3.2.2 Results of the Measurement

(1) Nitrogen Oxides at the Fixed Station

1) Outline

Table 3.2.6 shows the outline of the measurement result for nitrogen dioxide (NO_2) for which the ambient standard value has been established, while Table 3.2.7 for nitrogen monoxide (NO), nitrogen dioxide (NO_2), and nitrogen oxides (NOx). The concentration of nitrogen dioxide averaged over the entire period (244 days) was 0.047 ppm and its maximum one-hour value was 0.322 ppm. The ambient standard value (0.21 ppm for one hour) was exceeded for a total of 15 hours (0.3%) during the entire period. The total-period average of 0.047 ppm is about 1.5 times the annual average (0.03 ppm) of general ambient air monitoring stations in 23 wards of Tokyo in 1986.

Table 3.2.6 Outline of Measurement Result (NO_2)

Item	Effective measuring days	Measuring hours	Total-period average	Number of hours when the 1-hour value exceeded 0.21 ppm, and percentage		98% value of the 1-hour value	Number of hours when the 1-hour value exceeded 0.105 ppm	
	(days)	(hours)	(ppm)	(hours)	(%)	(ppm)	(hours)	(%)
Nitrogen dioxide (NO_2)	244	5878	0.047	15	0.3	0.133	266	4.5

Table 3.2.7 Outline of Measurement Result (NO, NO_2, NOx)

Item	Effective days (days)	Measuring hours (hours)	Total-period average (ppm)	Maximum 1-hour value (ppm)	Max. daily average (ppm)
Nitrogen monoxide (NO)	244	5878	0.036	0.378	0.096
Nitrogen dioxide (NO_2)	244	5878	0.047	0.322	0.093
Nitrogen oxides (NO_x)	244	5878	0.083	0.529	0.190

2) Monthly Fluctuation

Figure 3.2.5 shows change of monthly average for nitrogen monoxide, nitrogen dioxide, and nitrogen oxides, and Table 3.2.8 the monthly average, maximum and minimum. More details are given in the Appendices.

The concentration of nitrogen monoxide increased rapidly in December, the beginning of the winter season, and decreased gradually thereafter. The nitrogen dioxide concentration also increased rapidly in December, but kept relatively constant thereafter.

The high concentration in the winter can be explained by frequent thermal inversion and small precipitation in the winter.

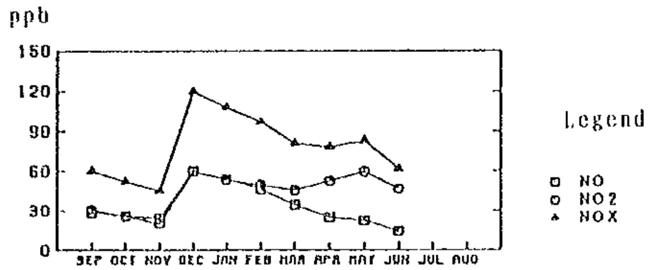


Figure 3.2.5 Monthly Fluctuation of Nitrogen Oxides

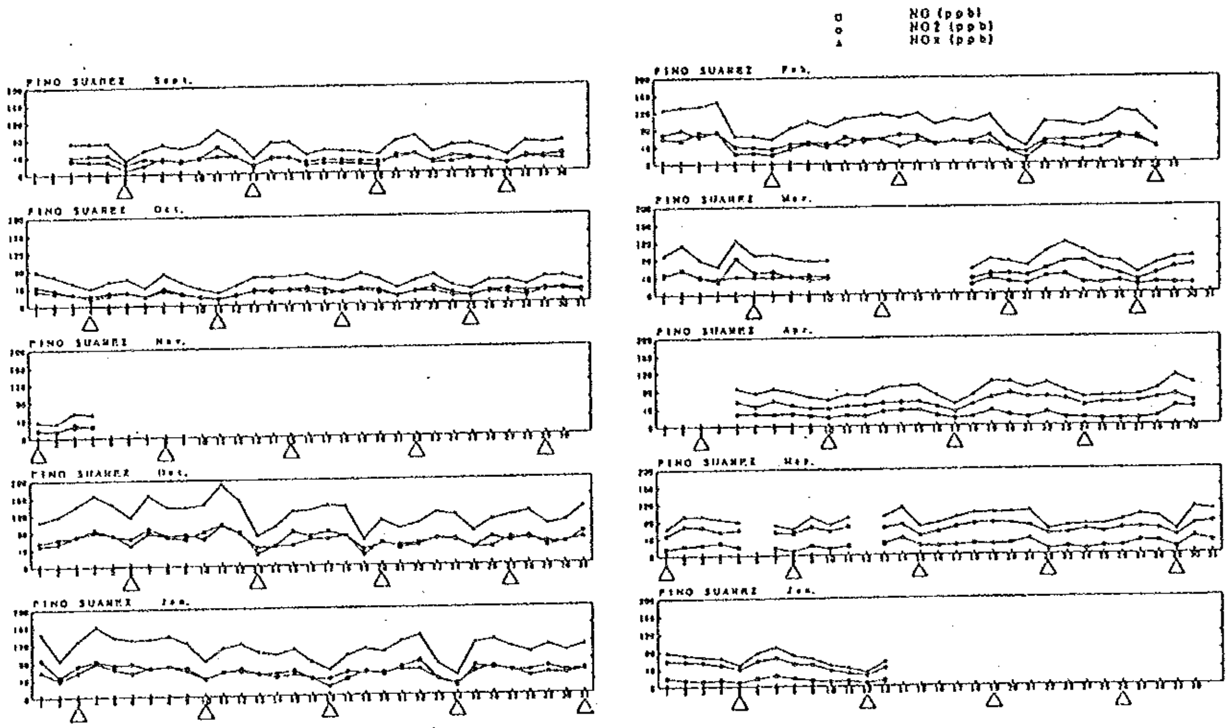
3) Daily Fluctuation

Figure 3.2.6 shows the change of the daily average for nitrogen monoxide, nitrogen dioxide, and nitrogen oxides. Comparison between holidays and weekdays shows that the concentration was lower on holidays. This may be attributed to considerably smaller traffic volume on holidays.

Table 3.2.8 Monthly Average, Maximum and Minimum Concentration of Nitrogen Oxides

Unit : ppm

Item / Month, Year	Nitrogen monoxide			Nitrogen dioxide			Nitrogen oxides			Effective measuring hours (hr)
	Monthly average	Maximum	Minimum	Monthly average	Maximum	Minimum	Monthly average	Maximum	Minimum	
Sept. 1987	0.0284	0.184	0.001	0.0311	0.124	0.008	0.060	0.226	0.011	661
Oct. 1987	0.0262	0.134	0.007	0.0256	0.111	0.007	0.0523	0.188	0.015	739
Nov. 1987	0.0245	0.123	0.007	0.0201	0.085	0.010	0.0451	0.141	0.018	104
Dec. 1987	0.060	0.342	0.003	0.0592	0.321	0.012	0.1197	0.467	0.017	741
Jan. 1988	0.0542	0.359	0.002	0.0533	0.223	0.009	0.1080	0.456	0.012	738
Feb. 1988	0.0465	0.378	0.003	0.0501	0.322	0.007	0.0971	0.529	0.019	669
Mar. 1988	0.0347	0.258	0.003	0.0458	0.231	0.008	0.0811	0.379	0.014	552
Apr. 1988	0.0250	0.238	0.003	0.0526	0.187	0.010	0.0781	0.311	0.013	640
May 1988	0.0226	0.169	0.003	0.0596	0.196	0.016	0.0826	0.283	0.021	723
June 1988	0.0145	0.109	0.003	0.0469	0.136	0.011	0.0619	0.203	0.016	311



Note : The simbol△ indicates holidays

Figure 3.2.6 Change of Daily Average Concentration of Nitrogen Oxides

4) Hourly Fluctuation

Figure 3.2.7 shows the daily hourly concentration of nitrogen oxides averaged over the measuring period. The daily hourly average concentration for each month is shown in the Appendices. Throughout the year, both nitrogen monoxide and nitrogen dioxide showed a single-peak type fluctuation in concentration, with the peak appearing in the morning. Conditions contributing to this phenomenon may include rapid increase in traffic volume and very calm wind in the morning. After peaking, the concentration decreases rapidly as the mixing depth grows. Traffic volume increases in the evening, but without much increase in the concentration because of active convective mixing under the temperature gradient close to the dry adiabatic lapse rate. Another pertinent factor considered is the wind speed which begins increasing in the afternoon and peaks around 18:00.

The concentration of nitrogen monoxide peaks around 8:00 and that of nitrogen dioxide around 10:00 with the time lag of about 2 hours between them.

The morning peaks of nitrogen monoxide and nitrogen dioxide are more significant in winter than in autumn. Peak values of the former are higher than those of the latter in autumn and winter, while the trend is opposite from spring to summer.

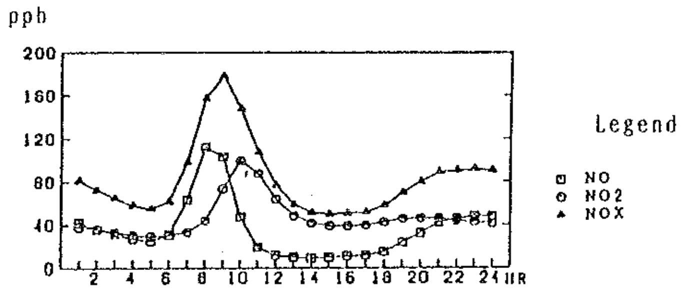


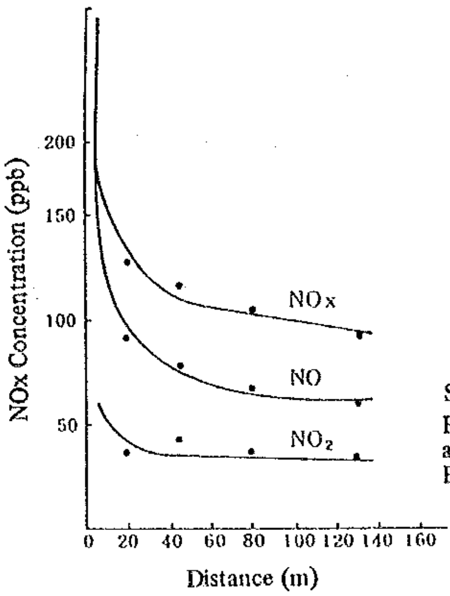
Figure 3.2.7 Daily Hourly Average Concentration of Nitrogen Oxides

(2) Measurement with the Monitoring Cars

1) Definition of Roadside and Off-road Points

Air pollution along the road is generally characterized by high concentration near the road, with the concentration decreasing rapidly as the distance from the road increases.

Figure 3.2.8 shows the typical concentration profile of nitrogen oxides along the distance from the road edge observed in Japan. At a distance of around 100 m, there exists almost no influence from the road.



Source:
Report of review on the roadside according to the ambient pollution prediction approach, Bureau of Environment Protection, Tokyo Metropolitan Government

Figure 3.2.8 Concentration Profile of Nitrogen Oxides Along the Distance from Road Edge (Japan)

Table 3.2.9 shows the distance of the measuring points from the road edge.

In the following description, measuring points of Nos. 1, 5, 7, 9, 10 and 19 within a distance of 40 m from the road edge are referred to as "roadside points" while the other points as "off-road points."

Table 3.2.10 and Figure 3.2.9 show the average concentration of the pollutants by point and Figure 3.2.10 the example of hourly fluctuation. The Appendices include the aggregate result and hourly change by point.

Table 3.2.9 Distance between Measuring Point and Road Edge

Measuring Point	Name of Road	Distance from the Road Edge (m)
5 : METRO CUAUHTEMOC	AV. CHAPULTEPEC	10
1 : ROSARIO	AV. PARQUE VIR	20
7 : ZARAGOZA Y LEON	CALZ. IGNACIO ZARAGOZA	40
9 : IZTAPALAPA	CALZ. ERMITA IZTAPALAPA	20
19 : AGRICOLA ORIENTAL	RIO CHURUBUSCO	10
10 : CENTRO No. 2	PASEO DE LA REFORMA	10
14 : AZCAPOTZALCO	AV. PARQUE VIR	450
11 : ECATEPEC	VIA. MORELOS	150
17 : CENTRO MEDICO	AV. CHAUHTEMOC EJE 1	250
18 : FUJIYAMA	BLVD. A LOREZ MATEOS	700
12 : D.M. NACIONAL	AV. GRANCANAL	420
4 : CUEMANCO	ANILLO PERIFERICO	620

2) Sulfur Dioxide (SO_2)

The average of all measuring points was 43 ppb. Comparison of measurement results between the off-road and the roadside points showed no difference. When compared with Tokyo (23 wards), where the annual average at the general ambient air monitoring stations was 9 ppb in 1986, the average at the off-road points is more than four-fold that of Tokyo. The annual average of the automobile exhaust gas monitoring stations in Tokyo was 12 ppb in 1986. The average at the roadside points in Mexico City is more than three-fold that of Tokyo.

The average was highest at 75 ppb at ECATEPEC (No. 11) which is northeast of Mexico City and lowest at 10 ppb at CUEMANCO (No. 4), to the south.

Hourly fluctuation by point showed a single-peak pattern, with the peak appearing at 8:00 to 10:00 in the morning. This trend is more remarkable at the points where the concentration is high.

3) Nitrogen Oxides (NO, NO_2, NO_x)

The average of all the measuring points was 60 ppb for nitrogen monoxide and 49 ppb for nitrogen dioxide.

When compared with Tokyo (23 wards), where the annual average at the general ambient air monitoring stations was 34 ppb for nitrogen monoxide and 30 ppb for nitrogen dioxide in 1986, the average of the off-road points in Mexico City was more than twice that of Tokyo for both nitrogen monoxide and nitrogen dioxide. In contrast, the annual average of the automobile exhaust gas stations in Tokyo was 84 ppb for nitrogen monoxide and 40 ppb for nitrogen dioxide in 1986. This indicates that the average for nitrogen monoxide at the roadside points was lower than that in Tokyo. The average concentration of nitrogen monoxide was highest at 122 ppb at CENTRO MEDICO (No. 17), a center of Mexico City and lowest at 3 ppb at CUEMANCO. The average concentration of nitrogen dioxide was highest at 68 ppb at METRO CUAUHTEMOC (No. 5), a center of Mexico City, and lowest at 19 ppb at CUEMANCO.

Hourly fluctuation at the points other than CUEMANCO (No. 4) indicated a single-peak pattern, with the peak appearing in the morning. The peak of nitrogen dioxide lagged that of nitrogen monoxide by about 2 hours.

4) Carbon Monoxide (CO)

The average of all the measuring points was 3.9 ppm. The average for the off-road points was 3.4 ppm, and for the roadside points 4.3 ppm.

When compared with Tokyo (23 wards), where the annual average at the general ambient air monitoring stations was 0.9 ppm in 1986, the annual average at the off-road points in Mexico City was more than three times that of Tokyo. The annual average at the automobile exhaust gas monitoring stations in Tokyo was 2.5 ppm in 1986, indicating that the average at the roadside points in Mexico City was nearly double that of Tokyo. The average by measuring point was highest at 6.8 ppm at CENTRO MEDICO, and lowest at 0.9 ppm at CUEMANCO.

Hourly fluctuation at each point indicates a dual-peak pattern, with a morning peak appearing from 8:00 to 10:00 and an evening peak between 20:00 to 22:00. The concentration level is higher in the morning.

5) Ozone (O_3)

The average of all the measuring points was 38 ppb. The average for the off-road points was 41 ppb and the roadside points 34 ppb: the average for the off-road points was higher by 7 ppb. The hourly average peak concentration by measuring point was highest at CUEMANCO with 134 ppb at 13:00, and lowest at ECATEPEC with 69 ppb at 13:00.

Hourly fluctuation at each point shows the peak appearing at 11:00 to 14:00.

6) Non-methane Hydrocarbons (NMHC)

The average of all the measuring points was 1.32 ppmC. The average for the off-road points was 1.12 ppmC and the roadside points 1.52 ppmC: the average for the roadside points was higher by 0.40 ppmC.

The average by measuring point was highest at 2.36 ppmC at AZCAPOTZALCO (No. 14) in the northwest of Mexico City and lowest at 0.21 ppmC at CUEMANCO.

Hourly fluctuation at each point indicates a single-peak pattern, with the peak appearing in the morning.

7) Suspended Particulate Matter (SPM)

Here, SPM refers to the suspended particulate matter whose diameter is smaller than or equal to 10 μm.

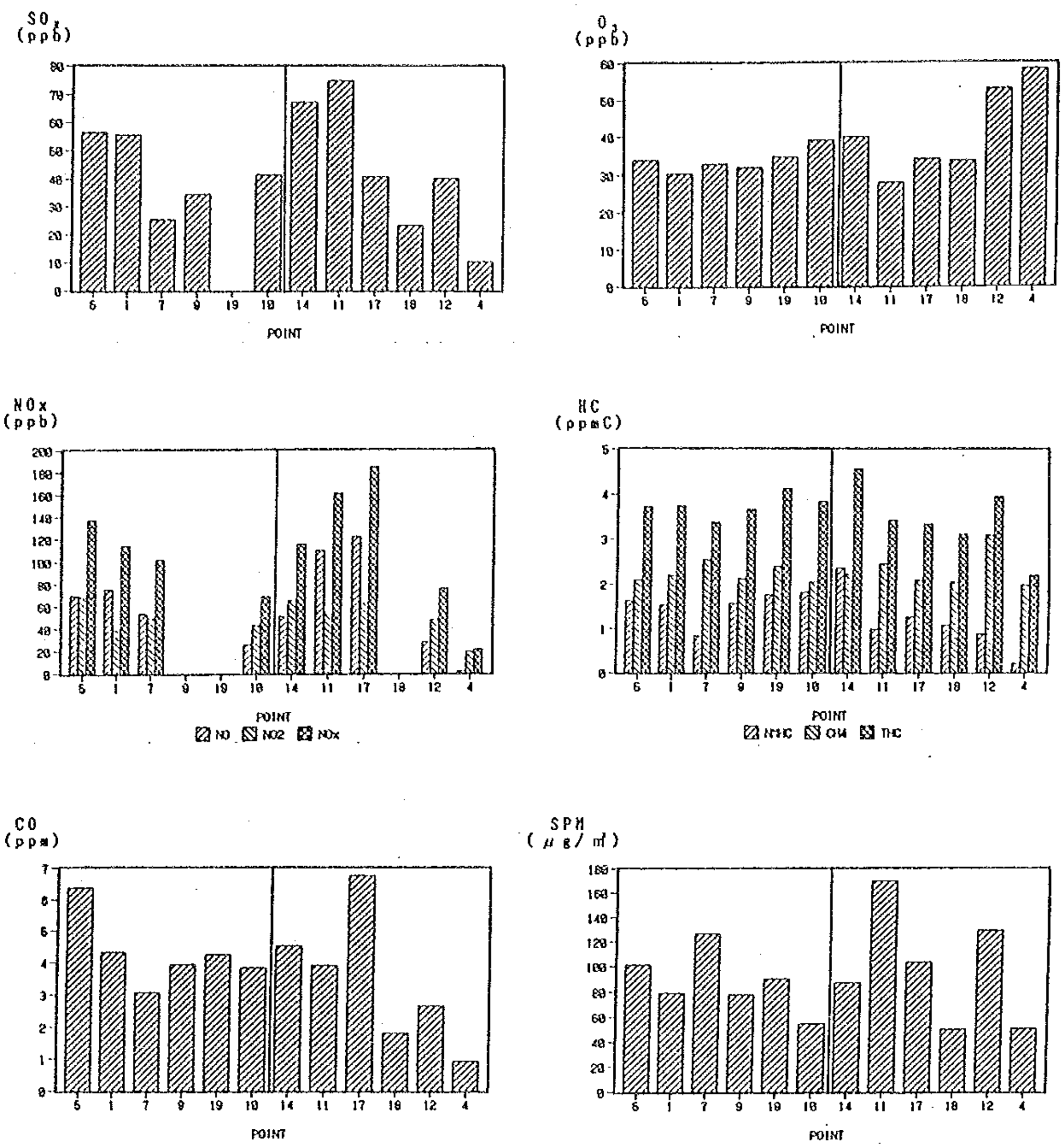
The average of all the measuring points was 93.4 $\mu g/m^3$.

The average for the off-road points was 98.4 $\mu g/m^3$, and the roadside points 88.4 $\mu g/m^3$: the concentration higher by 10 $\mu g/m^3$ at off-road.

When compared with Tokyo (23 wards), where the annual average of the general ambient air monitoring stations was 55 $\mu g/m^3$ in 1986, the average of the off-road points in Mexico City was approximately double that of Tokyo. The annual average of the automobile exhaust gas monitoring stations in Tokyo was 58 $\mu g/m^3$ in 1986. This indicates that the average of the roadside points in Mexico City was about 1.5 times that of Tokyo.

The average by measuring point was highest at 170 $\mu g/m^3$ at ECATEPEC, and lowest at 50 $\mu g/m^3$ at FUJIYAMA (No. 18) in the southwest and CUEMANCO.

Hourly fluctuation at each point indicated a single-peak pattern, with the peak appearing at 8:00 to 10:00 in the morning.



Road-side	Off-road
5 : METRO CUAUHTEMOC	14 : AZCAPOTZALCO
1 : ROSARIO	11 : ECATEPEC
7 : ZARAGOZA Y LEON.	17 : CENTRO MEDICO
9 : IZTAPALAPA	18 : FUJIYAMA
19 : AGRICOLA ORIENTAL	12 : D.M.NACIONAL
10 : CENTRO No.2	4 : CUEMANCO

Figure 3.2.9 Average Concentration by Point Measured with Monitoring Cars

Table 3.2.10 Average Concentration by Point Measured with Monitoring Cars

Item / Point	SO_2 ppb	NO ppb	NO_2 ppb	NOx ppb	CO ppm	O_3 ppb	NMHC ppmC	CH_4 ppmC	THC ppmC	SPM μg/m³
5 : METRO CUAUHTEMOC 87.DES 9～87.DES28	56	69	68	137	6.4	34	1.63	2.10	3.73	102
1 : ROSARIO 88.JAN10～88.FEB 1	55	76	39	114	4.3	30	1.54	2.19	3.74	79
7 : ZARAGOZA Y LEON 88.MAR23～88.APR13	25	53	49	102	3.1	33	0.83	2.54	3.37	127
9 : IZTAPALAPA 88.MAR16～88.APR 6	34	—	—	—	4.0	32	1.56	2.12	3.68	78
19 : AGRICOLA ORIENTAL 88.APR29～88.MAY24	—	—	—	—	4.3	35	1.75	2.39	4.14	90
10 : CENTRO No.2 88.MAY25～88.JUN15	41	26	43	69	3.8	39	1.80	2.05	3.85	55
Road-side Average	43	56	50	106	4.3	34	1.52	2.23	3.75	88.4
Tokyo Japan Annual Average *1	12	84	40	—	2.5	—	—	—	—	58
14 : AZCAPOTZALCO 87.DES 7～87.DES28	67	51	65	116	4.6	40	2.36	2.22	4.58	87
11 : ECATEPEC 88.JAN 6～88.JAN28	75	110	52	162	3.9	28	0.98	2.45	3.43	170
17 : CENTRO MEDICO 88.FEB12～88.MAR 4	41	122	63	185	6.8	34	1.26	2.08	3.34	104
18 : FUJIYAMA 88.FEB11～88.MAR 3	23	—	—	—	1.8	34	1.07	2.04	3.11	50
12 : D.M.NACIONAL 88.APR27～88.MAY21	40	28	48	76	2.7	53	0.86	3.10	3.96	129
4 : CUEMANCO 88.MAY24～88JUN13	10	3	19	21	0.9	58	0.21	1.98	2.19	50
Off-road Average	43	63	49	112	3.4	41	1.12	2.31	3.43	98.4
Tokyo Japan Annual Average *2	9	34	30	—	0.9	—	—	—	—	55
Total Average	43	60	49	109	3.9	38	1.32	2.22	3.59	93.4

Note *1 Average of the automobile exhaust gas monitoring stations in 23 wards in 1986.

*2 Average of the general ambient air monitoring stations in 23 wards in 1986.

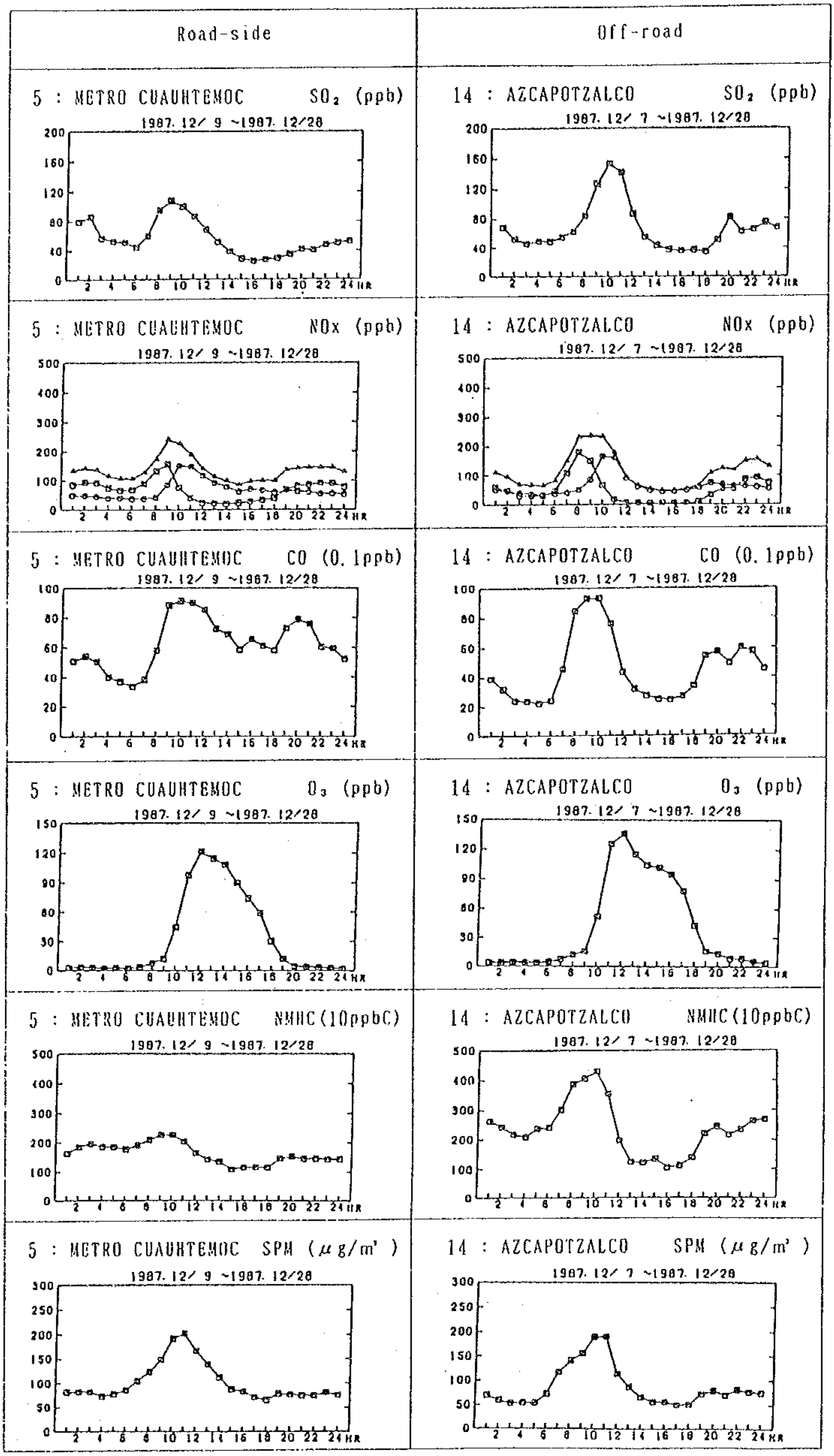


Figure 3.2.10 Hourly Fluctuation of Pollutant Concentration Measured with Monitoring Cars
(METRO CUAUHTEMOC and AZCAPOTZALCO, December 1987)

(3) TSP and Metal Concentration by Particle Size

Results of the measurement of TSP and metal concentration by particle size at each measuring point are shown in Table 3.2.11 and Figures 3.2.11 through 3.2.16. Monthly fluctuation is shown in the Appendices. Measuring points may be characterized as follows: OFICINA CENTRAL DE DDF is in the approximate center of Mexico City and has a largest traffic volume while TACUBA is in a district in the northwest of the City where factories and houses are mixed having a small traffic volume. SAN AGUSTIN is in a dwelling quarter slightly to the northeast of Mexico City. PEDREGAL is in a dwelling quarter located to the southeast of the City with a small traffic volume and no factory. ESTRELLA is located to the southeast of the City and has no factory, but it is a source of fugitive dust.

The average concentration of TSP over the entire period varried with point at 110 - 314 $\mu g/m^3$. The concentration was highest at ESTRELLA where fugitive dust was observed. OFICINA CENTRAL DE DDF and SAN AGUSTIN had similar levels, and low in TACUBA and PEDREGAL.

The particle size distribution showed slight differences among the measuring points, except that particles of 7 μm or larger were observed more often in OFICINA CENTRAL DE DDF, SAN AGUSTIN, and ESTRELLA.

For metallic elements, high contents of Fe, Na, Ca and Al were observed at all the points, followed by K and Pb. Among these, Fe, Na, Ca, Al and K are considered mainly originating from the soil. Pb was contained mostly in smaller particles and is considered mainly owing to the anti-knock agent contained in automobile gasoline. OFICINA CENTRAL de DDF showed a Pb content about twice the other points, indicating a large influence of automobile exhaust gases.

Measurements in Tokyo in 1983 showed 95 $\mu g/m^3$ for TSP, 2.66 $\mu g/m^3$ for Fe, 0.51 $\mu g/m^3$ for Zn, 0.013 $\mu g/m^3$ for Ni, 0.13 μ /m^3 for Pb, and 0.10 $\mu g/m^3$ for Mn. When compared with these values, the TSP concentration at PEDREGAL (the lowest concentration point) is on an equal level while the other points are on levels 1.5 to 3 times higher. Fe, Zn, and Mn levels at all the points were almost equal to the levels in Tokyo, Ni was about three times that of Tokyo, and

Pb about eight times at OFICINA CENTRAL DE DDF and three to four times at the other points. More details are given in the Appendices.

Table 3.2.11 TSP and Metallic Element Concentration by Particle Size

		OFICINA CENTRAL DE D.D.F	TACUBA	SAN AGUSTIN	PEDREGAL	ESTRELLA
TSP	(μg/m³)	183	146	183	110	314
Particle size distribution (%)	≧ 7 μm	38.7	32.2	41.4	33.6	43.0
	3.3～ 7.0μm	11.8	13.4	13.0	12.4	11.9
	2.0～ 3.3μm	6.6	7.5	7.1	7.3	6.4
	1.1～ 2.0μm	7.6	7.1	7.3	6.8	6.3
	< 1.1μm	35.4	39.8	31.0	39.8	32.3
Metallic Element (μg/m³)	Fe	3.55	2.15	3.71	2.75	3.42
	Zn	0.68	0.68	0.53	0.24	0.46
	Ni	0.03	0.03	0.03	0.03	0.02
	Pb	1.03	0.51	0.43	0.44	0.41
	V	0.15	0.14	0.07	0.07	0.09
	Mn	0.12	0.14	0.11	0.07	0.07
	Na	3.20	2.15	1.88	1.08	1.02
	Ca	4.22	2.15	3.90	2.17	4.08
	K	0.97	0.33	1.27	0.81	0.83
	Aℓ	2.03	1.79	5.15	2.16	3.32
	Total	15.98	10.07	17.08	9.82	13.72
	Ratio in TSP(%)	8.73	6.89	9.35	8.93	4.37

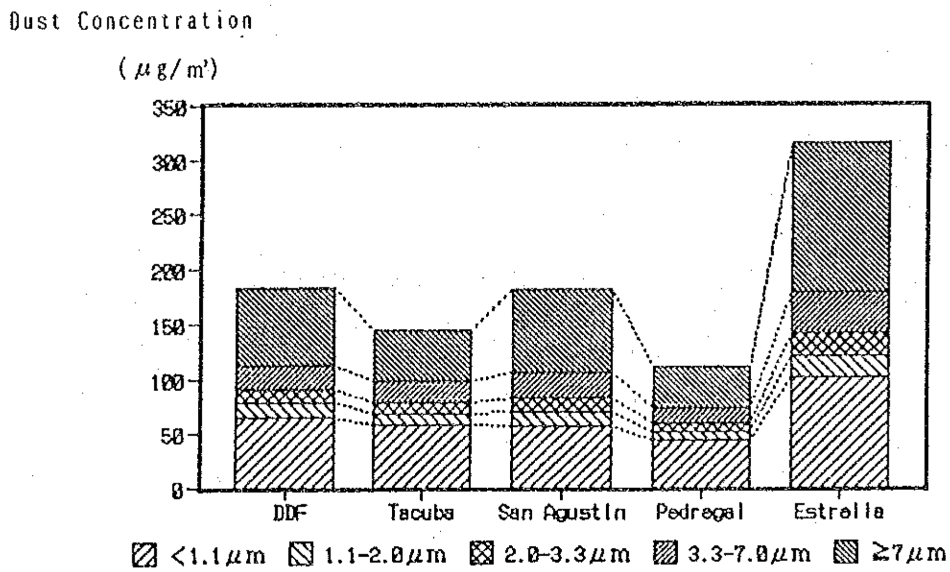


Figure 3.2.11 TSP Concentration by Particle Size

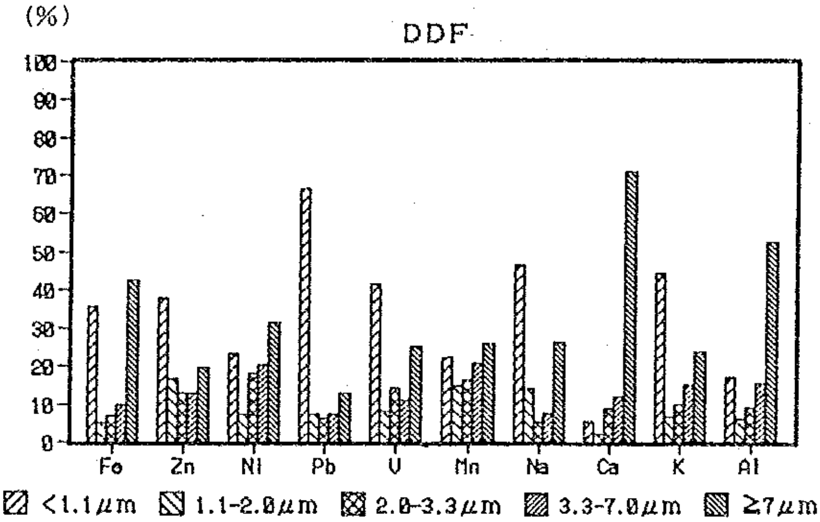


Figure 3.2.12 Metallic Element Distribution by Particle Size (DDF)

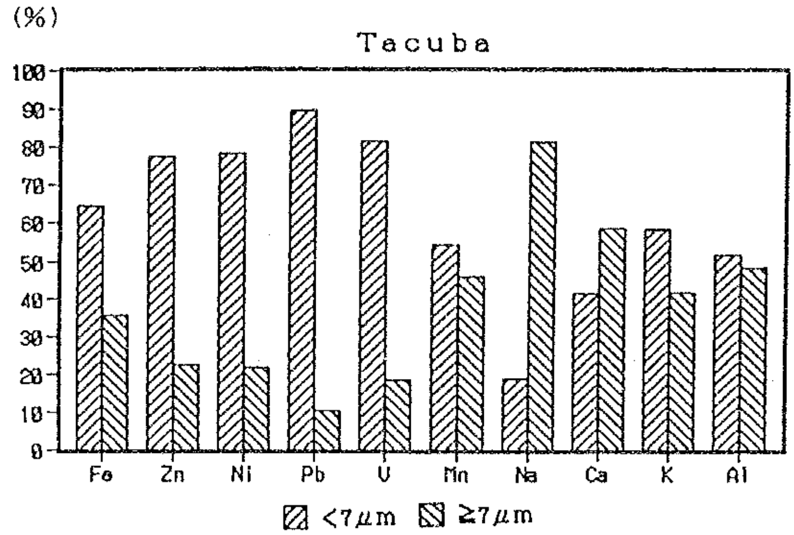


Figure 3.2.13 Metallic Element Distribution by Particle Size (TACUBA)

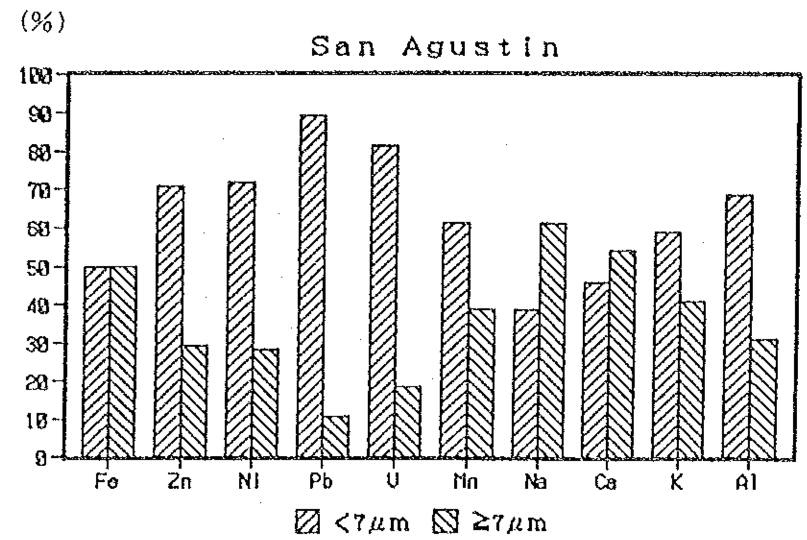


Figure 3.2.14 Metallic Element Distribution by Particle Size (SAN AGUSTIN)

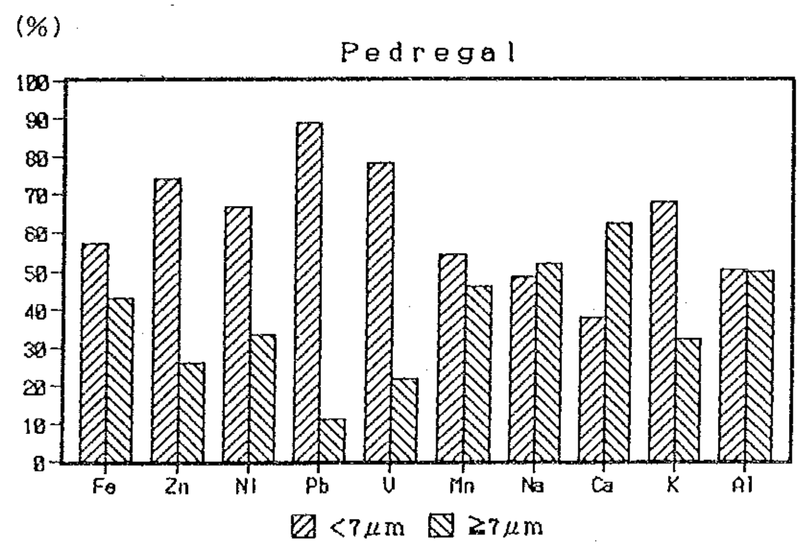


Figure 3.2.15 Metallic Element Distribution by Particle Size (PEDREGAL)

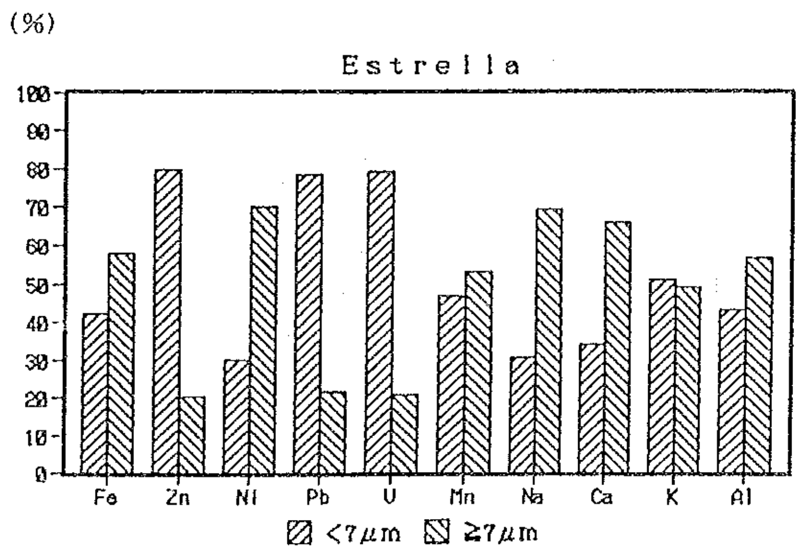


Figure 3.2.16 Metallic Element Distribution by Particle Size (ESTRELLA)

(4) Concentration of Nitrogen Oxides According to the Simplified Method

Table 3.2.12 shows the average concentration of nitrogen oxides at each crossing.

The concentration of NO ranges from 32 to 217 ppb with the average being 104 ppb, that of NO_2 from 17 to 94 ppb with the average of 64 ppb, and that of NO_x from 99 to 303 ppb with the average of 168 ppb.

The NO concentration exceeded 150 ppb at No. 1 (October and January), No. 3 (January), No. 6 (January), and No. 7 (February). NO_x exceeded 180 ppb at No. 1 (October, January, and March), No. 3 (January), No. 5 (December), No. 6 (January), No. 7 (February), No. 9 (September).

High averages of NO_x were indicated at Nos. 1, 3, and 7 which are located slightly off to the west of the center of Mexico City. The peripheral points of Nos. 2, 10, 11 and 12 showed lower values of 114 - 136 ppb.

On the monthly basis, January showed the highest value, followed by February and March, and June showed the lowest.

Details of measurement results are shown in the Appendices.

Table 3.2.12 Results of Nitrogen Oxides Measurement by Simplified Method

Unit : ppb

Measuring Point		Date	Average Value			
			NO	NO_2	NOx	
1	AV. INSURGENTES Y AV. SN. COSME	Oct. 6- 8, 1987	158	40	198	215
		Jan. 5- 7, 1988	160	88	248	
		Mar. 1- 3, 1988	126	72	198	
2	RIO CHURUBUSCO (CIRCUITO INTERIOR) Y MAGDALENA MIXHUCA (EJE 2 OTE).	Feb. 23-25, 1988	60	69	129	114
		Jun. 7- 9, 1988	32	67	99	
3	GLORIETA METRO INSURGENTES. (AV. CHAPULTEPEC Y AV. INSURGENTES).	Jan. 20-22, 1988	178	63	241	183
		Jun. 1- 3, 1988	49	76	125	
4	AV. REVOLUCION (CIRCUITO INTERIOR). Y. AV. SN ANTONIO (EJE 5 SUR).	Oct. 28-30, 1987	74	66	140	154
		Feb. 9-11, 1988	120	49	169	
5	AV. UNIVERSIDAD Y RIO MIXCOAC (CIRCUITO INTERIOR).	Dec. 14-16, 1987	131	57	188	172
		Mar. 15-17, 1988	93	63	156	
6	CALZADA DE LA VIGA Y RIO CHURUBUSCO (CIRCUITO INTERIOR).	Jan. 12-14, 1988	210	59	269	204
		Apr. 5- 7, 1988	76	62	138	
7	PASEO DE LA REFORMA Y MELCHOR OCAMPO (CIRCUITO INTERIOR).	Nov. 24-26, 1987	79	94	173	215
		Feb. 2- 4, 1988	217	86	303	
		Apr. 26-28, 1988	86	84	170	
8	EJE CENTRAL Y PASEO DE LA REFORMA CENTRO	Dec. 28-30, 1987	138	17	155	154
		Apr. 19-21, 1988	65	89	154	
9	FRAY SERVANDO TERESA DE MIER Y EJE CENTRAL	Dec. 21-23, 1987	98	51	149	180
		Mar. 23-25, 1988	124	87	211	
10	AV. UNIVERSIDAD CUAUHTEMOC Y DIVISION DEL NORTE	Nov. 10-12, 1987	57	76	133	131
		Feb. 16-18, 1988	63	58	121	
		Apr. 12-14, 1988	77	61	138	
11	RIO CONSULADO (C. I.) Y CALZADA DE LOS MISTERIOS	Mar. 8-10, 1988	119	47	166	136
		Jun. 14-16, 1988	48	58	106	
12	OCEANIA Y TRANSVAL	Nov. 3- 5, 1987	80	52	132	131
		Jan. 27-29, 1988	92	38	130	

3.3 Analysis of Meteorology and Air Quality Based on the SEDUE's Data

The ambient air quality monitoring and the surface wind observation are being made regularly by SEDUE at the points shown in Table 3.3.1 and Figure 3.3.1.

This section describes various analytical results on ambient air quality and meteorology based on the SEDUE's data for one year from December, 1986 to November, 1987.

Table 3.3.1 SEDUE's Monitoring Stations and Monitoring Items

Station Item	SO_2	NO_2	NOx	CO	O_3	HC	WD	WS
Z. LAGUNILLA				○				
E. VALLEJO	○							
S. STA. URSULA	○							
B. TACUBA	○					○	○	○
G. ENEP ACATLAN	○						○	○
M. LOS LAURELES	○							
H. LA PRESA	○							
J. LA VILLA	○							
N. SAN AGUSTIN	○				○		○	○
C. AZCAPOTZALCO	○				○			
F. TLALNEPANTLA	○	○	○	○	○		○	○
L. XALOSTOC	○	○	○	○	○		○	○
X. MERCED	○	○	○	○	○	○	○	○
T. PEDREGAL	○	○	○	○	○		○	○
Q. C. DE LA EST.	○	○	○	○	○		○	○
U. PLATEROS				○	○		○	○
Y. HANGARES	○				○	○	○	○
P. UAM IZTAPALAPA				○				
K. ARAGON				○				
O. NEZAHUALCOYOTL				○				
D. I. M. P.				○				
W. BENITO JUAREZ				○				
R. TAXQUEÑA				○				
V. INSURGENTES				○				
A. CUITLAHUAC				○				

Notes : WD is Wind Direction, WS is Wind Speed

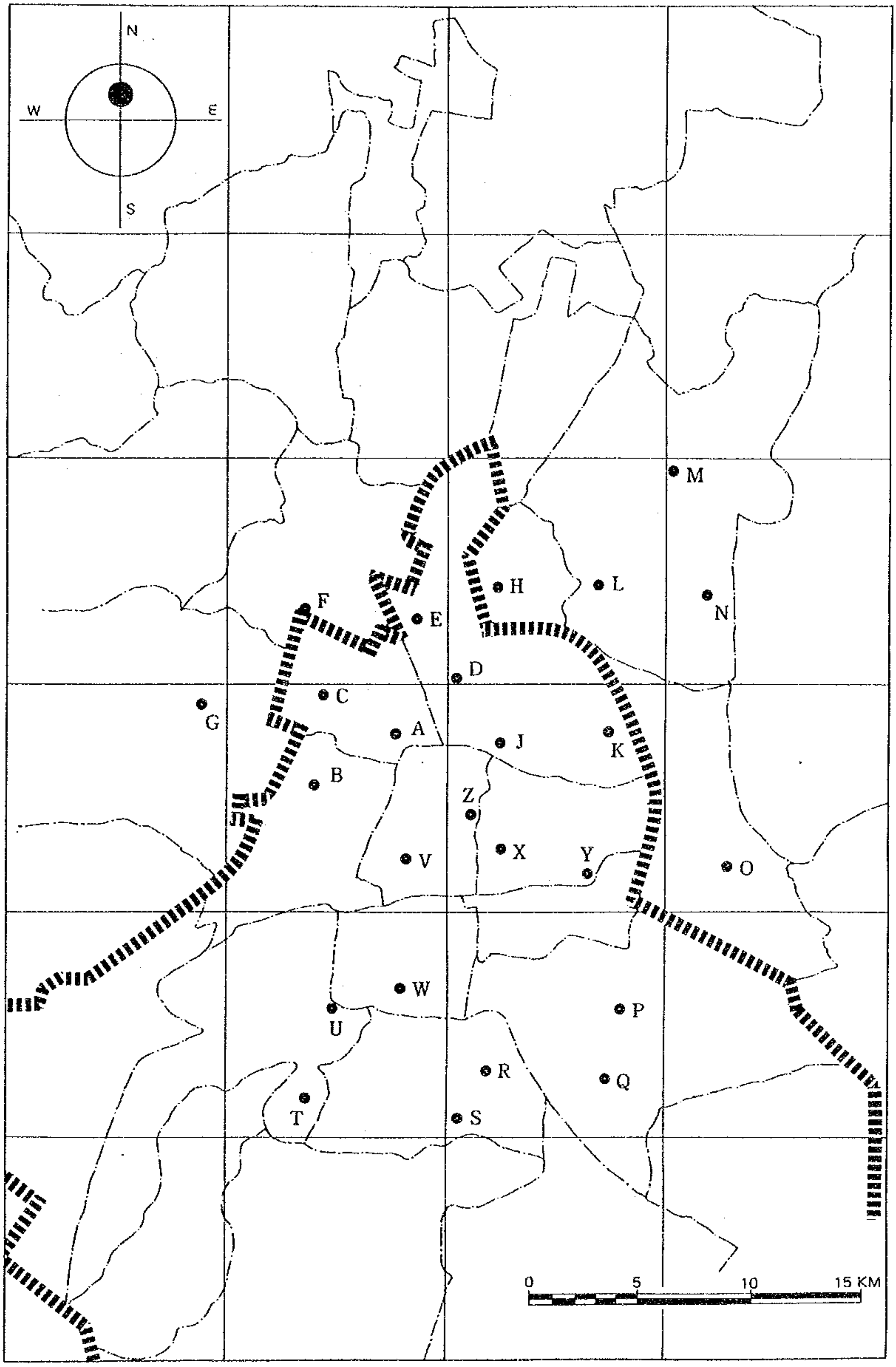


Figure 3.3.1 Location of the SEDUE Monitoring Stations

3.3.1 Surface Meteorology

This section describes the result of analysis on the SEDUE's meteorological data obtained at the ten stations shown in Table 3.3.1.

Note that due care should be taken for interpretation of the analytical result because no data were available in July 1987 and the period of observation was limited in April and May 1987.

(1) Wind Direction

The wind rose for one year from December, 1986 to November, 1987 is shown in Figure 3.3.2. This shows a frequent wind direction of NW in the northwestern area, NE in the northeastern area, and SW in the southern area. No particular predominant wind direction was observed in the central area.

(2) Wind Speed

1) Annual Average Wind Speed

The annual average wind speed is shown in Table 3.3.2. The wind speed is 2.0 - 2.6 m/s at the stations in the northwestern and the northeastern areas. In contrast, it is relatively low at 1.5 -1.6 m/s in the south, and even lower at 1.3 m/s at MERCED in the central area. At ENEP ACATLAN, the wind speed is as high as 3.9 m/s.

Table 3.3.2 Annual Average Wind Speed (Dec. 1986 - Nov. 1987)

Stations	Wind Speed (m/s)	Frequency of Calm (%)	Samples (hours)
TACUBA	2.3	1.3	2,555
ENEP ACATLAN	3.9	0.0	4,625
SAN AGUSTIN	2.6	0.1	4,798
TLALNEPANTLA	2.5	0.2	4,088
XALOSTOC	2.0	1.4	3,591
MERCED	1.3	31.1	5,160
PEDREGAL	1.6	11.6	3,447
C. DE LA EST.	1.5	13.8	5,565
PLATEROS	1.6	10.2	5,742
HANGARES	2.3	0.0	5,021

Definition: Calm $\leq$ 0.4 m/s (wind speed)

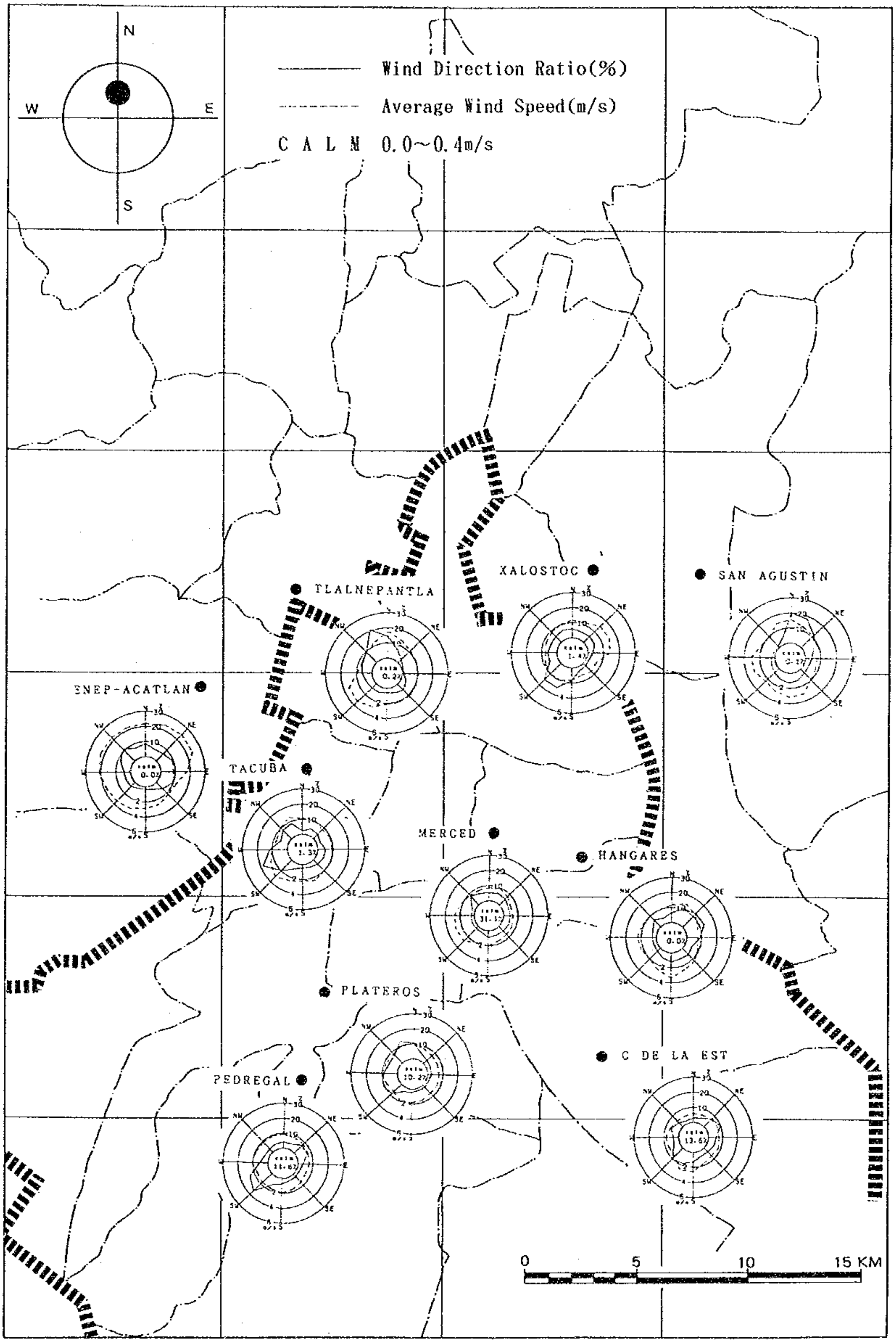


Figure 3.3.2 Wind Rose (Dec. 1986 - Nov. 1987)

2) Monthly Average Wind Speed

No particular monthly variation is observed in the monthly average wind speed shown in Figure 3.3.3.

3) Hourly Average Wind Speed

The hourly average wind speed for the one-year period is shown in Figure 3.3.4. Except ENEP ACATLAN, the wind speed increases gradually from 12:00 and peaks at 18:00, then gradually decreases to reach the lowest at around 7:00.

4) Wind Speed Class Appearance Frequency

Figure 3.3.5 shows the annual appearance frequency of wind speed classes. The most frequent class is 0.5 - 1.9 m/s except ENEP ACATLAN where the most frequent class is 4.0 -5.9 m/s.

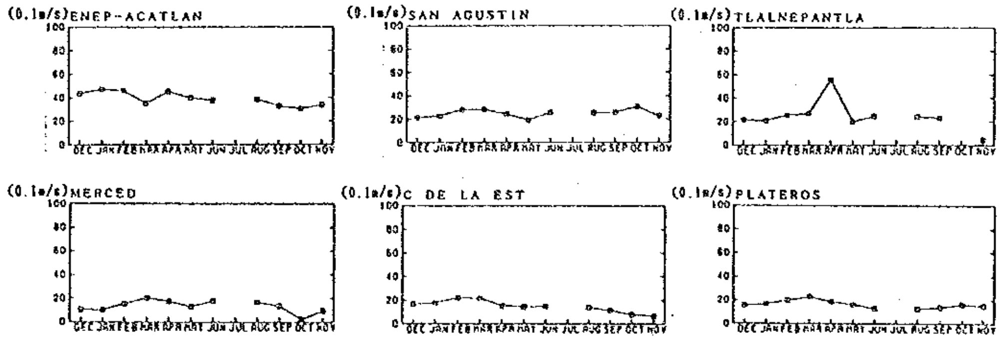


Figure 3.3.3 Monthly Average Wind Speed (Dec. 1986 - Nov. 1987)

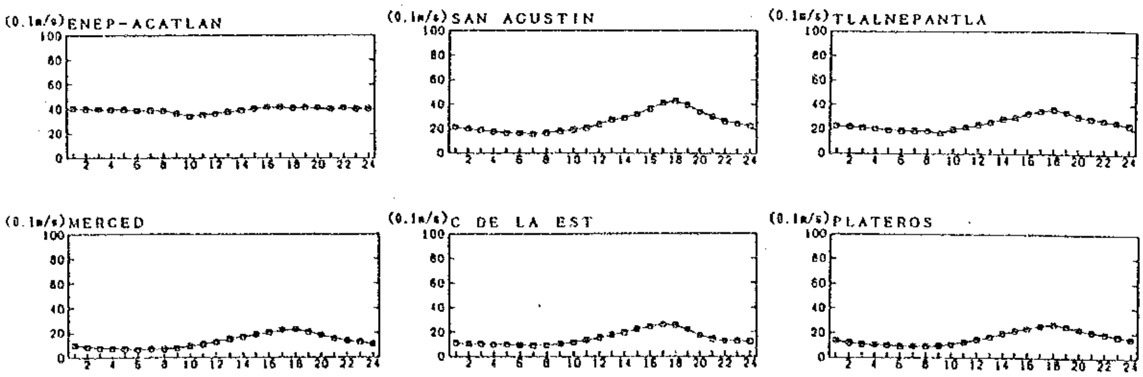


Figure 3.3.4 Time of Day Average Wind Speed (Dec. 1986 - Nov. 1987)

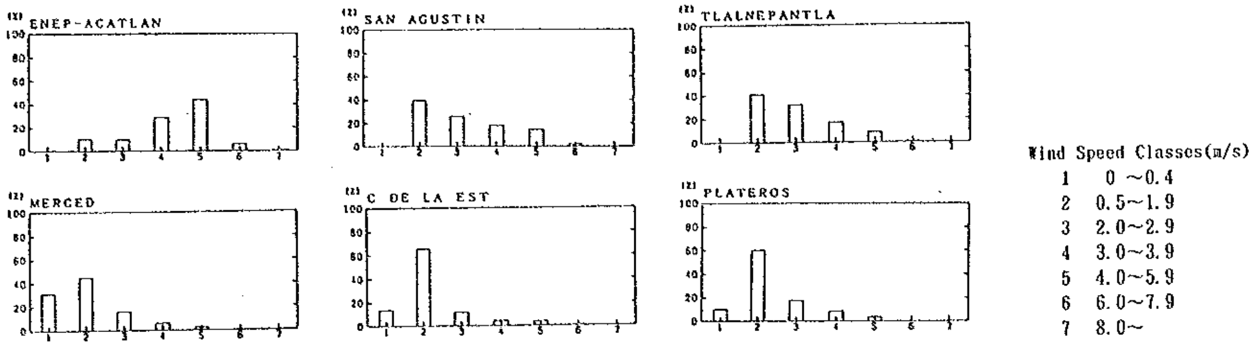


Figure 3.3.5 Frequency of Wind Speed Classes (Dec. 1986 - Nov. 1987)

(3) Similarity of Wind Between Observation Points

Figure 3.3.6 shows the dendrogram prepared on the basis of the cluster classification using the similarity of wind vector between two observation points as the index. Since analysis over the entire year is not practical due to insufficient data for wind direction and speed, the data in December and June were chosen to represent year because of relatively few void of data in these months.

This dendrogram shows that a cluster is formed between the points geographically close to each other. Difference between December and June is that TACUBA and ENEP ACATLAN in June have less similarity with the other points than in December.

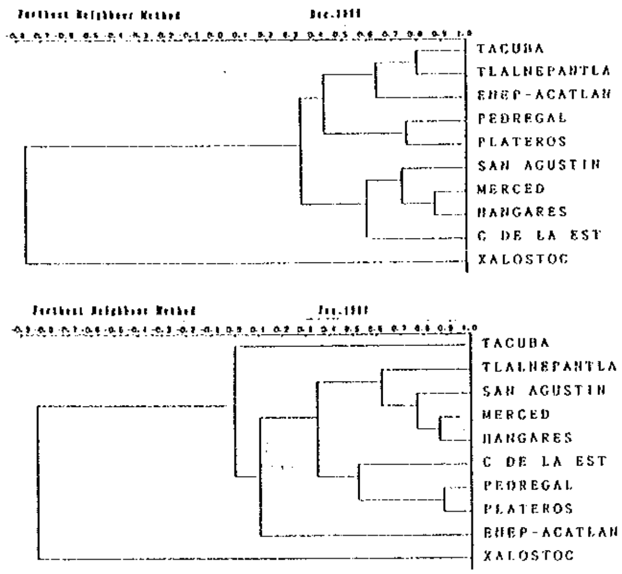


Figure 3.3.6 Dendrogram of Wind Vector Correlation

(4) Air Stability

The air stability was classified according to the method shown in Table 3.3.3, which was originally developed by Pasquill in 1961 and modified in Japan. The quantity of solar radiation and cloud amount observed at AEROPUERTO were used for classification. Figure 3.3.7 shows the frequency of occurence of the stability classes for one year from December 1986 to November 1987.

Table 3.3.3 Stability Classification

Wind speed (10m above ground) m/s	Solar radiation ($cal/cm^2 \cdot h$)			Mostly cloudy (8-10) (daytime/ nighttime)	Nighttime	
	$\geqq 50$	49-25	$\leqq 24$		Upper cloud (5-10) middle/lower clouds (5-7)	Cloud amount (0-4)
< 2	A	A-B	B	D	(G)	(G)
2 - 3	A-B	B	C	D	E	F
3 - 4	B	B-C	C	D	D	E
4 - 6	C	C-D	D	D	D	D
6 <	C	D	D	D	D	D

(Note)

1. As Pasquill's original text gives a qualitative description on solar radiation, it has been quantified through estimation of equivalent quantities.
2. The term "nighttime" refers to time zone from an hour before the sunset till an hour after the sunrise.
3. Both in the daytime and nighttime, the "mostly cloudy" (8-10) shall be regarded as neutral conditions (D) irrespective of wind speed.
4. Each one hour before and after the "nighttime" (as defined in Note 2 above) shall be regarded as neutral conditions irrespective of clouds.

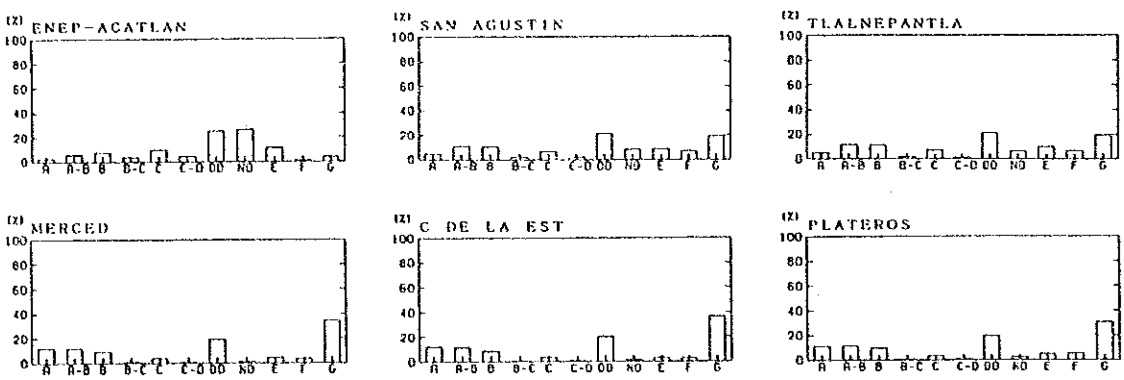


Figure 3.3.7 Frequency of Occurence of Atmospheric Stability Classes (Dec. 1986 - Nov. 1987)

3.3.2 Ambient Air Quality

(1) Annual Monitoring Results and Complience With Ambient Air Quality Standards

The ambient air quality standards for SO_2, NO_2, CO, O_3, and the recommended level for HC is shown in Table 3.3.4. The standard values are specified as one-hour value, daily average, and 8-hour average depending on the kind of pollutant.

Table 3.3.4 Ambient Air Quality Standards

Air Pollutants	Standards (ppm)	
SO_2 (sulfur dioxide)	daily mean	0.13
NO_2 (nitrogen dioxide)	hourly maximum	0.21
CO (carbon monoxide)	8-hour mean	13
O_3 (as photochemical oxidant)	hourly maximum	0.11
HC (hydrocarbon)	hourly maximum	0.24 1)

Note: 1) recommendable value.

Source: SEDUE, INFORME SOBRE EL ESTAD DEL MEDIO AMBIENTE EN MEXICO, 1986.

1) SO_2

SO_2 is measured at the 15 monitoring stations. The measurement result for one year from December 1986 to November 1987 is shown in Table 3.3.5.

The annual average of each point is high to the northwest and low to the south of Mexico City ranging from 0.026 ppm (LA PRESA, STA. URSULA) to 0.072 ppm (VALLEJO).

In the evaluation of the actual state in contrast to the standard value, measured data on the days with less than 20 measuring hours are excluded following the conventional statistical processing method used in Japan.

The ambient standard of daily average at 0.13 ppm was exceeded one day at TACUBA, LOS LAURELES, and MERCED and 17 days in VALLEJO. The maximum daily average at each station varied from 0.047 ppm (SAN AGUSTIN) to 0.243 ppm (VALLEJO).

Table 3.3.5 Annual Measurement Result for SO_2

Measuring Point	Effective Measurement Days (day)	Measuring Period (hour)	Annual Average (ppm)	No. of Days when the Daily Average Eceeded 0.13 ppm and Percentage (day)	(%)	The Value Excluding 2% of the Daily Average (ppm)	Max Daily Average (ppm)
VALLEJO	195	5,419	0.057	17	8.7	0.178	0.243
STA URSULA	220	5,839	0.026	0	0	0.051	0.072
TACUBA	200	5,395	0.056	1	0.5	0.112	0.137
ENEP-ACATLAN	180	4,916	0.072	0	0	0.103	0.117
LOS LAURELES	184	4,930	0.038	1	0.5	0.100	0.136
LA PRESA	210	5,553	0.026	0	0	0.062	0.073
LA VILLA	228	6,046	0.043	0	0	0.072	0.099
SAN AGUSTIN	57	1,645	0.026	0	0	0.043	0.047
ATZCAPOTZALCO	234	6,149	0.053	0	0	0.098	0.116
TLALNEPANTLA	171	4,516	0.049	0	0	0.098	0.108
XALOSTOC	158	4,269	0.055	0	0	0.109	0.115
MERCED	191	5,267	0.050	1	0.5	0.092	0.144
PEDREGAL	183	4,968	0.041	0	0	0.076	0.088
C DE LA EST	228	6,071	0.033	0	0	0.064	0.074
HANGARES	193	5,419	0.033	0	0	0.062	0.079

Table 3.3.6 Annual Measurement Result for NO_2

Measuring Point	Effective Measurement Days (day)	Measuring Period (hour)	Annual Average (ppm)	No. of Hours when the Hourly Value Eceeded 0.21 ppm and Percentage (hour)	(%)	98% Value of the Hourly Value (ppm)	Max. Hourly Value (ppm)
TLALNEPANTLA	242	6,161	0.039	16	0.3	0.124	0.322
XALOSTOC	22	617	0.028	1	0.2	0.085	0.213
MERCED	224	5,903	0.049	17	0.3	0.139	0.263
PEDREGAL	218	5,712	0.037	8	0.1	0.109	0.296
C DE LA EST	113	3,031	0.039	4	0.1	0.108	0.307

2) NO_2

NO_2 is measured at the five stations. The result for the one year is shown in Table 3.3.6. Because of very few measurements made at XALOSTOC in 1987, no meaningful evaluation can be made for this station.

The annual average except for XALOSTOC was in the range between 0.037 ppm (PEDREGAL) to 0.049 ppm (MERCED).

The hourly maximum at each station except for XALOSTOC was 0.263 ppm (MERCED) to 0.322 ppm (TLALNEPANTLA), and the ambient standard of 0.21 ppm was exceeded most frequently at MERCED for 17 hours.

3) CO

CO was measured at the 15 stations. The measurement result for the one year is shown in Table 3.3.7.

The annual average at each station varied from 1.8 ppm (UAM IZTAPALAPA) to 6.7 ppm (INSURGENTES), and high at CUITLAHUAC, INSURGENTES, and TAXQUENA along the major roads.

The 8-hour average at each station was taken for each time span of 0.00 - 8:00, 8:00 - 16:00, and 16:00 - 24:00 according to the conventional processing method used in Japan, excluding the time span when the period of measuring one-hour value was less than six hours. The maximum 8-hour average by station varied from 4.5 ppm (XALOSTOC) to 31.6 ppm (IMP), and the ambient standard of 13 ppm was exceeded at the six stations. The stations along the major roads (CUITLAHUAC, INSURGENTES, and TAXQUENA) showed high frequency of exceeding the standard value (50, 13, and 6 times respectively).

4) Photochemical Oxidants (as O_3)

Photochemical oxidants were measured as O_3 at the nine stations. The measurement result for the one year is shown in Table 3.3.8.

Since photochemical oxidants are one of significant factors in the daytime air pollution, statistics of measured results were taken for the daytime (5:00 - 20:00) as in the case in Japan.

The maximum hourly value in the daytime at each station is in the range between 0.154 ppm (SAN AGUSTIN) and 0.495 ppm (PEDREGAL), and the ambient standard of 0.11 ppm was exceeded at the all the stations.

5) HC

HC is measured as non-methane hydrocarbon at the three stations. The concentration is expressed in terms of methane. The measurement result for the one year is shown in Table 3.3.9.

The annual average at each station is in the range of 0.23 ppmC (HANGARES) to 0.34 ppmC (MERCED), and the maximum one-hour value 1.12 ppmC (HANGARES) to 4.57 ppmC (TACUBA). The ambient standard value of 0.24 ppmC was exceeded at all the stations.

Table 3.3.7 Annual Measurement Result for CO

Measuring Point	Effective Measurement Days (day)	Measuring Hour (hour)	Annual Average (ppm)	Frequency that the 8-hour Value Exceeded 13 ppm and Its Percentage (times)	(%)	98% Value of 8-hour Average (ppm)	Maximum 8-hour Average (ppm)
LAGUNILLA	214	5,634	3.8	1	0.5	8.6	14.9
TLALNEPANTLA	195	4,992	3.2	0	0	8.3	10.6
XALOSTOC	174	4,632	3.9	0	0	7.8	9.7
MERCED	216	5,738	3.5	0	0	8.0	11.7
PEDREGAL	199	5,298	2.6	0	0	5.4	9.8
C DE LA EST	178	4,662	3.7	0	0	7.2	8.8
PLATEROS	192	5,099	3.2	0	0	7.5	12.5
UAM-IZTAPALAPA	142	3,704	1.8	0	0	4.1	6.4
ARAGON	192	5,242	2.9	1	0.5	7.2	14.8
NEZAHUALCOYOTL	61	2,201	2.7	0	0	5.5	8.3
I M P	219	5,890	3.1	1	0.5	8.2	31.6
BENITO JUAREZ	232	6,149	3.4	0	0	8.4	12.3
TASQUENA	228	5,811	4.6	6	2.6	11.8	20.5
INSURGENTES	183	4,871	6.7	13	7.1	13.6	17.4
CUITLAHUAC	232	5,985	5.4	50	21.6	17.2	22.3

Table 3.3.8 Annual Measurement Result for Photochemical Oxidents

Measuring Point	Daytime Measuring Days (day)	Daytime Measuring Hours (time)	No. of Days and Hours When the Daytime One-hour Value Exceeded 0.11 ppm (day)	(time)	Maximum Daytime One-hour Value (ppm)	Annual Average of Daytime Maximum One-hour Values (ppm)
SAN AGUSTIN	184	2,448	5	6	0.154	0.053
ATZCAPOTZALCO	166	2,136	43	102	0.254	0.083
TLALNEPANTLA	210	2,898	36	107	0.492	0.082
XALOSTOC	242	3,254	14	21	0.161	0.066
MERCED	225	3,061	109	288	0.268	0.114
PEDREGAL	251	3,352	137	504	0.495	0.132
C DE LA EST	258	3,493	97	238	0.224	0.097
PLATEROS	239	3,213	156	503	0.286	0.137

Table 3.3.9 Annual Measurement Result for HC

Measuring Point	Daytime Measuring Days (day)	Daytime Measuring Hours (time)	No. of Days and Hours When the Daytime One-hour Value Exceeded 0.24 ppmC (day)	(time)	Maximum Daytime One-hour Value (ppmC)	Annual Average of Daytime Maximum One-hour Values (ppmC)
TACUBA	259	3,535	220	1,838	4.57	0.52
MERCED	176	2,308	149	1,697	1.74	0.46
HANGARES	273	3,633	199	1,213	1.02	0.32

(2) Monthly Variation of Ambient Air Quality

Figure 3.3.8 shows variation of the monthly average concentration of the pollutants. Since the measurement period was extremely short in April and May 1987, due attention should be given when considering variation of the monthly average.

1) SO_2

The concentration at all the stations showed a tendency to become higher during the dry season from October to February. However, different from other points, C.DE LA EST. showed a low concentration in November to January.

2) NO_2

The concentration is mostly high in November to April, the trend similar to the case of SO_2.

3) CO

The concentration is mostly high in November to March, as are the cases for SO_2 and NO_2. At INSURGENTES where annual average is high and the ambient standard is frequently exceeded, the monthly variation is small.

4) O_3

The concentration at XALOSTOC and C.DE LA EST. is high in May. Due to limited measurement period, no meaningful review can be made.

5) HC

The concentration was high in December to March at TACUBA and MERCED. HANGARES showed the opposite trend.

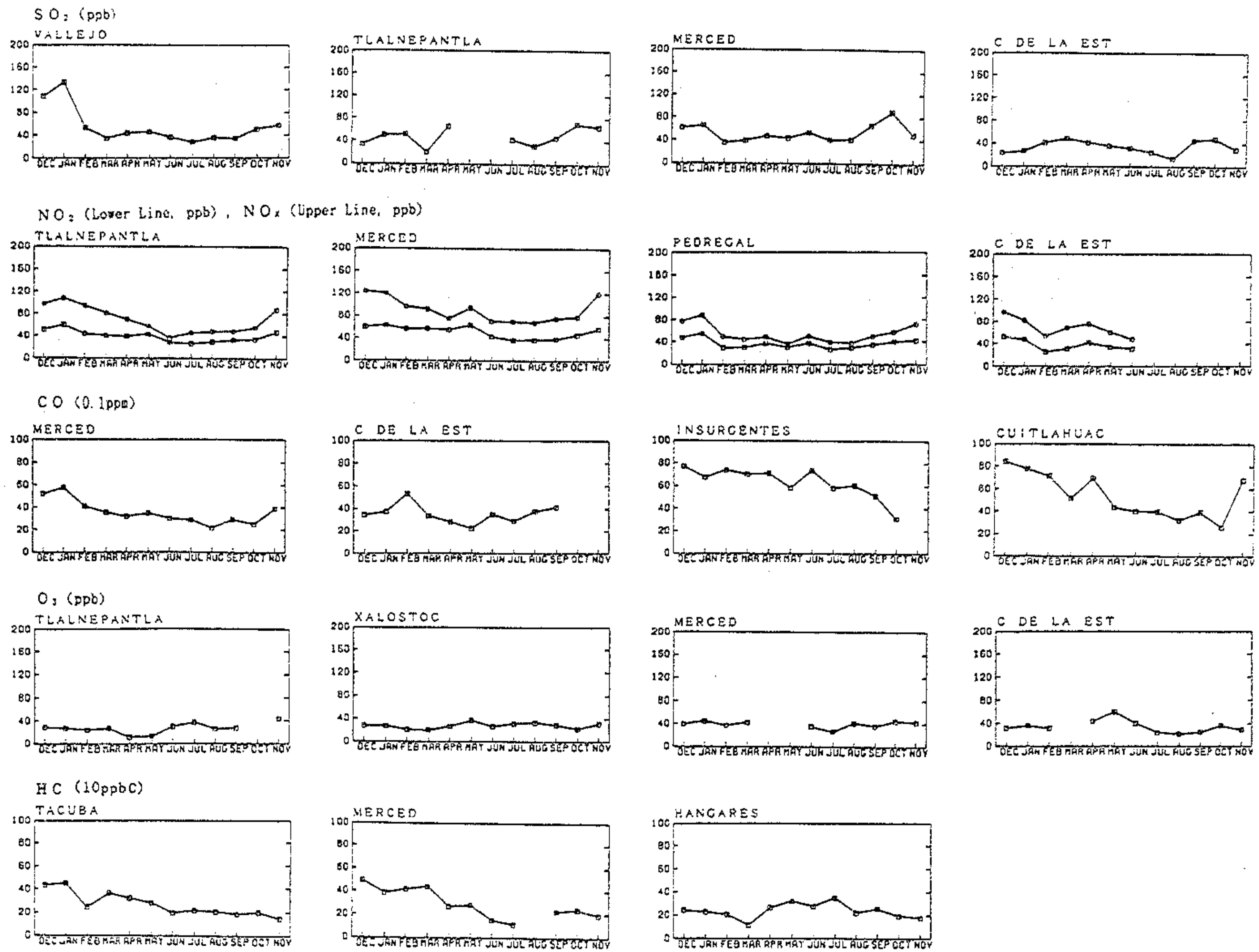


Figure 3.3.8 Monthly Average Concentration (Dec. 1986 - Nov. 1987)

(3) Hourly Variation of Ambient Air Quality

The daily hourly concentration averaged over the one year period is shown in Figure 3.3.9.

1) SO_2

The concentration begins increasing around 7:00 in the morning and peaks around 9:00 to 10:00. This trend is more significant at the stations where the concentration is relatively high. On the monthly basis, this pattern typically appears in October to February as shown in Figure 3.3.10 which is the example for TACUBA.

2) NO_2

The concentration of NO_2 increases in the morning and the hourly variation is similar to that of SO_2. The concentration of NOx, on the other hand, increases in the morning and at night. Increase of NOx concentration in the morning occurs earlier than that of NO_2. This pattern typically appears in October to March at the stations where the concentration is relatively high. Figure 3.3.11 shows the example of MERCED.

3) CO

As in the case of NOx, the concentration increases in the morning and at night. The increase at night is more noticeable at the stations where the concentration is relatively high, e.g., INSURGENTES.

4) O_3

The concentration begins increasing around 9:00 in the morning and peaks at 13:00, then decreases.

5) HC

The concentration begins increasing around 7:00 in the morning and peaks around 9:00, although the hourly variation is not as large as the cases for the other pollutants.

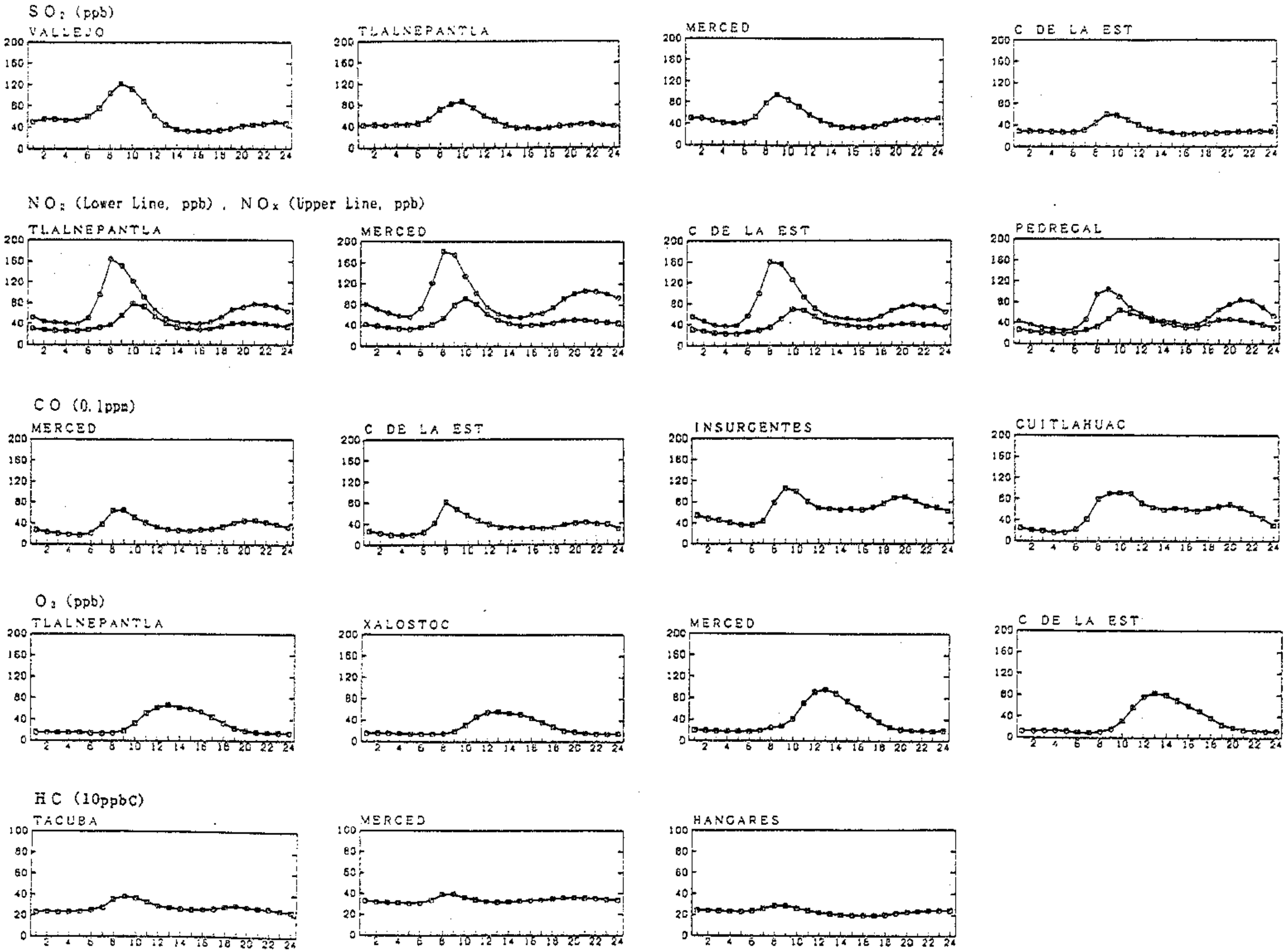


Figure 3.3.9 The Time-of-Day Average Concentration (Dec. 1986 - Nov. 1987)

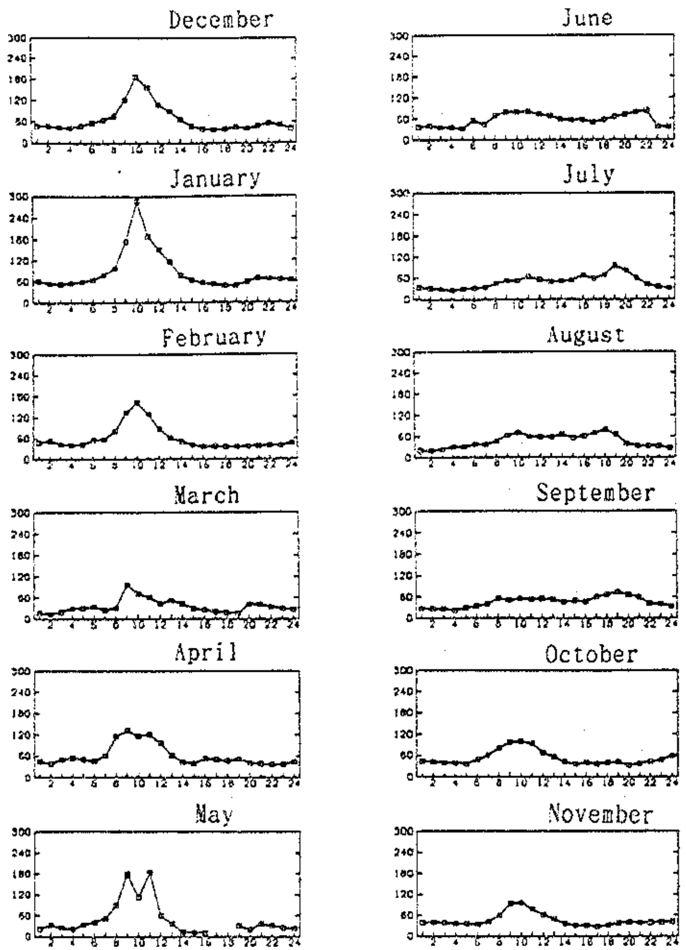


Figure 3.3.10 Monthly Time-of-Day Average Concentration of SO_2 (ppb) at TACUBA (Dec. 1986 - Nov. 1987)

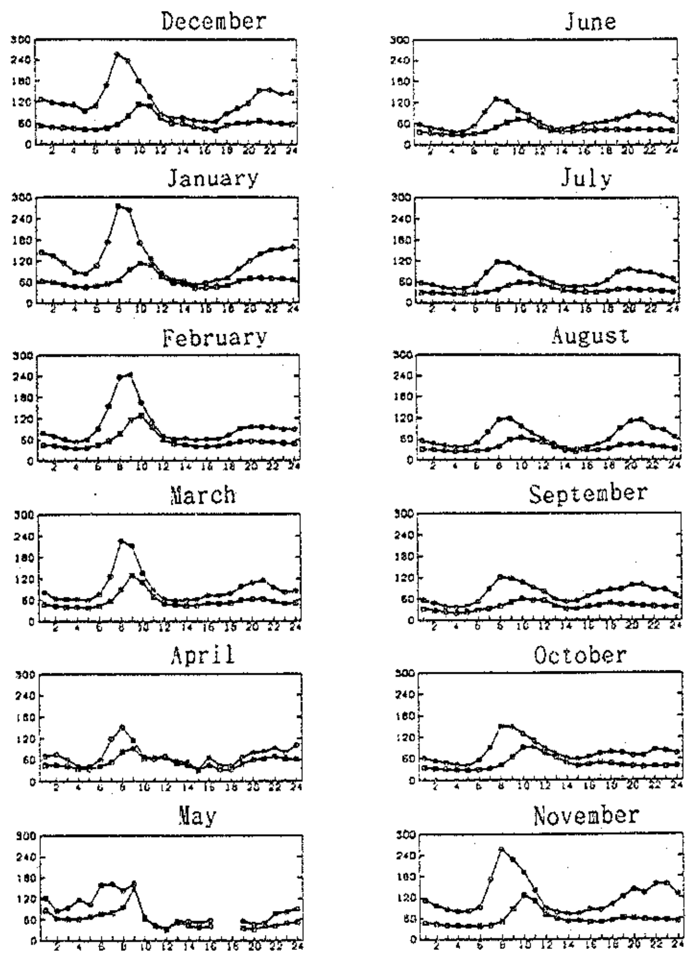
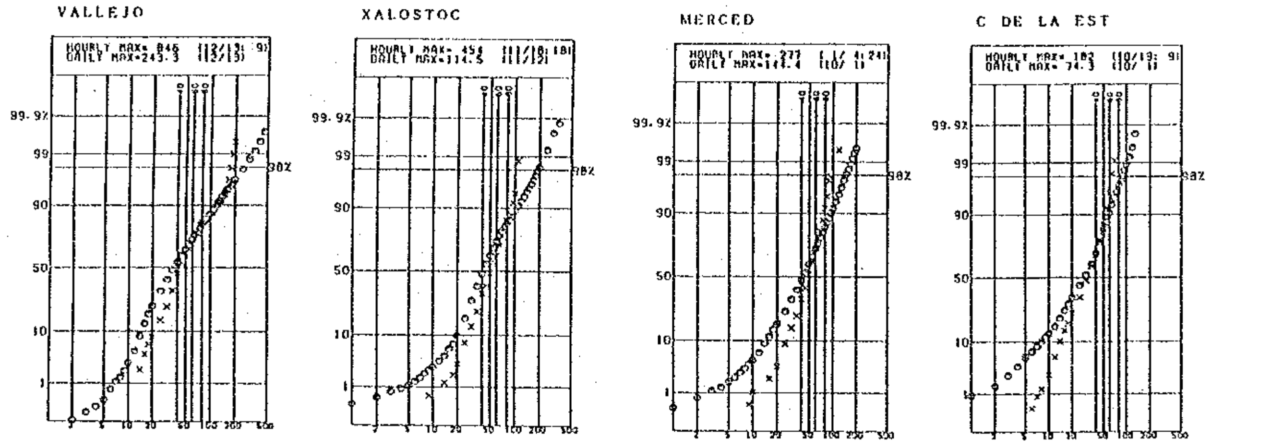


Figure 3.3.11 Monthly Time-of-Day Average Concentration of NO_2 and NOx (ppb) at MERCED (Dec. 1986 - Nov. 1987)

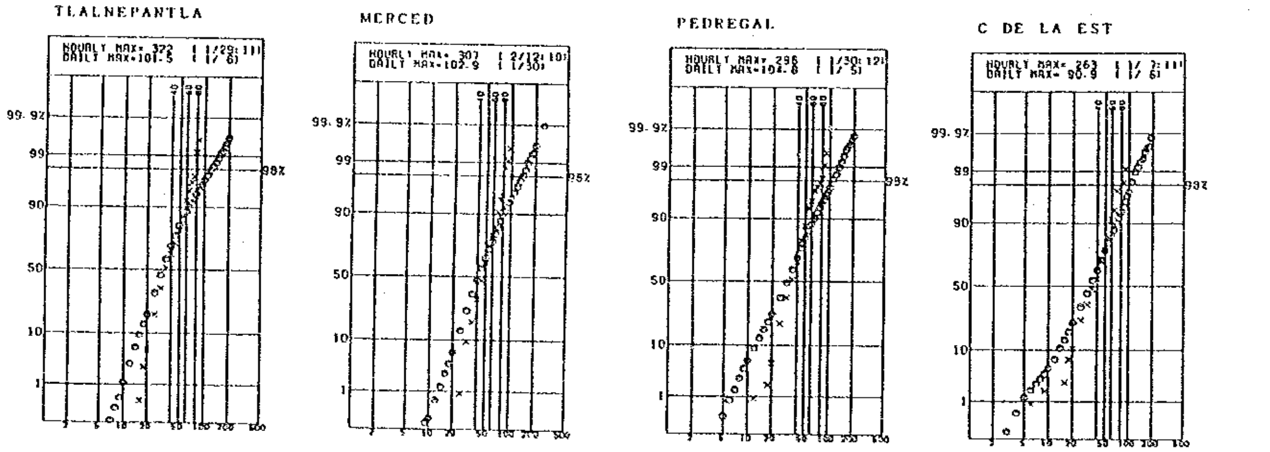
(4) Cumulative Appearance Distribution of Pollutant Concentration Values

Figure 3.3.12 shows the cumulative appearance distribution of the one-hour average and the daily average (or the 8-hour average for CO) concentration values for the pollutants for the one year period. The distribution was plotted on the logarithmic normal probability scale. Nearly the linear distribution for all of the pollutants indicates that the appearance distribution of concentration values for these pollutants can be approximated by the logarithmic normal distribution.

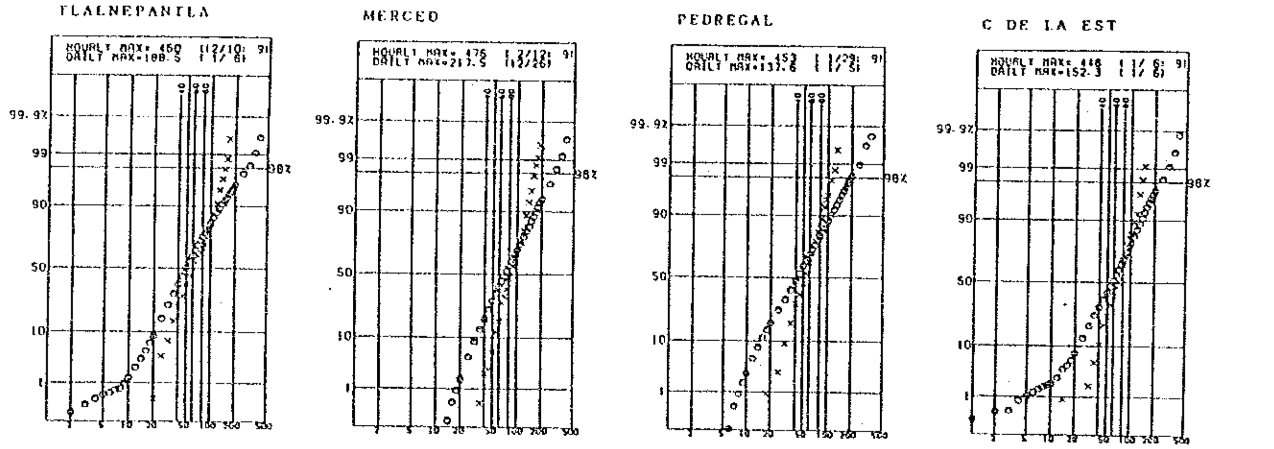
SO_2 (ppb)



NO_2 (ppb)



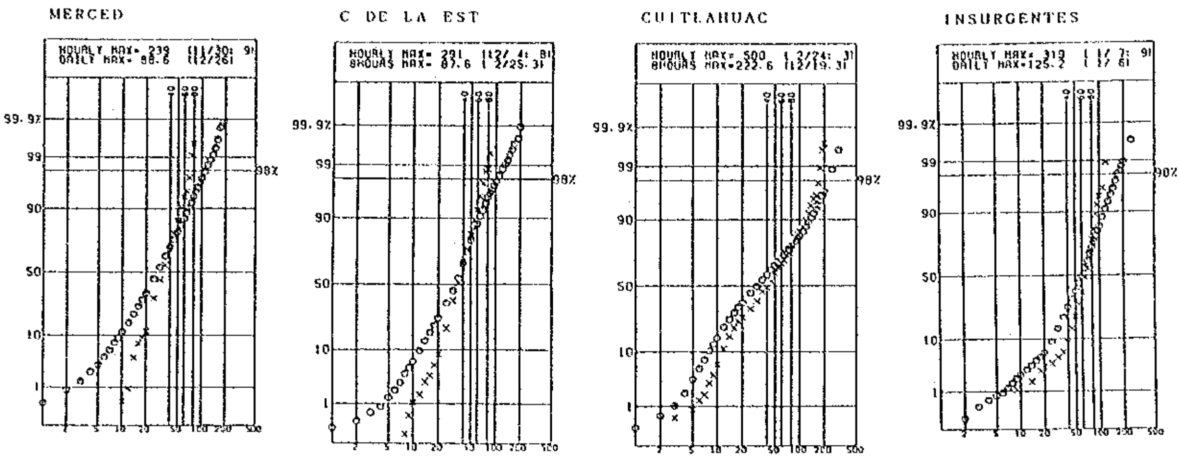
NO_x (ppb)



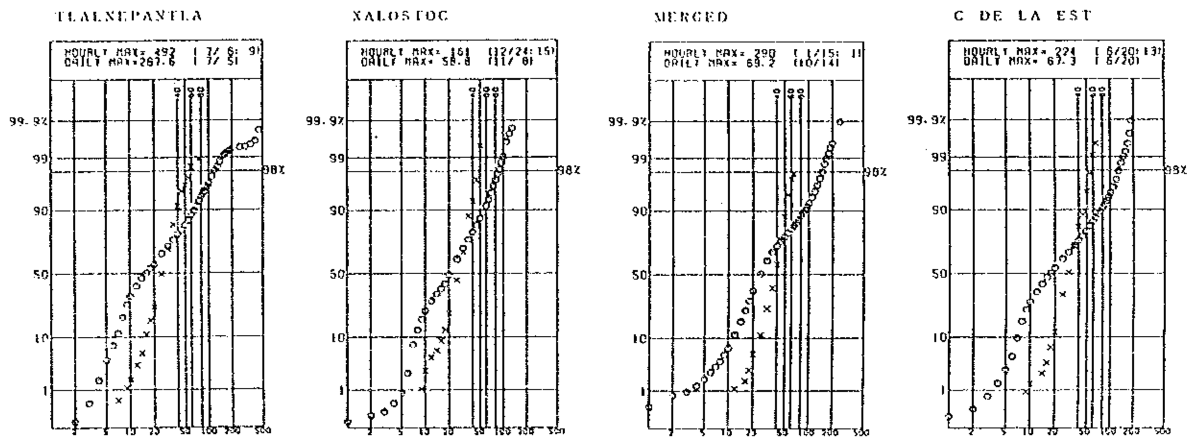
O : hourly mean
× : daily mean

Figure 3.3.12 (1) Probability Distribution Curve for SO_2, NO_2 and NOx (Dec. 1986 - Nov. 1987)

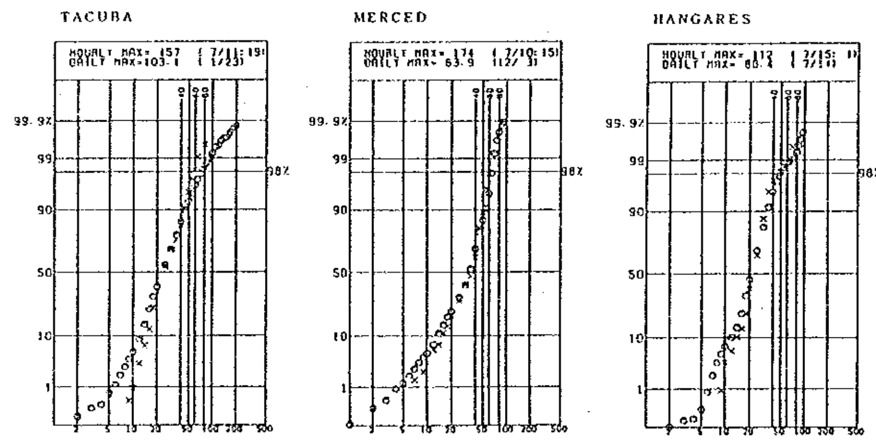
CO (0.1ppm)



O_3 (ppb)



HC (10ppbC)



O : hourly mean
× : daily mean

Figure 3.3.12 (2) Probability Distribution Curve for CO, O_3 and HC (Dec. 1986 - Nov. 1987)

3.3.3 Relation Between Air Quality and Meteorology

This section describes relations between the ambient concentration of pollutants and meteorological factors (wind direction, wind speed, and atmospheric stability) at the monitoring stations where wind direction and speed are also measured.

(1) Average Concentration by Wind Direction

Figure 3.3.13 shows the average concentration of pollutants classified by wind direction.

1) SO_2

Dependence of SO_2 concentration on the wind direction is observed at the stations where the annual average is relatively high. The concentration was high with the N to E winds at TACUBA, and with the NW winds at MERCED.

2) NO_2, NOx, and CO

The average concentration values for NO_2, NOx, and CO by wind direction are quite similar. This may be attributed to the considerable effect of automobile exhaust gas.

3) O_3

The concentration is generally high with the NE winds and low with the W winds excpet for XALOSTOC.

4) HC

Variation of the concentration with wind direction is relatively small.

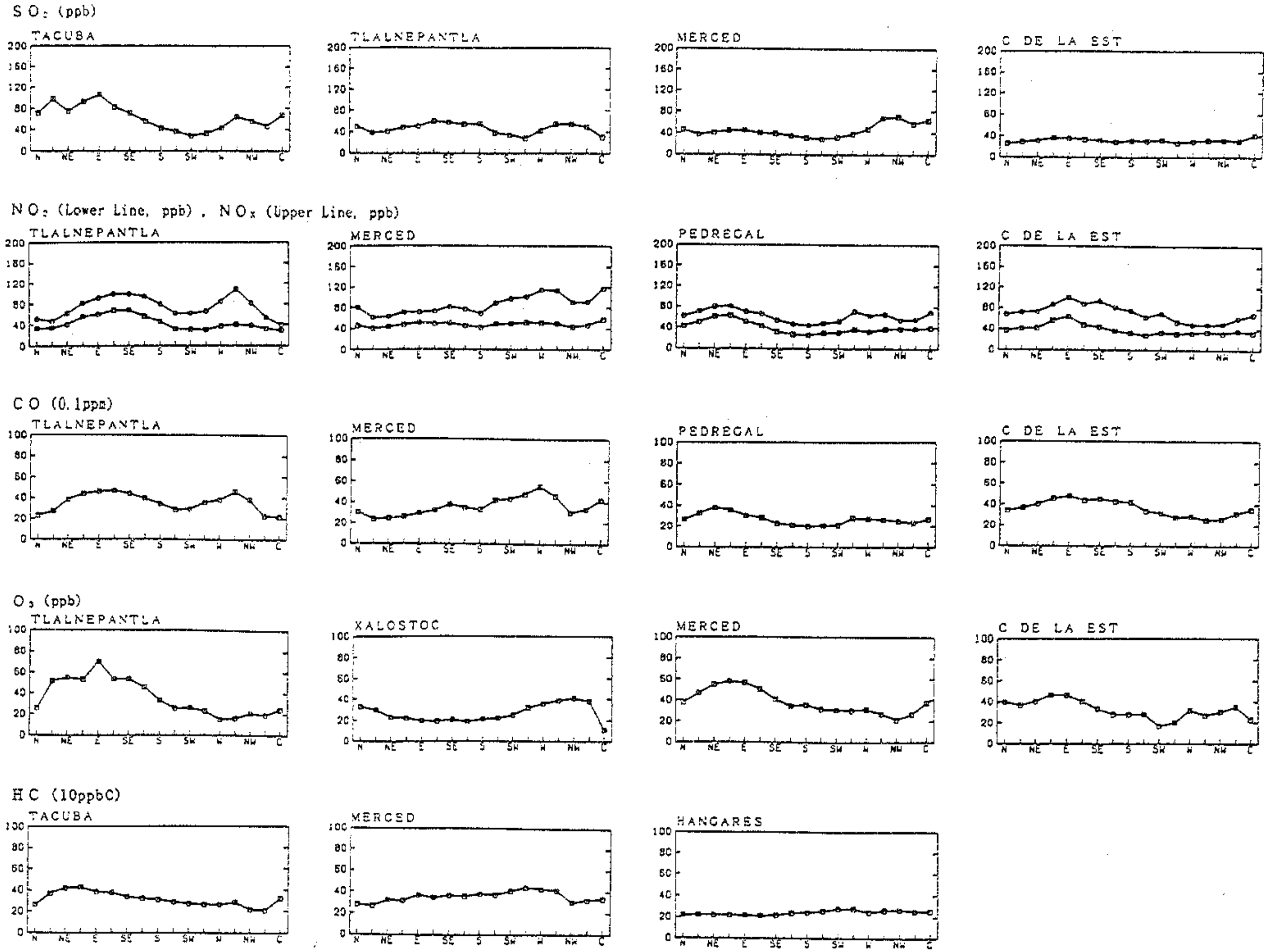


Figure 3.3.13 Average Concentration Classified by Wind Direction (Dec. 1986 - Nov. 1987)

(2) Average Concentration by Wind Speed

The wind speed is a major factor governing transport of pollutants discharged into atmosphere. Average pollutant concentration classified by wind speed is shown in Figure 3.3.14.

1) SO_2

The general trend is the decrease in the concentration with the increasing wind speed up to 6 m/s.

2) NO_2, NOx, and CO

Variation of the concentration with wind speed is similar to that of SO_2. The NOx concentration shows larger dependence on the wind speed.

3) O_3

Variation of the concentration with wind speed is different from station to station. No obvious trend is observed.

4) HC

Dependence of the concentration on wind speed is small.

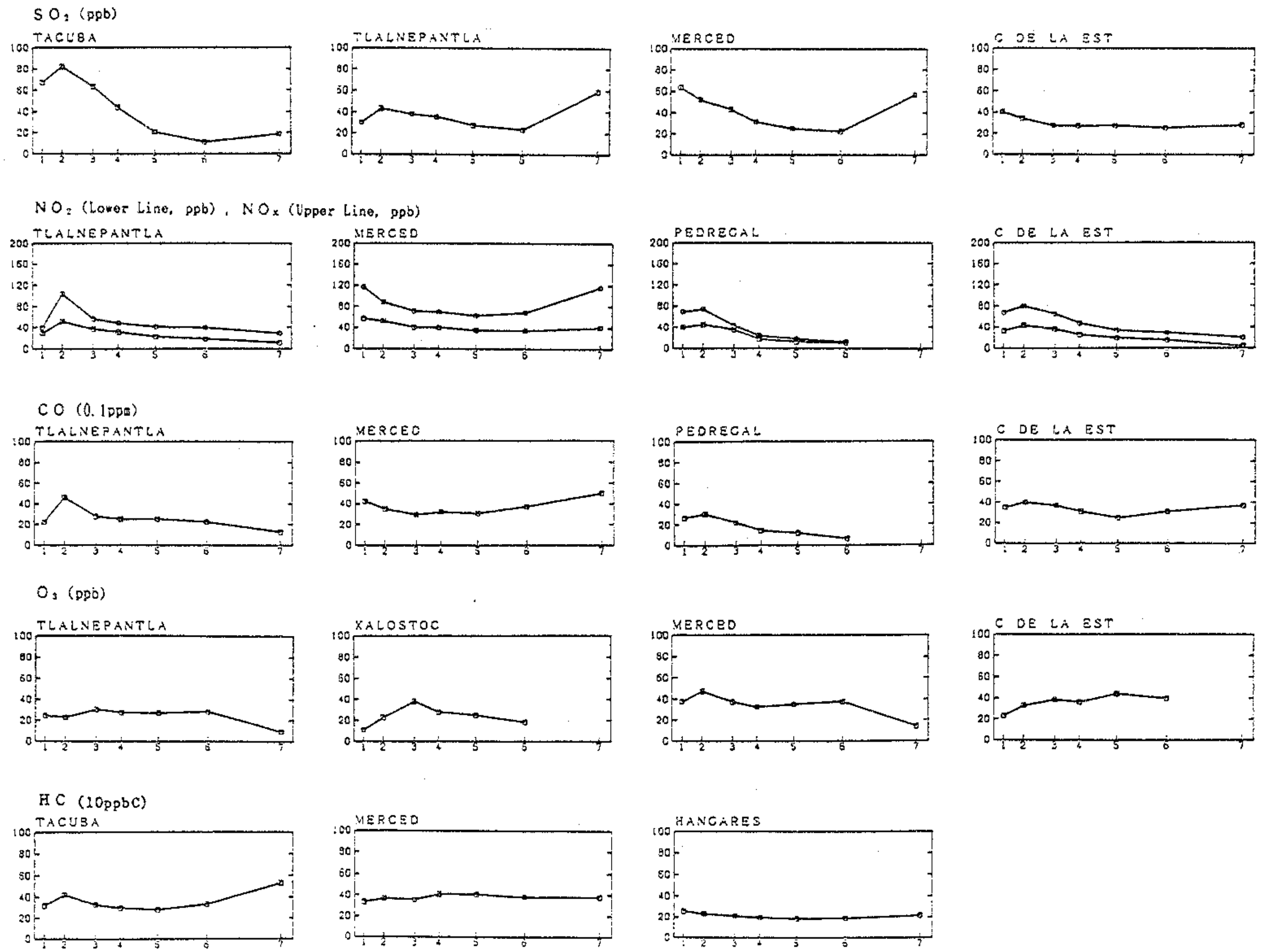


Figure 3.3.14 Average Concentration by Wind Speed (Dec. 1986 - Nov. 1987)

(3) Average Concentration by Atmospheric Stability

Atmospheric stability is one of factors affecting degree of air pollutant dispersion. Average concentration of pollutants classified by state of atmospheric stability is shown in Figure 3.3.15.

1) SO_2

Variation of the concentration with atmospheric stability is small except for TACUBA. At TACUBA, the concentration is high at the unstable cases of A, AB and B. This is considered to be influence of pollutant sources in the vicinity.

2) NO_2 and NOx

The concentration of NOx is relatively high at the unstable cases of A, AB and B, and at the stable cases of F and G. Time zones for high concentration of NOx are morning hours when the air is unstable and night hours when the air is stable.

3) CO

The overall trend is similar to that for NOx

4) O_3

The concentration is higher at the higher degrees of unstability, and vice versa. It is considered that photochemically reactive pollutants stay inert during the night and early morning hours when the atmosphere is stable, and as solar radiation increases and the air becomes unstable in the daytime, those pollutants become involved actively in the photochemical reactions to produce ozone.

5) HC

Concentration variation with the atmospheric stability is small.

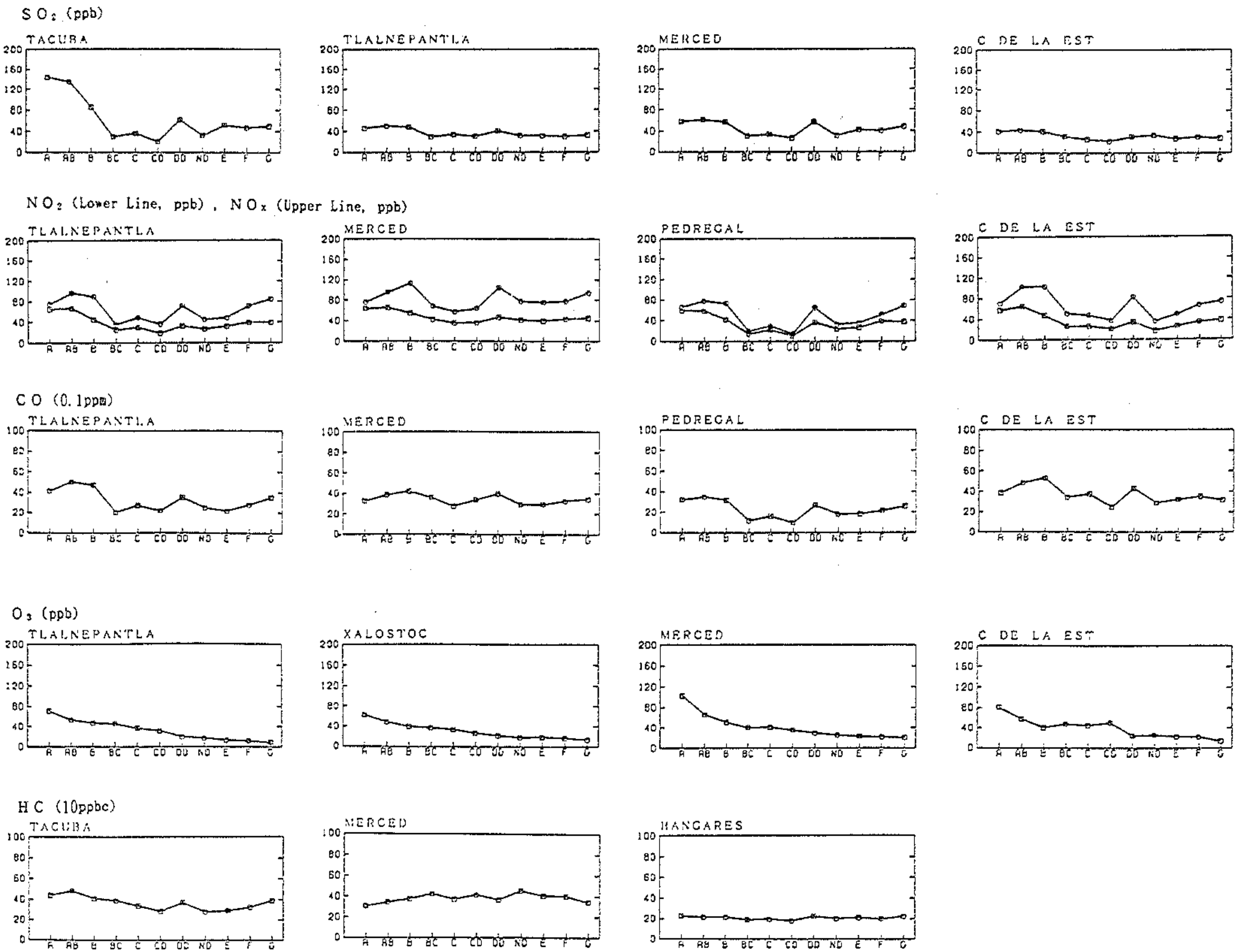


Figure 3.3.15 Average Concentration by Atmospheric Stability Classes (Dec. 1986 - Nov. 1987)

(4) Meteorological Conditions at the Time of High Concentration

1) Definition of High-concentration Days, and Monthly Appearance Distribution

The "high-concentration days" for each pollutant are determined as follows:

Computation of the daily average concentration for each station
↓
Selection of the highest five stations for each day and determination of the daily average concentration by taking average of the five stations
↓
Alignment of the above daily values from the highest downwoard
↓
Taking the highest 30 days from the above alignment to determine "high-concentration days."

Figure 3.3.16 shows the monthly number of high-concentration days for each pollutant. The high-concentration days for SO_2, NO_2, and CO appear frequently from November to April. In contrast, those for O_3 appear also in the summer months.

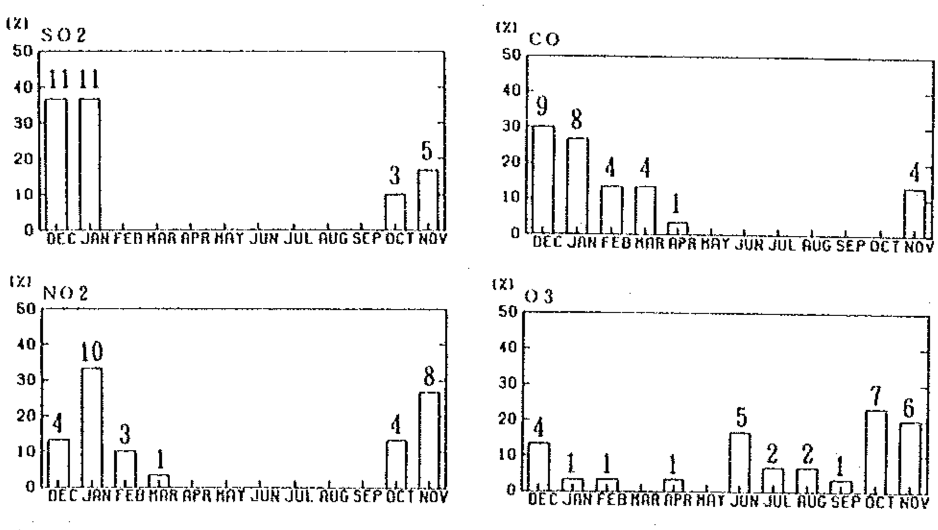


Figure 3.3.16 Monthly Appearance of High-Concentration Days

Table 3.3.10 shows the number of high-concentration days for each day of the week. High concentration seldom occurred on Sunday except for O_3. Only two Sundays were high-concentration days for SO_2 and no high-concentration of NO_2 and CO occurred on Sunday.

As shown in Table 3.3.11, high-concentration days tend to continue. Actually, two or more consecutive high-concentration days occurred at a total of 25 days for SO_2, 19 days for NO_2, 16 days for CO, and 18 days for O_3.

Table 3.3.12 shows the high-concentration days and their ranks for each pollutant.

Table 3.3.10 Number of High-Concentration Days by Day of Week (Dec. 1986 - Nov. 1987)

Air Pollutants	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.	Total
SO_2	2	4	5	5	6	6	2	30
NO_2	3	6	5	6	7	3	0	30
CO	3	4	9	6	5	3	0	30
O_3	5	2	2	6	5	4	5	30

Table 3.3.11 Times of Occurrence of Consecutive High-Concentration Days (Dec. 1986 - Nov. 1987)

Air Pollutants	2 days	3 days	4 days	5 days
SO_2	3	2	2	1
NO_2	6	1	1	0
CO	2	1	1	1
O_3	4	2	1	0

Many high-concentration days are common for these pollutants and, in the case of SO_2, NO_2, and CO, 10 days are common to them as shown in Figure 3.3.17. Two-thirds of high-concentration days for SO_2 and NO_2 and one-half of those for CO are common to other pollutants.

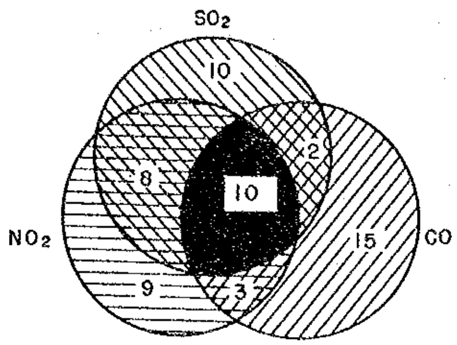


Figure 3.3.17 Overlap of High-Concentration Days for SO_2, NO_2 and CO

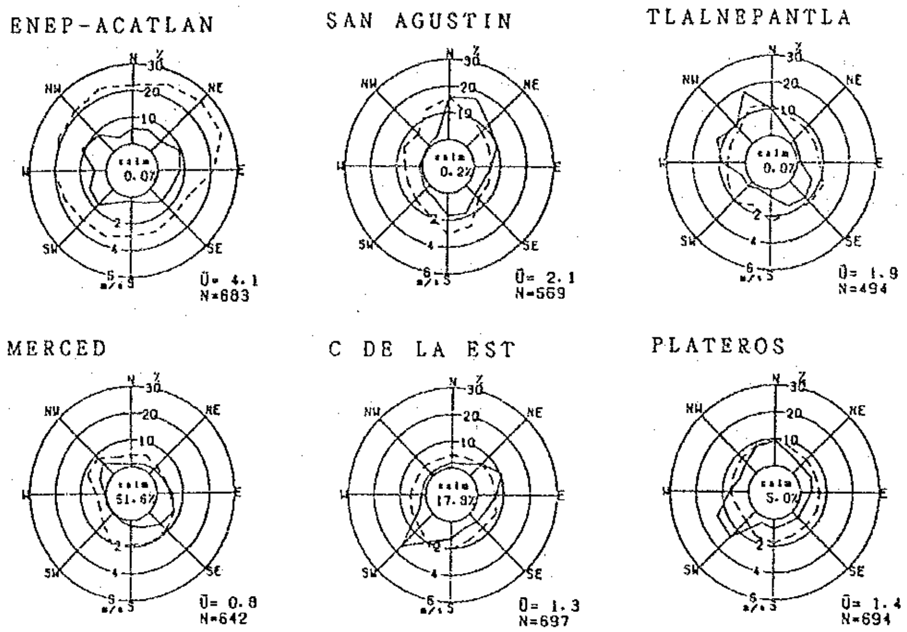
Table 3.3.12 Ranks of High-Concentration Days by Pollutant

date	SO_2	NO_2	CO	O_3
Dec. 3 wed.	10	–	–	–
10 wed.	–	–	13	–
11 thu.	–	–	8	–
12 fri.	19	–	–	–
13 sat.	2	–	–	–
14 sun.	28	–	–	–
16 tue.	7	–	4	29
17 wed.	4	7	3	9
18 thu.	9	11	11	16
19 fri.	23	–	15	–
20 sat.	30	25	22	27
24 wed.	–	–	14	–
26 fri.	21	9	7	–
27 sat.	11	–	–	–
Jan. 5 mon.	6	2	6	–
6 tue.	5	1	1	–
7 wed.	1	3	2	–
8 thu.	8	13	6	–
10 sat.	13	–	–	–
11 sun.	3	–	–	–
12 mon.	12	24	–	–
13 tue.	20	–	–	–
14 wed.	–	–	–	20
15 thu.	–	–	–	25
17 sat.	–	–	–	23
22 thu.	25	6	–	–
23 fri.	–	17	–	–
27 tue.	–	8	–	–
28 wed.	17	16	10	–
30 fri.	26	4	–	23
Feb. 2 mon.	–	–	16	–
10 tue.	–	26	–	–
11 wed.	–	29	–	–
12 thu.	–	27	–	–
13 fri.	–	–	19	–
20 fri.	–	–	30	–
25 wed.	–	–	29	–

date	SO_2	NO_2	CO	O_3
Mar. 14 sat.	–	–	21	–
16 mon.	–	–	18	–
17 tue.	–	–	9	–
18 wed.	–	–	26	–
20 fri.	–	18	–	–
Apr. 30 thu.	–	–	12	–
Jun. 19 fri.	–	–	–	11
20 sat.	–	–	–	4
21 sun.	–	–	–	19
22 mon.	–	–	–	25
29 mon.	–	–	–	13
Jul. 5 sun.	–	–	–	1
6 mon.	–	–	–	2
Aug. 2 sun.	–	–	–	20
30 sun.	–	–	–	26
Sep. 29 tue.	–	–	–	5
Oct. 1 thu.	14	19	–	21
2 fri.	24	–	–	–
5 mon.	–	–	–	15
8 thu.	–	–	–	8
14 wed.	–	–	–	3
16 fri.	–	–	–	30
18 sun.	–	–	–	10
19 mon.	–	15	–	7
23 fri.	16	20	–	–
31 sat.	–	28	–	–
Nov. 3 tue.	–	21	–	–
6 fri.	27	14	–	24
7 sat.	15	5	–	14
10 tue.	22	–	–	–
11 wed.	18	10	–	–
12 thu.	29	23	17	18
13 fri.	–	–	–	6
14 sat.	–	–	–	28
17 tue.	–	30	28	–
18 wed	–	12	27	–
27 fri.	–	22	24	–

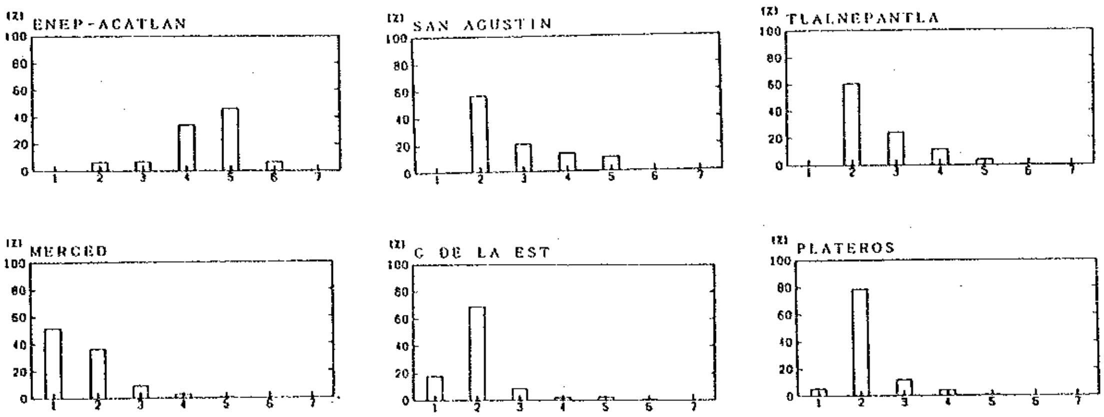
Note: 1) Numbers in the Table express the ranks of the daily average concentration.

2) Consecutive high-concentration days are indicated by enclosing their rank numbers by rectangular mark.



—— Wind Direction Ratio (%)
- - - Average Wind Speed (m/s)
calm 0.0~0.4m/s

Figure 3.3.18 Wind Rose for SO_2 High-Concentration Days



Wind Speed Classes(m/s)

1 0 ~0.4
2 0.5~1.9
3 2.0~2.9
4 3.0~3.9
5 4.0~5.9
6 6.0~7.9
7 8.0~

Figure 3.3.19 Frequency of SO_2 High-Concentration Days with Respect to Wind Speed

2) Meteorological Conditions in High-concentration Days

The meteorological conditions for high-concentration days are described below with reference to SO_2.

a. Wind Direction and Speed

The wind rose averaged for high-concentration days is shown in Figure 3.3.18. Different from the annual average wind rose, the frequent wind direction is SW at ENEP ACATLAN and NW at XALOSTOC and the NE winds are less at MERCED and HANGARES.

Table 3.3.13 shows the average wind speed for high-concentration days along with the annual average wind speed. The annual average wind speed is higher except for ENEP ACATLAN. Figure 3.3.19 shows frequency of occurence of high-concentration days with respect to wind speed.

Table 3.3.13 Average Wind Speed in SO_2 High-Concentration Days

Unit: m/s

Stations	High Concentration Days	Annual
TACUBA	1.8 (1.3)	2.3 (0.0)
ENEPACATLAN	4.1 (0.0)	3.9 (0.0)
SAN AGUSTIN	2.1 (0.1)	2.6 (0.2)
TLALNEPANTLA	1.9 (0.2)	2.5 (1.9)
XALOSTOC	1.4 (1.4)	2.0 (5.0)
MERCED	0.8 (31.1)	1.3 (51.6)
PEDREGAL	1.3 (11.6)	1.6 (9.5)
C. DE LA EST.	1.3 (13.8)	1.5 (17.8)
PLATEROS	1.4 (10.2)	1.6 (5.0)
HANGARES	1.9 (0.0)	2.3 (0.0)

( ): Indicates appearance ratio (%) of calm day.

b. Atmospheric Stability

Figure 3.3.20 shows the appearance distribution of the atmospheric stability class on high-concentration days. Comparison of this distribution with the annual appearance distribution (Figure 3.3.7) indicates that the frequent class is "unstable" in the daytime and "stable" at night because of low wind on high-concentration days.

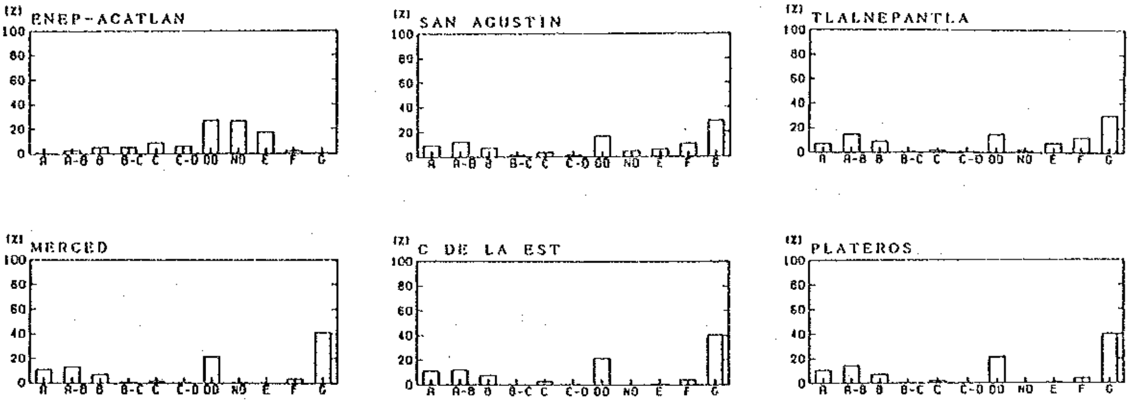


Figure 3.3.20 Air Stability Appearance Distribution in High-Concentration Days for SO_2

3) Hourly Average Concentration During High-concentration Days

Figure 3.3.21 shows the hourly average concentration of the pollutants for high-concentration days. When compared with the annual hourly average (Figure 3.3.9), the peaks of concentration are more significant.

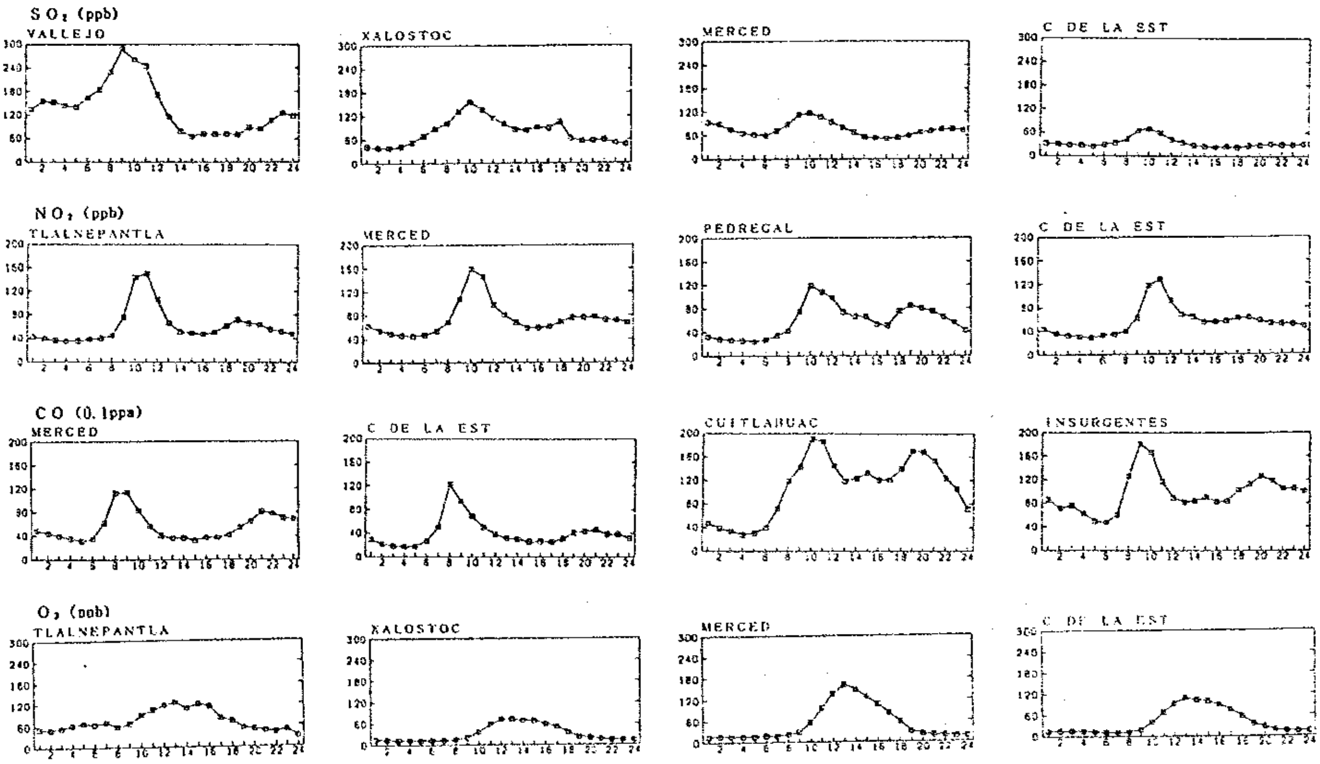


Figure 3.3.21 Hourly Average Concentration for SO_2 High-Concentration Day

3.4 Sources of Air Pollutants

Investigation of pollutant sources is one of the most important tasks involved in air pollution control planning. Reliable source data can be used for various purposes. In this study, a primary purpose of the source investigation is 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 Section 3.5.

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

The scope concerning estimation of amount of pollutant emissions is as follows.

(1) Object Area

The area considered is that shown in Figure 1.2.1, with 40 km from east to west and 60 km from north to south. Therefore, the estimation does not cover the whole area of the Mexico Valley.

(2) Pollutant Types and Sources Considered

Types of pollutant and types of source considered and main purpose of estimating emission quantity for each type of pollutant are given in the following table.

Pollutant	Source considered	Main purpose
SOx NOx	Mobile source • automobiles • jet airplanes Stationary source • factories • service and commercial establishments in DF	To develope a source model for air quality simulation
CO	Automobiles only (because of insignificance of other sources)	Same as for SOx and NOx
Smoke and soot	Stationary source • factories • service and commercial establishments in DF	Analysis of contribution of stationary sources to ambient concentration of TSP by the CMB method

Note: Service and commercial establishments include hotel, hospital, bathhouse, laundry, bakery and other small scale industries.

(3) Approach for the Estimation

Development of the source model for SOx, NOx and CO 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 large stationary sources, road by road for automobiles in major roads, and on the unit area basis for smaller stationary sources and automobiles in secondary roads. However, because of various constraints on the investigation including a limited length of time, it was not possible to cover practically all the sources in the object area. Sources that have to be excluded from the investigation include the following.

- service and commercial establishments in the area of the Mexico State
- automobiles in secondary roads outside the 20 km x 30 km area and some of the major roads in the area of the Mexico State
- number of automobiles increased from the years the traffic volume surveys were made
- other unknown sources

It is considered that the scope for the estimation of amount of pollutants described above 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.

3.4.1 Survey of Mobile Sources

Although automobiles and jet airplanes are considered as the mobile sources of air pollutants, automobiles constitute practically all of total quantity of pollutants from mobile sources. Figure 3.4.0 shows the procedure for estimating quantity of pollutant emissions from automobiles.

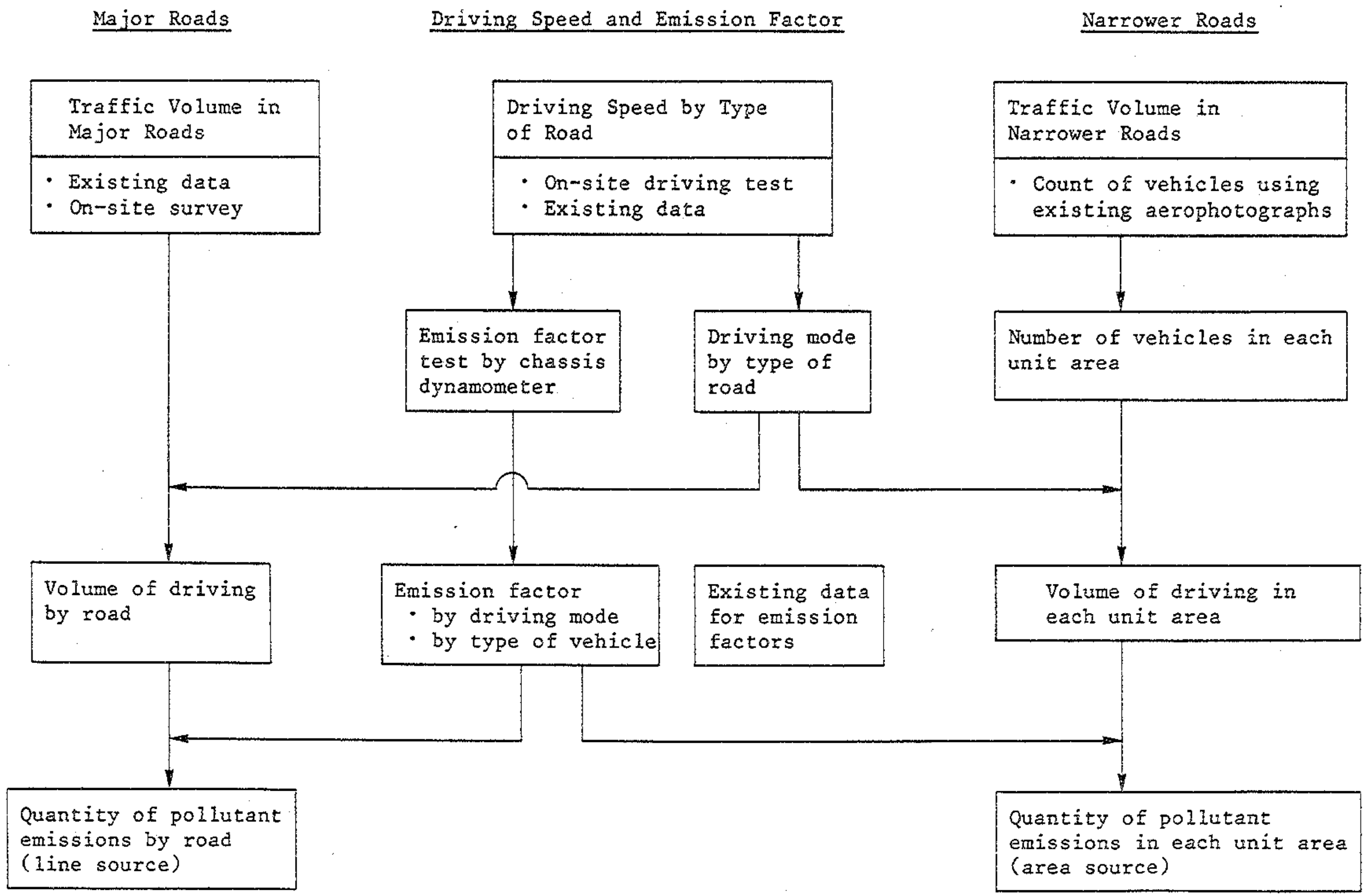


Figure 3.4.0 Procedure for Estimating Quantity of Pollutant Emissions from Automobiles

(1) Automobile Traffic Volume

The principal road network in the study area is shown in Figure 3.4.1. The major roads in Mexico City may be roughly classified as follows:

a. Access controlled roads (VIA DE ACCESSO CONTROLADA), such as peripheral highway (ANILLO PERIFERICO), inner circular highway (CIRCUITO INTERIOR), M. Aleman Street (VIADUCTO M. ALEMAN), and Tlalpan Street (VIADUCTO TLALPAN)

b. Vital roads (EJE VIALES) running straight in the east-west and the north-south directions

c. Main roads, such as Reforma Street (PASEO DE LA REFORMA), Insurgentes Street (INSURGENTES), and Zaragoza Street (CALZ I. ZARAGOZA)

Major roads in the State of Mexico include National Highway No. 57 branching from ANILLO PERIFERICO, National Highway No. 85 connected to INSURGENTES, and National Highway No. 136 which connects these national highways.

This study reviewed the traffic volume of these major roads using the data of the 1986 traffic volume survey (on 36 routes at 189 blocks) and the 1984 noise and traffic survey by DDF and the 1985 survey (28 blocks) by the State of Mexico. To supplement these surveys, a traffic volume survey was conducted in this study at 30 blocks on the major roads in July 1987.

To determine the traffic volume in narrower roads, the number of vehicles were counted using the existing aerial photographs taken in 1985 to 1986. In addition, a similar survey to that for major roads was conducted at nine points on narrower roads.

The automobile traffic volume surveys cited above are outlined in Table 3.4.1. The results are summarized hereafter, and more details are given in the Appendices.

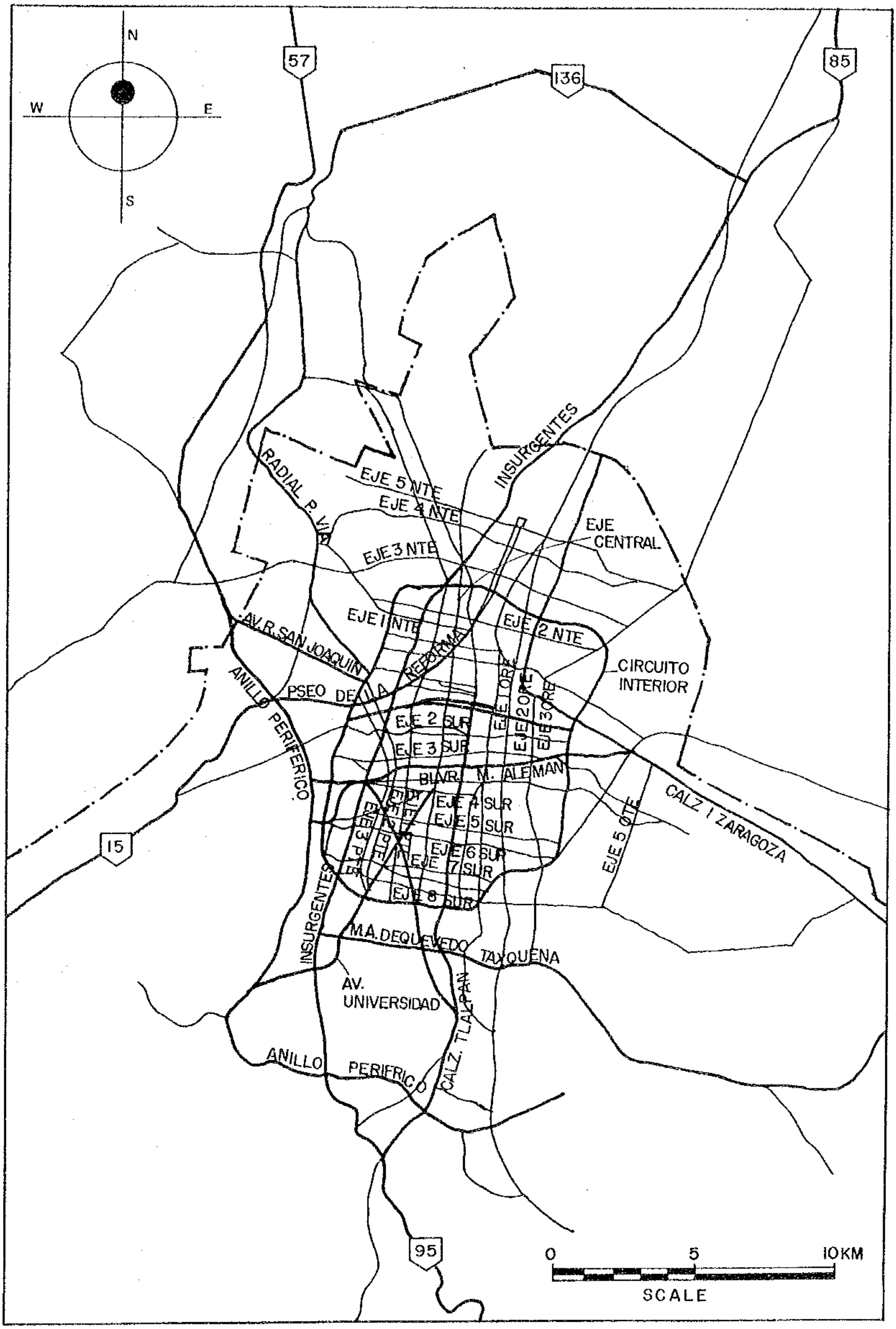


Figure 3.4.1 Major Road Network in Mexico City

Table 3.4.1 Outline of the Automobile Traffic Volume Surveys

Description	Details of Survey					Remarks
	Sites of Survey	Holiday/weekday Traffic Volume	Car Type Classification	Hourly Fluctuations	Other Item	
DDF traffic survey (1986)	189 blocks (20-hour average traffic volume)	Weekdays (Tue., Wed., Thu. in Sept. to Nov., 1986)	-	Not measured partially at night (av. 4 hr)	-	The survey area was limited within the DF.
	10 blocks (24-hour)	7 consecutive days (Sept. 26 to Oct. 2, 1986)	-	Not measured partially on Oct. 2 (Thu.)	-	
Mexico State traffic survey (1985)	28 blocks (16-hour: 6:00 - 22:00)	Weekdays	4 groups: · Passenger car · Bus · Combi · Truck	-	-	The survey area is a part of the Mexico State adjacent to DF.
DDF noise and traffic survey (1984)	122 points in major roads, 685 points in minor roads (1-hr each)	Weekdays	2 groups: · Large-sized car (above 3 tons) · Small-sized car (below 3 tons)	-	-	Survey area: 14 delegaciones and 70 zones within the DF.
JICA traffic survey (1987)	30 blocks (12-hour: 6:00 - 18:00)	Holiday (Sunday, July 26) Weekday (Wednesday, July 29)	4 groups: passenger car, bus, truck, combi	By time zones and car types; for 15-min/hr	-	21 points in major roads; 9 points in minor roads
JICA Aerophotograph reading survey (1987)	Areas of 20km from east to west, 30km from north to south	-	4 groups: passenger car, bus, truck, combi	-	Running cars and parked cars	Aerophotographs taken in 1985-86 owned by Aerofoto Co.

1) Major Roads

a. Daily traffic volume

The DDF traffic volume survey (1986) showed that the automobile traffic volumes in access controlled roads (VIA DE ACCESSO CONTROLADA) were larger than other major roads. Daily traffic volumes were 50,000 - 160,000 units/day in the peripheral highway (ANILLO PERIFERICO), 35,000 -230,000 units/day in Tlalpan Street (VIADUCTO TLALPAN), 30,000 - 200,000 units/day in the inner circular highway (CIRCUITO INTERIOR), and 30,000 -150,000 units/day in M. Aleman Street (VIADUCTO M. ALEMAN). In contrast, the traffic volume of linear vital roads (EJE VIALES) showed that the daily traffic volume did not exceed 100,000 units/day at all the points. Daily traffic volumes ranged from less than 10,000 units/day to about 100,000 units/day. As regards the main roads, INSURGENTES showed 35,000 -120,000 units/day and PASAO DE LA REFORMA 20,000 - 90,000 units/day. In the case of CALZ I. ZARAGOZA, the volume exceeded 160,000 units/day at some points.

The roads in the State of Mexico showed generally smaller traffic volume comparing with those in Mexico City. But VIA GUSTAVO BAZ running through the northern industrial district and some blocks of National Highway No. 85 showed traffic volumes exceeding 100,000 units/day.

b. Hourly variation

According to the DDF traffic survey report (1986), the weekday traffic volume in Mexico City is concentrated in the morning hours. It was pointed out that the traffic peak in the peripheral area occurred during morning hours, while the peak in the central area came often in the early afternoon hours. Peaks were also observed during homecoming hours in the evening.

Figure 3.4.2 shows example of hourly variation of traffic volume on weekday and holiday, which was constructed based on the results of the DDF traffic survey (1986) and the JICA traffic survey (1987). It shows almost the same pattern on weekday and holiday except that the hourly variation on holiday is smoother.

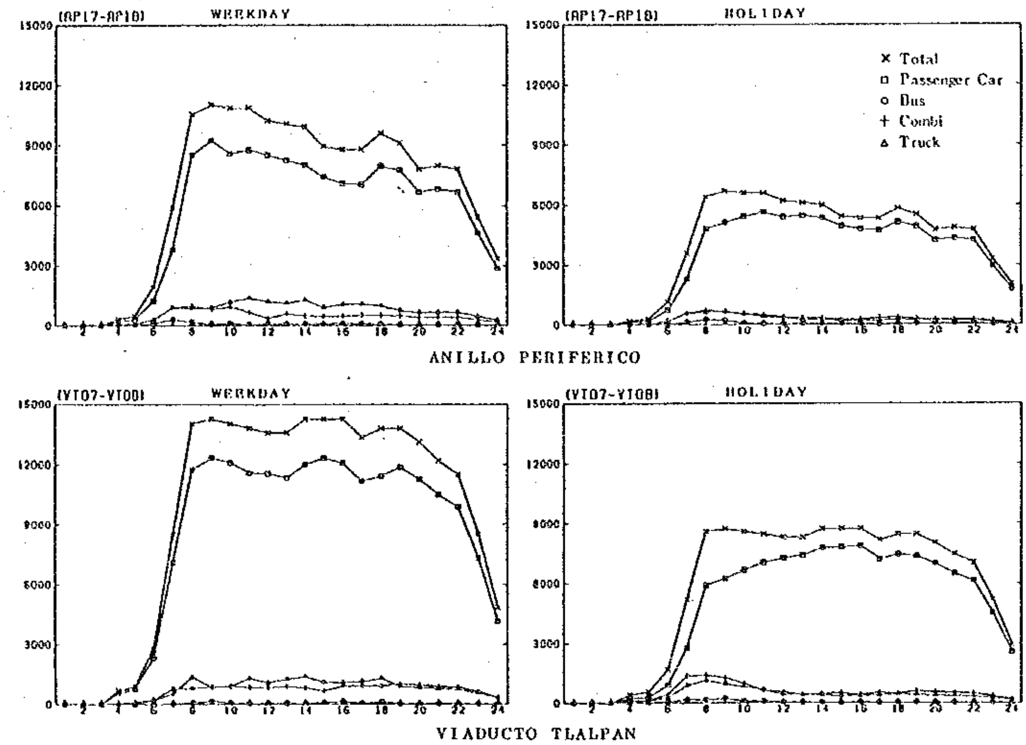


Figure 3.4.2 Example of Hourly Variation of Traffic Volume

c. Distribution of automobile types

Distribution of automobile types during the 12-hr daytime period in major roads observed in the JICA traffic survey (1987) indicated that passenger cars accounted for more than 80% at most points, making buses, trucks and combis together less than 20%. For CALZ I. ZARAGOZA, however, passenger cars accounted for less than 60% on both holidays and weekdays with combis and trucks together exceeding 30%. This is a significant difference from other major roads.

It is seen that the ratio of trucks tends to decrease on holidays in comparison to weekdays. Figure 3.4.3 shows, as an example, the difference in the automobile type distribution between weekday and holiday in CIRCUITO INTERIOR.

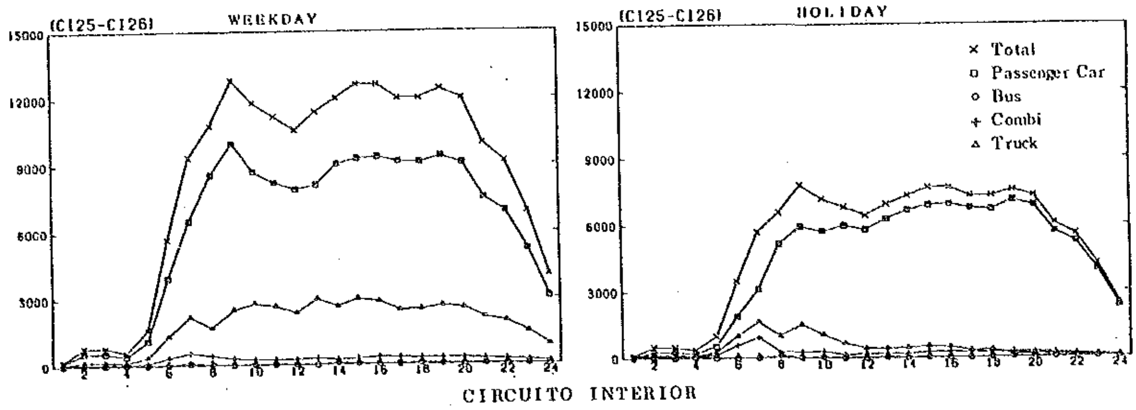


Figure 3.4.3 Example of Hourly Variation of Traffic Volume

d. Weekday/holiday variation of traffic volume

Difference in traffic volume between weekdays and holidays observed in the JICA traffic survey (1987) is shown in Figure 3.4.4. Relatively high correlation can be noted.

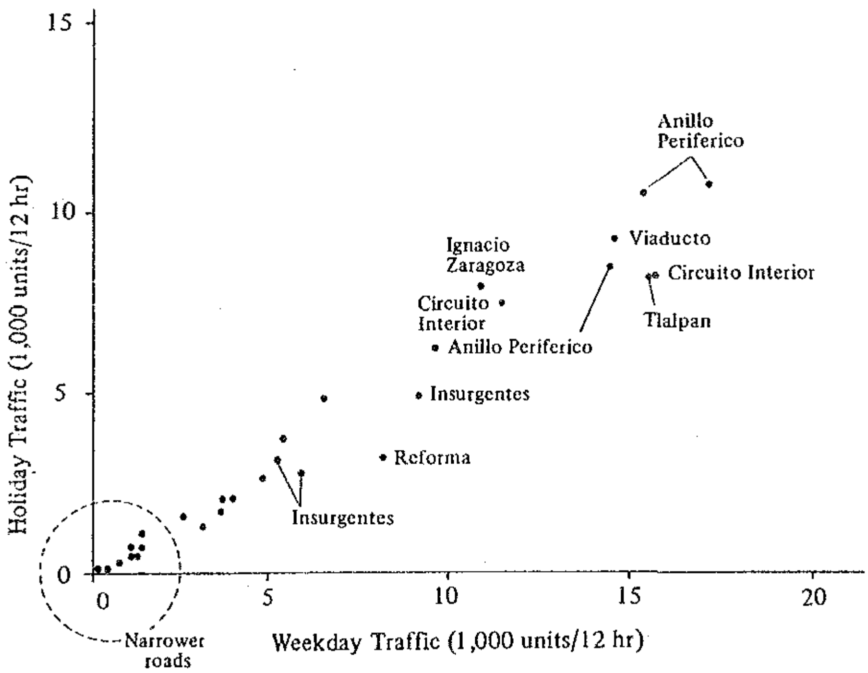


Figure 3.4.4 Traffic Volume on Weekday and Holiday

2) Narrower Roads

The survey grids for counting the number of cars on the aerial photographs are shown in Figure 3.4.5. The counting was made for each unit area of 1 km^2, and the results are outlined in Table 3.4.2 as average vehicle density for each DELEGACION.

The average of number of running cars per unit area was 300 as an average of 120 grids. The distribution of automobile types showed that passenger cars accounted for about 80% and buses, trucks and combis together accounted for about 20%, the distribution being similar to that in the major roads.

Among the delegaciones, the vehicle density was largest in CUAUHTEMOC with an average of 629 vehicles/km^2 followed by BENITO JUAREZ and COYOACAN with 385 and 366 vehicles/km^2, respectively.

As regards automobile types, passenger cars accounted for the highest percentage in all the delegaciones. The bus and combi percentage was relatively high in IZTACALCO, IZTAPALAPA, TLAHUAC, and the State of Mexico where new residential areas prevailing.

Table 3.4.3 shows daytime one-hour traffic volume in narrower roads averaged for DELEGACION obtained based on the results of the noise and traffic survey conducted at a total of 685 points by DDF in 1984. The average for all the points was 341 vehicles/hr, in which large-size cars accounted for 8.6%. The point-average traffic volume was largest at 571 vehicles/hr in MIGUEL HIDALGO, followed by 484 vehicles/hr in CUAUHTEMOC and 461 vehicles/hr in COYOACAN. The large-size car ratio was highest at 41.8% in AZCAPOTZALCO and around 10% in other DELEGACIONES.

3) Parked Cars

Distribution of parked cars in major and narrower roads that were counted on the aerial photographs is shown in Figure 3.4.6. The areas where parking car density is 3000 vehicles/km^2 or more are seen in CUAUHTEMOC such as ZOCALO and ZONA ROSA, indicating that many people working in these area use their car for commuting.

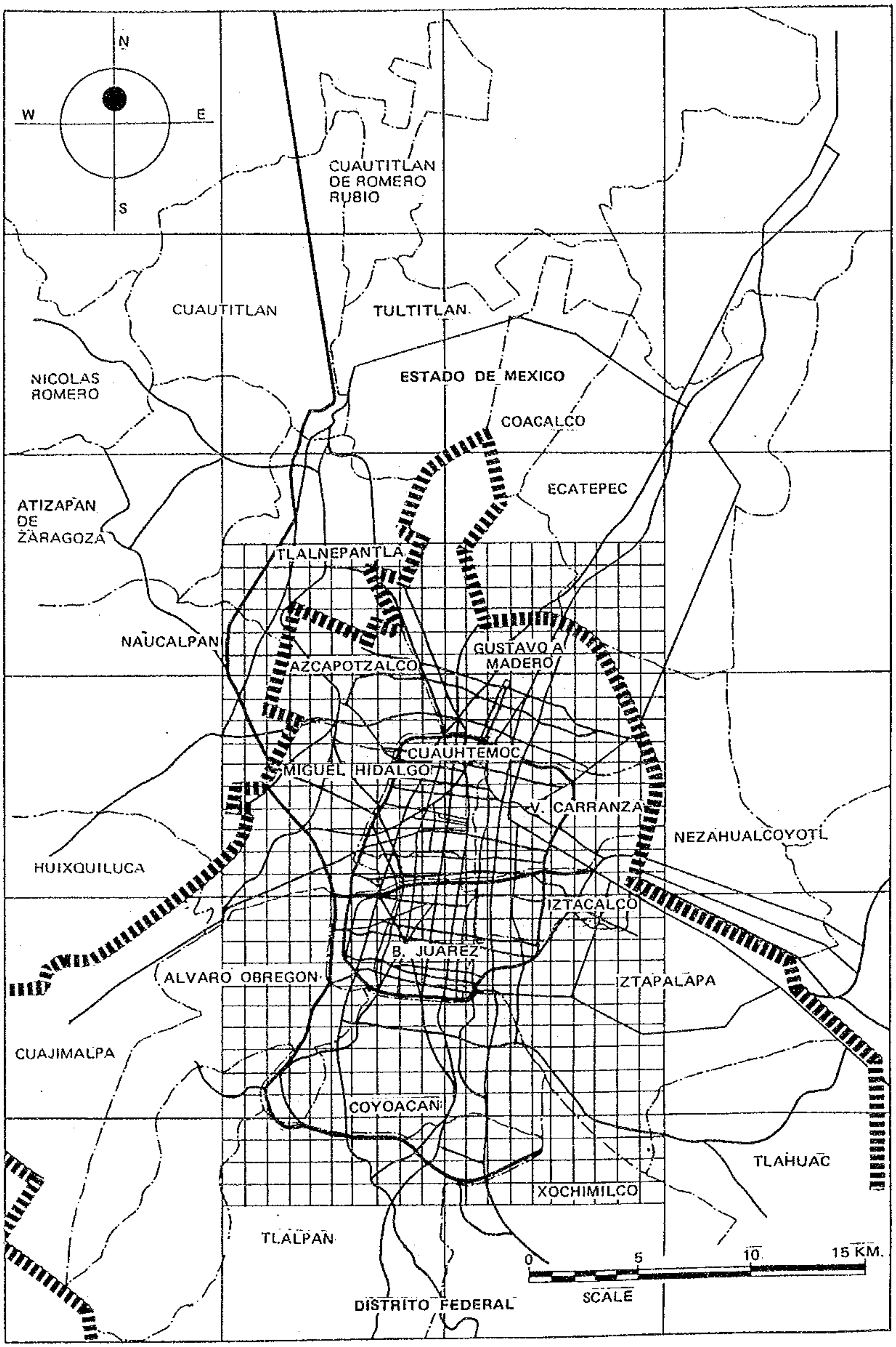


Figure 3.4.5 Survey Area for Counting Automobiles on Aerophotograph

Table 3.4.2 Vehicle Density in Narrower Roads
(Result of Counting on Aerophotographs)

DELEGACIONES	Average Vehicle Density (vehicles/km^2) (%)				
	Passenger Cars	Buses	Trucks	Combis	Total
ALVARO OBREGON	164 (82.0)	6 (3.0)	16 (8.0)	14 (7.0)	200 (100.0)
AZCAPOTZALCO	126 (74.6)	9 (5.3)	25 (14.8)	9 (5.3)	169 (100.0)
BENITO JUAREZ	322 (83.6)	5 (1.3)	30 (7.8)	28 (7.3)	385 (100.0)
COYOACAN	307 (83.9)	4 (1.1)	29 (7.9)	26 (7.1)	366 (100.0)
CUAUHTEMOC	509 (80.9)	10 (1.7)	60 (9.5)	50 (7.9)	629 (100.0)
GUSTAVO A. MADERO	109 (79.6)	8 (5.8)	11 (8.0)	9 (6.6)	137 (100.0)
IZTACALCO	62 (71.3)	3 (3.4)	12 (13.8)	10 (11.5)	87 (100.0)
IZTAPALAPA	112 (71.3)	5 (3.2)	26 (16.6)	14 (8.9)	157 (100.0)
MAGDALENA CONTRERAS	154 (80.2)	4 (2.1)	27 (14.1)	7 (3.6)	92 (100.0)
MIGUEL HIDALGO	202 (83.5)	7 (2.9)	18 (7.4)	15 (6.2)	242 (100.0)
TLAHUAC	28 (48.3)	4 (6.9)	13 (22.4)	13 (22.4)	58 (100.0)
TLALPAN	106 (79.7)	4 (3.0)	12 (9.0)	11 (8.3)	133 (100.0)
VENUSTIANO CARRANZA	149 (75.3)	14 (7.1)	20 (10.1)	15 (7.6)	198 (100.0)
XOCHIMILCO	118 (83.1)	4 (2.8)	14 (9.9)	6 (4.2)	142 (100.0)
ESTADO DE MEXICO	114 (65.5)	10 (5.7)	31 (17.9)	19 (10.9)	174 (100.0)
Average	241 (80.3)	23 (7.7)	7 (2.3)	29 (9.7)	300 (100.0)

Table 3.4.3 One-hour Traffic Volume in Narrower Roads Averaged for DELEGACION

(According to the 1984 Noise and Traffic Survey)

DELEGACION	Number of survey points	Traffic volume (vehicles/hr)	Large-size car ratio (%)
ALVARO OBREGON	72	348	6.4
AZCAPOTZALCO	44	349	41.8
BENITO JUAREZ	63	300	1.8
COYOACAN	30	461	3.2
CUAUHTEMOC	53	484	6.4
GUSTAVO A. MADERO	101	236	11.4
IZTACALCO	33	251	4.5
IZTAPALAPA	76	238	10.7
MAGDALENA CONTRERAS	36	246	4.1
MIGUEL HIDALGO	83	571	5.2
TLAHUAC	10	86	1.7
TLALPAN	42	255	4.1
VENUSTIANO CARRANZA	30	413	8.5
XOCHIMILCO	12	363	3.7
Average	685(total)	341	8.6

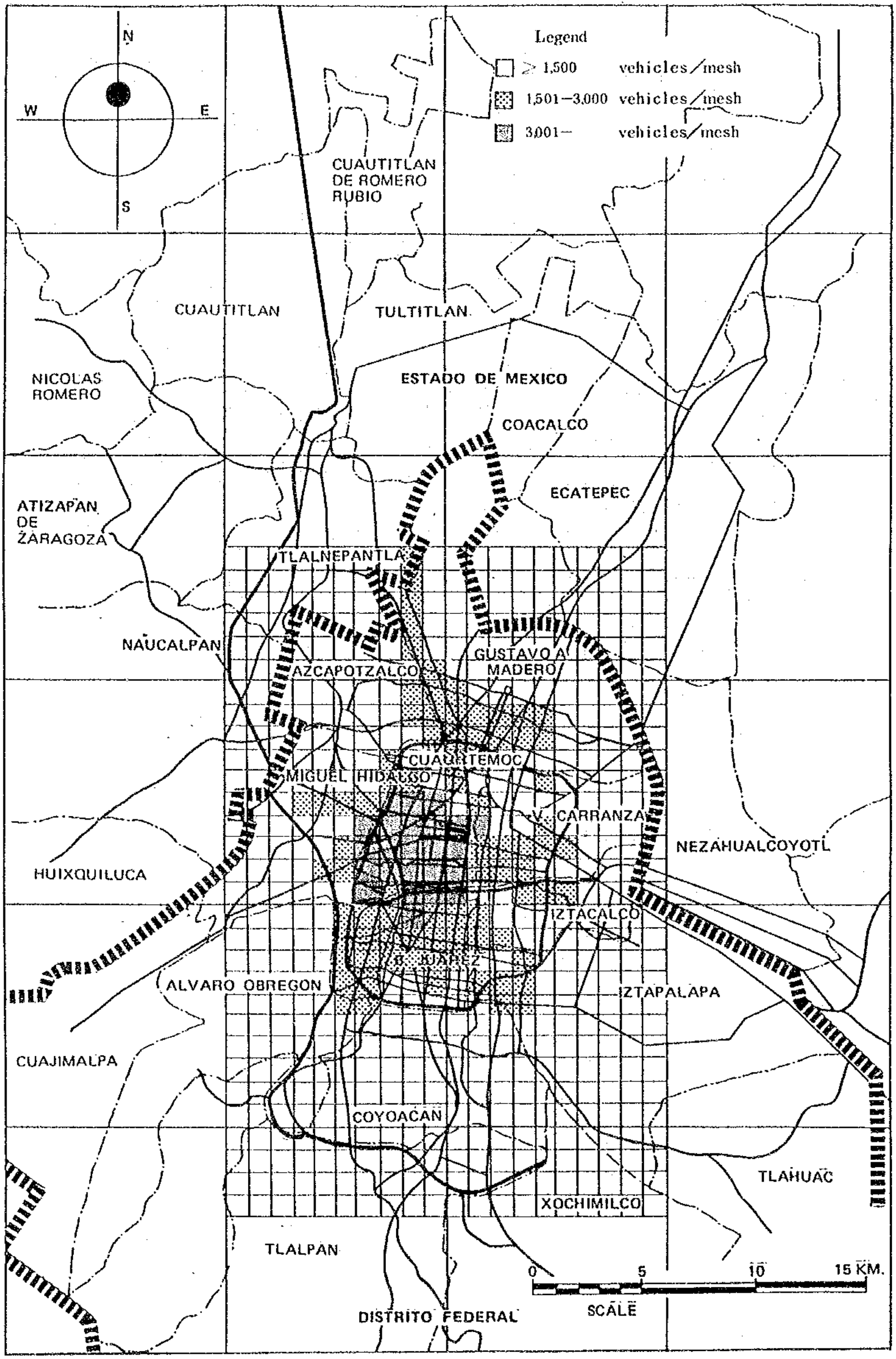


Figure 3.4.6 Automobile Road-Parking Distribution

The total number of vehicles parked on the roads in the survey area was 560,000, and the overall average density was about 930 vehicles/km^2. Passenger cars accounted for as high as about 90%.

(2) Automobile Driving Speed

1) Major Roads

Table 3.4.4 shows the automobile driving speed (average speed) on major roads estimated from existing data and the result of the driving speed test conducted in July 1987. The average speed was categorized into five classes: 20 km/h or less, about 25 km/h, about 30 km/h, about 45 km/h, about 60 km/h.

Table 3.4.4 Average Driving Speed in Major Roads by Time Zones

Road or Vehicle Category					Average Speed (km/h)	
					7-19 Hours	Other
Ordinary Road	Inner Part of CIRCUITO INTERIOR	Nothern Part			25	30
		Southern Part			30	30
	Outer Part of CIRCUITO INTERIOR				30	30
Access Controlled Road	Inner Part of CIRCUITO INTERIOR	VIADUCTO MIGUEL ALEMAN and CALZADA DE TLALPAN			45	60
	CIRCUITO INTERIOR	AV. RIO CONSULADO			45	60
		CALZADA M. OCAMPO			30	
		AV. REVOLUCION			25	
		AV. RIO CHURUBUSCO			60	
	Outer Part of CIRCUITO INTERIOR	PERIFERICO	From TOREO DE CUATRO CAMINOS to AV. PASEO DE LA REFORMA	N-S	30 20	60
				S-N	45	
			From AV. PASEO DE LA REFORMA to MOLINOS	N-S	60	
				S-N	45	
		Others			60	
Public Transport Vehicle	Collective Taxi (Combi)		Nothern Part of the inside of CIRCUITO INTERIOR		20	30
			Others		30	
	Bus (Ruta-100)				20	25

2) Narrower Roads

Table 3.4.5 shows the result of the driving speed test conducted by DDF in narrower roads from August to November, 1987.

Table 3.4.5 Average Driving Speed for Narrower Roads

Route NO.	Route Name	Date of Test	Start		Arrival		Recording Time (hrs)	Recording Distance (km)	Average Speed (km/h)
			Time	Odometer (km)	Time	Odometer (km)			
1.	CUAUHTEMOC I.	Aug. 13, 1987	13:15	11190.2	14:30	11209.5	1:15	19.3	15.44
2.	CUAUHTEMOC II.	Aug. 13, 1987	16:25	11234.3	17:31	11249.6	1:05	15.3	14.12
3.	BENITO JUAREZ	Aug. 13, 1987	14:50	11212.5	155:48	11230.1	0:58	17.6	18.2
4.	COYOACAN	Oct. 30, 1987	12:30	35934.7	13:25	35952.8	0:53	18.1	20.49
5.	ALVARO OBREGON	No data obtained because of suspension of the driving test due to traffic conditions							
6.	MIGUEL MIDALGO	Nov. 5, 1987	10.58	36246.8	12:00	36264.7	1:02	17.9	17.32
7.	AZCAPOTZALCO	Nov. 24, 1987	13:35	41036.0	14:43	41057.5	1:06	21.5	18.97
8.	CUSTAVO A. MADERO	Nov. 10, 1987	11:35	36565.4	12:50	36593.1	1:14	27.7	22.45
10.	IZTACALCO	Nov. 3, 1987	10:35	36031.2	11:40	36051.9	1:03	20.4	19.42
11.	INDUSTRIAL VALLEJO	Nov. 6, 1987	11:30	36365.8	12:15	36382.3	0:34	16.3	28.76
12.	ESTADO DE MEXICO	Nov. 26, 1987	11:36	41124.5	12:33	41145.2	0:54	20.3	22.55
13.	LAS LOMAS	Nov. 4, 1987	12:20	36167.2	13:05	36183.6	0:43	16.1	22.46

(3) Automobile Emission Factor

Automobile emission factors were determined based on the results of the chassis dynamometer test conducted in Mexico and the situation in automobile registration and emission regulation in Mexico City as well as on the review of the emission factor data in USA and Japan.

1) Chassis Dynamometer Test

The chassis dynamometer test was conducted to determinate the exhaust gas characteristics of automobiles operating in Mexico City. Twenty-eight test cars were used, and idling adjustment was made for two cars whose pollutant emissions during idling were relatively high. These two cars were tested twice, before and after the idling adjustment. The test items included hydrocarbon, carbon monoxide, nitrogen oxides, and fuel economy. The tests were made for three modes: LA-4 mode (hot start), the 10-mode, and high-speed mode (constant speed at 60 km /h). A chassis dynamometer owned by Nissan De Mexico was used.

The emission factors and fuel economy by automobile type and by test mode obtained through the tests are shown in Table 3.4.6.

In view of the changes of exhaust gas emission standards for passenger cars in the past, four-cylinder passenger cars were divided into three categories: up to 1979, 1980 - 1983, and after 1983.

Six- and eight-cylinder passenger cars were divided into two categories considering the number of test cars available: up to 1979 and after 1979.

The results showed that 6- and 8-cylinder passenger cars had higher levels of HC and CO emissions than 4-cylinder cars and that the older the models, the higher the emission. As to the fuel economy, 4-cylinder cars were superior to 6- and 8-cylinder cars by about two times, and differences by model years were small.

Table 3.4.6 Emission Factors and Fuel Economy as the Results of the Chassis Dynamometer Test (Average by Automobile Type)

Classification	Item	Car Model	Test Mode		
			LA-4	10	High-speed
Passenger Car (4-cylider)	HC	1984-	1.60	1.76	0.69
		1980-1983	2.28	2.94	0.68
		-1979	3.03	3.73	0.74
	CO	1984-	21.31	26.28	12.18
		1980-1983	23.41	29.64	9.85
		-1979	27.64	30.90	12.80
	NOx	1984-	1.25	0.86	0.96
		1980-1983	0.88	0.88	0.96
		-1979	1.05	0.91	0.68
	Fuel Economy	1984-	12.62	11.62	21.42
		1980-1983	10.91	10.59	19.36
		-1979	11.36	11.21	20.42
Passenger Car (6- and 8-cylinder)	HC	1980-	2.54	3.28	1.19
		-1979	3.40	4.42	2.17
	CO	1980-	57.22	68.96	32.72
		-1979	43.27	57.08	28.75
	NOx	1980-	0.81	0.78	0.47
		-1979	1.20	1.10	0.67
	Fuel Economy	1980-	6.70	5.43	11.42
		-1979	7.75	6.26	12.68
Light Truck	HC	-	6.62	10.68	2.74
	CO	-	63.07	74.17	30.08
	NOx	-	0.58	1.05	0.73
	Fuel Economy	-	6.70	6.22	10.97
Combi	HC	-	5.81	4.73	0.82
	CO	-	47.18	27.61	12.53
	NOx	-	1.88	2.53	1.61
	Fuel Economy	-	7.53	8.31	15.91

Unit HC, CO, NOx: g/km
Fuel Economy: km/liter

2) Setting of Emission Factors by Automobile Type

a. Classification of automobile type

Automobile types were classified into four classes: passenger car, truck, large-size bus, and small-size bus (COMBI). In view of the exhaust gas regulation, passenger cars were classified by the number of cylinders and model years. The emission factor for each class was determined, and the average for passenger car was taken by weighing each class. Trucks were classified into light trucks (gross weight 3,000 kg or less) and heavy trucks (gross weight greater than 3,000 kg) and the emission factor determined by weighing of each class.

In case of SOx, however, emission factors were determined according to the following equation.

$$SO_x = \begin{matrix}\text{fuel}\\\text{consumption}\\\text{rate}\end{matrix} \times \begin{matrix}\text{specific}\\\text{gravity of}\\\text{fuel}\end{matrix} \times \begin{matrix}\text{sulphur}\\\text{content}\end{matrix} \times \frac{m.w.SO_2}{m.w.S} \times 1000$$

$$\left(\frac{g}{km}\right) \quad \left(\frac{liter}{km}\right) \quad \left(\frac{kg}{liter}\right) \quad \left(\frac{\%}{100}\right) \quad \left(\frac{64g}{32g}\right) \quad \left(\frac{g}{kg}\right)$$

Kind of fuel, specific gravity and sulphur content were assumed, considering the Mexican fuel standards, as follows:

bus: diesel (s.g. = 0.85 kg/liter, S = 0.53%)
others: gasoline (s.g. = 0.75 kg/liter, S = 0.13%)

b. Classification of emission mode

The emission mode was classified into low-speed mode and high-speed mode, with the driving speed of 30 km/h and 60 km/h, respectively. The emission factor for the LA-4 mode was chosen for the low-speed mode, and that at 60 km/h for the high speed mode.

c. Road and emission mode

The emission modes for major roads and narrower roads for weekdays and holidays are shown in Table 3.4.7.

Table 3.4.7 Emission Mode by Type of Road

	Type of Road		Weekdays 7-19 Hours	Weekdays Others	Holidays
Ordinary Road		Major Road Narrower Road	B	B	B
Access Controlled Road	Inner Part of CIRCUITO INTERIOR	VIADUCTO MIGUEL ALEMAN and CALZADA DE TALPAN	A	A	A
	CIRCUITO INTERIOR	AV. RIO CONSULADO	A	A	
		CALZADA M. OCAMPO and AV. REVOLUCION	B	A	
		AV. RIO CHURUBUSCO	A	A	
	Outer Part of CIRCUITO INTERIOR	from TOREO DE CUATRO CAMINOS to AV. PASEO DE LA REFORMA	B	A	
		Others	A	A	

Note A: High-speed mode (60km/h)
B: Low-speed mode (30 km/h)

Table 3.4.8 Emission Factor and Fuel Economy by Automobile Types

Type of Automobile	Item	Driving Mode Low-speed	Driving Mode High-speed	Fuel
Passenger Car	HC (g/km)	2.63	1.11	Gasoline
	CO (g/km)	33.66	18.75	
	NOx (g/km)	1.05	0.75	
	SO_2 (g/km)	0.21	0.11	
	Fuel Economy (km/l)	9.23	17.27	
Truck	HC (g/km)	7.61	3.41	Gasoline
	CO (g/km)	84.19	40.15	
	NOx (g/km)	1.48	5.87	
	SO_2 (g/km)	0.37	0.22	
	Fuel Economy (km/l)	5.32	8.71	
Bus	HC (g/km)	5.50	4.76	Diesel
	CO (g/km)	7.66	6.77	
	NOx (g/km)	12.37	11.61	
	SO_2 (g/km)	15.27	11.55	
	Fuel Economy (km/l)	0.59	0.78	
Combi	HC (g/km)	5.81	0.82	Gasoline
	CO (g/km)	47.18	12.53	
	NOx (g/km)	1.88	1.61	
	SO_2 (g/km)	0.26	0.12	
	Fuel Economy (km/l)	7.53	15.91	

d. Emission factors by automobile types

Table 3.4.8 shows emission factors by automobile types. They were determined as follows.

i) Passenger car

The ratio of passenger cars by the number of cylinders and model year was determined from the number of registered cars as of October 1987 in ALVARO OBREGON, AZCAPOTZALCO, BENITO JUAREZ, COYOACAN, and CUAJIMALPA, and the number of cars sold in Mexico City in the 4-, 6-, and 8-cylinder categories in 1970 - 1986. Then, emission factors by driving mode were determined.

ii) Truck

According to the number of trucks sold during 1972 - 1986 in the United Mexican States, the shares of light trucks and heavy trucks were 63% and 37%, respectively.

The emission factors and fuel economy for light trucks were determined from the result of the chassis dynamometer test. The emission factors for heavy trucks at the low-speed mode were determined from the official data of the USA, and that for high-speed mode by multiplying the emission factor at low speed by the high-speed/low-speed emission factor ratio for lilght trucks. Fuel economy for heavy truck was determined from the ratio of heavy truck/light truck in fuel economy that was obtained using the USA data. From these results and the sales ratio mentioned above, emission factors and fuel economy were determined.

iii) Bus

As emission factors for large-size buses in Japan, the *following data may be used.*

$$HC = \frac{40.76}{V} + 1.154 \quad (g/km)$$

$$CO = \frac{59.99}{V} + 2.282 \quad (g/km)$$

$$NOx = \frac{100.25}{V} + 10.251 \ (g/km)$$

where, V = driving speed (km/h)

Source: On the Result of the Emission Factor Review Concerning Automobile Exhaust Gas, Pollution Bureau, Tokyo, March 1978.

With these data and the altitude compensation factor obtained from a chassis dynamometer test in USA on light diesel cars, the emission factors for Mexico City were determined. As the emission factors for the high-speed mode, those at 45 km/h were chosen because of no test data available for higher speeds.

Fuel economy for the low-speed mode was obtained using the DDF's data, and for the high-speed mode using the high-speed/low-speed fuel economy ratio for light trucks.

iv) Small-size bus (COMBI)

The emission factors for small-size bus (COMBI) were determined from the result of the chassis dynamometer test conducted in this study.

(4) Quantity of Automobile Pollutant Emission

Volume of driving was estimated based on the results of traffic volume surveys. Then, quantity of pollutant emissions was estimated by mutiplying the volume of driving by the emission factor presented earlier.

1) Volume of Driving by Automobile Type

Volume of driving by automobile type classified into line source and area source are shown in Table 3.4.9 and Figure 3.4.7. Line source corresponds to major roads, and area source to narrower roads.

As apparent from the table, the driving volume for passenger car accounts for 78%, followed by truck, Combi, and bus.

Table 3.4.9 Volume of Driving by Automobile Type

Unit: 1000 km/day
( ): percent

Automobile Type	Source		Total
	Line	Area	
Passenger Car	32507	28460	60967 (77.8)
Bus	981	1253	2234 (2.9)
Truck	4698	4417	9115 (11.6)
Combi	2696	3311	6007 (7.7)
Total	40882	37441	78323 (100.0)

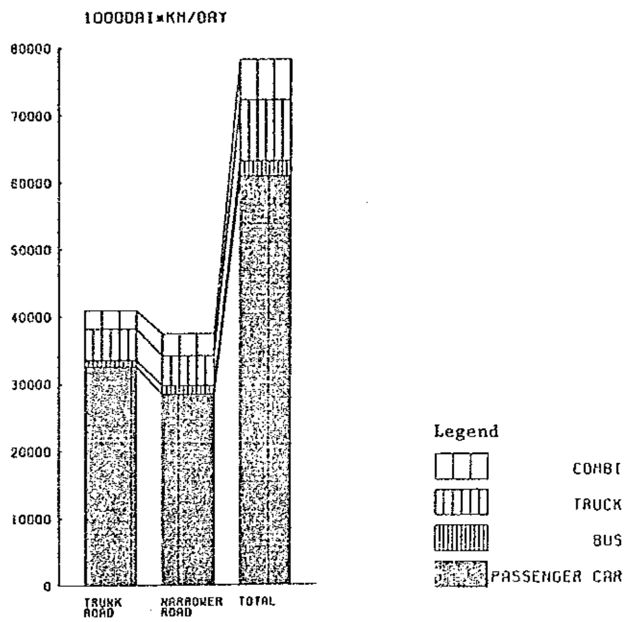


Figure 3.4.7 Volume of Driving by Automobile Type

2) Fuel Consumption by Automobile Type

Daily fuel consumption by automobile type estimated is shown in Table 3.4.10 and Figure 3.4.8.

Table 3.4.10 Daily Fuel Consumption by Automobile Type

Unit: ℓkl/day

Classification	Source		Total	Fuel
	Line	Area		
Passenger Car	2896	3083	5979	Gasoline
Bus	1566	2124	3690	Diesel
Truck	757	830	1587	Gasoline
Combi	304	440	744	Gasoline

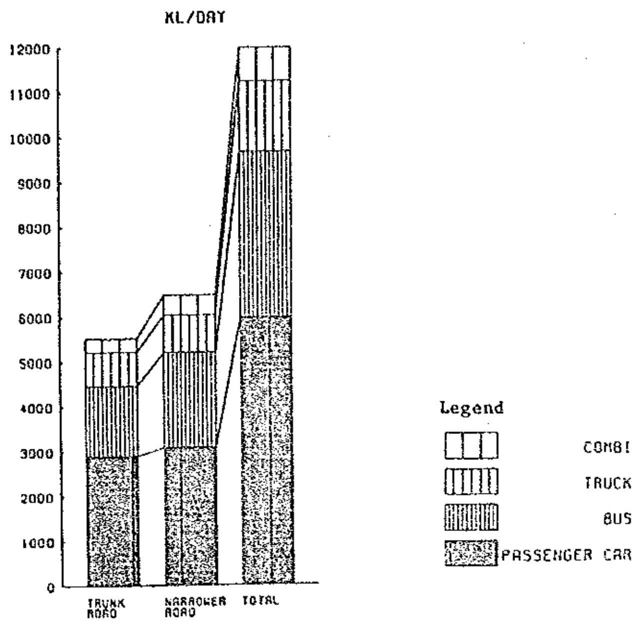


Figure 3.4.8 Daily Fuel Consumption by Automobile Type

3) Total pollutant emission by automobile type

Table 3.4.11 and Figure 3.4.9 show the pollutant emission volume per hour by automobile type, while Table 3.4.12 and Figure 3.4.10 the annual emission quantity by weight.

The pollutant emission ratio by automobile type is shown in the Table below.

Distribution of Pollutant Emissions by Automobile Type

Unit: %

Classification	Passenger Car	Bus	Truck	Combi	Total
CO	65.4	0.6	25.0	9.0	100
SO_2	23.8	67.4	6.1	2.7	100
NOx	53.5	24.2	12.4	9.9	100
HC	58.5	4.9	23.8	12.8	100

Table 3.4.11 Hourly Pollutant Emission Rate for Automobiles

Unit: Nm^3/h

Classification	Line				Area				Total			
	CO	SO_2	NOx	HC	CO	SO_2	NOx	HC	CO	SO_2	NOx	HC
Passenger Car	30768	84	623	3969	31941	88	606	4367	62709	172	1229	8336
Bus	242	206	242	297	320	279	315	402	562	485	557	699
Truck	11308	22	150	1568	12716	24	132	1830	24024	46	282	3398
Combi	3403	9	99	703	5208	13	126	1122	8611	22	225	1825
Total	45721	321	1114	6573	50185	404	1179	7721	95906	725	2293	14258

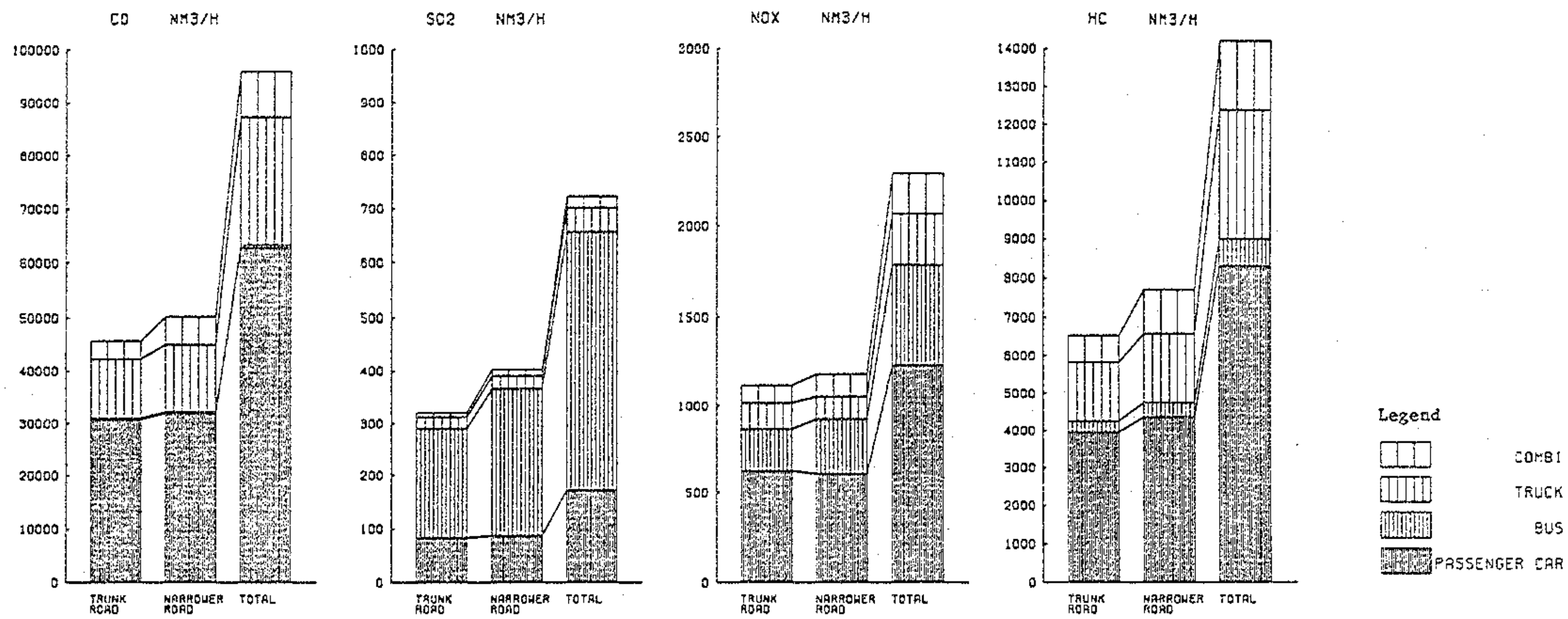


Figure 3.4.9 Hourly Pollutant Emission Rate for Automobiles

Table 3.4.12 Annual Pollutant Emission Rate for Automobiles

Unit: 1000 ton/year

Classification	Line				Area				Total			
	CO	SO_2	NOx	HC	CO	SO_2	NOx	HC	CO	SO_2	NOx	HC
Passenger Car	336.9	2.1	11.2	24.8	349.8	2.2	10.9	27.3	686.7	4.3	22.1	52.1
Bus	2.6	5.2	4.3	1.9	3.5	7.0	5.7	2.5	6.1	12.2	10.0	4.4
Truck	123.8	0.5	2.7	9.8	139.2	0.6	2.4	11.4	263.0	1.1	5.1	21.2
Combi	37.3	0.2	1.8	4.4	57.0	0.3	2.3	7.0	94.3	0.5	4.1	11.4
Total	500.6	8.0	20.0	40.9	549.5	10.1	21.3	48.2	1050.1	18.1	41.3	89.1

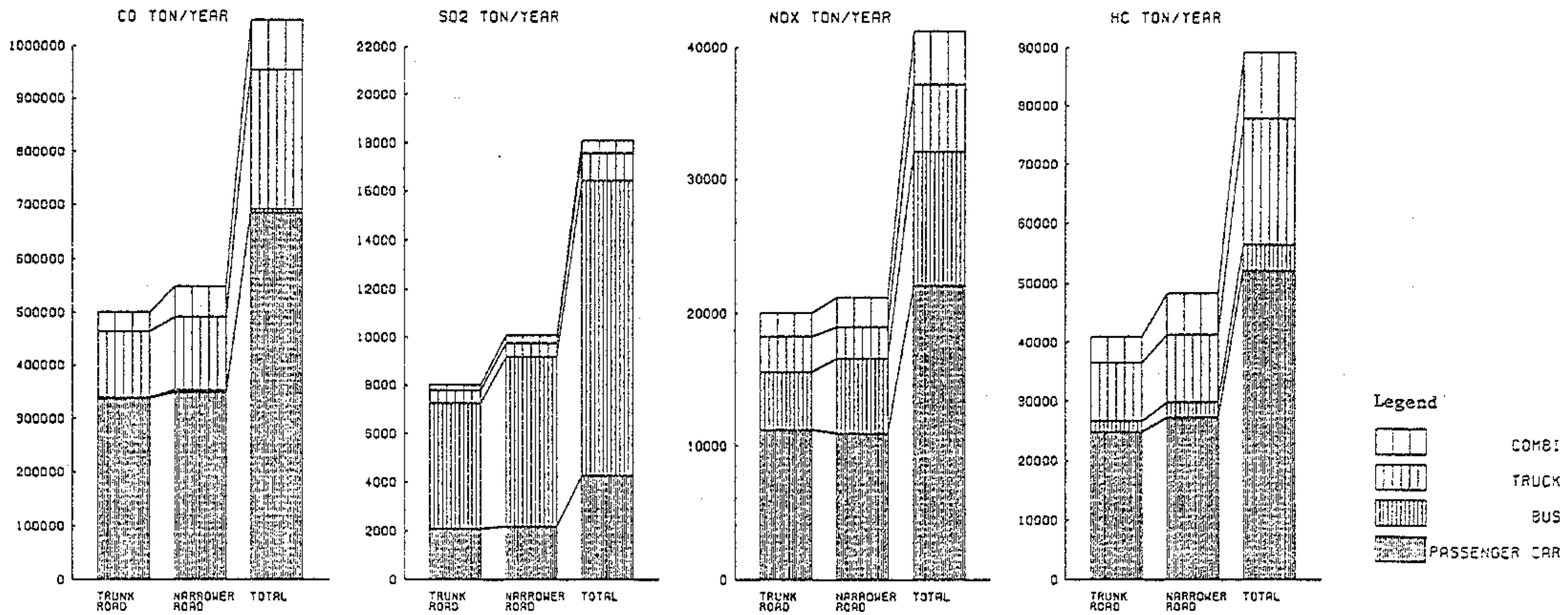


Figure 3.4.10 Annual Pollutant Emission Rate for Automobiles

(5) Airplane

1) Takeoff and Landing of Airplane

The number of airplane takeoffs or landings at the BENITO JUAREZ Airport in 1986 is shown in Table 3.4.13. The number of takeoffs and landings of jet planes is 155,534 while that of light planes 21,414.

As the airplane pollutant source, only jet planes were considered because of their large emission factors and frequent takeoff and landing.

The number of takeoff and landing cycles for jet plane is shown by month and type in Table 3.4.14.

The takeoff and landing route is shown in Figure 3.4.11.

Table 3.4.13 Annual Number of Takeoff and Landing at BENITO JUAREZ Airport

Unit: planes/year

Item	Category	Number of planes	Total
Annual number of takeoff and landing	Landing Takeoff	88,135 88,813	176,948
Number of takeoff and landing by plane type	Jet plane Light plane	155,534 21,414	
Number of takeoff and landing by time zone	13:00 to 19:00 20:00 to 02:00 03:00 to 12:00	76,383 70,143 30,422	

Table 3.4.14 Monthly Number of Takeoff and Landing Cycles by Aircraft Type

MONTH / AIR-CRAFT TYPE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
DC8	261	239	258	257	268	268	270	278	244	259	268	240	3110
B707	144	132	142	141	147	147	148	153	134	142	147	132	1709
DC9	2195	2010	2164	2160	2252	2252	2268	2337	2052	2175	2252	2012	26129
B727	2659	2434	2621	2617	2728	2728	2753	2831	2485	2635	2728	2437	31656
B737	189	173	187	186	194	194	196	202	177	188	194	174	2254
TU15	353	323	348	347	362	362	364	376	330	350	362	323	4200
IL62	26	24	26	26	27	27	27	28	24	26	27	24	312
DC10	379	347	374	373	389	389	391	403	354	376	389	347	4511
B747	235	215	232	231	241	241	243	250	220	233	241	216	2798
AB3	91	84	90	90	94	94	94	97	85	91	94	84	1088
TOTAL	6532	5981	6442	6428	6702	6702	6754	6955	6105	6475	6702	5989	77767

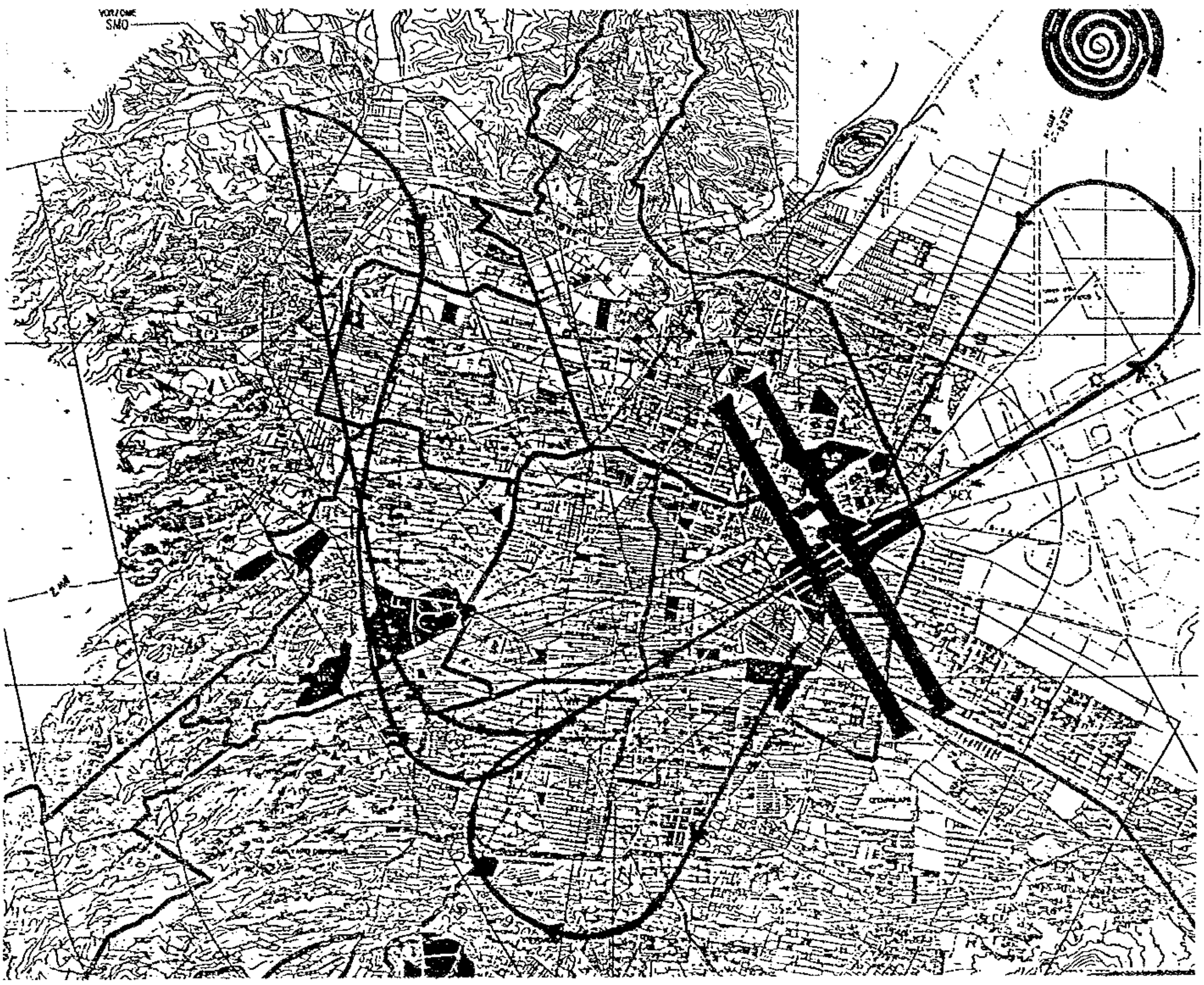


Figure 3.4.11 Routes of Airplane Takeoff and Landing

2) Emission Factor

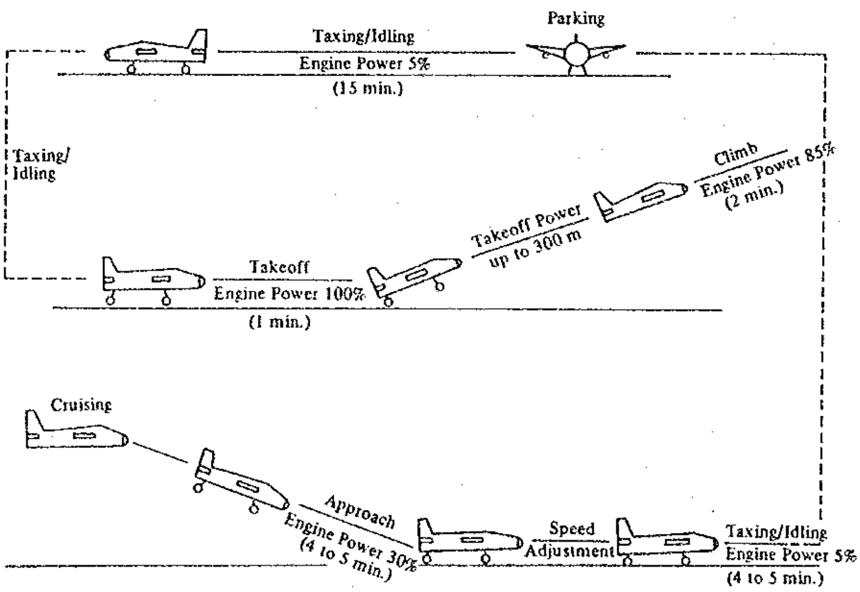
Air pollutants from airplane include SOx and NOx. Emission factors for NOx and fuel consumption by type of aircraft and by type of flight mode were set as shown in Table 3.4.15 with reference to the data in Japan.

The modes of flight are graphically shown in Figure 3.4.12. Height of pollutant emission during approach/landing and climbing was assumed in a zone from the ground to 500 m.

Table 3.4.15 NOx Emission Factor and Fuel Consumption Classified by Plane Type and Flight Mode

Unit: g/s/engine

	Mode of Flight				Aircraft Type
	Taxing/ idling	Takeoff	Climb	Approach/ Landing	
NOx	0.21	14.4	9.40	2.44	DC8, B707
Fuel Consumption	135	1,220	975	450	
NOx	0.83	94.1	52.6	6.51	DC10, B747 AB3
Fuel Consumption	220	2,650	1,730	640	
NOx	0.085	3.50	3.50	0.81	DC9, B727 B737, TU15
Fuel Consumption	115	755	755	465	
Cycle Time (min)	20	1	0.4	2.5	--



Note: For DC-8 and B727, engine power for approach is 40%.

Figure 3.4.12 Airplane Flight Mode

3) Pollutant Emission Quantity

The pollutant emission quantity by aircraft type is shown in Table 3.4.16. The airplane pollutant emission quantity is 27.76 t/year for SOx and 189.39 t/year for NOx.

Table 3.4.16 Quantity of Pollutant Emission From Aircraft

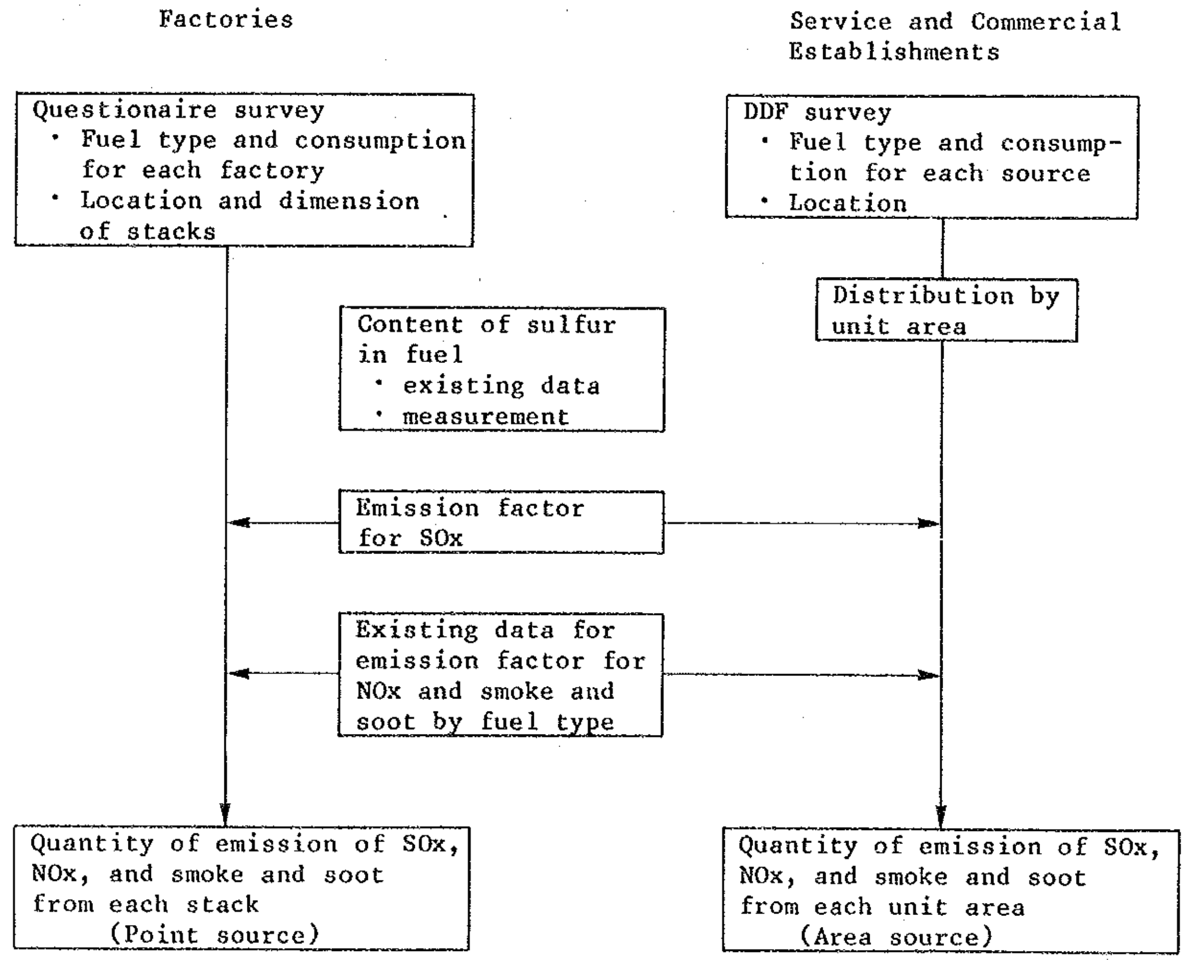
Unit: Upper Nm^3/hour
Lower ton/year

Aircraft Type	Taxing/Idling Take-Off		Climb Aproach/Landing		Total	
	SO_x	NO_x	SO_x	NO_x	SO_x	NO_x
DC8	0.041	0.386	0.016	0.205	0.057	0.591
	1.024	6.943	0.396	3.681	1.420	10.624
B707	0.011	0.106	0.004	0.056	0.015	0.162
	0.282	1.909	0.109	1.012	0.391	2.921
DC9	0.268	0.906	0.128	0.597	0.396	1.503
	6.705	16.305	3.214	10.739	9.919	27.044
B727	0.243	0.823	0.117	0.542	0.360	1.365
	6.092	14.812	2.920	9.756	9.012	24.568
B737	0.012	0.039	0.006	0.026	0.018	0.065
	0.289	0.704	0.139	0.463	0.428	1.167
TU15	0.032	0.109	0.015	0.072	0.047	0.181
	0.808	1.965	0.387	1.294	1.195	3.259
IL62	0.003	0.011	0.002	0.007	0.005	0.018
	0.080	0.194	0.038	0.128	0.118	0.322
DC10	0.080	2.498	0.026	0.842	0.106	3.340
	2.003	44.937	0.651	15.147	2.654	60.084
B747	0.066	2.067	0.022	0.697	0.088	2.764
	1.658	37.189	0.539	12.536	2.197	49.725
AB3	0.013	0.402	0.004	0.135	0.017	0.537
	0.322	7.231	0.105	2.438	0.427	9.669
Total	0.770	7.348	0.340	3.179	1.110	10.527
	19.264	132.190	8.499	57.195	27.763	189.385

3.4.2 Survey of Stationary Sources

Estimation of pollutant emissions from stationary sources was made based on the questionaire survey for factories, the DDF's data for service and commercial establishments, and existing information on emission factor. In addition, the on-site measurement of flue gas was conducted on the selected factories to confirm the estimated results.

The process for estimating quantity of pollutant emissions from stationary sources is outlined in the following diagram.



Process for Estimating Quantity of Pollutant Emissions From Statonary Sources

(1) Measurement of Factory Flue Gas

For measurement of factory flue gas, 20 facilities were selected from factories surveyed by questionnaire. Measurement was made for the period from September to October 1987. The results are shown in Table 3.4.17.

1) Outline of Facilities Measured

The facilities measured were one sintering furnace, four glass melting furnaces, nine drying ovens, five metal smelting furnaces, and one boiler. Among four glass melting furnaces, one was for production of glass plates and three for production of glass bottles. One of the nine drying ovens was a rotary kiln for aggregate drying, while the remaining eight ovens included three tunnel types and five spray types. The metal smelting furnaces included one electric furnace for steelmaking and four casting cupolas.

Thirteen facilities were equipped with dust collectors: five bag filters, five cyclones, three venturi scrubbers, four scrubbers, and two electrostatic precipitators, and five of these 13 facilities had two or more types of dust collectors incorporated.

2) Concentration and Quantity of Dust (Smoke and soot)

The concentration of dust in exhaust gas was in the range of 0.003 - 1.48 g/Nm^3, and the average of all the facilities was 0.37 g/Nm^3. Concentration variation among glass melting furnaces was particularly large at 0.03 -1.32 g/Nm^3. For drying ovens, the dust concentration was low (average 0.063 g/Nm^3) except for the aggregate kiln (1.16 g/Nm^3).

The dust emission quantity for all the facilities ranged from 0.022 kg/hr to 36.9 kg/hr (average 7.22 kg/hr) with considerable variation. But the variation was small in the case of the metal smelting furnaces. Dust emission was large at the aggregate drying oven (36.9 kg/hr) and the boiler (32.3 kg/ hr).

Table 3.4.17 Result of Factory Flue Gas Measurement

Name of Facility	Kind of Facility	Name of Factory under Measurement	Dust Collector	Flue Gas Quantity	Dust Concentration	NO_x Concentration	O_2 Concentration	Kind of Fuel
				Nm^3/hr.(Dry)	g/Nm^3	ppm	%	S content %
Sintering furnace	Cement sintering furnace Rotary Kiln	CEMENTOS ANAHVAC	E.P, B.F	128,000	0.10	250	7.0	Heavy Oil 3.416 (3.02)
Melting furnace	Glass melting furnace Tank oven	VIDRIERA MEXICO		23,200	0.11	785	11.3	Natural Gas 0
		VIDRIERA LOS REYES	V.S	71,600	0.15	184	17.8	Natural Gas 0
		VITRO VIDRIO PLANO		27,100	0.030	1,097	9.2	Natural Gas 0
		VIDRIERA ORIENTO		10,700	1.32	1,858	8.4	Heavy Oil 2.872 (3.02)
Drying oven	Aggregate drying kiln Rotary kiln	PLANTA DE ASFALT	B.F	31,800	1.16	81	12.5	Diesel 0.970 (1.00)
	Other drying ovens Tunnel type	VITRO FIBRAS	V.S	5,000	0.061	0	19.9	Natural Gas 0
		RAY-O-VAC		6,800	0.022	33	14.4	Natural Gas 0
		GENERAL MOTORS		92,200	0.011	17	16.8	Diesel 1.081 (1.00)
	Other drying ovens Spray type	FABRICA DE JABON LA CORONA	CY	21,000	0.013	9	17.5	Natural Gas 0
		PROCTOR & GAMBLE TOWER 1	CY, B.F	35,200	0.34	44	18.3	Heavy Oil 3.168 (3.02)
		PROCTOR & GAMBLE TOWER 2	CY, B.F	46,700	0.048	27	18.5	Heavy Oil 3.168 (3.02)
		COLGATE PALMOLIVE	CY, S, E.P	24,900	0.007	7	14.4	Natural Gas 0
		ANYL-HEX	CY, V.S	7,150	0.003	2	18.4	Natural Gas 0
Metal smelting furnace	Electric furnace	INDUSTRIAS NYLBO	S	24,000	0.17	36	18.8	Electricity 0
	Cupola	FUNDIDRA PANAMERICANA		1,340	1.48	26	17.6	Coke 5.7
		FUNDICION NARDO	B.F	11,000	0.46	5	15.1	Coke 5.7
		FUNDICION PANTITLAN	S	9,370	0.27	2	16.5	Coke 5.7
		ACEROS Y METALS NO FERROSOS	S	11,300	0.40	4	17.2	Coke 5.7
Boiler	45 ton/hr. Boiler	INDUSTRIAS CONASUPO		24,300	1.33	255	6.8	Heavy Oil 2.988 (3.02)

Remarks 1: Dust collector

E.P : Electrostatic Precipitator
B.F : Bag Filter
V.S : Venturi Scrubber
CY : Cyclone
S : Scrubber

Remarks 2: Numerical figures in parantheses for the S content are analytical values supplied from the Mexican team

3) Concentration and Quantity of NOx

Variation in the concentration of NOx by facility was large (0 - 1,858 ppm).

The glass melting furnace showed a high concentration of NOx (average 981 ppm, max. 1,858 ppm), but the concentration of NOx for the other facilities was relatively low (average 50 ppm). The NOx concentration averaged over all the facilities was 236 ppm.

Variation of the NOx concentration was large for the glass melting furnaces (100 - 2,000 ppm) and metal smelting furnaces (2 - 300 ppm) during batch operation (2 - 300 ppm). Other facilities showed small variation.

The NOx emission quantity averaged over all the facilities was 13.1 kg/hr. Similar to NOx concentration, the variation in NOx emission quantity was large (0 - 65.7 kg/hr).

Facilities with large NOx emission quantity included the cement sintering furnace (65.7 kg/hr) and glass melting furnaces (average 41.6 kg/hr). In contrast, metal smelting furnaces showed small NOx emission quantities (average 0.417 kg/hr).

4) Concentration and Quantity of SO_2

Fuels used in 20 facilities included heavy oil in five facilities, diesel in two facilities, coke in four facilities, and electricity in one facility. The remaining eight facilities used natural gas.

Concentration and emission quantity of SO_2 calculated from the S content in the fuel and fuel consumption indicated the average SO_2 concentration for the 20 facilities to be 524 ppm. While the drying ovens showed low concentrations with an average of 126 ppm, other facilities had high concentration with an average of 850 ppm.

SO_2 was not detected from facilities using natural gas.

The average emission quantity of SO_2 for the 20 facilities was 46.2 kg/hr.

The facility with the largest SO_2 emission was the cement sintering furnace at 523 kg/hr.

(2) Result of Sulfur-in-Fuel Analysis

Sulfur content was measured for six factories using heavy oil and diesel selected from the 20 factories that underwent emission measurement. For this analysis, a fluorescent X-ray sulfur-in-oil analyzer was used. Results of the analysis are shown in Table 3.4.18.

Table 3.4.18 Result of Sulfur-in-Fuel Analysis

Factory	Sulfer Content (%)	Kind of Fuel
Planta De Asfalt	0.97	diesel
General Motors	1.08	diesel
Conasupo	2.99	heavy oil
Procter & Gamble	3.17	heavy oil
Cementos Anahuac	3.42	heavy oil
Vidriera Oriental	2.87	heavy oil

(3) Survey of Emission Quantity

1) Method of Survey

The pollutant emission quantity for sources in Mexico City was surveyed by questionnaire in written form and interview or by data available from DDF, as shown in Table 3.4.19.

Table 3.4.19 Sources Surveyed

Type	Number	Survey method	Survey area
Factory	460	Questionnaire in written form and interview	16 DELEGACIONES in DF and a part of the Mexico State
Service and Commercial Establishments	4739	Data available from DDF	16 DELEGACIONES in DF

2) Questionnaire Survey for Factories

a. Outline of the survey

The number of factories by type and district surveyed with questionnaire is shown in Table 3.4.20. Of 460 factories under survey, 361 emit pollutants. The number by district is largest in the State of Mexico (209 out of 361 factories) while the number of chemical factories (147) is largest among industry types.

b. Fuel consumption

The fuel consumption by type of industry is shown in Table 3.4.21. The total heavy oil consumption is 1130.5 kl/year while that of natural gas is 1904.6 x 10^3 m^3/year.

By industry type, heavy oil consumption is large for electricity and ceramics while natural gas consumption is large for electricity, chemical, and petroleum.

c. Emission factor

The emission factors given in "Compilation of Air Pollutant Emission Factors, Second edition, US Environmental Protection Agency" was used.

Table 3.4.20 Number of Factories by Factory Type and DELEGACION

Type of Industry		AO	AZ	BJ	CO	CM	CU	CA	IC	IP	MC	MH	MA	TH	TP	VC	XO	EM	Total
Electricity	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Gas	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Food	Upper	0	5	1	0	0	4	1	0	1	0	2	0	0	0	1	0	13	28
	Lower	0	5	1	0	0	4	2	0	1	0	2	0	0	0	1	0	13	29
Spinning	Upper	0	1	0	0	0	1	0	3	1	0	1	0	0	0	0	0	7	14
	Lower	0	1	0	0	0	1	0	3	1	0	1	0	0	0	0	0	9	16
Lumber	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Paper	Upper	0	2	0	0	0	0	1	0	1	0	0	0	0	0	1	0	16	21
	Lower	0	2	0	0	0	0	1	0	1	0	0	0	0	0	1	0	19	24
Chemical	Upper	4	12	3	1	0	0	9	7	10	0	2	0	0	3	1	0	95	147
	Lower	4	21	4	1	0	0	12	13	12	0	4	0	0	4	2	0	117	194
Petroleum	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Rubber	Upper	0	4	0	1	0	0	0	0	0	0	6	0	0	0	0	0	4	15
	Lower	0	4	0	1	0	0	0	0	0	0	6	0	0	0	0	0	4	15
Leather	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
Ceramics	Upper	0	1	0	0	0	0	2	2	2	0	2	0	0	0	1	0	12	22
	Lower	0	1	0	1	0	0	3	2	2	0	3	0	0	0	2	0	13	27
Steel	Upper	1	3	0	0	0	0	2	3	0	0	0	0	0	0	1	0	8	18
	Lower	1	3	0	0	0	0	2	4	0	0	0	0	0	0	1	0	9	20
Non-iron metals	Upper	2	4	0	0	0	1	1	3	1	0	1	0	0	0	0	0	11	24
	Lower	2	4	0	0	0	1	2	3	1	0	1	0	0	0	0	0	11	25
Metal processing	Upper	0	6	1	0	0	1	2	1	0	0	3	0	0	0	0	0	8	22
	Lower	1	9	1	0	0	1	2	1	0	0	3	0	0	0	0	0	14	32
Machineries	Upper	0	2	0	0	0	0	1	0	1	0	0	0	0	0	0	0	4	8
	Lower	1	2	0	1	0	0	1	0	1	0	0	0	0	0	2	0	10	18
Electric equipment	Upper	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	4	6
	Lower	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	5	7
Precise equipment	Upper	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
	Lower	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	1	4
Arms	Upper	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
	Lower	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Others	Upper	0	0	1	1	0	0	0	1	1	0	1	0	0	0	0	0	21	26
	Lower	0	0	2	2	0	0	0	1	1	0	1	0	0	0	0	0	30	37
Total	Upper	7	40	6	3	0	7	20	20	19	0	18	0	0	3	9	0	209	361
	Lower	9	52	8	6	0	7	27	28	21	0	21	0	0	4	13	0	264	460

(Column heads: Code for DELEGACIONES)

Code for DELEGACIONES
- AO : ALVARO OBREGON
- AZ : AZCAPOTZALCO
- BJ : BENITO JUAREZ
- CO : COYOACAN
- CM : CUAJIMALPA DE MORELOS
- CU : CUAUHTEMOC
- GA : GUSTAVO A. MADERO
- IC : IZTACALCO
- IP : IZTAPALAPA
- MC : MAGDALENA CONTRERAS
- MH : MIGUEL HIDALGO
- MA : MILPA ALTA
- TH : TLAHUAC
- TP : TLALPAN
- VC : VENUSTIANO CARRANZA
- XO : XOCHIMILCO
- EM : EDO. DE MEXICO

Upper : Factories with Pollutant Emission
Lower : Total No. of Factories

Table 3.4.21 Fuel Consumption by Type of Fuel and Type of Industry

Type of Industry	Heavy Oil	Diesel	Kerosene	Other Liquid Fuels	Coal	Coke	Charcoal	Natural Gas	LPG
Electricity	87.2 763.6	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	99.4 870.4	0.0 0.0
Gas	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.8 6.7	0.0 0.0
Food	3.5 31.0	3.8 33.2	0.2 2.2	0.0 0.4	0.0 0.0	0.0 0.0	0.0 0.0	1.4 11.9	0.0 0.3
Spinning	2.1 18.0	0.6 4.9	0.3 3.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.1 1.0	0.1 0.7
Paper	5.4 47.6	0.0 0.3	0.2 1.6	3.5 30.9	0.0 0.0	0.0 0.0	0.0 0.0	8.2 71.9	0.0 0.0
Chemical	7.2 63.1	2.4 21.1	2.3 19.9	0.2 2.0	0.0 0.0	0.0 0.0	0.0 0.0	22.5 196.7	2.5 22.2
Petroleum	3.2 27.7	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	53.8 471.0	0.0 0.0
Rubber	0.5 4.5	3.0 26.6	0.0 0.1	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.8 6.9	4.1 36.0
Leather	0.1 0.9	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Ceramics	19.5 170.7	0.3 2.5	0.0 0.0	0.0 0.0	0.0 0.0	0.2 2.0	0.0 0.0	11.9 103.9	0.9 7.9
Steel	0.0 0.1	0.0 0.0	0.0 0.1	1.0 8.6	0.0 0.0	0.2 1.5	0.0 0.0	5.2 45.4	0.0 0.2
Non-iron metals	0.0 0.1	0.3 2.3	6.6 57.6	0.0 0.0	0.1 0.7	0.0 0.0	0.0 0.0	2.9 25.2	0.1 0.6
Metal processing	0.1 0.8	0.0 0.0	0.6 4.8	0.0 0.1	0.0 0.0	0.1 1.0	0.0 0.1	0.7 6.1	0.0 0.3
Machineries	0.0 0.0	0.0 0.1	0.0 0.1	0.0 0.0	0.0 0.0	0.1 1.1	0.0 0.0	0.1 1.0	0.0 0.0
Electric equipment	0.0 0.0	0.0 0.4	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.3 2.7	0.0 0.1
Precise equipment	0.0 0.0	0.0 0.1	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Arms	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Others	0.3 2.2	0.1 0.7	0.0 0.2	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	9.6 83.8	0.0 0.3
Total	129.0 1130.5	10.5 92.3	10.2 89.5	4.8 42.1	0.1 0.7	0.6 5.7	0.0 0.1	217.4 1904.6	7.8 68.7

Unit

Items	Upper	Lower
Liquid	m^3/hour	10^3m^3/year
Solid	ton/hour	10^3ton/year
Gas	10^3m^3/hour	10^6m^3/year

Quantity of pollutant emission was calculated by the Mexican side using these emission factors and fuel consumption, then checked and corrected when necessary.

d. Pollutant emission quantity

The quantity of pollutant emission from factories by factory type is shown in Table 3.4.22. The total emission quantity is 79,910.2 t/year for SOx, 23,062 t/year for NOx, and 3,026.9 t/year for smoke and soot.

The SOx emission quantity by factory type is largest at 54,717 t/year (68.5% of the total) for electricity, followed by 11,356 t/year (14.2% of the total) for ceramics.

For NOx, 14,426 t/year (62.5% of the total) is emitted by electricity, followed by 3,558 t/year (15.4% of the total) by petroleum.

As regards, smoke and soot, 884 t/year (29.2% of the total) is emitted by electricity, followed by 631 t/year (20.8% of the total) by chemical.

Tables 3.4.23 and 3.4.24 show the fuel consumption and pollutant emission quantity by factory type for ten major factories.

Table 3.4.22 Quantity of Pollutant Emission by Type of Industry

TYPE OF INDUSTRY	SOx	NOx	Smoke and Soot	SOx	NOx	Smoke and Soot
	(Nm^3/h)	(Nm^3/h)	(kg/h)	(ton/y)	(ton/y)	(ton/y)
Electric	2186.2	801.9	100.9	54717.4	14426.3	883.7
Gas	0.0	0.8	0.0	0.1	14.8	0.4
Food	89.7	8.5	6.5	2245.1	153.6	56.9
Spinning	53.5	20.9	7.9	1340.2	376.2	69.2
Paper	148.4	30.6	23.8	3714.8	551.3	208.5
Chemical	114.7	46.8	72.0	2870.2	841.5	630.8
Petroleum	67.7	197.8	18.5	1695.5	3558.0	162.4
Rubber	29.4	21.4	10.3	736.2	385.6	89.9
Leather	2.3	0.1	0.3	57.4	1.4	2.5
Ceramics	453.7	77.8	57.5	11355.7	1400.0	504.0
Steel	6.7	12.1	4.7	166.7	218.5	41.4
Non-iron metals	21.8	26.8	17.5	544.5	481.8	152.9
Metal prosessing	5.2	2.0	2.3	131.1	35.4	20.3
Machineries	1.4	0.5	1.1	35.0	9.1	9.8
Electric equipment	0.2	0.5	0.1	5.7	8.6	1.0
Precise equipment	0.1	0.0	0.0	1.8	0.8	0.3
Arms	0.0	0.0	0.0	0.0	0.0	0.0
Others	11.7	33.3	22.0	293.1	599.6	192.8
TOTAL	3192.8	1282.0	345.5	79910.2	23062.6	3026.9

Table 3.4.23 Fuel Consumption in 10 Major Factories

Unit

Items	Upper	Lower
Liquid	m^3/hour	$10^3 m^3$/year
Solid	ton/hour	10^3 ton/year
Gas	$10^3 m^3$/hour	$10^6 m^3$/year

Type of Industry	Number of Factory	Heavy Oil	Diesel	Kerosene	Other Liquid Fuels	Natural Gas	LPG
Food	3	2.4 21.0	3.8 32.9	0.0 0.0	0.0 0.1	0.0 0.0	0.0 0.0
Spinning	1	1.0 9.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Paper	1	3.6 31.4	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Chemical	2	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.7 5.7	0.0 0.0
Ceramics	2	19.2 167.8	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0	0.0 0.0
Non-iron metals	1	0.0 0.1	0.0 0.0	0.0 0.1	0.0 0.0	0.0 0.0	0.0 0.0
	10	26.2 229.4	3.8 32.9	0.0 0.1	0.0 0.1	0.7 5.7	0.0 0.0

Table 3.4.24 Quantity of Pollutant Emission from 10 Major Factories

Type of Industry	SOx (Nm^3/h)	NOx (Nm^3/h)	Smoke and Soot (kg/h)	SOx (ton/y)	NOx (ton/y)	Smoke and Soot (ton/y)
Food	66.1	2.9	3.2	1655.3	51.5	28.5
Spinning	23.1	15.5	3.8	577.9	278.0	33.6
Paper	79.8	2.6	9.9	1997.3	47.2	86.5
Chemical	0.0	0.9	0.1	0.1	16.1	0.9
Ceramics	444.0	60.2	52.7	11113.9	1083.0	461.5
Non-iron metals	0.4	0.1	1.9	8.8	2.0	17.0
Total	613.4	82.1	71.7	15353.2	1477.7	627.9

3) Service and Commercial Establishments

The number of service and commercial establishments by area and by type of business on the basis of data obtained from DDF is shown in Table 3.4.25. The number of establishments by area is largest at 772 in CUAUHTEMOC while that by type of business is largest at 1425 for laundry.

The fuel consumption by area and by fuel type is shown in Table 3.4.26. The consumption is largest in CUAUHTEMOC.

The fuel consumption by type of business and by type of fuel is shown in Table 3.4.27. Consumption of heavy oil is large at public bathhouses while natural gas at bakeries and TORTILLERIAS.

The pollutant emission quantity was calculated on the basis of the fuel consumption while referring to the emission factors given in the previously mentioned report of US Environmental Protection Agency.

The pollutant emission quantity from the service and commercial establishments is shown in Table 3.4.29.

Table 3.4.25 Number of Service and Commercial Establishment in DF

DELEGACIONES / Type of Business	AZ	GA	VC	CO	IP	IC	TP	AO	MH	CU	BJ	CM	TH	MA	XO	MC	TOTAL
Laundries	69	219	146	71	186	80	24	53	88	163	261	4	22	3	26	10	1425
Bathhouses	15	43	41	5	21	15	1	3	27	48	17	0	0	0	2	1	239
Bakeries	44	111	84	40	118	46	27	29	65	105	88	5	12	6	14	6	800
Flour Milling	19	69	36	5	55	16	8	8	34	24	25	1	14	6	18	4	342
Hotels	10	23	24	6	5	1	7	1	26	256	18	2	0	0	1	0	380
Hospitals	0	1	0	3	0	0	2	0	5	6	2	0	0	0	0	1	20
Sport Centers	1	4	0	18	1	1	4	5	11	3	23	1	0	0	2	1	75
Food	9	13	32	34	61	25	21	18	40	97	48	1	6	1	11	8	425
Others	2	1	1	0	0	0	1	2	0	6	0	0	0	0	0	0	13
TORTILLERIAS	43	77	95	9	238	137	11	49	67	64	42	4	58	14	85	27	1020
Coffee Milling	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	212	561	459	191	685	321	106	168	363	772	524	18	112	30	159	58	4739

Code FOR DELEGACIONES
AZ:AZCAPOTZALCO
GA:GUSTAVO A. MADERO
VC:V. CARRANZA
CO:COYOACAN
IP:IZTAPALAPA
IC:IZTACALCO
TP:TLALPAN
AO:A. OBREGON
MH:M. HIDALGO
CU:CUAUHTEMOC
BJ:B. JUAREZ
CM:CUAJIMALPA
TH:TLAHUAC
MA:MILPA ALTA
XO:XOCHIMILCO
MC:M. CONTRERAS

Table 3.4.26 Fuel Consumption by Service and Commercial Establishments by Delegacion

Unit :

Natural Gas	(m^3/mon)
Heavy Oil	(m^3/mon)
Diesel	(m^3/mon)
Kerosene	(m^3/mon)
Others	(kg/mon)

Kind of Fuel / DELEGACIONES	Natural Gas	Heavy Oil	Diesel	Kerosene	Others
AZCAPOTZALCO	389.3	206.0	85.2	77.5	0.0
GUSTAVO A. MADERO	605.5	271.7	349.8	307.8	0.1
V. CARRANZA	705.4	459.0	166.7	215.8	17.6
COYOACAN	232.7	201.5	401.9	20.1	3.5
IZTAPALAPA	1096.4	58.0	206.2	458.8	1.0
IZTACALCO	661.8	208.0	32.9	22.0	0.0
TLALPAN	248.5	51.0	121.4	0.6	0.0
A. OBREGON	275.6	245.0	127.3	9.8	2.0
M. HIDALGO	502.1	903.3	783.0	47.5	7.6
CUAUHTEMOC	2333.5	1338.8	1182.4	628.3	485.3
B. JUAREZ	1019.7	92.4	558.0	379.7	402.0
CUAJIMALPA	22.8	0.0	29.4	3.1	0.8
TLAHUAC	202.0	0.0	0.0	1.6	0.0
MILPA ALTA	28.0	0.0	0.0	0.0	0.0
XOCHIMILCO	254.2	25.0	22.3	59.2	12.0
M. CONTRERAS	176.6	76.0	10.0	3.3	0.0
TOTAL	8752.3	4135.7	4076.6	2235.1	932.0

Table 3.4.27 Fuel Consumption by Service and Commercial Establishments by Type of Business

Unit :

Natural Gas	(m^3/mon)
Heavy Oil	(m^3/mon)
Diesel	(m^3/mon)
Kerosene	(m^3/mon)
Others	(kg/mon)

Type of Business \ Kind of Fuel	Natural Gas	Heavy Oil	Diesel	Kerosene	Others
Laundries	1769.2	268.0	459.7	991.3	0.6
Bathhouses	0.0	2951.2	4.0	1174.7	0.0
Bakeries	2814.4	0.0	1024.3	9.0	0.0
Flour Milling	725.4	0.0	5.5	30.5	0.0
Hotels	38.5	135.0	1804.4	7.0	0.0
Hospitals	164.0	96.0	110.3	0.0	0.0
Sport Centers	87.4	657.5	590.3	8.4	0.0
Food	946.5	0.0	66.0	2.5	931.4
Others	17.0	28.0	12.0	10.0	0.0
TORTILLERIAS	2191.5	0.0	0.0	1.7	0.0
Coffee Milling	0.0	0.0	0.0	0.0	0.0
Total	8752.3	4135.7	4076.6	2235.1	932.0

Table 3.4.28 Emission Factor by Fuel Type

Item \ Kind of Fuel		Natural Gas	Heavy Oil	Diesel	Kerosene	Others
SOx	Specific Gravity(kg/l)	9.6×10^{-9}	0.982	0.582	0.793	-
	Sulfur Contents (%)	0.0	3.3	1.00	0.03	5.7
NOx		9600kg/$10^6 m^3$		7.2kg/kl		5kg/ton
Smoke and soot		240kg/$10^6 m^3$	2.75kg/kl			15kg/ton

Table 3.4.29 Quantity of Pollutant Emission From Service and Commercial Establishments

DELEGACIONES \ Item	SOx (Nm^3/h)	NOx (Nm^3/h)	Smoke and Soot (kg/h)
AZCAPOTZALCO	7.214	1.798	1.409
GUSTAVO A. MADERO	11.529	4.529	3.549
V. CARRANZA	15.893	4.102	3.215
COYOACAN	9.682	3.038	2.381
IZTAPALAPA	3.642	3.528	2.762
IZTACALCO	6.831	1.284	1.004
TLALPAN	2.613	0.844	0.661
A. OBREGON	8.776	1.863	1.460
M. HIDALGO	34.956	8.446	6.622
CUAUHTEMOC	52.146	15.353	12.040
B. JUAREZ	7.645	5.025	3.943
CUAJIMALPA	0.244	0.159	0.124
TLAHUAC	0.000	0.009	0.006
MILPA ALTA	0.000	0.000	0.000
XOCHIMILCO	0.986	0.520	0.407
M. CONTRERAS	2.478	0.436	0.341
TOTAL (ton/y)	164.634 4120.562	50.934 916.269	39.926 349.747