continual sampling by 24 hours for every three days

(6) Rectification for Ambient Air Condition

1) Normal Ambient Air

temperature: 25°C

barometric pressure: 760 mm of mercury column

2) Formula for Rectification

To determine the value of the air quality standards for the place concerned, the following formula should be used.

local standard values

$$= \text{standard values under the normal ambient air} \times \frac{\text{B.P.local}}{760} \times \frac{298°K}{273+t°C}$$

where: B.P.local = barometric pressure in millimeters of mercury

t°C = mean air temperature in degree centigrade

2.3.4 Emission Standards

The emission standards on air pollutant in Colombia were promulgated in the decree number 2 of 1982 by the kind of pollutant and the type of source facilities as shown in Table 2.3.1.

Table 2.3.1 Air Pollutant Emission Standard (Air Pollutant and Facility)

Designated pollutant or other requirement	Designated facilities
- particulates	- coal boiler - cement kiln - induction furnace or arc furnace for steel works - asphalt plant - other furnaces
- SO_2 - acid mist	- sulfuric acid production plant
- chimney height - sulfur content of fuel (6%)	- other boiler, furnace and machine with liquid fuel or solid fuel
- NO_2	- nitric acid production plant
- particulates - Ringelmann scale or opacity	- incinerator

Anybody who owns or operates the facilities designated in this decree is prohibited to emit such pollutants as particulates, sulfur-oxides, nitrogen-oxides and acid mist in case he comes under next three provisions.

(1) to generate pollutants in excess of the standard value stipulated in this decree in volume or concentration

(2) to discharge through the chimney which does not comply with the requirements or specifications stipulated in this decree

(3) to cause the worse pollution on the ground than the ambient air quality standards that is stipulated in this decree

In addition, in case that the additional proposed facility causes the pollution in excess of the ambient air quality standards in a certain zone, the additional installation of pollution source facilities will be prohibited.

The detail expression of the standards are given in Supporting Report 5.1.5.

2.3.5 Air Pollution Monitoring

The Environmental Protection Section, Environmental Sanitation Department of Health Bureau is conducting stationary pollutant emission source identification study and air quality monitoring. It has 13 monitoring stations within the city of Bogota, and the measurement activities had been conducted from 1984 to 1989. No measurement has ever been made for mobile sources.

CHAPTER 3 METEOROLOGY

CHAPTER 3 METEOROLOGY

3.1 Surface Meteorology

3.1.1 Summary of Observation Result

Wind vanes and anemometers were installed in five points shown in Fig. 3.1.1 in order to grasp meteorological characteristics of the area. And to classify the atmospheric stability a pyranometer and a balance meter were installed in station D. For details, refer to the Supporting Report.

The summary of observation is shown in Table 3.1.1.

Note here that "U" (Simon Bolivar) in the table means the result of surface meteorology observation obtained the upper layer observation point.

Table 3.1.1 Summary of Surface Meteorology Observation

Observation Point	Item	Observation Period	Obs. Hours	Average	Max.	Min.
A: Servicio de Salud	WD, WS	90' 11/16~8/31	6033	1.87 (E)	8.3	0.0
B: Laboratorio	WD, WS	90' 11/11~8/31	6687	2.02 (SE)	7.7	0.0
C: Puente Aranda	WD, WS	90' 11/12~8/31	6875	2.22 (SSE)	7.5	0.0
D: El Tunal	WD, WS	90' 11/14~8/31	6696	2.50 (SSE)	7.7	0.0
	SR	90' 11/16~8/31	6208	0.67	4.68	0.0
	NR	90' 11/16~8/31	6554	0.34	3.64	-0.50
E: San Juan de Dios	WD, WS	90' 11/11~8/31	6809	1.93 (S)	6.8	0.0
U: *(Simon Bolivar)*	WD, WS	90' 11/20~8/31	6285	2.61 (ESE)	13.0	0.0

Note 1. Figure in parentheses is prevailing wind direction.
2. WD: Wind Direction (16-direction mode)
WS: Wind Speed (m/s)
SR: Solar Radiation (MJ/m^2h)
NR: Net Radiation (MJ/m^2h)

3.1.2 Analysis of Observation Result

(1) Wind Rose

Fig. 3.1.2 shows the wind rose at each station.

The prevailing wind direction was WNW at station A, SE (though not so remarkable) at stations E and B, and SSE at station C. SSE and S direction were observed at extremely high frequency at station D, with the percentage running up to about 20%. The prevailing wind direction at station E was S. At station U, the prevailing wind direction was ESE. The wind speed was slightly high at 2.5 m/s at station D and low at around 1.8 m/s at station A and E. The wind speed at stations B and C can be ranked between these values and was 2.0 and 2.2 m/s respectively.

Proper attention should be paid when comparing data of station U with those of another station because this station is located slightly higher (about 37 m) above ground.

(2) Hourly Change of Wind Speed

Fig. 3.1.3 shows hourly change of wind speed at each station. In general, the wind speed was low at around 1 m/s between night and dawn, and reached the peak of about 3 - 4 m/s at around 14:00.

(3) Monthly Change of Wind Speed

Fig. 3.1.4 shows monthly change of wind speed at each station. In general, the wind speed was high in February and August and low in November, December, and March.

(4) Atmospheric Stability

The atmospheric stability was classified according to Table 3.1.2 while using the solar radiation and net radiation data obtained at station D and the wind speed observed at each station. The appearance frequency is shown in Fig. 3.1.5.

Table 3.1.2 Pasquill's Stability Classification (in Japan)

W.S. (m/s)	SR (cal/cm²•h)				NR (cal/cm²•h)		
	SR≥50	50>SR ≥25	25>SR ≥12.5	12.5>SR	NR>-1.8	-1.8≥NR >-3.6	-3.6≥NR
<2	A	A - B	B	D	D	(G)	(G)
2 ~ 3	A - B	B	C	D	D	E	F
3 ~ 4	B	B - C	C	D	D	D	E
4 ~ 6	C	C - D	D	D	D	D	D
6 <	C	D	D	D	D	D	D

(5) Similarity of Wind

The vector-correlation of wind was determined between observation points while using hourly wind direction and speed data in each point. The result is shown in Table 3.1.3.

Coefficient of correlation was not high as a whole. This means that each station was affected by the local wind.

Table 3.1.3 Vector-Correlation of Wind

	A	B	C	D	E	U
A : Servicio de Salud		5489	5676	5737	5445	5190
B : Laboratorio	0.54		6313	6157	6038	5660
C : Puente Aranda	0.55	0.58		6380	6264	5838
D : El Tunal	0.41	0.40	0.62		6131	5758
E : San Juan de Dios	0.41	0.45	0.61	0.71		5588
U : (Simon Bolivar)	0.46	0.38	0.46	0.43	0.43	

Note right-upper : sample-counts
left-lower : correlation coefficient

$$r(V_a, V_b) = \frac{\Sigma V_{ai} \cdot V_{bi} \cdot \cos\Delta\theta_i}{\Sigma V_{ai} \cdot V_{bi}}$$

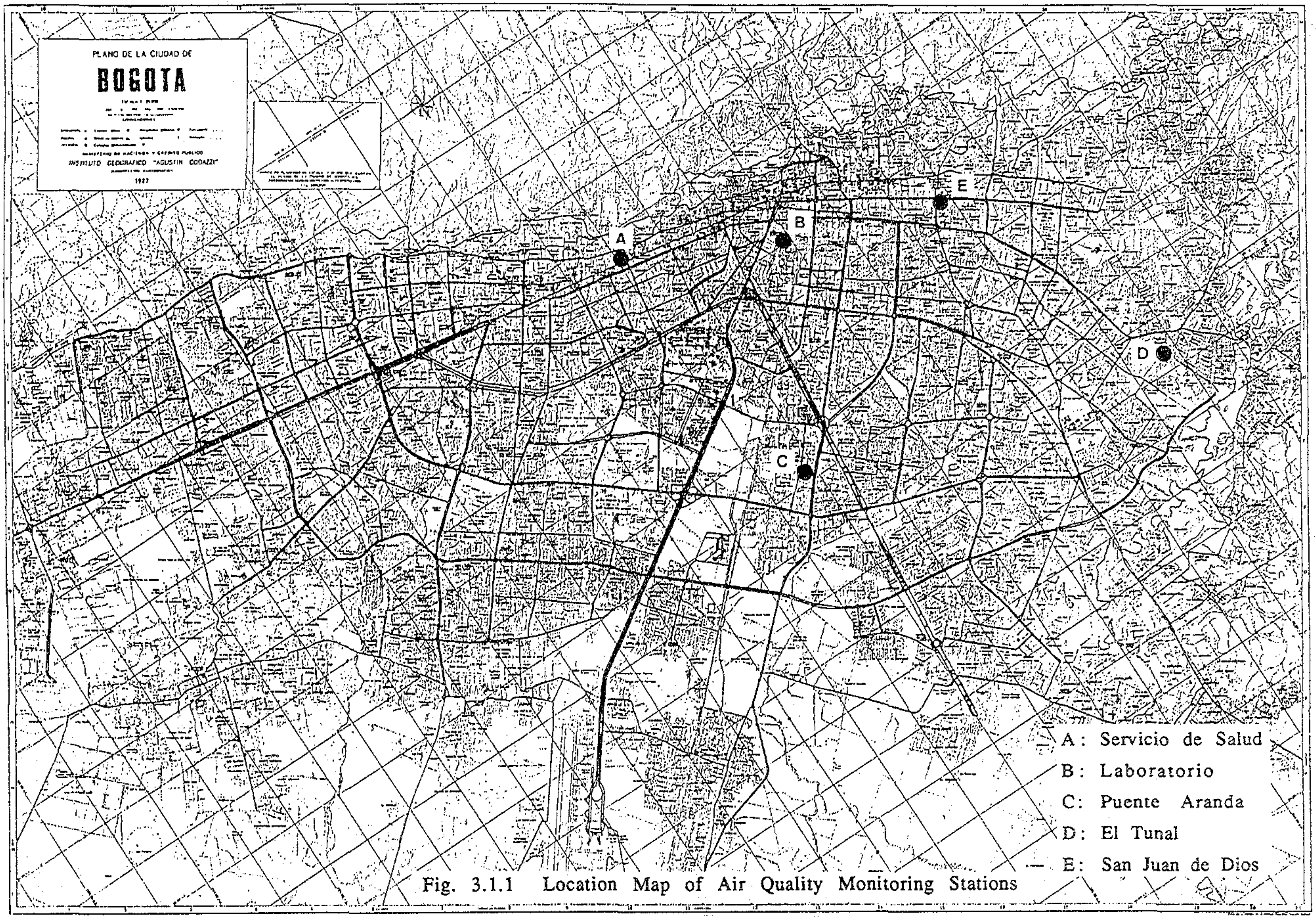


Fig. 3.1.1 Location Map of Air Quality Monitoring Stations

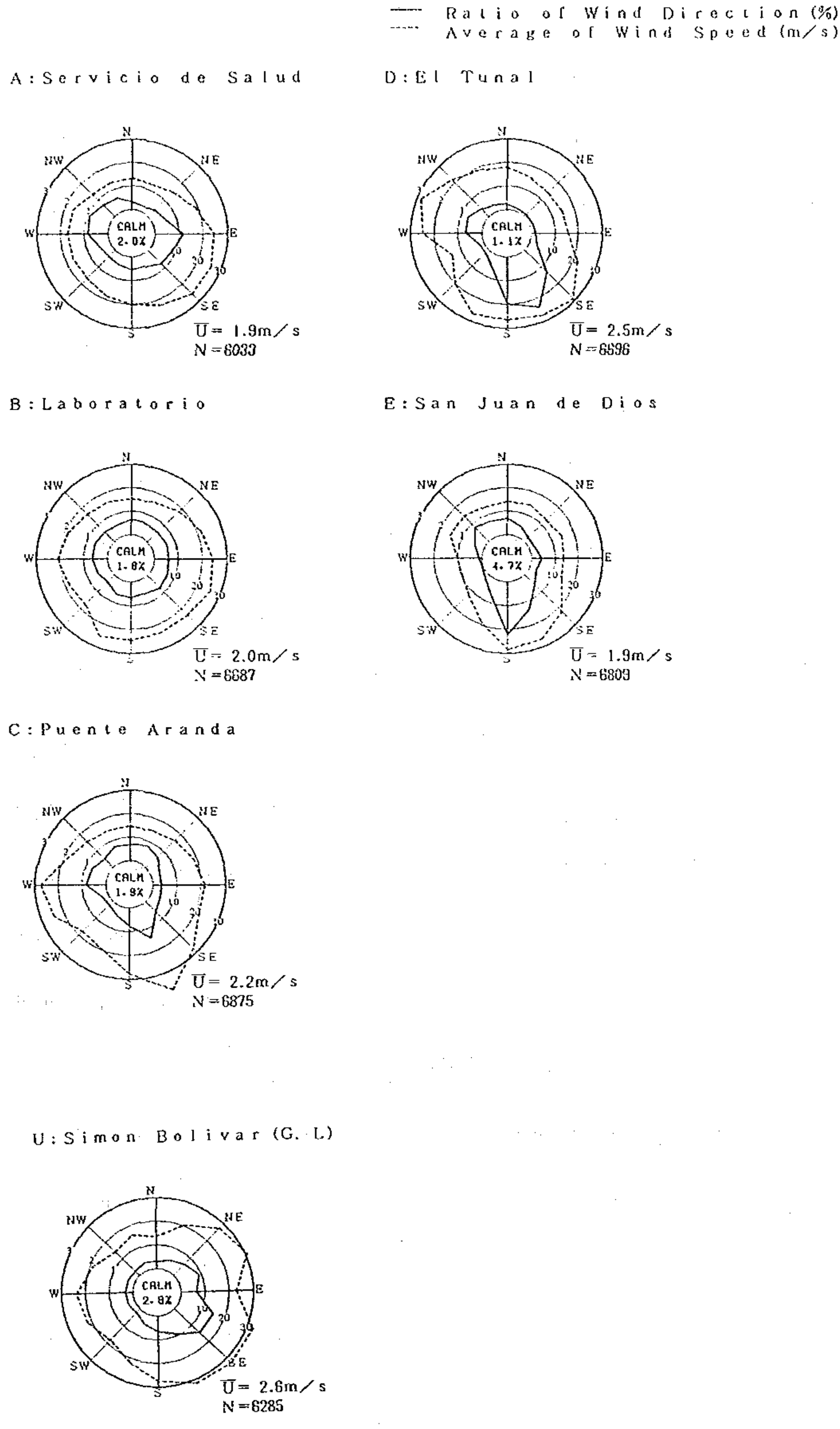


Fig.3.1.2 Wind Rose

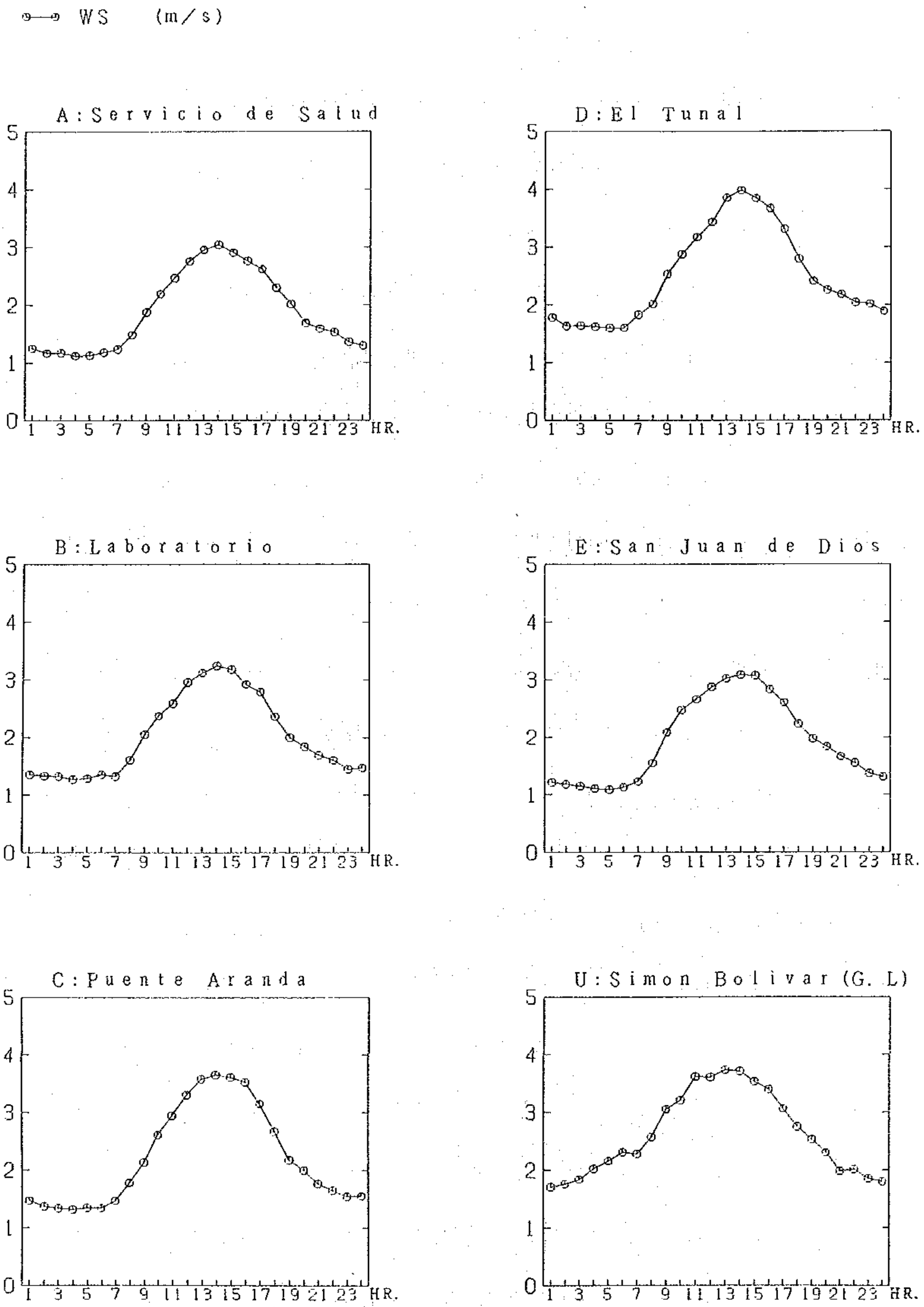


Fig. 3.1.3 Hourly Change of Wind Speed

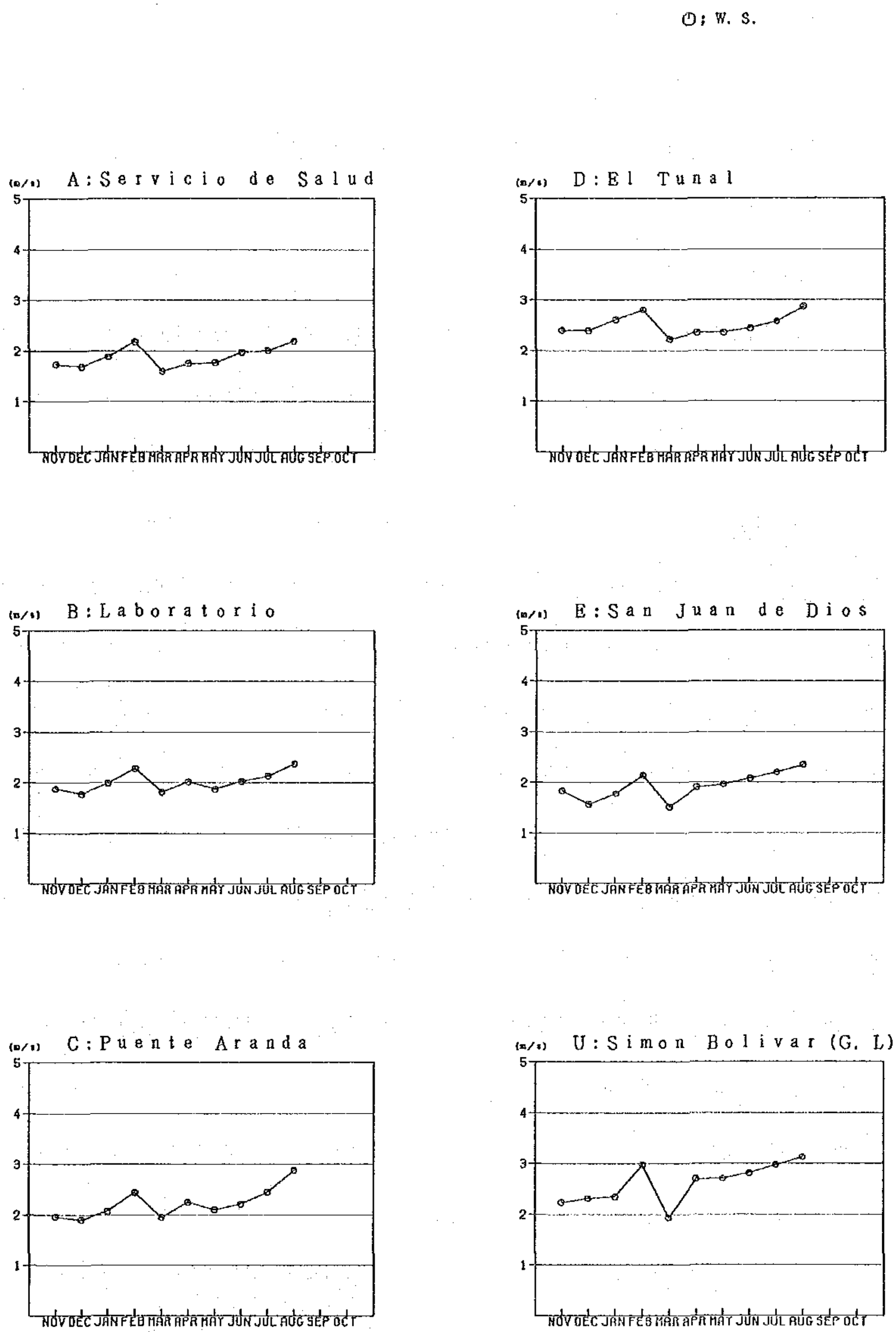


Fig. 3.1.4 Monthly Change of Wind Speed

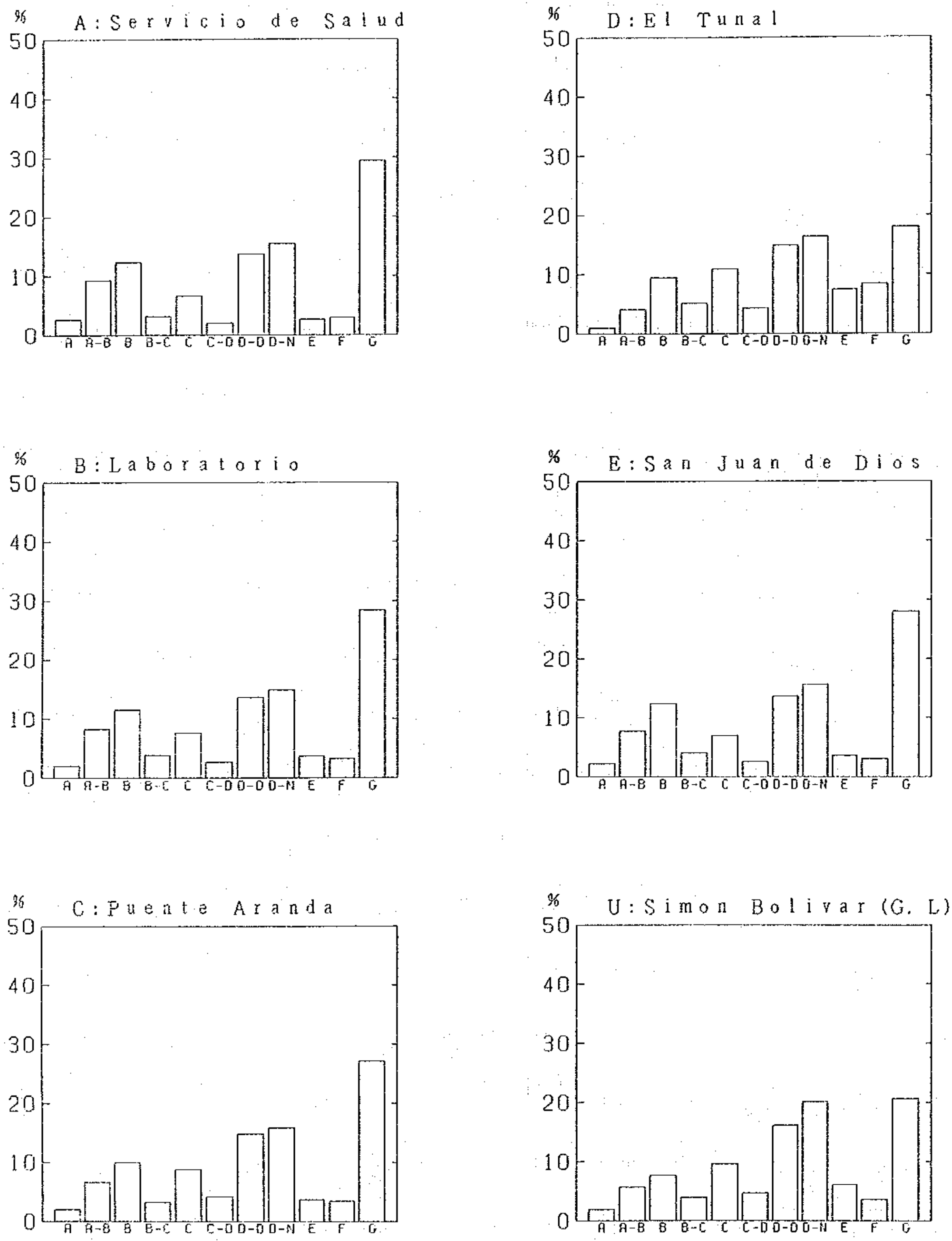


Fig. 3.1.5 Appearance Frequency of Atmospheric Stability

3.2 Upper Layer Meteorology

3.2.1 Summary of Observation Result

Upper layer meteorology observation was conducted four times, each time for seven days, at Hospital Simon Bolivar (Carrela 7, Calle 169). The result is summarized in Table 3.2.1.

Table 3.2.1 Summary of Upper Layer Meteorology Observation

Unit W.S.; m/s, TEMP; °C

Height (m)		1st 11/2~11/18	2nd 11/29~12/5	3rd 2/22~2/28	4th 5/28~6/3	Total
0	W.S.	1.78 4.6	1.74 4.3	2.54 6.1	2.52 5.4	2.18 6.1
	TEMP	14.6 19.6	14.3 20.2	14.8 18.3	15.3 20.0	14.8 20.2
	SAMP	(41)	(40)	(46)	(50)	(177)
50	W.S.	2.92 5.7	2.27 6.5	3.86 7.8	3.46 6.7	3.17 7.8
	TEMP	13.8 17.4	13.7 18.4	14.1 17.5	14.7 19.3	14.1 19.3
	SAMP	(41)	(40)	(46)	(50)	(177)
100	W.S.	3.44 7.6	2.42 8.5	4.46 8.4	3.73 8.4	3.54 8.5
	TEMP	13.4 16.9	13.4 17.7	13.7 16.6	14.1 18.0	13.7 18.0
	SAMP	(41)	(40)	(44)	(49)	(174)
150	W.S.	3.38 5.9	2.27 4.3	4.95 8.4	3.56 7.2	3.57 8.4
	TEMP	13.0 16.6	13.1 17.4	13.1 16.2	13.7 17.6	13.3 17.6
	SAMP	(40)	(39)	(43)	(45)	(167)
200	W.S.	3.23 5.5	2.54 6.5	5.08 8.2	3.70 7.3	3.66 8.2
	TEMP	12.7 15.8	12.7 16.9	12.7 16.0	13.2 17.0	12.8 17.0
	SAMP	(40)	(38)	(41)	(44)	(163)
250	W.S.	3.02 5.7	2.54 6.5	5.54 8.7	3.80 7.5	3.73 8.7
	TEMP	12.3 15.2	12.3 16.6	12.1 15.0	12.8 16.5	12.4 16.6
	SAMP	(39)	(38)	(39)	(43)	(159)
300	W.S.	3.04 6.8	2.53 7.0	5.11 8.5	4.01 7.6	3.64 8.5
	TEMP	11.9 14.8	12.0 16.0	11.8 14.6	12.4 16.1	12.0 16.1
	SAMP	(37)	(38)	(34)	(41)	(150)
350	W.S.	2.95 6.7	2.87 8.3	4.90 7.2	3.86 8.4	3.60 8.4
	TEMP	11.3 14.3	11.7 15.7	11.2 14.1	12.0 15.6	11.6 15.7
	SAMP	(34)	(38)	(30)	(41)	(143)
400	W.S.	2.73 4.8	2.66 5.7	4.83 8.1	3.57 7.4	3.36 8.1
	TEMP	10.8 13.8	11.4 15.2	10.8 13.9	11.7 15.0	11.2 15.2
	SAMP	(32)	(37)	(26)	(39)	(134)
450	W.S.	2.98 5.0	2.67 6.1	5.00 8.5	3.63 7.1	3.48 8.5
	TEMP	10.3 12.8	11.2 15.0	10.5 13.3	11.4 14.5	10.9 15.0
	SAMP	(27)	(35)	(24)	(38)	(124)
500	W.S.	3.15 5.5	2.88 6.2	5.14 6.9	3.48 7.4	3.53 7.4
	TEMP	9.9 12.3	10.8 14.4	10.1 13.1	11.0 14.3	10.5 14.4
	SAMP	(26)	(34)	(21)	(37)	(118)

Note : left ; Ave., right ; Max.

3.2.2 Analysis of Observation Result

(1) Average Wind Rose

Fig. 3.2.1 shows the average wind rose by height determined from upper layer meteorology observation.

The wind speed was nearly constant at 100m or more while the wind direction had a tendency to gather toward ESE.

(2) Vertical Profile of Temperature

Fig. 3.2.2 shows the averaged profiles of temperature obtained from four times of the observation. The temperature of "0 m" seemed to be slightly high. There might be some effect of being warmed by solar radiation, because it was measured on the roof of a building.

(3) Appearance of Inversion Layer

The appearance situation of inversion layer was grasped by two viewpoints below.

① By setting fixing height (100m or 200m), each data was classified to lower inversion, upper inversion, other inversion and no inversion. The summary is shown in Tables 3.2.2 to 3.2.3. Note that only the time for which all data up to the fixing height were obtained was used as an effective sample.

② Table 3.2.4 shows the appearance situation of surface inversion. The effective sample was the time for which at least 0 and 50m data had been obtained.

In either case, an inversion was defined as $t_{i+1} > t_i$ (t_i ; i-th temperature). All section in which inversion continued was treated as one inversion layer.

The result shows that the inversion layer appeared most frequently in the second observation with the percentage of 25.6% (fixing height 100m). And the lower inversion was most frequent of all inversions. The average Δt was also highest in the second observation.

It may be interesting to consider this fact in conjunction with the widest temperature range in the second observation as known from Fig. 3.2.2.

The surface inversion appeared most frequently at 10.0% in the second observation.

For reference

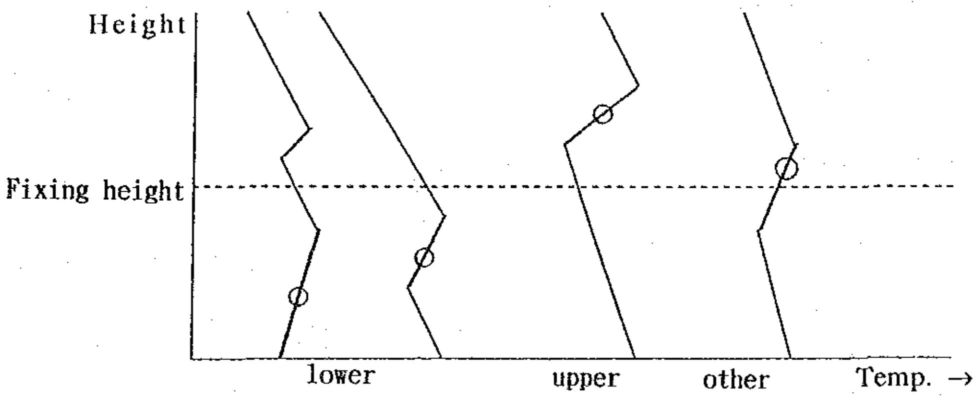


Table 3.2.2 Appearance Situation of Inversion Layer
(Fixing height=100m)

	Lower	Upper	Other	No Inv.	Samples
1st	5 (12.5%)	3 (7.5%)	0 (–)	32 (80.0%)	40
Ave. Δt (°C)	0.20	0.37	–	–	
Ave. Δz (m)	60.0	50.0	–	–	
2nd	5 (12.8%)	3 (7.7%)	2 (5.1%)	29 (74.4%)	39
Ave. Δt (°C)	0.66	0.37	1.85	–	
Ave. Δz (m)	60.0	66.7	150.0	–	
3rd	3 (7.3%)	0 (–)	0 (–)	40 (93.0%)	43
Ave. Δt (°C)	0.33	–	–	–	
Ave. Δz (m)	50.0	–	–	–	
4th	4 (8.9%)	2 (4.4%)	0 (–)	39 (86.7%)	45
Ave. Δt (°C)	0.13	0.25	–	–	
Ave. Δz (m)	50.0	50.0	–	–	
Total	17 (10.2%)	8 (4.8%)	2 (1.2%)	140 (83.8%)	167
Ave. Δt (°C)	0.34	0.34	1.85	–	
Ave. Δz (m)	55.9	56.3	150.0	–	

Note Unit ; Δt : °C, Δz : m
( ) : %

Table 3.2.3 Appearance Situation of Inversion Layer
(Fixing height=200m)

	Lower	Upper	Other	No Inv.	Samples
1st	8 (23.5%)	3 (8.8%)	0 (-)	23 (67.6%)	34
Ave. Δt (°C)	0.26	0.10	-	-	
Ave. Δz (m)	56.3	50.0	-	-	
2nd	10 (26.3%)	6 (15.8%)	0 (-)	22 (57.9%)	38
Ave. Δt (°C)	0.81	0.98	-	-	
Ave. Δz (m)	80.0	66.7	-	-	
3rd	3 (9.4%)	3 (9.4%)	0 (-)	26 (81.3%)	32
Ave. Δt (°C)	0.33	0.10	-	-	
Ave. Δz (m)	50.0	50.0	-	-	
4th	6 (14.3%)	2 (4.8%)	0 (-)	34 (81.0%)	50
Ave. Δt (°C)	0.17	0.85	-	-	
Ave. Δz (m)	50.0	50.0	-	-	
Total	27 (18.5%)	14 (9.6%)	0 (-)	105 (71.9%)	177
Ave. Δt (°C)	0.45	0.59	-	-	
Ave. Δz (m)	63.0	57.1	-	-	

Table 3.2.4 Appearance Situation of Surface Inversion

	Appearance	Ave. Δ t (°C)	Ave. Δ z (m)	Samples
1st	2 (4.9%)	0.25	75.0	41
2nd	4 (10.0%)	0.55	62.5	40
3rd	1 (2.2%)	0.20	50.0	46
4th	3 (6.0%)	0.13	50.0	42
Total	10 (5.6%)	0.33	60.0	146

(4) Calculation of the P Value (Power law of wind speed)

The p value was calculated from the wind speed by height obtained at the upper layer observation point (Simon Bolivar).

It was attempted to classify the values with the atmospheric stability, which was deduced from solar radiation and net radiation at station D (El Tunal), into "Unstable", "Neutral", and "Stable". But there was no case to be classified into "Stable" because observation was conducted in the daytime only. Note that the p value was calculated from the wind speed averaged in each class (height, stability). Estimated heights included two cases of o - 100m and 0 - 200m. The results are shown in Tables 3.2.5 and 3.2.6.

As known from the result, the p value under "Unstable" was larger than that under "Neutral" in all cases. However, the numerical value in the "Total" column shows substantial difference among observations.

Table 3.2.5 P Value Calculation Result (Data from 0 to 100m)

	Unstable	Neutral	Stable	Total*
1st (11/2~)	– (–)	– (–)	– (–)	0.446 (82)
2nd (11/29~))	0.245 (48)	0.191 (22)	– (–)	0.231 (80)
3rd (2/22~)	0.496 (49)	0.241 (41)	– (–)	0.379 (90)
4th (5/28~)	– (–)	– (–)	– (–)	0.275 (99)
Total	0.378 (97)	0.220 (63)	– (–)	0.333 (351)

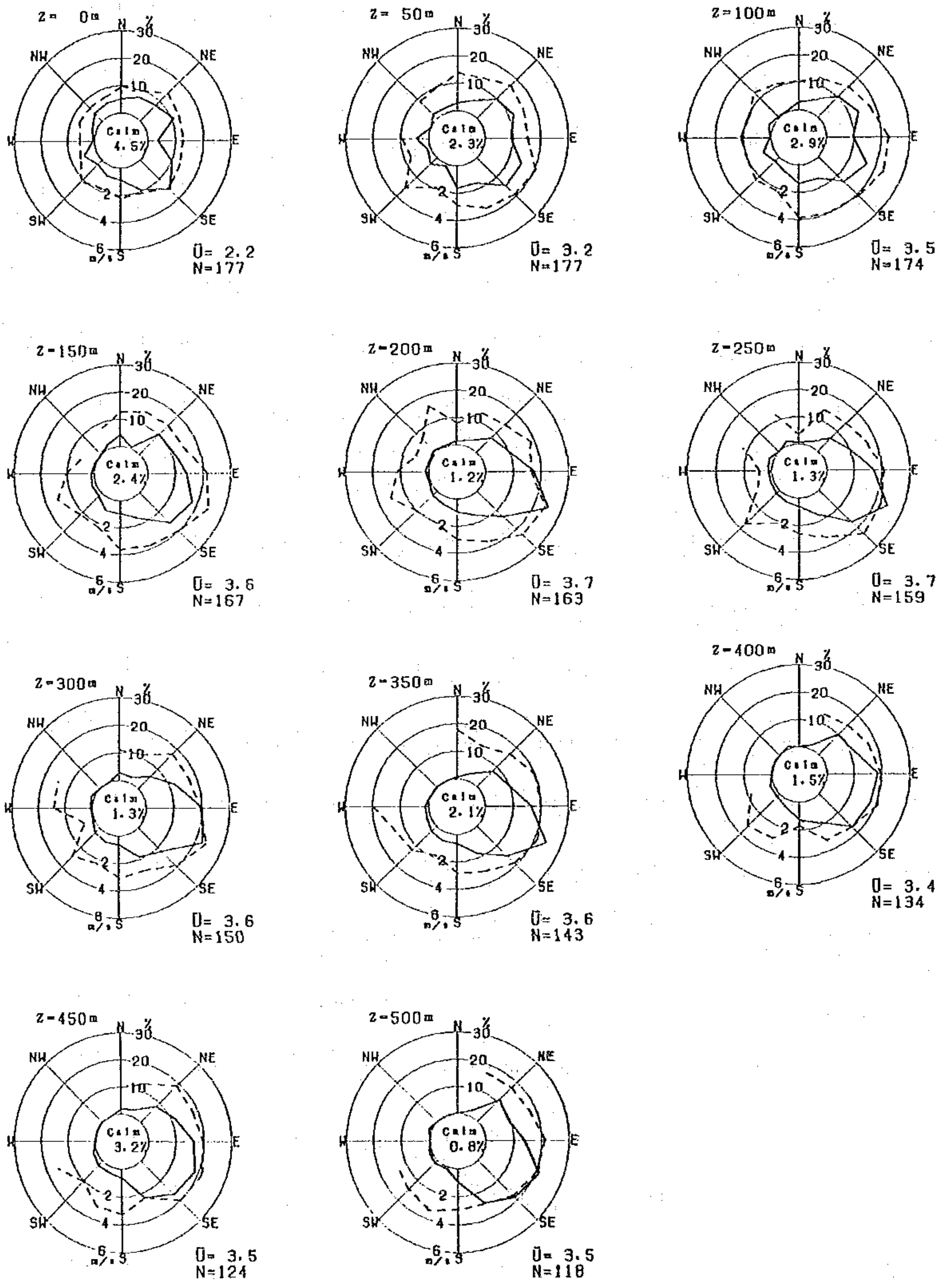
Table 3.2.6 P Value Calculation Result (Data from 0 to 200m)

	Unstable	Neutral	Stable	Total*
1st (11/2~)	– (–)	– (–)	– (–)	0.378 (162)
2nd (11/29~))	0.220 (95)	0.132 (42)	– (–)	0.194 (157)
3rd (2/22~)	0.449 (93)	0.253 (81)	– (–)	0.358 (174)
4th (5/28~)	– (–)	– (–)	– (–)	0.228 (188)
Total	0.341 (188)	0.205 (123)	– (–)	0.290 (681)

Note: "Total" covers all cases in which wind speed data were obtained even though solar radiation or net radiation weren't observed. Accordingly, the "Total" is larger than the sum of "Unstable" and "Neutral".

Fig. 3.2.1 Wind Rose of Upper Layer "Total"

at Simon Bolivar



Temperature Profile (Average)

Observed Point : Simon Bolivar (U. L.)

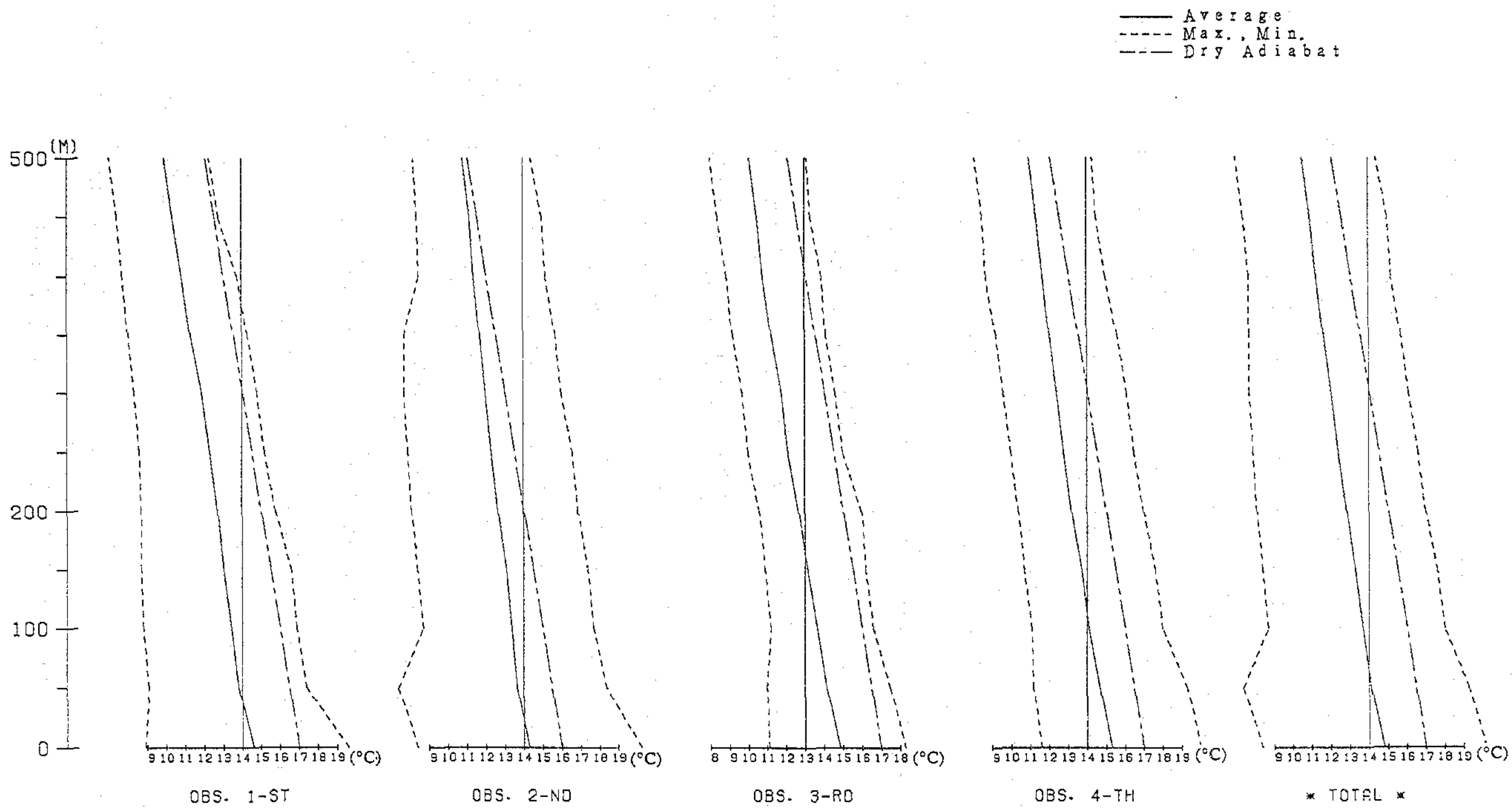


Fig. 3.2.2 Averaged Profile of Temperature

CHAPTER 4 AMBIENT AIR QUALITY

CHAPTER 4 AMBIENT AIR QUALITY

4.1 Concentration at Monitoring Stations

4.1.1 Summary of Measurement Results

The results of measurement at monitoring stations are shown in Table 4.1.1.

The SO_2 value ranged from 7.0 to 25.2 ppb in average, and was lowest at the station A and highest at station E. The CO value ranged from 1.5 to 8.5 ppm in average, and was lowest at station D and highest at station E. The NOx value ranged from 27.1 to 101.2 ppb in average while the NO_2 value ranged from 16.5 to 33.3 ppb. They were lowest at station D and highest at station E. As regards SPM, the average value ranged from 43 to 70 $\mu g/m^3$, with the lowest value at station B and the highest at station C.

Table 4.1.2 shows state of compliance with the national ambient air quality standard values of Colombia.

Values of SO_2, NO_2, and SPM were all under the standards. As regards SPM, however, the national standard of Colombia is based on measurement with the high-volume air sampler, but in this study the β-ray absorption method was used at monitoring stations, covering the particle diameter of 10 μm or less. As a result, there exists difference in the concentration from existing stations (see 4.3). Since existing stations are measuring SP, the difference between SPM and SP may be clarified through comparison if data for the same period are available.

The CO value exceeded the standard at stations A and E. At station E, the excess was high at 13% of 8 hours value. The O_3 value exceeded the standard in all two stations.

Table 4.1.1 Summary of the Measurement at Monitoring Stations

('90.11 ~ '91.8)

Station	Item	SO_2 ppb	CO ppm	NOx ppb	NO ppb	NO_2 ppb	SPM $\mu g/m^3$	T-HC ppmC	CH_4 ppmC	n-CH4 ppmC	O_3 ppb
A: Servicio de Salud	Ave.	7.0	4.70	60.4	33.1	27.2	53.1	-	-	-	-
	Hour	5513	4973	6478	6478	6478	6502	-	-	-	-
	Max.	71	23.9	331	265	215	387	-	-	-	-
	Min.	0	0.0	0	0	0	0	-	-	-	-
B: Laboratorio	Ave.	9.9	2.28	27.4	7.3	20.0	43.3	-	-	-	-
	Hour	6248	5292	6212	6212	6212	5612	-	-	-	-
	Max.	90	16.3	212	110	144	397	-	-	-	-
	Min.	0	0.0	0	0	0	0	-	-	-	-
C: Puente Aranda	Ave.	22.9	1.99	39.2	16.0	23.2	70.2	3.87	2.01	1.86	10.7
	Hour	6419	5755	6488	6488	6488	5415	4164	4164	4164	6153
	Max.	89	19.3	245	217	132	322	15.3	4.7	13.0	123
	Min.	0	0.0	0	0	0	0	1.7	0.9	0.1	0
D: El Tunal	Ave.	8.6	1.53	27.1	10.6	16.5	59.1	-	-	-	-
	Hour	6008	5647	6153	6153	6153	6669	-	-	-	-
	Max.	73	9.9	258	221	139	567	-	-	-	-
	Min.	0	0.0	0	0	0	0	-	-	-	-
E: San Juan de Dios	Ave.	25.2	8.45	101.2	68.0	33.3	62.2	4.69	1.99	2.70	6.7
	Hour	6502	6422	6102	6102	6102	5845	4451	4451	4451	3716
	Max.	147	29.5	344	312	282	575	13.3	4.1	11.1	114
	Min.	0	0.0	1	0	0	0	1.7	1.3	0.0	0

Table 4.1.2 State of Compliance with the Ambient Air Quality Standard

Item	SO_2			NO_2	SPM		CO		O_3
Station Standard	3 Hour 573.1	Daily 152.8	Ann. 38.2	Ann. 53.2	Daily 400.0	Ann. 100.0	1 Hour 43.7	8 Hour 13.1	1 Hour 86.6
A : Servicio de Salud	o	o	o	o	o	o	o	1.4%	o
B : Laboratorio	o	o	o	o	o	o	o	o	o
C : Puente Aranda	o	o	o	o	o	o	o	o	0.4%
D : El Tunal	o	o	o	o	o	o	o	o	o
E : San Juan de Dios	o	o	o	o	o	o	o	13.0%	0.2%

Note 1. For SPM, arithmetic average is used.
2. '%' is the ratio over the standard.

4.1.2 Analysis of the Air Quality Concentration

(1) Hourly Change

Fig. 4.1.1 shows hourly change of air **quality** concentration and Fig. 4.1.2 shows that in weekend.

Change of SO_2 was a one-peak type, with the peak appearing at 8:00 to 9:00. The concentration in stations B, C, and D reached the bottom at 12:00 to 14:00 and rose gradually toward midnight. In station E, however, the concentration remained high in daytime after reaching the peak in the morning and lowered toward night.

As regards CO, it was a two-peak type, with peaks appearing at 7:00 to 9:00 in the morning and at 18:00 - 20:00 in the evening respectively.

NOx showed two peaks during hourly change. The first was a morning peak at 7:00 - 8:00 and the second was a evening one at 18:00 to 22:00 with a gentle slope. The peak of NO appeared early at 7:00 while that of NO_2 delayed by one to two hours. Note that the morning peak was lower at weekend for both CO and NOx.

As regards SPM, the morning peak at 8:00 to 9:00 was remarkable and there was no particular peak in the evening.

As for HC, CH_4 was nearly constant while NMHC and T-HC had a peak at 7:00 for station C and 8:00 for station E.

O_3 had a sharp peak, which started at around 8:00 and reached the top at around 10:00. But the concentration level differed substantially between stations C and E.

(2) Weekly Change

Fig. 4.1.3 shows the weekly change.

The SO_2 value was low in all stations on Sunday and high on Friday or Saturday.

CO was low on Sunday and high on Friday, but high on Saturday at stations D and E.

As regards NOx, the pattern seemed to be similar to CO.

The SPM value was low on Sunday and high on Saturday or Friday.

As for HC, CH_4 was nearly constant while the NMHC and T-HC were high on Friday and low on Saturday and Sunday. At station E, however, they were high on Wednesday and Saturday and low on Sunday.

(3) Monthly Change

Fig. 4.1.4 shows monthly change.

As for SO_2, there was remarkable difference among stations.

As regards CO, there was no particular difference among stations B, C and D. Though the data in April was lacking at station A, there was remarkable change, which had a peak in March, at stations A and E.

NOx had a similar pattern to CO in stations other than station E. NO_2 had the highest value in March at every station.

SPM seemed to have a peak in March at every station.

As for HC, NMHC and T-HC had a peak in November, but no particular consideration was made because the measurement was started in this month and the period of it was too short of a week.

As regards O_3, the concentration level of station E lowered extremely from March and the data in July was lacking. This fact needs to be taken into account when considering the analytical result in following sections.

(4) Correlation between Pollutants at Each Station

Fig. 4.1.5 shows correlation of daily mean value between NOx and CO, NOx and SPM, and SPM and CO.

The coefficient of correlation was high in all cases. Especially it was very high between NOx and CO, which were considered to be caused by motor vehicles. At station E which is located along a road, the values varied widely.

Fig. 4.1.1 ① Hourly Change

YEAR ; 1990

(Total)

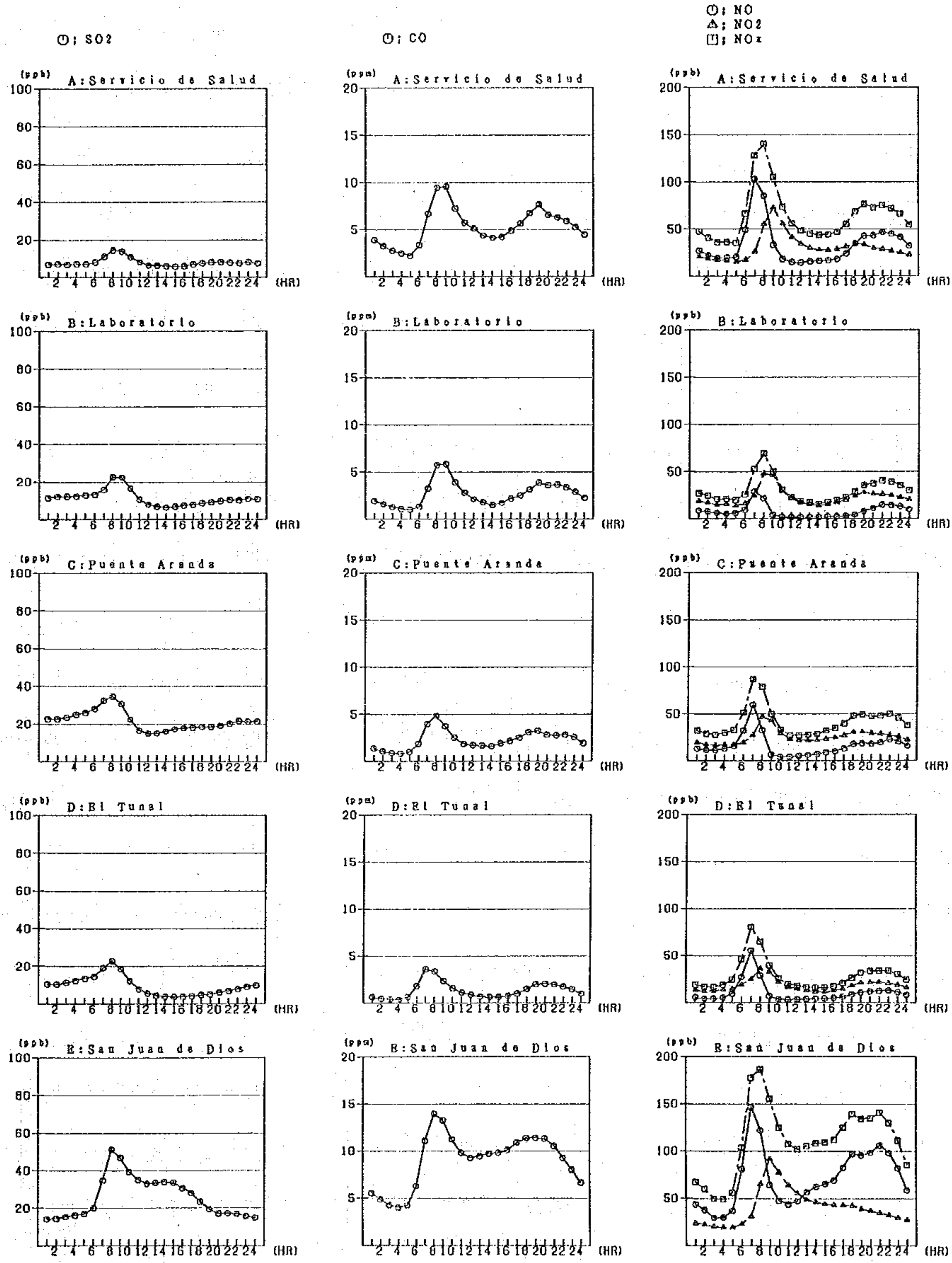


Fig. 4.1.1 ② Hourly Change

YEAR ; 1990

(Total)

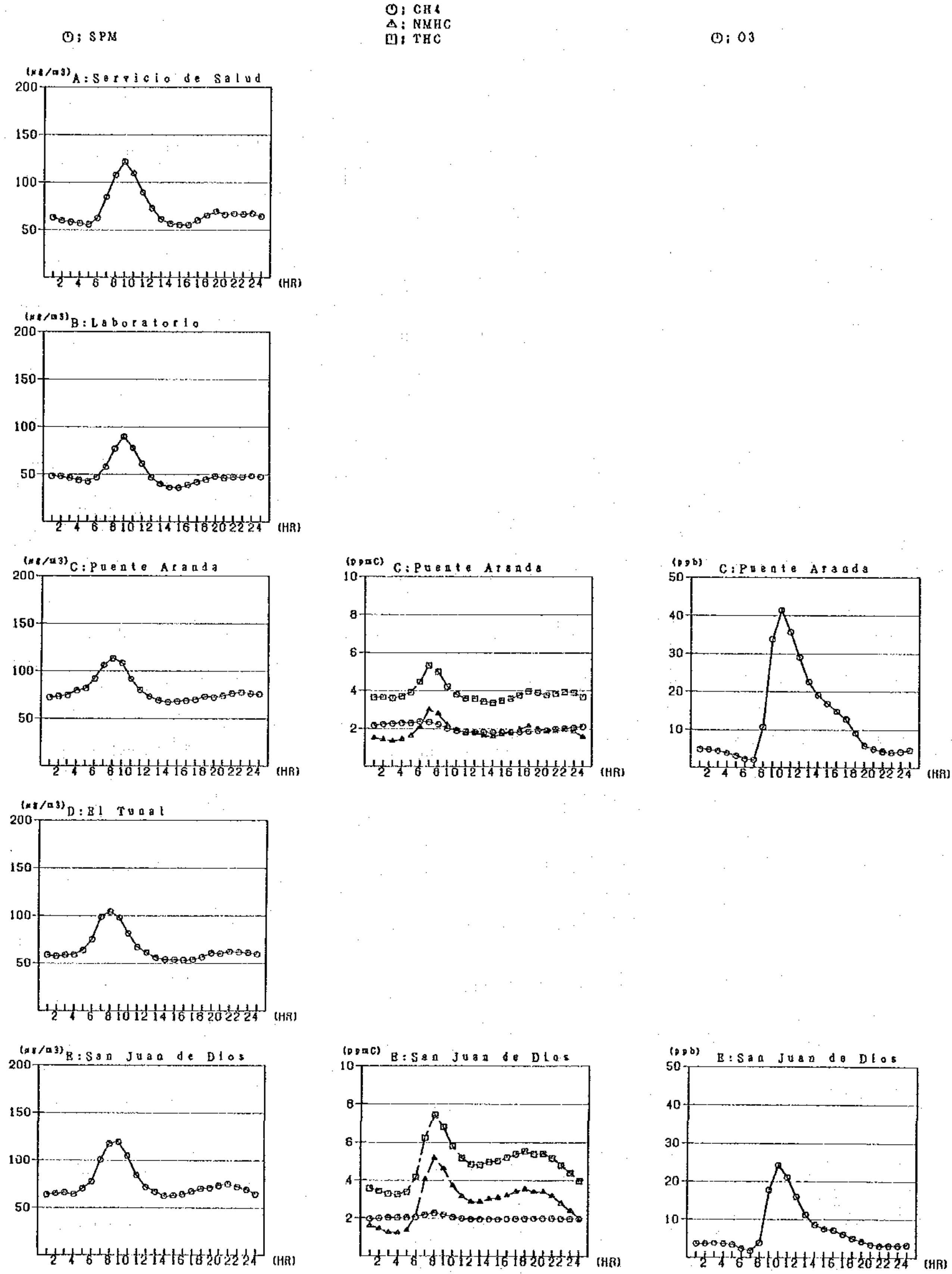


Fig. 4.1.2 ① Hourly Change

YEAR ; 1990

Week End (SAT, SUN)

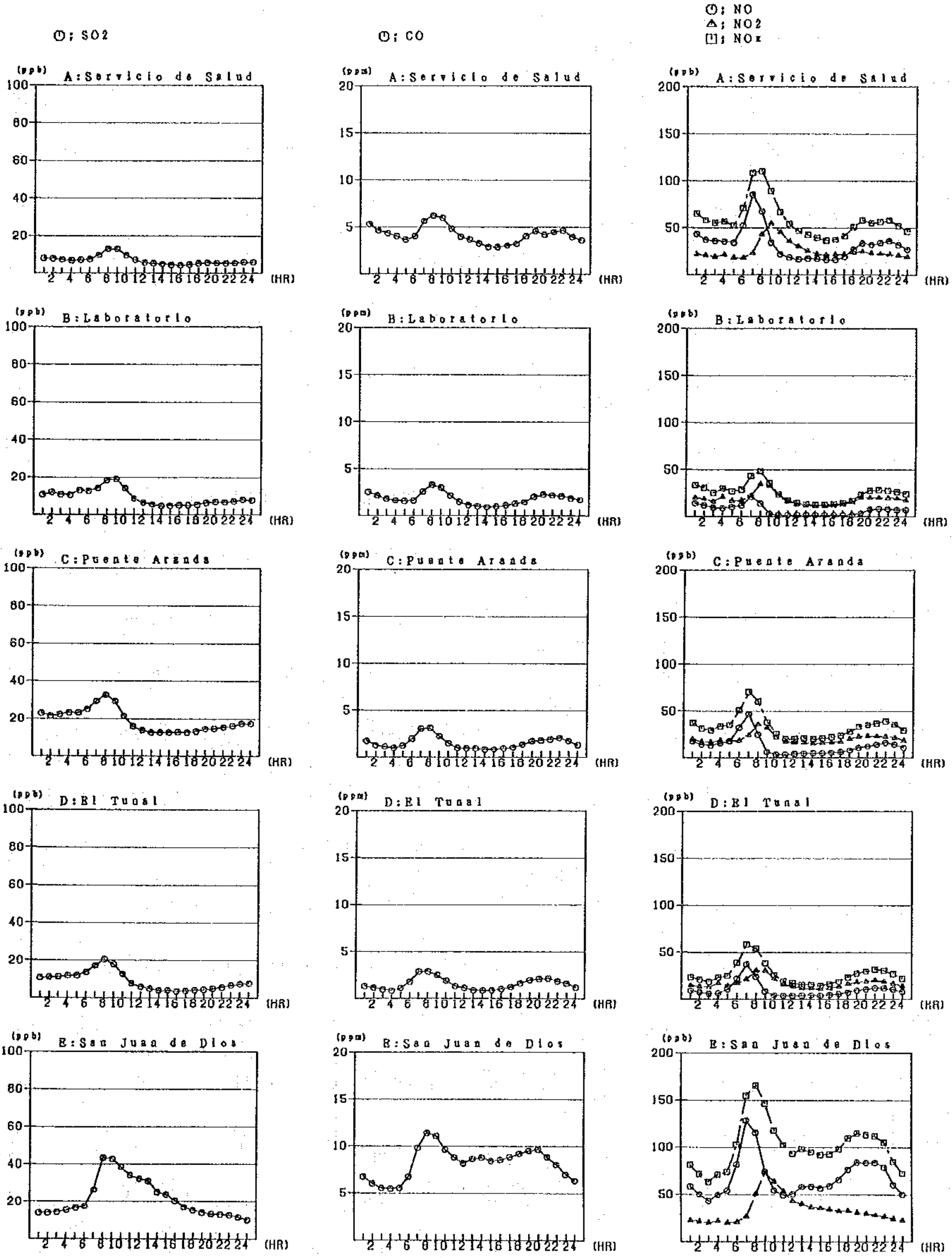


Fig. 4.1.2 ② Hourly Change

YEAR ; 1990

Week End (SAT, SUN)

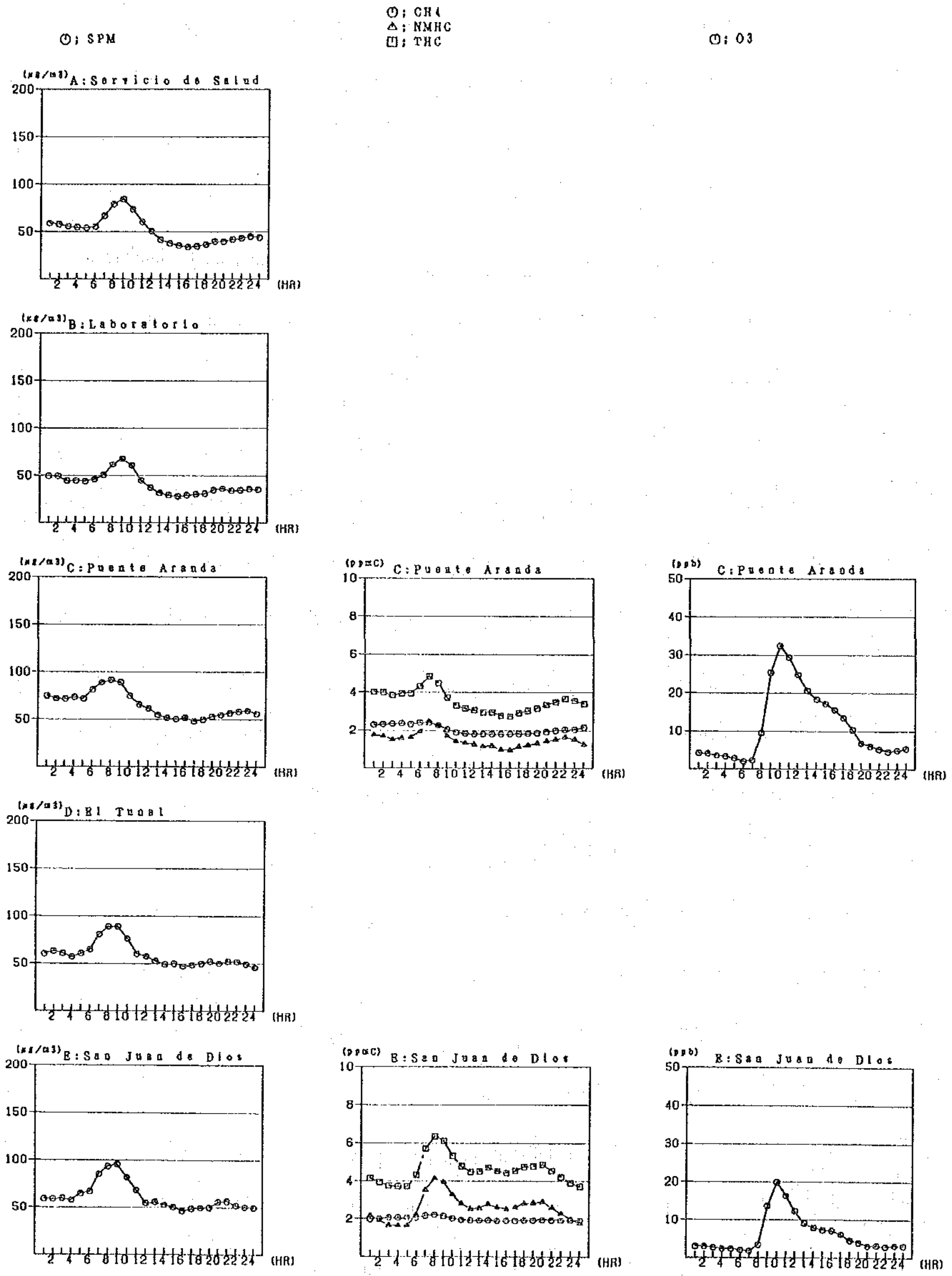


Fig. 4.1.3 ① Weekly Change

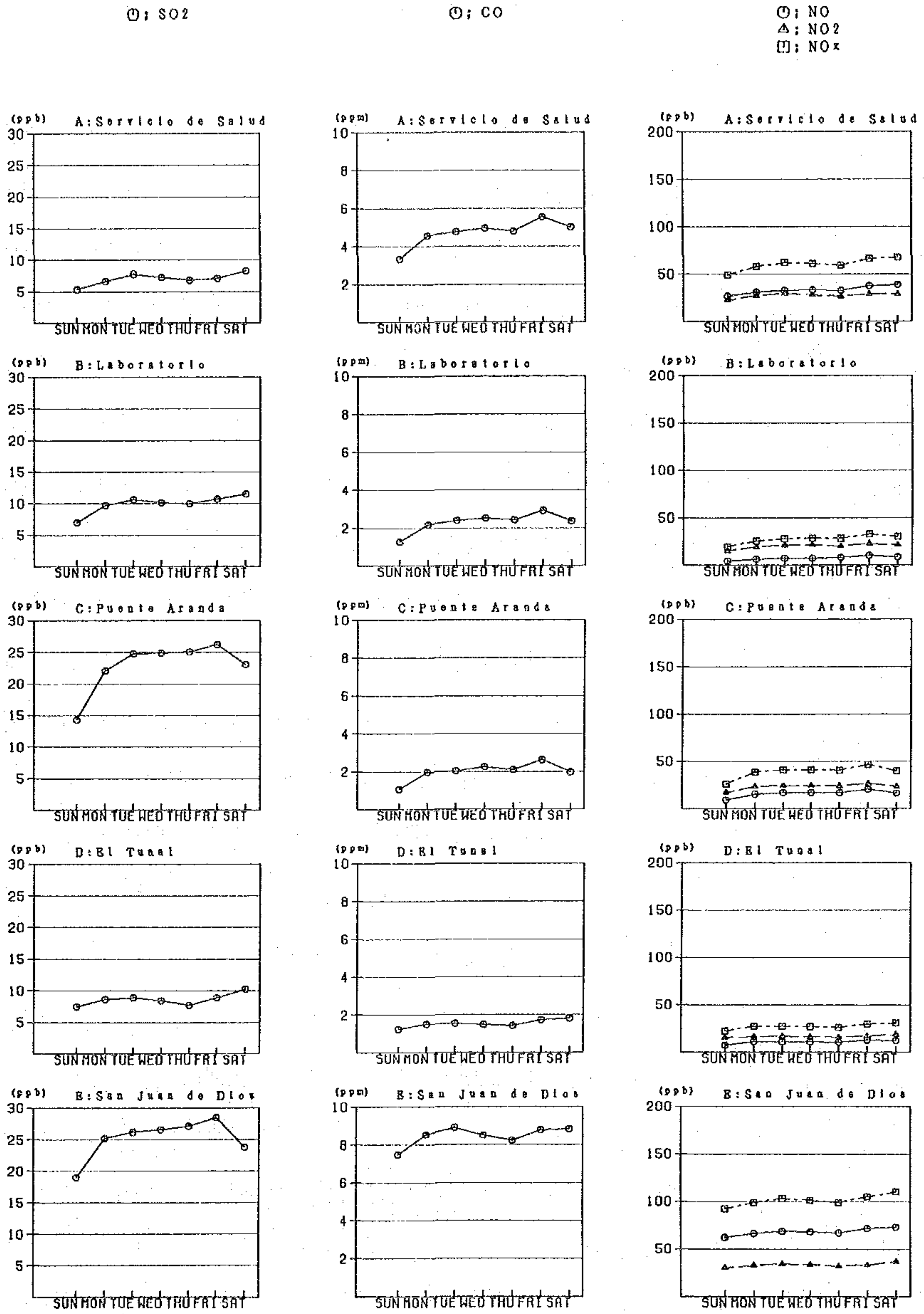


Fig. 4.1.3 ② Weekly Change

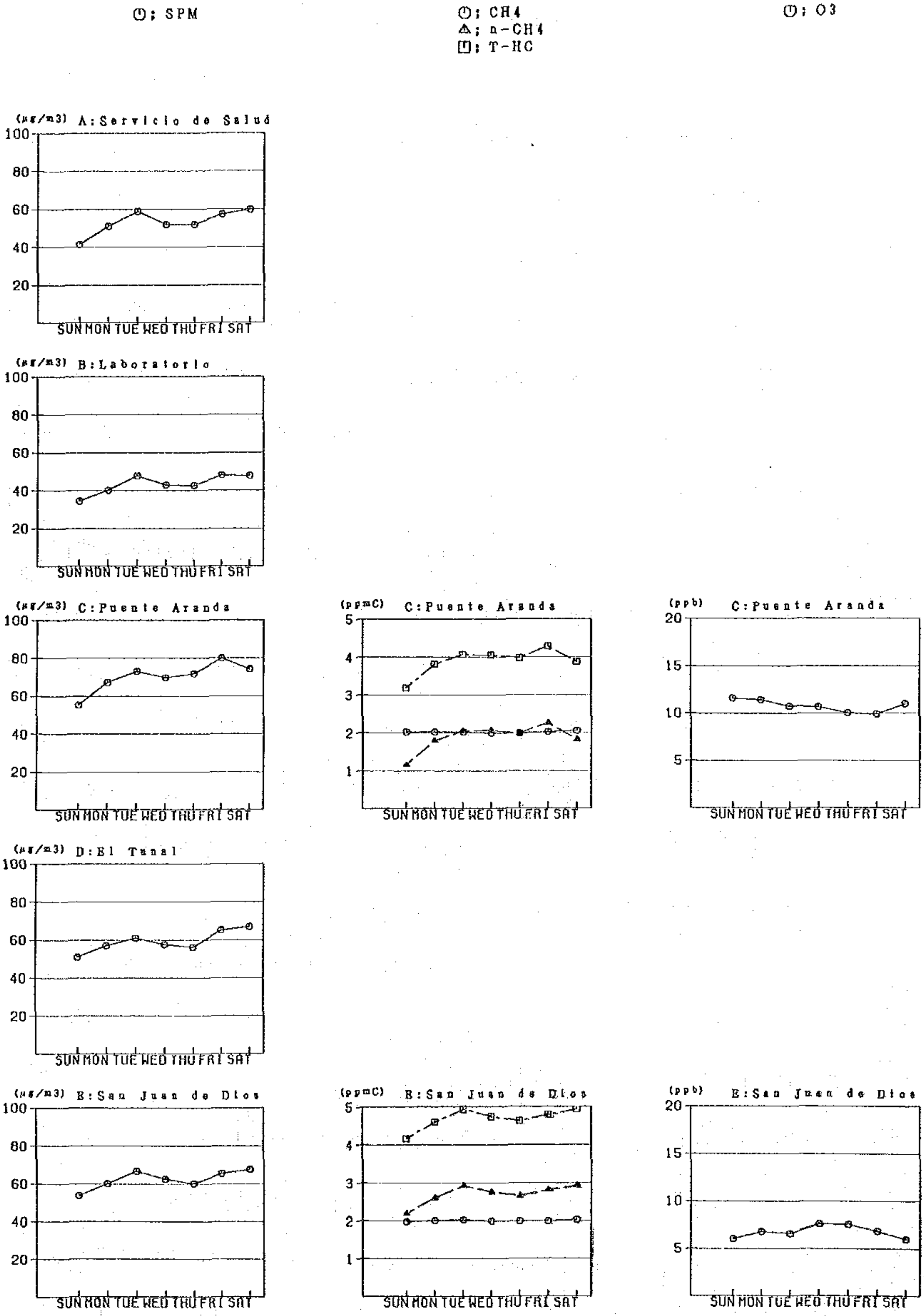


Fig. 4.1.4 ① Monthly Change

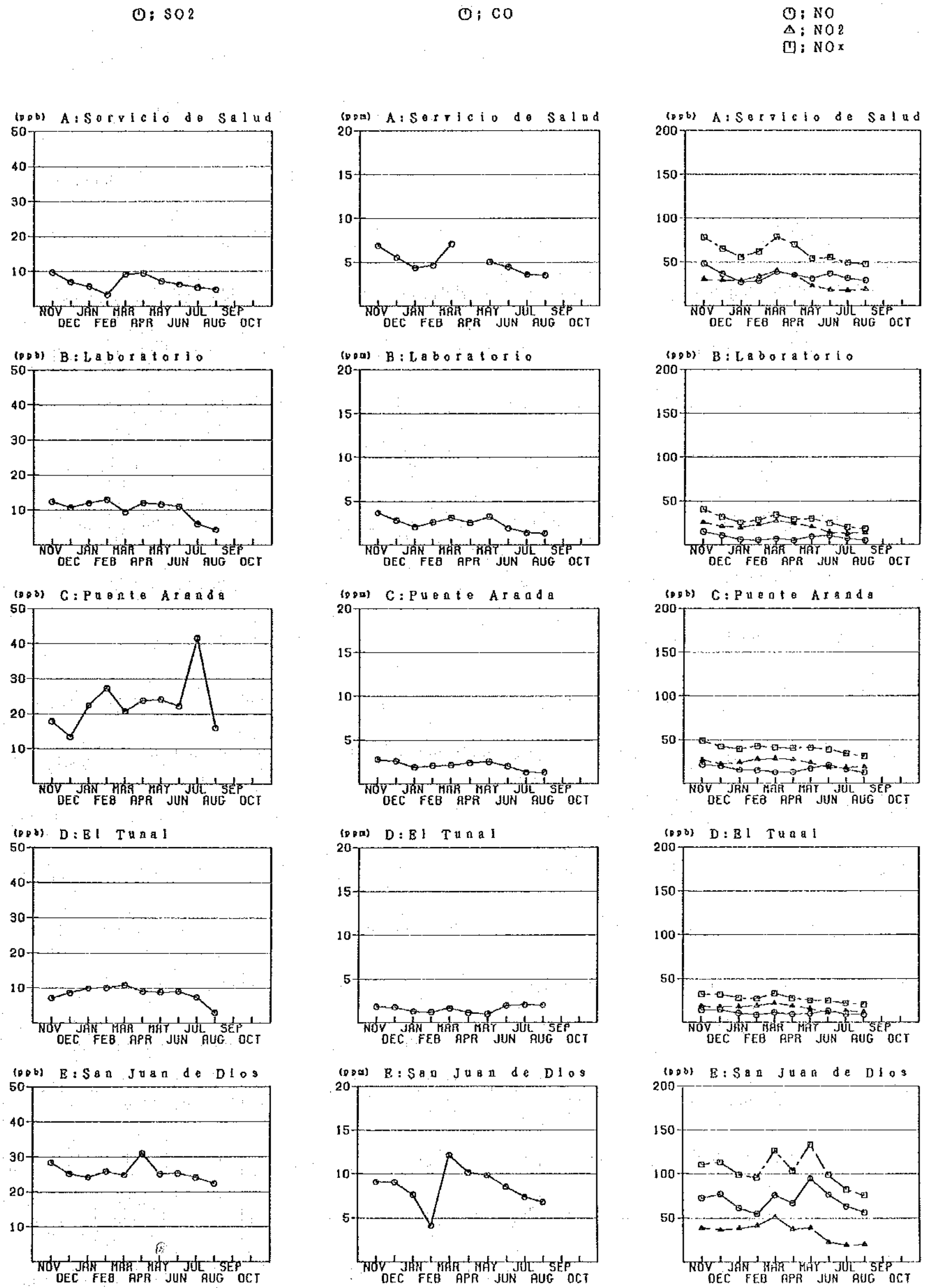


Fig. 4.1.4 ② Monthly Change

○; SPM

○; CH4
△; n-CH4
□; T-HC

○; O3

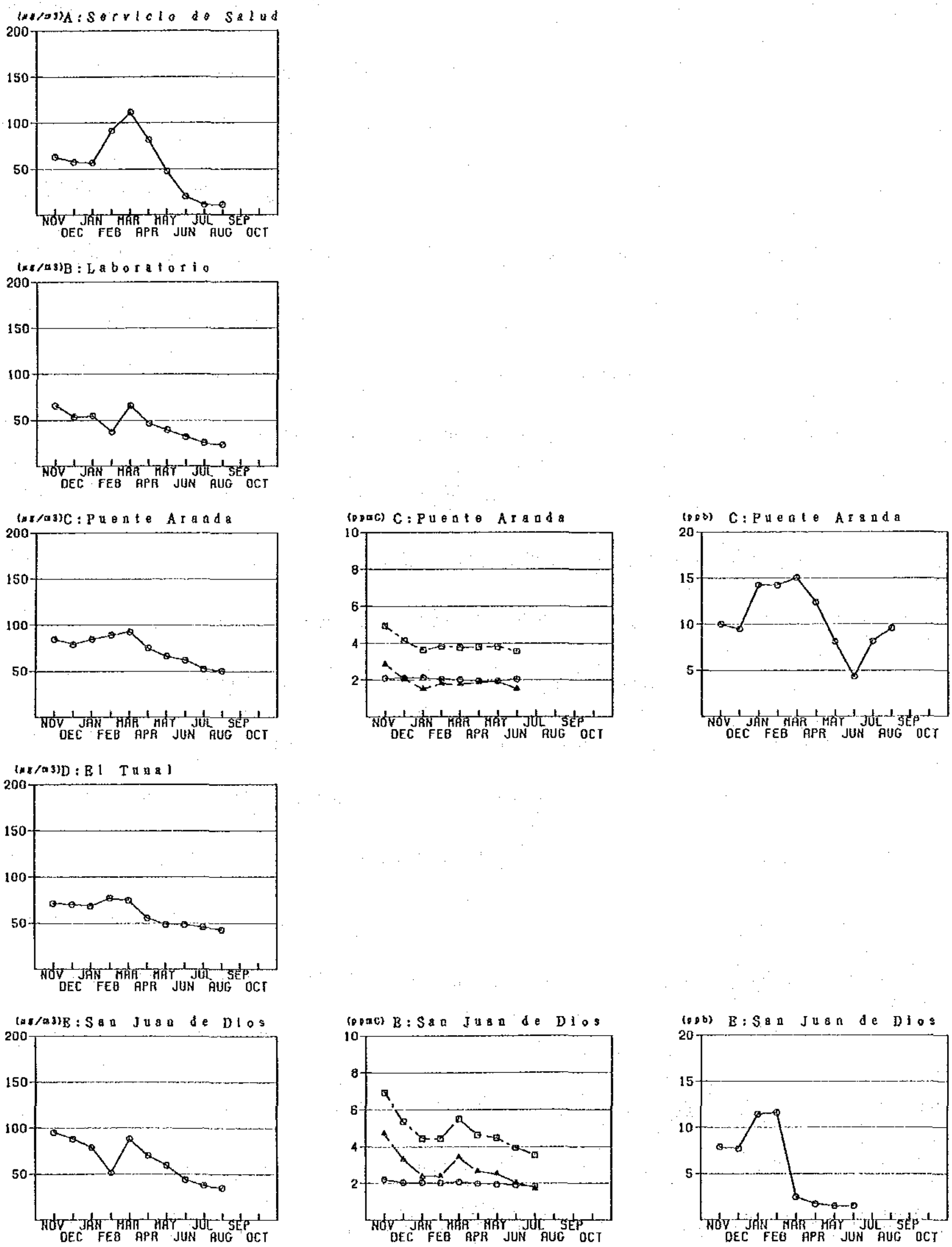
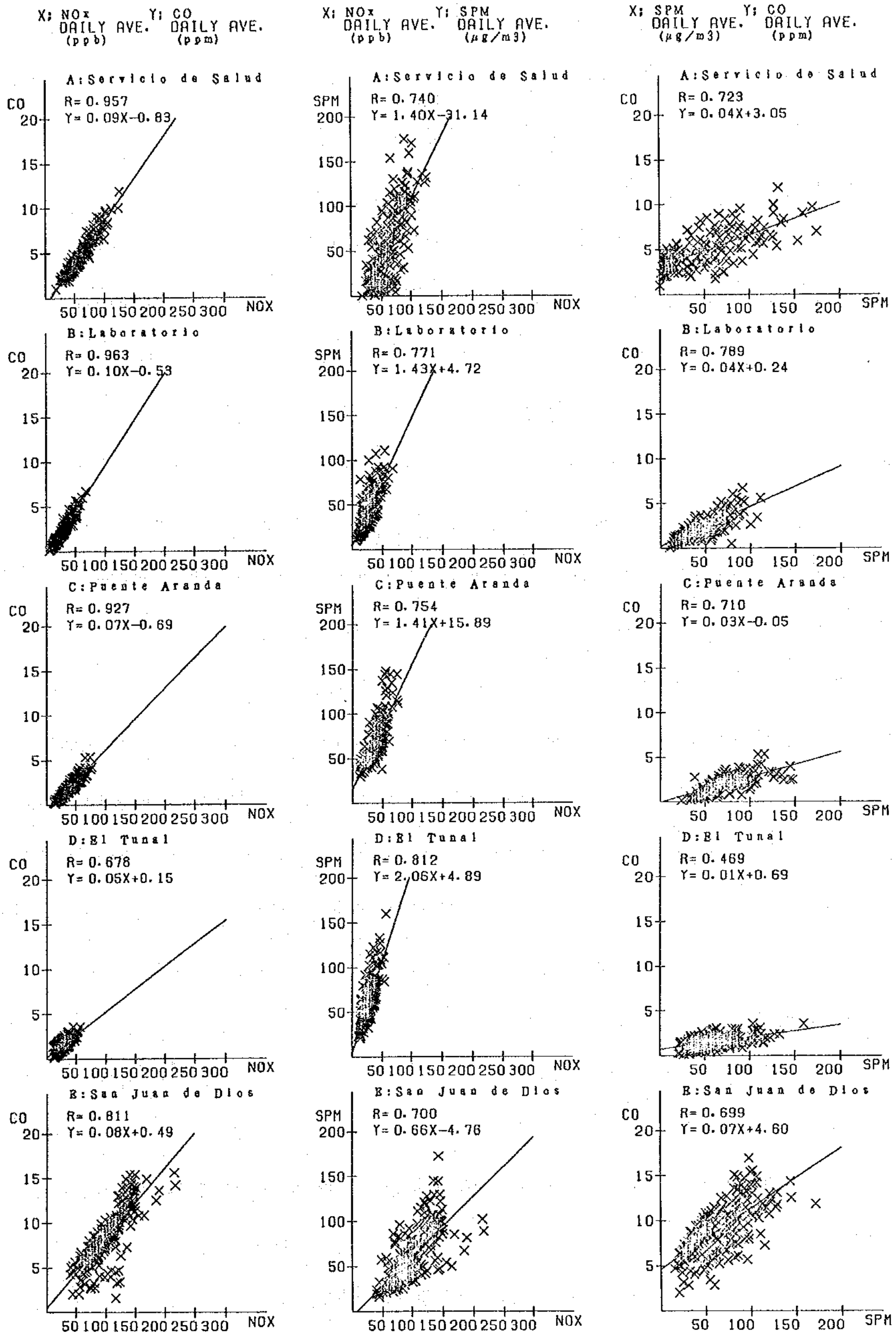


Fig. 4.1.5 Scatter of Daily Value

YEAR : 1990



4.1.3 Relationship with Meteorology

(1) Concentration Classified by Wind Direction

Fig. 4.1.6 shows the average concentration classified by wind direction.

SO_2 had peaks in SW to NNW at station A, in SW to NNE at station B, in SW, NNW, and N at station C, and in NE and WSW at station D. As known from the wind rose (Fig. 3.1.2), these were directions in which the wind speed was low. At station E, however, the concentration was high in SSE and S directions where the wind speed was high.

As for CO, there was no remarkable change by wind direction at stations B, C and D. But, station A had peaks in SW to NE and station E had them in W to N.

As regards NOx, the concentration was high in the wind direction similar to SO_2 at all stations except station E. At stations A and E where NOx was high, NOx and NO showed the similar pattern. And the pattern of NOx and NO was different from NO_2.

Generally speaking, the pattern of SPM was similar to that of NOx except station D.

As regards HC, CH_4 showed no particular pattern, while NMHC and T-HC showed a pattern similar to that of NOx.

(2) Concentration Classified by Wind Speed

Fig. 4.1.7 shows the average concentration classified by wind speed.

The SO_2 concentration decreased as wind speed increased, at stations A, B and D. But at station C, there was no particular change. It was interesting that the concentration rose in proportion to the wind speed at station E. This seemed to reflect the fact that the wind speed was high during daytime when the SO_2 sources were active. But this viewpoint did not explain the relationship completely.

As for CO, there was no remarkable change, but at stations A and E located along a road, the concentration decreased as the wind speed increased.

As regards NOx, the concentration was low where the wind speed was high. But NO_2 showed less change.

The SPM concentration was highest in the weak wind ranges at 0 - 0.4 and 0.5 - 1.9 m/s and decreased with the wind speed. At station D, it rose again in the strong wind range.

As for HC, CH_4 had no remarkable change while NMHC and THC were low in the strong wind. Especially at station E, there was a substantial change.

The O_3 concentration had a tendency to rise with the wind speed.

(3) Concentration Classified by Atmospheric Stability

Fig. 4.1.8 shows the average concentration classified by atmospheric stability.

SO_2 and CO had no particular change. But, at station E, the SO_2 concentration was high in unstable side. This means that the concentration was high in daytime.

As regards NOx, the concentration was high at D-D (D in daytime). This is considered to correspond to the morning peak of concentration.

The SPM concentration was high on both ends of strong unstable and strong stable sides. This is considered to correspond to the weakness of wind.

Fig. 4.1.6 ① Average Concentration Classified by Wind Direction

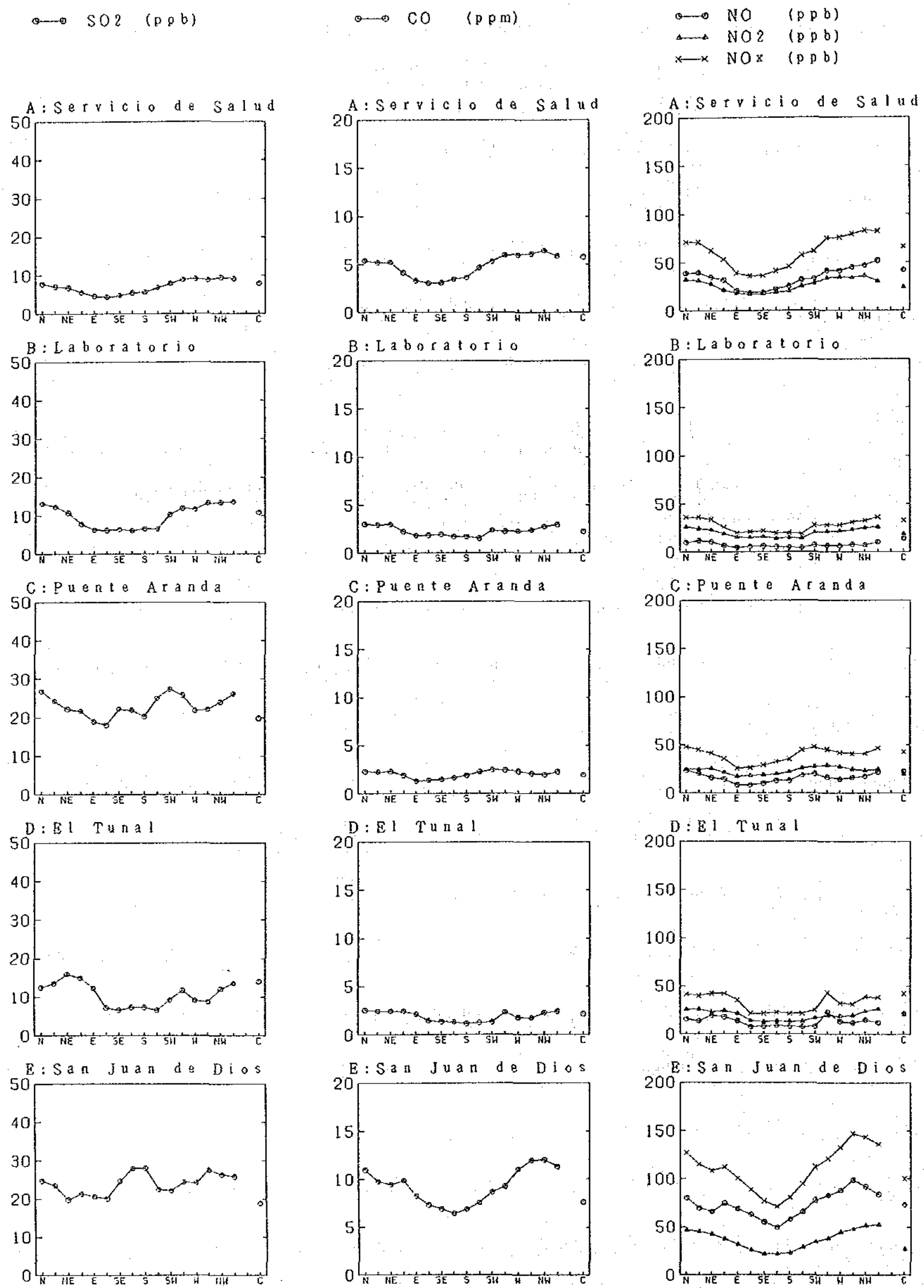


Fig. 4.1.6 ② Average Concentration Classified by Wind Direction

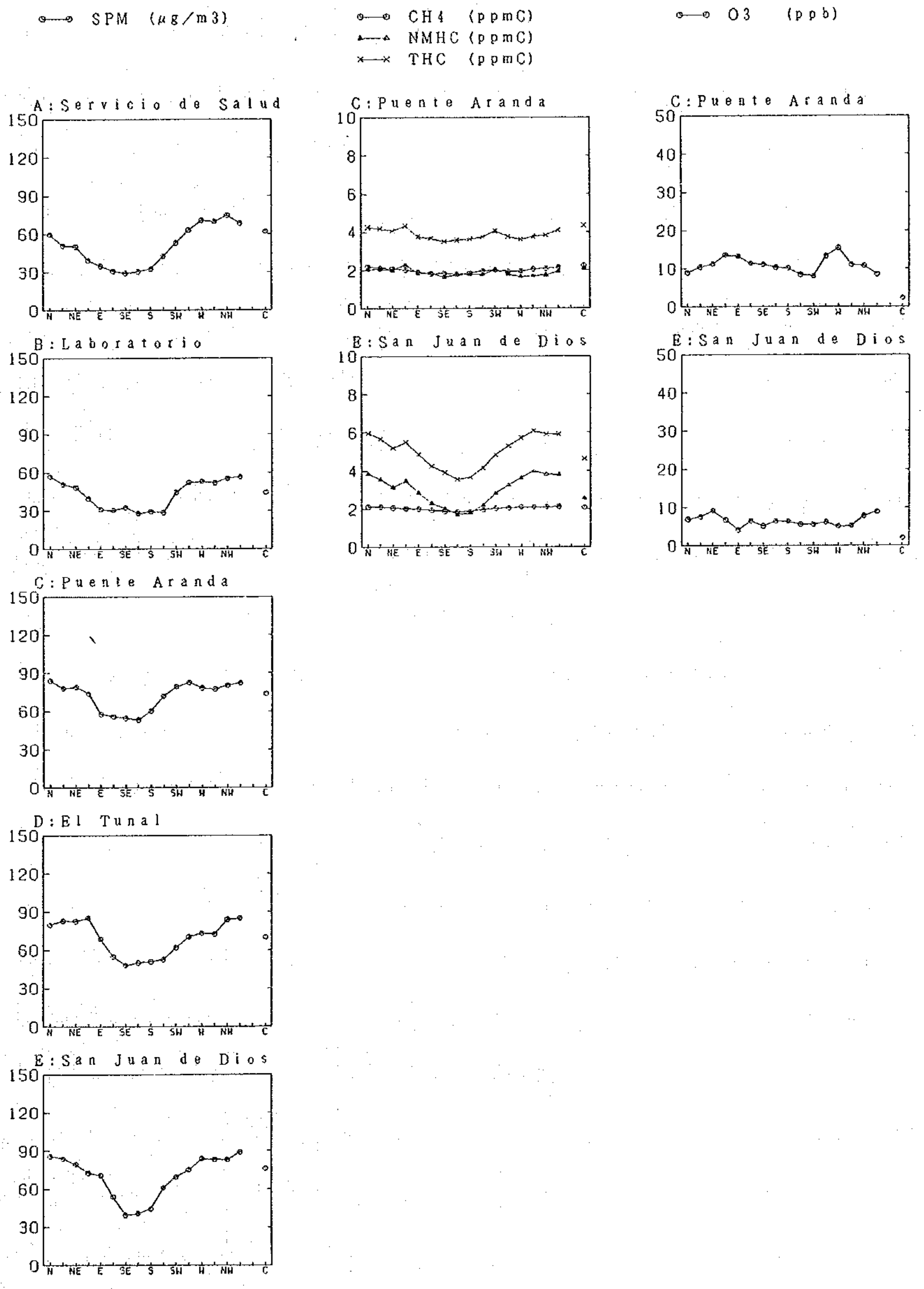


Fig. 4.1.7 ① Average Concentration Classified by Wind Speed

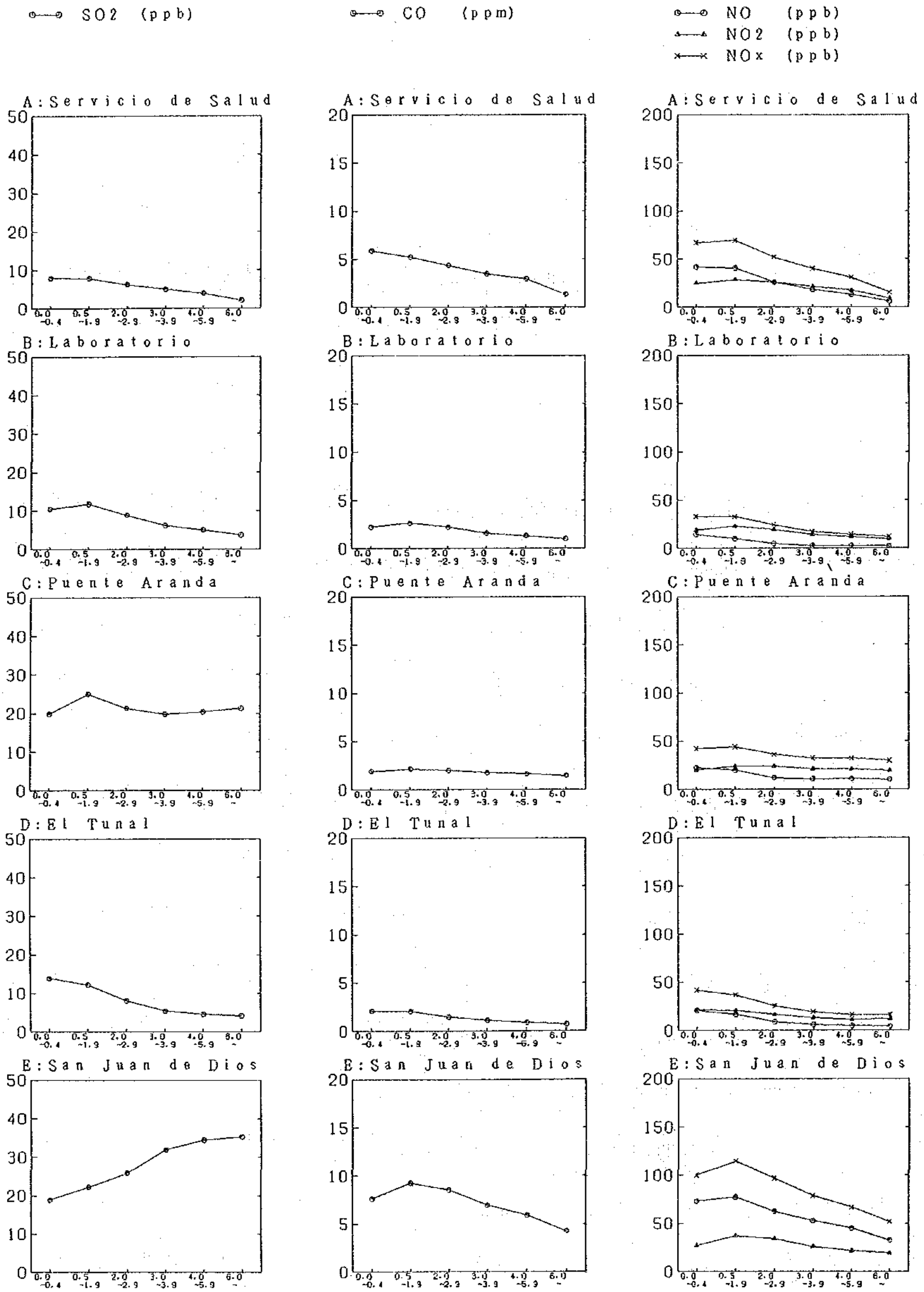


Fig. 4.1.7 ② Average Concentration Classified by Wind Speed

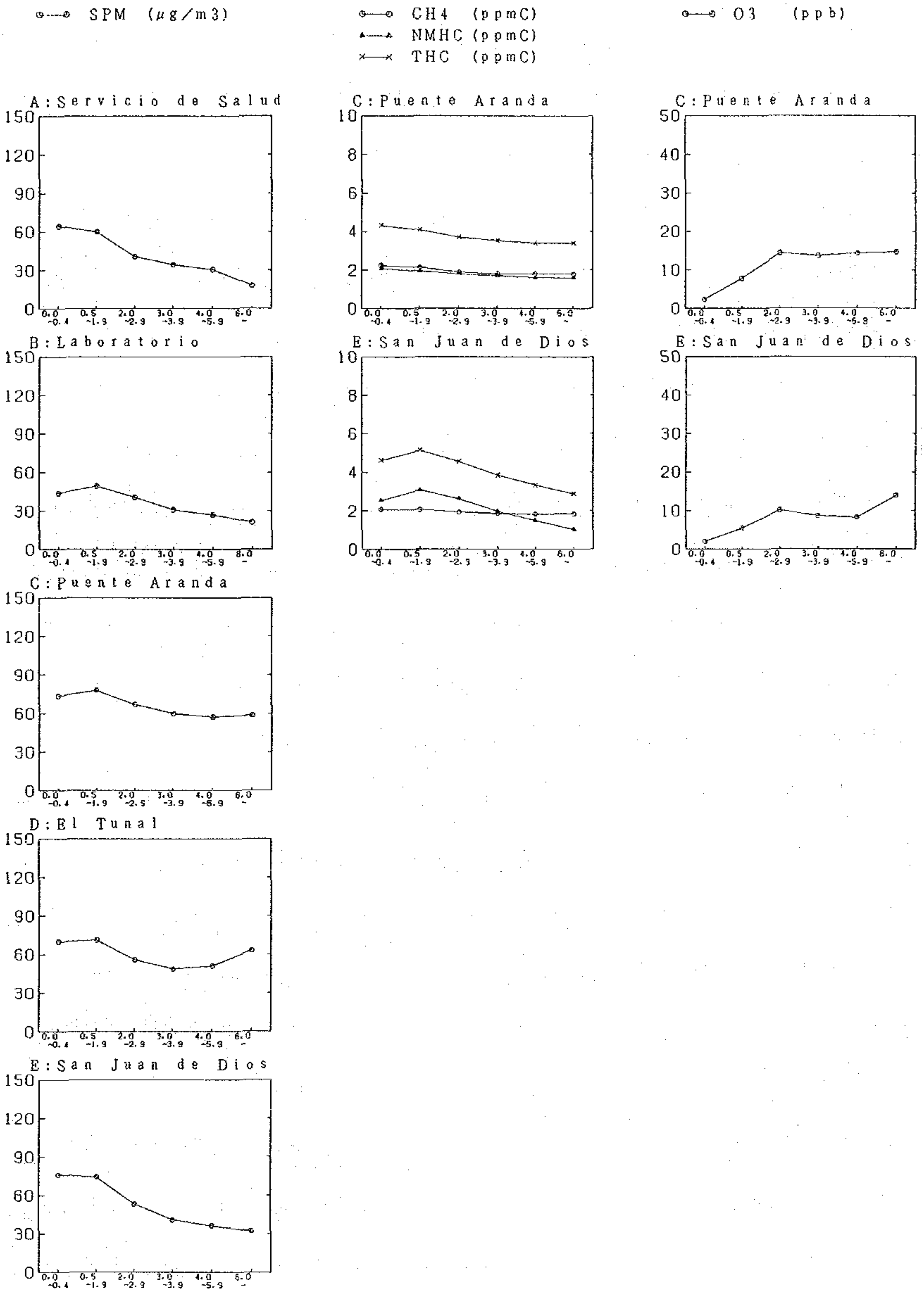


Fig. 4.1.8 ① Average Concentration Classified by Atmospheric Stability

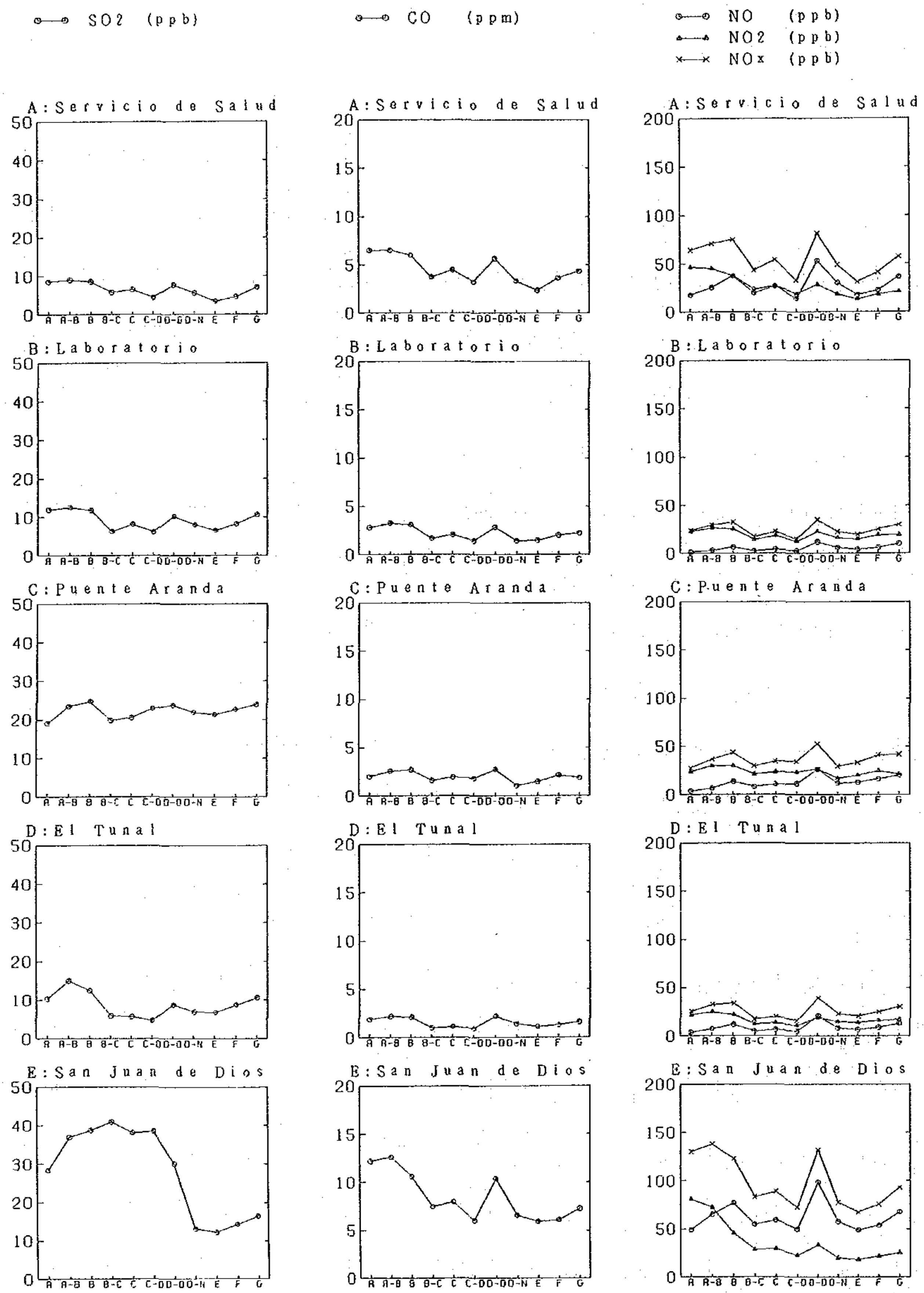
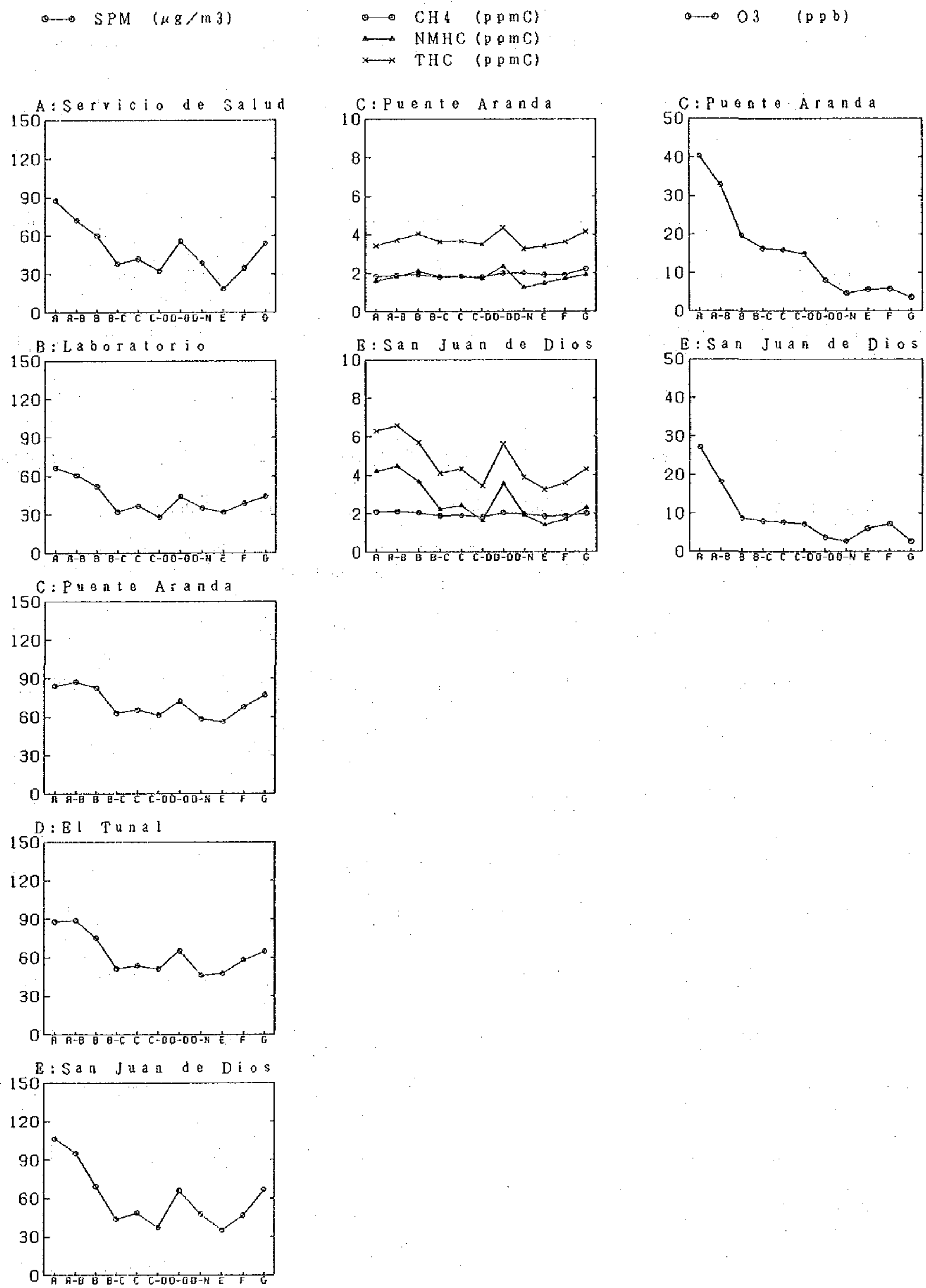


Fig. 4.1.8 ② Average Concentration Classified by Atmospheric Stability



4.1.4 Metal Elements of SPM

SPM was sampled with a low-volume air sampler at five stations (A through E) shown in Fig. 3.1.1. The result of measurement from November, 1990 to July, 1991 is shown in Table 4.1.3.

Table 4.1.3 ① Concentration of SPM and Metal Elements

Unit: μg/m³N

Item	Station A (Servicio de Salud)								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
SPM	31.9	65.6	77.6	26.5	50.9	17.1	39.4	6.8	11.7
Zn	0.20	0.28	0.28	0.35	0.13	0.069	0.25	0.037	0.070
Cd	N.D	(0.002)	N.D	N.D	(0.002)	(0.003)	N.D	N.D	(0.003)
Ni	(0.077)	0.11	(0.058)	(0.036)	(0.049)	(0.010)	(0.032)	(0.016)	(0.071)
Co	(0.009)	N.D	N.D	(0.037)	N.D	(0.012)	(0.031)	(0.006)	(0.006)
Fe	0.34	0.55	0.56	0.93	0.73	0.31	0.29	0.13	0.11
Mn	(0.005)	N.D	(0.011)	(0.028)	N.D	(0.006)	(0.005)	N.D	N.D
Pb	0.26	0.35	0.38	0.33	(0.14)	(0.079)	N.D	N.D	N.D
Cu	(0.018)	(0.034)	(0.072)	(0.027)	(0.057)	(0.018)	(0.012)	(0.004)	N.D
Al	(0.11)	N.D	(0.021)	(0.44)	0.81	(0.55)	(0.20)	N.D	6.84
V	N.D	N.D	(0.039)	(0.053)	N.D	N.D	N.D	N.D	N.D
Cr	(0.003)	(0.038)	N.D	(0.001)	(0.018)	(0.053)	N.D	N.D	N.D

Note that: ① Figure in parentheses is under the quantitative limit.
② The unit is expressed as μg/m³N (converted to the standard atmospheric pressure).

Table 4.1.3 ② Concentration of SPM and Metal Elements

Unit: $\mu g/m^3N$

Item	Station B (Laboratorio)								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
SPM	36.1	58.2	69.3	105.7	64.6	21.0	43.2	9.0	23.2
Zn	0.32	0.32	0.52	0.089	0.21	0.13	0.19	0.066	0.20
Cd	(0.002)	N.D	N.D	(0.004)	N.D	(0.002)	N.D	(0.004)	(0.002)
Ni	(0.030)	(0.040)	(0.049)	(0.040)	(0.035)	(0.025)	(0.023)	(0.041)	(0.089)
Co	(0.014)	N.D	N.D	(0.063)	N.D	N.D	(0.010)	(0.005)	(0.011)
Fe	0.41	0.44	0.83	0.13	0.64	0.19	0.25	0.11	0.29
Mn	(0.009)	N.D	(0.019)	(0.006)	(0.006)	(0.007)	(0.012)	(0.001)	(0.009)
Pb	0.22	(0.19)	0.31	(0.091)	0.26	0.27	(0.11)	N.D	N.D
Cu	0.10	(0.035)	(0.039)	(0.020)	(0.027)	(0.058)	(0.090)	(0.020)	(0.009)
Al	(0.084)	N.D	(0.71)	N.D	1.2	0.87	N.D	N.D	N.D
V	(0.027)	N.D	(0.13)	N.D	N.D	N.D	N.D	N.D	N.D
Cr	N.D	(0.031)	N.D	N.D	N.D	(0.053)	N.D	(0.008)	N.D

Table 4.1.3 ③ Concentration of SPM and Metal Elements

Unit: $\mu g/m^3N$

Item	Station C (Puente Aranda)								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
SPM	77.7	82.3	93.8	75.4	39.2	15.4	31.4	24.0	7.3
Zn	0.67	0.53	0.26	0.78	0.38	0.38	0.75	0.32	0.047
Cd	(0.006)	N.D	N.D	0.002	(0.005)	N.D	(0.005)	(0.006)	(0.001)
Ni	(0.093)	(0.084)	(0.044)	0.11	0.12	(0.084)	(0.084)	(0.078)	(0.074)
Co	(0.010)	N.D	N.D	(0.061)	N.D	N.D	(0.004)	(0.003)	(0.016)
Fe	0.74	0.45	0.20	0.91	0.76	0.43	0.49	0.24	0.12
Mn	(0.042)	(0.007)	(0.004)	0.051	N.D	(0.014)	(0.020)	(0.010)	(0.002)
Pb	0.44	0.31	(0.079)	0.56	(0.14)	(0.16)	N.D	N.D	N.D
Cu	0.12	(0.024)	(0.029)	(0.043)	(0.020)	0.12	0.12	(0.021)	(0.005)
Al	(0.23)	N.D	(0.039)	(0.064)	1.4	(0.021)	(0.70)	N.D	N.D
V	(0.055)	N.D	N.D	(0.14)	N.D	N.D	N.D	N.D	N.D
Cr	(0.004)	(0.028)	N.D	N.D	N.D	(0.046)	(0.007)	(0.001)	N.D

Table 4.1.3 ④ Concentration of SPM and Metal Elements

Unit: μg/m³N

Item	Station D (El Tunal)								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
SPM	47.1	85.2	79.2	80.5	59.6	15.6	52.1	31.5	25.0
Zn	0.54	0.38	0.35	0.61	0.25	0.32	0.34	0.13	0.11
Cd	N.D	N.D	N.D	N.D	(0.006)	(0.0003)	N.D	N.D	(0.002)
Ni	(0.048)	(0.074)	(0.083)	(0.027)	0.16	(0.023)	N.D	0.035	(0.035)
Co	(0.007)	N.D	(0.008)	(0.009)	N.D	N.D	(0.013)	N.D	(0.017)
Fe	0.69	0.56	1.2	1.0	1.2	0.79	0.50	0.25	0.29
Mn	(0.008)	(0.012)	(0.014)	0.16	(0.014)	(0.012)	(0.009)	N.D	N.D
Pb	0.24	0.71	0.44	1.1	0.24	(0.071)	N.D	(0.10)	(0.003)
Cu	(0.064)	(0.034)	(0.045)	(0.038)	(0.033)	(0.035)	(0.014)	(0.027)	(0.009)
Al	(0.31)	(0.088)	0.92	(0.76)	3.3	(0.65)	1.3	N.D	N.D
V	N.D	(0.11)	N.D	(0.076)	N.D	N.D	1.4	N.D	N.D
Cr	N.D	(0.028)	N.D	N.D	N.D	(0.075)	N.D	(0.010)	N.D

Table 4.1.3 ⑤ Concentration of SPM and Metal Elements

Unit: μg/m³N

Item	Station E (San Juan de Dios)								
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July
SPM	58.7	95.7	105.8	74.2	68.9	20.4	43.5	21.6	3.9
Zn	0.35	0.60	0.32	0.49	0.20	0.18	0.28	0.077	0.040
Cd	N.D	N.D	N.D	N.D	(0.003)	(0.001)	N.D	(0.005)	N.D
Ni	(0.086)	(0.046)	0.097	0.095	0.22	(0.008)	(0.049)	(0.080)	(0.034)
Co	N.D	N.D	(0.029)	0.92	N.D	N.D	N.D	N.D	(0.008)
Fe	0.39	0.85	0.75	0.69	0.74	(0.046)	0.38	0.15	(0.054)
Mn	(0.006)	(0.013)	(0.016)	0.067	N.D	(0.003)	(0.011)	(0.004)	N.D
Pb	0.27	0.41	1.1	0.55	0.31	(0.17)	N.D	N.D	N.D
Cu	(0.053)	(0.030)	(0.061)	(0.017)	(0.039)	(0.022)	(0.022)	(0.027)	N.D
Al	(0.028)	(0.55)	(0.43)	(0.087)	2.6	(0.49)	N.D	N.D	N.D
V	(0.009)	(0.13)	(0.063)	(0.11)	N.D	N.D	N.D	N.D	N.D
Cr	N.D	(0.057)	N.D	N.D	N.D	(0.045)	N.D	N.D	N.D

4.1.5 Size Distribution of Suspended Particle

Size distribution of suspended particle was measured with Andersen high-volume air sampler at two stations (B and C) shown in Fig. 3.1.1. The measurement result is shown in Tables 4.1.4 to 4.1.5 and Figs. 4.1.9 - 4.1.10.

The date of measurement is as listed below:

1st	November 14, 1990 - November 19, 1990
2nd	February 28, 1991 - March 5, 1991
3rd	April 15, 1991 - April 22, 1991
4th	May 17, 1991 - May 22, 1991

Table 4.1.4 Summary of Particle Size Distribution (Station B)

Item / Date / Particle Diameter	Distribution : F (%)			
	90'11	91'3	91'4	91'5
7.0 µm and above	35.9	38.0	50.2	47.2
3.3 ~ 7.0 µm	9.4	19.8	12.2	11.5
2.0 ~ 3.3 µm	3.8	6.3	5.6	5.6
1.1 ~ 2.0 µm	4.9	6.3	5.6	5.3
1.1 µm under	46.0	29.5	26.4	30.3

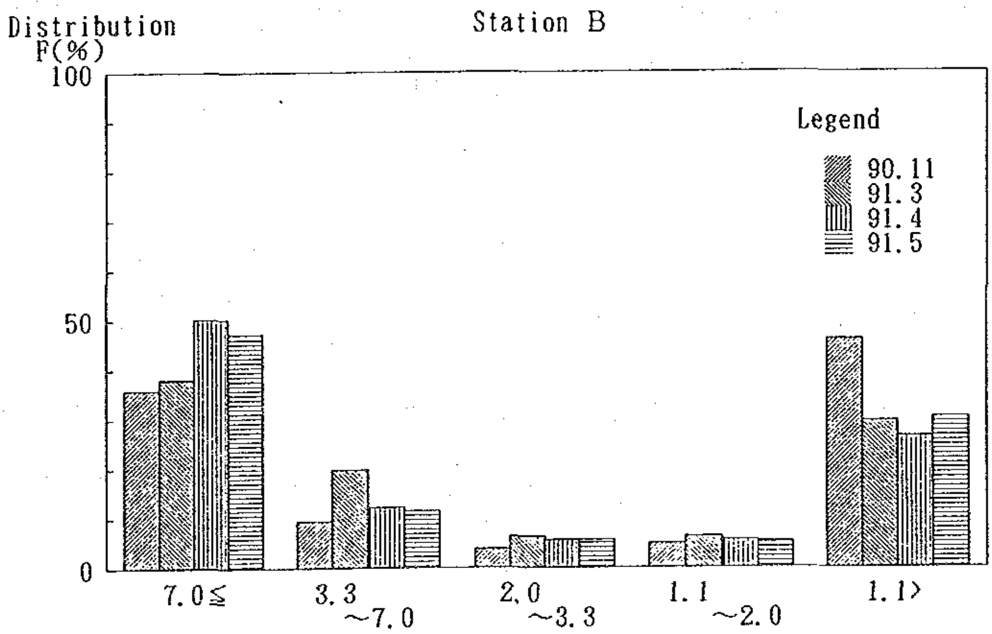


Fig. 4.1.9 Distribution

Table 4.1.5 Summary of Particle Size Distribution (Station C)

Particle Diameter \ Item / Date	Distribution : F (%)			
	90'11	91'3	91'4	91'5
7.0 µm and above	5.5	41.3	54.2	52.3
3.3 ~ 7.0 µm	17.2	12.2	11.0	9.4
2.0 ~ 3.3 µm	13.8	6.8	4.4	4.9
1.1 ~ 2.0 µm	6.7	5.4	4.7	3.9
1.1 µm under	56.5	34.1	25.7	29.6

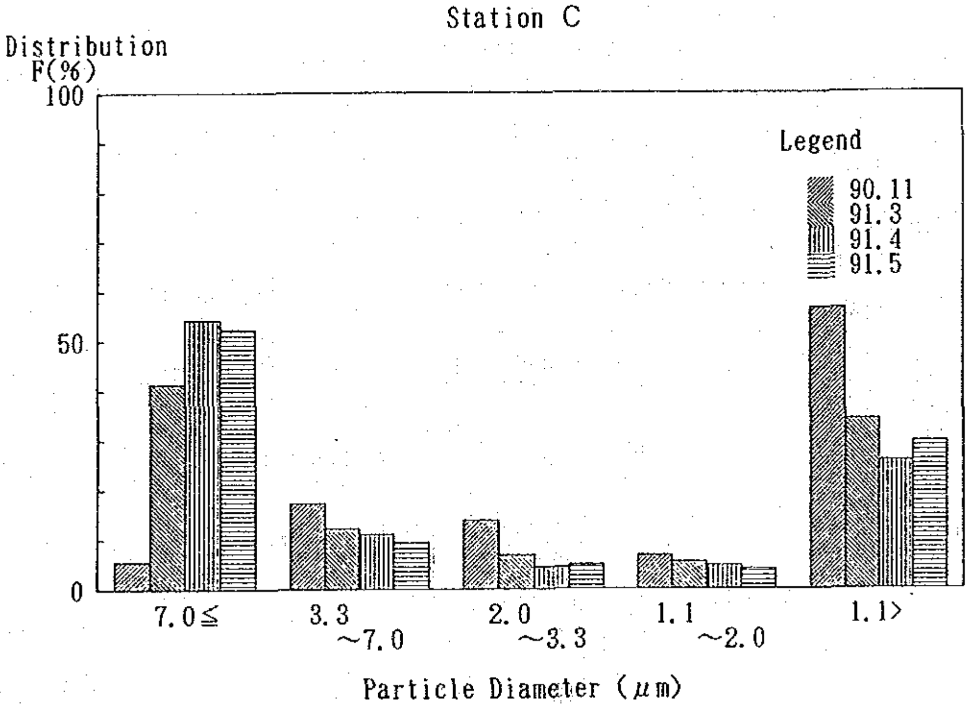


Fig. 4.1.10 Distribution

4.2 Ambient Air Quality by Simplified Measurement

4.2.1 Regional Distribution of SOx and NOx Concentration

In order to grasp the regional distribution of SOx and Nox concentration in Bogota City, shelters were installed at 50 points in the city. Measurement period is shown below:

Measurement period

1st	November 2, 1990 - November 26, 1990
2nd	February 1, 1991 - February 26, 1991
3rd	April 1, 1991 - April 25, 1991
4th	May 31, 1991 - July 2, 1991

(1) SOx Concentration by PbO_2 Method

In the PbO_2 method, the sulfate ion of lead sulfate produced by the reaction between sulfur oxides and lead dioxide is quantatively analyzed.

The average of results from first to fourth measurements is shown in Fig. 4.2.1. Note that most of numerical figures were below the quantitative limit.

Note also that "I" through "X" mean the existing stations in Bogota City while "A" through "D" mean the monitoring stations installed in this study.

(2) NOx Concentration by NO_2 Plate Method

In the NO_2 plate method, NO_2 was collected with triethanol filter paper, and NOx was collected with triethanol filter paper impregnated with PTIO, and they were measured by Saltzman absorption spectrophotometry.

The average of results from first to fourth measurements is shown in Fig. 4.2.2. The concentration level tended to be lower in the circumferential area of the city. Compared with the concentration of the monitoring stations, NOx was higher and NO_2 was lower.

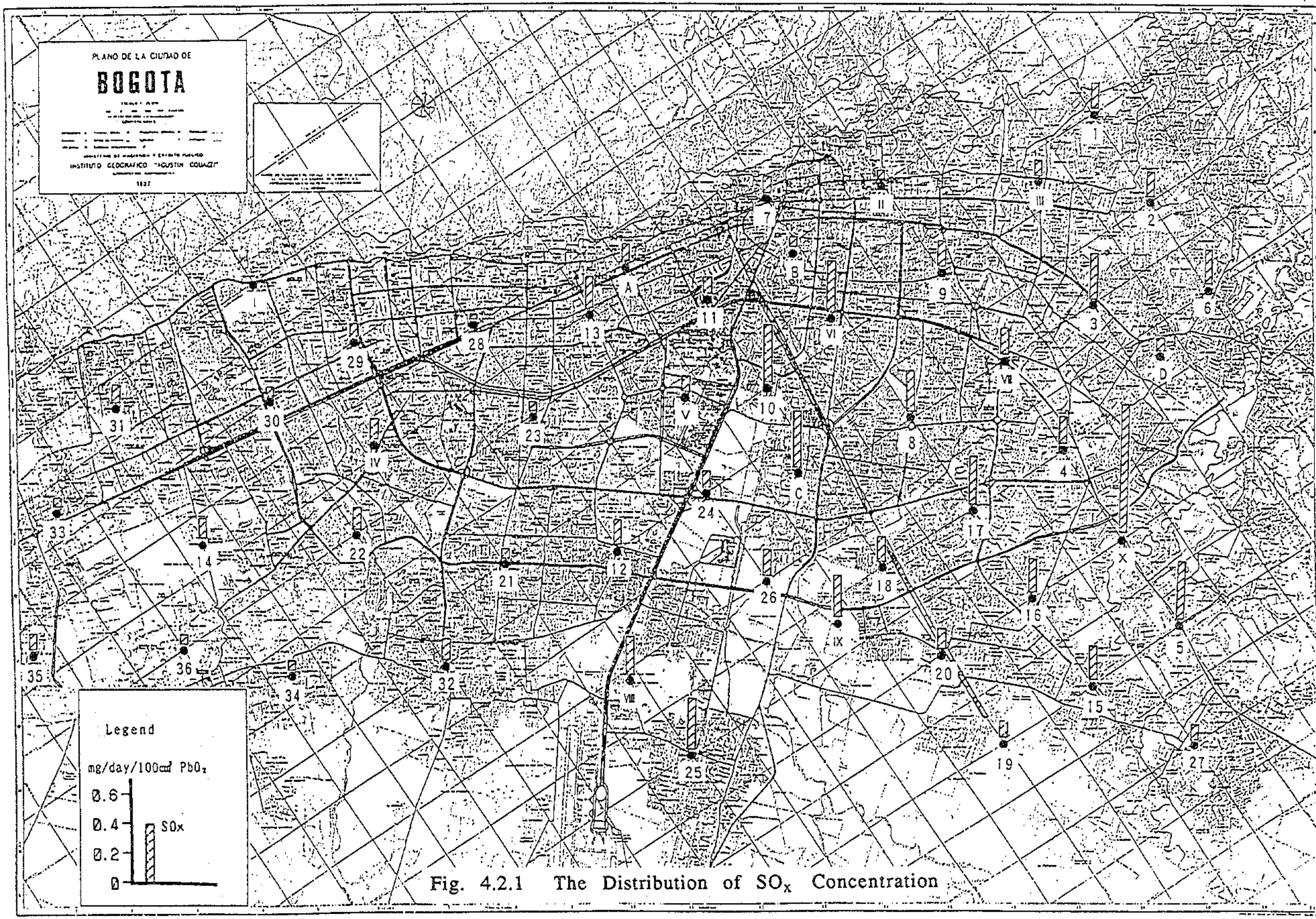


Fig. 4.2.1 The Distribution of SO_x Concentration

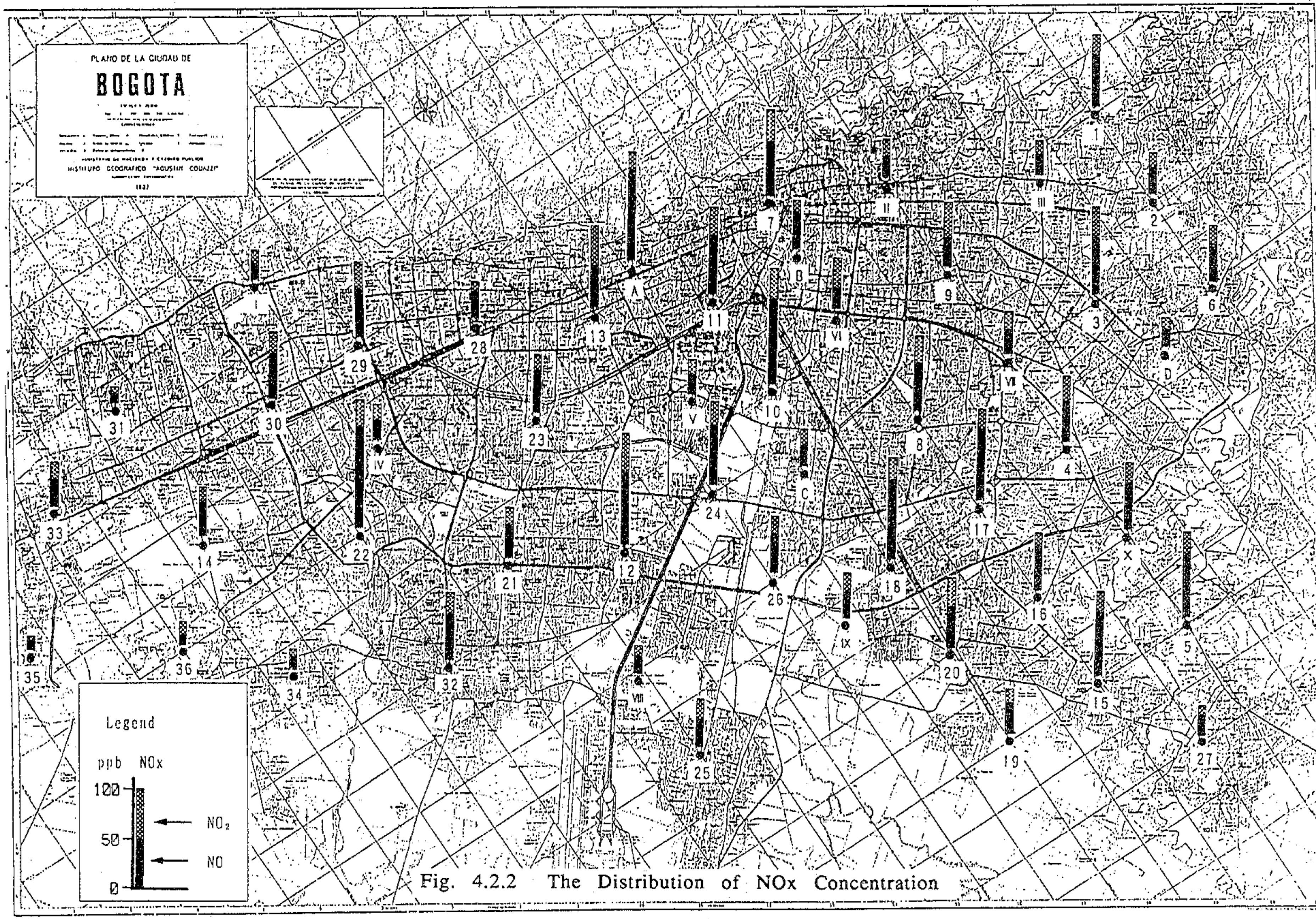


Fig. 4.2.2 The Distribution of NOx Concentration

4.2.2 NOx and CO Concentration Distribution around Road

In order to grasp the influence of road, the NOx and CO concentration was measured with the detector tube at six points shown in Fig. 4.2.3.

The period of measurement is shown below.

1st	NOx	December 11, 1990 (S-1 point)
		March 4 - 7, 1991 (S-2 ~ S-6 points)
	CO	November 21 ~ 23, 1990 (S-2 ~ S-6 points)
		December 11, 1990 (S-1 point)
2nd	NOx	March 7, 1991 (S-1 point)
		March 18~ 20, 1990 (S-2 ~ S-6 points)
	CO	March 4 ~ 7, 1991

The NOx concentration showed damping by distance at Point S-4 shown in Fig. 4.2.4, but at other points showed no particular tendency. In certain points, the concentration rose up under the influence of motor vehicles running close to.

The CO concentration was nearly constant at 40m points.

In some points located at other than road-edge, it showed high value due to the motor vehicles running close to as in the case of NOx.

The measurement result at Point S-6 is shown in Fig. 4.2.5 as a example.

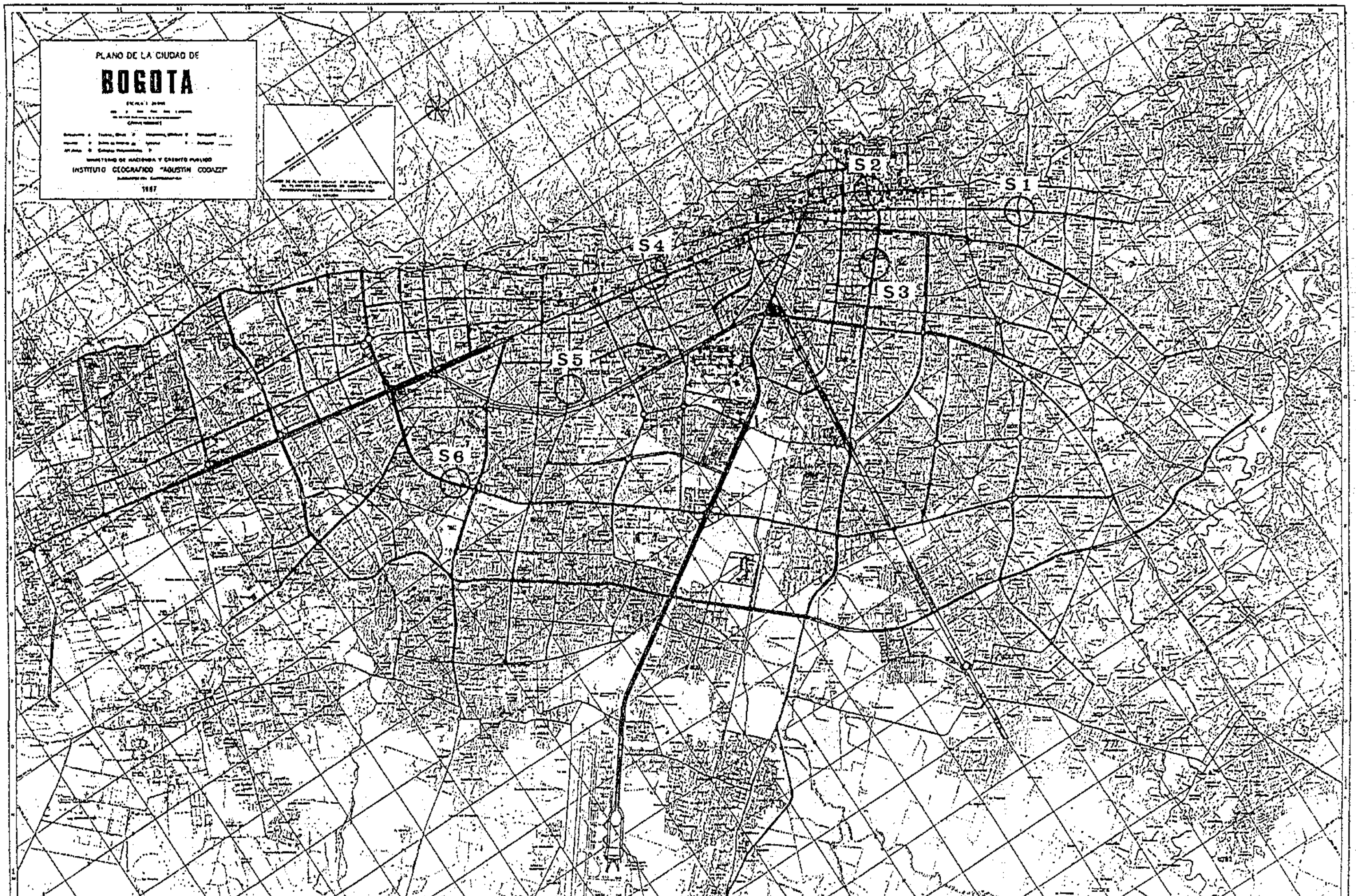


Fig. 4.2.3 Location of Measuring Point (Detector - Tube Method)

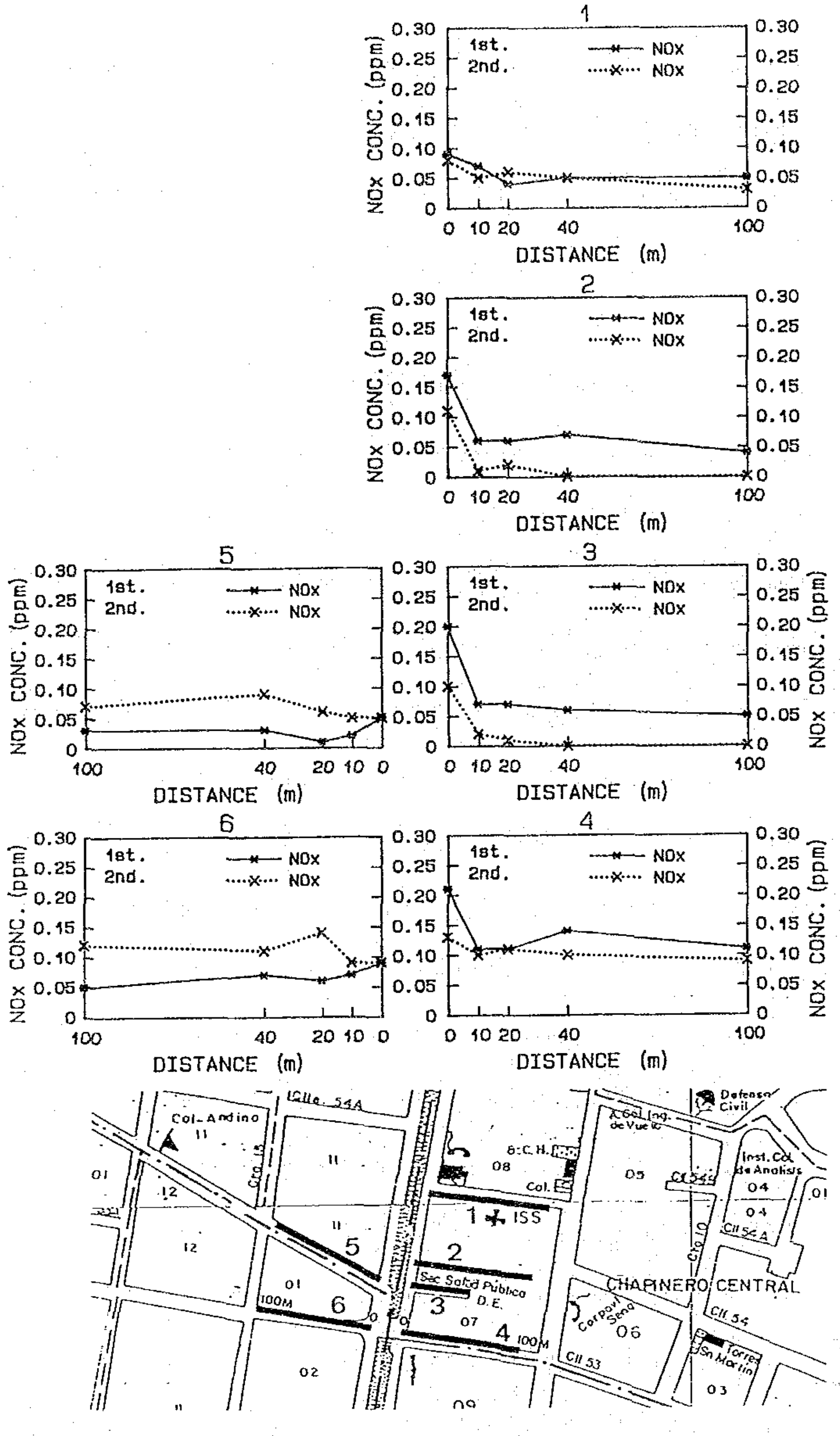


Fig. 4.2.4 NOx Concentration and Sampling (Point S-4)

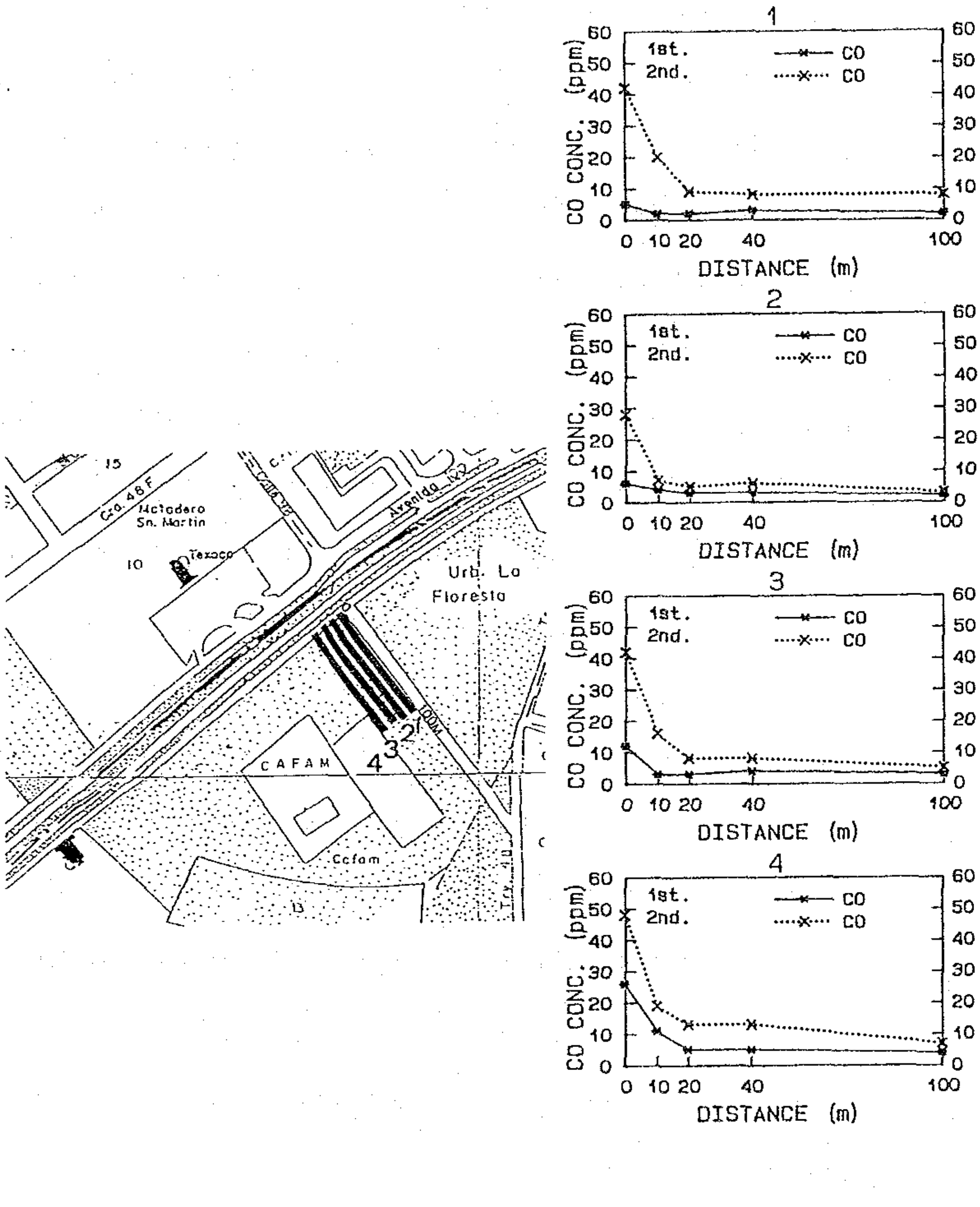


Fig. 4.2.5 CO Concentration and Sampling (Point S-6)

4.3 Concentration at Monitoring Stations Managed by Servicio de Salud de Bogotá D.E.

Fig. 4.3.1 shows the locations of the existing monitoring stations managed by Servicio de Salud de Bogotá D.E.

The yearly change of concentration of the respective station is shown in Table 4.3.1, and the monthly change of the concentrations is shown in Fig. 4.3.2.

The ambient air quality standards are shown in Appendix. As for SO_2, 2 stations in industrial zone exceeded the standard value in the past. But recently, all stations satisfy the standard value. Concerning NO_2, all stations satisfy the standard value. But as for SP, many stations exceed the standard value.

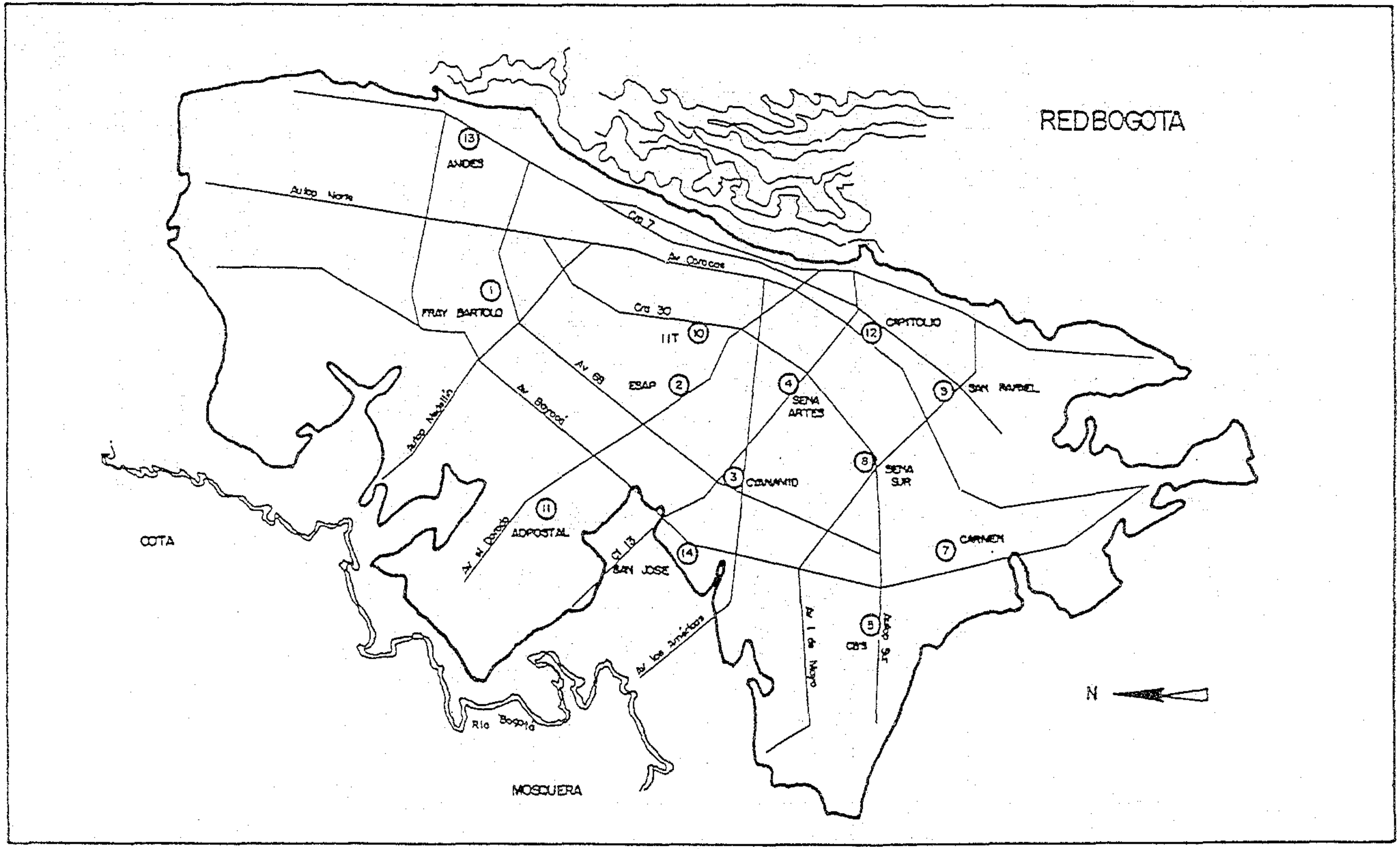


Fig. 4.3.1 Distribution de las estaciones de muestreo de contaminantes del aire de la ciudad de Bogotá D.E.

Table 4.3.1 Yearly Change of Concentration at the Stations Managed by Bogota D.E.

Unit: $\mu g/m^3$

No.	Stations	Zone	Item	1983	1984	1985	1986	1987	1988	1989
1	Fray Bartolome	Residence	SO_2	12.8	13.2	16.3	18.8	13.8	13.8	-
			NOx	14.2	20.5	24.9	33.3	19.5	21.7	-
			SP	97.7	70.0	79.2	92.2	80.7	77.4	77.8
2	E.S.A.P.	Institution	SO_2	14.9	15.0	17.9	19.7	14.1	23.9	-
			NOx	18.6	23.7	30.1	31.3	24.0	21.4	-
			SP	83.7	71.9	57.7	87.0	83.5	94.2	86.7
3	Cyanamid	Industry	SO_2	43.1	41.6	44.1	28.1	23.7	20.5	-
			NOx	30.8	33.6	39.4	29.0	26.6	24.6	-
			SP	177.2	134.0	143.7	141.4	151.7	160.8	141.3
4	Sena Artes	Industry	SO_2	22.9	19.7	24.5	21.1	14.5	15.7	-
			NOx	23.0	33.2	35.0	21.5	28.5	30.9	-
			SP	186.6	164.4	187.6	181.0	168.4	175.8	174.0
5	C.B.S.	Industry	SO_2	43.4	41.1	49.0	35.0	23.7	16.5	-
			NOx	15.1	25.0	38.2	32.1	24.8	24.8	-
			SP	219.9	160.7	148.7	126.3	208.9	181.9	185.6
6	Radio Faro de Techo		Out of Use							
7	Carmen	Residence	SP	177.3	171.5	166.6	150.4	145.1	142.0	147.3
8	Sena Sur	Commerce, Residence	SO_2	22.6	16.1	22.5	22.3	17.8	13.7	-
			NOx	-	26.3	35.8	31.8	27.2	22.7	-
			SP	190.4	179.0	185.6	184.6	151.5	144.0	154.5
9	San Rafael	Residence	SP	118.5	102.3	109.6	71.4	91.6	100.6	89.0
10	I.T.T.	Residence	SO_2	17.1	14.3	19.7	18.0	15.0	15.2	-
			NOx	21.9	28.8	32.0	34.9	28.5	24.1	-
			SP	132.9	92.0	94.9	81.8	99.0	100.9	97.2
11	Adpostal	Industry	SO_2	16.5	14.6	20.7	20.4	15.8	14.6	-
			NOx	-	18.2	30.6	30.9	21.3	20.2	-
			SP	100.2	84.9	108.8	92.0	93.1	98.8	94.6
12	Capitolio	Institution, Commerce	SO_2	15.1	15.8	16.5	17.8	15.2	17.7	-
			NOx	-	26.6	27.5	31.3	16.8	20.9	-
			SP	98.7	113.8	103.5	93.5	98.7	112.1	88.8
13	Andes	Residence	SP	67.6	61.1	74.2	73.1	71.1	75.0	64.4
14	San Jose	Industry, Residence	SP	122.9	103.7	133.0	129.9	127.3	132.0	153.0

Fig. 4.3.2 ① Monthly Change of Pollutant Concentration
(from Jul., 1983 to Dec., 1989)

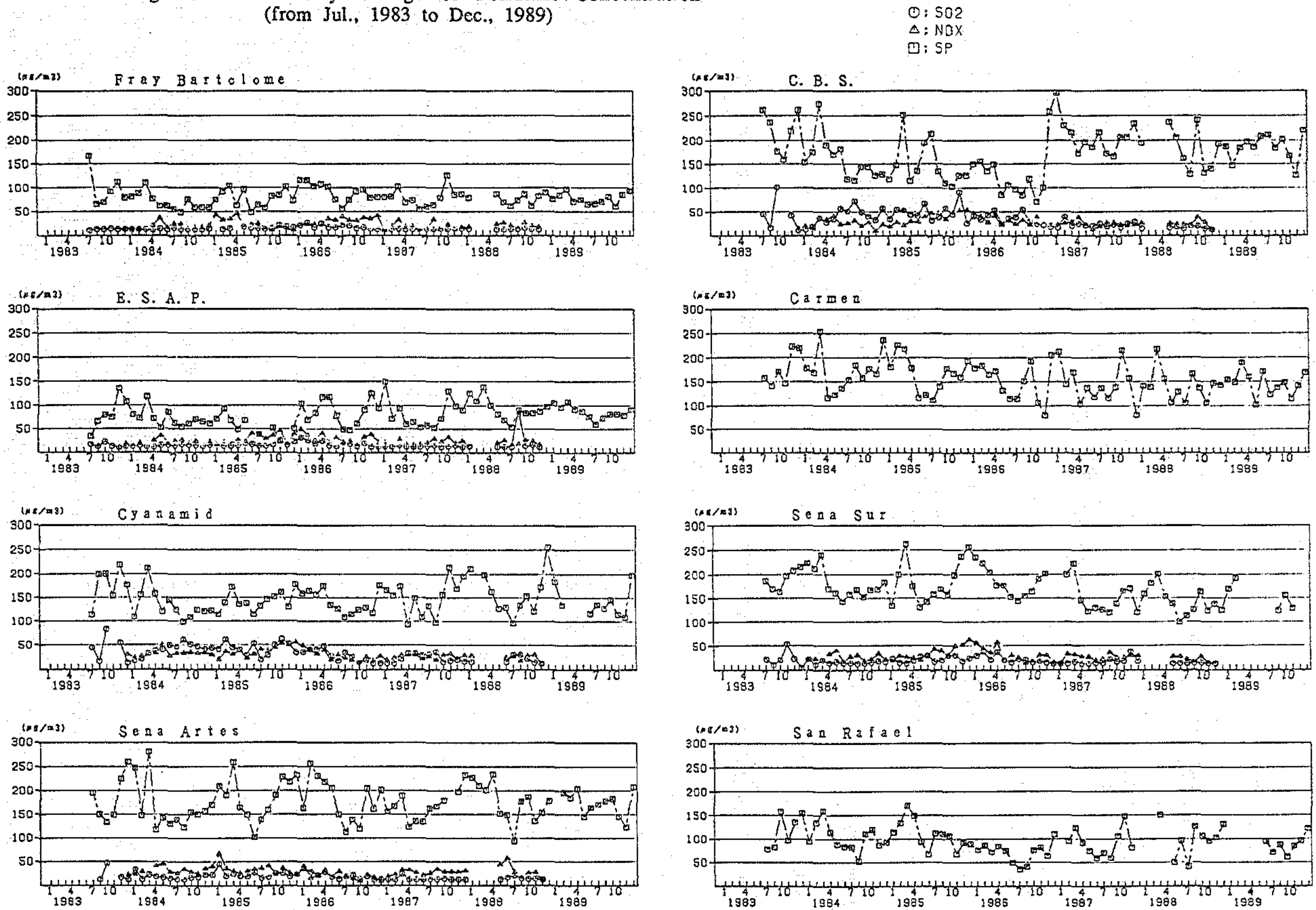
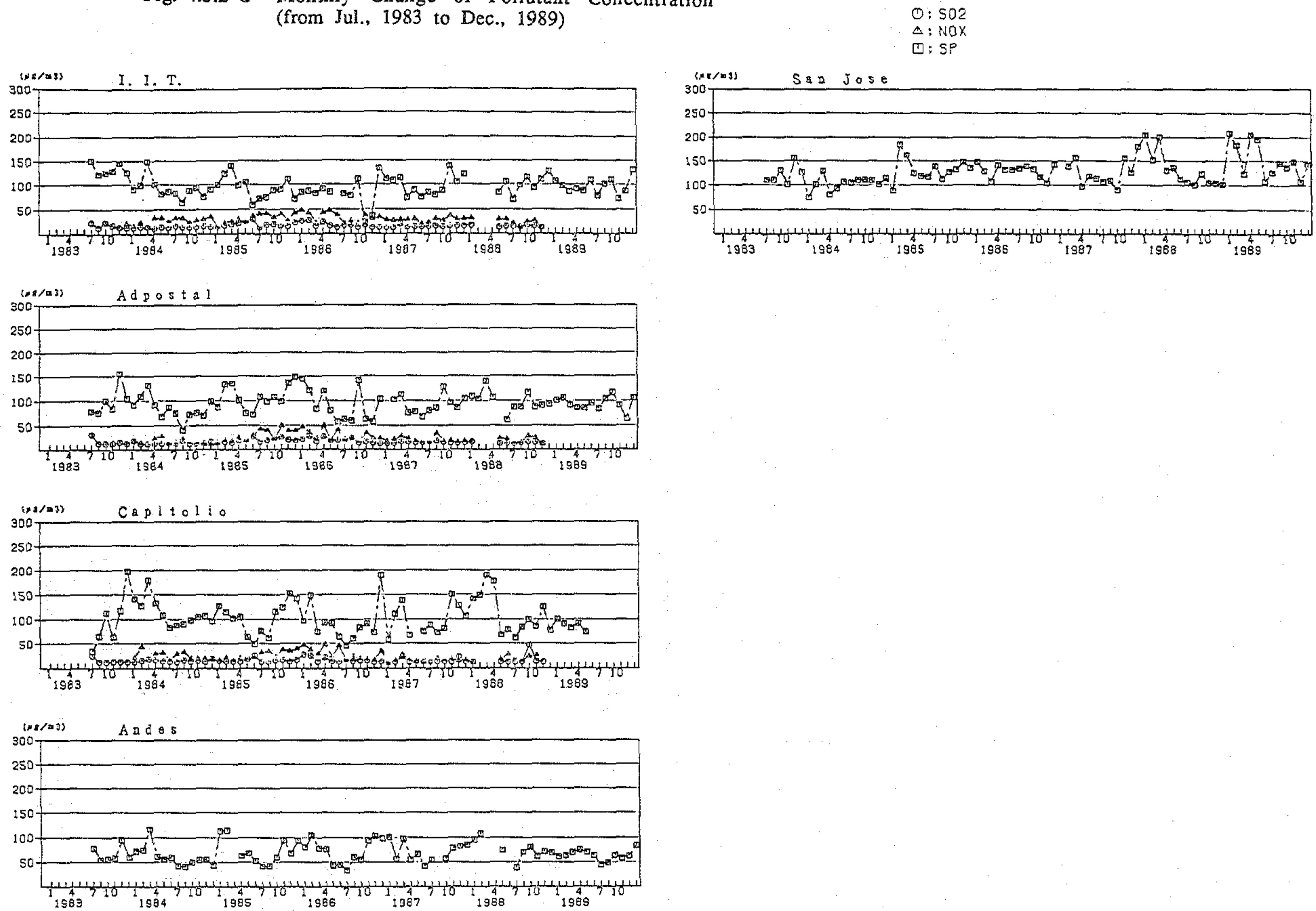


Fig. 4.3.2 ② Monthly Change of Pollutant Concentration (from Jul., 1983 to Dec., 1989)



CHAPTER 5 ANALYSIS OF PRESENT STATE OF AIR POLLUTANT SOURCES

CHAPTER 5 ANALYSIS OF PRESENT STATE OF AIR POLLUTANT SOURCES

Investigation of pollutant sources is one of the most important tasks involved in air pollution control planning. In this study, primary purpose of the source investigation was to estimate the quantity of air pollutant emissions to prepare a "source model" as an essential part of the air quality simulation model described in Chapter 6.

This chapter describes processes and results of various investigations conducted on air pollutant sources and presents the amount of pollutant emissions by source estimated based on these results.

Development of the source model for CO, SOx and NOx requires not only the regional total 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. Considering such requirements, the source 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 secondary roads. However, because of various constraints on the investigation including a limited length of time, it was not possible to cover all the sources in the object area. It is considered that the estimation of amount of pollutants in this study will give a value for regional total quantity of pollutant emissions that is lower than the actual value. The portion of pollutant emissions that was not accounted for in a source model for air quality simulation is generally expressed as the background concentration of the pollutant.

5.1 Factories

To estimate air pollutant emissions from factories and establishments the questionnaire investigation for factories, measurement of flue gas and fuel analysis were conducted.

5.1.1 Questionnaire Investigation for Factories

154 factories were investigated with questionnaire. The major investigation items include outline of smoke and soot emitting facilities (type, scale and operation), fuel type and its consumption, stacks (diameter and height), and exhaust gas treatment facilities.

(1) Types of Industries

In Table 5.1.1 are shown the number of the factories by industrial types covered by the investigation. Most of the industries were associated with living; food and drink industries (311, 312, 313): 31.2%, textile industry (321): 9.7%, and ceramic, stone and clay products industry (361) (manufacturing bricks and clay pipes): 13.0%.

Table 5.1.1 Number of Factories Surveyed and Annual Fuel Consumption by Industrial Type

No.	Industry	Number	Annual Fuel Consumption		
			Liquid	Solid	Gas
1	Food and kindered products	42	40,818	4,629	257
2	Drink feed	6	31,019	51,600	
3	Tobacco	1	566		
4	Textile	15	18,368	2,082	
5	Leather, leather products	2	719		
6	Footgear products	3	1,037		
7	Lumber and wood products	4	55	4,391	
8	Furniture and fixtures	2	7,541	5,018	
9	Pulp, paper and allied products	3	3,696	1,792	
10	Industrial chemical products	3	1,637		
11	Other chemical products	7	2,010	120	
12	Petroleum, coal and products	2	999		304
13	Rubber products	3	2,677		
14	Plastic products	1			606
15	Ceramic, stone and clay products	20	2,686	79,960	
16	Glass products	1	912		
17	Mineral and nonmetal products	1	624		
18	Iron and steel	4	3,399		
19	Non-ferrous metals and products	2	545		
20	Transportation equipment	1	15,140		
21	Auto industry	2	897		
22	Other manufacturing industries	12	7,750	159	622
23	Hospitals	9	3,222		
24	Hotels	6	2,772		
25	Other establishments	2	142		
	Total	154	149,231	149,751	1,789

Unit liquid and gas : kℓ

solid : ton

(2) Types of Facilities

Table 5.1.2 shows the types and number of smoke and soot emitting facilities. Boilers (205 units, 53.8%) and kilns for bricks and clay pipes (83 units, 21.8%) accounted for 75.6% of the total 381 units.

Table 5.1.2 Number of Facilities Surveyed and Annual Fuel Consumption by Facility Type

No.	Facility Type	Number	Liquid				Solid			Gas
			Crude oil	Light oil	Fuel oil	Others	Coal	Coke	Wood	Propane gas
1	Boiler	205	97669.8	17751.4	1923.5	39.8	62048.0		2725.0	
2	Gas furnace	4								605.6
3	Melting furnace for casting iron and steel	4						4920.0		
4	Melting furnace for aluminium	2			90.8	317.9				
5	Metal heat treating furnace	24	353.7	17359.4						
6	Petroleum refinery heater	8								303.8
7	Brick kiln (tunnel kiln)	30	2238.1				40438.0			
8	Brick kiln (downdraft round kiln)	23	447.6				15792.0			
9	Other kiln for bricks and clay pipes	30		339.1			23730.0			
10	Glass melting furnace	1	912.1							
11	Direct heating furnace for inorganic chemical products	2		624.5						
12	Direct heating furnace for foodstuff	26	122.6	726.5						257.2
13	Drying oven	15		7869.3					98.0	622.3
14	Incinerator for domestic waste	1		90.8						
15	Incinerator for industrial waste	4	4.5	57.7						
16	Burning kiln	1		65.3						
17	Other furnaces	1		227.1						
	Total	381	101748.4	45111.1	2014.3	357.7	142008.0	4920.0	2823.0	1788.9

Unit Liquid and gas : kℓ/year
Solid : ton/year

(3) Fuels Used

The major types of the fuels used were liquid, solid and gas fuels. The liquid fuels include crude oil (Crudo de Castilla), light oil (ACPM), fuel oil and so on. Among the solid fuels were included coal (carbon mineral), cokes (carbon coque) and wood (madera). The gas fuel was propane gas (gas propano).

The annual consumption of the major fuels, namely, crude oil, light oil and coal were 101,748 kl, 45,111 kl and 142,008 tons respectively.

① Fuel consumption by industrial type

Table 5.1.1 shows the annual fuel consumption by industrial type. As to the liquid fuels, the most consuming industry was food industry (311 and 312), which consumed 40,818 kl/year, accounting for 27.4% of their total consumption, followed by drink industry (313) (31,019 kl/year, 20.8%). With solid fuels, the most consuming industry was ceramic industry (361), which consumed 79,960 tons/year, accounting for 53.4% of their total consumption, followed by drink industry (313) (51,600 tons/year), 34.5%).

② Fuel consumption by facility type

As to crude oil, the most consuming facility were boilers, which used 97,670 kl/year, accounting for 96.0% of the total consumption. With light oil the most consuming facility were also boilers, which consumed 17,751 kl/year, accounting for 39.4% of the total consumption, followed by metal heat treating furnaces (17,359 kl/year, 38.5%). As to coal, kilns for bricks and clay pipes consumed 79,960 tons/year, accounting for 56.3% of the total consumption, followed by boilers (62,048 ton/year, 43.7%).

(4) Exhaust Gas Treatment Facility

There were 26 dust collectors. The number of the dust collectors by facility type is shown in Table 5.1.3. 19 units were attached to boilers. The number of cyclones and baghouses were 14 and 8 respectively.

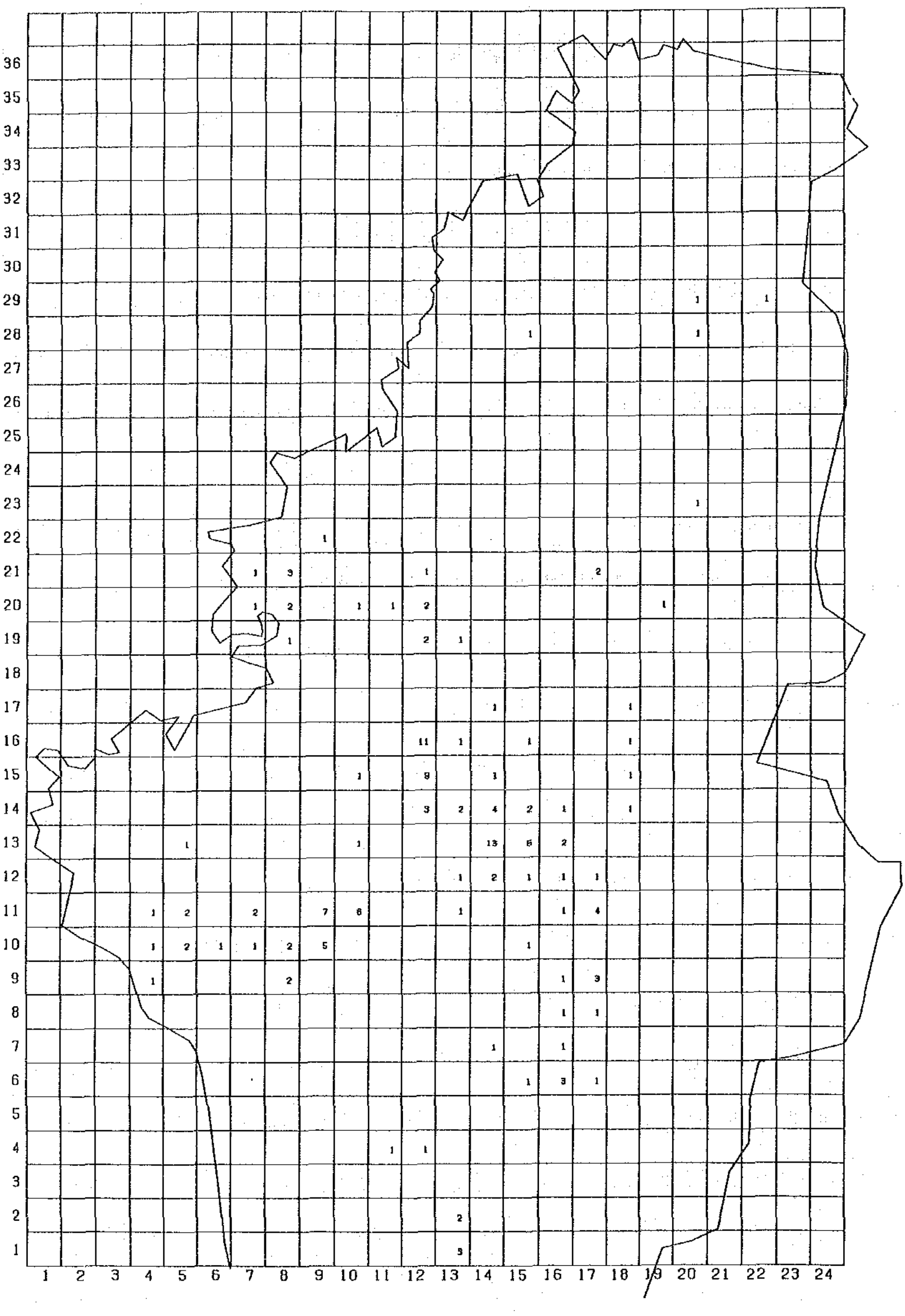
Table 5.1.3 Dust Collectors by Facility Type

Facility	Baghouse	Cyclone	Multiple cyclone	Spray tower	Total
Boiler	8	7	1	3	19
Direct heating furnace for foodstuff		4			4
Drying oven		2			2
Burning kiln		1			1
Total	8	14	1	3	26

(5) Factory Distribution

The distribution of the factories for questionnaire is shown in Fig. 5.1.1. The factories are widely located at the central part of the study area.

Fig. 5.1.1 Distribution of the Factory for Questionnaire



5.1.2 Factory Flue Gas Measurement

(1) Measuring Method

51 factories (facilities) were selected for measuring flue gas. Among them 41 are factories selected for questionnaire. Items and method of measurement are shown below:

SOx: JIS K 0103 (Methods for Determination of Sulfur in Flue Gas - Turbidimetric method)

NOx: JIS K 0104 (Methods for Determination of Oxides of Nitrogen in Flue Gas - PDS method)

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

O_2: JIS B 7983 (Continuous Analyzer for Oxygen in Flue Gas - Paramagnetic method)

(2) Facilities Measured

The facilities for flue gas measurement included 28 facilities using liquid fuel, 20 facilities using solid fuel, two facilities using propane gas, and one facility using electricity.

As to liquid fuel, 18 facilities were using crude oil while 10 using light oil or fuel oil.

With solid fuel, 17 facilities were using coal (including one facility which burns coal and woods), two burning woods, and one burning cokes.

As to facility type, the number of boilers and kilns for bricks and clay pipes, driers and incinerators were 30, 9, 5, 2 respectively. The other 5 facilities were a heating furnace, a plating furnace, a roaster, a baking furnace, an electric arc furnace, and a melting furnace.

(3) Measurement Result

① Dust

The range of dust concentration varied considerably from 0.011 g/m^3N to 21 g/m^3N. The average dust concentration of 51 facilities (excluding 2 measurements during coal feeding) was 0.77 g/m^3N.

With fuel types, the average concentration of coal firing facilities was 0.24 g/m^3N while that of the facilities with liquid fuels was 0.47 g/m^3N.

Among the liquid burning facilities, the average concentration of those using light oil and fuel oil was 0.20 g/m^3N, showing that there is little difference in dust concentration among the liquid fuels.

With the coal firing facilities, the concentration at coal feeding is about 2 to 5 times higher than that at normal operation.

The highest concentration was 21 g/m^3N of the melting furnace using cokes.

② SOx concentration

The range of SOx concentration was very wide: from N.D to 1,390 ppm.

As to fuel type, the average concentration of the coal firing facilities was 87 ppm while that of the facilities with liquid fuels was 657 ppm.

As regard liquid fuel, the average concentration of the facilities using light oil and fuel oil was 201 ppm, which is about 1/5 of the average concentration of 912 ppm of the crude oil burning facilities.

With coal firing facilities, the SOx concentration was also about 30 to 50% higher during coal feeding than that at normal operation.

③ NOx concentration

The range of the NOx concentration was very wide: from N.D to 681 ppm (at 4% oxygen: N.D - 2,168 ppm)

As to fuel type, the average concentration of coal firing facilities was 85 ppm (at 4% oxygen: 398 ppm), while that of the liquid fuel burning facilities was 150 ppm (at 4% oxygen: 230 ppm).

④ O_2 concentration

The range of the O_2 concentration was from 3.0 to 20.4%.

The average O_2 concentration of the liquid fuel burning facilities was 10.1%, while that of the coal firing facilities was 16.9%.

5.1.3 Fuel Analysis

58 fuel samples were analysed; 51 samples were taken from the factories selected for measuring flue gas and the other 7 samples include 2 of cocinol, 1 of kerosene, 2 of regular gasoline (gasoline corriente), 2 of extra gasoline (gasolina extra). The summary of the fuel analysis is shown in Table 5.1.4.

The fuel analysis shows that the sulfur content of the crude oil is 2.3%, which is 3.5 times as high as that of crude oils in the world (0.65%), and that the sulfur content of the light oil is about 0.4%, which is not much different from that of light oils in the world.

The sulfur content of the gasoline is about 0.06%, which is about 7.5 times higher than that in Japan (0.0087%).

With sulfur content of the coal, among 13 samples, 1 sample is about 1.2%, while the other 12 samples is from 0.6 to 0.7%, which shows that much low-sulfur content coals are used. On the other hand, the nitrogen content is about 2% which is much higher than that of liquid fuels. As a result, under some combustion condition NOx emission will possibly be high.

Table 5.1.4 Fuel Characteristics

1. Liquid and Solid Fuels

	ULTIMATE ANALYSIS (%)						H V Kcal/kg	D_4^{15} g/ml	Go m^3N/kg	Go' m^3N/kg
	C	H	S	N	M	A				
Crude oil	87.3	10.8	2.3	0.44	-	-	10160	0.98	11.32	9.70
Fuel oil	87.0	10.9	2.4	0.40	-	-	10200	0.97	11.33	9.71
Light oil	88.2	12.9	0.4	0	-	-	10800	0.87	12.00	10.36
Kerosene	87.2	13.3	0.12	0	-	-	11700	0.80	12.05	10.42
Cocinol	86.9	13.8	0.07	0	-	-	11900	0.92	12.18	10.56
Regular gasoline	80.7	12.2	0.06	0	-	-	11600	0.90	-	-
Extra gasoline	79.0	11.6	0.07	0	-	-	11750	0.89	-	-
Coal	77.0	5.36	0.57	1.91	1.44	13.69	7630	-	8.63	8.03
Coal	74.2	5.2	0.74	1.82	1.68	16.37	6960	-	8.38	7.80
Cokes	89.0	0	0.53	0.30	-	9.0	7200	-	7.93	7.93
Wood	51.0	6.0	-	0.1	-	-	5850	-	5.41	4.74

Note; HV - Heat Value, D - Gravity, Go - Theoretical Wet Combustion Gas Volume
Go' - Theoretical Dry Combustion Gas Volume

2. Propane Gas

C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	H V Kcal/kg	Ao m^3N/m^3N	Go m^3N/m^3N	Go' m^3N/m^3N	D_4^{15} g/ml
0.38	30.03	67.43	2.16	16560	28.91	31.36	26.64	0.54

Note: Ao - Theoretical Air Volume *1 m^3N = 1.40 *l*

5.1.4 Air Pollutant Emission Factors

Emission factors for factories were set based on the results of the flue gas measurement and fuel analysis and existing data in the U.S. and Japan. The emission factors for Dust, SOx and NOx (as NO_2) are shown in Table 5.1.5.

Table 5.1.5 Emission Factors for Factories and Establishments

No.	Facility Type	Fuel Used	SOx	Dust	NOx (as NO_2)
1	Boiler	Crude oil Fuel oil Machine oil	45.08 kg/kℓ 46.56 kg/kℓ 46.56 kg/kℓ	9.27 kg/kℓ	5.28 kg/kℓ
		Light oil	6.96 kg/kℓ	0.58 kg/kℓ	2.98 kg/kℓ
		Coal	8.84 kg/ton	12.00 kg/ton	4.78 kg/ton
		Wood	-	2.26 kg/ton	1.44 kg/ton
2	Gas furnace	Propane gas	-	0.20 kg/kℓ	1.35 kg/kℓ
3	Melting furnace for casting iron and steel	Coke	8.84 kg/ton	2.70 kg/ton	1.20 kg/ton
4	Melting furnace for alminium	Fuel oil	46.56 kg/kℓ	14.39 kg/kℓ	3.61 kg/kℓ
		Kerosen	1.92 kg/kℓ	42.79 kg/kℓ	1.58 kg/kℓ
5	Metal heat treating furnace	Crude oil Light oil	45.08 kg/kℓ 6.96 kg/kℓ	1.20 kg/kℓ	1.00 kg/kℓ
6	Petroleum refinery heater	Propane gas	-	36.18 kg/kℓ	1.49 kg/kℓ
7	Brick and clay pipe kiln	Coal	11.47 kg/ton	8.18 kg/ton	8.31 kg/ton
8	Glass melting furnace	Crude oil	45.08 kg/kℓ	4.91 kg/kℓ	5.71 kg/kℓ
9	Direct heating furnace for inorganic chemical products	Light oil	6.96 kg/kℓ	1.80 kg/kℓ	9.60 kg/kℓ
10	Direct heating furnace for foodstuff	Crude oil Light oil	45.08 kg/kℓ 6.96 kg/kℓ	1.20 kg/kℓ	1.50 kg/kℓ
		Propane gas	-	0.22 kg/kℓ	1.30 kg/kℓ
11	Drying oven	Light oil	6.96 kg/kℓ	1.80 kg/kℓ	9.60 kg/kℓ
		Wood	-	2.26 kg/ton	1.44 kg/ton
		Propane gas	-	0.20 kg/kℓ	1.35 kg/kℓ
12	Incinerator	Light oil	6.96 kg/kℓ	20.10 kg/kℓ	1.65 kg/kℓ
13	Burning kiln	Light oil	6.96 kg/kℓ	1.80 kg/kℓ	9.60 kg/kℓ
14	Other furnaces	Light oil	6.96 kg/kℓ	1.80 kg/kℓ	9.60 kg/kℓ

Note 1 Emission factors for boiler, brick and clay pipe kiln, drying oven(wood) and Incinerator were caculated from the flue gas measurement results.
Note 2 As to SOx emission factors, the following assumption is taken; percentages of sulfur contents in the fuels emitted in the atmosphere as for the liquid fuels, and coal and coke are 100% and 77.5% respectively. (# 4017)

(1) Dust and NOx

The emission factors for caldera, horno de ladrillo y tubo, horno para secar (madera) and incinerador de desperdicios were estimated from the flue gas measurement results. The values for horno de gas, horno de fundición de aluminio, hornos de calentamiento directo, horno para secar (ACPM and gas propano), horno para cocer and otros hornos were set based on the EPA report (#4015). The other factors were set based on data in Japan. The efficiency of the dust collectors (Table 5.1.6) was set based on the EPA report (#4016).

Table 5.1.6 Efficiency of Dust Collector

Collector	Efficiency (%)
Baghouse	99.7
Cyclone	65.3
Multiple cyclone	74.2
Spray tower	94.5

Source: #5016

(2) SOx

The EPA report (#4017) shows that 77.5% of fuel sulfur is emitted through coal combustion. With liquid fuels, 100% of fuel sulfur is assumed to be emitted. With gas propano and madera no SOx emission was assumed. As to the sulfur content in colas, hornos de ladrillo y tubo were assumed to use coals with 0.74% of sulfur, and the other coal firing facilities were assumed to use coals with 0.57% of sulfur (see Table 5.1.4).

5.1.5 Quantity of Air Pollutant Emission

The quantity of air pollutant emission was estimated based on the fuel consumption and the emission factors. The total annual emissions of Dust, SOx and NOx were 2,198 tons, 6,504 tons and 1,688 tons respectively.

(1) Air Pollutant Emissions by Industrial type

Air pollutant emissions by industrial type is shown in Table 5.1.7.

Table 5.1.7 Air Pollutant Emissions by Industrial Type

(Unit: ton/year)

No.	Industry	Dust	SOx	NOx
1	Food and kindered products	310.1	1509.1	214.4
2	Drink feed	767.8	1854.2	410.4
3	Tobacco	5.2	25.5	3.0
4	Textile	144.1	797.7	104.0
5	Leather, loather products	2.1	29.2	3.6
6	Footgear products	9.3	45.8	5.4
7	Lumber and wood products	3.1	15.1	12.1
8	Furniture and fixtures	27.0	92.9	78.4
9	Pulp, paper and allied products	54.1	173.8	29.1
10	Industrial chemical products	12.4	59.7	7.7
11	Other chemical products	8.7	38.7	12.1
12	Petroleum, coal and products	20.3	45.0	5.7
13	Rubber products	9.8	55.0	10.2
14	Plastic products	0.1	0.0	0.8
15	Ceramic, stone and clay products	676.0	1038.2	686.8
16	Glass products	4.5	41.1	5.2
17	Mineral and nonmetal products	0.0	4.3	1.9
18	Iron and steel	10.6	67.8	6.9
19	Non-ferrous metals and products	14.0	2.2	2.7
20	Transportation equipment	18.2	105.4	15.1
21	Auto industry	0.5	6.2	2.8
22	Other manufacturing industries	69.7	332.6	44.0
23	Hospitals	18.1	104.1	14.4
24	Hotels	10.7	59.1	10.7
25	Other establishments	1.9	1.0	0.3
	Total	2198.3	6503.7	1687.7

① Dust

As to dust emission by industrial type, drink industry (313) accounted for 720 tons (32.8% of the total emission), followed by ceramic industry (361) (manufacturing bricks and clay pipes) (676 tons, 30.8%), food industry (313, 312) (335 tons, 15.3%) and textile industry (321) (159 tons, 7.2%).

② SOx

With SOx emission by industrial type, drink industry (313) amounted to 1,854 tons (28.5%), followed by food industry (312, 313) (1,509 tons, 23.2%), ceramic industry (361) (1,038 tons, 16.0%) and textile industry (321) (798 tons, 12.3%).

③ NOx

As to NOx emission, ceramic industry (361) amounted to 687 tons (40.8%), followed by drink industry (313) (410 tons, 24.3%) and food industry (311, 312) (214 tons, 12.7%).

(2) Air Pollutant Emissions by Facility Type

Air pollutant emissions by facility type is shown in Table 5.1.8.

① Dust

As to dust emission by facility type, boilers amounted to 1,434 tons (65.2% of the total emission), followed by kilns for bricks and clay pipes (679 tons, 30.9%).

② SOx

With SOx emission, boilers' emission was dominant (5,167 tons, 79.4%), followed by kilns for bricks and clay pipes (1,041 tons, 16.0%).

③ NOx

As to NOx emission, boilers emitted 880 tons (52.1% of the total emission), followed by kilns for bricks and clay pipes (690 tons, 40.9%).

Table 5.1.8 Air Pollutant Emissions by Facility Type

(Unit: ton/year)

No.	Facility Type	Dust	SOx	NOx
1	Boiler	1433.8	5167.1	879.5
2	Gas furnace	0.1	0.0	0.8
3	Melting furnace for casting iron and steel	13.3	40.4	5.9
4	Melting furnace for alminium	14.9	4.9	0.8
5	Metal heat treating furnace	21.3	136.8	17.7
6	Petroleum refinery heater	11.0	0.0	0.5
7	Brick kiln (tunnel kiln)	349.1	564.7	354.6
8	Brick kiln (downdraft round kiln)	132.8	201.3	135.0
9	Other kilns for bricks and clay pipes	196.9	274.5	200.0
10	Glass melting furnace	4.5	41.1	5.2
11	Direct heating furnace for inorganic chemical products	1.1	4.3	6.0
12	Direct heating furnace for foodstuff	1.6	10.6	2.1
13	Drying oven	14.4	54.8	76.5
14	Incinerator for domestic waste	1.8	0.6	0.1
15	Incinerator for industrial waste	1.3	0.6	0.1
16	Burning kiln	0.0	0.5	0.6
17	Other furnace	0.4	1.6	2.2
	Total	2198.3	6503.8	1687.6

5.2 Motor Vehicles

5.2.1 Traffic Volume

(1) Road Network

1) Arterial Roads

The present state of arterial road network in Santafe de Bogota City is shown in Fig. 5.2.1. The network is fundamentally formed by north-south directional avenues called carreras and east-west directional streets called Calles. Several parts of the network are still under construction, therefore, the whole network has not been accomplished yet.

These arterial roads are mostly used for public transportation route by buses, small buses and micro buses. Most parts of blocks are paved and separated into driveway and sidewalk, however, the pavement is not adequately maintained.

2) Alleys

The traffic volume of every alleys was surveyed through observation of aerial photographs.

The surveyed area covers the whole territory of Santafe de Bogota City where exists alleys in use; it is shown in Fig. 5.2.2 enclosed by squares of one kilometer x one kilometer with broad lines.

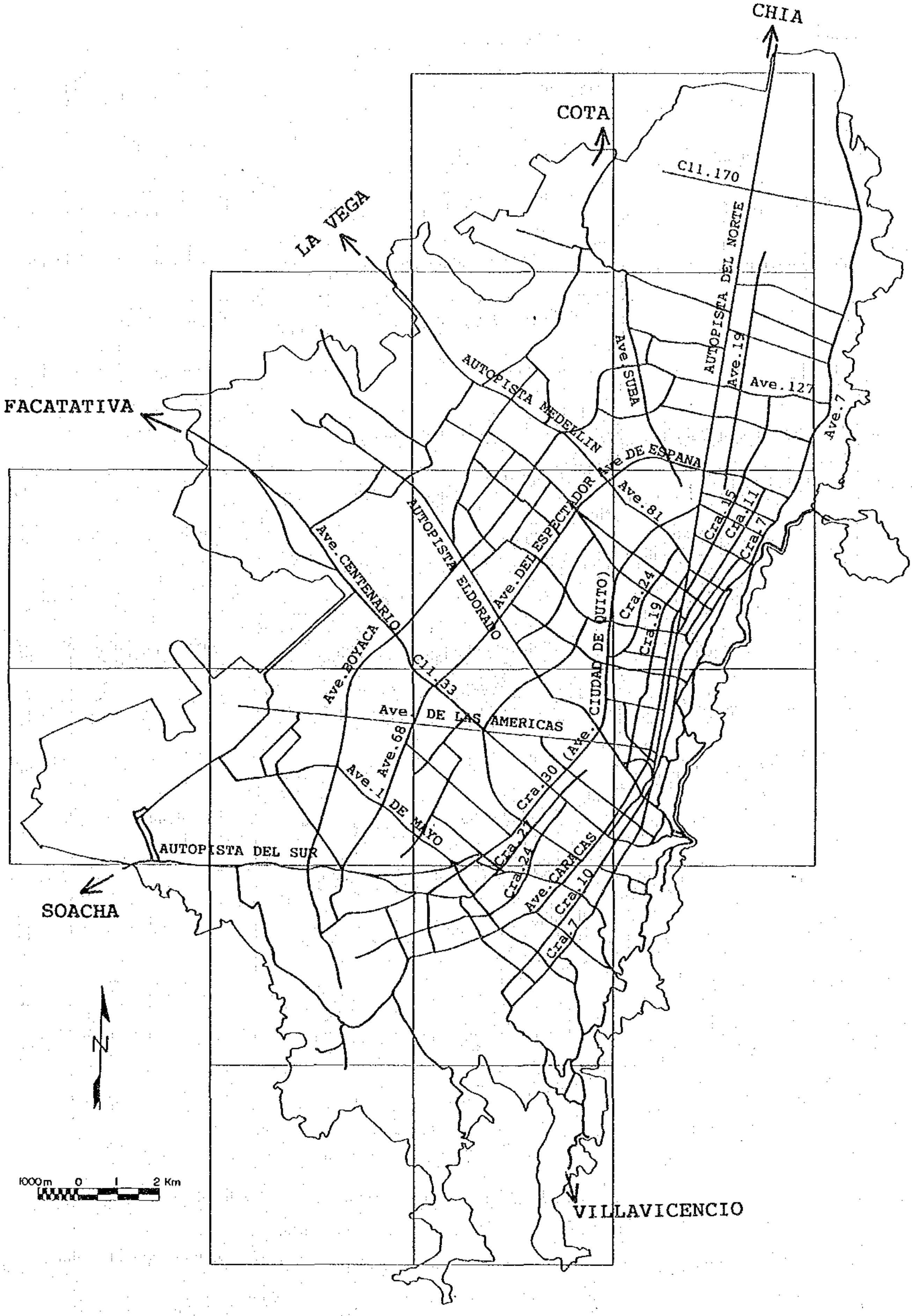


Fig. 5.2.1 Network of Major Roads in Bogota D.E.

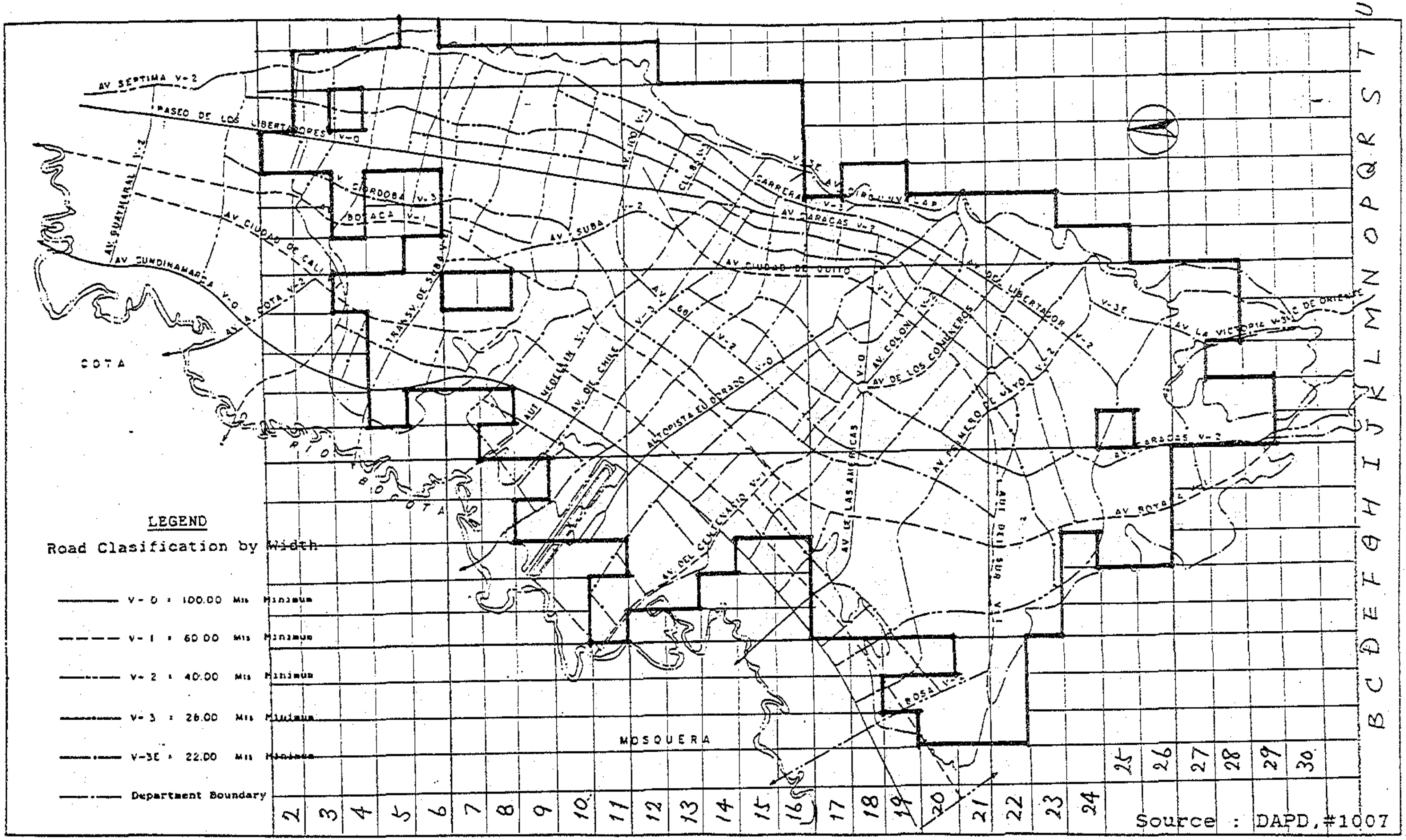


Fig. 5.2.2 Surveyed Area on Traffic Volume of Alleys

(2) Traffic Volume of Arterial Roads

An on-site traffic volume survey was conducted at 46 points on arterial roads in Santafe de Bogota City. Survey points were selected after due examination of road network of Santafe de Bogota City.

The following overviews were acquired on the characteristics of the traffic in Santafe de Bogota City from the results of the survey.

1) Weekday

a) Traffic Volume

The heaviest traffic was observed on AUTOPISTA NORTE, an arterial road in the north of the city, on which approximately 132,000 units/day. This was followed by Carrera 30 (Ave. CIUDAD DE QUITO) with approximately 93,000~112,000/day. Ave. 68 (Ave. DEL ESPECTADOR) with approximately 82,000~87,000/day, Ave. DE LAS AMERICAS with approximately 86,000/day, AUTOPISTA ELDORADO with approximately 77,000~79,0000/day and Ave. BOYACA with approximately 64,000/day. Traffic was heavy on the roads which spread radially from the center of the city to the north and the west, as well as on the circular roads which connect above mentioned radial roads.

Also the results indicated that other arterial roads in urbanized zone had a heavy traffic with more than 30,000 units/day.

b) Chronological Change

Traffic in Santafe de Bogota City underwent chronological changes, with heavier traffic during the periods between 07:00 and 09:00 as well as between 18:00 and 20:00, thus corresponding to the "rush hours" caused by commuters. The peak hours, however, differed more or less according to district.

There was another peak observed during the period between 12:00 and 14:00, most likely due to lunchtime transportation.

The pattern of hourly fluctuation showed two peaks, one in the morning and the other in the evening. Morning peaks were higher with the survey points on the direction towards the city center, while evening peaks were higher with those on the direction towards the outside of the city.

On Survey Point on AUTOPISTA NORTE, which had the heaviest traffic, traffic was by far the heaviest during the evening rush hour (between 19:00 and 20:00). Its northward traffic was as heavy as 9,000 vehicles/hour.

In the city center, morning and evening peaks were less prominent and traffic was heavy throughout the day. Therefore its fluctuation pattern thus showed a table-like shape.

In most survey points, more than 90% of traffic per day concentrated on the period between 06:00 and 22:00.

c) Component of Vehicle Types

The roads with higher percentage of trucks showed less trucks in the morning and in the evening, as was observed typically on Ave. 68. This was achieved through traffic restrictions against trucks heavier than 4.5 tonnes (No trucks from 07:00 to 09:00 as well as from 18:00 to 20:00 in the city center: from 07:00 to 08:00 as well as from 18:00 to 19:00 in the surrounding districts) as a measure to dissolve traffic congestions in the city center.

Overall buses (buses and busetas) shared a higher percentage of 20% - 30% in the south and west of the city than it did in the north. The percentage of buses was also high in the city center, with approximately 70% at Carrera 10, which was higher than that of passenger cars.

Trucks share a high percentage at the survey points on AUTOPISTA SUR, AUTOPISTA LLANO and Ave. CENTENARIO, all of which were on the roads linking suburbs and Santafe de Bogota City. Also trucks shared a remarkably high percentage on survey point on Carrera 86 located in the west of the city.

2) Sundays

a) Traffic Volume

Both radial roads spreading from the city center to the north and the west of the city and circular roads connecting the radials showed heavier traffic than did other roads. On the contrary, roads acting as bypasses for such arterial roads for example Cra.9 saw far less traffic than on weekdays.

According to the comparison between traffic on weekdays and on Sunday, average traffic on Sundays was approximately 70% of that on weekdays although on some roads Sunday traffic exceeded weekday traffic. On AUTOPISTA DEL SUR and AUTOPISTA LLANO which connect Santafe de Bogota City with its suburbs, car traffic out of the city to suburbs on Sundays seems to exceed that on weekdays.

b) Chronological Change

The fluctuation pattern of Sundays was generally different from that of weekdays. There are no morning and evening peak hours and the pattern showed a gradual curve with a mild peak during the day.

In most survey points, more than 90% of traffic per day concentrated on the period between 06:00 and 22:00 except the survey point on the road leads to the eastern plane district.

c) Component of Vehicle Type

As in weekdays, buses shared a higher percentage of 20 - 30% in the city center as well as the south and west of the city than in the north of the city. Carrerra 10 showed a particularly high percentage of buses (approximately 60%), which was higher than that of passenger cars.

Unlike the results on weekdays, percentage of trucks was generally low on Sundays, and the highest figure of barely above 10% was observed at only one survey point on Carrera 86, which is in the west end of the city.

3) Saturdays

a) Traffic Volume

On average, traffic on Saturdays was around 90% of traffic on weekdays. As was the case with Sunday traffic, on survey points on AUTOPISTA DEL SUR and AUTOPISTA LLANO, volume of traffic on Saturdays exceeded that on weekdays. Also Carrera 7 showed heavier traffic on Saturdays than on weekdays.

b) Chronological Change

The fluctuation pattern changed very little at morning, and the evening peaks had the same gradual curve with a mild peak as that of Sundays.

The traffic volume during the period between 06:00 and 22:00 is almost 90% of the whole traffic per day or showing less concentration than on weekdays and Sundays. On average traffic of the above mentioned period was 88% of the whole traffic per day.

c) Component of Vehicle Type

As on weekdays and Sundays, survey points in south, west and the center of Santafe de Bogota City showed higher percentage of buses than in the north of the city. Percentage of trucks on Saturdays was a little lower than that on weekdays but higher than that on Sundays.

(3) Traffic Volume of Alleys

A survey on traffic volume of alleys was conducted by means of aerial photograph observation at 273 squares of one km^2. In each square the number of vehicles by three types, automobiles, buses and trucks, was counted and the length of roads was also measured.

The total of the vehicles observed on the alleys out of the photographs, which cover the area of 273 km^2, was about 74,000: automobiles 62,000 (84%), buses 7,000 (10%) and trucks 5,000 (6%). And the total length of the alleys was about 3,200 km.

So the average density of vehicles was 272 units/km^2 with the average interval of 43 meters assuming the cars were running in a line.

With these outputs the equivalent traffic volume by the hour on a single road was presumed for each square by assuming the traveling speed on alleys as 14 km/h according to the result of on-site survey along the alleys as follows:

$$Nh = \frac{V \times 1000}{L / n}$$

where, Nh: traffic volume per hour (units/hour)

V: average traveling speed (km/hour)

L: total length of alleys within a square

n: total number of vehicles within a square

And the equivalent traffic volume per day was also presumed by assuming the hourly fluctuation pattern as was taken from the result of the on-site survey at the neighboring point.

Then the average equivalent traffic volume was obtained as 305 units/h and 5,100 units/day for the whole alleys in the survey area.

(4) Driving Conditions

1) Survey on License Plates

There is some discrepancy between the total number of vehicles frequently driving through Bogota city and the total number of vehicles registered at Santafe de Bogota City. One of the main reasons for this is the background that some vehicles used inside Santafe de Bogota City are registered at other cities or at other states due to various reasons including easier registration procedure.

A sampling survey on registration locations of vehicles driving in Bogota City was conducted, in order to obtain basic data to estimate the proportion of vehicles registered outside of Santafe de Bogota City which occupy the roads in the City.

The survey was conducted at 4 points along major arterial roads in the city (see Fig. 5.2.3). Registration numbers thus observed were classified into three categories: those registered at Santafe de Bogota City, registered at the other cities of Cundinamarca and registered at the other states/departamentos.

The following overviews were gained out of the results.

a) Trucks

Although percentage of trucks was not high enough to ensure reliable result, most trucks observed were registered at outside Santafe de Bogota City except on Ave. 1 de Mayo, where approximately 50% of trucks observed were registered in the city.

b) Buses

Apart from Ave. CARACAS where the percentage of buses registered in Santáfe de Bogota City is relatively low, more than 95% of buses observed were registered in the city.

c) Jeeps and Light Trucks

Approximately 60% of jeeps and light trucks on Ave. 7 were registered in the city, while about 40% were registered outside the city. On other roads 40 - 50% were registered in the city while 50 - 60% were registered outside the city.

d) Passenger Cars

On Ave. 7, approximately 40% of passenger cars were registered in the city while approximately 60% were registered outside the city. On other roads, 60 - 70% were registered in the city while 30 - 40% were registered outside the city.

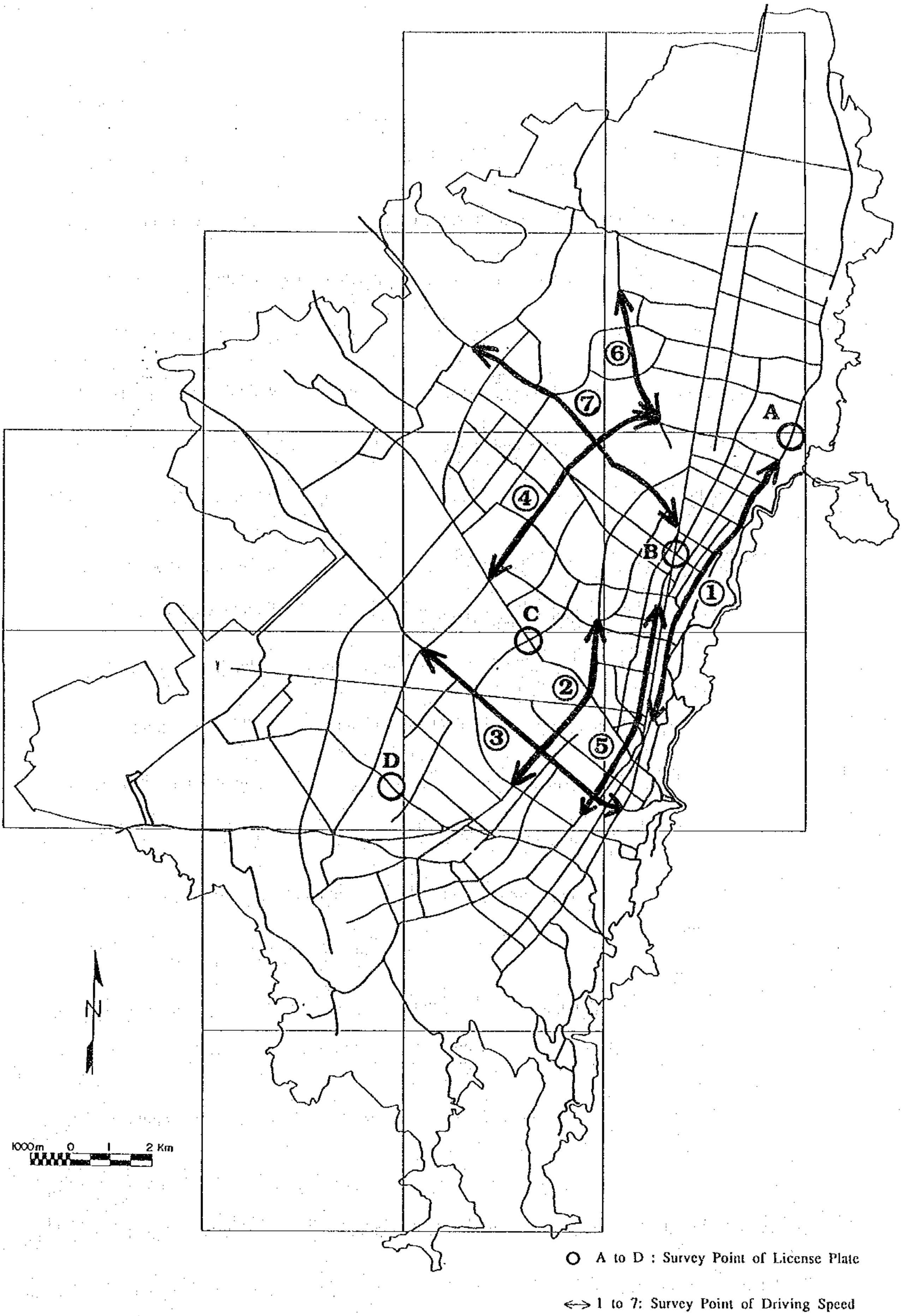


Fig. 5.2.3 Location Map of Traffic Conditions Survey

2) Driving Speed of the Vehicles

Another survey was conducted in order to measure average driving speed of vehicles in Santafe de Bogota City. By taking a passenger car among the ordinary traffic flow, the time elapsed while driving along a certain distance of the way was measured. Average driving speed was then calculated by the time and the distance it had been taken from the survey. Fig. 5.2.3 shows surveyed roots.

One remarkable characteristic of buses in Santafe de Bogota City was that they do not have clearly defined bus stops and stop very frequently for the passengers either to get on or to get off the bus. Average driving speed of buses was therefore considered impossible to calculate from above mentioned survey and a questionnaire was conducted to the staffs in Servicio de Salud de Bogotá D.E. to find out driving conditions of buses during commuting hours.

Out of results of driving survey and questionnaires, the following facts have been obtained.

a) Passenger Cars

Results of the driving survey show that average driving speed on arterial roads was approximately 20 km/h during traffic congestion and was 20 - 30 km/h during normal traffic. On Ave. CARACAS, however, the average speed during traffic congestion was approximately 15 km/h, which shows that the road was more crowded than the others.

On other ordinary roads, the average speed was between 10 and 15 km/h.

b) Buses

The average speed of buses going through Ave. CARACAS and Ave. 10 was slower than the others, sometimes lower than 10 km/h during traffic congestion on these roads. During normal traffic, however, these roads in the city center allowed the buses to drive at approximately 15 km/h.

The average speed on suburban roads was 15 - 20 km/h during traffic congestions and it was higher than 20 km/h under normal traffic.

On Ave. CARACAS and on Ave. 10, number of times car stopped per kilometer was 5 to 10, that was, the car had to stop every 100 or 200 meter. This suggests that not only traffic congestions but also overstops of buses slow down the average speed of other vehicles.

5.2.2 Measurement of Exhaust Gas from Motor Vehicles

A measurement of exhaust gas from automobiles was conducted for CO, NOx and HC while the engine was idling. The sample group of 160 vehicles consists of three types of fuel and covers from small sized vehicles to large ones and from very old to new vehicles as shown in Fig. 5.2.1.

As the result of measurement the following facts have been picked out.

a) Generally speaking gasoline vehicles had higher concentration of CO and HC than diesel vehicles, while diesel vehicles have higher concentration of NOx. An LPG car showed the lowest concentration of NOx and lower of CO and HC compared to gasoline vehicles.

b) Most of gasoline vehicles showed higher concentration of CO than the figure used for emission control in Japan of 4.5%.

c) All of gasoline vehicles showed higher concentration of HC than the figure of the emission standard in Japan (1,200 ppm), and the concentration also showed the trend of ascending in proportion to the age of the vehicle.

d) It seems that the pollution by CO and HC has been caused largely by gasoline vehicles, particularly by large sized or very old vehicles.

Table 5.2.1 Results of Exhaust Gas Measurement

Fuel Type	Size	Year Type	Number of Samples	Average Concentration CO (%)	NOx (ppm)	HC (ppm)
Gasoline	large	~ 1974	20	6.2	22	3,400
		75 ~ 84	18	6.8	19	2,400
		85 ~	6	4.7	27	1,500
	small	~ 1974	34	5.0	61	2,100
		75 ~ 84	29	6.6	37	1,200
		85 ~	30	6.8	37	920
Diesel	large	~ 1974	9	0.25	160	210
		75 ~ 84	9	0.15	87	290
		85 ~	4	0.21	100	190
LPG	small	1984	1	0.34	6	440