the highest in Morning Peak, and lower in Off Peak and Evening Peak.

The speed of vehicles has a close relation to the amount of emission. Generally slower speed vehicles emit more HC, CO and SOx, and less NOx. This means there are differences in emission amount between cars on a crowded road and those on a less crowded road. The average speeds in four zones, determined from the travel speed survey are listed in Table 5.2.9.

For expressways (Fereral Highway, LK-Seremban Expressway and KL-Karal Highway), different speeds from general roads were set in Zone 4. Average speed of motorcycles was assumed to be 40 km/h or less.

Table 5.2.9 Regional Vehicle Average Speed

Unit:km/h

Time zone		Weekdays				Holidays			
		07-09	10-15	16-20	21-06	07-09	10-15	16-20	21-06
General Roads	Zone 1	20	20	15	20	35	25	25	35
	Zone 2	25	25	20	25	35	30	30	35
	Zone 3	30	35	25	35	45*	40	40	45*
	Zone 4	35	40	35	40	50*	45*	45*	50*
Express Way Zone 4	F.H.	40	50*	40	50*	60*	55*	55*	60*
	KL. S KL. K	50*	65*	50*	65*	65*	55*	55*	60*

* : Motorcycle : 40km/h

Classification of Zone

Zone 1: Inside Inner Ring Road

Zone 2: Zone between Inner Ring Road and Middle Ring Road

Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya

Zone 4: Kelang Valley Region (outside of Kuala Lumpur and Petaling Jaya)

Fig. 5.2.6 (1) Routes of Travel Speed Survey in Kuala Lumpur City

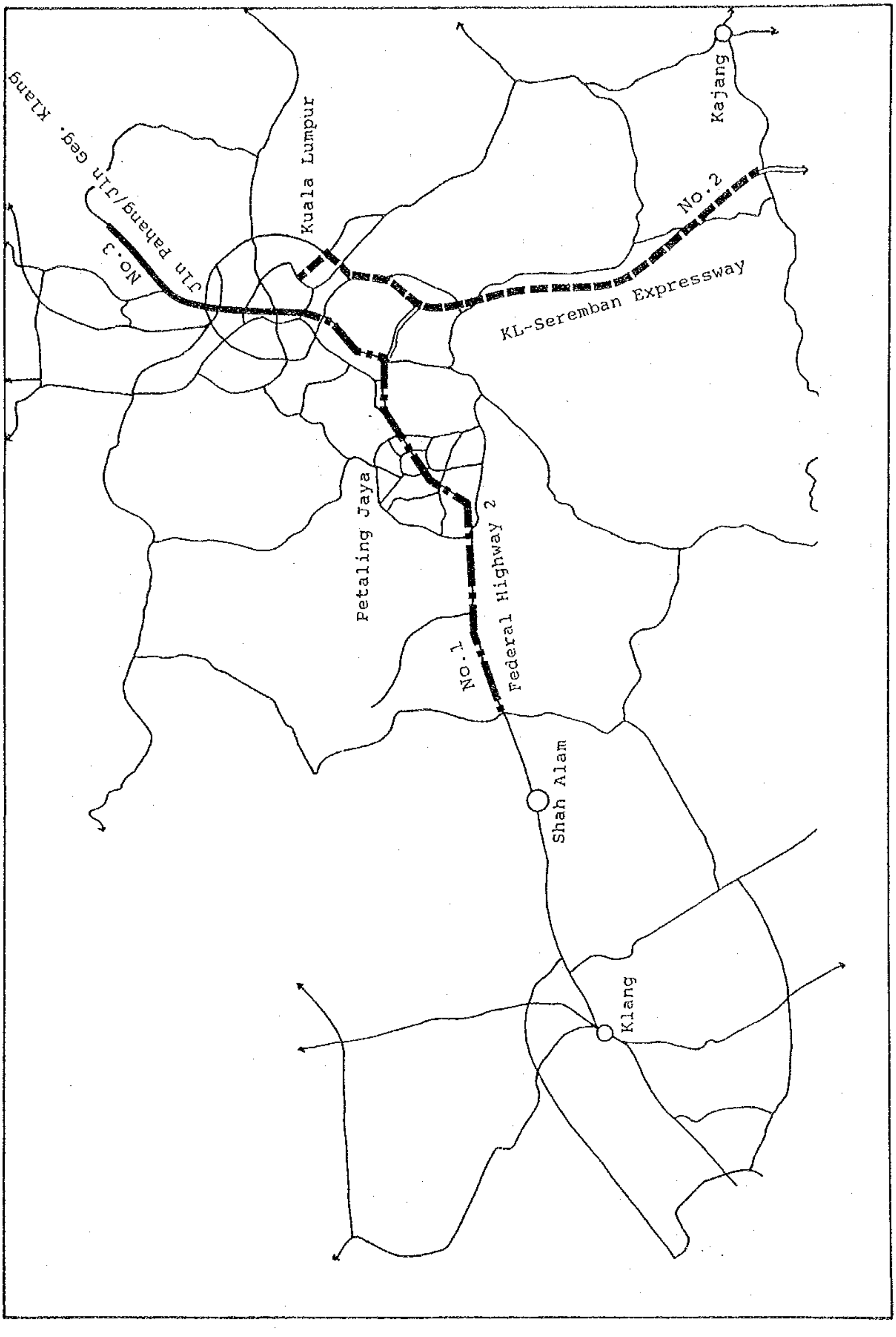


Fig. 5.2.6 (2) Routes of Travel Speed Survey in Kelang Valley Region

5.2.4 Measurement of Exhaust Gas at Idling State

Exhaust gas from motor vehicles was analysed for CO, NOx and HC while the engine was at idling state. The sample group of 236 vehicles consisted of nine types of vehicle and five types of fuel. And the analysis covered from small sized vehicles to large sized ones. The result was arranged according to their type and their fuel as shown in Table 5.2.10. The detailed results of the exhaust gas measurement at idling state are shown in Section 3.2.4 in the Supporting Report.

Table 5.2.10 Results of Exhaust Gas Measurement

Fuel Type	Vehicle Type	Number of Samples	Average Concentration		
			CO (%)	HC (ppm)	NOx (ppm)
Petrol	Motorcycle	30	2.4	4,060	13
	Taxi	12	4.8	268	140
	Motor Car	64	3.9	276	88
	Van	27	4.6	404	67
	Small Truck	12	5.1	397	46
Diesel Oil	Taxi	6	0.1	0	273
	Motor Car	5	0.0	28	152
	Van	5	0.0	0	117
	Small Truck	19	0.1	29	149
	Mini Bus	20	0.1	14	106
	Large Truck	18	0.0	0	171
	Standard Bus	15	0.1	9	171
LPG	Small Car*	3	5.2	513	52

Note: Small Car - Taxi and Motor Car

(1) CO

The average concentration of CO by petrol fuelled vehicles (range from 2.4 to 5.1%) is higher than that by diesel vehicles (range from 0.0 to 0.1%). There is no clear relationship between vehicle age and CO concentration. The concentration of CO in exhaust gas may depend on maintenance of the vehicle.

(2) HC

The notable thing is that the average concentration of HC by motorcycle is very high at 4,060 ppm. It is fifteen times higher than that of taxi and motor car and ten times higher than that of small truck. The concentration of diesel vehicles is the lowest at less than 30 ppm. The average concentration of HC by LPG vehicles is over 500 ppm and higher than petrol vehicles.

(3) NOx

The average concentration of NOx from diesel vehicles (range from 106 ppm to 273 ppm) is higher than those from petrol and LPG vehicles.

5.2.5 Chassis Dynamometer Test Results

Thanks to PROTON, 17 petrol fuelled vehicles were tested for their exhaust emissions. The particulars of the tests were as follows.

a) Tested cars: Petrol fuelled
b) Fuel: Unleaded petrol
c) No. of cars: 17
d) Test modes: ECE mode (ECE), Japanese ten mode (J-10), Constant speed (60)
(Average speed) ECE (18.7km/h), J-10 (17.8km/h), 60 (60km/h)
e) Measured: Emission factors of HC, CO and NOx and Fuel economy
f) Air conditioner: On/Off effects on emission factors for three cars out of 17.

Detailed results by the chassis dynamometer are described in Section 3.2.3 in the Supporting Report.

(1) Air Conditioner Off

The test results for all vehicles are shown in Table 5.2.11. The test results for the ECE mode for engine capacities 1500cc or less according to the model year are summarized in Table 5.2.12. Further, emission factors were arranged in three yearly groups (before 1985, 1986-1991, and 1992) in Table 5.2.13.

Table 5.2.11 Results of Exhaust Gas Measurement by Chassis Dynamometer Test

Vehicle	Engine	Model	Mileage	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle
No.	(cc)	Year	(km)	ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	Name
1	1300	1988	100276	3.08	3.43	0.17	5.25	6.03	0.45	3.39	3.53	3.49	11.94	11.99	22.05	PROTON SAGA
2	1300	1990	48261	2.75	3.28	0.17	5.67	6.62	0.42	3.83	3.65	3.50	10.52	11.20	20.58	PROTON SAGA
3	1500	1989	42440	2.86	3.35	0.86	15.80	17.27	3.39	3.90	4.01	3.97	9.83	10.11	18.24	PROTON SAGA
4	1000	1986	100404	2.19	2.35	0.63	11.99	10.34	5.46	1.39	1.28	1.13	12.42	12.42	27.79	CHARADE
5	1500	1992	977	2.26	3.01	0.68	4.50	5.01	0.34	2.66	2.77	2.88	10.34	10.44	18.97	ISWARA
6	1500	1983	186660	3.04	3.40	0.85	17.93	18.50	4.34	1.17	1.27	0.95	9.05	9.31	18.98	F. LASER
7	1400	1983	366173	2.61	2.56	1.02	25.04	24.76	13.93	1.27	1.61	1.48	10.75	10.78	16.55	M. TREDIA
8	1200	1978	424672	2.08	2.46	0.80	18.50	19.65	9.88	0.71	0.76	0.62	11.16	11.32	18.93	H. CIVIC
9	1500	1986	154688	2.61	3.09	0.61	9.37	11.79	2.54	1.33	1.39	1.05	9.82	9.42	21.12	PROTN SAGA
10	1800	1991	22113	0.77	0.77	0.04	4.79	5.26	0.22	1.30	1.48	0.85	7.49	7.09	13.03	RENAULT
11	1500	1990	20884	2.19	2.80	0.59	7.05	8.41	1.13	2.23	2.72	2.83	10.15	10.37	18.77	PROTON SAGA
12	2000	1987	70966	0.31	0.26	0.02	2.34	2.68	0.04	0.33	0.25	0.38	9.95	10.79	19.74	H. ACCCORD
13	1500	1989	43789	2.63	3.43	0.81	15.34	16.45	3.11	1.96	2.00	1.86	9.63	11.69	25.51	PROTON SAGA
14	1000	1984	421328	3.82	3.72	0.88	24.10	18.48	9.97	1.77	2.12	0.77	11.94	14.67	28.59	CHARADE
15	1500	1991	15037	2.76	3.37	0.86	8.43	8.88	0.94	2.77	2.99	3.21	10.64	12.80	25.81	PROTON SAGA
16	1500	1992	80	2.36	2.96	0.67	3.34	3.87	0.49	1.23	1.33	1.21	9.86	10.29	18.97	PROTON ISWARA
17	1500	1992	1500	2.42	3.13	0.72	7.09	7.64	0.82	2.69	2.79	3.04	10.14	10.54	24.56	PROTON SAGA

Engine Capacity: less than 1500cc

Vehicle	Engine	Model	Mileage	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle
No.	(cc)	Year	(km)	ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	Name
8	1200	1978	424672	2.08	2.46	0.80	18.50	19.65	9.88	0.71	0.76	0.62	11.16	11.32	18.93	H. CIVIC
7	1400	1983	366173	2.61	2.56	1.02	25.04	24.76	13.93	1.27	1.61	1.48	10.75	10.78	16.55	M. TREDIA
14	1000	1984	421328	3.82	3.72	0.88	24.10	18.48	9.97	1.77	2.12	0.77	11.94	14.67	28.59	CHARADE
4	1000	1986	100404	2.19	2.35	0.63	11.99	10.34	5.46	1.39	1.28	1.13	12.42	12.42	27.79	CHARADE
1	1300	1988	100276	3.08	3.43	0.17	5.25	6.03	0.45	3.39	3.53	3.49	11.94	11.99	22.05	PROTON SAGA
2	1300	1990	48261	2.75	3.28	0.17	5.67	6.62	0.42	3.83	3.65	3.50	10.52	11.20	20.58	PROTON SAGA

Engine Capacity: 1500cc

Vehicle	Engine	Model	Mileage	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle
No.	(cc)	Year	(km)	ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	Name
6	1500	1983	186660	3.04	3.40	0.85	17.93	18.50	4.34	1.17	1.27	0.95	9.05	9.31	18.98	F. LASER
9	1500	1986	154688	2.61	3.09	0.61	9.37	11.79	2.54	1.33	1.39	1.05	9.82	9.42	21.12	PROTON SAGA
3	1500	1989	42440	2.86	3.35	0.86	15.80	17.27	3.39	3.90	4.01	3.97	9.83	10.11	18.24	PROTON SAGA
13	1500	1989	43789	2.63	3.43	0.81	15.34	16.45	3.11	1.96	2.00	1.86	9.63	11.69	25.51	PROTON SAGA
11	1500	1990	20884	2.19	2.80	0.59	7.05	8.41	1.13	2.23	2.72	2.83	10.15	10.37	18.77	PROTON SAGA
15	1500	1991	15037	2.76	3.37	0.86	8.43	8.88	0.94	2.77	2.99	3.21	10.64	12.80	25.81	PROTON SAGA
17	1500	1992	1500	2.42	3.13	0.72	7.09	7.64	0.82	2.69	2.79	3.04	10.14	10.54	24.56	PROTON SAGA
5	1500	1992	977	2.26	3.01	0.68	4.50	5.01	0.34	2.66	2.77	2.88	10.34	10.44	18.97	PROTON ISWARA
16	1500	1992	80	2.36	2.96	0.67	3.34	3.87	0.49	1.23	1.33	1.21	9.86	10.29	18.97	PROTON ISWARA

Engine Capacity: more than 1500cc

Vehicle	Engine	Model	Mileage	HC(g/km)			CO(g/km)			NOx(g/km)			Fuel Economy(km/l)			Vehicle
No.	(cc)	Year	(km)	ECE	10	60	ECE	10	60	ECE	10	60	ECE	10	60	Name
12	2000	1987	70966	0.31	0.26	0.02	2.34	2.68	0.04	0.33	0.25	0.38	9.95	10.79	19.74	H. ACCCORD
10	1800	1991	22113	0.77	0.77	0.04	4.79	5.26	0.22	1.30	1.48	0.85	7.49	7.09	13.03	RENAULT

Table 5.2.12 Emission Rates of Motor Car by Model Year (ECE Mode)

Model Year	HC (g/km)	CO (g/km)	NOx (g/km)	Fuel Economy (km/l)	Mileage (km)
1978	2.08	18.50	0.71	11.16	424,672
1983	2.83	21.49	1.22	9.80	276,417
1984	3.82	24.10	1.77	11.94	421,328
1986	2.40	10.68	1.36	11.12	127,546
1988	3.08	5.25	3.39	11.94	100,276
1989	2.75	15.57	2.93	9.73	43,115
1990	2.47	6.36	3.03	10.34	34,573
1991	2.76	8.43	2.77	10.64	15,037
1992	2.35	4.98	2.19	10.11	852

Table 5.2.13 Average Emission Rates of Motor Car by Model Year (ECE Mode)

Model Year	HC (g/km)	CO (g/km)	NOx (g/km)	Fuel Economy (km/l)	Mileage (km)
- 1985	2.91	21.36	1.23	10.97	374139
1986 - 1991	2.69	9.26	2.70	10.75	64109
1992	2.35	4.98	2.19	10.11	852

(2) Effects of Air Conditioners

Effects on the emission factors when air-conditioners are on were analyzed with three cars. Change of emission rates by air conditioning is given in Table 5.2.14. The summary for keeping the air conditioner on is as follows.

HC:	no change
CO:	15% increase
NOx:	30% increase
Fuel economy:	10% decrease

Table 5.2.14 Change of Emission Rates by Air-conditioning

Vehicle No.		13	14	15	Ave.
HC	ECE	-10.6	-11.0	-21.0	-14.2
(%)	J-10	-16.9	5.4	-14.5	-8.7
	60	4.9	1.1	18.6	8.2
	Ave.	-7.5	-1.5	-5.6	-4.9
CO	ECE	7.3	-9.0	20.9	6.4
(%)	J-10	12.8	-3.7	47.7	18.9
	60	25.7	2.4	46.8	25.0
	Ave.	15.3	-3.4	38.5	16.8
NOx	ECE	32.1	54.8	-32.9	18.0
(%)	J-10	31.5	41.0	42.5	38.4
	60	31.7	22.1	22.7	25.5
	Ave.	31.8	39.3	10.4	27.2
Fuel	ECE	-10.6	-10.8	-16.4	-12.6
Economy	J-10	-10.0	-9.0	-17.3	-12.1
(%)	60	-7.6	-6.2	-12.4	-8.7
	Ave.	-9.4	-8.7	-15.4	-11.1

5.2.6 Emission Factor

Emission factors of current motor vehicles were established from the result of the chassis dynamometer tests and published data in the USA and Japan. Five pollutants that are being considered are HC, CO, NOx, SOx and PM. SOx emission factor is calculated from the following formula which uses known fuel consumption (liters/km) and sulphur content in fuel (% wt).

$$\underset{(g/km)}{SOx} = \underset{(l/km)}{\text{fuel consumption rate}} \times \underset{(g/ml)}{\text{specific gravity}} \times \underset{(\%)}{\text{sulphur content}} \times \frac{\text{molecular weight } SO_2}{\text{moledular weight of S}} \times \underset{(ml/l)}{1000 \times 1/100}$$

Selected values of specific gravity and sulphur content of petrol and diesel oil obtained from the fuel analyses are given in Table 5.2.15.

Table 5.2.15 Characteristics of Fuels for Motor Vehicles

Fuel Type	Specific Gravity	Sulphur Content (weight %)
Petrol	0.78	0.003
Diesel oil	0.85	0.323

In setting emission factors for HC, CO, and NOx, deterioration with increase of cumulative mileage and change with average vehicle speed were considered. Changes of emission factors only with average vehicle speed was considered for SOx. PM emission factors were established for individual types of vehicle irrespective of their mileage. Vehicle speed was taken into consideration only on the PM emission factors for buses. A detailed process for setting current emission factors is described in Section 3.2.7 in the Supporting Report.

(1) Classification of Vehicles

Based on RTD's annual statistical bulletin (#6006), Table 5.2.16 shows engine types of vehicles surveyed for traffic volume. Light duty trucks are assumed to be petrol fuelled, and medium and heavy (or large) duty trucks are diesel fuelled. Trucks with engine capacity of 5,000cc and less are considered medium trucks and more than 5,000cc are considered large trucks. The ratio of the medium and large trucks registered is given in Table 5.2.17. Table 5.2.18 shows the ratio of engine type for van and taxi.

Table 5.2.16 Classification of Motor Vehicles by Engine Type

No.	Vehicle Type	Petrol	Diesel
1	Motorcycle	o	
2	Motor car	o	
3	Van	o	o
4	Taxi	o	o
5	Mini bus		o
6	Medium/Large bus		o
7	Small truck	o	
8	Medium		o
9	Large truck		o
10	Lorry/Trailer		o

Note: Engine capacity
Medium truck; 5000cc or less
Large turck; 5501 or more

Table 5.2.17 Ratio of Medium and Large Trucks to the Total Number of Trucks

	Ratio
Medium Truck	0.849
Large Truck	0.151

Table 5.2.18 Ratio of Van and Taxi according to Their Engine Type

Engine Type	Van	Taxi
Petrol	0.849	0.509
Diesel	0.151	0.491

(2) Emission Factors for HC, CO, NOx, SOx and PM

Emission factors for different types of vehicles operating in KVR are given in Table 5.2.19.

Table 5.2.19 Average Emission Rate for Motor Vehicles (1992) (HC, CO, NOx , SOx and PM)

(Unit: g/km)

Vehicle Type		Average Speed(km/h) 15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	27.18	20.79	17.30	15.12	13.52	12.35					
	CO	44.19	34.03	28.12	24.58	21.98	19.85					
	NOx	0.21	0.19	0.19	0.19	0.20	0.21					
	SOx	0.002	0.002	0.002	0.002	0.002	0.002					
	PM	0.205	0.205	0.205	0.205	0.205	0.205					
Motor Car	HC	3.47	2.57	2.07	1.75	1.50	1.32	1.15	1.02	0.90	0.80	0.73
	CO	36.04	26.44	21.05	17.68	15.16	13.30	11.62	10.27	9.09	8.25	7.58
	NOx	1.51	1.58	1.65	1.74	1.81	1.88	1.93	1.99	2.02	2.07	2.11
	SOx	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
	PM	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Van	HC	2.96	2.25	1.83	1.57	1.36	1.19	1.05	0.93	0.83	0.75	0.69
	CO	59.10	43.43	34.60	29.06	24.91	21.86	19.10	16.89	14.97	13.59	12.48
	NOx	2.80	2.89	2.98	3.11	3.22	3.33	3.40	3.49	3.54	3.64	3.70
	SOx	0.119	0.104	0.096	0.089	0.085	0.081	0.080	0.078	0.076	0.074	0.072
	PM	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Taxi	HC	2.57	1.99	1.63	1.40	1.22	1.07	0.95	0.85	0.76	0.69	0.63
	CO	33.48	24.75	19.77	16.59	14.22	12.47	10.90	9.66	8.57	7.80	7.18
	NOx	2.07	2.00	1.95	1.93	1.92	1.93	1.93	1.95	1.97	2.00	2.03
	SOx	0.371	0.323	0.296	0.278	0.263	0.252	0.247	0.240	0.234	0.230	0.226
	PM	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235
Mini Bus	HC	5.66	4.92	4.30	3.82	3.38	3.05	2.76	2.53	2.31	2.17	2.02
	CO	11.37	9.20	7.62	6.35	5.45	4.72	4.17	3.75	3.45	3.21	3.03
	NOx	4.92	4.44	4.07	3.77	3.55	3.40	3.29	3.22	3.22	3.22	3.29
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
	PM	1.603	1.408	1.028	1.028	1.028	1.028	1.028	1.028	1.028	1.028	1.028
Medium/Large Bus	HC	7.60	6.59	5.76	5.09	4.55	4.07	3.68	3.39	3.10	2.91	2.71
	CO	26.68	21.68	17.79	14.87	12.79	11.12	9.73	8.76	8.06	7.50	7.09
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
	PM	4.481	3.935	2.872	2.872	2.872	2.872	2.872	2.872	2.872	2.872	2.872
Small Truck	HC	6.14	4.79	4.05	3.51	3.10	2.73	2.40	2.13	1.89	1.69	1.55
	CO	64.04	51.08	44.22	39.26	35.45	31.64	27.83	24.40	21.73	19.82	18.68
	NOx	2.95	3.10	3.31	3.57	3.82	4.08	4.30	4.52	4.66	4.81	4.92
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	PM	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Medium/Large Truck	HC	3.88	3.37	2.94	2.61	2.31	2.08	1.88	1.73	1.58	1.49	1.38
	CO	8.00	6.48	5.35	4.46	3.83	3.32	2.93	2.63	2.42	2.25	2.12
	NOx	6.22	5.61	5.15	4.78	4.49	4.29	4.15	4.07	4.05	4.07	4.17
	SOx	2.201	2.026	1.916	1.852	1.797	1.760	1.733	1.706	1.687	1.678	1.659
	PM	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632
Lorry/Trailer	HC	5.31	4.60	4.03	3.55	3.18	2.84	2.57	2.37	2.17	2.03	1.89
	CO	18.64	15.14	12.43	10.39	8.93	7.77	6.80	6.12	5.63	5.24	4.95
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448
	PM	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389