3.4 Method and analysis of measurement

3.4.1 Outline of observation and measurement

Observation and measurements were held twice, the first one in September and October, and the second one in March.

The schedule is shown in table 3.4.1-1.

Table 3.4.1-2 indicates the out line of each item.

Table 3.4.1-1 The schedule of observation and measurement

Item	First measurement (October)	Second measurement (February, March)
Meteorological observation	○	○
Ambient Air Quality	○	○
Automotive Source	○	—
Stationary Source	○	○

Table 3.4.1-2 List of observation/measurement procedure and instrument

Measurement Procedure	Instrument
1. Meteorological Observation	
1.1 Surface Meteorology	
(1) Surface wind	
Wind direction, speed and turbulence at 10m above surface will be measured by the ultra sonic anemometer. The data is necessary for determination of the parameter that is used for the prediction model of air pollutant diffusion. Point : AGHDACIYE AREA (l point) Period :For 1 year Schedule : Hourly continuos observation	1. Ultra sonic anemometer 2. Data logger (with connecting cable) 3. Observation pole(10m aluminum pole, flange, branch wire, base) 4. setting up tools5. Recording paper
(2) Solar radiation	
Solar radiation will be measured by the pyranometer. The data is necessary for classification of the atmospheric stability that is used for the prediction model of air pollutant diffusion. Point, period and schedule are the same as surface wind observation.	1. Pyranometer(with cable) 2. observation pole (2m aluminum pole,flange,branch wire,base) 3. recorder for 6 item 4. recording paper
(3) Radiation balance	
Radiation balance will be measured by the net radiometer. The data is necessary for classification of atmospheric stability. Point, period and schedule are the same as surface wind observation.	1. Net Radiometer (with cable) 2. Flange (Pole is common use with pyranometer) 3. Recorder for 6 items (Recorder is common use with Pyranometer) 4. Polyethylene dome
1.2 Upper Layer Meteorology	
(1) Raball observation	
Wind direction and speed between the surface to 2000m height will be observed by tracking of the released sonde using the theodolite to know the characteristics of the wind field in the considering area of air pollutant diffusion. Point : AGHDACIYE AREA (1 point) Period : For 7 days Schedule : For 7 days, Twice a day (at 8 and 13 o clock)	1. Theodolite (with data cable) 2. Electric cable 3. Data logger (attached printer, with connecting cable) 4. IC card 5. Recording paper
(2) Low-level sonde observation	
Temperature, humidity and pressure between the surface and 2000m height will be measured by the radio sonde to know the characteristics of depth of the mixing layer in which the air pollutant diffuse. Point, period and schedule are the same as raball observation.	1. Receiver (Common use with captive sonde obs.) 2. Portable antenna 3. Data processor (with printer) 4. Sonde sensor checker 5. Non break down electric supply 6. Assmann aspiration psychrometer 7. Aneroid barograph 8. Electric cable 9. AVR (with 2kV step down trans) (1,5,6,7,8,9; Common use with captive sonde obs.) 10. Low-level sonde (100 pieces) 11. Water poured battery with miniature electric bulb

	12. Recording paper (for printer) 13. Hose with buoyancy adjust weight (10m long, for filling balloon with He gas)
(3) Captive sonde observation	
Temperature, humidity and pressure between the surface and 700 height will be measured by the captive balloon to know the characteristics of the inversion height that controls diffusion of the air pollutant. Point : AGHDACIYE AREA (1 point) Period : For 7 days Schedule : For 7 days, 8 times a day (At 3,6,9,12,15,18,21 and 24 o clock)	1. Captive sonde system(Captive balloon, Captive sonde, Winch) 2. A set of sonde receiver(Receiver, Portable antenna) 3. Digitizer 4. Data processor 5. Non down electric supply 6. Acumen aspiration psychrometer 7. Aneroid barograph 8. Electric cable 9. AVR 10. Flash light 11. Dry batteries 12. Recording paper 13. Hose (10m long, for filling balloon with He gas)
2. Ambient Air Quality	
2.1 Simplified Measurements	
(1) Nox (NO + NO_2)	
Diffusion of the gaseous molecules Point : 31points Period :8 days(Rehearsal 1 day + measurement 7 days) Sampling time : 24 continuous passive sampling. Analysis: Spectrophotometric analysis.	1. Simultaneous sampling 2. Shelter 3. Filter for NO2 4. Filter for Nox 5. Analytical Implement
(2) SO2	
Diffusion of the gaseous molecules.(same as NOx) Point : 31points Period :6 days(measurement 6 days) Sampling time : 72 continuous passive sampling. Analysis: Chromatography analysis.(in Japan)	1. Simultaneous sampling 2. Shelter 3. Filter for SO2 4. Analytical Implement
(3) CO	
Air bag sampling with minisamplers and Salan bag. Point : Surface points:13points Vertical points: 5points Period : 4 days(Rehearsal 1 day + measurement 3 days) Samplingtime : 5:00-21:00(16 hours continuous sampling, 1 sampling in each hour) Analysis: NDIR detector analysis.	1. Mini-sampler 2. Timer Control Unit 3. Pump Unit 4. Air Bag 5. Alkaline Dry Cell 6. Tygon Tube 7. Filter 8. Tape Measure 9. CO Monitor
(4) HC	
Air bag sampling with indirect sampling system and Tedolar bag. Point : 5 points Period : 4 days(Rehearsal 1 day + measurement 3 days) Sampling time : 5 minute sampling for each hour from 5:00 to 20:00). Analysis: FID detector analysis. Item:THC,NMHC,CH_4	1. Indirect Sampling Set 2. Tedlar bag 3. Digital Flow Meter 4. Gas Leak Detector 5. HC Monitor
(5) VOC	

Absorption sampling using Tenax GC absorbent. Point : Several points in MOT. Period : 1 days Sampling time : About 10 minutes . Analysis : Gas chromatography with thermal description injector.(in Japan)	1. Bake Out Equipment for Sampling Tube 2. Personal Mini Pump 3. Tenax GC Tube 4. High Purity N2 Gas 5. Pressure regulator
2.2 CMB Measurement	
Collection of SPM on the filters by filtration of the ambient air with use of Low volume Air sampler. Point : MOT government office building ground floor. Period : 7 days continuous sampling. Analysis: Radio activation analysis. Atomic absorption spectrometry analysis Fluorescent X-ray analysis Ion chromatography.(in Japan)	1. Low-volume Air Sampler 2. Teflon packing 3. Silicon packing 4. Pump blade 5. Pump element 6. Bypass filter 7. Electric Power Cable 8. Desiccatoe 9. Filter 10. Petri dish
3. Automotive Source	
3.1 Traffic Volume Survey	
(1) Traffic volume survey	
Traffic Volumes is recorded with video cameras installed at the survey locations and later played back, during which the traffic volume is measured by vehicle type. Survey locations : 20 location Survey time: 24 hours Type of vehicles: 7categories Survey date: Working day and holiday	1. Color Video Camera 2. Lens 3. Camera Housing 4. Video Coaxial Cable Connector 5. Video tape recorder 6. Color Monitor 7. Connecting Cable 8. Tape 9. Manual Counter 10. Stop Watch
3.2 Chassis Dynamo Test	
(1) Chassis dynamo test	
3.3 Field Driving Test	
(1) Traversing speed survey	
The survey was carried out by driving selected routs with vehicles installed speed meters and analysers. Routs: 19 routs	1. Non-contact Velocity Meter 2. Rotating Meter for Gasoline engine 3. Rotating Meter for Diesel engine 4. Pressure Gauge 5. Data Analyzing System 6. Thermometer 7. IC Memory Card 8. Analyzer 9. Calibration Gas 10. AC/DC Converter 11. Recorder 12. Calibration Unit
4. Stationary Source	
4.1 Flue Gas Measurements	
(1) Flow rate of gas	
Insert the measuring apparatus into the measuring hole	1. Pitot tube

and set it as to fit the measuring point. Measurement of gas temperature, velocity and pressure. Factory name : Brick factory Power plant Tehran refinery Cement factory	2. Rubber bag 3. Thermocouple 4. Thermo pile 5. Compensating wire 6. Manometer
(2) Concentration of gas composition (CO_2, O_2, CO, H_2O)	
Use the tube made of glass or metal. To prevent the penetration of dust, full its tip with glass fiber or others. Insert it in duct through a measuring hole to lead the flue gas into the absorption tube. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. Gas Detector 2. Moisture absorption tube 3. Suction pipe with heater 4. Orsat Analyzer 5. Distribution tube 6. Rubber bag
(3) Concentration of Nox, Sox	
Use the tube made of glass or metal. To prevent the penetration of dust, full its tip with glass fiber or others. Insert it in duct through a measuring hole to lead the flue gas into the analyzer. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. MODEL VIA-510 (For NOX) Method NDIR, 2. MODEL VIA-510 (For SOX),Method ND IR 3. MODEL ES-510 (Sampler For O2,SOX) 220V 4. MODEL ES-510 (Sampler For O2,SOX) 220V 5. Recorder 6. Standard Gas 7. Pressure Regulator
(4) Concentration of dust	
Traverse the measuring points by using one dust collector to take a dust sample in the same sucking time at each point. Factory name : Brick factory Power plant Tehran refinery Cement factory	1. Sampling apparatus for dust 2. Printer paper and inkribon 3. Flange 4. Filter paper 5. Desiccatoe 6. Stop watch 7. Silica wool

3.4.2 Method of measurement and analysis

(1) Meteorological observation

The surface and upper meteorological observation was made by the JICA study team in autumn (October 8 - 15, 1996) and in winter (February 22 - March 1, 1997). The purpose of surface observation is to know the wind field and atmospheric turbulence and stability, which are governing pollutant diffusion in the surface boundary layer. The items of the surface observation are wind direction, wind speed, standard deviations of wind direction and speed, solar radiation in the daytime and radiation balance in the night-time. On the other hand, upper air is observed for the purpose of knowing the characteristics of the inversion and mixing layer, of which appearance and intensity affect the surface pollutant concentration, because they control the vertical transportation of the pollutants. Profiles of temperature, relative humidity, wind direction and speed were derived a by low level sonde and captive sonde. Details of these observation are as follows:

1) Surface meteorological observation

① Observation site

The Meteorological Bureau at Aghdasiyeh located 15km NE from the center of Tehran City was selected as the site of surface meteorological observation. Its altitude is 1548m above sea level and about 300m higher than that of the center of the city. There is the Elburz mountains to the north behind the observation site and its slope gradually descending to the south.

② Items and methods of observation

Items and methods of observation are summarized in Table 3.4.2-1. Solar radiation means here the total energy of the direct solar radiation and the diffuse sky radiation, while radiation balance indicates the balance (difference) between incomings and outgoings of radiation energy. If the balance is negative, it is equivalent to radiative cooling. The intensity of solar radiation controls activities of the thermal convection in the daytime, and the net radiation determines radiative cooling on the surface in the night-time. Therefore, both of them are the definitely important factors for determining atmospheric stability in the surface boundary layer.

Table 3.4.2-1 Items and methods of surface meteorological observation

Item	Instrument	Height of sensor	Reading
Wind direction Wind speed Standard deviation	Model DA-200 2-component ultra sonic anemometer	10m	Every 10 minutes
Solar radiation	Model MS43F Pyranometer	3m	The value is the average of the data for 10 minutes before reading time
Radiation balance	Model MF11 Net Radiometer	1.5m	

③ Observation period

The routine observation was started on October 4 in 1996 by the JICA study team and operated by them until March 2 in 1997. Thereafter, the job of operation and maintenance of the observation equipment was handed over to the Iranian side and observation has been made continuously. Analysis of the surface meteorology in this report was based on the data before March 1.

2) Upper layer meteorological observation

① Observation site

The upper layer meteorological observation was made at the same site with the surface meteorological observation

② Items and methods of observation

The items and methods of observation are summarized in Table 3.4.2-2.

Table 3.4.2-2 Items and methods of upper layer meteorological observation

Item	Method	Instrument	Observation schedule	Observation height
Wind direction Wind speed	Raball	Theodolite (Model : KDT-3)	For 7 days Twice a day (8:00, 13:00)	Every 50m Up to 2000m
Wind direction Wind speed Temperature	Captive sonde	Sonde system (Model : CBS-T-14) Gas : helium	For 7 days Every 3 hours	Every 50 m Up to 700m
Temperature	Low level sonde	Sonde system (Model : JWA-94W) Balloon : rubber(100g) Gas : helium Ascent speed : 200m/min	Same as raball Observation	

③ Observation period

Observation was carried out in autumn and winter for the period of full seven days as shown below.

Autumn : from 12:00 on October 8 to 9:00 on October 15 in 1996

Winter : from 15:00 on February 22 to 13:00 on March 1 in 1997

④ Observation achievement

Achievement lists of observation runs in autumn and winter are shown in Table 3.4.2-3. In these field surveys, it was determined that each observation altitude to be reached by a captive sonde and low level sonde should be 700m and 2000m, respectively. Figures in the table denote the altitude where the sonde reached actually. After the sonde reached the target altitude, the captive sonde was pulled down while keeping observation. On the other hand, as for the low level sonde, signal receiving was discontinued as soon as it got to the altitude. In such cases where the observation was completed, the target altitudes are shown in the table. And " - " denotes that the observation was canceled or ended unsuccessfully.

Table 3.4.2-3 Achievement list of captive sonde and low level sonde observations

upper : temperature
lower : wind unit : m

October 8 - 15, 1996

	Captive Sonde								Low-level Sonde Raball	
Date	3:00	6:00	9:00	12:00	15:00	18:00	21:00	24:00	8:00	13:00
Oct.8				700 700	700 700	700* 700*	700 700	700 700		2000 2000
Oct.9	700 700	600 600	700 700	700 700	700 700	700 700	700 700	700 700	2000 2000	2000 2000
Oct.10	700 700	700 700	700 700	700 700	- -	700 700	700 700	700 700	2000 2000	2000 2000
Oct.11	- -	700 700	700 700	400 400	50 50	700 700	700 700	- -	- -	2000 2000
Oct.12	- -	600 600	700 700	250 250	- -	100 100	400 400	700 700	2000 2000	2000 2000
Oct.13	600 600	- -	700 700	700 700	600 600	700 700	700 700	700 700	2000 2000	2000 2000
Oct.14	- -	500 500	500 500	100 100	- -	50 50	700 700	650 650	2000 2000	2000 2000
Oct.15	400 400	700 700	700 700						2000 2000	

* : Surface data is missing.

upper : temperature
lower : wind unit : m

February 22 - March 1, 1997

	Captive Sonde								Low-level Sonde Raball	
Date	3:00	6:00	9:00	12:00	15:00	18:00	21:00	24:00	8:00	13:00
Feb.22					100 100	50 50	- -	50 50		
Feb.23	100 100	100 100	700 700	- -	- -	250 250	700 700	700 700	2000 2000	2000 2000
Feb.24	700 700	700 700	700 700	50 50	700 700	700 700	700 700	700 700	2000 surface	2000 700
Feb.25	700 700	700 700	700 700	50 50	450 450	700 700	700 700	450	2000 1300	2000 2000
Feb.26	700 700	100 100	700 700	500 500	700 700	150 150	100 100	100 100	2000 2000*	2000 2000
Feb.27	600 600	700 700	250 250	- -	- -	200 200	100 100	700 700	2000 2000	2000 2000
Feb.28	500 500	300 300	600 600	650 650	- -	700 700	700 700	700 700	2000 1400	2000 2000
Mar.1	700 700	700 700	700 700	700 700					2000 2000	2000 2000

* Data at 50 - 550m are missing.

- Raball observation and low level sonde observation

The total of 14 runs were supposed to be carried out in each season. The measurement from the surface to 2000m altitude should be accomplished at every run.

Autumn : 13 out of 14 runs were accomplished completely, except the run at 8:00 on October 11.

Winter : All of 14 runs for temperature were completed successfully. On the other hand, 13 runs of wind observation were accomplished, but the run at 8:00 on February 24 was unsuccessful.

- Captive sonde observation

The total of 56 runs were supposed to be carried out in each season. The measurement from the surface to 700 m altitude should be accomplished at every run. In order to avoid the accident, several runs under the conditions of wind stronger than 6 m/s or rain were canceled.

Autumn : Thirty-four runs were accomplished completely, and 41 runs could obtain data from the surface to the level higher than 500m. On the other hand, 9 runs could not reach 50m because of strong wind or rain. The wind tended to be stronger in the afternoon, so that 4 out of 7 runs scheduled at every 15:00 could not reach 50m.

Winter : Twenty-seven runs were accomplished completely, and 32 runs could obtain data from the surface to the level higher than 500m. On the other hand, 6 runs could not reach 50m because of strong wind or rain as in the case of the run in autumn. Similar to the runs in autumn, 3 out of 7 runs scheduled at 15:00 every day could not reach 50m.

3) Method of analysis

The atmospheric condition is an important factor controlling the pollutant diffusion and advection. Generally, urban air pollution is considered to be a localized phenomenon which is characterized by not only artificial circumstances but also natural environment such as flora, topography, and weather. Because of such a locality of the background of the air pollution, it is significant to know the local climate in the area concerned for each season in order to know accurately the characteristics of the local air pollution. For this purpose, it is necessary to know the general weather conditions in the specific period based on the statistics of the observation data as well as climatological characteristics based on the analysis using the data accumulated for a long term.

① Analysis of surface meteorology

The items of the statistics for the analysis of surface meteorology using the data obtained by the JICA study team are shown in the following table (Table 3.4.2-4). The statistics were made to know the characteristics of the atmospheric behavior which was essential to the pollutant diffusion and advection in the boundary layer. The period for statistics (daytime, night-time and whole day) was determined in the light of the diurnal variation of the wind and atmospheric stability.

Table 3.4.2-4 Items of statistics for surface meteorology

Meteorological element	Items for statistics	Period for statistics
Wind direction Wind speed	The most frequent wind direction	Whole period
	Frequency of the wind direction by classified wind speed	Day/night/whole day
Wind speed	Average wind speed	Whole period
	Average wind speed for each wind direction	Day/night/whole day
Atmospheric stability	Frequency of atmospheric stability	Whole period

* The division of daytime and night-time is determined based on the time of sunrise and sunset.

daytime : 7:00 - 17:00 night-time : 18:00 - 6:00

② Analysis of upper layer meteorology

The items of the statistics for the analysis of the upper layer meteorology using the captive sonde data are shown in the following table. The data were compiled for every 50m from surface to 700m. The statistics were made to know the vertical atmospheric structure and its diurnal variation which are typical in the region and season concerned. Especially, our interest was in the inversion layer and thermal mixing layer which control the vertical advection of the pollutants and is relevant to fumigation. Therefore, they were thought to have considerable influence on the surface concentration. The period for statistics (hourly, daytime, night-time and whole day) was determined in the light of the diurnal variation of the wind and atmospheric stability as well as surface meteorology.

Table 3.4.2-5 Items of the statistics for upper layer meteorology

Items for statistics	Period for statistics
Frequency of wind direction at each altitude	Day/night/whole day
Profile of average wind speed	Day/night/whole day/hourly
Frequency of classified wind speed	Day/night/whole day
Profile of average temperature	Day/night/whole day/hourly
Profile of average temperature gradient	Day/night/whole day/hourly
Frequency of classified temperature gradient	Day/night/whole day

* The division of daytime and night-time is determined based on the time of sunrise and sunset.

daytime : 7:00 - 17:00 night-time : 18:00 - 6:00

(2) Simplified and Additional measurements of air pollutants

The simplified measurements of NOx (NO_2 and NO) and SO_2, and the additional measurements of CO and HC were carried out in two seasons, i.e. autumn (October '96; the first measurement) and winter (February - March '97; the second measurement), with the simultaneous meteorological observations.

The ambient air quality of MOT is now monitored by some organizations mentioned in 4.2.1. Most of these air-monitoring stations are located at the cross-section of main roads or near the road. At these stations, it is supposed that the measured data are affected by the direct emission from vehicles. Therefore, simplified measurements and additional measurements were planned and conducted for the purpose of grasping the representative concentration of pollutants which were not affected by vehicles directly and of complementing the existing monitoring data. Especially, CO is considered as pollutant to be given priority in the investigation because of its high concentration observed in the past monitoring activities in the MOT. The sampling points and sampling time were selected on the assumption that CO concentration data should be utilized as input data and the materials for verification of the simulation model.

The time schedules of the simplified and additional measurements are shown in Table 3.4.2-6(1) for autumn and in Table 3.4.2-6(2) for winter. Table (a) shows the date when sampling and measurements were carried out and table (b) shows the sampling time and frequency during the period.

The explanation of each sampling point is shown in Table 3.4.2-7, and the latitude and longitude of them are summarized in Table 3.4.2-8. And their locations are plotted in the map (Fig. 3.4.2-1). Basically, the same sampling points were used for both measurement periods.

The VOC concentration was planned for measurement mainly during winter. During the autumn period, more than 20 samples at roadsides and in residential areas were collected as a test run.

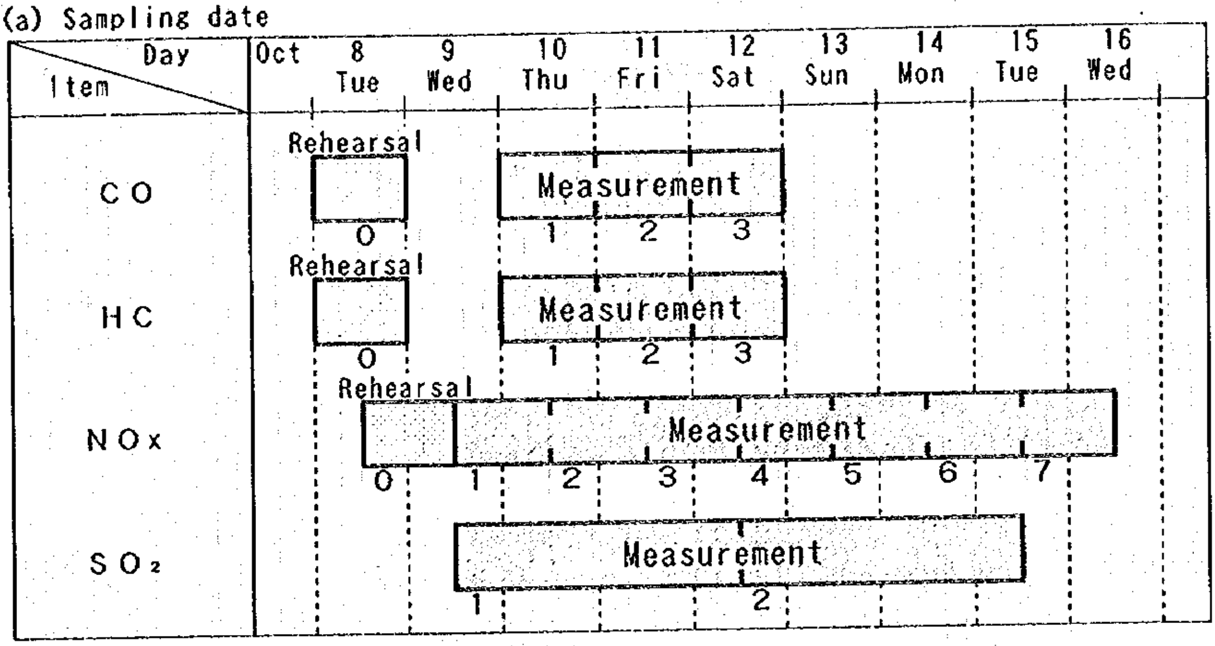
Each target pollutant and its measurement methodology are explained below:

In addition, CO, HC, NOx and SO_2 were measured in spring (May – June '97; the third measurement) in the same way with those in autumn and winter. The time schedules of the spring measurement are shown in Appendix 3.4.2-F of the final report.

Table 3.4.2-6(1) Schedule of Simplified / Additional measurements (1)

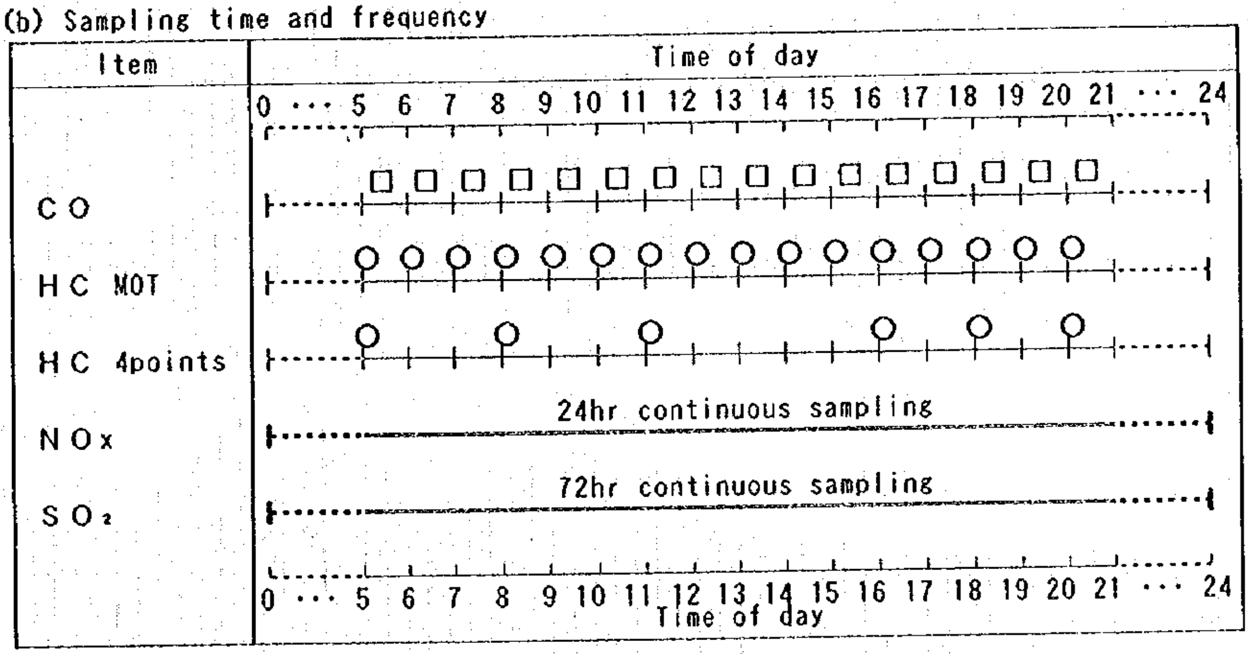
Autumn (Oct. '96)

(a) Sampling date



<Note> The number of each bar means Run No.

(b) Sampling time and frequency



<Notes> □ ; 1 hour Sampling

○ ; 5 minute Sampling

H C MOT ; HC taken at MOT government office building

Table 3.4.2-6 (2) Schedule of Simplified / Additional measurements (2)
Winter (Feb.-Mar. '97)

(a) Sampling date

Item \ Month / Day	February 21 Fri	22 Sat	23 Sun	24 Mon	25 Tue	26 Wed	27 Thu	28 Fri	March 1 Sat	2 Sun	3 Mon	4 Tue	5 Wed	6 Thu	7 Fri	8 Sat	9 Sun
CO		1		2		3		4									
HC		1		2		3		4									
NOx	0	1	2	3	4	5	6	7									
SO_2	1	1	1	1	2	2	2	2									
VOC																1	2

<Note> [Run No.] : Measurement

(b) Sampling time and frequency

Item	Time of day (0 ··· 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 ··· 24)
CO	□ every hour from 5 to 20
HC MOT	◎ every hour from 5 to 20
HC 4points	◎ at 5, 8, 11, 16, 18, 20
NOx	24hr continuous sampling
SO_2	96hr continuous sampling
VOC MOT,AQCC	◎ every hour from 6 to 20
VOC 4points	◎ at 6, 8, 11, 16, 18, 20

<Notes>
□ ; 1 hour Sampling
◎ ; 10 minute Sampling
HC MOT ; HC taken at MOT government office building
VOC MOT,AQCC ; VOC taken at MOT building and AQCC

Tablo 3.4.2-7 Measurement Points of CO, HC, NOx, SO_2 and VOC

Point No.	Explanation, Name of facilities	Measurement : O				
		CO	HC	NOx	SO_2	VOC
1	Public hall of the 13th-ward	O		O	O	
2	504 Hospital of Army	O		O	O	
3	Public hall of the 4th-ward	O	O	O	O	O
4	Public hall of Area 3, the 11th-ward	O		O	O	
5	Public hall of Area 6, the 2nd-ward	O		O	O	
6	Public hall of the 5th-ward	O	O	O	O	O
7	Teheran Railway station	O		O	O	
8	Public hall of the 18th-ward	O	O	O	O	O
9	Basij Sepah Center	O		O	O	
10	Facilities of Taxi organization of MOT	O	O	O	O	O
11	Public hall of the 15th-ward	O		O	O	
12	Facilities of MOT related brick and cement	O		O	O	
131	MOT government office building ground floor	O				
132	ditto, 2nd floor (10m)	O	O*1	O*2	O*2	O*1
133	ditto, 4th floor (20m)	O				
134	ditto, 7th floor (30m)	O				
135	ditto, roof (40m)	O				
136	ditto, roof (50m)	O				
14	AQCC building			O	O	O*1
15	AQCC mobile station			O	O	
16	Electrical bus station			O	O	
17	Facilities of the 16th-ward			O	O	
18	Synoheh clinic			O	O	
19	Water and wastewater organization			O	O	
20	Abbas-abad agriculture and animal husbandry area			O	O	
21	Public hall of 1st-Area, the 15th-ward			O	O	
22	Ekbatan town			O	O	
23	17 Shahrivar park			O	O	
24	TTTO building			O	O	
25	Fire fighting station of the 9th-ward			O	O	
26	Golf lands and Tennis club			O	O	
27	Mrs. Moghadam dentistry			O	O	
28	Meteorological station, Aghdasiyeh			O	O	
29	Shahid Abbaspoor University			O	O	
30	PARS Electric Factory			O	O	
31	Apartment of an AQCC staff			O	O	

<Notes> *1 : Each hour sampling *2 : 1st floor VOC : Winter measurement

Table 3.4.2-8 Latitude and Longitude of Sampling point

Point No.	Latitude		Longitude	
	deg(°N)	min	deg(°E)	min
1	35	41.408	51	26.705
2	35	43.877	51	27.229
3	35	44.576	51	29.508
4	35	42.027	51	22.803
5	35	42.563	51	21.557
6	35	43.971	51	18.902
7	35	39.568	51	23.933
8	35	38.992	51	20.901
9	35	35.930	51	18.508
10	35	39.488	51	27.032
11	35	38.402	51	28.852
12	35	36.952	51	30.311
13[*1]	35	40.871	51	24.918
14	35	44.000	51	26.295
15	35	41.568	51	29.524
16	35	43.475	51	31.426
17	35	38.308	51	25.311
18	35	37.354	51	23.835
19	35	35.475	51	26.344
20	35	35.260	51	21.359
21	35	40.442	51	21.475
22	35	42.335	51	18.852
23	35	40.228	51	18.934
24	35	43.582	51	23.754
25	35	46.751	51	20.246
26	35	46.697	51	23.689
27	35	48.550	51	27.050
28	35	48.054	51	29.181
29	35	45.220	51	33.361
30	35	42.643	51	12.918
31	35	43.086	51	26.279

<NOTE> [*1] : 131 - 136

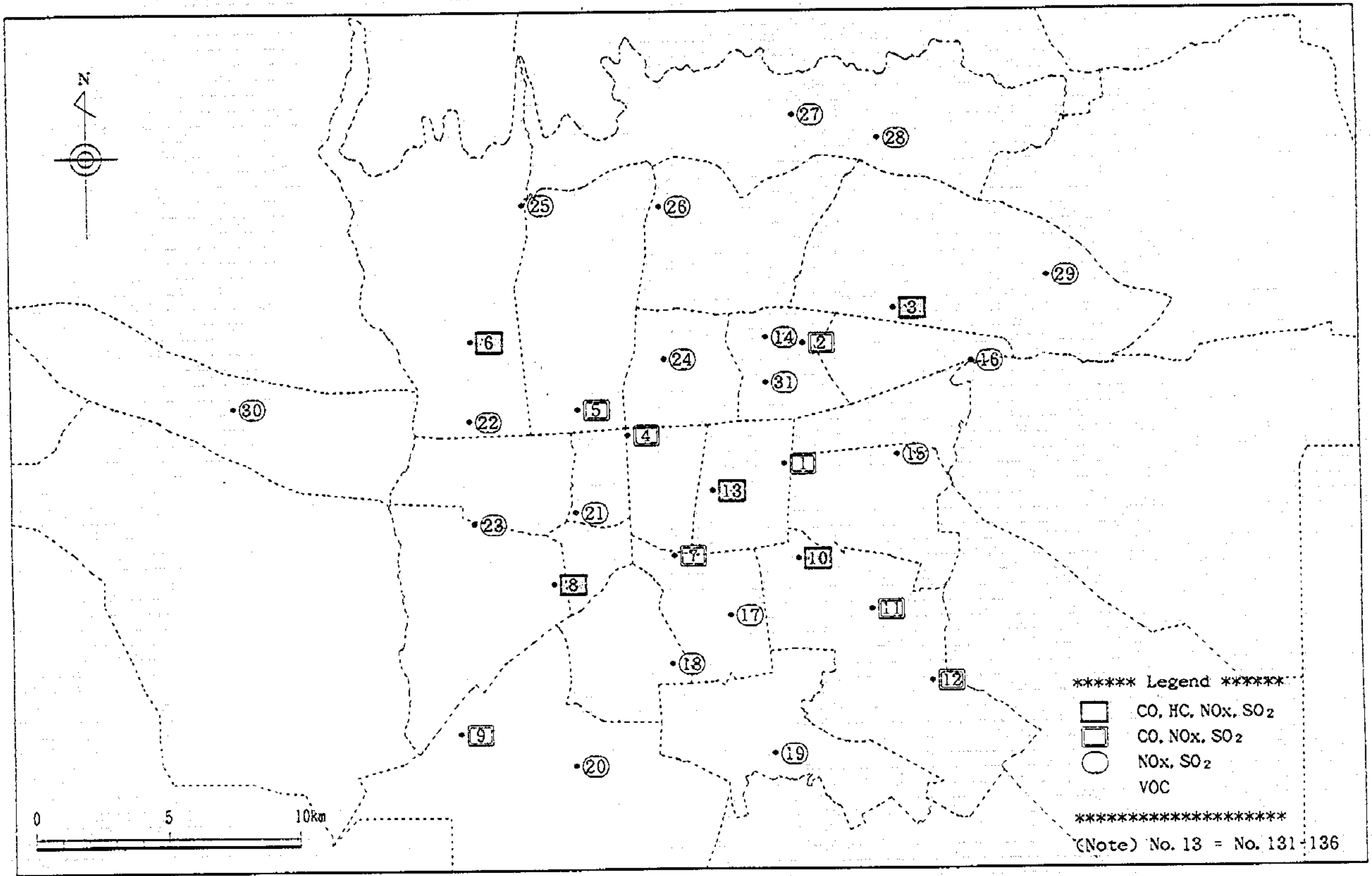


Fig. 3.4.2-1 Location of sampling points of Simplified/Additional measurements

Chapter 4

Clarification of pollution mechanism and characteristics

4. Clarification of pollution mechanism and characteristics

4.1 Meteorological condition in Tehran

The analysis of the meteorological background related to air pollution in Tehran was made based on the field survey data obtained by the JICA study team and existing data belonging to IRIMO. The field survey data consist of the surface meteorological data for five months from October, 1996 to February, 1997, and the two sets of the upper layer meteorological data obtained for the periods of October 8 - 15, 1996 and February 22 - March 1, 1997. And the IRIMO data for one year from January to December in 1994 are used for the analysis and comparison. For reference, almost all of these observation data and statistics are compiled in the data book and supporting report, respectively.

4.1.1 Surface meteorological condition

(1) Statistics based on the data obtained during the field survey

1) Frequency of wind direction

The monthly statistics of wind direction for five months from October, 1996 to February, 1997 at Aghdasiyeh are shown in Fig.4.1.1-1. The wind rose for the total observation period is also shown. As there is no particular difference among the monthly the wind roses, the wind system around the site remains unchanged through the period. The most prevailing wind in the daytime is SSW or SW, and the total frequency of S~WSW accounts for 50 - 60 %; on the other hand, in the night-time, NE is the most prevailing and NNE and NE account for 50 - 60%.

Aghdasiyeh, the observation site, is located on the slope gradually descending to southwest, and Elburz mountains are on the north behind the site. The above mentioned diurnal change of wind direction, namely the wind alternation of day and night, reflects the characteristics of "mountain and valley wind", which is the thermally induced local wind system in the mountainous region. Coincidence of the directions of prevailing wind and slope inclination supports this speculation. The SSW or SW wind is considered to be a kind of valley wind ascending along the slope during the daytime, due to the buoyancy of the heated air near the ground surface. On the contrary, the mechanism and the circulation are reversed at night. Surface cooling induces the cold air drainage down the slope. NE is regarded to be a mountain wind.

2) Mean wind speed and frequency of classified wind speed for each wind direction

The monthly mean wind speed is given in the lower right corner of each wind rose. The mean wind speed during the night-time (1.0～1.2 m/s) is somewhat weaker than that during the daytime (1.1～1.5 m/s). The calm frequency at night is 7～14%, 5～10 percentage points more than in the day. As for the frequency of classified wind speed for each wind direction, the wind of 1.0～1.9 m/s is the most dominant and the next is that of 0.5～0.9 m/s. Consequently, most of the surface wind around the site are less than 2.0 m/s not only in the night but also in the daytime. It is the distinctive feature of this area that calm or breezy condition at surface is dominant all day through.

3) Atmospheric stability

Fig.4.1.1-2 shows the monthly and total frequency of the classified atmospheric stability based on the data from October, 1996 to February, 1997. Atmospheric stability is derived from the table of "Pasquill's atmospheric stability classification" (Table 4.1.1-1) which gives us the stability class according to the data of wind speed, solar radiation (daytime) and radiation balance (night-time). The monthly histogram for the frequency of stability class suggests the existence of active convection in the daytime and strong inversion in the night-time. In the daytime, the strongly unstable classes ("A", "A-B", "B") and the neutral class "D" account for 24 - 27 % and 11 - 17%, respectively, but other classes can hardly be seen. On the other hand, in the night-time, the strongly stable class ("G") amounts to 47 - 54 %, while each class of "D", "E" and "F" accounts for only less than 7%. The strongly stable class and strongly unstable class occupy the majority because the gradient wind was weak and fine weather was lasting and precipitation was exceptionally little. It is supposed that such condition tends to persist at least in autumn and winter, because any particular seasonal variation cannot be seen in the monthly histograms.

Table 4.1.1-1 Pasquill's atmospheric stability classification

Wind Speed (U; m/s)	Solar radiation (T) kW/m²				Radiation balance (Q) kW/m²		
	T≧0.60	0.60>T ≧0.30	0.30>T ≧0.15	0.15>T	Q≧-0.020	-0.020>Q ≧-0.040	-0.040>Q
U<2	A	A - B	B	D	D	G	G
2≦U<3	A - B	B	C	D	D	E	F
3≦U<4	B	B - C	C	D	D	D	E
4≦U<6	C	C - D	D	D	D	D	D
6≦U	C	D	D	D	D	D	D

notes;

① Regarding the direction of radiation energy transportation, upward is "minus" and downward is "plus".

② The values of solar radiation and radiation balance are the average of data for 10 minutes before the observation time.

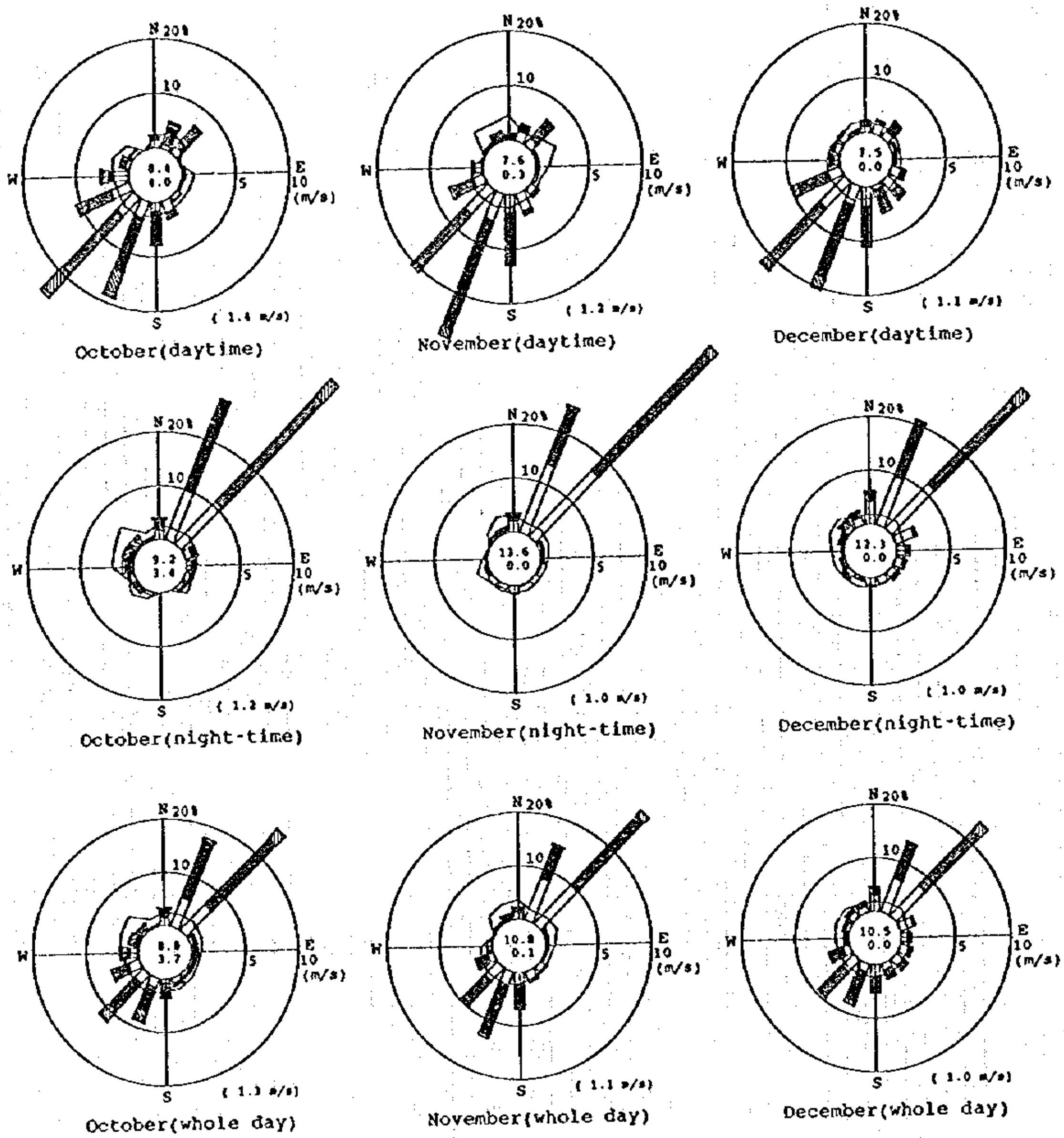
③ The values of solar radiation and radiation balance are applied for evaluation of atmospheric stability in the daytime and night-time, respectively.

④ The units of solar radiation and radiation balance are unified at kW/m².

⑤ Classification of wind speed is based on the Pasquill's method (Japanese type).

⑥ Each class stands for the level of atmospheric stability as follows:

A : unstable (strong)
B : unstable (medium)
C : unstable (weak)
D : neutral
E : stable (weak)
F : stable (medium)
G : stable (strong)
A - B : middle of A and B
B - C : middle of B and C
C - D : middle of C and D



Observation point ; Aghdasiyeh
Observation period ; October, 1996 - February, 1997

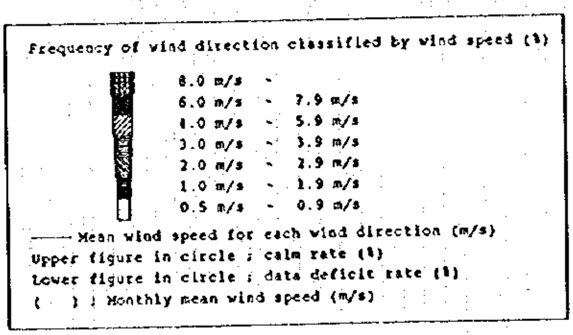
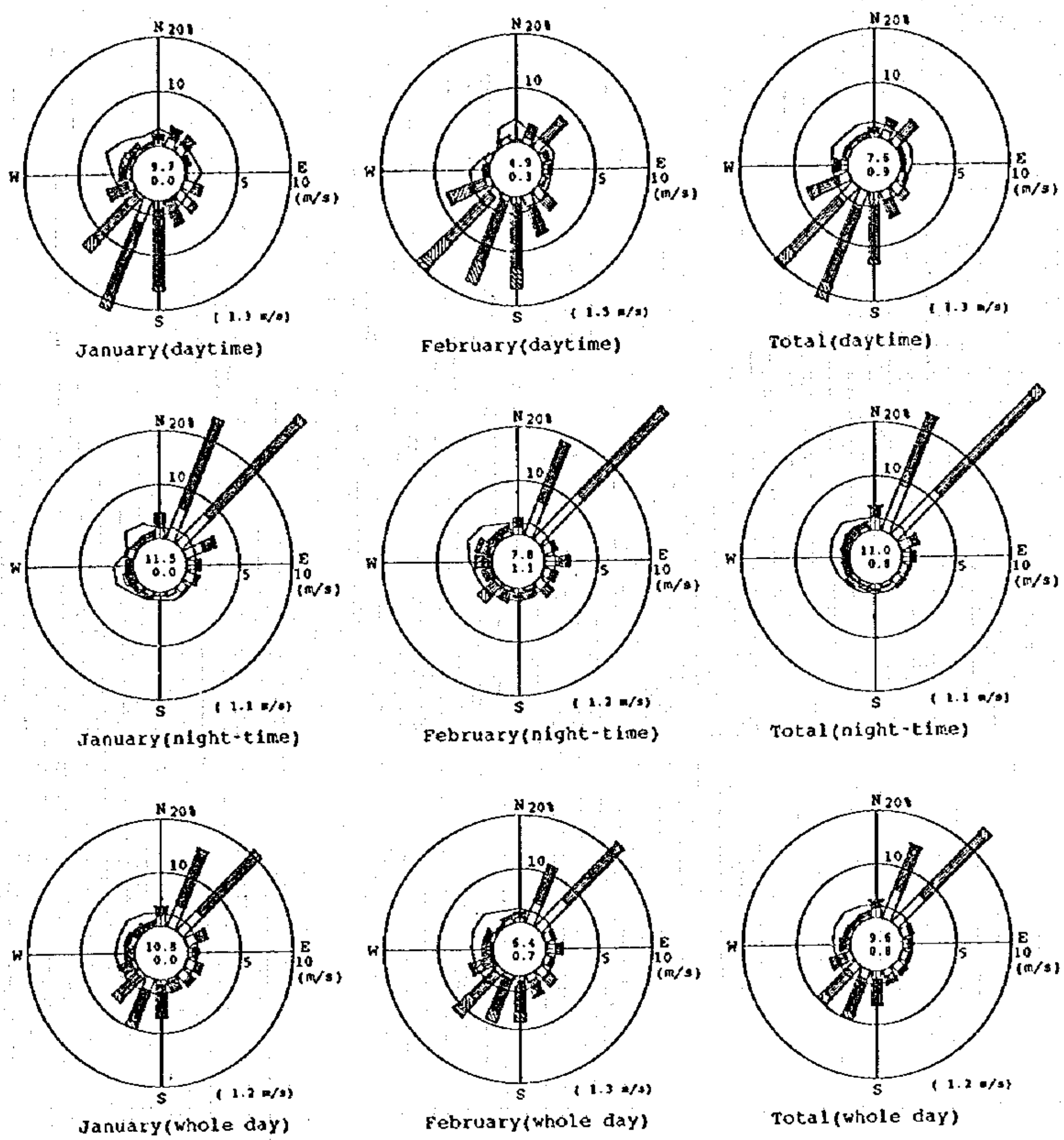


Fig.4.1.1-1(1) Wind rose for monthly frequency of wind direction classified by wind speed, and monthly mean wind speed at each wind direction.



Observation point ; Aghdasiyeh
Observation period ; October, 1996 - February, 1997

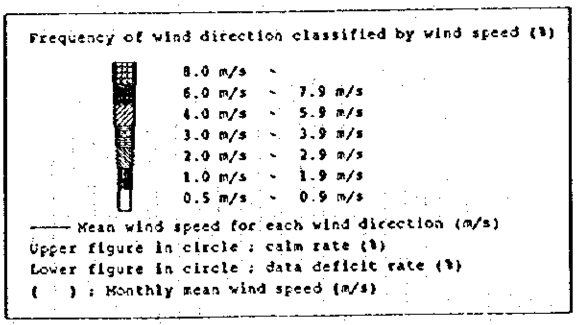


Fig.4.1.1-1(2) Wind rose for monthly frequency of wind direction classified by wind speed, and monthly mean wind speed at each wind direction.

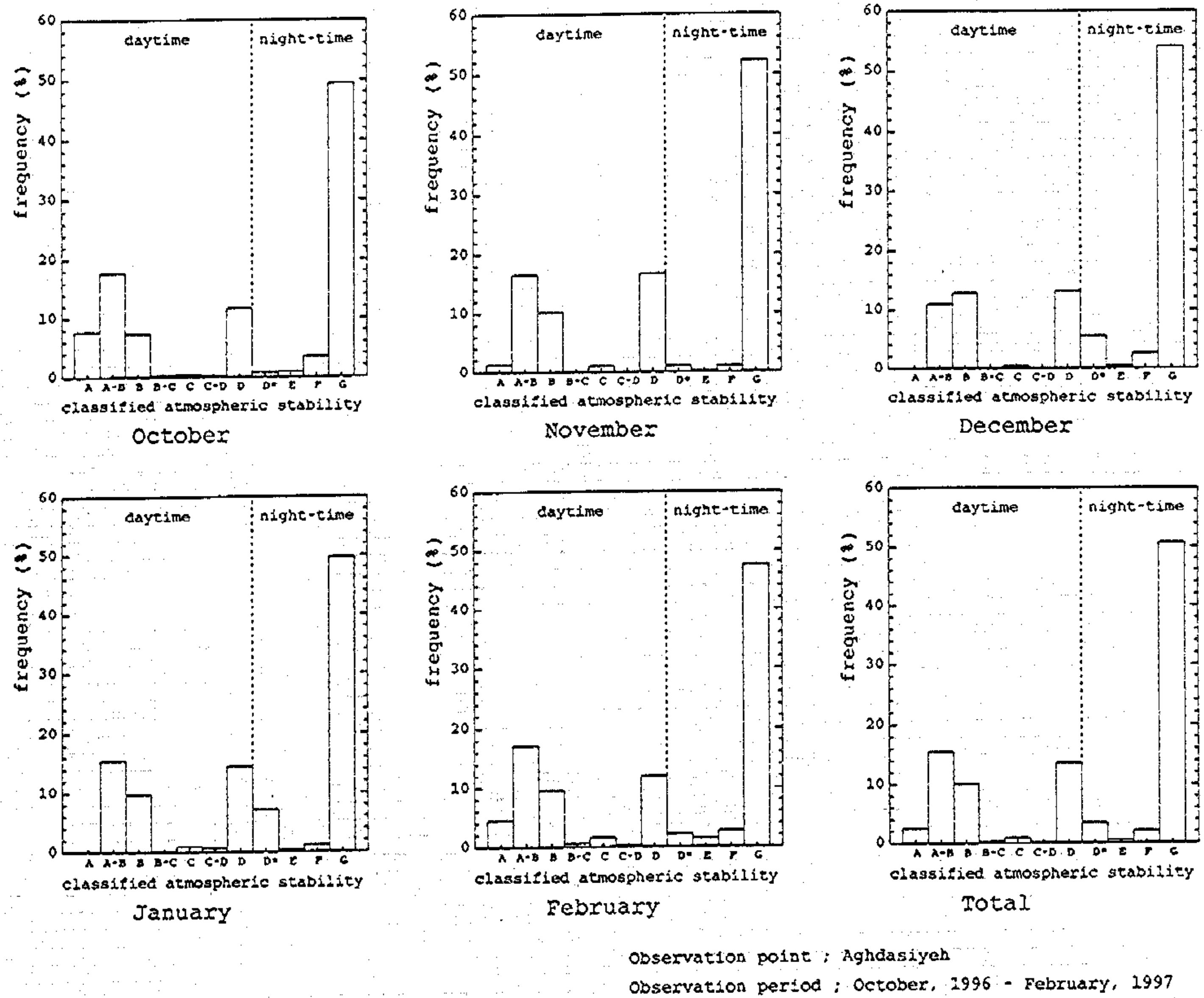


Fig.4.1.1-2 Frequency of the classified atmospheric stability.

4.1.2 Characteristics of weather condition in Tehran

Based on the statistics of the observation data obtained through the field survey and existing data, the characteristics of weather condition are summarized as follows.

The wind rose and mean wind speed at surface based on the data of Mehrabad Airport in 1994 are shown in Fig.4.1.2-1. Fig 4.1.2-2(1)~(3) shows vertical profiles of temperature observed by the captive sonde in October, 1996 and February, 1997.

① The wind at Aghdasiyeh is considerably affected by the northern mountains. In the daytime, deep and somewhat strong southwesterlies go up the mountain slope. On the contrary, the wind system in the night-time is characterized by the shallow (~100m) cold air drainage down the slope as the northeasterlies, and above the flow, easterlies or westerlies blow parallel to the mountains. Generally, the wind is not strong except southwesterlies in the daytime. The vertical profile of the mean wind speed at this site is unique for its stratified structure. The wind is very weak in the surface boundary layer any time in a day. Above the layer, the wind speed increases rapidly with height up to 50m. Above 50m, the wind speed is almost constant regardless of height, suggesting the air is well mixed by convection transporting the momentum vertically. This typical structure of wind speed well corresponds to the temperature profile.

On the other hand, in the light of the comparison between the statistics and profiles of wind based on the existing data at Mehrabad and the field survey data at Aghdasiyeh, the considerable differences are recognized in the wind system at the surface level and in the upper layer depending on the observation site. As mentioned above, wind at Aghdasiyeh is distinguished by its diurnal change of local circulation which is supposed to be the so-called 'mountain and valley wind'. While at Mehrabad, westerly is prevailing at the surface level and the upper layer in all seasons except summer when the southeasterlies are dominant in the upper air. The fact shows the wind system in this region is different from place to place and has local characteristics.

② The surface inversion layer appears every night during the upper air observation. The inversion does not develop upward but becomes intense because of radiation cooling. The depth of the inversion is suppressed below 100m, and in some cases, the inversion intensity (the temperature difference between the top and bottom of the layer) exceeds 5℃. In the upper air, inversion layer tends to correspond to the layer where the wind direction changes.

③ The depth of the thermal mixing layer in the daytime is estimated at around 1000 ~ 1500m. When the southwesterlies prevail deep in the upper layer, the vertical temperature gradient is almost constant through the layer in question(surface~2000m) and agrees with the dry adiabatic lapse rate, suggesting that the thermal mixing layer develops in the air higher than 2000m.

④ The statistics of the atmospheric stability at the surface level show that the classes of "strongly stable" in the night-time and "strongly unstable" in the daytime are dominant. These facts and the vertical temperature gradient, which is equivalent to the dry adiabatic lapse rate in the daytime, are consistent with the thermal convection, which develops in the daytime and is suppressed in the night-time.

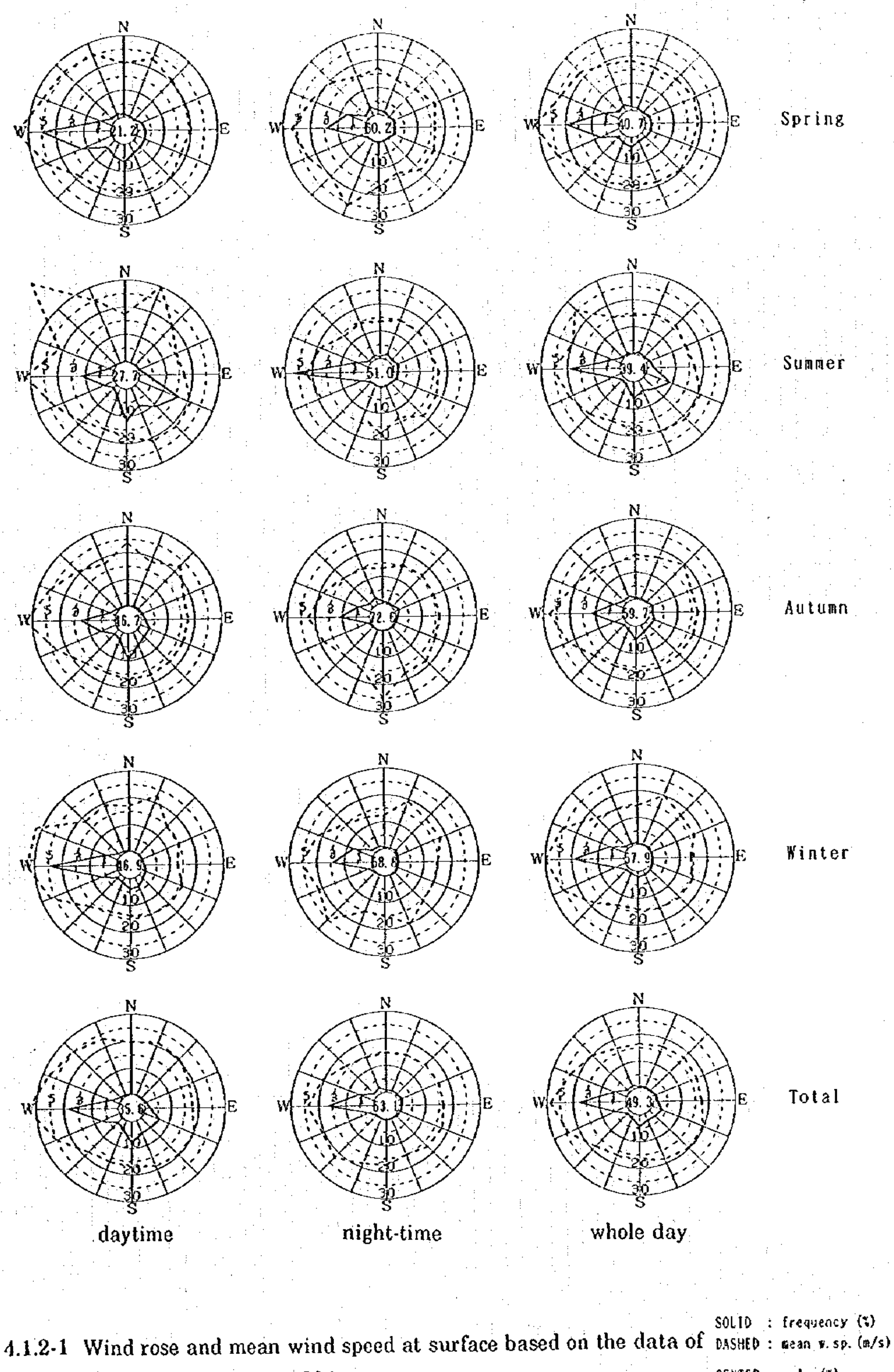


Fig. 4.1.2-1 Wind rose and mean wind speed at surface based on the data of Mehrabad Airport in 1994.

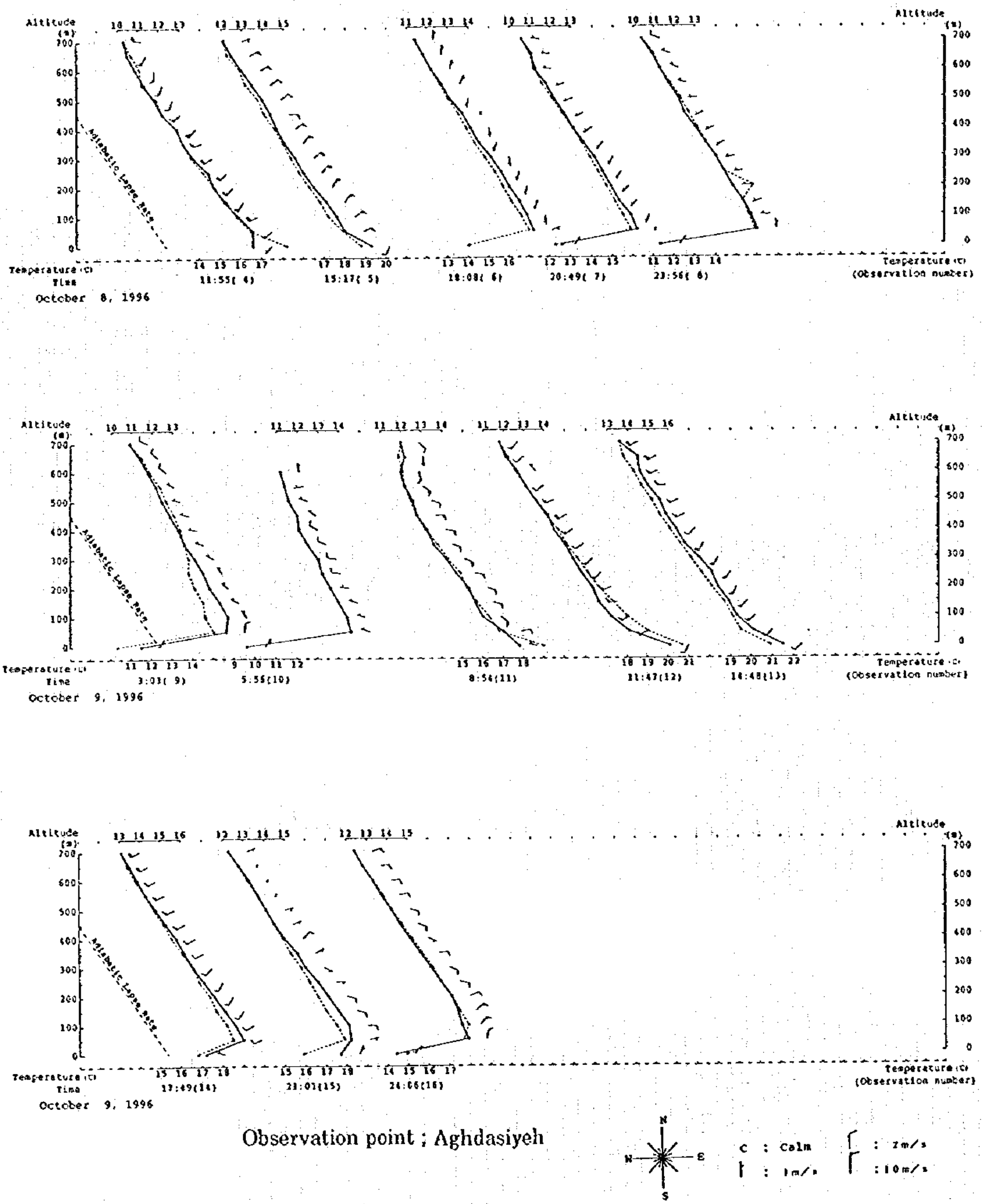
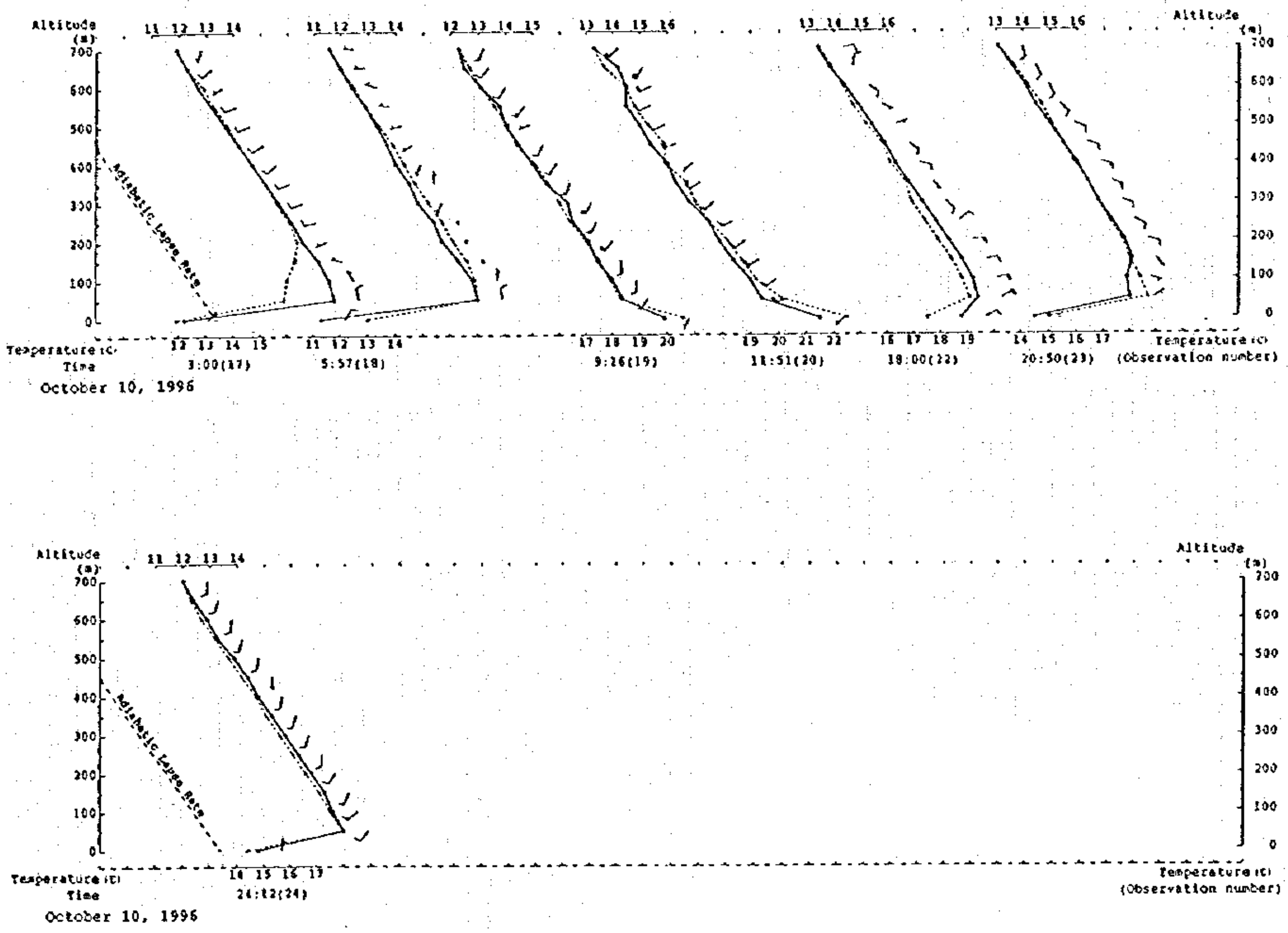


Fig.4.1.2-2(1) Vertical profiles of temperature observed by the captive sonde.



Observation point ; Aghdasiyeh

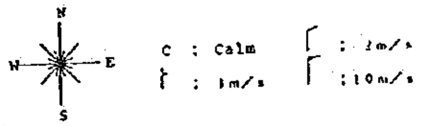


Fig.4.1.2-2(2) Vertical profiles of temperature observed by the captive sonde.

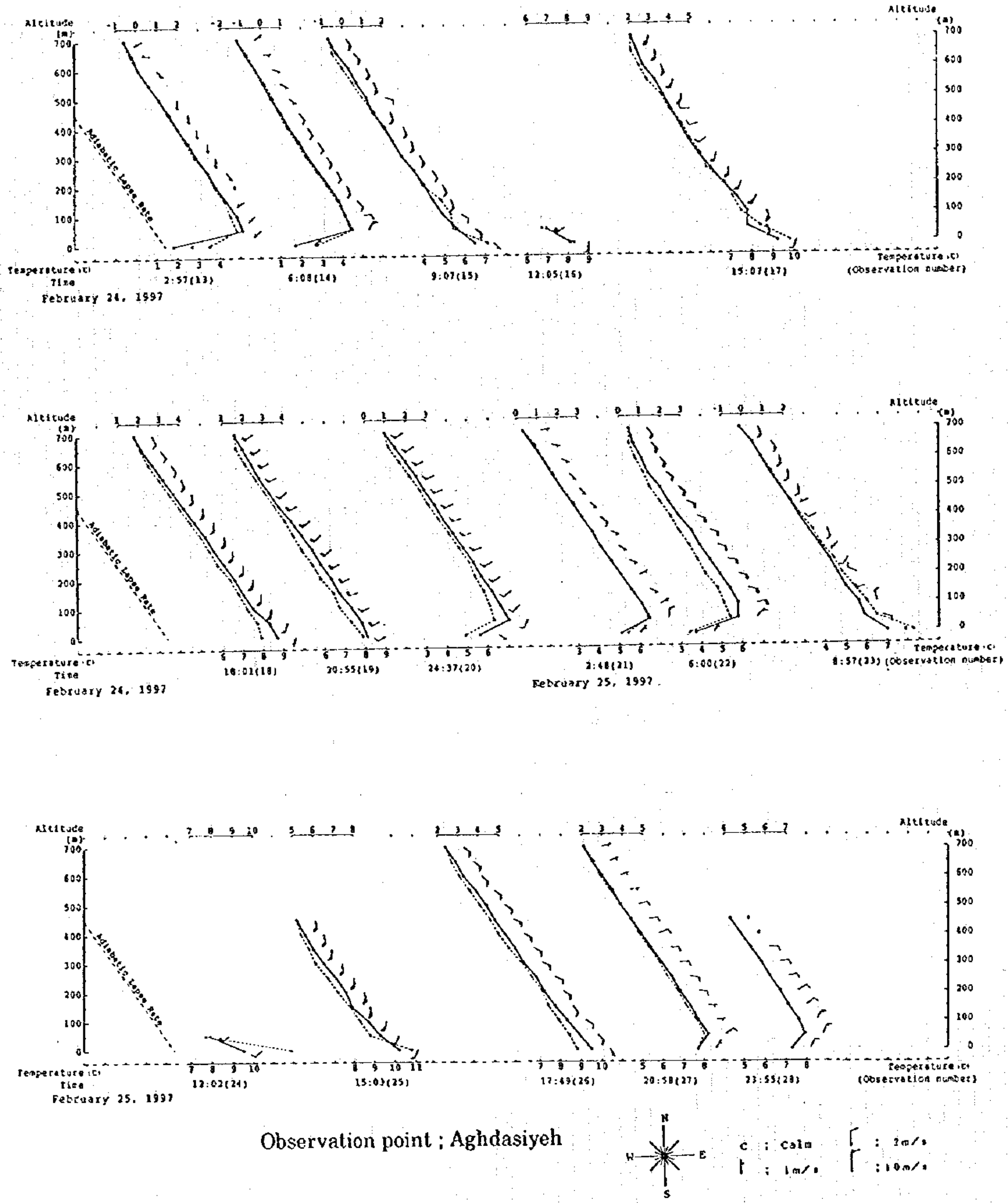


Fig.4.1.2-2(3) Vertical profiles of temperature observed by the captive sonde.

4.2 Quality of ambient air

4.2.1 Summary of the results

(1) Variations of the pollutant concentration in several cycles

Based on the pollutant concentration data monitored at the stations located in a heavy traffic area (Fatemi) and a crowded commercial area (Bazar) in Tehran, the characteristics of the pollutant concentration variations in the several cycles are summarized below.

The annual average concentrations of SO_2, NO_2, NO, NOx, CO, O_3, THC, and PM10 for the period from October 1995 to September 1996 at Bazar and Fatemi, as well as the national environmental standards of some countries and the WHO air quality guideline for comparison, are summarized in Table 4.2.1-1. The annual averages of the several pollutant concentrations (SO_2 and PM10) at these stations are higher than the WHO air quality guideline. For example, the SO_2 concentration at Bazar is 63.4 ppb that is 2.4 times as large as the WHO air quality guideline. The CO concentration at Fatemi is 9.8 ppm that is about 4 times as large as the WHO guideline, on the assumption that the annual average guideline would be one fourth of the 8 hour guideline. The concentration of pollutants from the mobile sources, such as NO, CO and THC, are higher at Fatemi, while those of SO_2, O_3 and PM10 are higher at Bazar.

Table 4.2.1-1 Annual average concentration of pollutants and environmental standards

	SO_2	NO	NO_2	NOx	CO	O_3	THC	PM10
Bazar	63.4	61.3	49.9	110.5	7.9	24.8	4.4	123.2
Fatemi	35.4	141.5	43.2	185.2	9.8	14.2	4.9	101.9
WHO guideline	17 – 26	—	—	—	—	—	—	60 – 90
U.S.A. standard	35	—	60	—	—	—	—	50/50
Germany standard	57	—	60	—	—	—	—	100
Japan standard	(20)	—	(20~30)	—	—	—	—	(50)

notes;

1) unit : SO_2, NO, NO_2, NOx, O_3 ; ppb CO, THC ; ppm (The original concentrations in $\mu g/m^3$ are converted into the value in ppb or ppm under the condition of Tehran (20℃, 880hPa)).

PM10 ; $\mu g/m^3$

2) For the U.S.A. federal standard, the figure before the slash is the first standard and that following the slash is the second standard. The first standard is for protecting citizen's health. The second standard is for protecting citizen's public welfare (fauna, flora, properties etc.).

3) The Japan standard in PM10 column is for SPM (suspended particulate matter). Both PM10 and SPM designate the particles in the air, of which diameter is less than 10 μm. However, the exclusion method of the large particles (>10 μm) is different. As a result of that difference, PM10 includes some particles somewhat larger than 10 μm but SPM never does.

4) Japan does not establish the annual standard. The figures in the table are provided only for reference.

Seasonal changes in the pollutant concentrations have the characteristic cycles. The monthly averages of all pollutants (as shown in Fig. 4.2.1-1(1) ~(2)) except O_3 tend to increase and reach the maximum in cool seasons. In view of the dependence of the concentrations upon not only the source activities but also atmospheric stability which affect the pollutant transportation and diffusion, the cool season is considered to provide the favorable background for the high concentration. On the other hand, O_3 concentration is higher in summer, when the solar ultra-violet radiation necessary for the photochemical process producing O_3 becomes strong. According to the simplified measurement data obtained by the JICA study team, the NO_2, CO and HC concentrations are higher in autumn than in winter, though the SO_2 concentration is higher in winter than in autumn.

As for the diurnal variations based on annual averages, the characteristics common to all pollutants but O_3 is the presence of two peaks a day, at around 9:00 in the morning and 22:00 in the late evening. Especially, the concentrations of NO, CO and PM10, to which traffics make a large contribution, are clearly periodical. Compared to Bazar, diurnal change in Fatemi has complete cycles, and shows distinct two peaks, a wider diurnal range and a higher concentration. Two peaks of the concentration in the morning and late evening are thought to be caused by increased traffic in rush hours and the stable layer near the surface, which are favorable for stagnation of pollutants. On the other hand, the O_3 concentration has only one conspicuous peak in the afternoon, because the O_3 generation depends on the strength of solar ultra-violet radiation.

Compared to the data obtained by the JICA study team in October 1996, the diurnal variations of CO at many stations in MOT based on the simplified measurement data show the similar pattern to those at Fatemi, having two peaks in a day. However, the concentrations at Fatemi in the same period are considerably higher than those at the JICA points. These facts suggest that the CO concentration is highly dependent on the distance from streets as well as the traffic volume, while the diurnal variation pattern is controlled by activities of pollutant sources (traffic volume etc.) and the meteorological conditions such as atmospheric stability, wind direction and speed. As for the simple measurement data of NMHC and THC, their autumn variations show the same pattern as CO; however, the concentrations in winter are low and almost constant.

As for the concentration change in a week based on the annual average, it is not easy to identify the variation pattern. However, drop of concentration on Friday (the Iranian holiday) is recognized in the variations of CO and PM10 at both stations, those of NO at Fatemi and those of THC at Bazar. Because all these pollutants are emitted from traffics, the traffic volume apparently contributes to these concentration changes in a week, while the concentrations of SO_2, NO_2, and O_3 do not seem to have close relationship with the day of the week. As for the seasonal average, the summer and autumn curves particularly show weekly cycles that fall to the minimum on Friday.

Fig. 4.2.1-2(1) ～ Fig. 4.2.1-2(4) are the diurnal variation of pollutant concentrations showing the extracted serious air pollution examples monitored at Bazar and Fatemi. Table 4.2.1-2 shows the extracted data of the WHO air quality guideline to be used for evaluation of the air pollution effect on human health in Tehran. The original concentrations in this table in $\mu g/m^3$ are converted into the values in ppm under the conditions of both the sea level (25℃, 1013hPa) and Tehran (20℃, 880hPa).

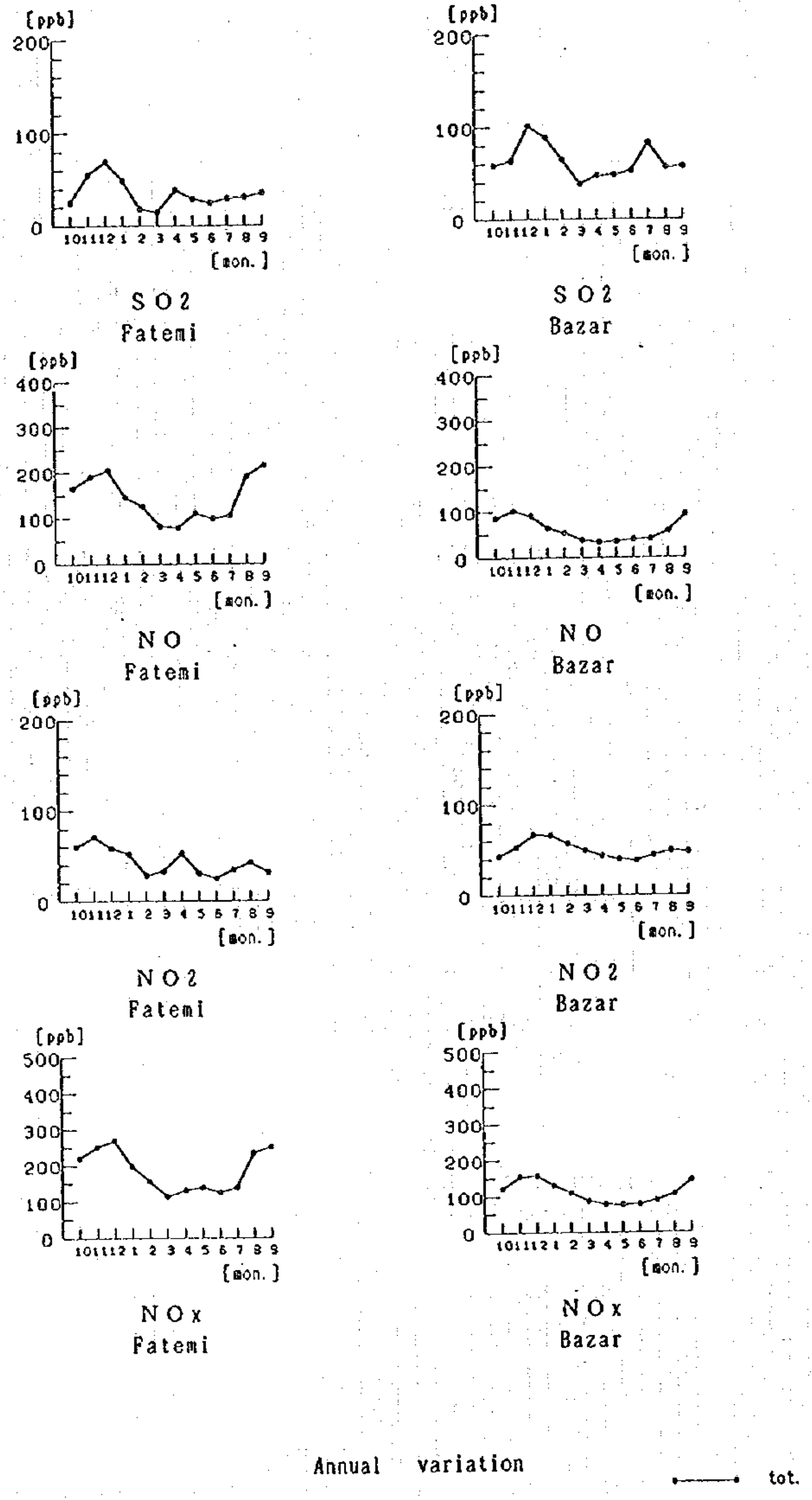


Fig.4.2.1-1(1) The monthly variations of average pollutant concentrations at Bazar and Fatemi (October, 1995 ~ September, 1996).

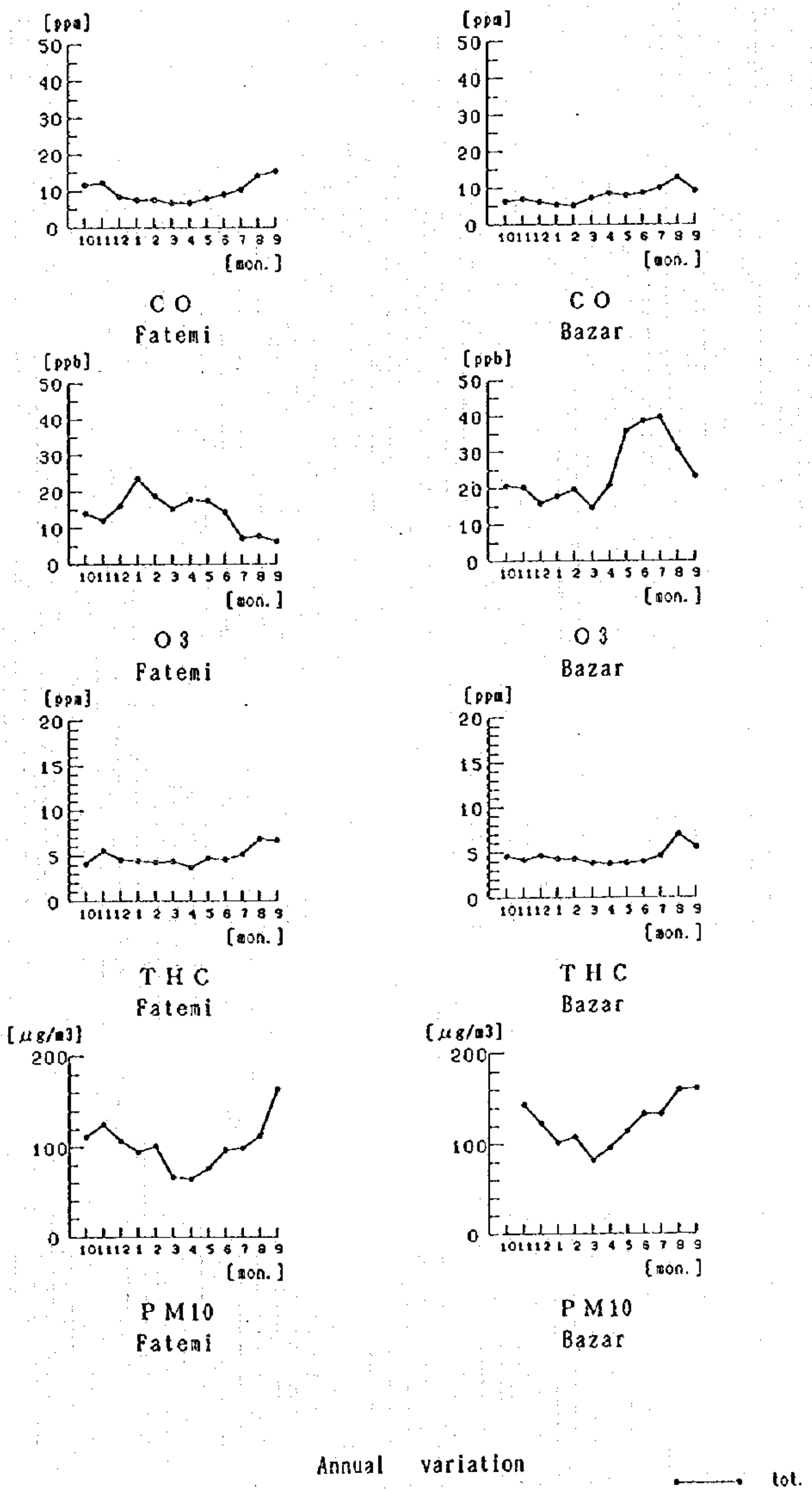


Fig.4.2.1-1(2) The monthly variations of average pollutant concentrations at Bazar and Fatemi (October, 1995 ~ September, 1996).

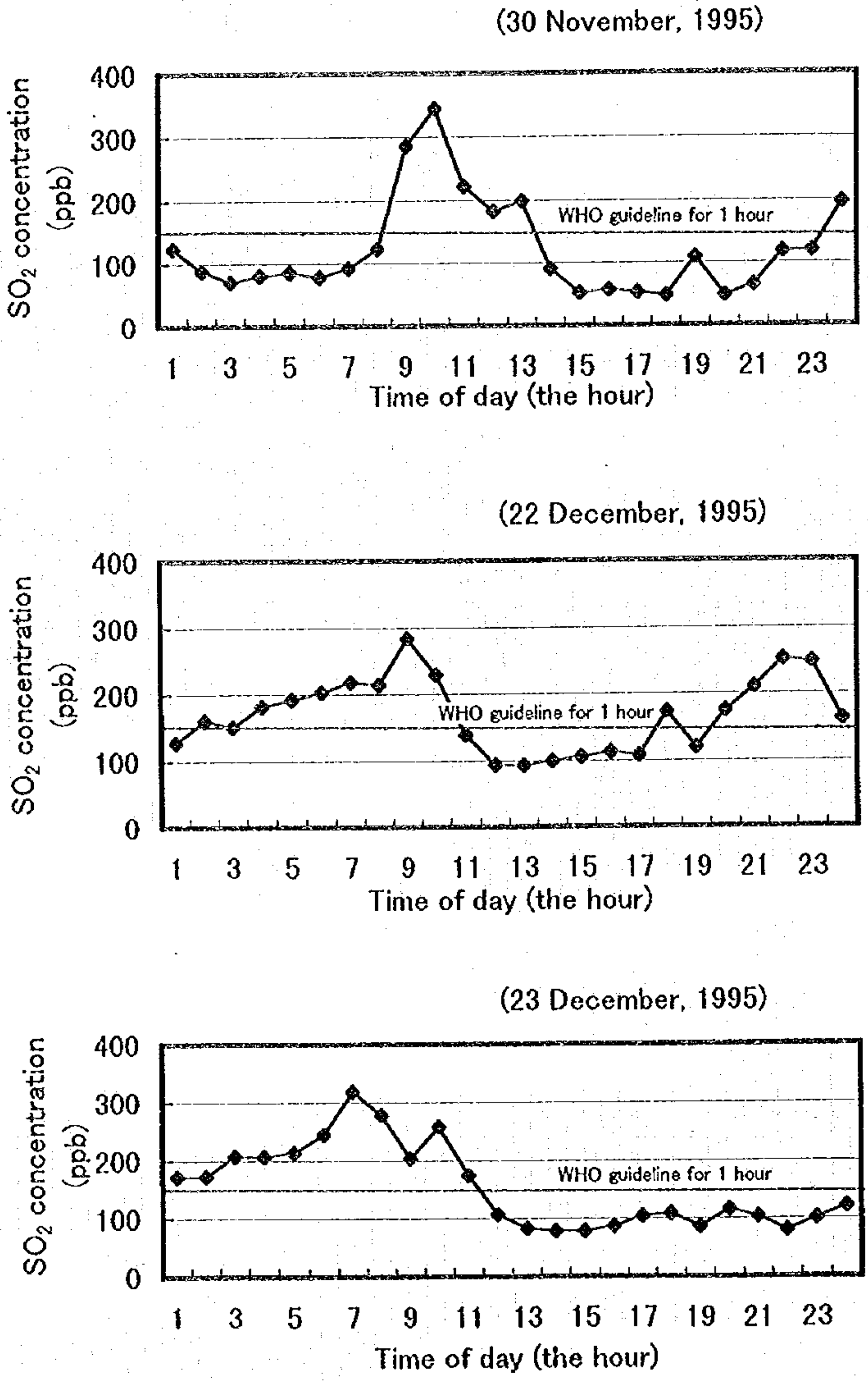


Fig. 4.2.1-2(1) Diurnal variation of SO_2 concentration during serious pollution at Bazar.

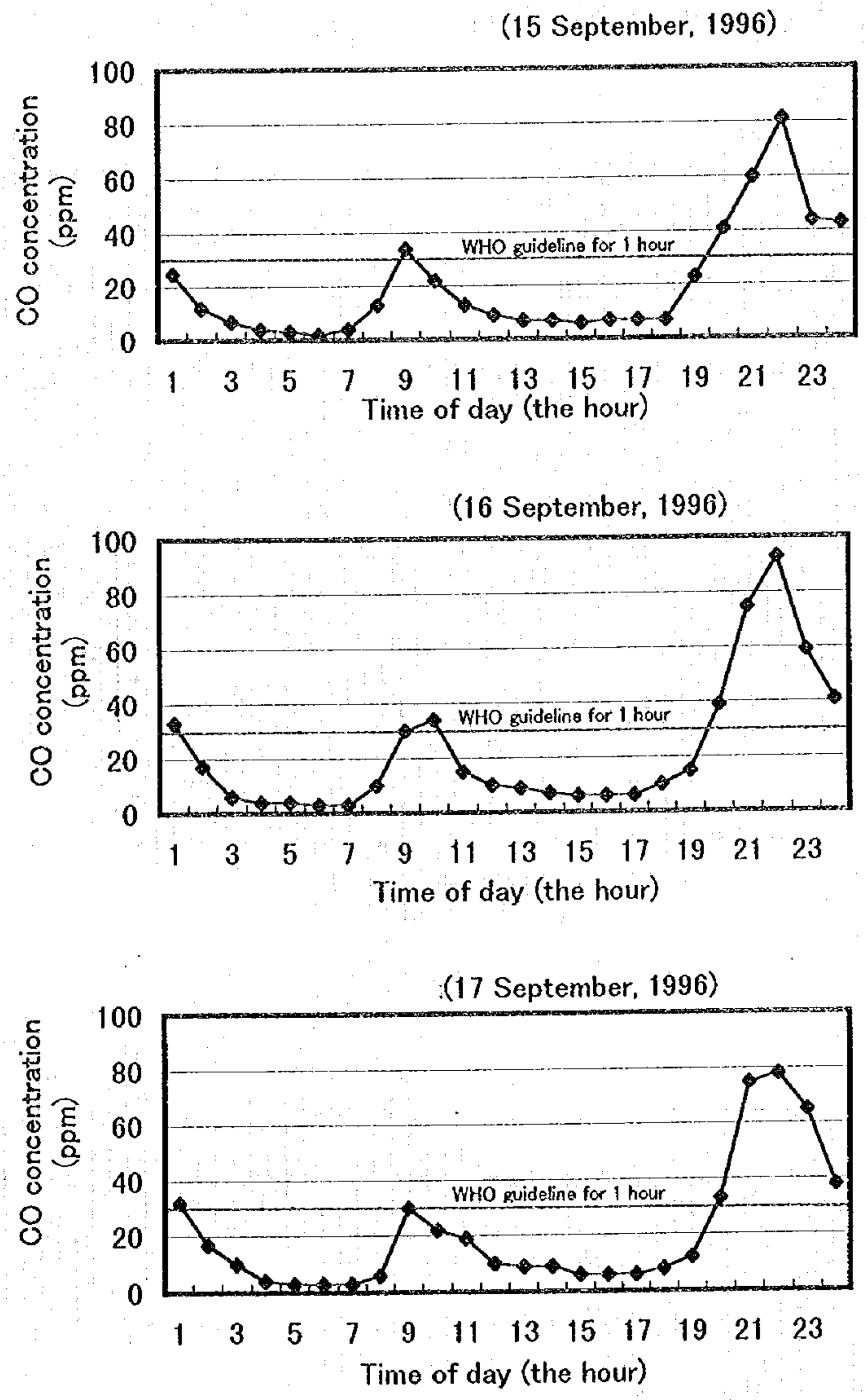


Fig. 4.2.1-2(2) Diurnal variation of CO concentration during serious pollution at Fatemi.

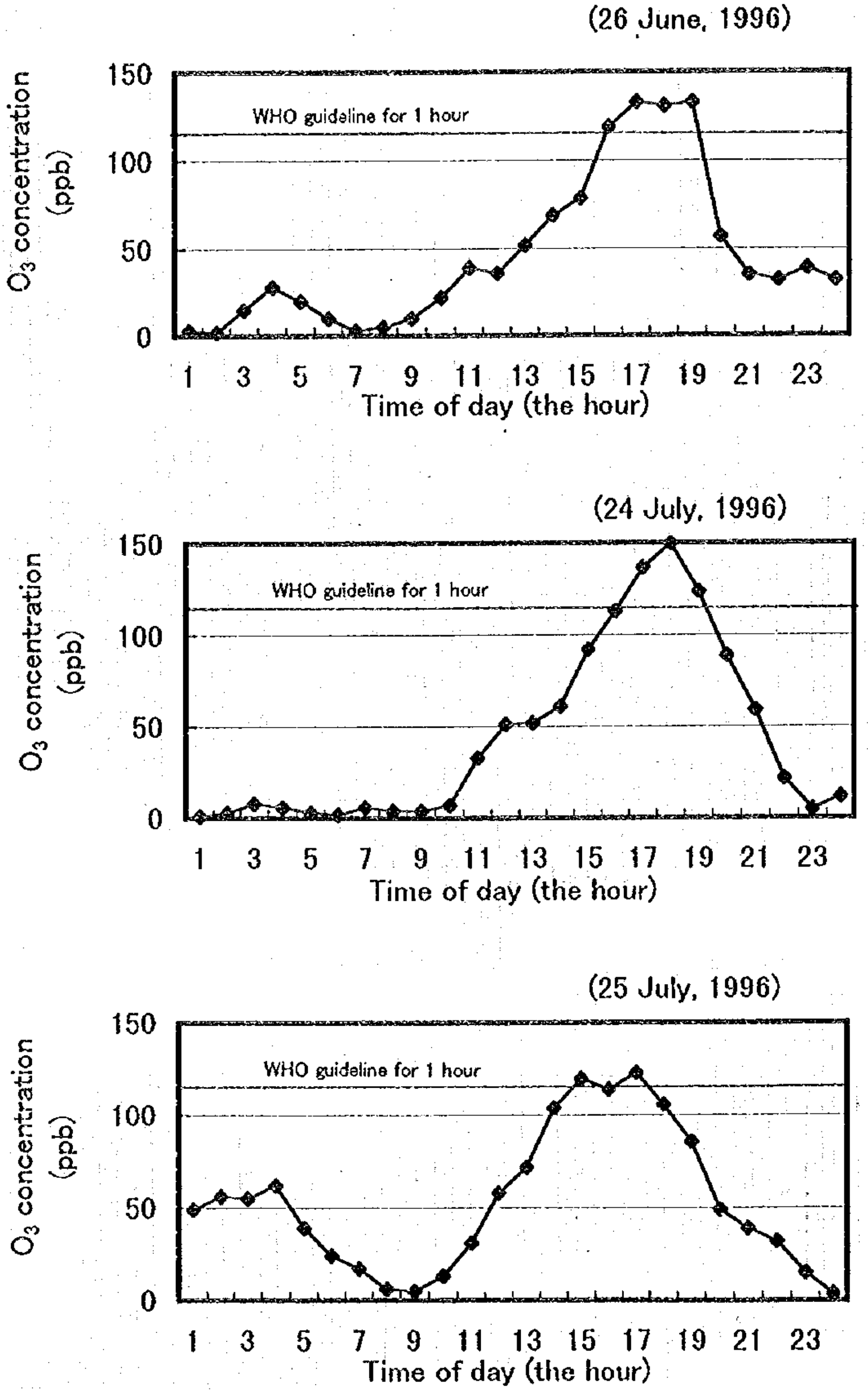


Fig. 4.2.1-2(3) Diurnal variation of O_3 concentration during serious pollution at Bazar.

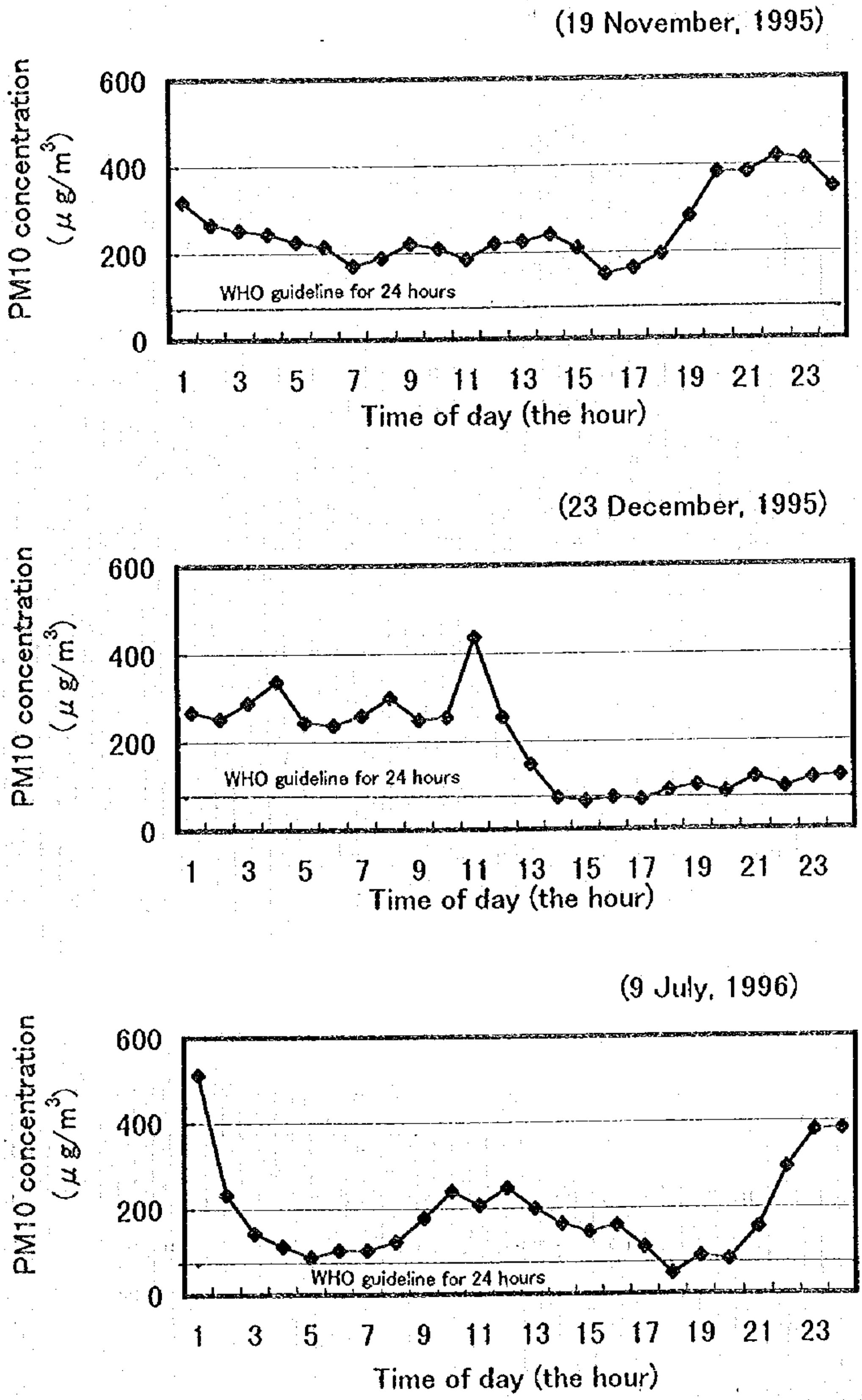


Fig. 4.2.1-2(4) Diurnal variation of PM10 concentration during serious pollution at Bazar.

Table 4.2.1-2 WHO air quality guideline (extracted)

Pollutant	Time-weighted average (μgm^{-3})	Converted value[2] (ppm, sea level)	Converted value[3] (ppm, Tehran)	Averaging time
Sulfur dioxide[a,b]	350	0.14	0.151	1 hour
	100 – 150[1]	0.04 – 0.06	0.043 – 0.065	24 hours
	40 – 60[1]	0.015 – 0.023	0.017 – 0.026	1 year
Carbon monoxide[a,c]	30	26	30	1 hour
	10	9	10	8 hours
Nitrogen Dioxide[a,d]	400	0.21	0.241	1 hour
	150	0.08	0.09	24 hours
Ozone[a,e]	150 – 200	0.08 – 0.10	0.087 – 0.115	1 hour
	100 – 120	0.05 – 0.06	0.058 – 0.069	8 hours
PM10	70[1]	-	-	24 hours

Note; 1 Combined value of SO_2/SPM guideline

2 Conversion into ppm is made on the basis of 25℃, 1atm (1013hPa).

3 Conversion into ppm is made on the basis of 20℃, 880hPa.

Sources; [a](WHO, 1987) [b](WHO, 1979a) [c](WHO, 1979b)

[d](WHO, 1977) [e](WHO, 1978)

The daily maximum SO_2 concentration on November 30, 1995 at Bazar is 345ppb that is 2.3 times as large as the WHO guideline for the 1 hour average. The daily maximum CO concentration on September 16, 1996 at Fatemi is 93ppm that is 3.1 times as large as the WHO guideline. The daily maximum O_3 concentration on July 24, 1996 at Bazar is 150ppb that also exceeds the WHO guideline (87-115ppb). The daily average of PM10 concentration on July 9, 1996 at Bazar is 192$\mu g/m^3$ that is 2.7 times as large as the WHO guideline for 24 hours(70$\mu g/m^3$).

(2) Distribution of pollutant concentration in Tehran.

Based on the data obtained by the field survey by the JICA study team, distribution characteristics of the pollutant concentrations are described. As for CO, the concentration in downtown areas is higher than other places, while that in the suburban area is lower. Also the common feature of the NO_2 concentration distributions is that the concentration in the center part of MOT is slightly higher than that of the outskirts of MOT. And the SO_2 concentrations in the center and a little southern part of MOT are slightly higher than northern parts of MOT.

(3) Meteorological aspects on air pollution in Tehran

Influences of the wind direction and speed on the pollutant concentration are discussed on the basis of the monthly average data obtained at Fatemi and Bazar. The concentrations of SO_2, NO_2 and PM10 do not seem to depend on the wind direction, while the high NO concentrations are observed at both stations when the northerlies (WNW – ENE) are blowing. The concentrations of CO and THC tend to be high only at Fatemi, under the northwesterlies and northeasterlies. The relationships between O_3 and the wind direction are opposite to those of NO, CO and THC. The concentration reaches a high value when southerlies (E – WSW) blow. As mentioned in the final report section 4.1.1, northerlies prevails in the night-time when the atmosphere is strongly stable, and southerlies blow in the daytime when atmosphere is unstable and mixed. It is suggested that concentration depends on not the wind direction but the atmospheric stability.

The concentrations of all pollutants but O_3 and PM10 at both stations are inversely correlated to the wind speed. Especially, the concentration is reduced remarkably with increase in the wind speed in autumn and winter. In contrast to these pollutants, the O_3 concentration increases in proportion to the wind speed which increases in the daytime when not only the atmospheric convection become active but also photochemical reactions producing O_3 occur under the strong solar radiation.

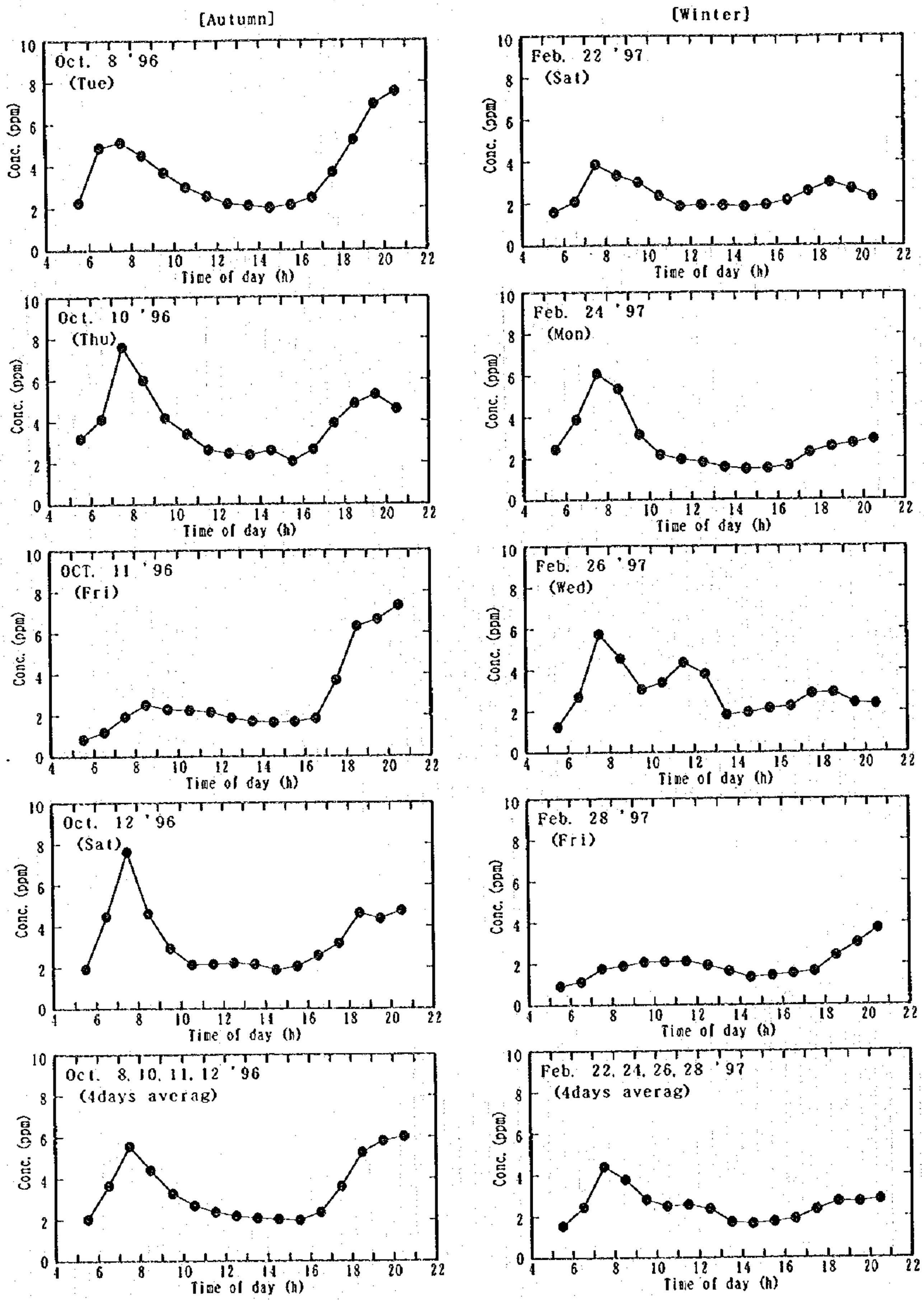


Fig. 4.2.1-3 Diurnal variation of average CO concentration
Average of all surface measurement data for each day of the week
(Total 13 points ; No. 1-12 and 132)

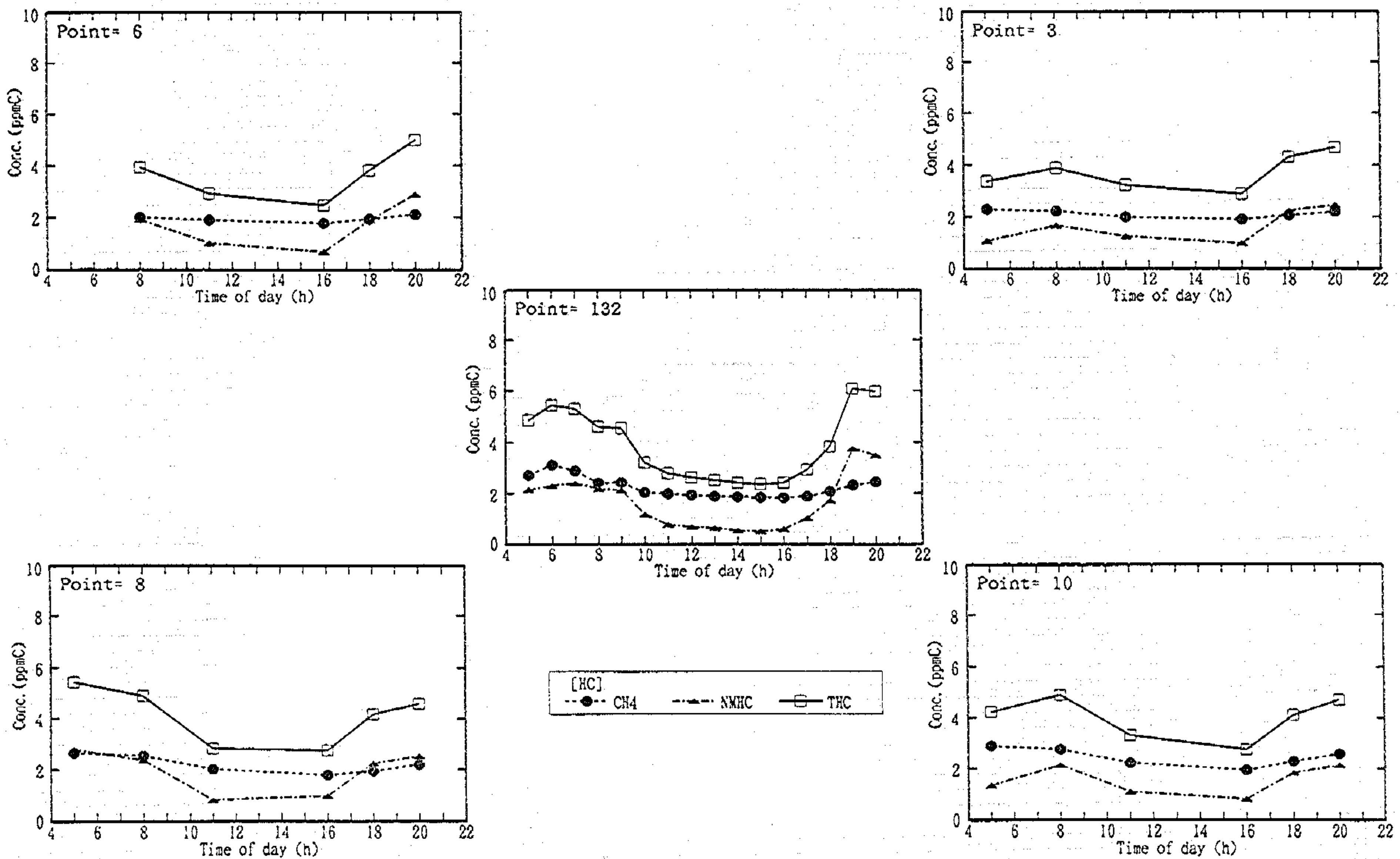


Fig. 4.2.1-4 (1) Diurnal variation of HC concentration (5)
Autumn Run0-Run3 Oct. 8, 10, 11, 12 '96 (4 days average)

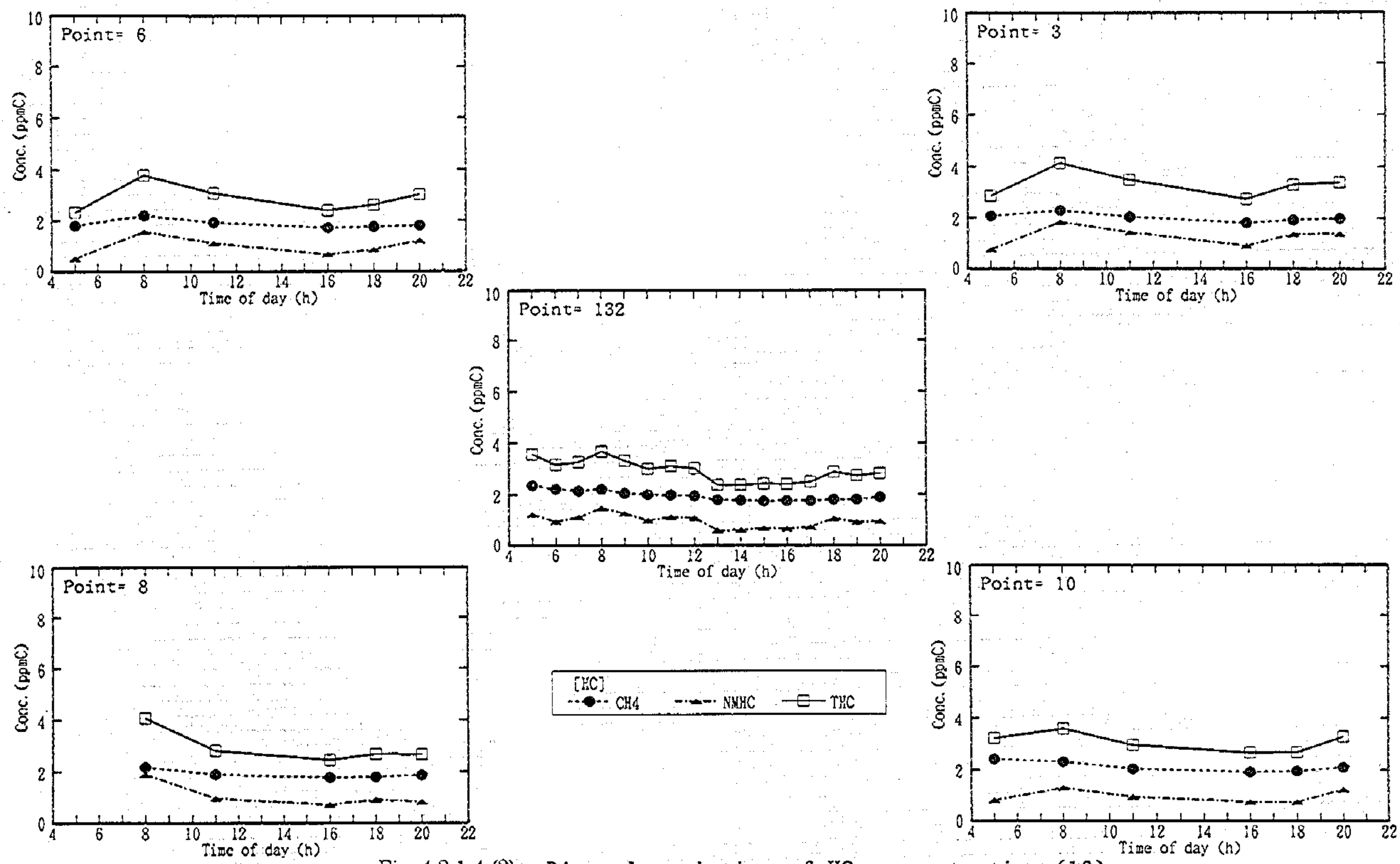


Fig. 4.2.1-4 (2) Diurnal variation of HC concentration (10)
Winter Run1-Run4 Feb. 22, 24, 26, 28 '97 (4 days average)

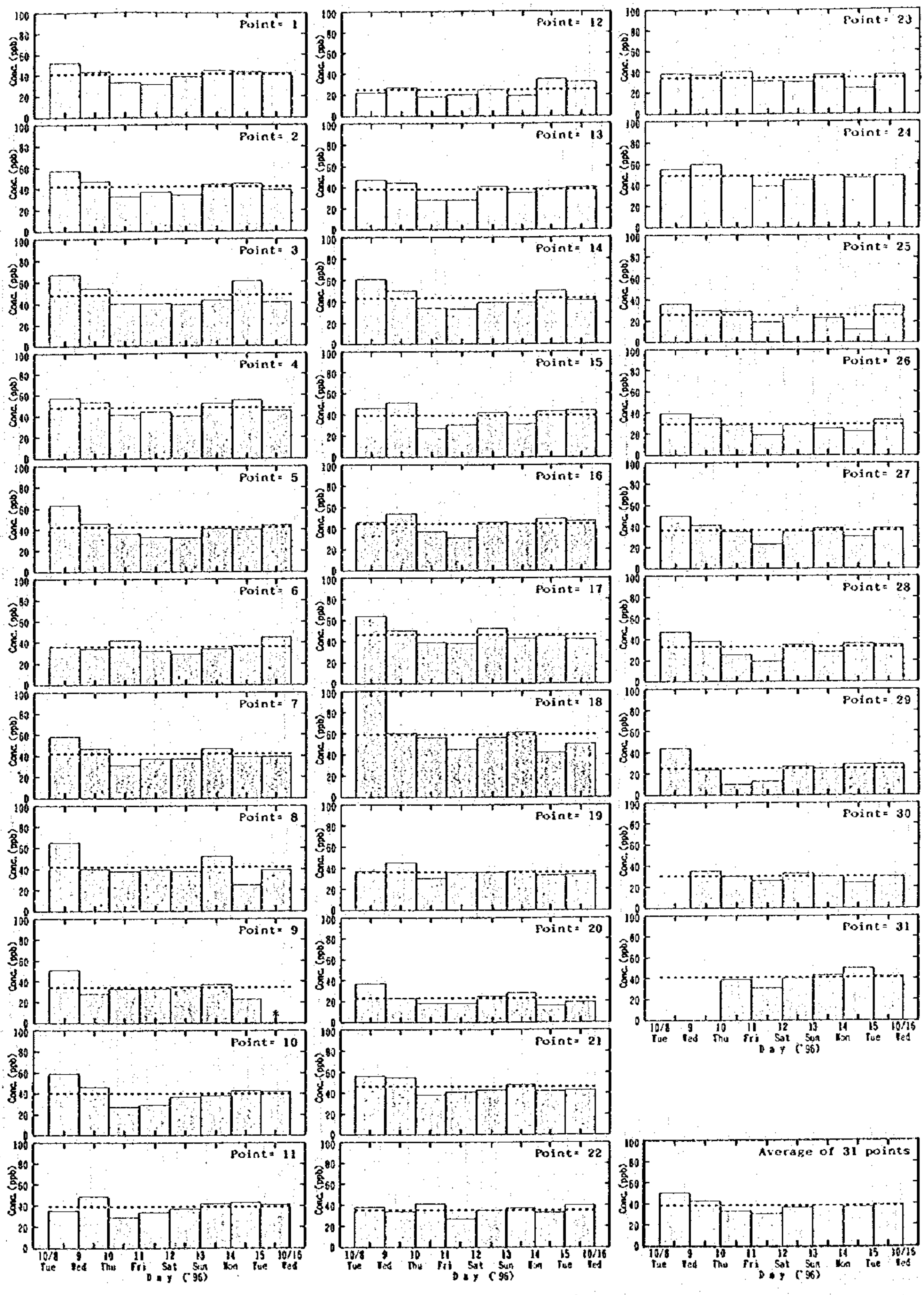


Fig. 4.2.1-5(1) Daily variation of NO_2 concentration (1)
(Autumn)

(Notes) * : Missed data
----- : Average

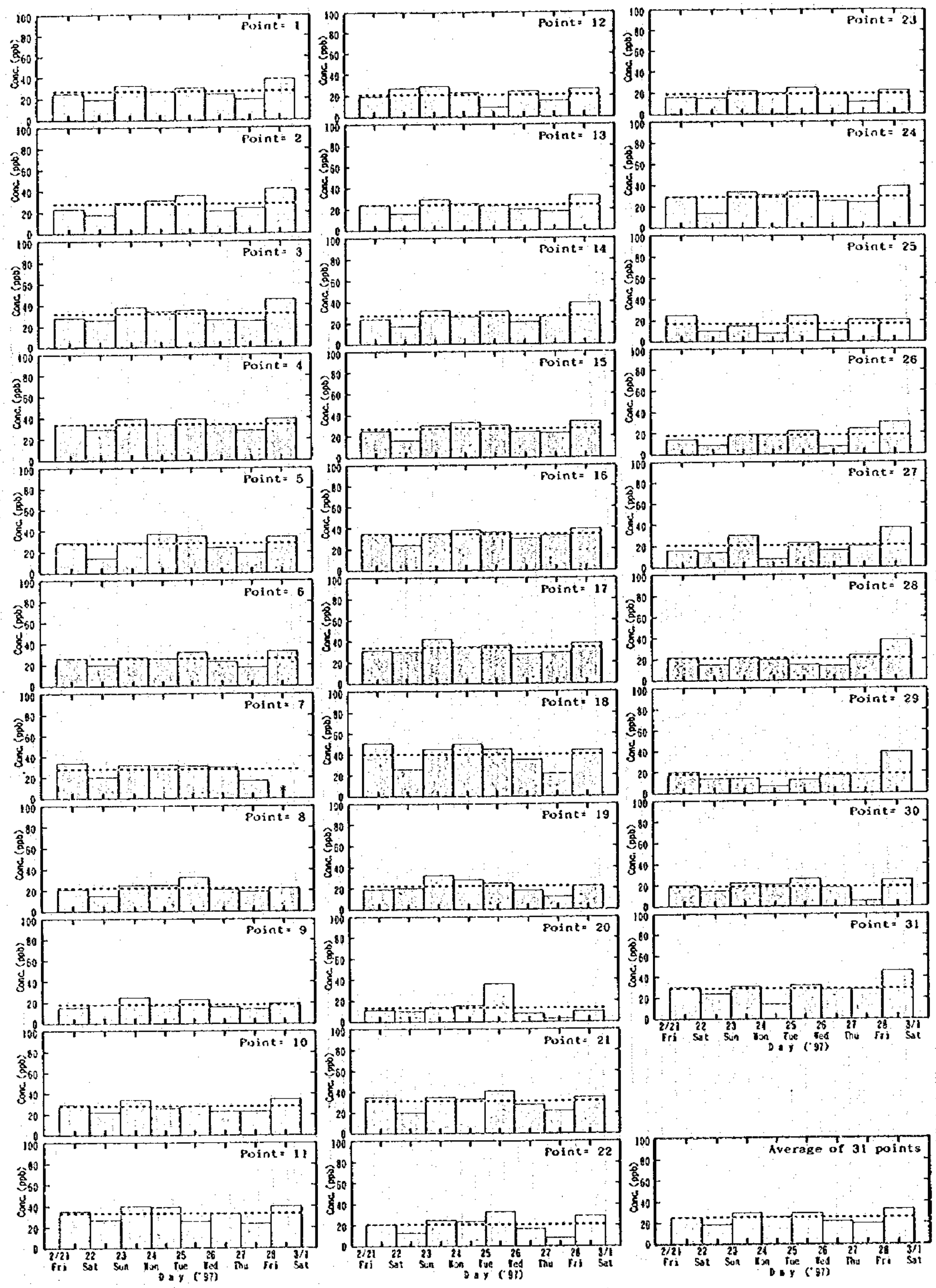


Fig. 4.2.1-5(2) Daily variation of NO_2 concentration (2)
(Winter)

(Notes) * : Missed data
..... : Average

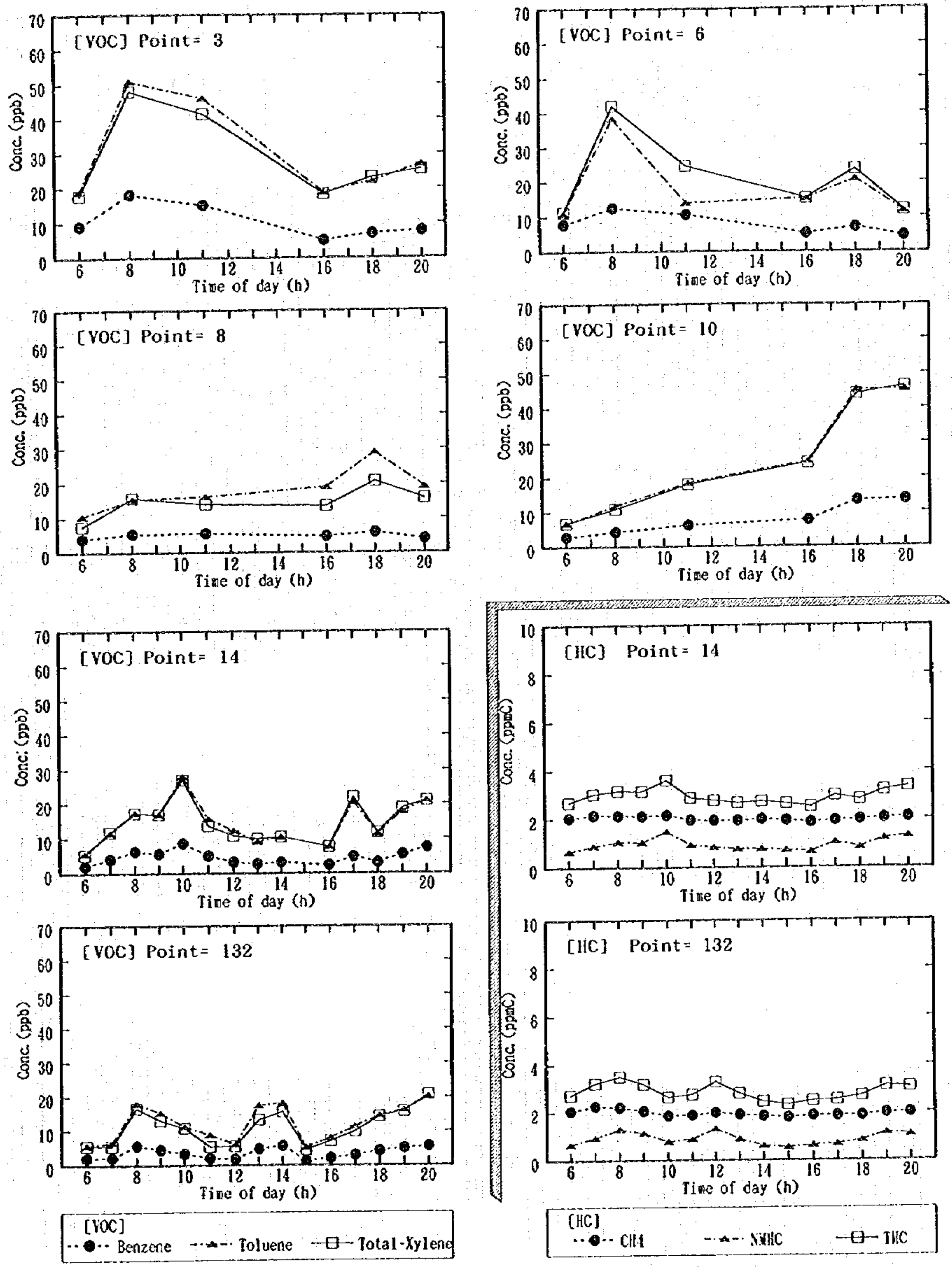


Fig. 4.2.1-6(1) Diurnal variation of VOC and HC concentrations (1)
Winter - Run 1 Mar. 8 '97

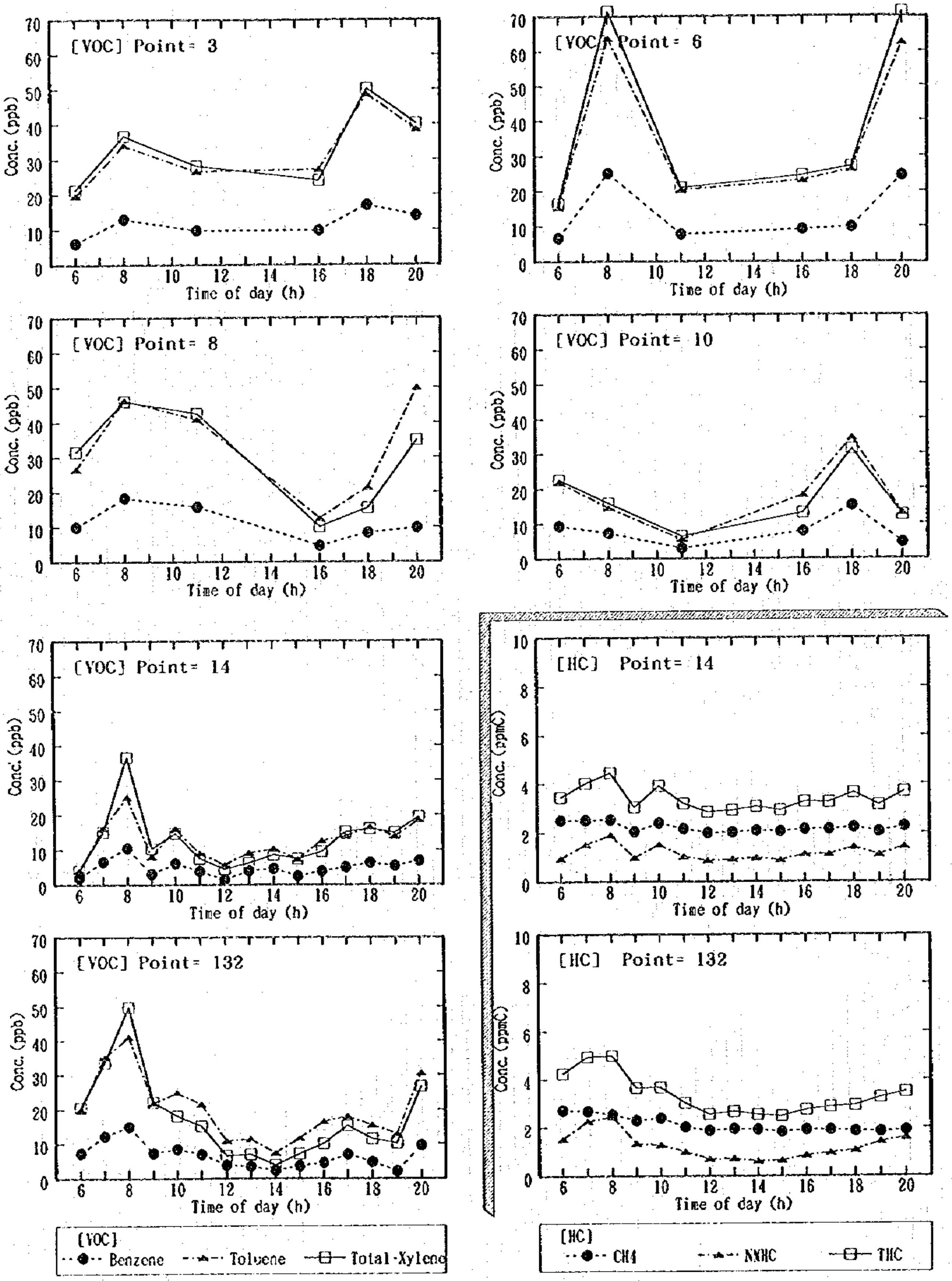


Fig. 4.2.1-6(2) Diurnal variation of VOC and HC concentrations (2)
Winter - Run 2 Mar. 9 '97

Table 4.2.1-3 Comparison of the concentrations of SPM and its components measured and analyzed in Tehran and Japan

Item	Concentration of Pollutants (ng/m^3)						Ratio of [Tehran]/[Kawasaki]*4	
	Measured in Tehran		Measured in Japan					
	Autumn	Winter	Kawasaki (Kanagawa)*1		Nohoro (Hokkaido)*2		Autumn	Winter
	Average	Average	Average	(Min-Max)	Average	(Min-Max)		
SPM*3	94	68	35	(19-47)	7	(5-10)	2.7	1.9
Al	2336	1273	340	(130-530)	54	(19-120)	6.9	3.7
Cl	829	939	260	(44-710)	38	(<20-120)	3.2	3.6
Cu	<30	<30	30	(16-49)	27	(4.7-130)	~1	~1
Mn	63	36	33	(22-53)	3.2	(1.9-6.4)	1.9	1.1
V	30	30	7.1	(4.2-14)	1.7	(0.49-4.3)	4.2	4.2
As	16	20	2.4	(2.0-3.4)	0.76	(0.37-1.4)	6.7	8.3
Cr	8.4	1.1	15	(9.5-21)	<0.5	(<0.5-3.7)	0.6	0.1
Fe	2121	1247	1100	(690-1600)	66	(<40-120)	1.9	1.1
Th	0.47	0.21	0.071	(0.05-0.11)	<0.02	(<0.01-0.29)	6.6	3.0
Zn	628	360	240	(140-330)	31	(18-50)	2.6	1.5
Pb	815	527	87	(54-120)	<10	(<10-10)	9.4	6.1

(Notes) Concentration data in Japan are quoted from "Annual report of the air pollution of Japan (1995)"

*1 : Kawasaki is selected as the typical industrial area of Japan

*2 : Nohoro is selected as the typical rural area of Japan

*3 : unit of SPM = $\mu g/m^3$

*4 : Based on the average data

4.3 Traffic volume survey

4.3.1 Traffic volume survey

MOT has established an area in the central part of the City in which unauthorized vehicles entry is restricted. In addition, controls have also been placed on the entry of large trucks into the city, as well as on the flow of traffic by establishing a large number of one-way streets.

In order to analyze the present status of pollution and evaluate impacts of these measures, it is necessary to understand the current status, such as the traffic volume within Tehran and their daily fluctuation patterns. Such variables are characterized by places, time and land usage in each area of the City, such as, commercial, industrial and residential areas and are affected by traffic regulations or restrictions.

The objectives of this survey are to understand the characteristics inherent with the volume of traffic and their daily fluctuation patterns within Tehran, and to correlate these findings for preparation of an effective countermeasure.

The survey was implemented at the 20 major intersections in Tehran as indicated in Fig.4.3.1-1. In selecting these locations, (1) past traffic volume survey results, (2) road types, (3)present status of traffic control, and (4) land usage have been taken into consideration. The names of the survey points and their numbers shown in Fig.4.3.4-1 are as follows:

1 BOZORG-RAH-E-RESALAT
2 MEDAN-E-FATEMI
3 MEDAN-E-ENQELAB
4 MEYDAN-E-GOMROK
5 INTERSECTION, SHAHID MOSTAFA KHOMEYNI and MOLAVI
6 INTERSECTION, JOMHURI-YE-ESLAMI and FERDOWSI
7 BOZORG-RAH-E-SHAHID DOKTOR CHAMRAN
8 BOZORG-RAH-E-SHEYKH FAZL-OL-LAH-NURI
9 MEYDAN-E-RESALAT
10 MEYDAN-E-KHORASAN

11 MEYDAN-E-AZADI

12 MEYDAN-E-VALI-YE-ASR

13 MEYDAN-E-SHUSH

14 INTERSECTION, VALI-YE-ASR and ENQELAB

15 INTERSECTION, SOHRVARDI and SHAHID AYATOLLA BEHESHITI

16 INTERSECTION, SABALAN and DAMAVAND

17 JADDEH-YE-KHORASAN

18 INTERSECTION, FADA'IYAN-E-ESLAM and JADDEH-YE-VARAMIN

19 INTERSECTION, QUAZVIN and AZARI

20 BOZORG RAH-E-AYATOLLAH-E-SADR

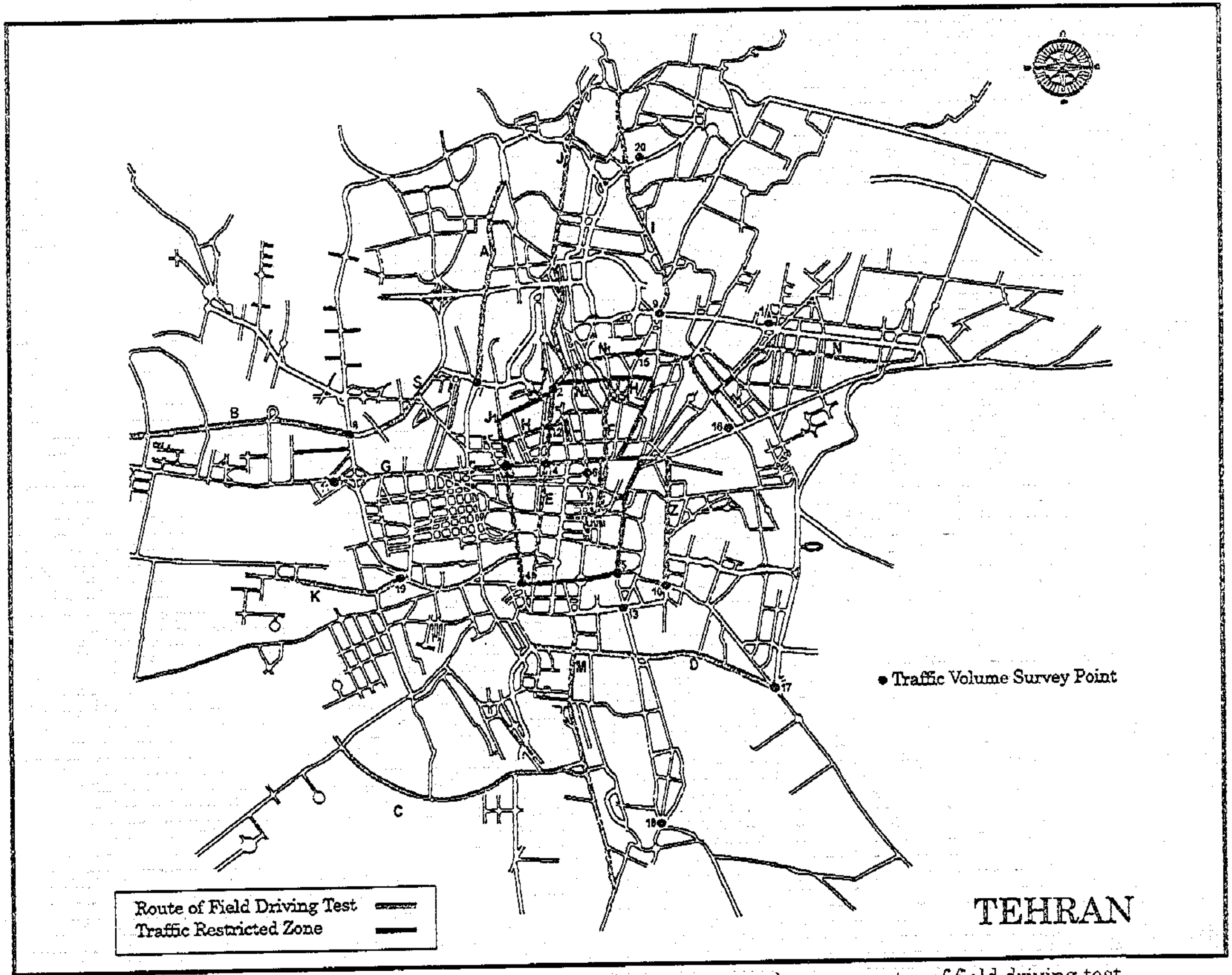


Fig. 4.3.1-1 Survey Sites of traffic volume survey and survey routes of field driving test

At each surveying point, a video camera with a recorder unit was installed to count traffics and classified by vehicle types and driving pictures were later played back. The types of vehicle were classified into seven categories, i.e. passenger cars, pick-ups, mini-buses, buses, mini trucks, trucks and motor cycles. Although recordings were made continuously over a 24hour period from midnight, measurements and counting were selectively carried out so as to meet the study objectives. The measurements were based on 10 minute periods from the beginning of every hour during the off-peak time, i.e. total of 10 minutes every hour, and additionally 10 minutes at a frequency of every 20 minutes during the peak hours totaling 30 minutes every hour.

-Measurement/Counting time in off-peak times;

12:00 midnight to 05:00, 10:00 to 15:00, 21:00 to 23:00

-Measurement/Counting time in peak times;

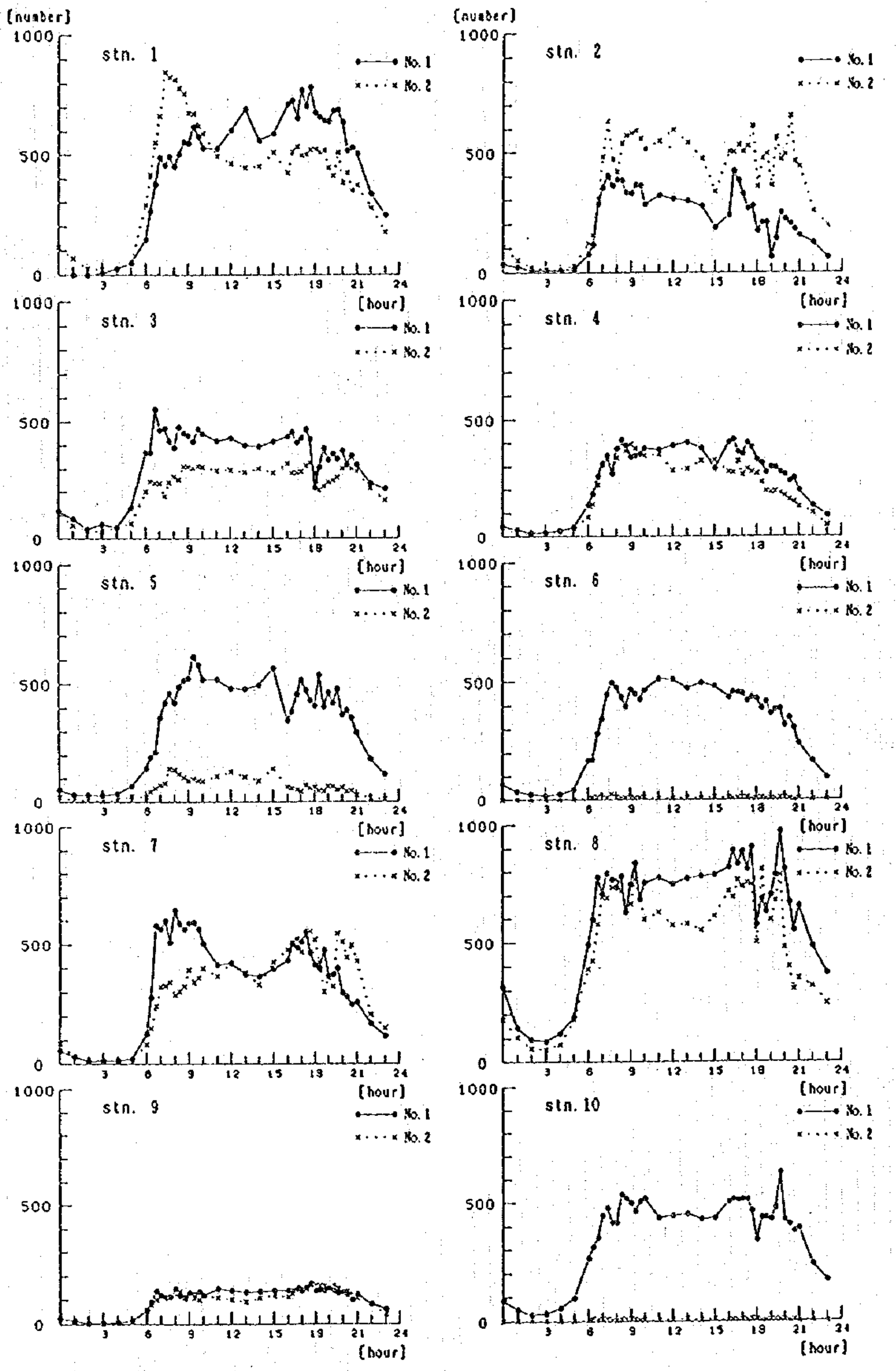
06:00 to 09:00, 16:00 to 20:00

The survey was carried out on two separate days; a normal working day and a holiday. As Thursday is a half-day and Friday is a holiday in Iran, Friday was selected as the holiday for the survey, and Monday was selected as the normal working day.

1st survey (working day) : October 7, 1996 (Monday)
2nd survey (holiday) : October 11, 1996 (Friday)

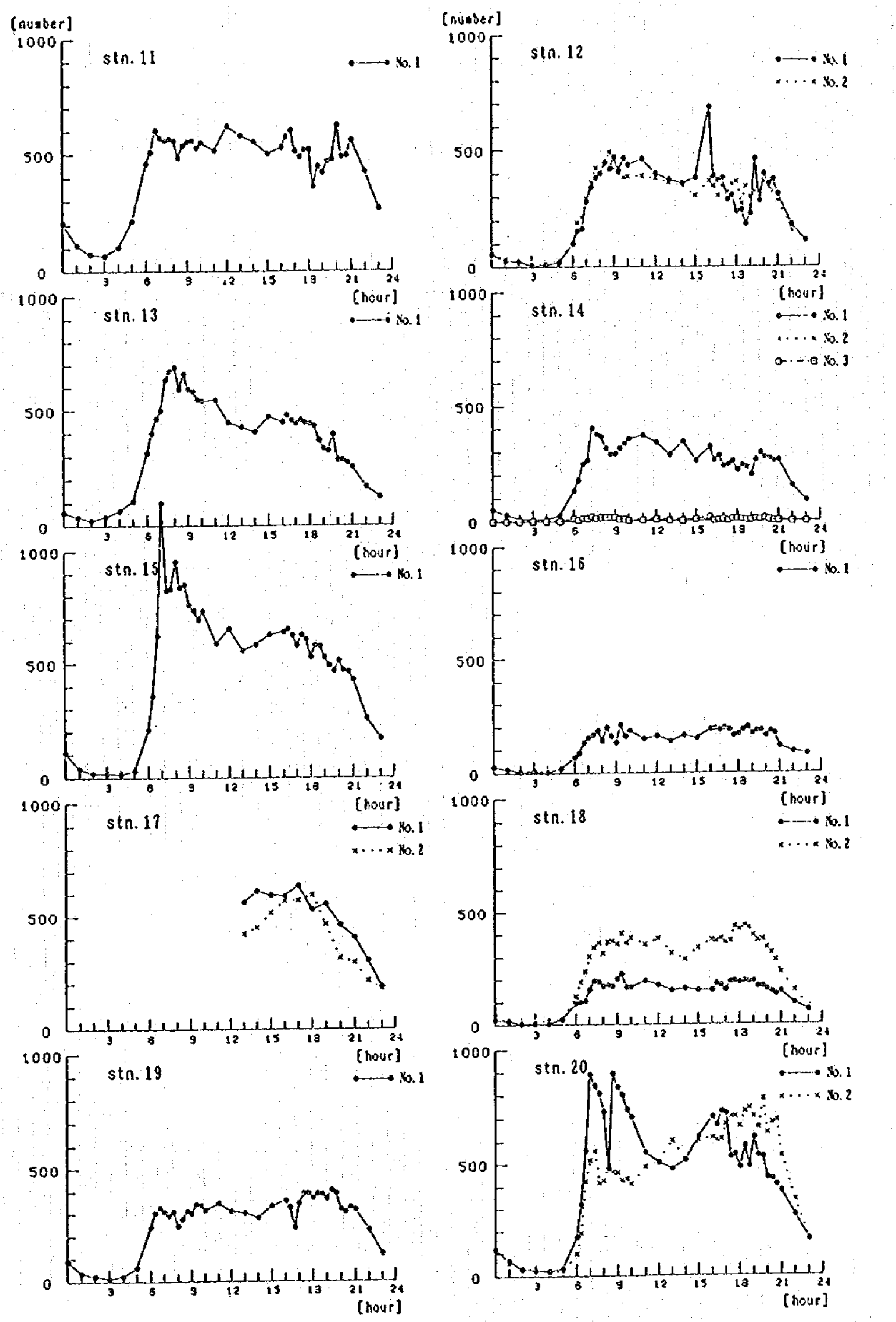
(1) Daily traffic volume fluctuations

The daily fluctuation patterns at each survey point are outlined in Fig.4.3.1-2(1) to 4.3.1-2(4).



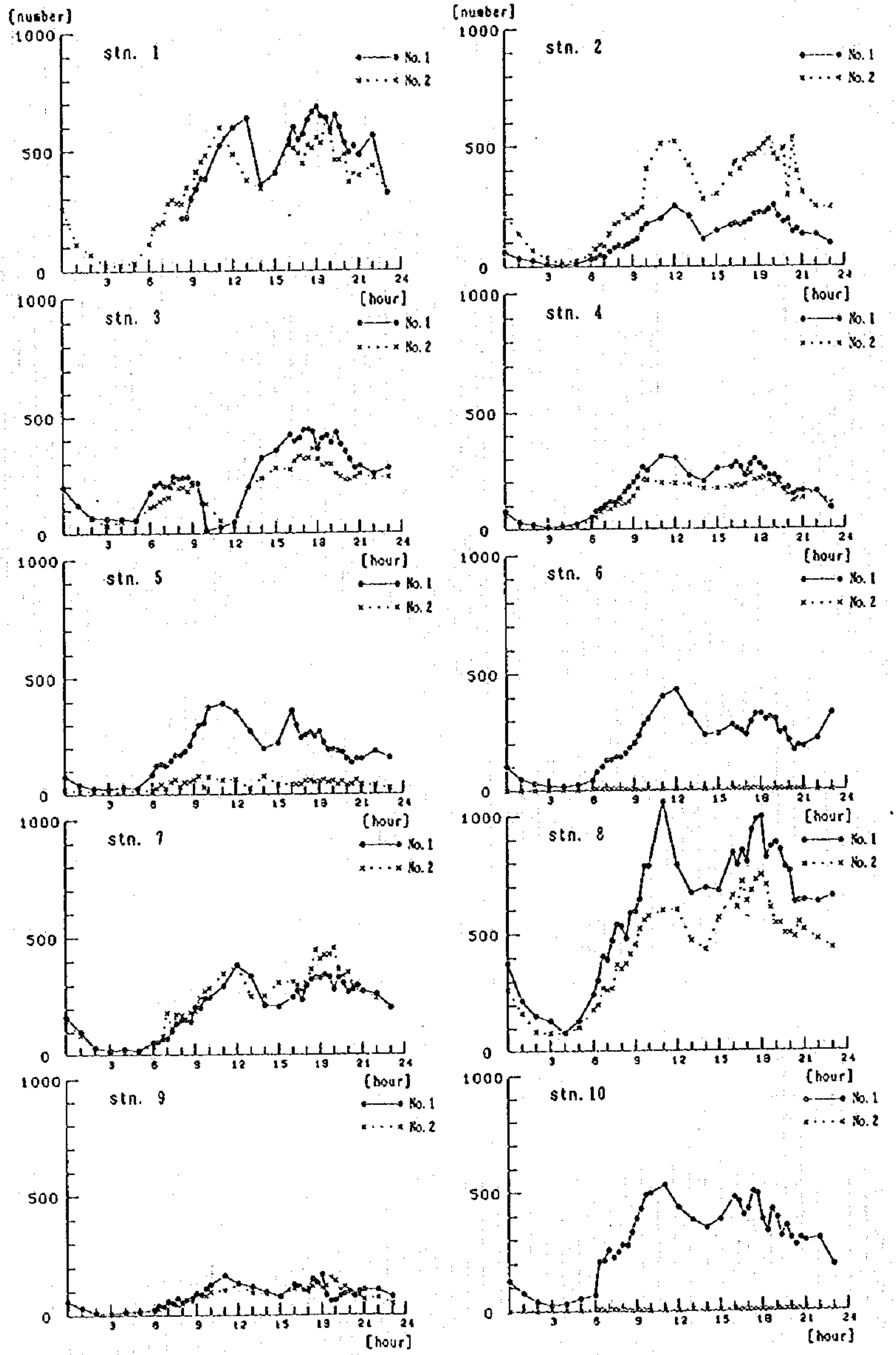
Traffic Volume (10min.) 1996 Oct. 7 Monday

Fig.4.3.1-2(1) Fluctuation of daily traffic Volume



Traffic Volume (10min.) 1996 Oct. 7 Monday

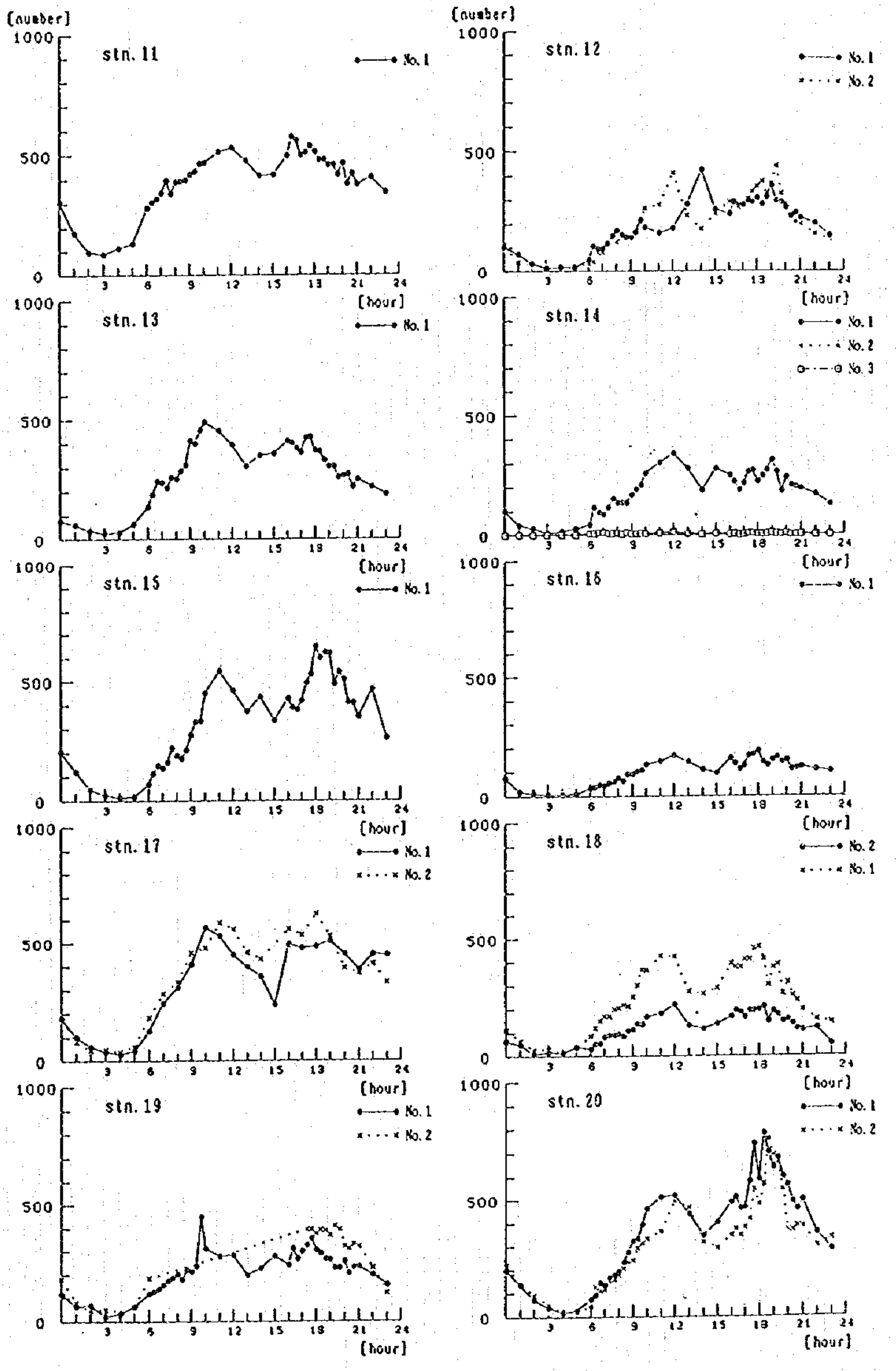
Fig.4.3.1-2(2) Fluctuation of daily traffic Volume



Traffic Volume (10min.)

1996 Oct. 11 Friday

Fig.4.3.1-2(3) Fluctuation of daily traffic Volume



Traffic Volume (10min.)

1996 Oct. 11 Friday

Fig.4.3.1-2(4) Fluctuation of daily traffic Volume

4.4 Analysis of emission from mobile sources

4.4.1 Projection of characteristics of transportation and traffic in GTA

(1)Traffic volume

The database mentioned in 4.3.1 includes traffic volume in 1994 and 2001 classified by the car type and link. In this report, the traffic volume given by the database is used to calculate an amount of emission of CO, SOx, and NOx.

(2)Car velocity

The database mentioned above includes the average speed of each link estimated by TCTTS.

In this report, the traffic speed given by the database is used to calculate amount of emission of CO, SOx and NOx.

(3)Emission factor

The emission of CO, SOx and NOx is specified according to each vehicle type as shown in Table 4.4.1-1, on the basis of the results of chassis dynamo tests, field driving tests and analysis of existing data.

CO emission factors

It is known that as amount of CO emissions from diesel automobiles is negligible compared with that of gasoline automobiles. Accordingly, it was assumed in this report that CO was not emitted from diesel automobiles but only from gasoline automobiles. We made regression analysis of the results of the chassis dynamo test conducted by the study team, and then specified the CO emission factor as a function of vehicle speed on the basis of the vehicle's age and by taking the existing data into account. For example, when a five year old passenger car is running 30.0 km/h, the emission factor (EF) is estimated at 26.4 g/km by applying 1242.0 for "a", -15.0 for "b "and 30.0 for "V" in the following equation:

$$EF = a \cdot V^{-1} + b$$

The results are shown in Table 4.4.1-1. In the case where a passenger car is aged 15 years, "a" is 1242.0, "b" is 18.1, and EF is therefore 59.5 g/km.

As for motor cycles, since the age of all motor cycles is not known, it is assumed that all motor cycles are 10 years of age. Furthermore, an emission factor for high altitudes (23.6 g/km) specified by the U.S. Environmental Protection Agency (EPA) was used.

Tble4.4.1-1(1)Emission factor for each type of vehicle in Tehran

Car type	Pollutant	Car age	Component ratio	Equation : $EF = a \cdot v^{-1} + b$ (g/km)		
Passenger car (Gasoline)	CO	-	-	a	b	c
		0 ~ 10	44 %	1242	-15.0	-
		10 ~ 20	36 %	1242	18.1	-
		20 ~	20 %	1242	70.0	-

Car type	Pollutant	Car age	Component ratio	Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
Passenger car (Gasoline)	NOx	-	-	a	b	c
		0 ~ 10	44 %	2.300E+00	-1.410E-02	7.337E-04
		10 ~ 20	36 %	1.374E+00	-1.275E-02	3.499E-04
		20 ~	20 %	5.045E-01	-1.367E-02	3.211E-04

Car type	Pollutant	Car age	Component ratio	Equation : $EF = a + b \cdot v + cv^2$ (litre/km)		
Passenger car (Gasoline)	SOx	-	-	a	b	c
		0 ~ 10	44 %	1.759E-01	-4.264E-03	3.710E-05
		10 ~	56 %	2.564E-01	-7.639E-03	7.250E-05

Car type	Pollutant	Car age	Component ratio	Equation : $EF = a \cdot V^b$ (g/km)		
Passenger car (Gasoline)	HC	-	-	a	b	c
		0 ~ 10	44 %	12.950	-0.556	-
		10 ~ 20	36 %	36.303	-0.556	-
		20 ~	20 %	70.300	-0.556	-

Table4.4.1-1(2)Emission factor for each type of vehicle in Tehran

Car type	Pollutant	Car age	Component ratio		Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
Motor cycle (Gasoline)	CO	Fix	-		23.6g/km		
	NOx	Fix	-		0.4g/km		
	SOx	Fix	-		-		
Bus・truck (Gas oil)	Pollutant	Car age	Component ratio		Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
	CO	-	Bus	Truck	a	b	c
		-	-	-	8.723E-01	2.080E-02	2.130E-05
Bus・truck (Gas oil)	Pollutant	Car age	Component ratio		Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
	NOx	-	Bus	Truck	a	b	c
		0 ~ 10	38 %	50 %	1.583E+00	-4.001E-02	4.108E-04
		10 ~ 20	31 %	26 %	1.107E+00	-3.190E-02	3.238E-04
		20 ~	31 %	24 %	1.030E+00	-3.001E-02	2.835E-04
Bus・Truck (Gas oil)	Pollutant	Car age	Component ratio		Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
	SOx	-	Bus	Truck	a	b	c
		0 ~ 10	38 %	50 %	7.891E-02	-2.047E-03	1.924E-05
		10 ~	62 %	50 %	1.008E-01	-2.895E-03	2.703E-05
Bus・Truck (Gas oil)	Pollutant	Car age	Component ratio		Equation : $EF = a \cdot V^b$ (g/km)		
	HC	-	Bus	Truck	a	b	c
		Fix	-	-	1.441	-0.555	-
Taxi (LPG)	Pollutant	Car age	Component ratio		Equation : $EF = a + b \cdot v + cv^2$ (g/km)		
	CO	-	-		a	b	c
		Fix	-		28.0	1.2	-

SOx emission factors

The amount of SOx emissions does not depend on the state of fuel combustion, while that of CO and NOx does. It can be obtained from the amount of fuel consumption and that of sulfur content. The value of emission to be obtained from the amount of fuel consumption is given by the following equation:

$Q = W \times Sp \times Si \times 10^{-2} \times 64/32$

Q : The amount of SOx emissions (g)

W : The amount of fuel consumption (litre)

Sp : Specific gravity

Si: The amount of sulfur content (wt%)

Accordingly, the amount of fuel consumption by passenger cars, buses and trucks are shown in Table 4.4.1-1 as a function of vehicle speed on the basis of a vehicle's age. The expression of fuel consumption shown in the Table is in terms of consumption per ton of gross vehicle weight. Consequently, in calculating the amount of fuel consumption, the results calculated according to the expressions in the table must be multiplied by the gross vehicle weight of each type of vehicle. In this report, we defined the gross vehicle weight as the average vehicle weight plus one-half of the maximum load capacity. The gross vehicle weight of each type of vehicle is as follows:

Bus : 10 ton

Mini bus : 3.0 ton

Truck : 8.0 ton

Pick up : 1.2 ton

When a 20 year old truck is running at 30.0 km/h, the amount of fuel consumption is calculated at 0.72 lit/km by applying 1.008E-01 for "a", 2.895E-03 for "b", 2.703E-05 for "c" and 30.0 for "V", and multiplying the obtained value, 0.12 lit /ton. km, with the gross vehicle weight, 6.0 ton.

$EF = a + b \cdot V + c \cdot V^2$

NOx emission factors

We specified NOx emissions from gasoline automobiles as shown in Table4.4.1-2, using the same procedure used to determine CO emissions: we made regression analysis, taking the existing data into account. Since chassis dynamo tests cannot be carried out on diesel automobiles in Tehran, it is impossible to specify NOx emissions comparing with the results obtained from the tests carried out on carried out on the spot. Accordingly, in calculating NOx emissions from buses and trucks, we used the equation introduced in the Japanese NOx manual.

As for motor cycles, on account of difficulty in knowing the ages of all motor cycles, as in the case of CO emissions, it is assumed that all motor cycles are 10 years of age, and the emission factors for high altitudes (0.4 g/km) specified by the U.S. Environmental Protection Agency (EPA) were used.

4.4.2 Analysis of emission amount from automobiles

The emission estimates of CO, SOx and NOx in GTA under the conditions specified in 4.4.1 are shown in Table 4.4.2-1.

Fig.4.4.2-1 Amount of CO, SOx,NOx and HC emission from automobiles

Year	No	Car type	Unit	Pollutants			
				CO	HC	SOx	NOx
1994	1	Mobile source(total)	ton/year	826,804	81,691	8,340	39,610
	(1)	Motor Cycle	ton/year	64,085	16,293	179	1,086
	(2)	Passenger Car	ton/year	478,017	41,296	1,177	21,865
	(3)	Taxi	ton/year	158,572	13,336	331	5,381
	(4)	Pick Up	ton/year	105,660	9,099	262	5,030
	(5)	Mini Bus	ton/year	4,164	360	1,325	1,245
	(6)	Bus	ton/year	8,492	756	2,995	2,784
	(7)	Truck	ton/year	7,814	551	2,071	2,219

4.5 Analysis of emission from stationary source

4.5.1 Measured results of target emission source

The results of measurement of exhaust gas emissions from stationary source described in section 3.4.2(4) of the final report are evaluated below.

(1) Brick manufacturing company (Sofal Jadid)

CO emission is very high although natural gas is used and an excess air ratio is very high, supposedly due to improper combustion of fuels in a furnace. It is believed that combustion can be improved by exchange of burner tips and that much energy can be saved by cutting an excess air ratio.

(2) Thermal power plant (Besat)

Measurement was conducted when natural gas was fueled. Further NOx can be reduced by cutting an excess air ratio since it is higher than in the case of usual operation of a thermal power plant.

(3) Tehran Refinery

Outlet temperatures of exhaust gas are higher than 430 C, meaning that energy conservation is possible through waste heat recovery with concurrent reduction of pollutants. As SOx emission is very high due to burning of high sulfur residues, countermeasures for total SOx reduction are to be considered.

(4) Tehran Cement

The SPM concentrations have been high in No.4 and No.6 facilities during the time of first and second field surveys although electrostatic precipitators are installed. NOx emission is high in all factories while CO emission is abnormally high in the No.4 factory. SOx are practically not emitted because SOx can be absorbed in the process by chemical reaction with $CaCO_3$ except flue gas from utilities units.

(5) Combustion appliances for household use

Extremely high CO emission is observed in a hot water heater located on the closed ground floor supposedly due to imperfect combustion in the shortage of air supply. In general, CO emitted from the room heater is rather high compared with the projected emission factors, supposedly due to a lack of fresh air exchange in the closed room.

Table 4.5.1-1 shows the measured emission factors in comparison with the projected factors. Except some cases of CO, NOx and SOx mentioned above, the observed factors are almost the same with the projected ones within the allowable limit.

Table 4.5.1-2 compares the measured concentration of SOx, NOx and SPM with the emission standards in Japan, the outcome of which are described below.

- SOx : The K value of emissions from Tehran Refinery is larger than the expected value of 3.0, while the K values of the other emission sources are within the allowable limit.

  (Note) Q=K *10^-3*He^2

  where, Q : Allowable limit of emission value of SOx (Nm3/h)

  K : Constant defined by areas

  1) General emission standard (3.0-17.5)

  2) Special emission standard(1.17-2.34)

  He : Effective height of stack(m)

- NOx : NOx emissions of all the factories other than the brick and power plants are 40% higher on an average than the emission standard in Japan.
- SPM: In Tehran Cement, 5 out of 7 measurements are higher than the standard in Japan.

As a whole, a great deal of emission of pollutants can be reduced by means of strict combustion control and waste heat recovery procedures, since so many cases of imperfect combustion are observed for the room heaters as an example due to a design philosophy which have not fully taken thermal efficiency into account as well as improper operation and maintenance of these equipment.

Table 4.5.1-1 : Comparison of emission factors between measurement & projected values

(1) First field survey

Item	Unit	Sofal Jadid		Besat		Tehran Refinery								Tehran Cement							
		(Brick)		(power plant)		2H-101		2H-151		2H-181		Boiler		No.4		No.5		No.6		No.7	
Date	-	96.09.22		96.09.24		96.09.28		96.09.29		96.10.01		96.10.02		96.10.05		96.10.06		96.10.08		96.10.09	
Fuel	-	Natural Gas		Natural Gas		Gas & Oil		Gas & Oil		Gas & Oil		Heavy Oil		Natural Gas		Natural Gas		Natural Gas		Natural Gas	
(Measured vs Projected)		Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd
Outlet Temp	C	97		-		429	180	-	180	446	180	426	180	148		188		128		115	
Excess Air Ratio		12.8		2.32		1.52		1.32		1.55		1.24		2.19		1.97		2.03		3.25	
Emission Factor																					
CO	g/Gj	113	7	0	7	27	16	-		49	16	0	16	2370	7	0	7	9.1	7	33	7
SOx	g/Gj	8.8	1	2.5	1	1747	1637	-		2150	1637	-	1637	9.4	1	0	1	0	1	0	1
NOx	g/Gj	68	73	60	234	297	325	-		382	325	98	325	368	73	190	73	471	73	536	73
SPM	g/Gj	0	6	-	6	28	70	-		28	70	5.3	70	321	6	5.3	6	372	6	23	6

(2) Second field survey

Item	Unit	Room Heater								Cooking Burner				Boiler		Tehran Cement						Tehran Refinery			
		Gas Oil		Kerosene		Fire Place		Heater(NG)		NG		LPG		Water heater		No.4		No.6		No.7		2H-101		Boiler	
Date	-	97.02.18		97.02.18		97.02.19		97.02.19		97.02.22		97.02.22		97.02.20		97.02.25		97.02.26		97.03.06		97.03.01		97.03.02	
Fuel	-	Gas Oil		Kerosene		Natural Gas		Natural Gas		Natural Gas		LPG		Natural Gas		Natural Gas		NG + HO		Natural Gas		FG + FO		Fuel Oil	
(Measured vs Projected)		Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd
Outlet Temp	C	-		-		-		-		-		-		-		145		158		126		429	180	460	180
Excess Air Ratio																2.17		2.31		2.19		1.73		1.14	
Emission Factor																									
CO	g/Gj	106	15	595	15	234	8	32.2	8	0	8	0	8	10200	8	1850	7	0	7	30.3	7	0	12	884	12
SOx	g/Gj	316	447	103	64	13.1	1	0	1	21.2	1	3.9	1	-	1	7.7	1	0	1	0	1	4870	1404	2100	1404
NOx	g/Gj	24.2	71	17.6	62	46.5	50	45	50	23.3	50	61.8	50	12.5	50	425	73	407	73	331	73	746	175	360	175
SPM	g/Gj	-	55	-	22	-	7	-	7	-	7	-	7	-	7	212	6	284	6	89.4	6	91.8	67	-	67

(Note) [shaded] Measured emission factors > projected emission facrors

Table 4.5.1-1 : Comparison of emission factors between measurement & projected values

(1) First field survey

Item	Unit	Sofal Jadid (Brick)		Besat (power plant)		Tehran Refinery 2H-101		Tehran Refinery 2H-151		Tehran Refinery 2H-181		Tehran Refinery Boiler		Tehran Cement No.4		Tehran Cement No.5		Tehran Cement No.6		Tehran Cement No.7	
Date	-	96.09.22		96.09.24		96.09.28		96.09.29		96.10.01		96.10.02		96.10.05		96.10.06		96.10.08		96.10.09	
Fuel	-	Natural Gas		Natural Gas		Gas & Oil		Gas & Oil		Gas & Oil		Heavy Oil		Natural Gas		Natural Gas		Natural Gas		Natural Gas	
(Measured vs Projected)		Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd
Outlet Temp	C	97		-		429	180	-	180	446	180	426	180	148		188		128		115	
Excess Air Ratio		12.8		2.32		1.52		1.32		1.55		1.24		2.19		1.97		2.03		3.25	
Emission Factor																					
CO	g/Gj	113	7	0	7	27	16	-		49	16	0	16	2370	7	0	7	8.1	7	33	7
SOx	g/Gj	8.6	1	2.5	1	1747	1637	-		2150	1637	-	1637	9.4	1	0	1	0	1	0	1
NOx	g/Gj	68	73	60	234	297	325	-		382	325	98	325	368	73	140	73	471	73	538	73
SPM	g/Gj	0	6	-	6	28	70	-		28	70	5.3	70	321	6	5.3	6	372	6	23	6

(2) Second field survey

Item	Unit	Room Heater Gas Oil		Room Heater Kerosene		Room Heater Fire Place		Room Heater Heater(NG)		Cooking Burner NG		Cooking Burner LPG		Boiler Water heater		Tehran Cement No.4		Tehran Cement No.6		Tehran Cement No.7		Tehran Refinery 2H-101		Tehran Refinery Boiler	
Date	-	97.02.18		97.02.18		97.02.19		97.02.19		97.02.22		97.02.22		97.02.20		97.02.25		97.02.26		97.03.06		97.03.01		97.03.02	
Fuel	-	Gas Oil		Kerosene		Natural Gas		Natural Gas		Natural Gas		LPG		Natural Gas		Natural Gas		NG + HO		Natural Gas		FG + FO		Fuel Oil	
(Measured vs Projected)		Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd	Meas'd	Proj'd
Outlet Temp	C	-		-		-		-		-		-		-		145		158		126		429	180	460	180
Excess Air Ratio																2.17		2.31		2.19		1.73		1.14	
Emission Factor																									
CO	g/Gj	106	15	595	15	234	8	32.2	8	0	8	0	8	10200	8	1850	7	0	7	30.3	7	0	12	884	12
SOx	g/Gj	316	447	103	64	13.1	1	0	1	21.2	1	3.9	1	-	1	7.7	1	0	1	0	1	4870	1404	2100	1404
NOx	g/Gj	24.2	71	17.6	62	46.5	50	45	50	23.3	50	61.8	50	12.5	50	425	73	407	73	331	73	746	175	360	175
SPM	g/Gj	-	55	-	22	-	7	-	7	-	7	-	7	-	7	212	6	284	6	89.4	6	91.6	67	-	67

(Note) [shaded] Measured emission factors > projected emission facrors

Table 4.5.1-2 ; Comparison table between measured emission concentration and emission standard in Japan

(1) First field survey

Item	Unit	Sofal Jadid		Besat		Tehran Refinery								Tehran Cement							
		(Brick)		(power plant)		2H-101		2H-151		2H-181		Boiler		No.4		No.5		No.6		No.7	
Date	-	96.09.22		96.09.24		96.09.28		96.09.29		96.10.01		96.10.02		96.10.05		96.10.06		96.10.08		96.10.09	
Fuel	-	Natural Gas		Natural Gas		Gas & Oil		Gas & Oil		Gas & Oil		Heavy Oil		Natural Gas		Natural Gas		Natural Gas		Natural Gas	
(Measured vs stadard)		Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd
SOx	K	0.27	3.00		3.00	3.22	3.00		3.00	4.10	3.00	4.91	3.00	0.11	3.00	0.03	3.00	0.02	3.00	0.02	3.00
NOx	ppm	69	250	132	150	154	100	125	100	188	100	212	150	311	250	199	350	418	250	516	250
SPM	g/m3	>0.005	0.1		0.15	0.023	0.1		0.1	0.024	0.1	0.023	0.15	0.56	0.1	0.009	0.1	0.67	0.1	0.045	0.1

(2) Second field survey

Item	Unit	Tehran Cement						Tehran Refinery			
		No.4		No.6		No.7		2H-101		Boiler	
Date	-	97.02.25		97.02.26		97.03.06		97.03.01		97.03.02	
Fuel	-	Natural Gas		NG + HO		Natural Gas		FG + FO		Fuel Oil	
(Measured vs stadard)		Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd
SOx	K	0.10	3.00	0.02	3.00	0.01	3.00	3.21	3.00	3.62	3.00
NOx	ppm	325	250	302	250	272	250	144	100	173	150
SPM	g/m3	0.34	0.1	0.43	0.1	0.15	0.1	0.036	0.1		0.15

(Note) [shaded] Measured concentration >standard in Japan

Table 4.5.1-2 : Comparison table between measured emission concentration and emission standard in Japan

(1) First field survey

Item	Unit	Sofal Jadid		Besat		Tehran Refinery								Tehran Cement							
		(Brick)		(power plant)		2H-101		2H-151		2H-181		Boiler		No.4		No.5		No.6		No.7	
Date	-	96.09.22		96.09.24		96.09.28		96.09.29		96.10.01		96.10.02		96.10.05		96.10.06		96.10.08		96.10.09	
Fuel	-	Natural Gas		Natural Gas		Gas & Oil		Gas & Oil		Gas & Oil		Heavy Oil		Natural Gas		Natural Gas		Natural Gas		Natural Gas	
(Measured vs stadard)		Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd
SOx	K	0.27	3.00		3.00	3.22	3.00		3.00	4.10	3.00	4.61	3.00	0.11	3.00	0.03	3.00	0.02	3.00	0.02	3.00
NOx	ppm	69	250	132	150	154	100	125	100	168	100	212	150	311	250	199	350	418	250	516	250
SPM	g/m3	>0.005	0.1		0.15	0.023	0.1		0.1	0.024	0.1	0.023	0.15	0.56	0.1	0.009	0.1	0.57	0.1	0.045	0.1

(2) Second field survey

Item	Unit	Tehran Cement						Tehran Refinery			
		No.4		No.6		No.7		2H-101		Boiler	
Date	-	97.02.25		97.02.26		97.03.06		97.03.01		97.03.02	
Fuel	-	Natural Gas		NG + HO		Natural Gas		FG + FO		Fuel Oil	
(Measured vs stadard)		Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd	Meas'd	Stan'd
SOx	K	0.10	3.00	0.02	3.00	0.01	3.00	3.21	3.00	3.62	3.00
NOx	ppm	325	250	302	250	272	250	144	100	173	150
SPM	g/m3	0.34	0.1	0.43	0.1	0.15	0.1	0.036	0.1		0.15

(Note) [shaded] Measured concentration >standard in Japan

4.5.2 Estimation of emission quantities in GTA

(1) Summary of emission quantities

1) Total GTA

As shown in Table 4.5.2-1, contributions of stationary emission sources and mobile emission sources to total emission of air pollution in GTA are projected in the case of 1994 at 29% and 71% respectively, demonstrating the dominance of mobile sources.

Concerning the contribution of each pollutant, stationary sources share 97% and 71% in SOx and NOx while mobile sources share 94%, 70% and 88% in CO, HC and SPM respectively.

The year of 1994 is selected for estimation of emission quantities, since publicized statistic data for energy consumption in Iran are available in the most abundance in this year among the several latest years.

Table 4.5.2-1 : Emission quantity of air pollutants in GTA (1994)

(ton/year, %)

Source	SOx	NOx	CO	HC	SPM	(Total)
Stationary	253,981	95,571	51,421	34,701	25,113	460,786
Mobile	8,340	39,610	826,806	81,690	182,717	1,139,163
(Sub-total)	262,321	135,181	878,227	116,391	207,830	1,599,949
Stationary	96.8	70.7	5.9	29.8	12.1	28.8
Mobile	3.2	29.3	94.1	70.2	87.9	71.2
(Sub-total)	100.0	100.0	100.0	100.0	100.0	100.0

The emissions from stationary sources in total Iran is projected in the same procedure with the case of GTA, which is shown in Table 4.5.2-2 for reference.

Table 4.5.2-2 : Stationary emission quantity of air pollutants in total Iran (1994)

(ton/year)

Source	SOx	NOx	CO	HC	SPM	(Total)
Stationary	1,186,885	470,315	140,181	168,212	95,486	2,061,079

(Note) Emissions from flaring associated gas are not included in this projection

2) Sector-wise emission

As shown in Table 4.5.2 -3 and Fig 4.5.2 -1, the following features are revealed.

(a) SOx emissions from the manufacturing sector shares 64% of the total, followed by energy conversion of 19%, general service & household of 14% and the transport sector of 3%. In the manufacturing sector, nonmetal products have the biggest share of 32%, and Tehran Refinery alone 13%, while the transport sector shares only 3% in contrast to other kinds of emissions, since this sector uses low sulfur gasoline and diesel oil. The thermal power plants in GTA share only 6% since most of the fuels have already been substituted by natural gas except in winter when supply of natural gas is sometimes short.

(b) NOx emission has tendency similar to SOx although the share of the transport sector reaches 29% of total emission. Nonmetal products and Tehran Refinery have 11% and 9.0% shares respectively, followed by power plants of 8.7%. The general service and household sector has 11% share, though this sector has numerous consuming units.

(c) Most HC emission comes from the transport sector accounting for 70%, Tehran Refinery 14% and commercial & general 12%; the combined share of these 3 sectors totals 96%. HC emission sources of the commercial sector are represented by petrol stations, printing shops, dry cleaning shops and petroleum depots and not by shops of electric metal plating and painting, since information of these sources is not available despite their possible substantial volume. It is estimated that leakage of natural gas from rubber hose connections is substantial due to a lack of proper maintenance, especially in the commercial/household sector although their volume is not estimated at this stage.

(d) CO and SPM emissions are negligible in the case of stationary emission sources, since the transport sector has a dominant share of 94% and 88% respectively.

(e) Respecting the emission of stationary sources on the whole, nonmetal products, refinery, and iron & steel are ranked high as illustrated in Fig 4.5.2-2, but as far as the average emission per company is concerned, iron & steel is the first, which implies that pollution control can be most effectively put into practice in this sector.

Table 4.5.2-3 : Sectorwise emission quantity of air pollutants in GTA (combustion+evaporation)
(Stationary source)

(ton/year)

	Sector	Emission volume											
		SOx		NOx		CO		HC		SPM		(Total)	
			(%)		(%)		(%)		(%)		(%)		(%)
1	Total Manufacturing	167,923	64.0	56,541	41.8	47,538	5.4	2,948	2.5	16,968	8.2	291,916	18.2
1.1	31 Food Products	21,242	8.1	8,275	6.1	3,577	0.4	534	0.5	3,059	1.5	36,687	2.3
1.2	32 Textile	8,118	3.1	2,921	2.2	4,516	0.5	278	0.2	888	0.4	16,721	1.0
1.3	33 Wood Products	979	0.4	301	0.2	994	0.1	52	0.0	113	0.1	2,439	0.2
1.4	34 Paper & Products	3,627	1.4	1,473	1.1	1,823	0.2	80	0.1	424	0.2	7,427	0.5
1.5	35 Industrial Chemicals	12,379	4.7	6,148	4.5	7,262	0.8	324	0.3	1,686	0.8	27,799	1.7
1.6	36 Non-metal products	83,425	31.8	15,430	11.4	6,688	0.8	774	0.7	5,526	2.7	111,844	7.0
1.7	37 Iron & Steel	19,252	7.3	13,402	9.9	7,145	0.8	327	0.3	2,720	1.3	42,846	2.7
1.8	38 Machinery	6,348	2.4	3,223	2.4	10,984	1.3	536	0.5	956	0.5	22,047	1.4
1.9	39 Other Industries	12,553	4.8	5,367	4.0	4,549	0.5	42	0.0	1,595	0.8	24,106	1.5
2	General Service and Household	35,720	13.6	15,051	11.1	2,893	0.3	15,347	13.2	6,291	2.5	74,301	4.6
2.1	Household	15,029	5.7	12,487	9.2	2,387	0.3	1,091	0.9	3,756	1.8	34,750	2.2
2.2	Commercial & General	20,691	7.9	2,563	1.9	506	0.1	14,256	12.2	1,535	0.7	39,551	2.5
3	Energy Conversion	50,289	19.2	23,900	17.7	953	0.1	16,401	14.1	2,836	1.4	94,380	5.9
3.1	Electric Generation	16,069	6.1	11,736	8.7	445	0.1	722	0.6	1,188	0.6	30,161	1.9
3.2	Refinery	34,220	13.0	12,164	9.0	508	0.1	15,679	13.5	1,648	0.8	64,219	4.0
	(Sub-total)	253,981	96.8	95,571	70.7	51,421	5.9	34,701	29.8	25,113	12.1	460,786	28.8
4	Transport	8,340	3.2	39,610	29.3	826,806	94.1	81,690	70.2	182,717	87.9	1,139,163	71.2
	(Total)	262,321	100.0	135,181	100.0	878,227	100.0	116,391	100.0	207,830	100.0	1,599,949	100.0

Fig 4.5.2-1(1) : Sctorwise emission quantity of air pollutants in GTA (1994)

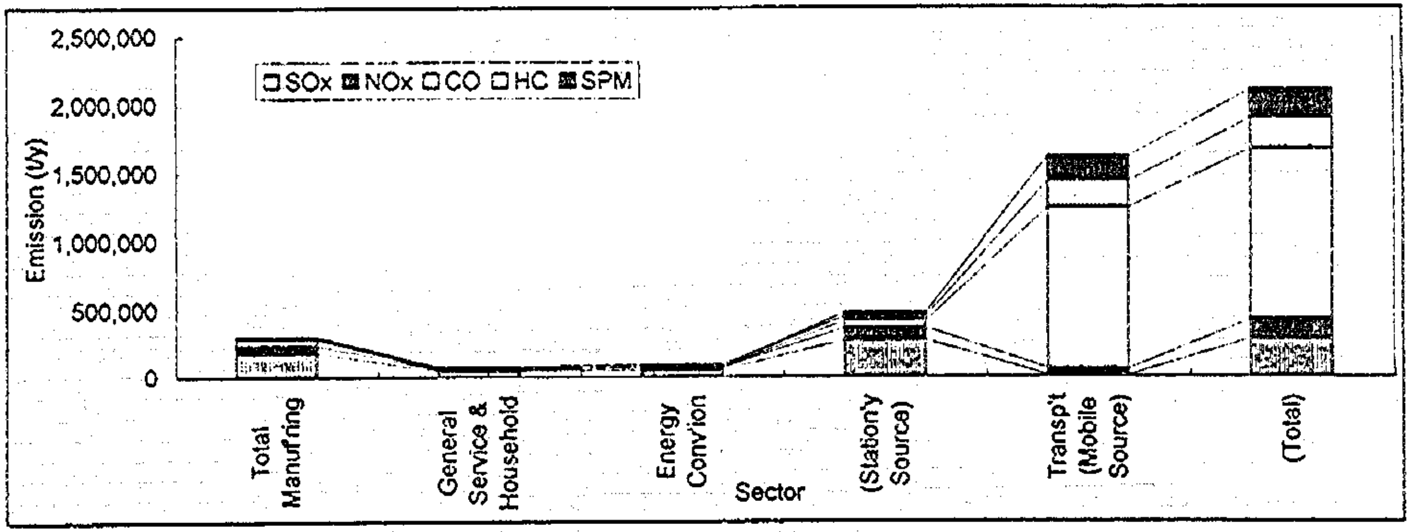


Fig 4.5.2-1(2) : Sctorwise emission quantity of air pollutants in GTA (1994)

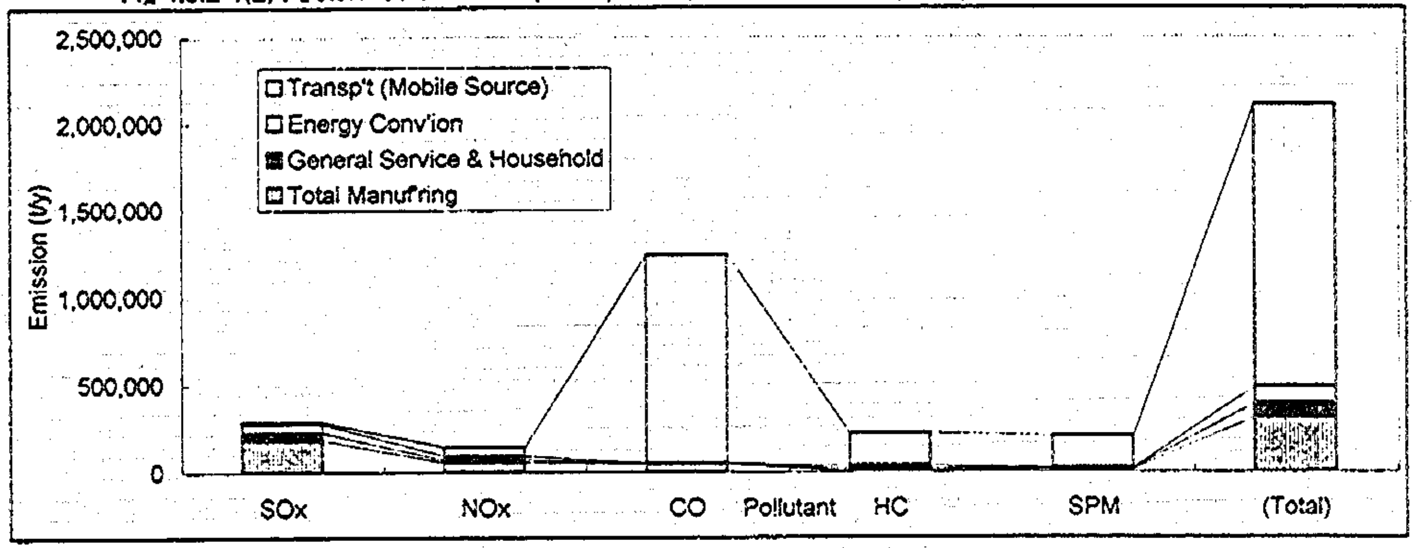
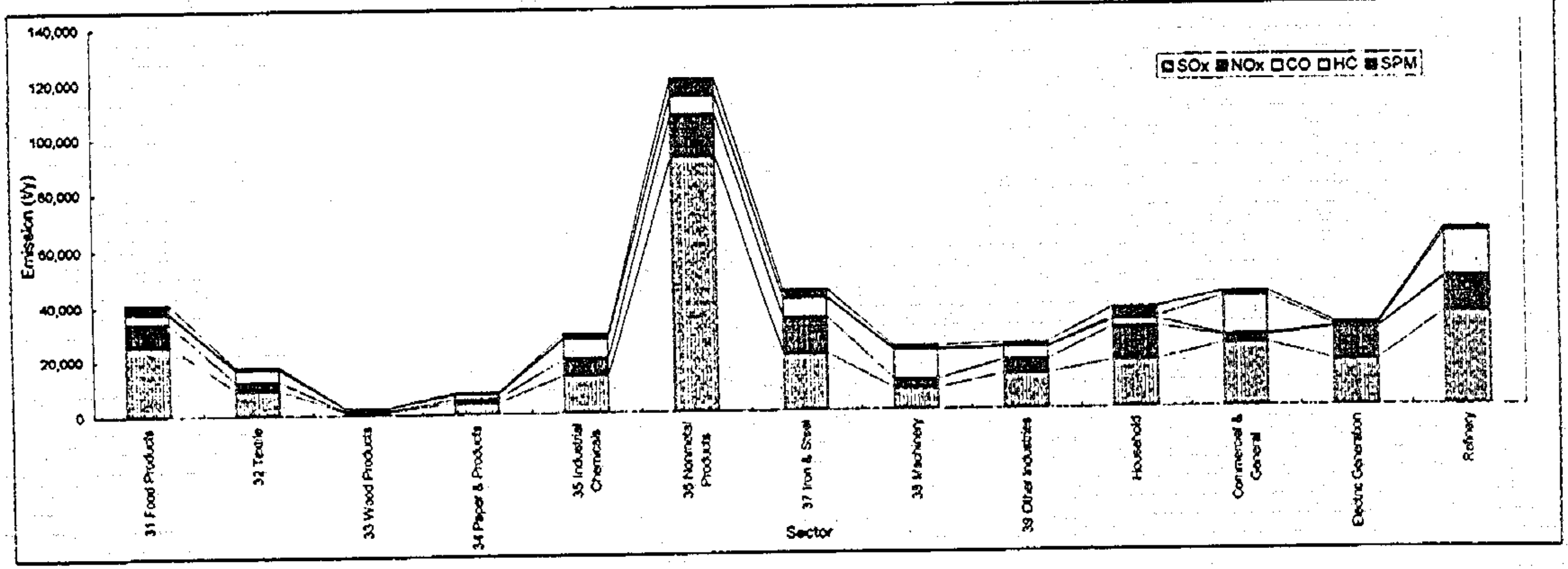


Fig4.5.2-2 : Sctorwise emission quantity of air pollutants in GTA (1994)



Chapter 5

Development of simulation model and projection of long term ambient air concentration in GTA

5. Development of simulation model and projection of long term ambient air concentration in Greater Tehran Area

5.1 Development of simulation model

5.1.1 Basic model

The main role of dispersion model is to predict a future situation according to several scenarios and to evaluate effectiveness of countermeasures. The validation process under the current condition with optimized categorization/parameterization is important for confirmation of model performance. The total flow for the model development is summarized in the following chart.

At each step of the flow, the results obtained by the activities are utilized. For example, measured air quality data are analyzed in relation to the meteorological condition and utilized to set suitable categorization. Measurement at the target factories and statistical analyses on fuel consumption are utilized to set specifications of the stationary sources. For mobile sources, the emission factor is set based on the chassis-dynamo test. The traffic volume survey data are also combined with the existing data of TCTTS/TTTO.

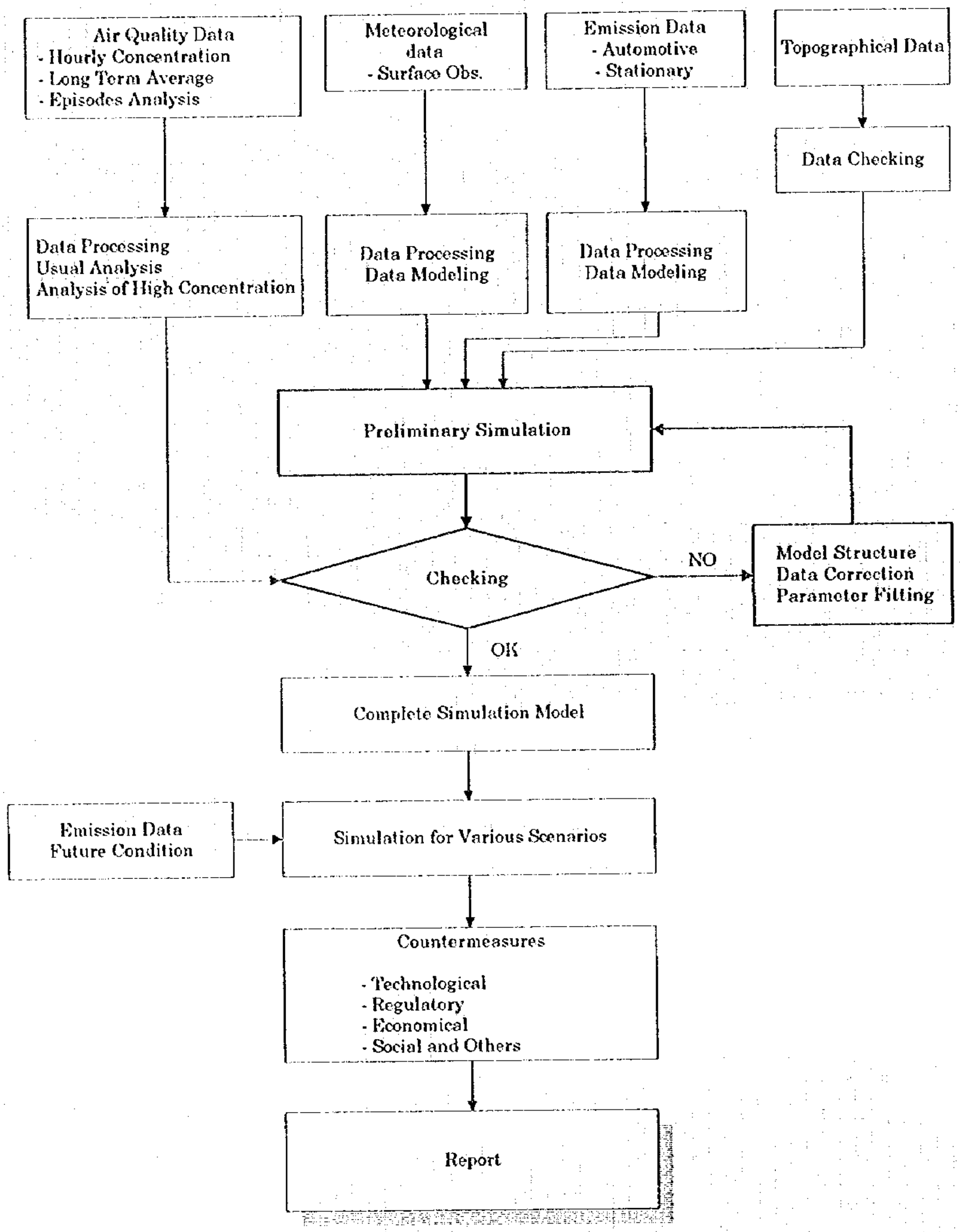


Fig. 5.1.1-1 Total Flow of the Simulation

5.2 Diffusion Potential

5.2.1 Concept

The "diffusion potential" is defined as an impact of the modeled emission source based on CDM(Climatological Dispersion Model). CDM is based on the formulation similar to the model described in section 5.1 and has a merit of easy handling. The characteristics of diffusion field can be clarified through comparison with the other areas.

5.2.2 International comparison

The meteorological data measured at Mehrabad Airport (1950-60) are applied to the model with some assumption on stability setting and the duration of calm.

(1) Elevated sources

Three type stacks are considered as elevated sources. The dimensions for the modeled stacks are as follows:

Table 5.2.2-1 Modeled Stacks

element	type		
	small	middle	large
stack height(m)	20	50	200
stack diameter(m)	0.5	3	7
gas emission rate(m^3N/h)	10000	25000	200000
gas temperature(C)	100	100	200
concentration at stack(ppm)	1000	1000	1000

The results are shown in the table below. The values of three Asian cities (Tokyo(Japan), Jakarta (Indonesia) , Dalian (China)) and Mexico city are also shown for comparison. Tehran has the lowest concentration for a small stack. For middle/large -sized stacks, Tehran's concentration is larger than those of Dalian and Tokyo but less than half of those of Jakarta and Mexico City.

Table 5.2.2-2 Concentration for Elevated Sources (unit : ppb)

city	type		
	small	middle	large
Tehran	2.67	0.95	4.08
Tokyo	4.22	0.62	1.04
Jakarta	4.44	2.15	11.89
Dalian	3.92	0.42	0.08
Mexico City	4.10	1.46	9.59

(2) Ground sources

A road link , shown in the following table, is assumed as an example of ground source.

Table 5.2.2-3 Modeled Link

element	specification
link length(m)	2
link direction	W-E
link height(m)	1.5
gas emission rate(m^3N/h)	1
initial spread(m)	3

The concentrations at surrounding 48 points (16 direction, distance from source: 20m,60m,100m) are calculated. The mean and maximum values among 16 directions are shown in the table below.

Tehran shows greater concentration (lower potential) than Tokyo and Dalian for the mean value. The maximum value however does not show a wide deviation from the mean for the Tehran case and is ranked in the lower concentration class except for a small source distance.

Table 5.2.2-4 Concentration for Ground Sources (unit : ppb)

source distance / city	20m mean	20m maximum	60m mean	60m maximum	100m mean	100m maximum
Tehran	169.3	188.2(SW)	42.9	48.5(SW)	21.4	24.7(NE)
Tokyo	64.0	167.3(NNE)	21.8	66.0(NNE)	11.8	36.8(NNE)
Jakarta	453.1	504.8(N)	80.2	98.2(N)	31.9	41.4(N)
Dalian	50.8	99.1(S)	17.6	37.3(S)	9.4	20.4(S)
Mexico city	262.5	341.9(NE)	48.2	81.3(NE)	22.0	40.4(NE)

(3) Comments

Most of the emission sources in GTA are categorized as 'ground sources' or 'small stacks'. The result shows that the diffusion condition in Tehran is not bad for such sources. The actual high concentration accordingly implies excess of pollutant emission.

5.3 Prediction in future condition

5.3.1 Future scenarios in the year 2010

Figure 5.3.1-1(1)~(3) show the annual(1994) concentration of CO, SO_2, NOx, respectively. All those simulations include both impacts of stationary sources and mobile sources (vehicles).

The meteorological condition is assumed to be the same with present situations.

Future emission from vehicles is calculated on the basis of predicted traffic volume and assumed future emission factors. The traffic volume predictions are based on TCTTS's results for two scenarios; one is 'do nothing' (1994 network meeting 2001 demand) and the other is 'existing + funded' (existing and funded network meeting 2001 demand). The change of the traffic volume from the year 2001 to 2010 is estimated on the values between 1994 and 2001. Two scenarios for emission factor changes are 'do nothing' (same as present) and 'best' (including full countermeasures for emission reduction).

Future conditions of stationary sources are considered to have the following three scenarios. In 'do nothing' the amount of pollutants is assumed to increase in proportion to the economic growth rate. 'Best' is based on the schedule of the pollution reduction plan and 'common' is the intermediate reduction between 'do nothing' and 'best'. All of them are targets for the year 2010. See section 6.3 for detailed description of these scenarios. No change of CO emission from stationary sources is assumed because their contribution is small enough compared with vehicles.

The calculation settings are summarized in Table 5.3.1-1. 'do nothing' scenarios is the worst combination ,i.e. 'do nothing' for both of stationary and mobile sources. On the contrary, 'best' scenario includes all effects of countermeasures. The estimated emission amounts are shown in Table 5.3.1-2. Their ratio to the present values are also indicated for reference.

Table 5.3.1-1 Future setting for calculation

scenario	stationary sources	mobile	sources
		traffic volume	emission factor
do nothing	do nothing	do nothing	same as present
common	common	existing and funded	reduced
best	best	existing and funded	reduced

Table 5.3.1-2 Present and future emission amount

1994 (present) unit : ton/year

	mobile	stationary	total
CO	826806	51421	878227
	94.1%	5.9%	100.0%
SOx	8340	253981	262321
	3.2%	96.8%	100.0%
NOx	39610	95571	135181
	29.3%	70.7%	100.0%

2010 (future)

		mobile	*/1994*	stationary	*/1994*	total	*/1994*
CO	do nothing	1378748	*1.668*	51421	*1.000*	1430169	*1.628*
		96.4%		3.6%		100.0%	
	common	336158	*0.407*	51421	*1.000*	387579	*0.441*
		86.7%		13.3%		100.0%	
	best	336158	*0.407*	51421	*1.000*	387579	*0.441*
		86.7%		13.3%		100.0%	
SOx	do nothing	11017	*1.321*	524585	*2.065*	535602	*2.042*
		2.1%		97.9%		100.0%	
	common	5084	*0.610*	286237	*1.127*	291321	*1.111*
		1.7%		98.3%		100.0%	
	best	5084	*0.610*	83902	*0.330*	88986	*0.339*
		5.7%		94.3%		100.0%	
NOx	do nothing	53931	*1.362*	188220	*1.969*	242151	*1.791*
		22.3%		77.7%		100.0%	
	common	33143	*0.837*	146396	*1.532*	179539	*1.328*
		18.5%		81.5%		100.0%	
	best	33143	*0.837*	109304	*1.144*	142447	*1.054*
		23.3%		76.7%		100.0%	

note: percentage: component ratio to total emission
italic: ratio to value of year 1994
The CO emission from stationaly sources is assumed to be the same with present situations.

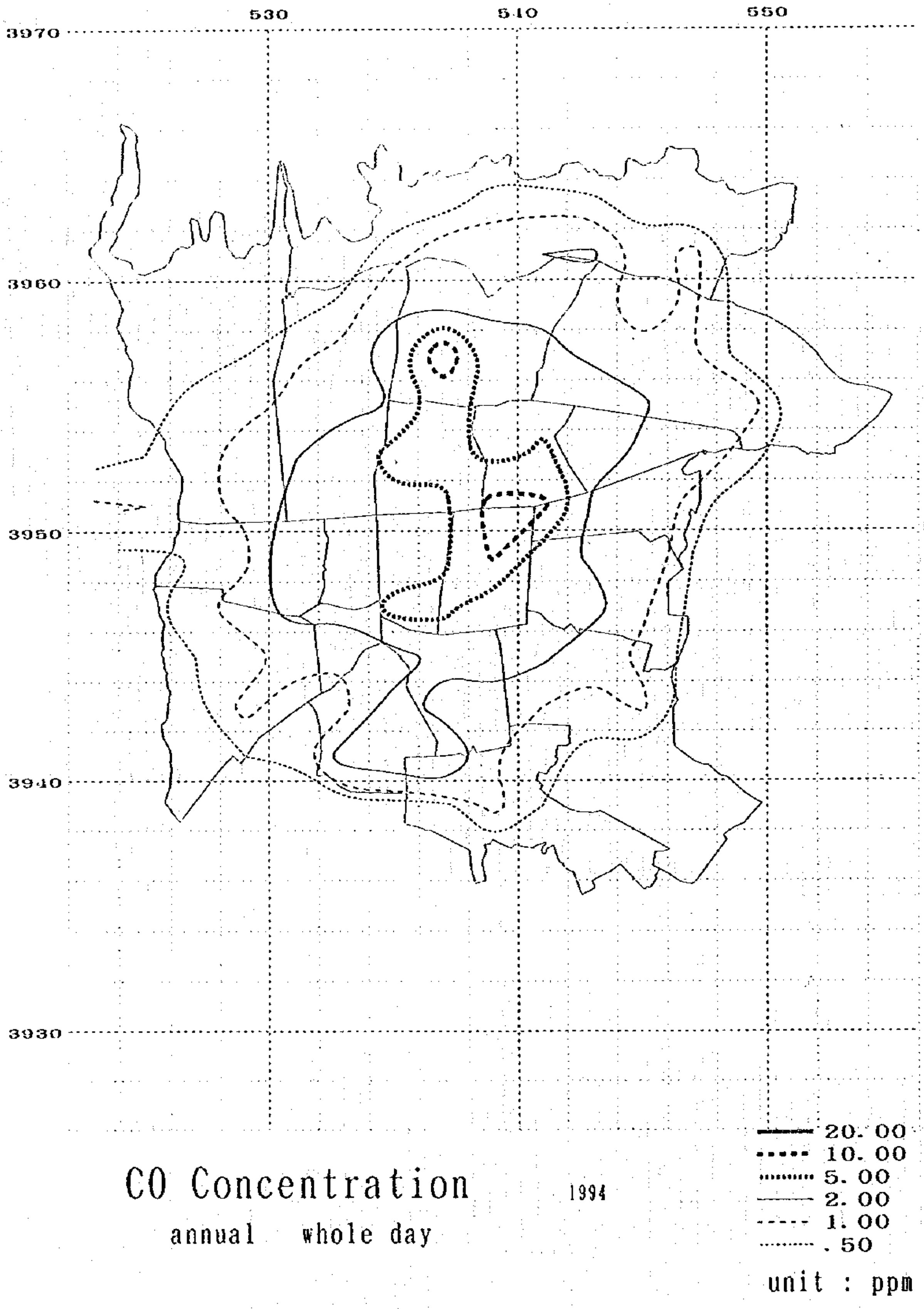


Fig. 5.3.1-1(1) CO concentration (annual, whole day)

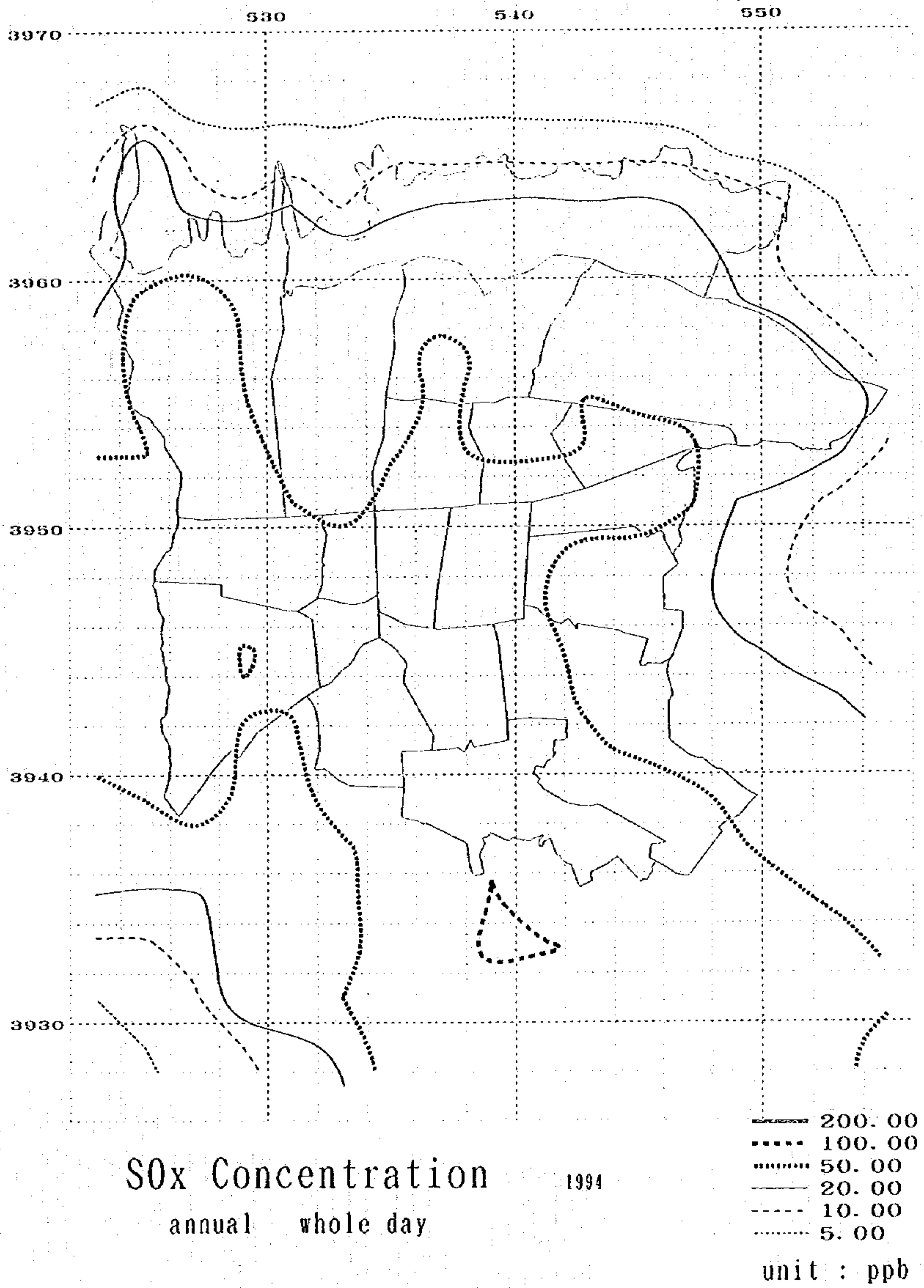


Fig. 5.3.1-1(2) SO_2 concentration (annual, whole day)

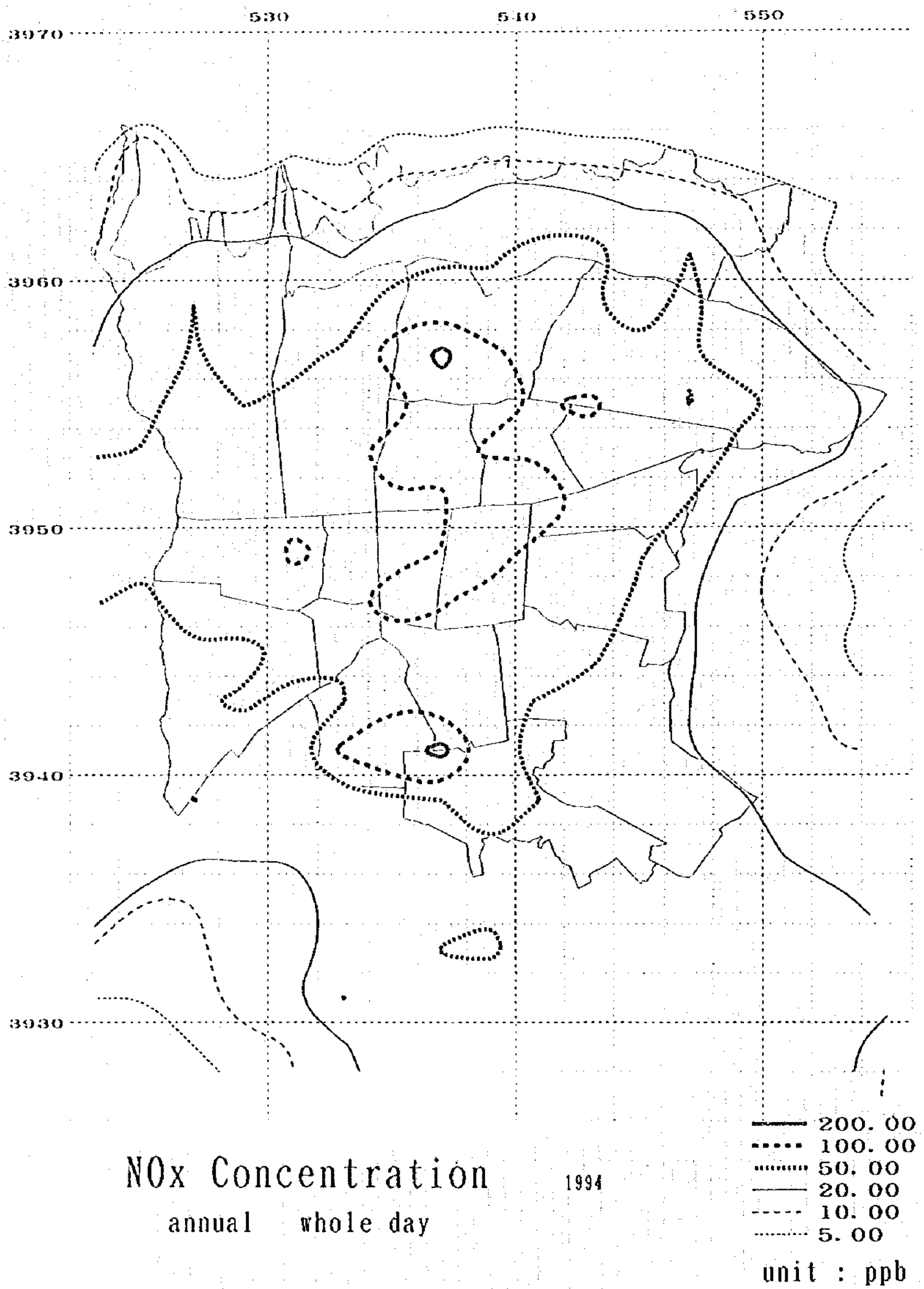


Fig. 5.3.1-1(3) NOx concentration (annual, whole day)

5.3.2 Simulation based on the future scenarios.

Figures 5.3.2-1 (1)-(3) are simulated annual concentrations in 'do nothing' case. Figures 5.3.2-2 (1)-(3) are same but for 'best' case.

(1) CO

In 'do nothing' case, the maximum CO concentration increases to 25.8 ppm from 14.4 ppm (present value), while it decreases to 4.3 ppm in 'best' case. In 'best', the area whose concentration is over 2 ppm can be seen only at some junctions and city center. The shape of the contours differs from those of present (1994) or 'do nothing' due to the effect of the included road network plans.

(2) SO_2

In 'do nothing', the maximum SO_2 doubles from 104 ppb (present value) to 209 ppb, while it is reduced to 39 ppb for 'best'. In both cases, their maximum values appear in the industrialized southern area and the concentrations in twenty districts are around a half of them.

(3) NOx and NO_2

The maximum NOx increases from 232 ppb (present value) to 348 ppb in 'do nothing' while it slightly decreases to 160 ppb in 'best'. In 'do nothing', more than half of twenty districts is covered with 100ppb contours. In 'best', 100ppb contours cover only small part and the annual concentration of most part of the city is the value between 40-70ppb.

Using the conversion formula , NO_2 concentrations are mostly a half of NOx. Then in 'best' case no values of the concentration exceed 50ppb except for in some small areas.

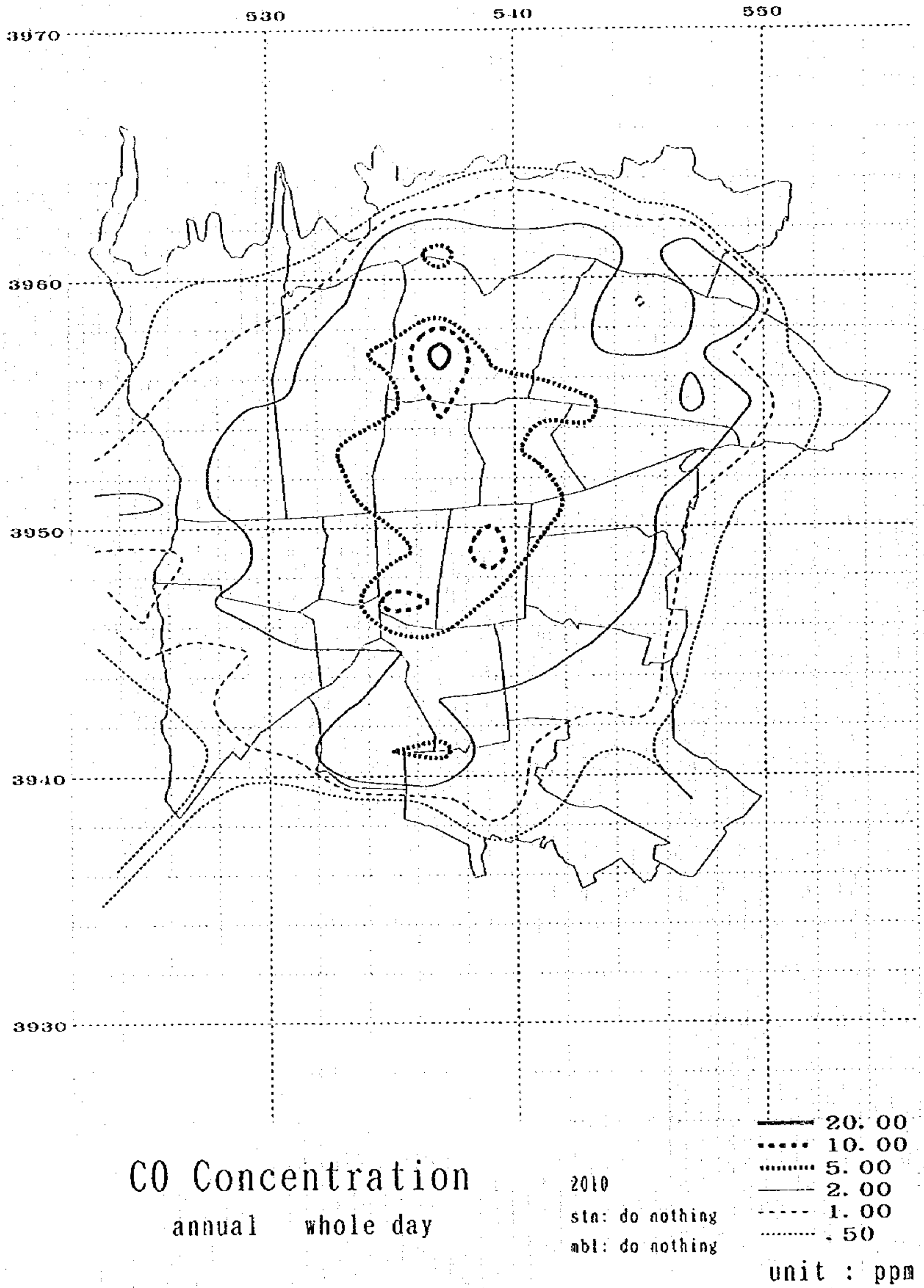


Fig. 5.3.2-1(1) Future CO concentration (do nothing, annual, whole day)

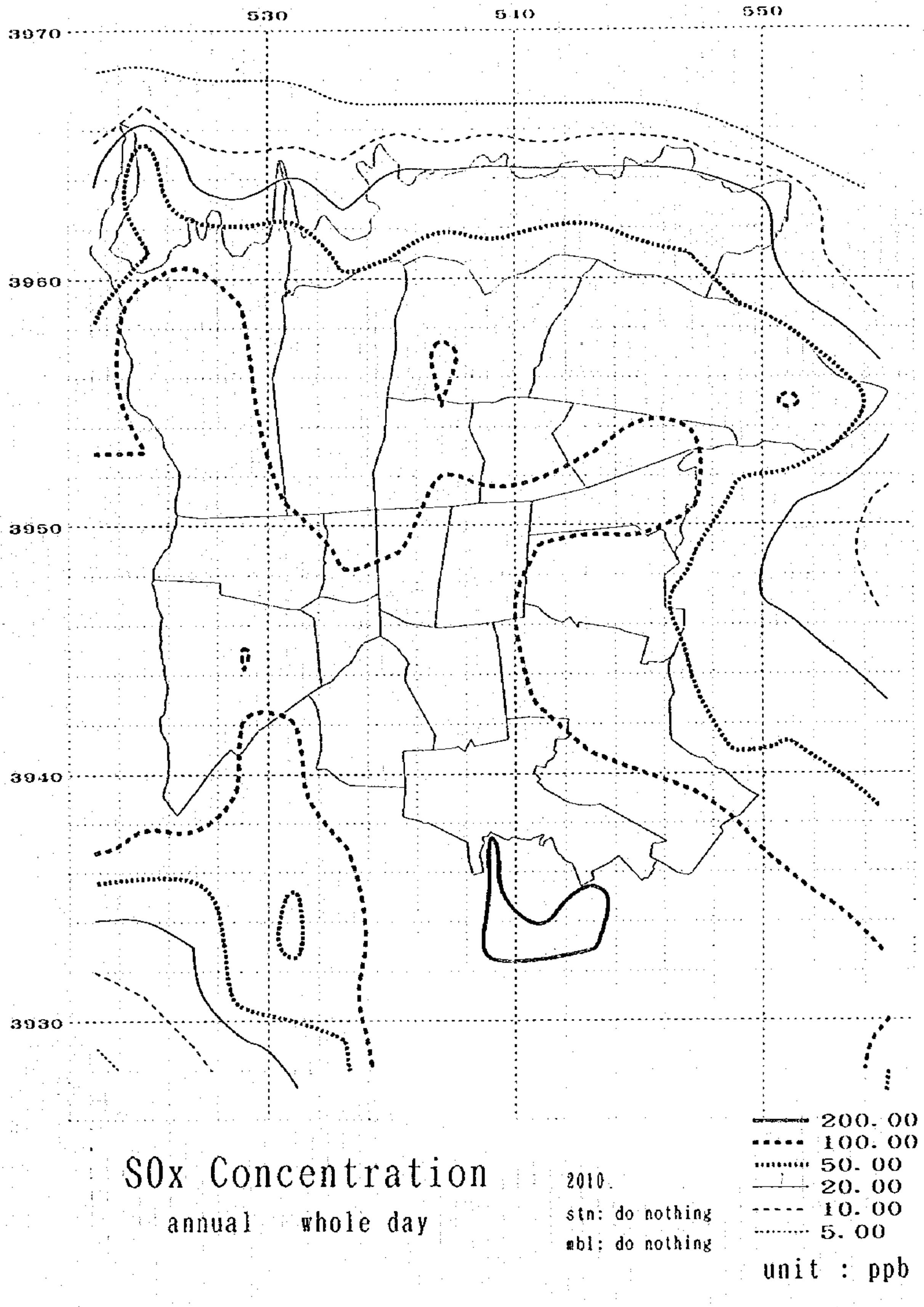


Fig. 5.3.2-1(2) Future SO_2 concentration (do nothing, annual, whole day)

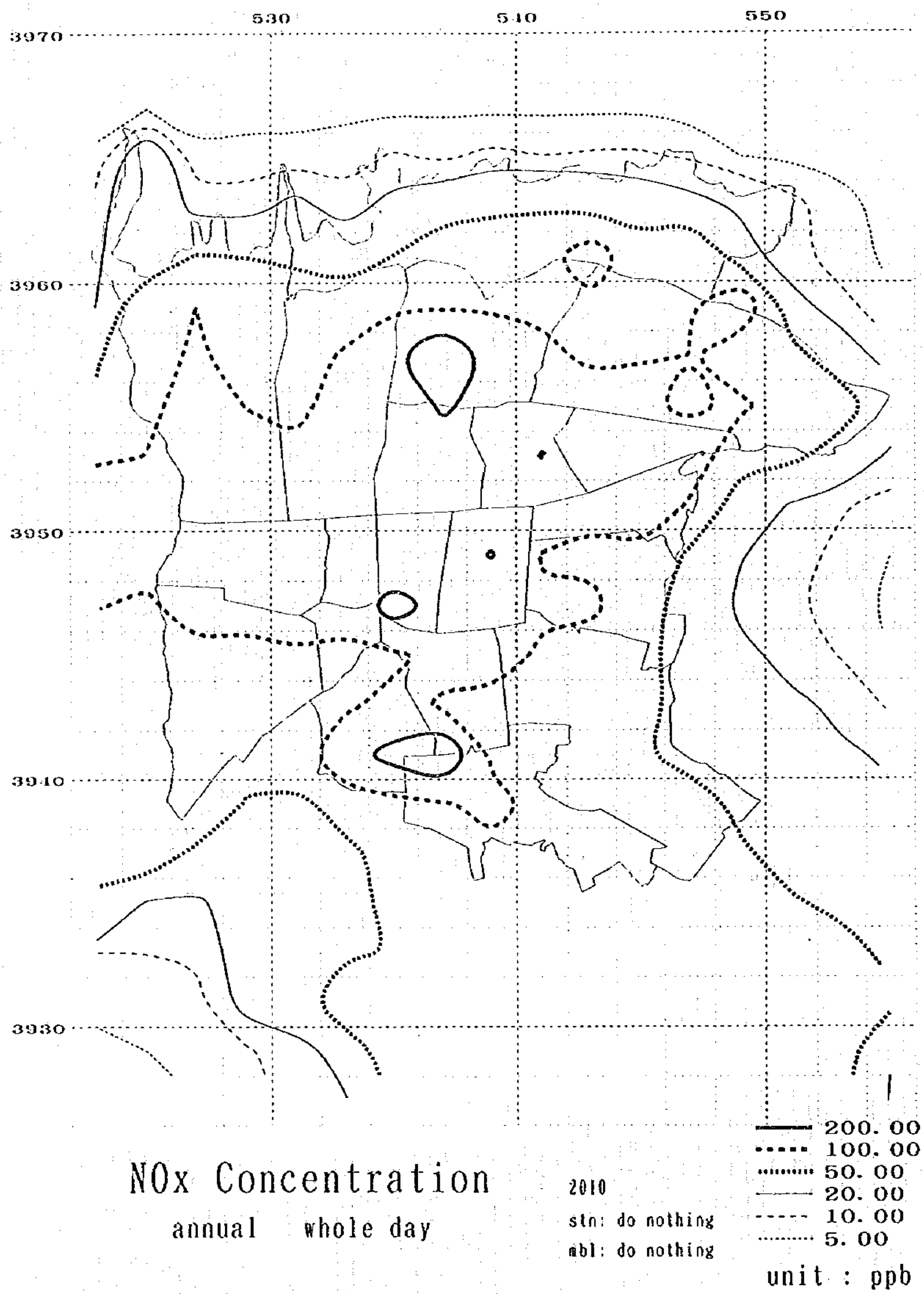


Fig. 5.3.2-1(3) Future NOx concentration (do nothing, annual, whole day)

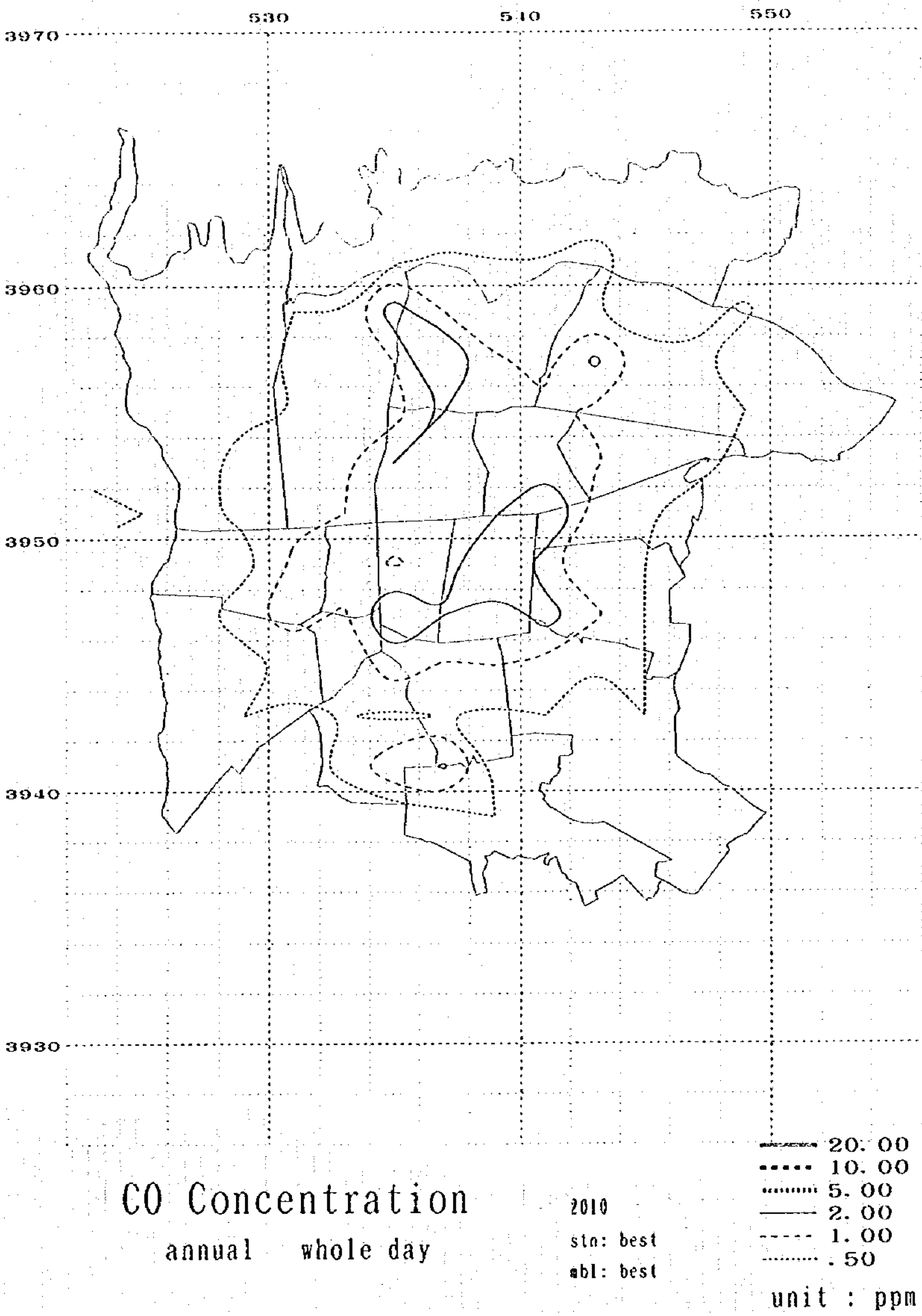


Fig. 5.3.2-2(1) Future CO concentration (best, annual, whole day)

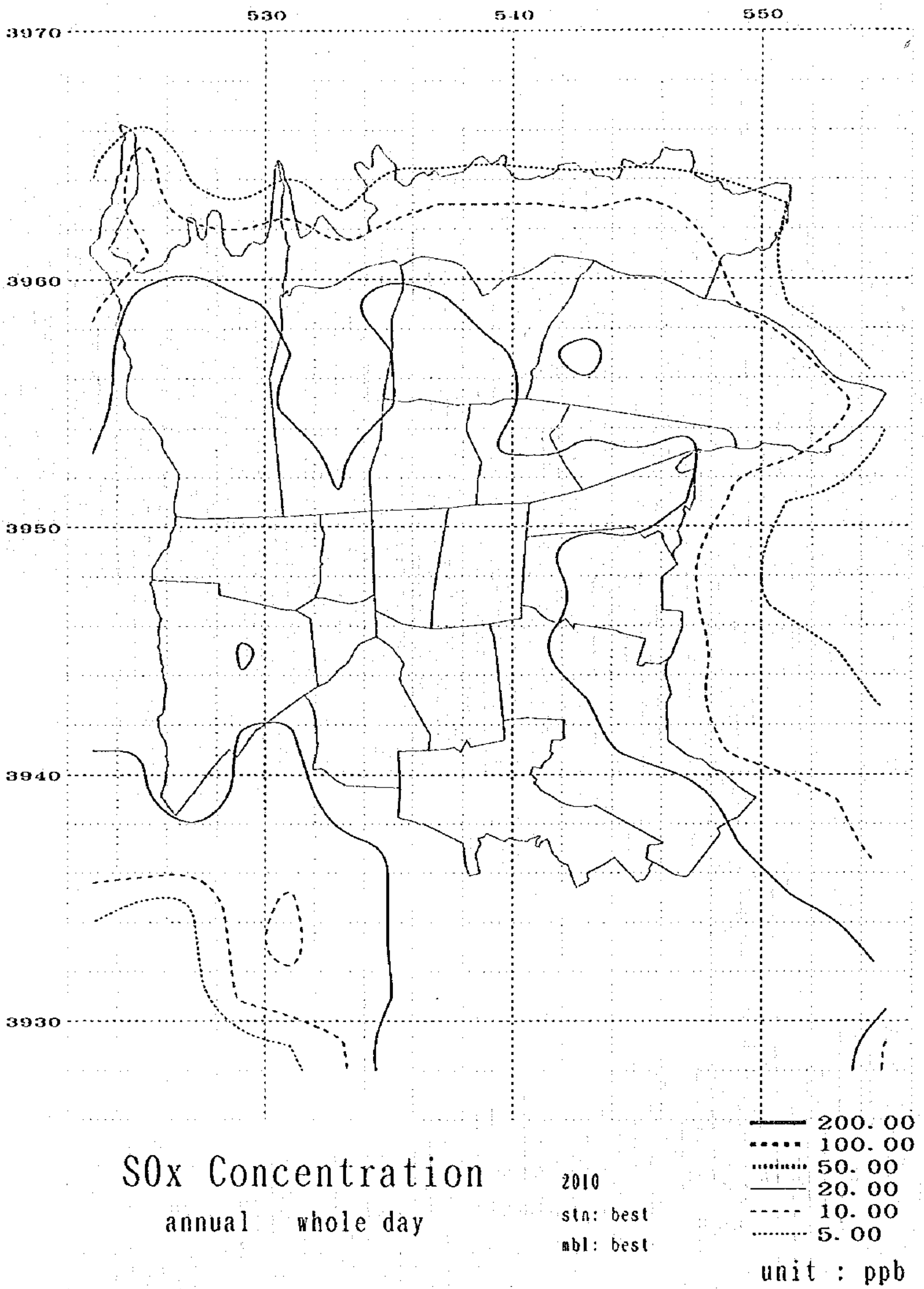


Fig. 5.3.2-2(2) Future SO_2 concentration (best, annual, whole day)

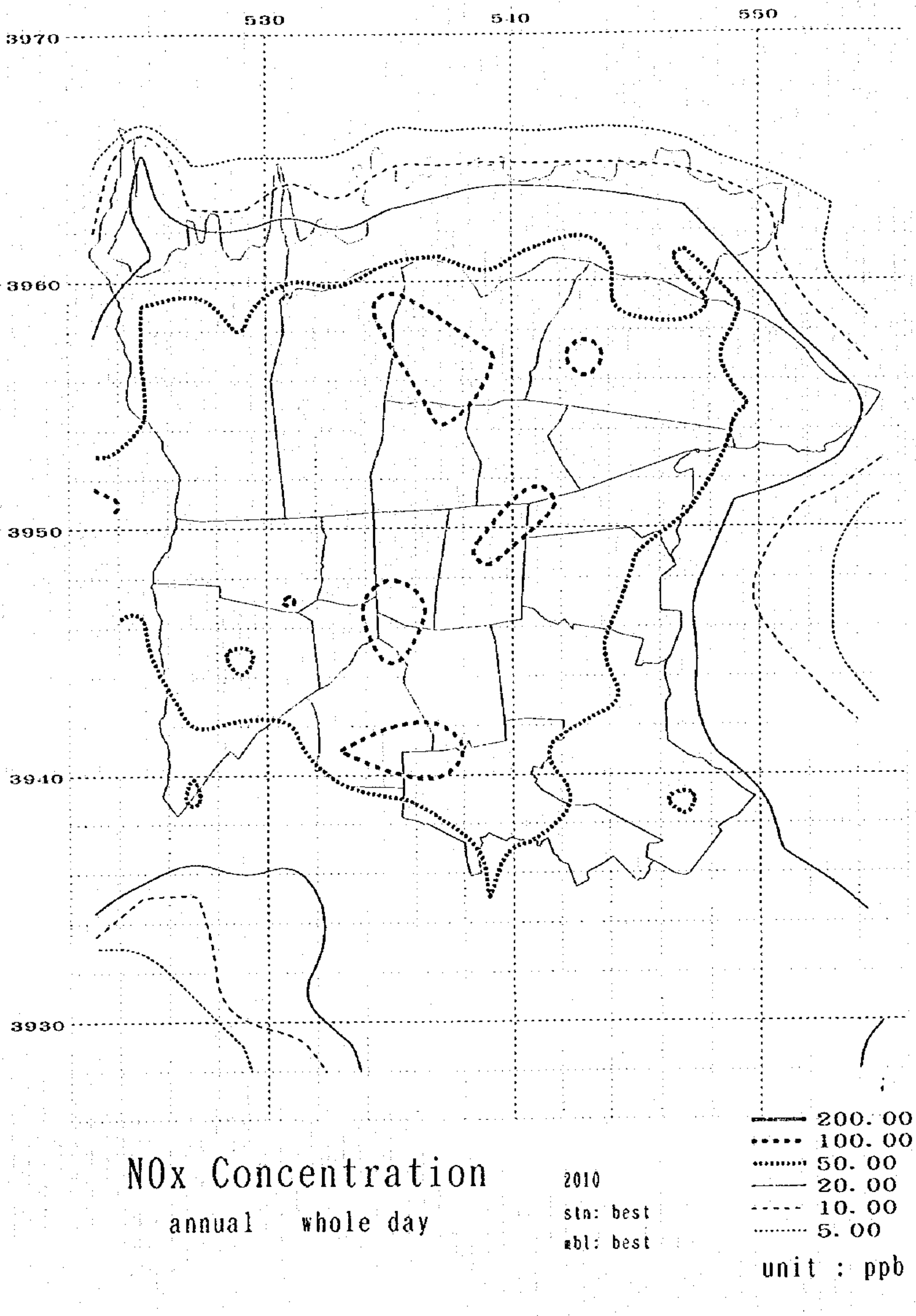


Fig. 5.3.2-2(3) Future NOx concentration (best, annual, whole day)