

Fig. 4. 2. 3-4(1) NO₂ Concentration (1)

(Notes)
 Unit : ppb
 - : Missed data
 ⊙ : No. 13 (NOT office bldg.)

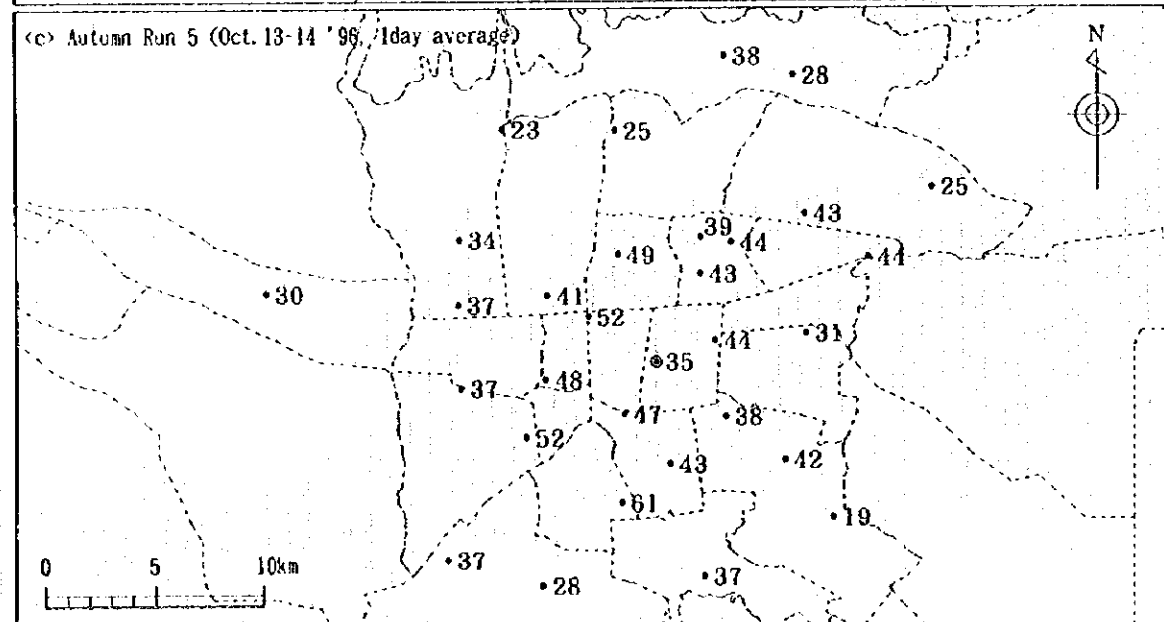
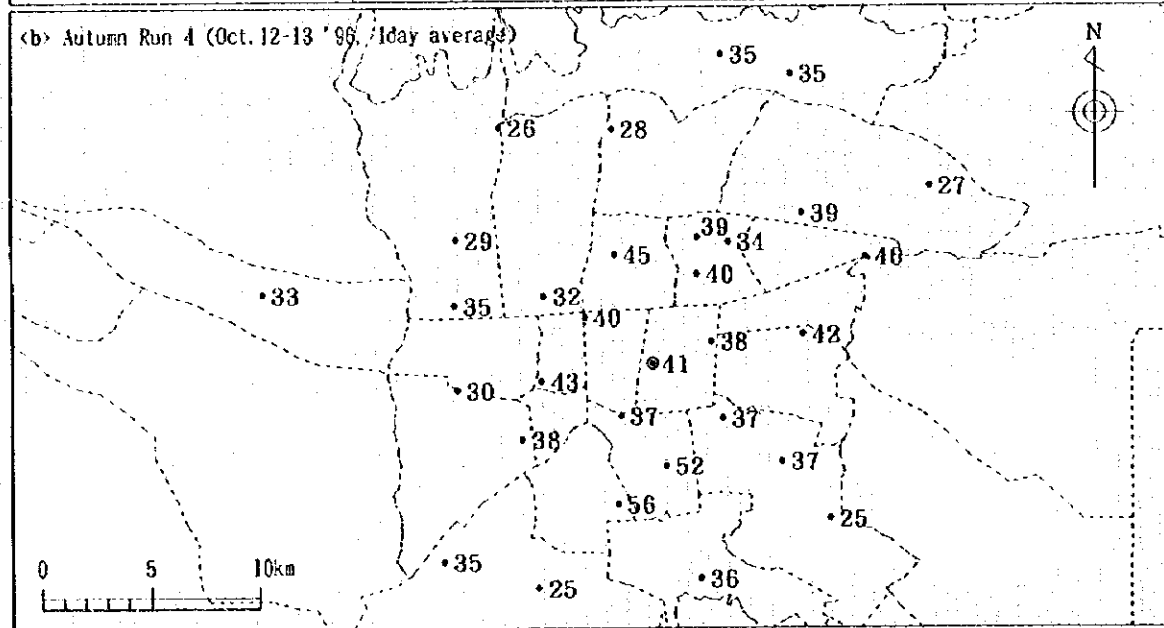
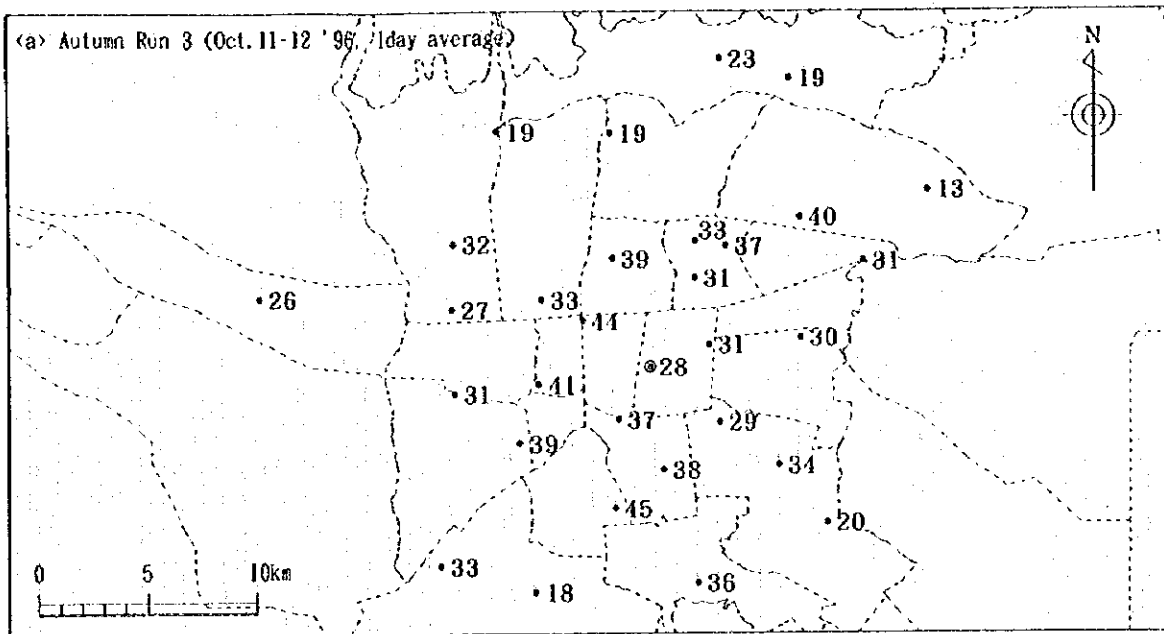


Fig. 4. 2. 3-4(2) NO₂ Concentration (2)

(Notes)
 Unit = ppb
 - : Missed data
 ● : No. 13 (NOI office bldg.)

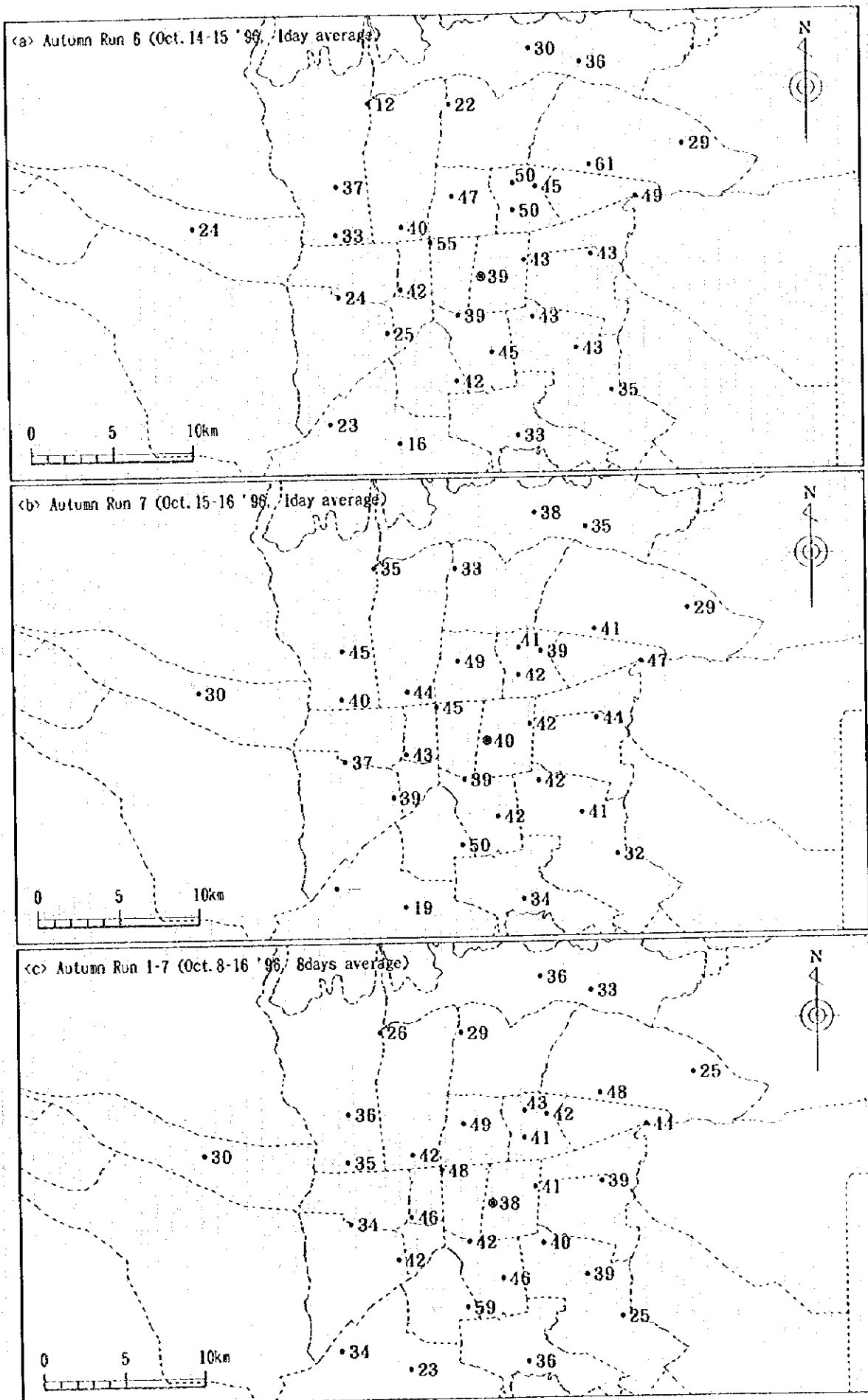


Fig. 4.2.3-4(3) NO₂ Concentration (3)

(Notes)
 Unit = ppb
 - : Missed data
 ● : No. 13 (NOT office bldg.)

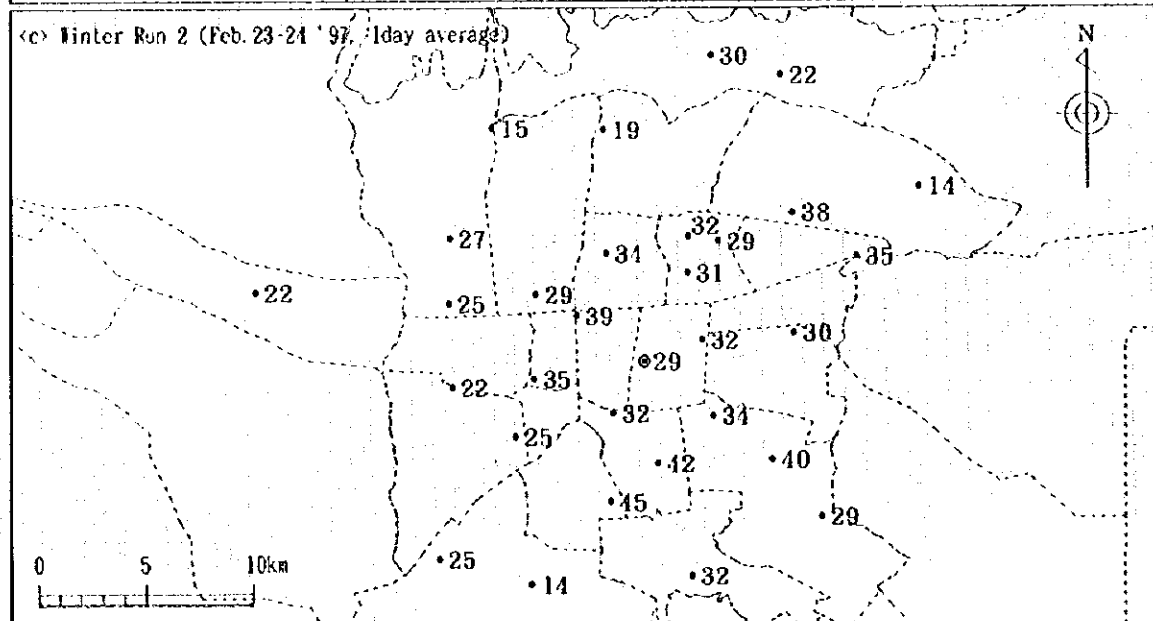
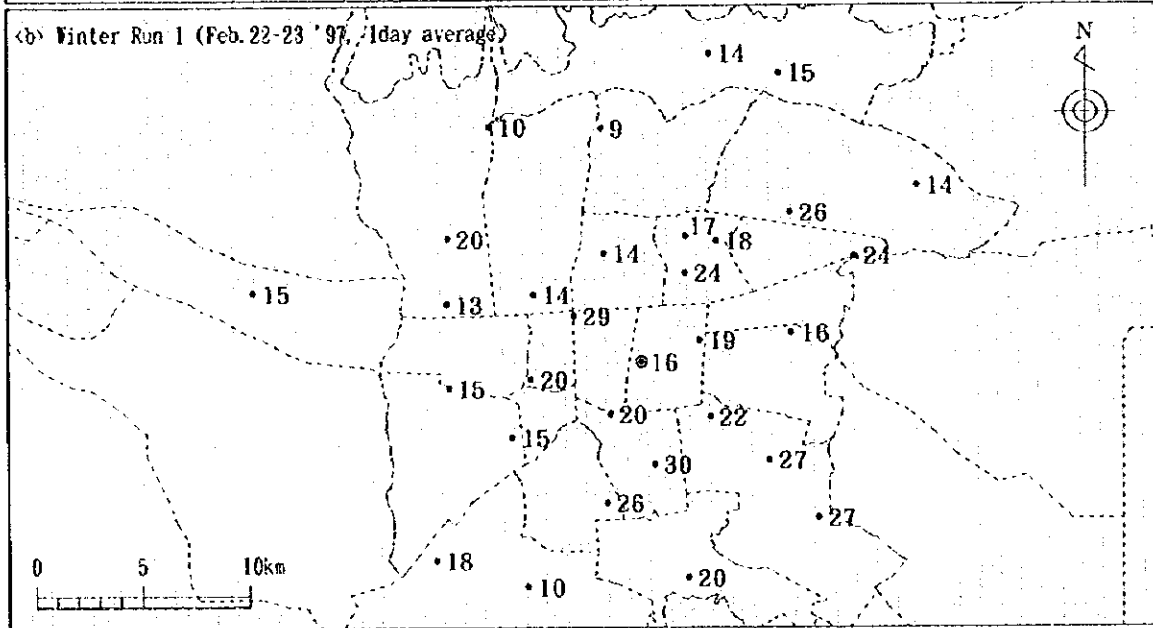
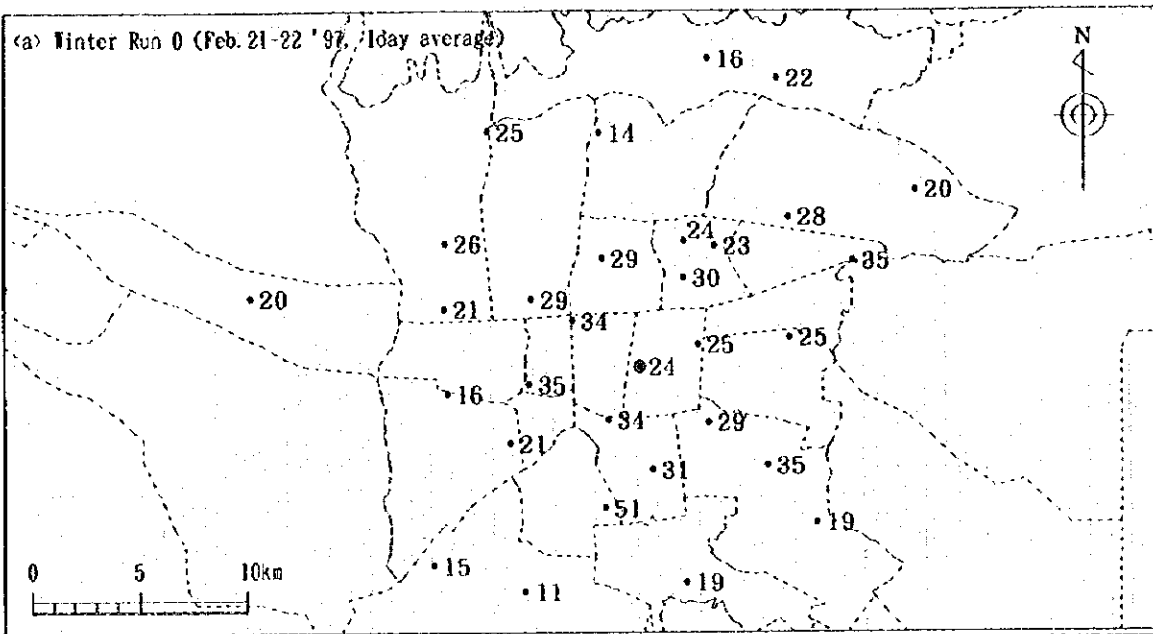


Fig. 4. 2. 3-4(4) NO₂ Concentration (4)

(Notes)
 Unit : ppb
 - : Missed data
 ⊙ : No. 13 (NOT office bldg.)

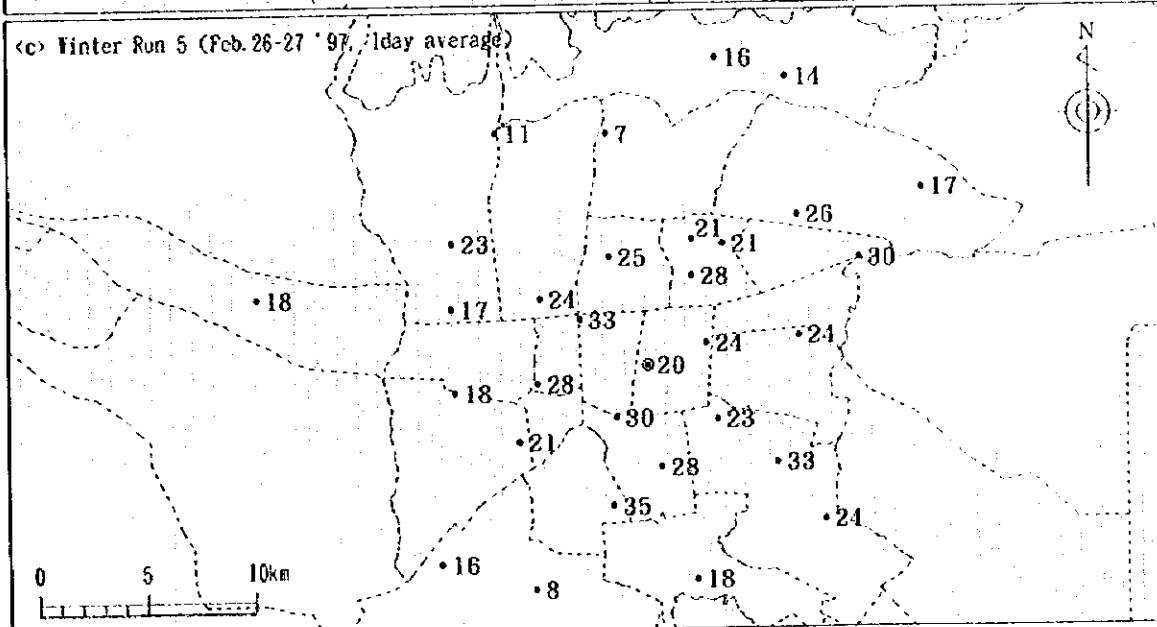
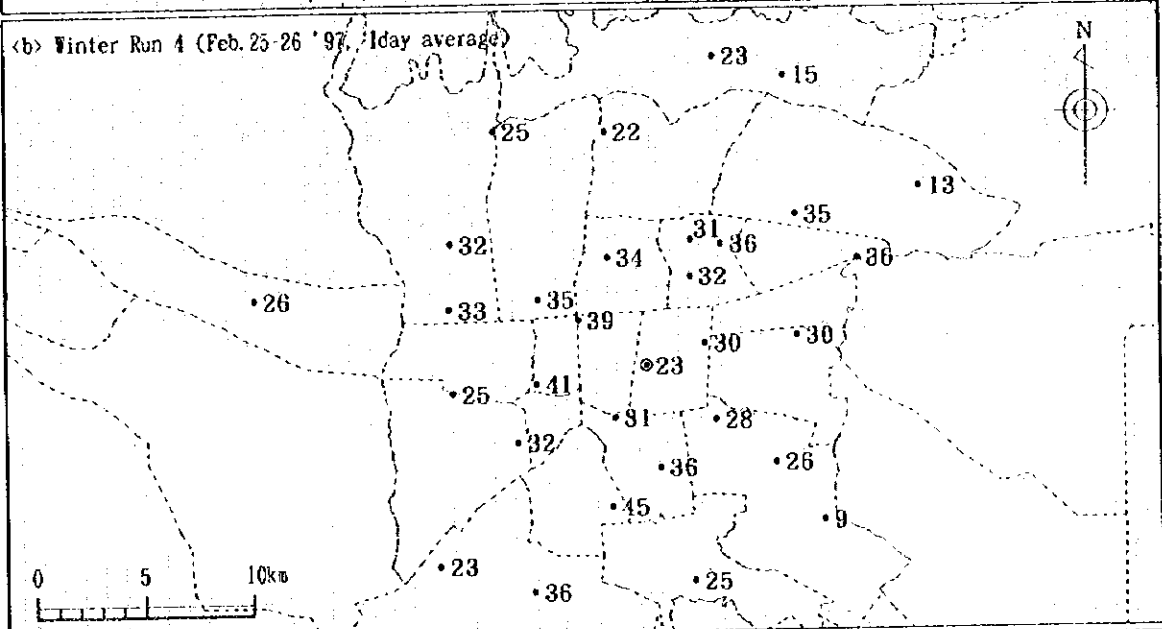
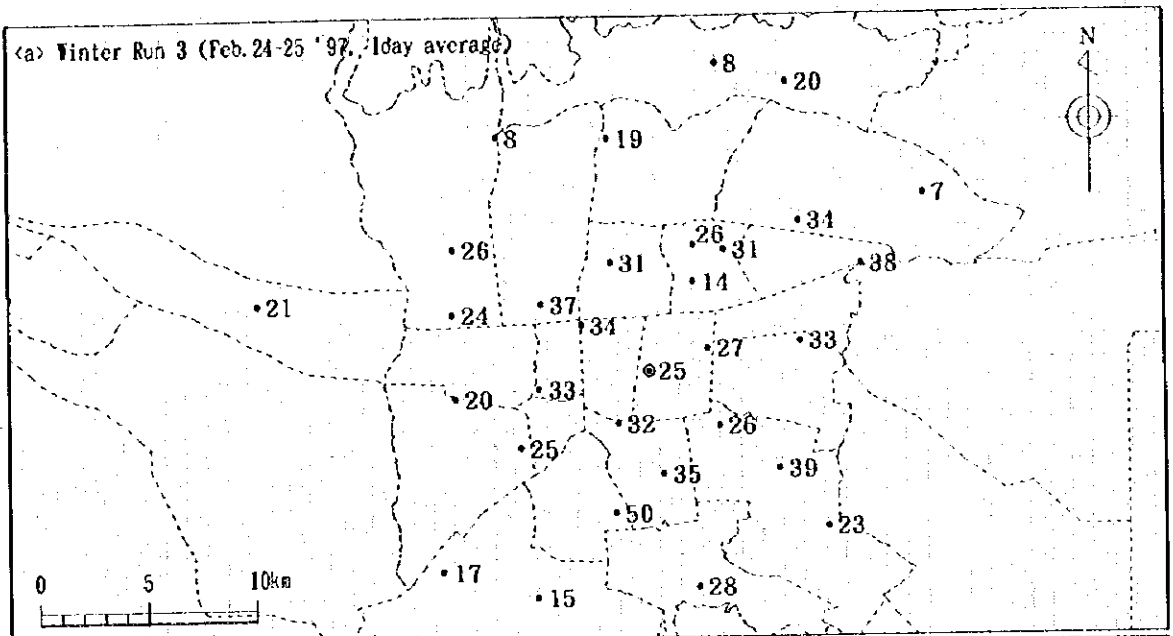


Fig. 4.2.3-4(5) NO₂ Concentration (5)

(Notes)
 Unit : ppb
 - : Missed data
 ⊙ : No. 13 (901 office bldg.)

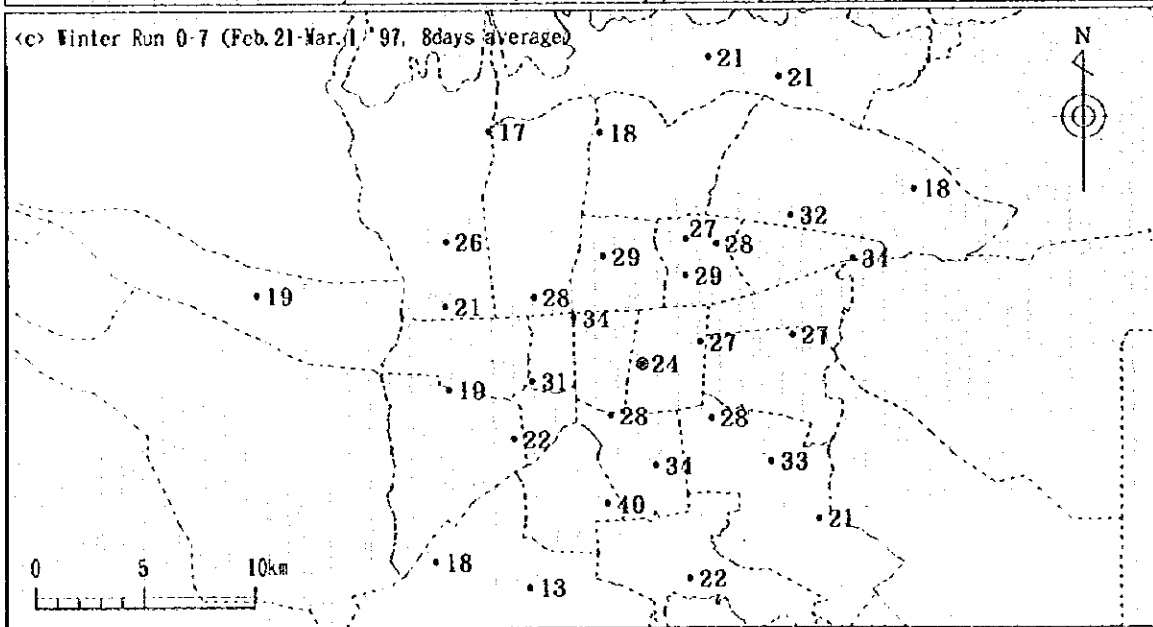
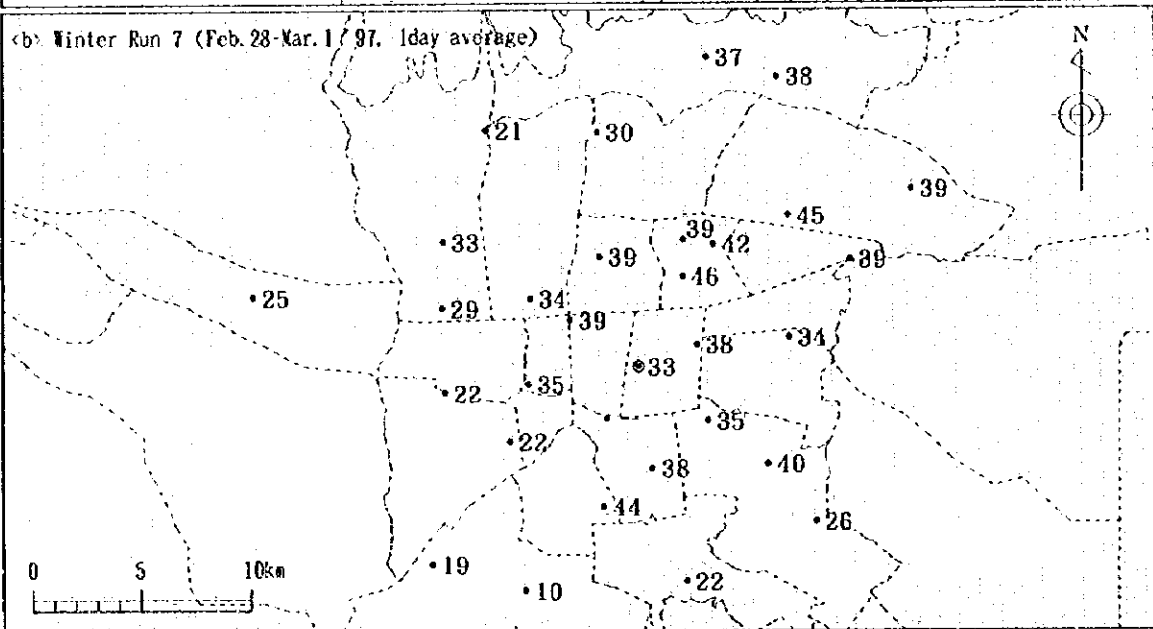
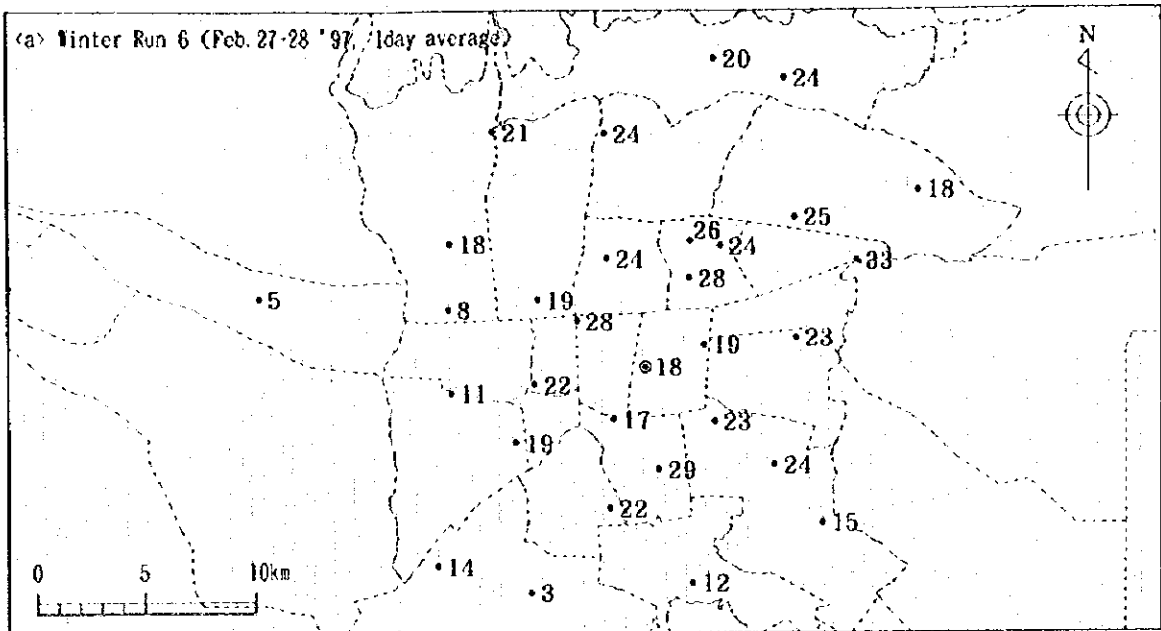


Fig. 4. 2. 3-4(6) NO₂ Concentration (6)

(Notes)
 Unit = ppb
 - : Missed data
 ● : No. 13 (NOT office bldg.)

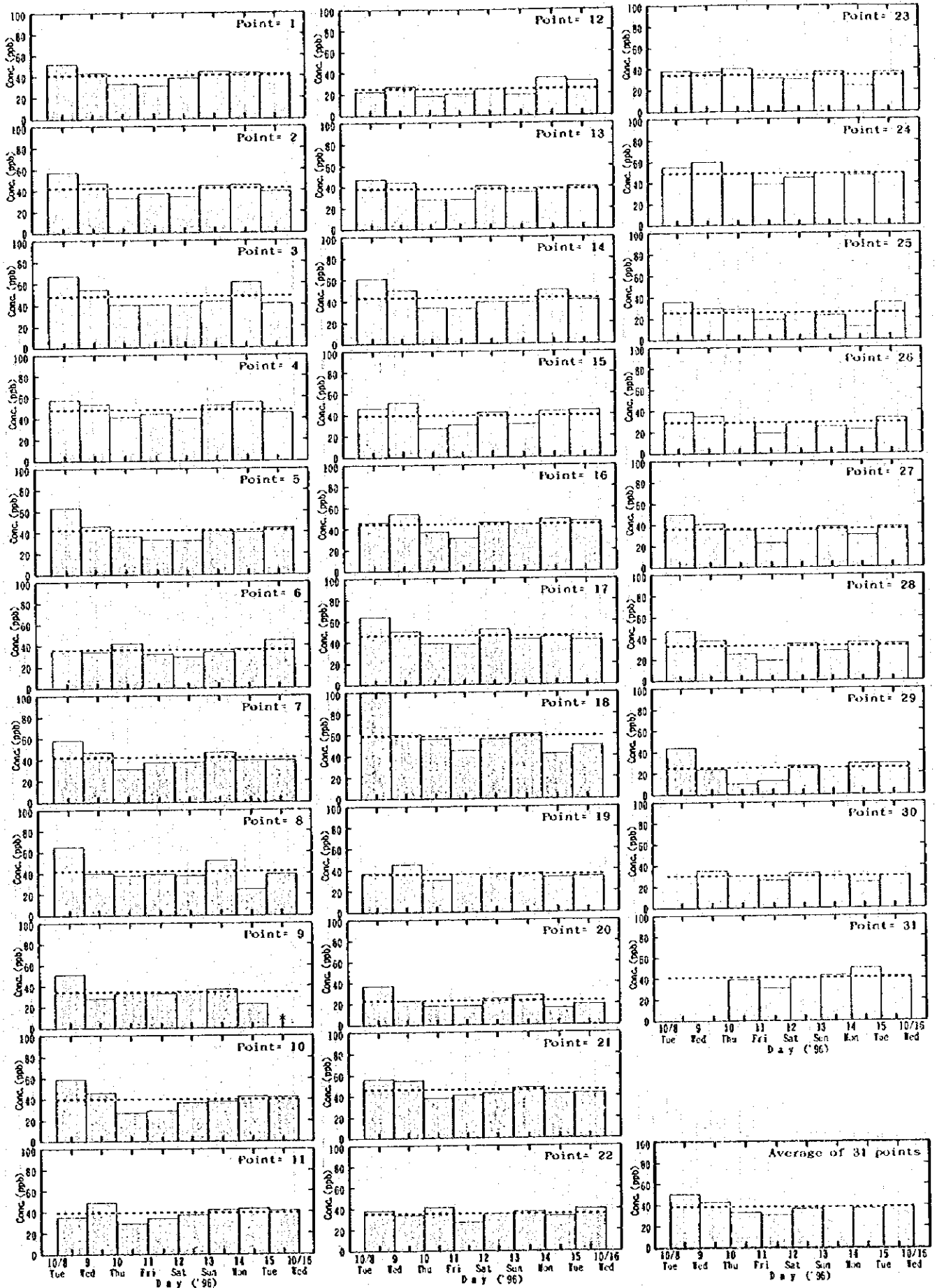


Fig. 4.2.3-5(1) Daily variation of NO_2 concentration (1)
(Autumn)

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

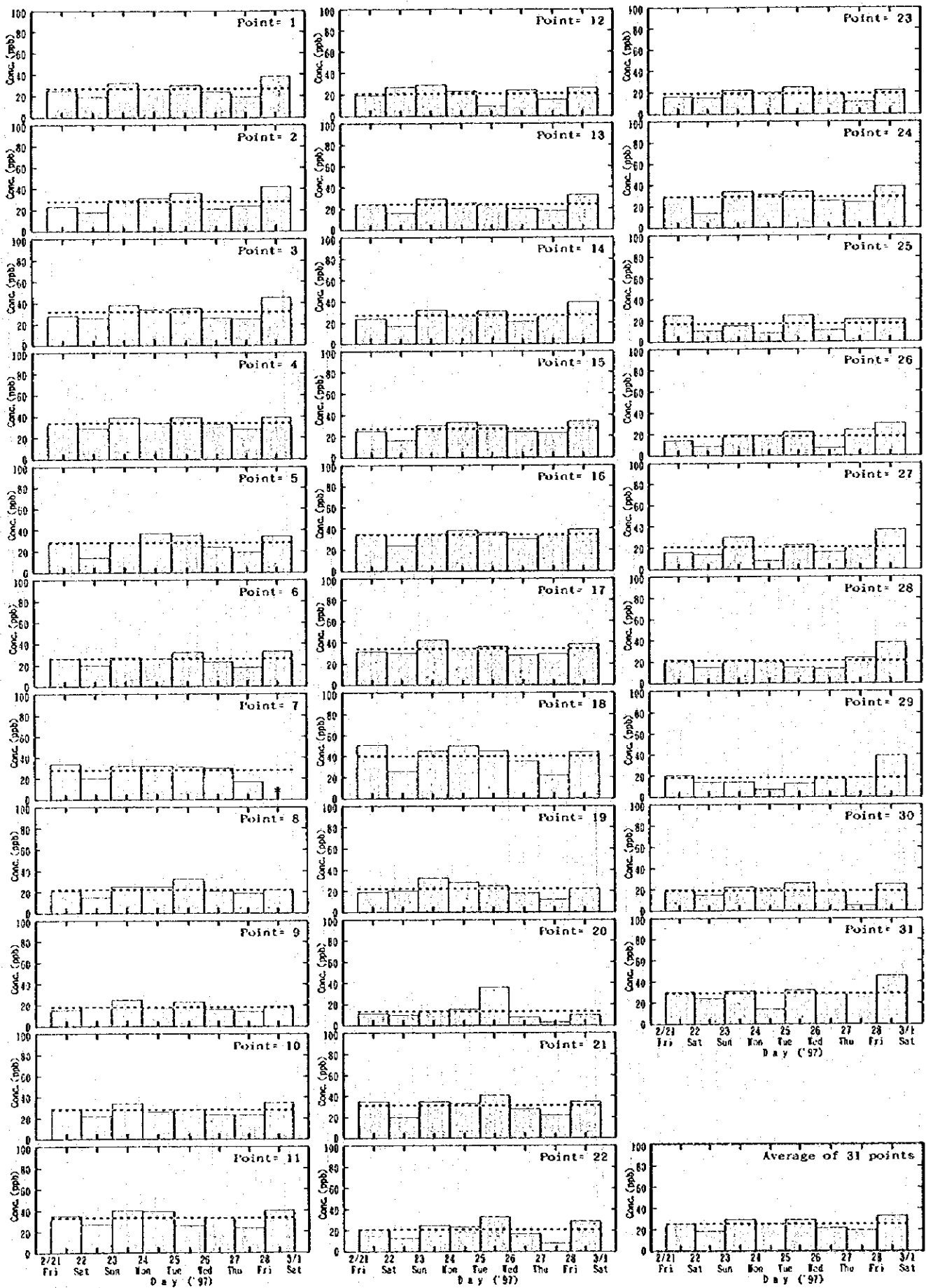


Fig. 4.2.3-5(2) Daily variation of NO_2 concentration (2)
(Winter)

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

Table 4.2.3-6 SO₂ Concentration using passive sampler

Autumn (First measurement work)				Winter (Second measurement work)			
Point No.	3 days sampling data		Average	Point No.	4 days sampling data		Average
	Run 1	Run 2	Run 1,2		Run 1	Run 2	Run 1,2
	(10/9-10/12)	(10/12-10/15)	(10/9-10/15)		(2/21-2/25)	(2/25-3/1)	(2/21-3/1)
1	12	21	16	1	23	26	24
2	6	9	8	2	9	48	28
3	17	15	16	3	16	23	20
4	11	12	12	4	16	17	17
5	9	9	9	5	15	17	16
6	18	14	16	6	25	32	28
7	14	12	13	7	22	.	.
8	22	32	27	8	22	.	.
9	13	15	14	9	49	.	.
10	8	8	8	10	11	33	22
11	13	12	12	11	21	21	21
12	11	11	11	12	15	16	15
13	10	13	11	13	21	26	24
14	8	8	8	14	7	20	13
15	11	11	11	15	9	14	11
16	19	14	16	16	17	20	19
17	20	18	19	17	29	40	35
18	19	20	19	18	22	24	23
19	7	9	8	19	8	11	10
20	8	17	13	20	14	20	17
21	12	14	13	21	20	20	20
22	12	12	12	22	12	14	13
23	15	13	14	23	17	.	.
24	8	8	8	24	8	.	.
25	7	6	6	25	10	27	19
26	6	6	6	26	10	23	17
27	5	3	4	27	7	15	11
28	7	7	7	28	15	29	22
29	7	6	6	29	7	.	.
30	9	7	8	30	10	18	14
31	4	13	8	31	7	18	13
Average	11	12	12	Average	16	23	19

(Note) - ; Missed data

unit=ppb

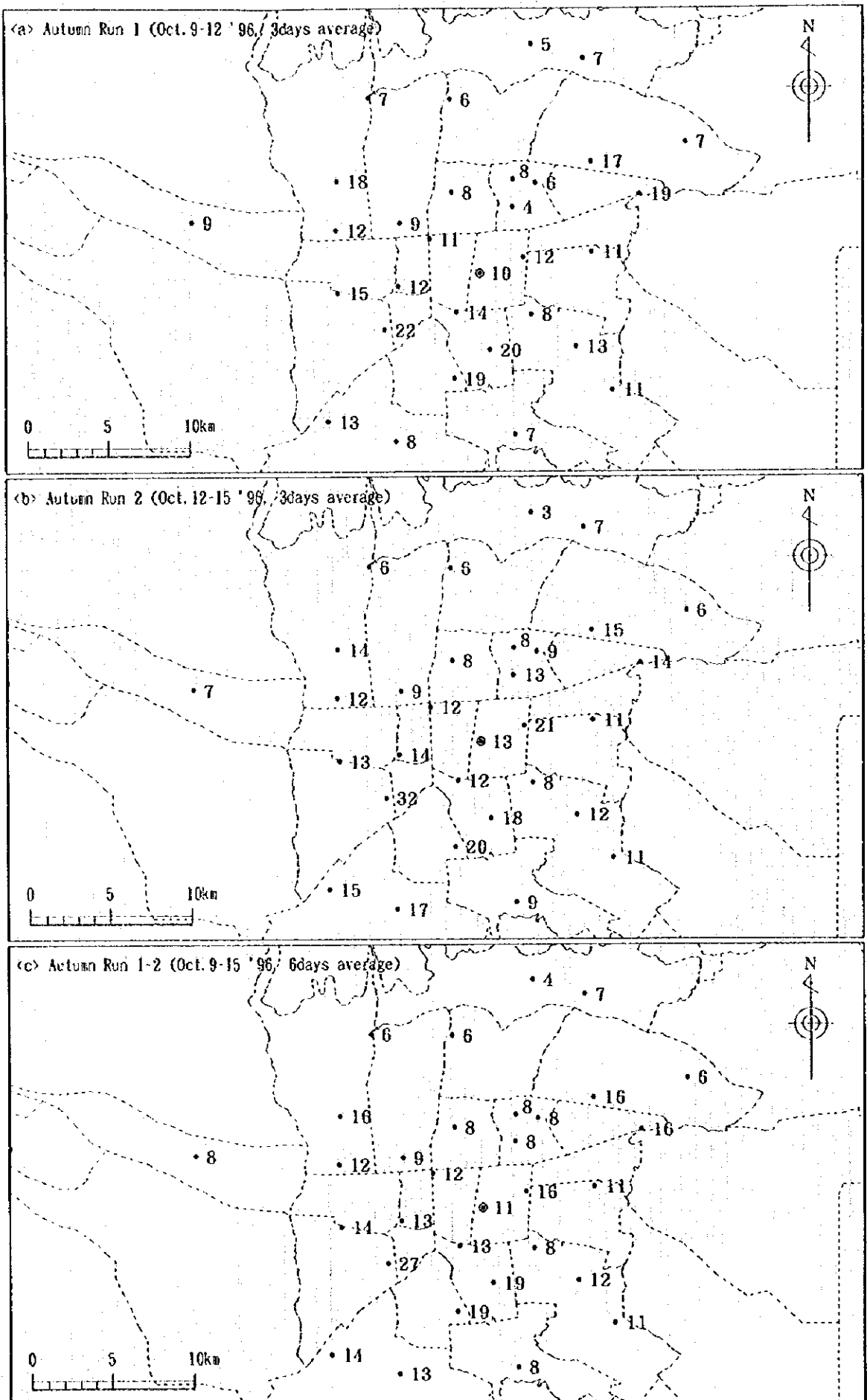


Fig. 4.2.3-6(1) SO₂ Concentration (I)

(Notes)
 Unit = ppb
 - ; Missed data
 ● ; No. 13 (MOI office bldg.)

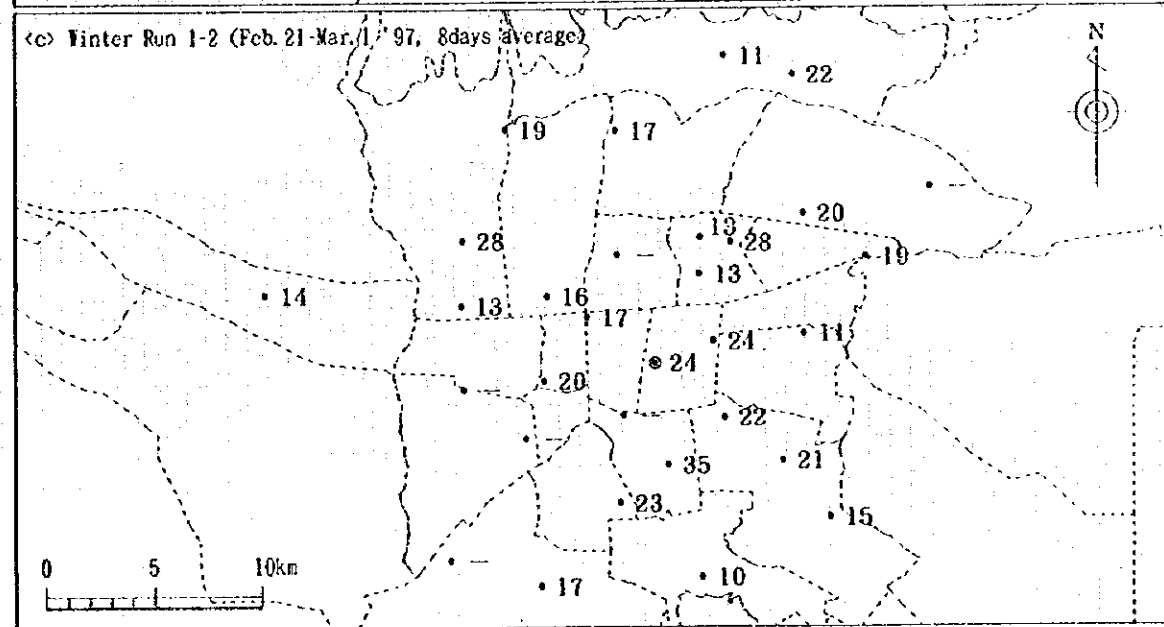
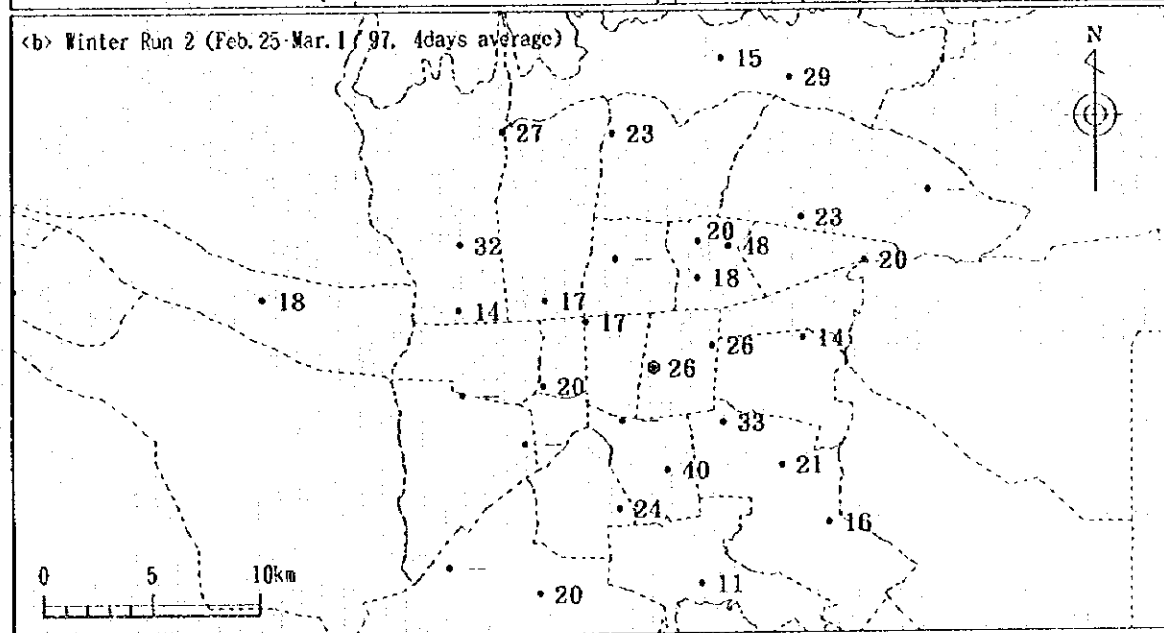
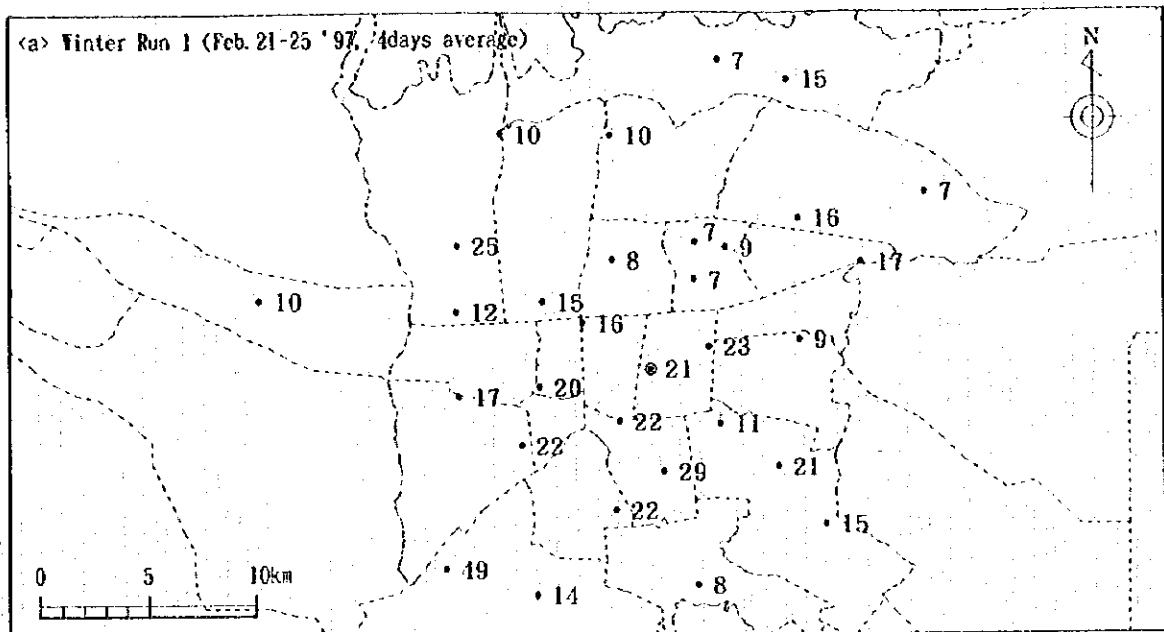


Fig. 4. 2. 3-6(2) SO₂ Concentration (2)

(Notes)
 Unit = ppb
 - ; Missed data
 ● ; No. 13 (MOT office bldg.)

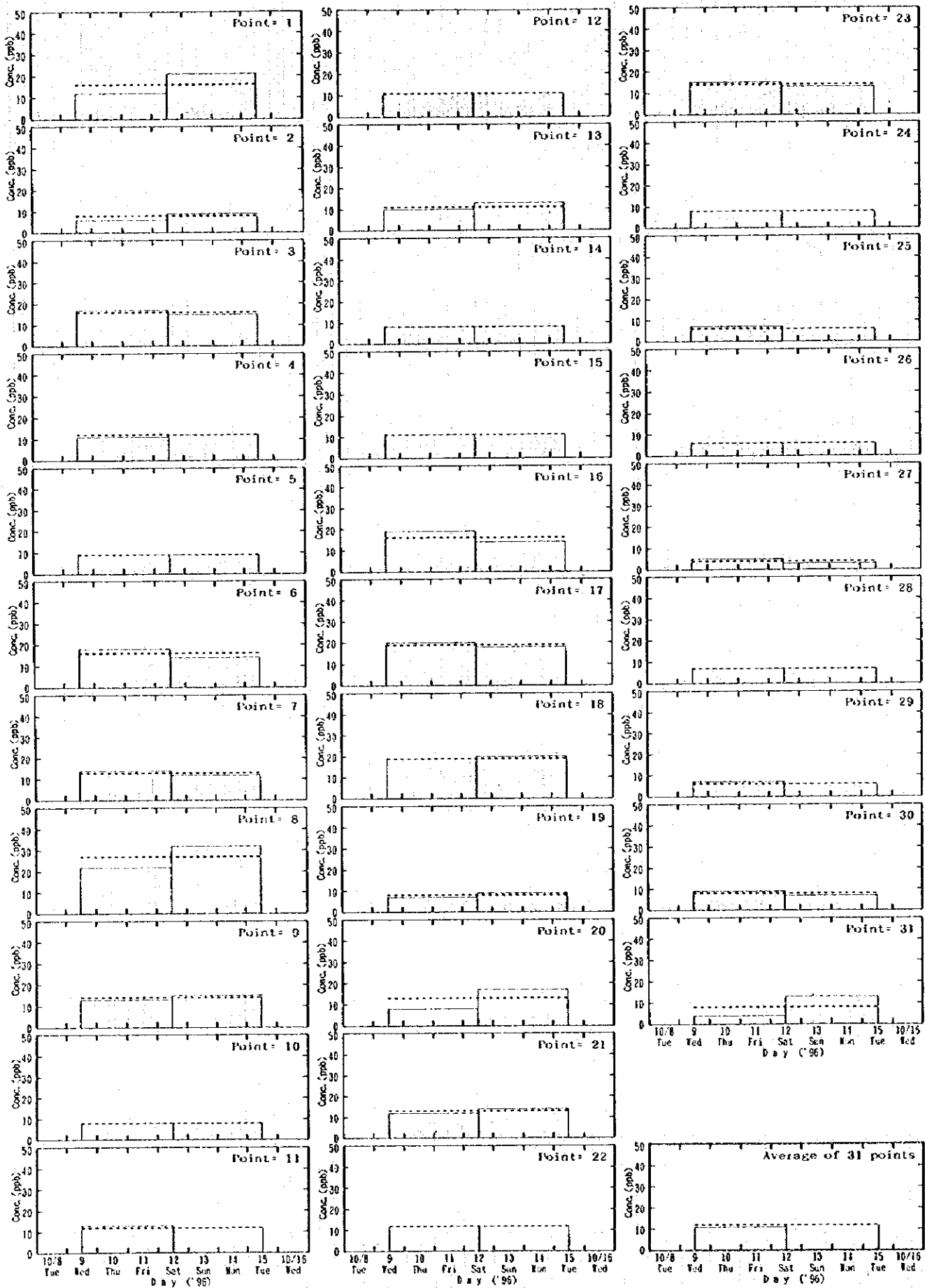


Fig. 4.2.3-7(1) Variation of SO₂ concentration (1)
(Autumn)

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

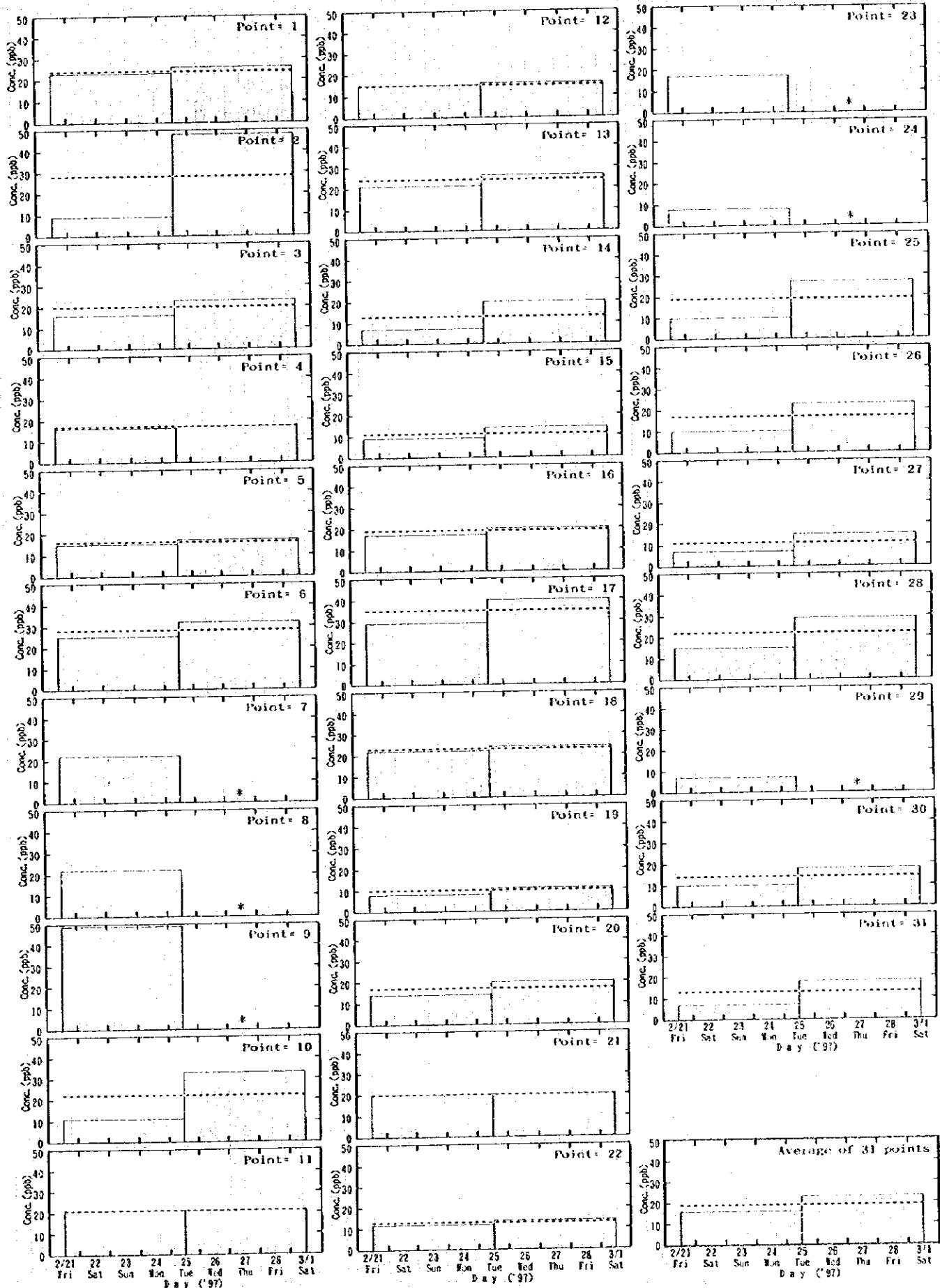


Fig. 4.2.3-7(2) Variation of SO₂ concentration (2)
(Winter)

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

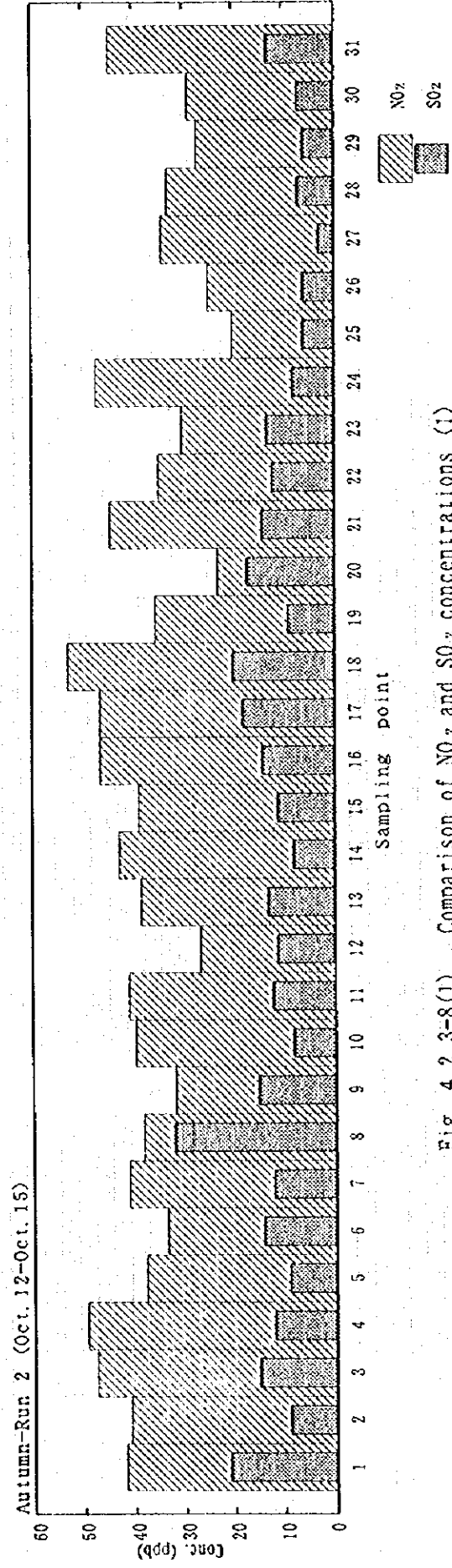
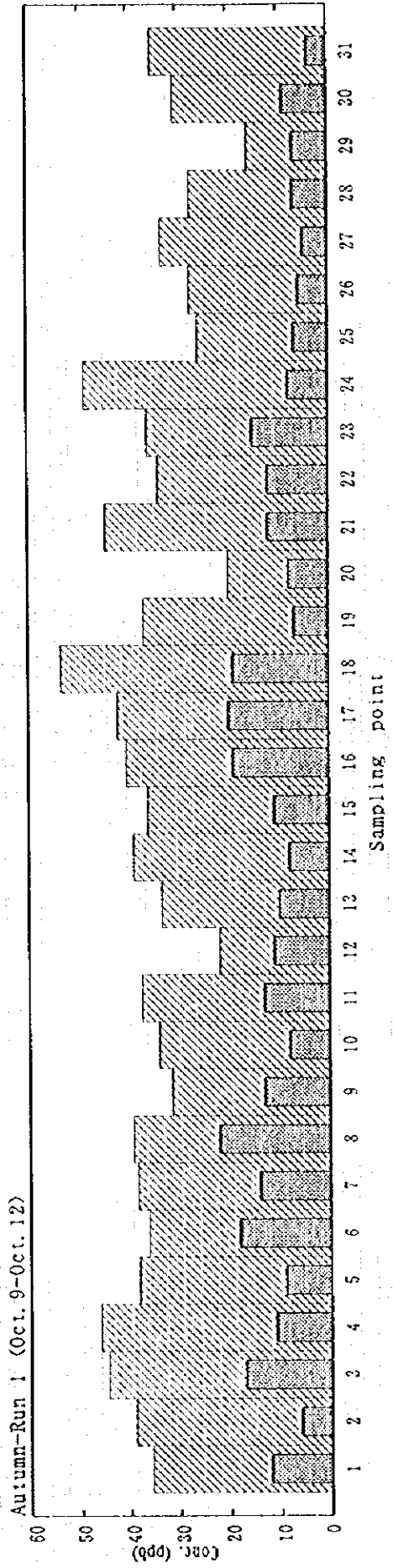


Fig. 4. 2. 3-8(1) Comparison of NO₂ and SO₂ concentrations (1)
(Autumn)

(Note) NO₂ is average value for the same period with SO₂.

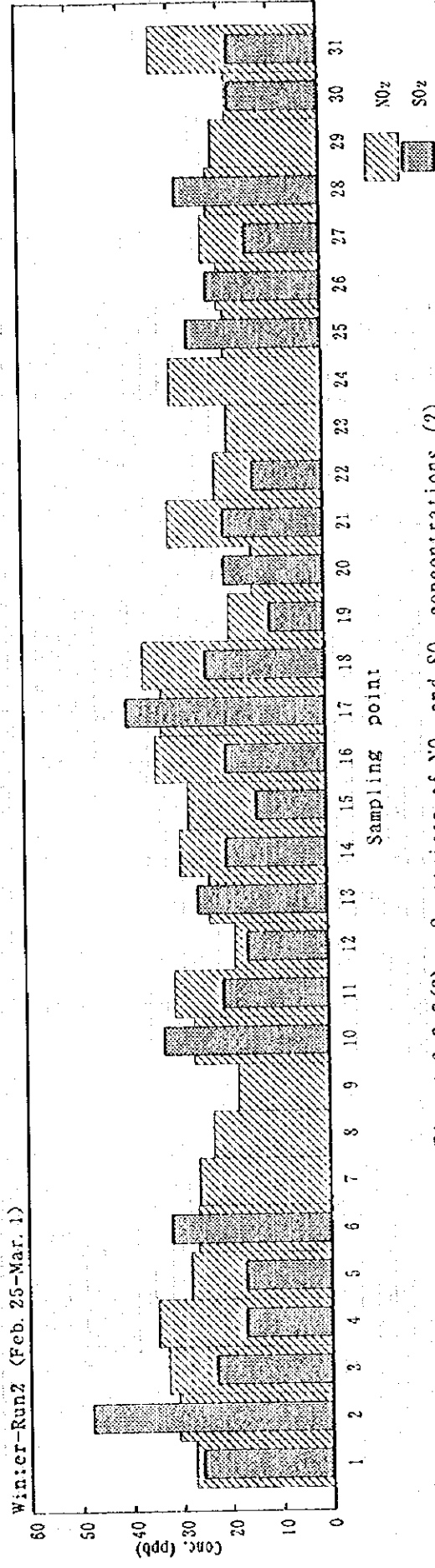
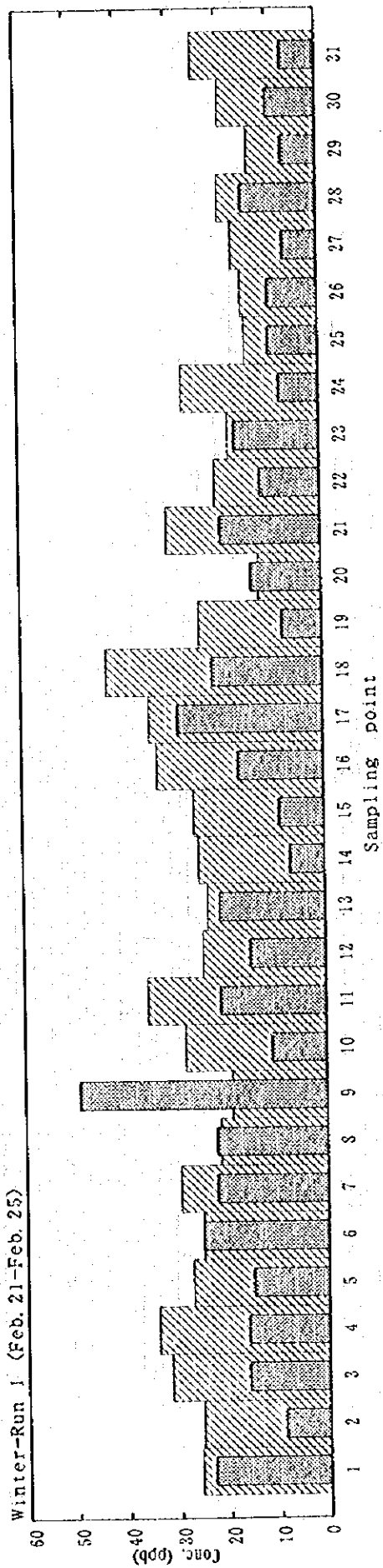


Fig. 4.2.3-8(2) Comparison of NO₂ and SO₂ concentrations (2)
(winter)

(Note) NO₂ is average value for the same period with SO₂.

3) VOC

The VOC (Volatile Organic Compound) concentration data of MOT taken in autumn and winter are shown in Table 4.2.3-7 and Tables 4.2.3-8(1) - (2), respectively. The diurnal variation of the VOC concentration in winter is shown in Fig. 4.2.3-9(1) - (2). The VOCs selected for the figure are Benzene, Toluene and Total-Xylene, which consists of o-, m-, p-Xylene and Ethylbenzene. Diurnal variation of a Toluene / Benzene ratio obtained during the winter measurement is shown in Fig. 4.2.3-10. For comparison, VOC data taken in Japan are also shown due to courtesy of the National Institute for Resources and Environment (NIRE); i.e. the VOC concentration, diurnal variation of VOC and a Toluene / Benzene ratio are shown in Table 4.2.3-9 and Fig. 4.2.3-11, respectively. These Japanese data were taken at the roadsides near Tokyo using the same techniques.

In Fig. 4.2.3-9, each of Benzene, Toluene and Total-Xylene shows a very similar variation pattern. In general, VOCs show two peaks in the morning and in the late evening; however, there is some difference in the variation pattern among the sampling points. The concentration of VOCs measured in Tehran is almost the same with or even higher than that of Japan. It can be said that the VOC concentration in Tehran is considerably high in view of the difference in the site conditions between Tehran and Japan; most measuring points in Teheran are located off streets, while those in Japan are along roads with extremely heavy traffic. Especially, as shown in Table 4.2.3-7, the VOC concentrations on very crowded roads are quite high, reaching 10 to 100 times of the maximum concentration measured in Japan.

Regarding a Toluene / Benzene ratio, Benzene is emitted mainly from motor vehicles, while Toluene is released not only from motor vehicles but also from painting factories, printing factories, manufacturing factories of plastics, etc. Exhaust gases from motor vehicles include VOCs which have not burned completely. And the composition of VOCs resembles those of fuels. It is said that a Toluene / Benzene ratio of gasoline is 2 to 4 on average. A Toluene / Benzene ratio in winter is close to this value, stays almost constant from morning to late evening, and also close to the value measured at roadsides, on the roads and at gas stations as shown in Table 4.2.3-7. On the other hand, in Table 4.2.3-9 and Fig. 4.2.3-11, the concentration of Toluene at Bijogi-hachiman increases abruptly from 9:00 to 10:00 a.m., and subsequently stays relatively high. The ratio also has a conspicuous peak

and changes parallel to the concentration of Toluene. There are small but many iron manufacturing factories in the neighborhood of the sampling site. It is considered that the peak is caused by the smoke emitted from these factories and transported by the wind at that time. In the case where there are other sources than motor vehicles, The ratio significantly changes. Therefore, a motor vehicle appears to be the major source of VOC.

At the MOT government office building (No. 132) and AQCC (No. 14), the HC concentration was measured following the same schedule with VOC, and each diurnal variation is also shown in Fig. 4.2.3-9. Three components of VOC and NMHC (THC) at these sampling points exhibit similar variation patterns. Though these three VOC components are only a portion of NMHC, the similarity between the diurnal variation of VOCs and NMHC probably suggests that NMHC be also originated mainly in automotive sources.

Table 4.2.3-7 VOC concentration taken at the autumn measurement

Sampling date : Oct. 29 '96	Sample name	Sampling time	Concentration (ppb)					T/B ratio	
			Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene		Total Xylene
Residence	AQCC (Point=14)	08:57-09:07	6.3	15.1	4.7	15.7	5.5	25.9	2.4
	AQCC (Point=14)	09:10-09:20	8.4	19.6	5.6	18.7	6.8	31.1	2.3
	AQCC (Point=14)	12:45-12:55	9.5	31.6	6.7	22.1	8.5	37.4	3.4
	AQCC (Point=14)	12:59-13:09	10.4	44.9	9.2	29.6	11.2	50.0	4.3
	AQCC (Point=14)	17:12-17:22	6.7	24.2	5.6	19.1	7.0	31.7	3.6
	AQCC (Point=14)	17:25-17:36	9.6	28.5	7.1	24.9	9.0	41.0	3.0
Residence	Apartment of AQCC staff	08:01-08:12	16.6	41.4	10.6	36.4	13.2	60.1	2.5
	Apartment of AQCC staff	08:14-08:25	13.1	36.8	9.5	32.0	11.9	53.3	2.8
	Apartment of AQCC staff	12:50-13:00	11.3	33.8	7.4	24.2	9.1	40.8	3.0
	Apartment of AQCC staff	13:01-13:11	13.1	36.8	7.6	24.3	9.3	41.2	2.8
	Apartment of AQCC staff	17:31-17:41	15.0	37.4	9.5	32.5	11.6	53.6	2.5
	Apartment of AQCC staff	17:43-17:55	13.0	31.4	7.9	26.9	9.5	44.3	2.4
Cross section	FATEMI	08:50-09:01	14.4	34.7	10.3	37.1	13.5	60.9	2.4
	FATEMI	09:03	4.1	10.0	3.6	12.9	4.4	20.9	2.4
	FATEMI	12:06-12:18	8.2	16.6	5.8	21.4	8.0	35.3	2.0
	FATEMI	12:23-12:33	11.0	23.8	7.7	28.1	9.9	45.7	2.2
	FATEMI	17:59-18:09	15.5	34.2	10.0	36.9	12.8	59.7	2.2
	FATEMI	18:11-18:21	26.6	58.8	17.6	64.6	22.1	104.3	2.2
Near road, On the road	Enghelab square	09:41-09:55	37.3	88.2	24.8	90.9	33.1	148.3	2.4
	Road Valiasr-Motahari-Bukharest	10:25-10:36	79.7	183.2	58.1	215.8	79.0	352.9	2.3
	Road Gaem Magam farahani	17:33-17:43	107.1	214.0	71.8	264.0	72.2	408.0	2.0
	Road Karegar	18:00-18:12	165.5	314.2	112.6	421.5	149.1	683.2	1.9
	Road Tohid	18:16-18:27	106.4	224.3	76.8	290.1	104.4	471.3	2.1
	Valiasr GS Gasoline	09:29-09:40	73.1	179.7	56.5	211.1	71.9	339.5	2.5
Gas station	Hafes-Engalobe	18:46-18:56	124.6	262.0	84.7	314.5	111.1	510.3	2.1
	GS LPG	10:31-10:52	8.9	25.9	6.6	24.6	8.9	40.2	2.9

(Notes) Total Xylene = Ethylbenzene + m,p-Xylene + o-Xylene. T/B ratio = Toluene / Benzene.

Table 4.2.3-8(1) VOC concentration taken at the winter measurement(1)

Run 1
Mar. 8 '97

Sampling time	Point=3										Point=6										Point=8									
	Benzene		Toluene		Ethyl- Benzene		m.p. Xylene		o- Xylene		Total Xylene		T/B ratio		Benzene		Toluene		Ethyl- Benzene		m.p. Xylene		o- Xylene		Total Xylene		T/B ratio			
	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc		
2(06:00-06:10)	9.1	19.0	3.0	11.8	3.0	17.8	2.1	7.8	10.9	1.7	6.9	2.8	11.3	1.4	4.0	10.6	1.4	5.3	0.9	7.6	2.6									
3(07:00-07:10)																														
4(08:00-08:10)	18.2	50.8	7.8	31.8	8.3	48.0	2.8	12.4	38.3	6.9	27.3	7.7	41.9	3.1	5.4	15.5	2.6	10.4	2.8	15.9	2.8									
5(09:00-09:10)																														
6(10:00-10:10)																														
7(11:00-11:10)	15.0	46.0	6.9	27.1	7.5	41.5	3.1	10.5	13.8	3.7	13.7	7.2	24.6	1.3	5.5	16.2	2.3	9.1	2.6	14.0	2.9									
8(12:00-12:10)																														
9(13:00-13:10)																														
10(14:00-14:10)																														
11(15:00-15:10)																														
12(16:00-16:10)	5.0	18.8	3.1	11.9	3.2	18.3	3.7	5.1	15.0	2.6	10.2	2.4	15.2	2.9	4.7	19.0	2.2	8.8	2.5	13.5	4.1									
13(17:00-17:10)																														
14(18:00-18:10)	6.9	21.8	3.8	15.1	4.1	23.0	3.2	6.9	20.7	3.7	15.2	4.6	23.5	3.0	5.8	28.9	3.5	13.5	3.7	20.6	5.0									
15(19:00-19:10)																														
16(20:00-20:10)	7.7	26.7	4.1	16.6	4.6	25.3	3.5	4.5	11.6	1.9	7.7	2.2	11.8	2.6	3.9	19.1	2.6	10.2	3.0	13.7	4.8									

Sampling time	Point=10										Point=14										Point=132										
	Benzene		Toluene		Ethyl- Benzene		m.p. Xylene		o- Xylene		Total Xylene		T/B ratio		Benzene		Toluene		Ethyl- Benzene		m.p. Xylene		o- Xylene		Total Xylene		T/B ratio				
	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc	Conc			
2(06:00-06:10)	2.8	6.8	1.2	4.5	1.0	6.8	2.4	2.0	5.6	1.0	3.7	0.5	5.2	2.8	2.0	5.6	1.0	3.8	0.6	5.5	2.8										
3(07:00-07:10)								4.0	11.6	2.0	8.1	1.7	11.8	2.9	2.2	6.5	1.0	4.0	0.5	5.5	3.0										
4(08:00-08:10)	4.2	11.9	1.9	7.3	1.7	10.9	2.9	6.2	17.4	2.9	11.5	3.0	17.4	2.8	5.6	17.9	2.7	10.8	3.0	16.6	3.2										
5(09:00-09:10)								3.6	17.0	2.9	11.1	2.9	16.9	3.1	4.5	15.3	2.2	8.5	2.3	13.0	3.4										
6(10:00-10:10)								8.6	28.0	4.6	17.2	5.3	27.0	3.2	3.8	11.2	1.9	7.2	1.7	10.8	3.4										
7(11:00-11:10)	6.2	18.4	2.9	11.7	3.4	18.0	3.0	4.9	15.7	2.4	8.9	2.3	13.6	3.2	2.0	8.7	1.0	3.9	0.5	5.4	4.4										
8(12:00-12:10)								3.2	12.2	2.0	7.0	1.8	10.7	3.8	1.8	6.1	1.0	3.9	0.6	5.5	3.4										
9(13:00-13:10)								2.7	8.9	1.6	5.8	2.4	9.8	3.9	4.8	17.5	2.4	8.7	2.2	13.3	3.6										
10(14:00-14:10)								3.0	10.4	1.9	6.8	1.7	10.4	3.5	5.6	18.1	3.0	11.3	1.2	15.6	3.2										
11(15:00-15:10)								3.4	11.6	2.1	7.8	2.5	11.6	3.6	1.3	5.2	0.9	3.9	0.4	4.5	4.0										
12(16:00-16:10)	7.6	24.5	3.7	15.6	4.7	24.1	3.2	2.3	7.6	1.3	5.2	0.9	7.5	3.3	2.1	8.0	1.3	5.0	0.7	7.1	3.7										
13(17:00-17:10)								4.7	20.4	3.6	14.5	4.0	22.0	4.3	2.9	11.3	1.7	6.7	1.4	9.9	3.9										
14(18:00-18:10)	13.3	45.1	6.9	28.3	8.7	43.9	3.4	3.0	11.3	2.0	8.0	1.7	11.7	3.8	4.2	14.6	2.4	9.5	2.4	14.2	3.5										
15(19:00-19:10)								5.3	17.7	3.1	12.5	3.3	18.8	3.3	5.0	16.2	2.6	10.3	2.8	15.9	3.2										
16(20:00-20:10)	13.5	45.2	7.2	29.7	9.2	46.1	3.4	7.3	21.0	3.5	13.9	3.6	20.9	2.9	5.5	20.0	3.3	13.6	3.7	20.7	3.6										

unit=ppb (notes)

*Missed data. *Data which includes some error.
Total Xylene = Ethyl-Benzene + m.p.Xylene + o-Xylene
T/B ratio = [Toluene]/[Benzene]

Table 4.2.3-8(2) VOC concentration taken at the winter measurement(2)

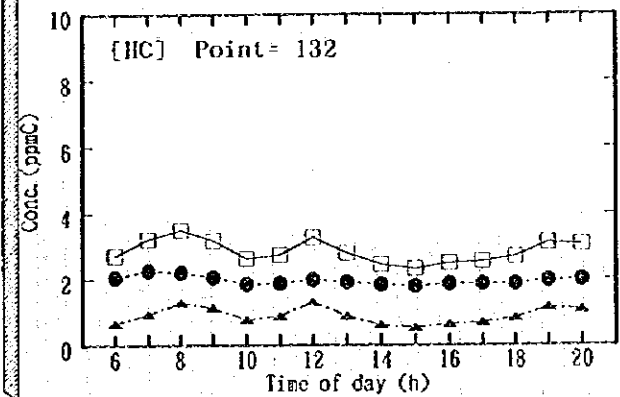
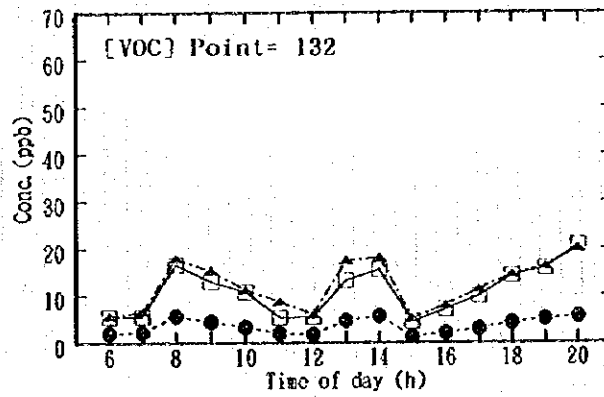
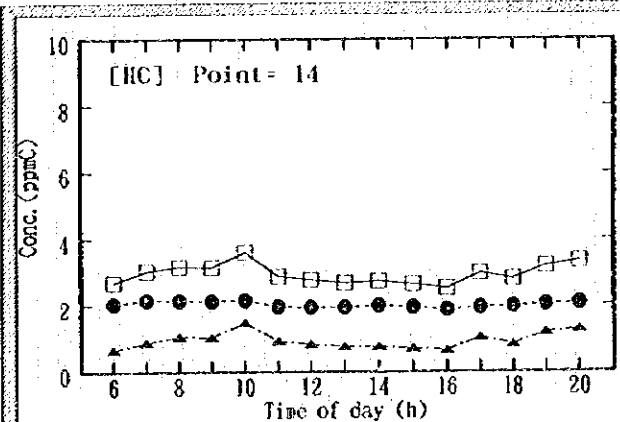
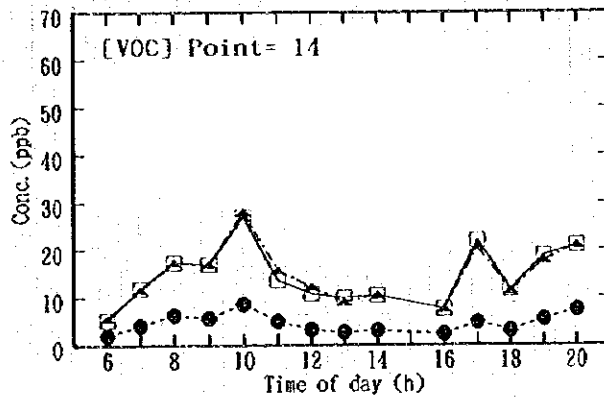
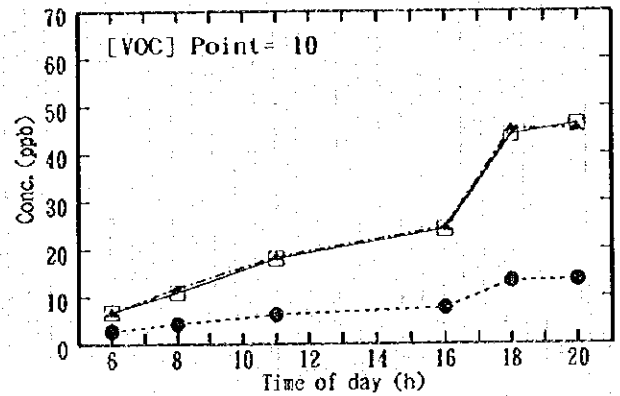
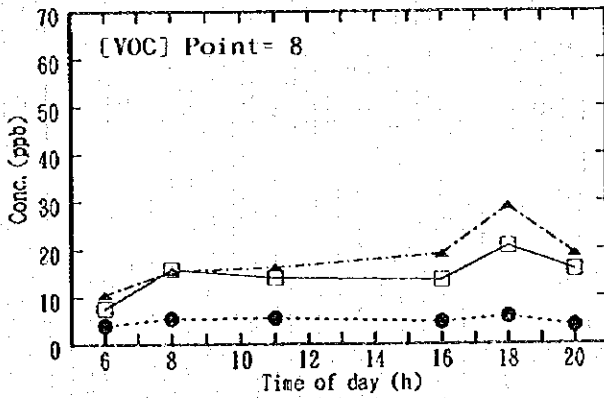
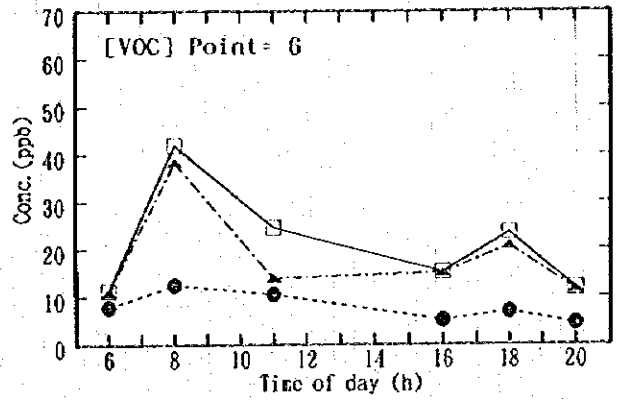
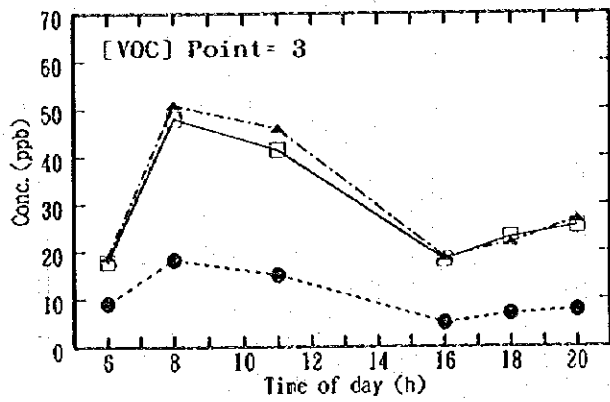
Run 2
Mar. 9 '97

Sampling time	Point=3					Point=6					Point=8										
	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio
	9.4	21.9	3.7	14.4	4.4	22.5	2.3	1.9	4.0	0.6	2.3	1.1	4.1	2.2	7.4	19.9	3.5	13.0	4.0	20.5	2.7
2(06:00-06:10)	6.1	19.6	3.4	13.3	4.6	21.3	3.2	6.6	15.3	2.8	10.6	3.2	16.5	2.3	10.1	26.6	5.0	19.7	6.9	31.6	2.6
3(07:00-07:10)																					
4(08:00-08:10)	12.9	34.0	5.8	23.1	7.9	36.7	2.6	25.1	63.7	11.3	44.6	15.3	71.4	2.5	18.3	46.2	7.1	28.3	10.7	46.0	2.5
5(09:00-09:10)																					
6(10:00-10:10)																					
7(11:00-11:10)	9.7	26.6	4.5	17.7	5.8	28.1	2.7	7.7	20.3	3.5	13.3	4.2	20.9	2.6	15.7	40.8	6.7	26.8	9.0	42.5	2.6
8(12:00-12:10)																					
9(13:00-13:10)																					
10(14:00-14:10)																					
11(15:00-15:10)																					
12(16:00-16:10)	9.8	27.1	4.0	15.3	4.8	24.1	2.8	9.2	23.2	4.0	15.2	5.4	24.5	2.5	4.7	12.5	1.6	5.5	3.0	10.1	2.7
13(17:00-17:10)																					
14(18:00-18:10)	16.9	48.4	8.0	31.3	10.9	50.1	2.9	9.9	26.3	4.4	17.3	5.5	27.1	2.7	8.4	21.3	2.5	8.7	4.3	15.5	2.5
15(19:00-19:10)																					
16(20:00-20:10)	14.0	38.5	6.3	24.8	9.0	40.1	2.8	24.4	62.4	11.1	44.1	16.1	71.3	2.6	9.8	49.9	5.6	21.7	7.5	34.9	5.1

Sampling time	Point=10					Point=14					Point=132										
	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio	Benzene	Toluene	Ethyl- Benzene	m.p. Xylene	o- Xylene	Total Xylene	T/B ratio
	9.4	21.9	3.7	14.4	4.4	22.5	2.3	1.9	4.0	0.6	2.3	1.1	4.1	2.2	7.4	19.9	3.5	13.0	4.0	20.5	2.7
2(06:00-06:10)	7.3	14.6	2.6	10.1	3.1	15.8	2.0	10.5	25.1	5.4	22.7	8.5	36.5	2.4	15.0	41.1	7.9	31.2	10.7	49.9	2.7
3(07:00-07:10)								3.0	8.0	1.3	5.2	4.0	10.4	2.7	7.3	21.9	3.5	13.5	5.2	22.1	3.0
4(08:00-08:10)								6.1	16.0	2.5	9.6	2.7	14.8	2.6	8.5	24.9	3.1	11.5	3.5	18.1	2.9
5(09:00-09:10)	2.9	5.5	1.2	4.4	0.8	6.4	1.9	3.8	8.9	1.2	4.6	1.8	7.6	2.4	7.0	21.5	2.5	9.6	3.1	15.2	3.1
6(10:00-10:10)								1.3	5.8	0.8	2.9	0.8	4.5	4.6	3.9	10.8	1.3	4.4	1.0	6.6	2.7
7(11:00-11:10)								3.9	9.1	1.4	4.8	0.1	6.3	2.3	3.5	11.3	1.3	4.5	1.1	6.9	3.2
8(12:00-12:10)								4.6	10.3	1.4	5.1	2.1	8.6	2.2	2.3	7.3	0.9	3.0	0.0	3.9	3.2
9(13:00-13:10)								2.4	7.3	1.2	4.1	2.1	7.4	3.0	3.6	11.6	1.4	4.7	1.0	7.1	3.2
10(14:00-14:10)	7.9	18.2	2.3	8.3	2.5	13.1	2.3	3.8	12.6	1.7	6.3	1.5	9.5	3.4	4.5	16.5	1.3	6.6	1.7	10.1	3.6
11(15:00-15:10)								4.9	13.8	2.3	8.4	4.4	15.1	2.8	7.0	18.0	2.7	9.8	2.8	15.3	2.6
12(16:00-16:10)								6.2	16.4	2.8	10.3	3.0	16.1	2.7	4.7	15.5	2.1	7.6	1.9	11.5	3.3
13(17:00-17:10)	15.2	34.5	4.8	18.3	8.3	31.3	2.3	4.9	13.8	2.3	8.4	4.4	15.1	2.8	2.1	12.9	1.9	7.1	1.3	10.2	6.1
14(18:00-18:10)								5.4	13.9	2.5	9.2	3.2	14.9	2.6	2.1	12.9	1.9	7.1	1.3	10.2	6.1
15(19:00-19:10)								6.8	18.5	3.2	12.2	4.0	19.4	2.7	9.5	30.5	4.4	16.6	5.6	26.6	3.2
16(20:00-20:10)	4.6	13.0	1.6	7.7	3.1	12.5	2.8														

unit=ppb

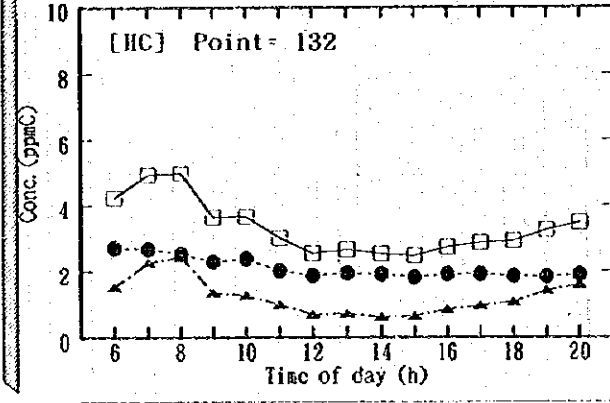
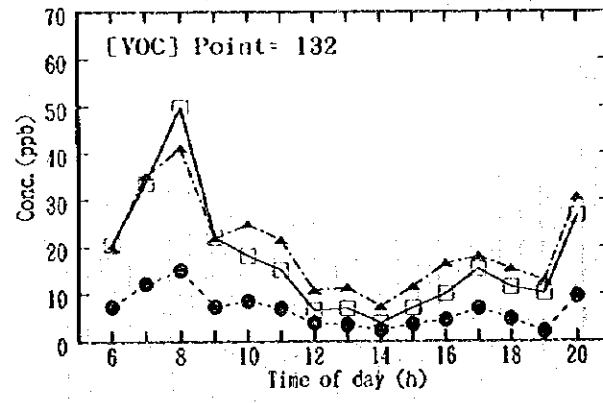
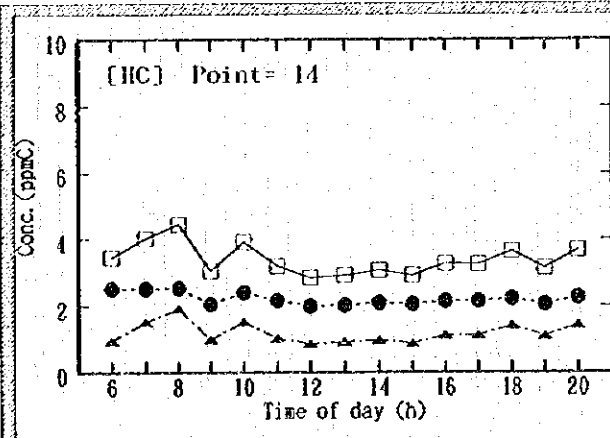
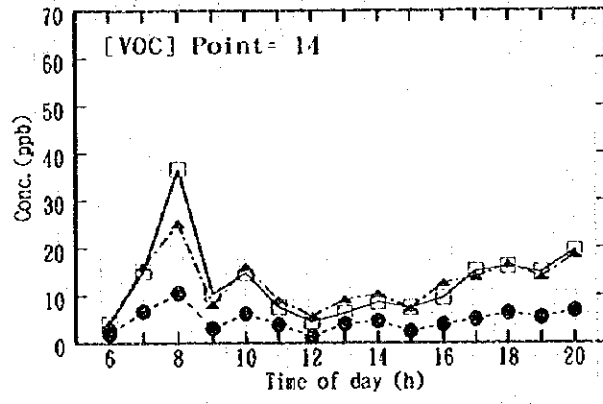
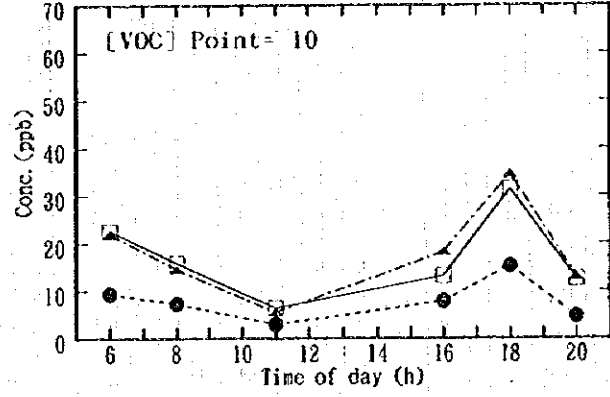
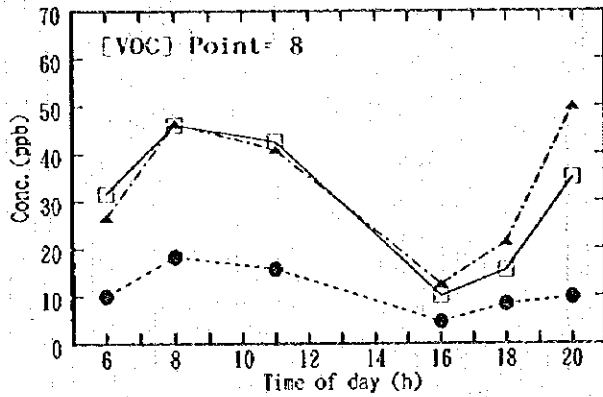
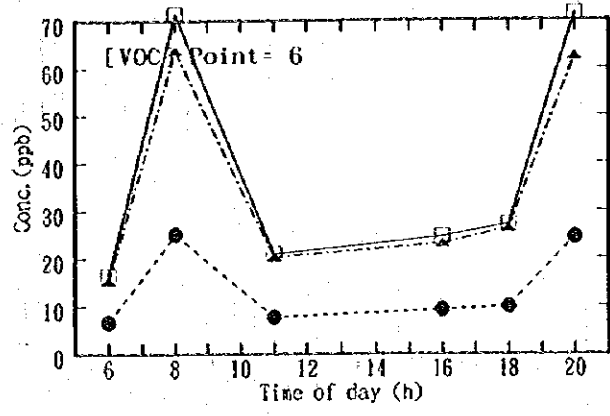
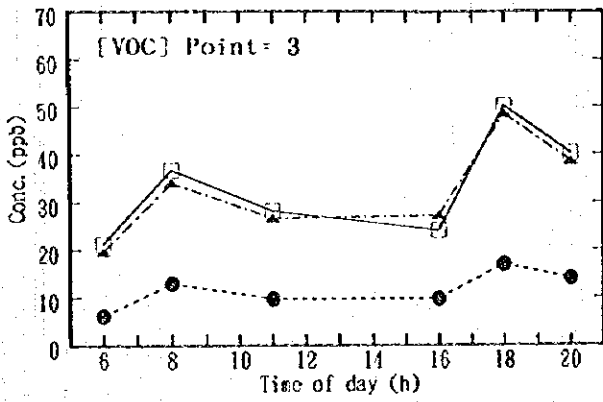
(notes)
-Missed data. *Data which includes some error
Total Xylene = Ethyl-Benzene + m,p-Xylene + o-Xylene
T/B ratio = [Toluene]/[Benzene]



[VOC]
 ● Benzene ▲ Toluene □ Total-Xylene

[HC]
 ● CH4 ▲ NMHC □ THC

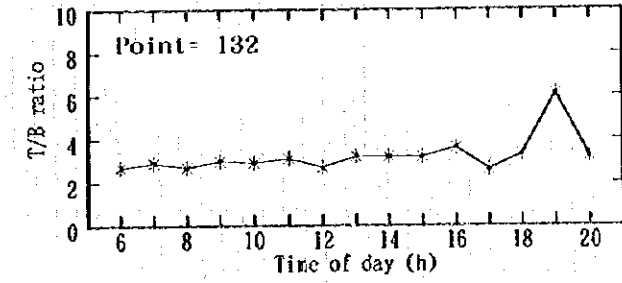
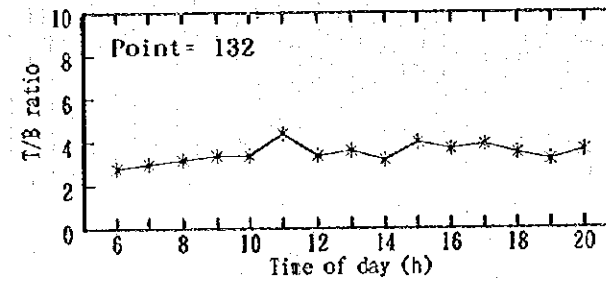
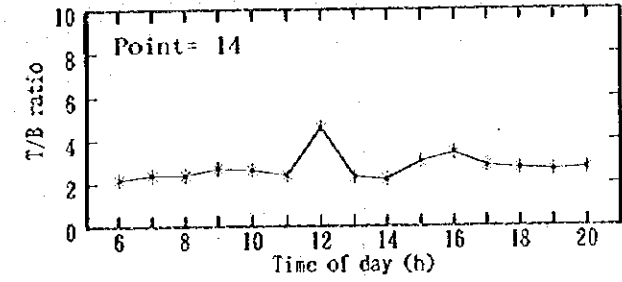
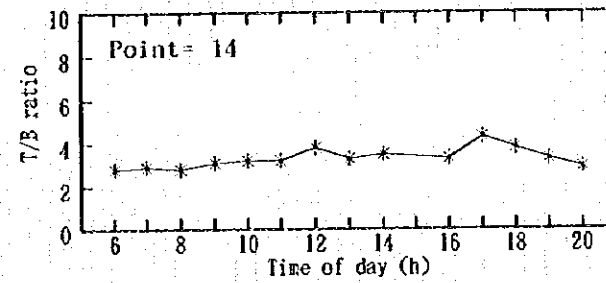
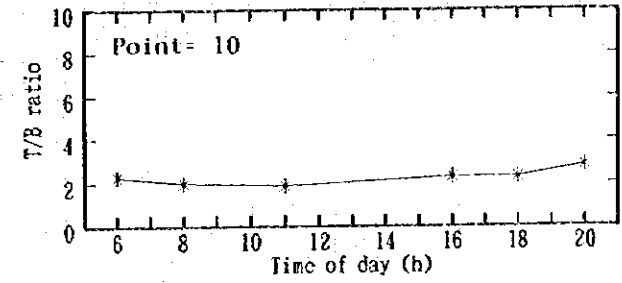
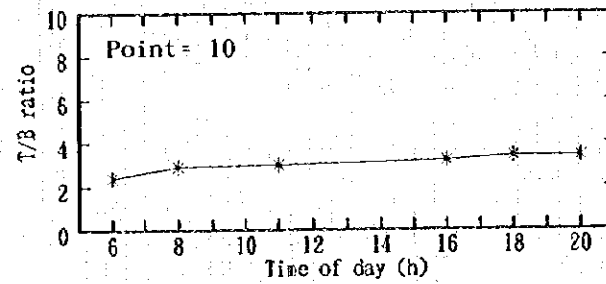
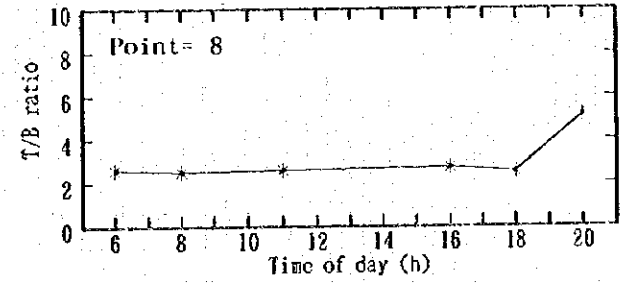
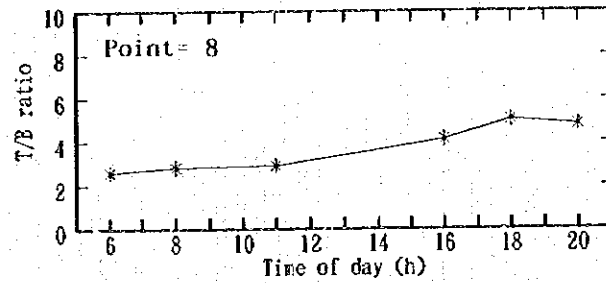
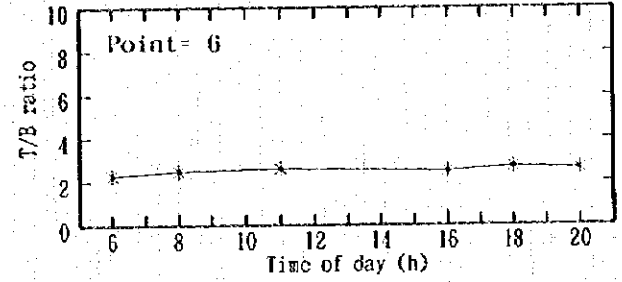
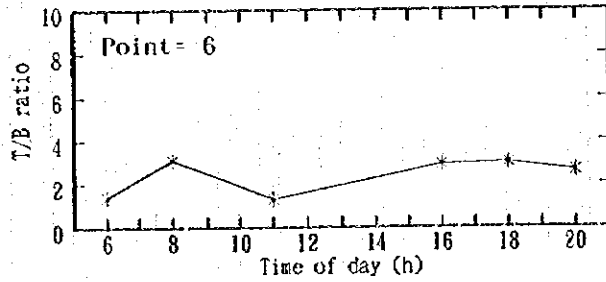
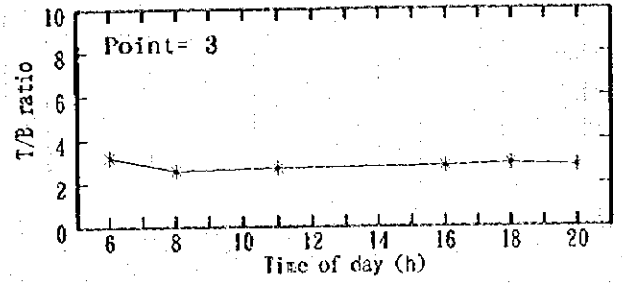
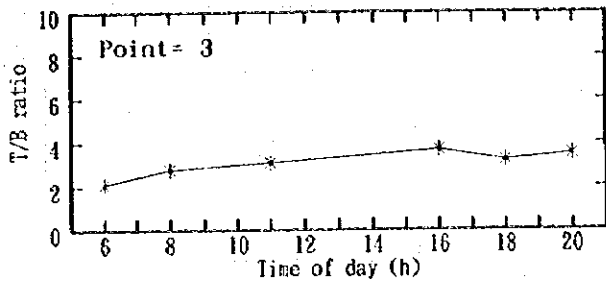
Fig. 4.2.3-9(1) Diurnal variation of VOC and HC concentrations (1)
 Winter - Run 1 Mar. 8 '97



[VOC]
 ● Benzene ▲ Toluene □ Total-Xylene

[HC]
 ● CH4 ▲ NMHC □ THC

Fig. 4.2.3-9(2) Diurnal variation of VOC and HC concentrations (2)
 Winter - Run 2 Mar. 9 '97



[Winter-Run 1 Mar. 8 '97]

[Winter-Run 2 Mar. 9 '97]

Fig. 4.2.3-10 Diurnal variation of Toluene/Benzene ratio

Table 4.2.3-9 Example of VOC concentration measured in Japan

Sampling Point	Sampling time	Concentration (ppb)					T/B ratio		
		Benzene	Toluene	Ethylbenzene	m,p-Xylene	o-Xylene		Total Xylene	
Bijogi-hachiman (Sep. 12 '96)	06:00	4.1	19.3	1.8	2.8	1.2	5.8	4.7	
	07:00	3.2	10.6	1.3	2.5	1.0	4.8	3.3	
	08:00	1.9	5.6	0.6	1.2	0.6	2.4	2.9	
	09:00	3.3	55.6	1.7	2.4	1.0	5.1	16.8	
	10:00	2.5	89.6	1.3	1.7	0.9	3.9	35.8	
	11:00	1.8	13.4	0.8	1.3	0.5	2.6	7.4	
	12:00	3.6	21.2	1.3	1.6	0.8	3.7	5.9	
	13:00	3.3	19.0	1.2	1.8	0.8	3.8	5.8	
	14:00	2.6	16.3	1.7	2.3	0.9	4.9	6.3	
	15:00	3.4	25.5	1.9	2.8	1.2	5.9	7.5	
	16:00	3.7	20.9	2.2	3.2	1.2	6.6	5.6	
	17:00	3.2	15.1	1.9	2.9	1.2	6.0	4.7	
	18:00	3.7	26.1	2.9	4.3	1.6	8.8	7.1	
	19:00	2.7	10.8	3.0	4.1	1.5	8.6	4.0	
	Tokyo metropolitan expressway No.13	09:00	4.3	10.8	1.3	2.9	1.1	5.3	2.5
		10:00	3.9	11.0	1.3	2.8	1.1	5.2	2.8
		11:00	3.5	11.1	1.3	2.6	1.0	4.9	3.2
		12:00	2.8	11.5	1.4	2.3	0.9	4.6	4.1
		09:00	4.7	13.4	2.3	4.6	1.8	8.7	2.9
10:00		4.8	11.4	2.1	3.9	1.6	7.6	2.4	
11:00		3.8	10.5	1.6	3.0	1.2	5.8	2.8	
12:00		2.5	6.2	1.0	1.8	0.7	3.5	2.5	
09:00		3.7	9.1	1.4	2.6	1.0	5.0	2.5	
10:00		2.9	7.8	1.4	2.3	0.9	4.6	2.7	
11:00		2.2	6.5	1.3	2.0	0.8	4.1	3.0	
12:00		1.8	3.5	0.4	0.9	0.4	1.7	1.9	
13:00		1.3	4.3	0.5	0.8	0.3	1.6	3.3	

(Notes) Total Xylene = Ethylbenzene + m,p-Xylene + o-Xylene. T/B ratio = Toluene / Benzene.

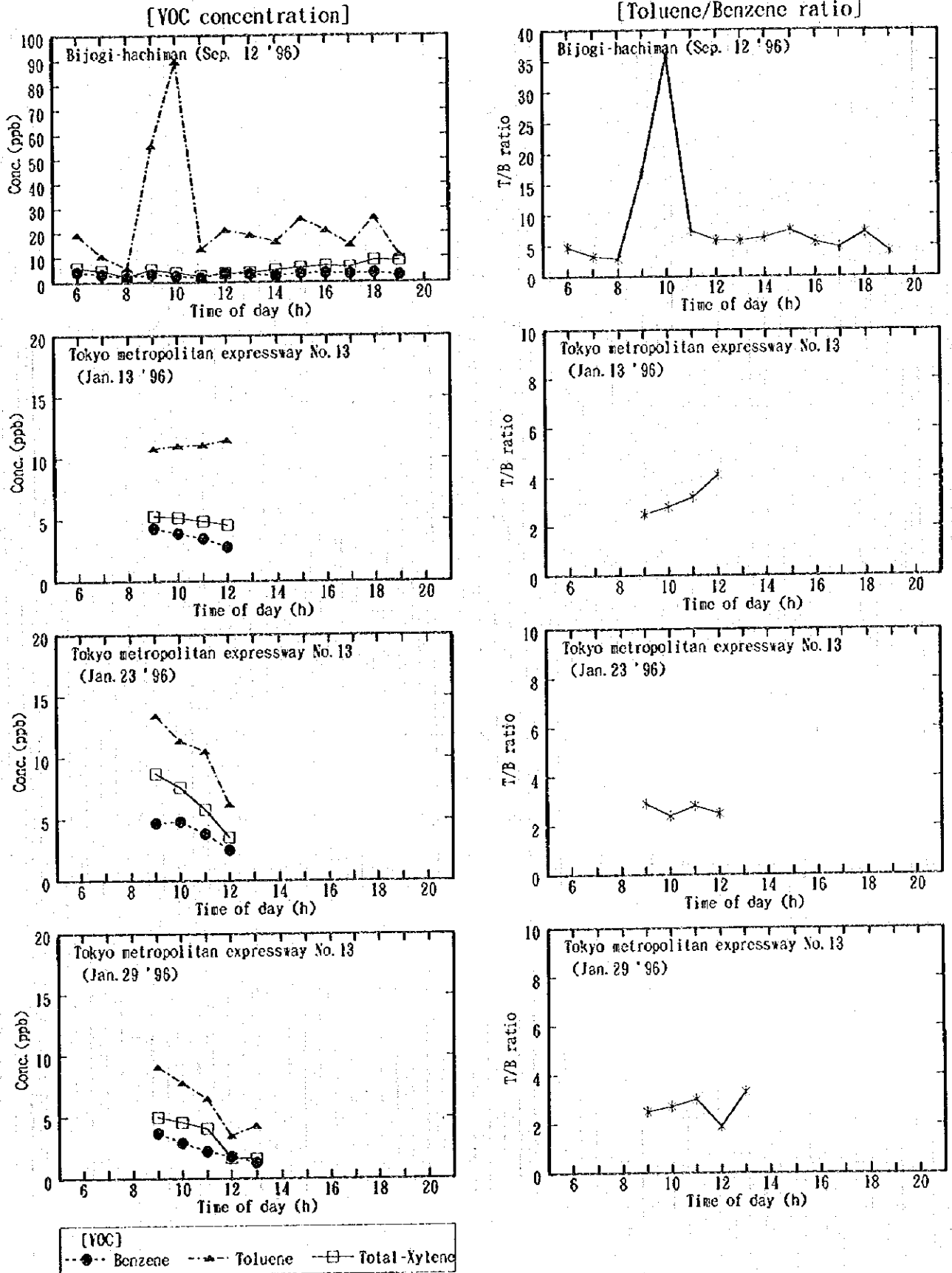


Fig. 4.2.3-11 Diurnal variation of VOC concentration measured in Japan

(2) SPM concentration

The ambient concentration of each component analyzed in Japan and Tehran is shown in Table 4.2.3-10 and Table 4.2.3-11, respectively. In these tables, components to be analyzed are listed for each analysis method. The data sampled with a quartz filter was employed for the analysis of the SPM ($\leq 10 \mu\text{m}$) concentration, because a quartz filter was one of the most popular filters for collection of particulate matters. The SPM concentrations listed on both tables are the values measured in Tehran before the sample was divided into two parts for the following analyses in respective countries.

As well as SPM, PM-10 indicates the concentration of the particulate matters of which diameters are less than $10 \mu\text{m}$; their filtering method, however, is not the same. The monitoring stations in Tehran employ PM-10, while on the other hand, SPM is used in Japan. Therefore, when the SPM concentration is compared with PM-10, it must be noted that there is difference in the upper limit of particulate penetration into the filter between SPM and PM-10. The low-volume air sampler used for collection of airborne particles in these two measurements has the centrifugal separation type grading device called a cyclone pre-separator, which eliminates coarse particles. This device can remove almost all particles whose diameter is larger than $10 \mu\text{m}$, and the diameter which corresponds to 50 % of the penetration ratio is $7 \sim 8 \mu\text{m}$ in the SPM measurement. On the other hand, as for PM-10, the diameter with a 50 % penetration ratio is $10 \mu\text{m}$. Therefore, usually the concentration of SPM is lower than PM-10. In Table 4.2.3-10, the data below the detection limit are shown by indicating its detection limit with "<" and treated as half an amount of the detection limit for the average calculation.

As a whole, the results of the analysis in Tehran differ much from those in Japan. For example, the concentrations of some components like *Ca* and *Pb* are close to the values analyzed in Japan, though other ones such as *Mn* considerably differ. And "ND" meaning "below the detection limit" is often seen in the Tehran data. Such differences are supposed to come from differences in analytical devices. The sensitivity of atomic absorption analysis is not so high as that of the Radio activation analysis. When the concentration is around the detection limit, an analytical error is larger than in the case where it exceeds the detection limit. On the other hand, some signs of "ND" of metals are acceptable, especially in the case

of trace compounds such as *V* and *Sc*. Usually, however, the concentration of sulfate (SO_4^{2-}) is comparatively high, possibly causing errors in analysis of autumn samples.

For the CMB measurement, because it is necessary to analyze many components including trace elements, analytical devices with high sensitivity will be indispensable in the future.

The explanation of SPM composition and CMB analysis described in 4.2.4 is made mainly based on the results analyzed in Japan by taking account of a number of available data.

In Table 4.2.3-10, about 54% of SPM in the autumn measurement and about 63% in the winter measurement are explained by accumulation of each component. In accumulation, the concentrations of SO_4^{2-} and *Cl* are neglected to prevent double counting of *S* and *Cl*. The SPM concentration in the autumn measurement is higher than that in winter as well as the gaseous pollutants except SO_2 . These components are divided roughly into two types; one is the component of which concentration in autumn is higher than that in winter and the other is the concentration on almost the same level in both seasons. In general, while the SPM components coming from natural sources, such as *Al* and *Ca*, are included in the former group, the components mainly originated in human activities such as *S*, *V* and *C* and the secondary particles such as NO_x and SO_4^{2-} belong to the latter.

Table 4.2.3-12 shows the comparison of the concentrations of SPM and its components measured and analyzed in Tehran and Japan. The data listed in the table as the Japanese data are quoted from "Annual Data Book of Air Pollution in Japan (1995)" published by the Environment Agency of Japan. From the National Air Pollution Monitoring Network of Japan, Kawasaki and Nohoro were selected as a typical industrial area and rural area respectively. Kawasaki is one of the biggest industrial and commercial cities adjacent to Tokyo, whose situation is close to Tehran except that more big factories are densely built up there.

The data of Tehran are the averages for each measuring period, while those of Japan are annual averages that are the medians between the maximum and the minimum of monthly mean data. In the table, the concentration ratios of Tehran and Kawasaki are also listed. The concentrations of *Cu*, *Mn*, *Cr* and *Fe* are almost identical in both cities, while those of

other components in Tehran are generally higher than those in Kawasaki: especially, and the concentrations of *As* and *Pb* in Tehran are 6 to 9 times higher than those in Kawasaki. It can be said that the concentrations of these two components are quite high even though the difference in the period for the average is considered. Furthermore, because these two pollutants have very high toxicity, long-term accumulation of those pollutants may have adverse effects on public health.

Table 4.2.3-10 SPM concentration analyzed in Japan

(a) Autumn (October '96)

Item	Run 1	Run 2	Run 3	Average
	(10/3-10/10)	(10/10-10/17)	(10/17-10/24)	(10/3-10/24)
1. SPM ($\leq 10 \mu\text{m}$)¹				
	108.324	72.140	100.691	93.731
2. Radio activation analysis²				
Al	3.234	2.139	1.638	2.336
Br	0.229	0.124	0.308	0.220
Ca	5.971	3.681	4.418	4.690
Cl	1.144	0.597	0.745	0.829
Cu	<0.03	<0.03	<0.03	<0.03
Mn	0.080	0.049	0.060	0.063
Ti	0.179	0.085	0.134	0.133
V	0.036	0.017	0.036	0.030
As	0.016	0.0095	0.0208	0.016
K	1.393	1.045	1.042	1.160
La	0.0011	0.0011	<0.0005	0.0009
Na	0.796	0.497	0.645	0.646
Sb	0.022	0.0075	0.021	0.017
Sm	0.00020	0.00015	0.00015	0.00017
W	<0.002	<0.001	<0.002	<0.002
Ag	0.0011	<0.001	<0.001	<0.001
Ba	0.075	<0.045	0.079	0.051
Ce	0.0036	0.0016	0.0019	0.0024
Co	0.0011	0.00090	0.00079	0.00094
Cr	0.0109	0.0018	0.0091	0.0084
Cs	0.0013	<0.0002	0.0006	0.0006
Fe	2.835	1.443	2.085	2.121
Hf	<0.0002	<0.0001	<0.0002	<0.0002
Lu	<0.00005	0.00005	<0.00005	<0.00005
Ni	<0.020	<0.015	<0.020	<0.018
Sc	0.00070	0.00048	0.00036	0.00051
Se	0.0100	0.0070	0.0104	0.0091
Th	0.00065	0.00044	0.00031	0.00047
Zn	0.697	0.393	0.794	0.628
3. X-ray fluorescent analysis²				
Pb	0.746	0.458	1.241	0.815
S	11.941	9.452	17.372	12.925
4. Ion Chromatography¹				
NO ₃ ⁻	1.927	1.372	3.055	2.119
SO ₄ ²⁻	8.767	5.912	11.661	8.783
Cl ⁻	0.580	0.241	0.452	0.425
NH ₄ ⁺	1.826	1.510	3.219	2.186
5. Carbon¹				
C-org	7.851	5.478	12.713	8.684
C-ele	10.812	7.045	14.742	10.872

(Notes) Filter : #1-Quartz, #2-Cellulose nitrate. * : below Detection limit

(b) Winter (February-March '97)

Item	Run 1	Run 2	Average
	(2/5-2/19)	(2/19-3/1)	(2/5-3/1)
1. SPM ($\leq 10 \mu\text{m}$)¹			
	65.228	69.979	67.515
2. Radio activation analysis²			
Al	1.0169	1.549	1.273
Br	0.082	0.059	0.071
Ca	2.381	3.472	2.906
Cl	0.694	1.202	0.939
Cu	<0.03	0.029	<0.03
Mn	0.035	0.037	0.036
Ti	0.082	0.088	0.085
V	0.035	0.025	0.030
As	0.017	0.024	0.020
K	1.389	1.656	1.517
La	0.00055	0.00099	0.00076
Na	0.546	0.481	0.514
Sb	0.016	0.024	0.020
Sm	0.00006	0.00013	0.00009
W	<0.0010	<0.0008	<0.0009
Ag	<0.0005	<0.0008	<0.0006
Ba	<0.0248	0.0427	0.0206
Ce	0.00094	0.00168	0.00130
Co	0.00015	0.00040	0.00042
Cr	0.0022	<0.0021	0.0016
Cs	0.00050	0.00061	0.00055
Fe	1.116	1.389	1.247
Hf	<0.0001	0.00016	0.00011
Lu	<0.00003	<0.00003	<0.00003
Ni	0.025	0.013	0.019
Sc	0.00021	0.00029	0.00025
Se	0.0018	0.0021	0.0019
Th	0.00016	0.00026	0.00021
Zn	0.347	0.374	0.360
3. X-ray fluorescent analysis²			
Pb	0.521	0.534	0.527
S	12.897	11.218	12.058
4. Ion Chromatography¹			
NO ₃ ⁻	2.057	1.842	1.953
SO ₄ ²⁻	10.126	8.198	9.198
Cl ⁻	0.261	0.528	0.389
NH ₄ ⁺	1.866	1.457	1.669
5. Carbon¹			
C-org	6.019	6.867	6.427
C-ele	12.058	9.113	10.656

(unit= $\mu\text{g}/\text{m}^3$)

Table 4.2.3-11 SPM concentration analyzed in Tehran

(a) Autumn (October '96)

Item	Run 1	Run 2	Run 3	Average
	(10/3-10/10)	(10/10-10/17)	(10/17-10/24)	(10/3-10/24)
1. SPM ($\leq 10 \mu\text{m}$)¹				
	108.324	72.140	100.691	93.731
2. Atomic absorption analysis²				
Al	ND	ND	ND	ND
Ca	4.229	4.228	3.822	4.093
Mn	ND	ND	ND	ND
V	ND	ND	ND	ND
K	1.990	0.995	1.985	1.657
Na	0.318	0.318	0.963	0.534
Fe	0.657	0.328	0.0	0.328
Sc	ND	ND	ND	ND
Zn	1.314	1.234	1.449	1.332
Pb	0.707	ND	1.062	0.590
3. Fluorescent X-ray analysis²				
S	2.687	5.074	7.445	5.071
4. Spectrophotometric analysis¹				
NO ₃ ⁻	0.735	0.358	1.052	0.715
SO ₄ ²⁻	ND	ND	ND	ND
Cl ⁻	ND	ND	ND	ND
NH ₄ ⁺	1.839	0.249	3.375	1.822

(Notes) Filter : #1-Quartz, #2-Cellulose nitrate. *ND* : below Detection limit

(b) Winter (February-March '97)

Item	Run 1	Run 2	Average
	(2/5-2/19)	(2/19-3/1)	(2/5-3/1)
1. SPM ($\leq 10 \mu\text{m}$)¹			
	65.228	69.979	67.515
2. Atomic absorption analysis²			
Al	ND	ND	ND
Ca	2.227	2.983	2.591
Mn	0.699	0.620	0.661
V	ND	ND	ND
K	12.202	8.333	10.340
Na	0.600	0.616	0.622
Fe	0.387	0.967	0.666
Sc	ND	ND	ND
Zn	0.422	0.454	0.437
Pb	0.511	0.732	0.617
3. Fluorescent X-ray analysis²			
S	3.274	3.953	3.601
4. Spectrophotometric analysis¹			
NO ₃ ⁻	4.310	1.282	2.868
SO ₄ ²⁻	2.827	3.552	3.176
Cl ⁻	ND	ND	ND
NH ₄ ⁺	0.868	1.028	0.915

(unit= $\mu\text{g}/\text{m}^3$)

Table 4.2.3-12 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
	Average	Winter Average	Kawasaki (Kanagawa)*1 Average	(Min-Max)	Nohoro (Hokkaido)*2 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	(590-1600)	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 = μ g/m³

*4 : Based on the average data

4.2.4 Chemical mass balance (CMB) analysis

The CMB analysis is a method to know the contribution of each emission source to the ambient aerosol based on the ingredients composition of the aerosol collected at a certain location and data of the ingredients composition of particulate matters of an emission sources using indicative elements as tracers. The CMB analysis needs data of the ingredients composition of particulate matters of an emission source whose contribution to the pollution of the region to which the analysis applies are considered substantial. Because MOT, however, does not have the data of the emission source, which is the most important, this report has used the emission source data of NBS (National Bureau of Standards, USA) as the proxy to carry out the CMB analysis. How these data resemble those of MOT is not known. Since a little variation of the ingredients composition may significantly affect the analysis outcome, the analysis result is expressed numerically in the contribution of each emission source but can not be claimed to be quantitative. Consequently, the outcome is meaningful only for reference at the present time.

However, should MOT have accurate emission source data in the future, the CMB analysis would be an important method for knowing the information on emission sources of the ambient aerosol. Consequently, this CMB analysis has been made mainly for the purpose of technology transfer. Its outline and outcome are described below.

(1) Method used in CMB analysis

The suspended particulate matters are collected with an air filter sampler or a dust jar, while the constituent elements are detected with the fluorescent X-ray analysis, radio activation analysis and others. Most of detectable elements are metallic elements such as *Al, Ca, V, Mn, Fe, Zn, As, Pb, K, Mg, Ba, Cr, Co, Cu, and Se*. Emission sources are classified into some types so that the composition of elements of each source will be unique to itself. An example is shown in Table 4.2.4-1. The data listed in the table are quoted from Currie et al.¹⁾ of NBS and this list will also be referred to for the CMB analysis of these measurements mentioned in the following paragraphs.

An example of composition of SPM in the ambient air collected in Tehran is shown in Table 4.2.4-2. The data listed in the table are also used for the CMB analysis. Contribution of

each emission source to the receptor is estimated to find the approximation of the receptor composition nearest to the source composition. Further details of the method are explained with notations. The total concentration m is expressed by the sum of contribution of each emission source, measured in the environment M_j (g/m^3 j denotes emission sources, 1,2,3, ... p .)

$$m = \sum_{j=1}^p M_j$$

Total concentration C'_i of the element i is expressed by the following equation:

$$C'_i = \sum_{j=1}^p F'_{ij} X_{ij} M_j$$

where F'_{ij} : Ratio of element i at emission source j .

X_{ij} : Changing ratio of element i .

(proportion of the ratio of element i at receptor to at emission source)

Other notations are the same as before.

Usually, calculation is carried out assuming $X_{ij}=1$, which means that the ratio of element i is constant, and the concentration is normalized by total concentration m . Namely,

$$C_i = \sum_{j=1}^p F_{ij} S_j$$

where $C_i = C'_i/m$

F_{ij} : Ratio of element i at source j (viewed from the receptor point).

When $X_{ij}=1$, equal to F'_{ij} .

$$S_j = M_j/m.$$

Usually, the contribution ratio of each emission source to the concentration S_j is estimated from the measured values of C_i (Table 4.2.4-2) and F_{ij} (Table 4.2.4-1) with the CMB method. More details of the method are explained in the report of EPA²⁾ of USA.

Special material method

If a special material called tracer exists in the emission source j and other sources do not contain it, the last equation can be simplified as follows:

$$C_i = F_{i,j} S_j$$

Of course, such condition cannot be satisfied perfectly in the actual case, and this method has a disadvantage in that the information obtained from other elements is not used. It is, however, useful to get the first guess because of its simplicity.

Least square error method

If $i > j$, S_j can be estimated by the least square error method. This is the standard method and used by Miller et al.(1972)³⁾, Friedlander (1974)⁴⁾ and Gatz(1975)⁵⁾ and others. In Japan, Mizohata and Mamuro (1980)⁶⁾⁷⁾ used the same method. The condition of the least square error method is written as follows:

$$\frac{\partial \varepsilon}{\partial S_j} = 0: \quad \varepsilon = \sum_{i=1}^n \frac{C_i - \sum_{j=1}^p F_{i,j} S_j}{C_i}$$

Where ε is a square error and the other notations are the same with the above.

According to the above condition, j dimensional simultaneous linear equations of S_j can be derived and S_j values are obtained from the measured values of C_i and F_{ij} .

In the above equation, C_i and F_{ij} are regarded as having the same weight. In the actual measurements, however, this condition may not always be satisfied. If the weight of the measured value is different for each element, the last equation can be rewritten as follows:

$$\varepsilon^2 = \sum_{i=1}^n \left(\frac{\left(C_i + \sum_{j=1}^p F_{i,j} S_j \right)^2}{\sigma_i^2 C_i^2 + \sum_{j=1}^p \sigma_{i,j}^2 F_{i,j}^2 S_j^2} \right)$$

Where σ_i, σ_{ij} is coefficients expressing reliability of C_i, F_{ij} respectively.

The method based on the last equation is called "Effective variance least-squares method", which is used for identification of the emission source of SPM in the measurement in Tehran.

(2) CMB analysis

The CMB analysis was executed using the CMB codes (program) of "CMBVLJ" developed by Mizohata of Osaka Prefecture University in Japan. This code is based on the codes of John Watson, EPA and Thomas Dzubay, EPA in USA. Both EPA codes were delivered to many organizations studying air pollution in USA. The CMBVLJ code inherited their advantages but succeeded in eliminating their disadvantages.

The CMBVLJ code is for CMB calculation with an effective variance least-squares method. Composition of elements at the sources and elemental concentrations of SPM are required as input data. Up to 50 chemical elements can be treated and up to 30 among them can be chosen for fitting. For source data, up to 30 sources can be registered and 12 at most can be treated. Iteration of the program is terminated when variation of all source contribution become less than 0.5 % or when the number of iteration exceeds 25 times. The CMBVLJ code is written for IBM-PC and also available for NEC-PC.

The source profile used in this analysis is shown in Table 4.2.4-1. In the table, the concentration of each element is expressed as a percentage in the total suspended matters except CC which means the relative isotopic abundance, $^{14}C/C$. As to sources, "Oil" means the fuel used by motor vehicles and stationary sources, and "Wood" includes not only woods but also other plants like barley.

The environmental concentration data of these two seasons of measurements are shown in Table 4.2.4-2, listing error data of each element. The concentration of C is the sum of C-org and C-ele. Usually, an analytical error is smaller than that of sampling. Therefore, the sampling error is assumed at 5 % for the concentration for each component. In case of the radio activation analysis, however, a counting error of γ -ray of some species reaches 20~30 %. Consequently, for the component whose analytical error exceeds 5 %, the analytical error is given the priority.

Among the elements listed in the table, 9 elements were chosen as the "Tracer" elements, i.e. *C, Na, Al, K, V, Mn, Fe, Zn, and Pb*. *Si* is not an analyzed item, and *Cl, Ca, Cr, Ni, Cu, Ti, As* and *Br* are not used because of scarcity in the air or uncertainty of their concentrations. *S* is not used either, because its ambient concentration is higher than in Japan and USA, and its source composition is not maintained in the process of transportation. As the target sources, 8 from the 9 sources in Table 4.2.4-1, 8 are adopted except "Coal".

The CMB analysis was made for each run in the two measurements, i.e. 3 runs in autumn and 2 runs in winter, respectively. The results of the CMB analysis are shown in Table 4.2.4-3(1) - (2) for each run and Table 4.2.4-4 is the summary for each season. "Basalt" was excluded from the target, because the result proved its contribution was insignificant. Generally, comparison between the observed and calculated concentration for each element is satisfactory, though *Cr* is overestimated and *S* is underestimated. An attention should be paid, however, to a large error in calculated values. This is perhaps because of the uncertainty arising from the use of the emission source data that are not of MOT for the analysis. The contribution of each emission source to SPM is summarized as follows:

Contribution of each emission source

Source	Season		Total
	Autumn	Winter	
Steel	3	2	2
Incinerator	2	2	2
Oil	31	39	34
Sandblast	16	10	14
Soil	6	4	6
Wood	21	27	23
Road	5	5	5
Unknown	16	11	14

(unit=%)

In general, "Oil", namely combustion of fossil oil, makes a major contribution to the ambient SPM, around 30 - 40%. The second largest contribution is made by "Wood", over

20%, which may be overestimated in view of the location of data collection at the center part of MOT. This may be caused by the high concentration of *C* in SPM. "Wood", more than half of "Sandblast", "Soil" and a part of "Road" are considered to be natural emission sources, whose contribution totals about 40%. As pointed out previously, though the outcome of CMB analysis should be used only for reference information because of lack of emission source data available for CMB analysis, the above discussions suggest that natural sources as well as artificial sources appear to contribute to SPM of MOT.

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- 2) E P A ; Receptor model technical series, Vol. 1. Overview of model. Application to particulate source apportionment, FPA450-4/81-016a, Vol. 2. Chemical mass balance. EPA-4450/4-16b (1981).
- 3) Miller M. S., S. K. Friedlander and G. M. Hidy ; A chemical element balance for Pasadena aerosol. *J. Colloid Interface Science* 39 (1). 165-176 (1972).
- 4) Friedlander. S. K. ; Chemical element balance and identification of air pollution sources. *Atmos. Environ.*, 7.3.234-240 (1974).
- 5) Gatz D.F. ; Relative contributions of different sources of urban aerosol : Application of a new estimation method to multiple site in Chicago. *Atmos. Environ.* 9.1.1-17 (1975).
- 6) Mizohata R. and T. Mamuro ; Identification of emission source of particulate material in Sakai (1), *Journal of Air Pollution Society*, 15, 5, 198-206 (1980).
- 7) do (2) 15, 6, 225-233

Table 4.2.4-1 Composition of elements at emission source

Element	Composition of Elements									
	Steel		Incinerator		Oil		Sandblast		Basalt	
	Conc.	Error	Conc.	Error	Conc.	Error	Conc.	Error	Conc.	Error
C	14.9158	1.2133	3.9991	0.3399	19.8625	1.6090	0.5178	0.0614	0.0150	0.0212
Na	0.9263	0.1126	13.2260	1.3426	2.0676	0.2268	0.8519	0.1052	2.0168	0.2216
Al	1.3196	0.2079	0.4855	0.0828	0.6088	0.1013	0.8117	0.1318	8.5596	1.2939
Si	0.8995	0.1399	0.7424	0.1164	7.6428	1.1514	31.9002	4.7900	16.6164	2.4975
S	2.4918	0.2515	13.2183	1.3238	12.3929	1.2413	0.8074	0.0827	0.0226	0.0043
Cl	3.3141	0.3319	29.7407	2.9746	1.3071	0.1312	2.9330	0.2938	0.0196	0.0025
K	1.0200	0.1035	24.8110	2.4856	0.1329	0.0148	0.6993	0.0715	0.8580	0.0873
Ca	6.3410	0.8887	1.1073	0.1560	1.0614	0.1496	0.8123	0.1147	4.6793	0.6421
Ti	0.1448	0.0123	0.1013	0.0088	0.1100	0.0095	0.3615	0.0296	0.7910	0.0640
V	0.0189	0.0017	0.0025	0.0004	0.0691	0.0057	0.0028	0.0001	0.0223	0.0020
Cr	0.2818	0.0231	0.0890	0.0074	0.0131	0.0039	0.6299	0.0507	0.0118	0.0012
Mn	1.5216	0.1218	0.0360	0.0030	0.0118	0.0010	0.1280	0.0103	0.1633	0.0132
Fe	12.3333	0.6172	0.5721	0.0289	1.3300	0.0668	6.5979	0.3302	8.1767	0.4091
Ni	0.3072	0.0303	0.0093	0.0010	0.0050	0.0006	0.2811	0.0282	0.0035	0.0010
Cu	0.2310	0.0231	0.4248	0.0128	0.0593	0.0062	0.7772	0.0780	0.0096	0.0013
Zn	2.8211	0.2823	2.1030	0.2110	0.1126	0.0115	0.4174	0.0419	0.0083	0.0010
As	0.0082	0.0020	0.0129	0.0025	0.0235	0.0036	0.0107	0.0023	0.0012	0.0013
Br	0.0091	0.0008	0.0831	0.0067	0.0399	0.0033	0.0047	0.0005	0.0001	0.0001
Pb	0.7876	0.0631	1.6663	0.1334	0.4123	0.0331	0.6276	0.0503	0.0001	0.0001
CC	0.0000	0.7458	1.9995	0.3599	0.0000	0.9931	0.0000	0.0259	0.0000	0.0000
SPM	100.0000	0.0000	100.0000	0.0000	100.0000	0.0000	100.0000	0.0000	100.0000	0.0000

Element	Composition of Elements							
	Soil		Wood		Coal		Road	
	Conc.	Error	Conc.	Error	Conc.	Error	Conc.	Error
C	6.8593	0.5687	57.5515	4.6241	0.7045	0.0761	42.9000	3.4523
Na	0.4271	0.0627	0.3327	0.0533	0.4459	0.0616	5.2500	0.5150
Al	18.6744	2.8112	0.8216	0.1332	16.4018	2.4703	6.2000	0.9100
Si	43.5951	6.5443	0.7981	0.1247	15.5397	2.3360	14.7000	2.2100
S	0.0229	0.0043	0.0866	0.0107	13.3569	1.3407	0.6100	0.0630
Cl	0.0092	0.0014	1.0030	0.1008	1.8979	0.1903	0.8100	0.0815
K	1.0066	0.1022	0.9426	0.0958	0.8047	0.0320	0.5000	0.0515
Ca	2.0306	0.2853	0.7769	0.1098	3.5386	0.4964	1.3900	0.1956
Ti	1.2629	0.1017	0.0019	0.0009	0.9011	0.0728	0.3200	0.0263
V	0.0280	0.0024	0.0002	0.0002	0.0797	0.0066	0.0100	0.0010
Cr	0.0310	0.0028	0.0003	0.0003	0.0330	0.0029	0.0100	0.0011
Mn	0.2030	0.0163	0.0020	0.0003	0.0248	0.0021	0.0900	0.0073
Fe	9.9605	0.4983	0.1032	0.0055	7.1649	0.3555	2.9500	0.1478
Ni	0.0103	0.0011	0.0003	0.0002	0.0635	0.0065	0.0070	0.0008
Cu	0.0161	0.0019	0.0003	0.0003	0.0380	0.0041	0.0050	0.0003
Zn	0.0391	0.0041	0.0617	0.0064	0.0688	0.0071	0.2500	0.0252
As	0.0020	0.0014	0.0012	0.0013	0.0162	0.0028	0.0010	0.0013
Br	0.0010	0.0002	0.0096	0.0009	0.0011	0.0002	3.1300	0.2505
Pb	0.0310	0.0026	0.0100	0.0009	0.1197	0.0097	9.0100	0.7209
CC	6.6535	0.8231	62.1556	8.0572	0.0009	0.0352	0.0006	0.0006
SPM	100.0000	0.0000	100.0000	0.0000	100.0000	0.0000	100.0000	0.0000

(unit=%)

Table 4.2.4-2 Atmospheric concentration of each component for CMB analysis

(Conc.=ng/m³)

Element	Autumn-Run 1		Autumn-Run 2		Autumn-Run 3		Winter-Run 1		Winter-Run 2	
	Conc.	Error	Conc.	Error	Conc.	Error	Conc.	Error	Conc.	Error
SPM	108324	5416	72140	3607	100691	5035	65228	3261	69979	3499
C	18663	933	12523	626	27455	1377	18107	905	15980	799
Na	796	88	497	70	645	65	546	27	481	29
Al	3234	162	2139	107	1638	82	1017	51	1549	77
Si	-	-	-	-	-	-	-	-	-	-
S	11941	597	9452	473	17372	869	12897	645	11218	561
Cl	1141	80	597	66	745	60	694	35	1202	60
K	1393	460	1045	334	1042	386	1389	431	1656	431
Ca	5971	418	3681	331	4418	309	2381	214	3472	243
Ti	179	43	85	34	134	35	82	29	88	30
V	36	1.8	17	0.9	36	1.8	35	1.8	25	1.3
Cr	10.9	1.7	4.8	1.2	9.4	1.8	2.2	0.9	0	0
Mn	80	4	49	2.5	60	3	35	1.8	37	1.9
Fe	2836	227	1443	188	2085	188	1116	89	1389	111
Ni	0	0	0	0	0	0	0	0	0	0
Cu	0	0	0	0	0	0	0	0	0	0
Zn	697	35	393	20	794	40	347	17	374	19
As	16	0.8	9.5	0.5	21	1.1	17	0.9	24	1.2
Br	229	11	124	6.2	308	15	82	4.1	59	3
Pb	746	37	458	23	1241	62	521	26	534	27

(Note) Concentration of the element which is below detection limit is treated as "0"

Table 4.2.4-3(1) Result of CMB analysis for each Run (1)

(Conc.=ng/m³)

(a) Autumn-Run 1

Element	Fit ¹	Observed conc.		Calculated conc.		Ratio Calc/Obs	Concentration originated in each emission source						
		Conc.	Error	Conc.	Error		Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road
C	1	18700	933	18877	16518	1.01	432	120	6978	101	634	8949	1662
Na	1	796	88	1613	1517	2.03	27	398	726	167	39	52	203
Al	1	3230	162	2520	3139	0.78	38	15	214	159	1726	128	240
Si	0			13703	17939	0.00	26	22	2685	6247	4029	124	569
S	0	11900	697	5022	4736	0.42	72	998	4354	158	2	13	24
Cl	0	1140	80	2213	3109	1.94	96	895	459	574	1	156	31
K	1	1390	460	1220	2277	0.88	30	748	47	137	93	147	19
Ca	0	5970	418	1111	785	0.19	184	33	373	159	188	121	54
Ti	0	179	43	246	280	1.37	4	3	39	71	117	0	12
V	1	36	2	28	26	0.79	1	0	24	1	3	0	0
Cr	0	11	2	153	320	14.01	8	3	15	123	3	0	0
Mn	1	80	4	97	112	1.21	44	1	4	25	19	0	3
Fe	1	2840	227	3183	3816	1.12	358	17	467	1292	921	16	114
Ni	0	0	0	67	143	0.00	9	0	2	55	1	0	0
Cu	0	0	0	194	396	0.00	7	13	21	152	1	0	0
Zn	1	697	35	289	328	0.42	82	63	40	82	4	10	10
As	0	16	1	11	10	0.71	0	0	8	2	0	0	0
Br	0	229	11	141	198	0.61	0	3	14	1	0	1	121
Pb	1	746	37	694	686	0.93	23	50	145	123	3	2	349
SPM	1	168000	5420	89290	70404	0.83	2900	3010	35134	19582	9243	15549	3873

(b) Autumn-Run 2

Element	Fit ¹	Observed conc.		Calculated conc.		Ratio Calc/Obs	Concentration originated in each emission source						
		Conc.	Error	Conc.	Error		Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road
C	1	12500	626	12663	9084	1.01	281	127	3383	44	435	7269	1121
Na	1	497	70	1068	861	2.15	17	419	352	73	27	42	137
Al	1	2140	107	1665	1858	0.78	25	15	104	69	1185	104	162
Si	0			7321	11616	0.00	17	24	1303	2725	2767	101	384
S	0	9450	473	2675	2178	0.29	47	419	2112	69	1	11	16
Cl	0	597	65	1627	1895	2.72	63	942	223	251	1	127	21
K	1	1050	334	1685	1363	1.03	19	787	23	60	64	119	13
Ca	0	3680	331	668	457	0.18	120	35	181	69	129	98	36
Ti	0	85	34	144	174	1.70	3	3	19	31	80	0	8
V	1	17	1	15	12	0.85	0	0	12	0	2	0	0
Cr	0	48	12	716	2121	14.92	54	28	73	538	20	0	3
Mn	1	49	3	58	70	1.19	29	1	2	11	13	0	2
Fe	1	1440	183	1764	2466	1.22	233	18	227	564	632	13	77
Ni	0	0	0	32	93	0.00	6	0	1	24	1	0	0
Cu	0	0	0	96	263	0.00	4	13	10	66	1	0	0
Zn	1	393	20	192	205	0.49	53	67	19	36	2	8	7
As	0	95	5	58	54	0.61	2	4	40	9	1	2	0
Br	0	124	6	93	113	0.75	0	3	7	0	0	1	82
Pb	1	458	23	430	405	0.94	15	53	70	54	2	1	235
SPM	0	72100	3610	52234	41832	0.72	1856	3168	17044	8544	6348	12631	2613

(c) Autumn-Run 3

Element	Fit ¹	Observed conc.		Calculated conc.		Ratio Calc/Obs	Concentration originated in each emission source						
		Conc.	Error	Conc.	Error		Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road
C	1	27600	1870	28090	27559	1.02	320	6	6939	92	123	17012	3568
Na	1	645	65	1457	1796	2.26	20	21	722	151	8	99	437
Al	1	1640	82	1480	2071	0.90	28	1	213	144	336	243	516
Si	0			10598	16246	0.00	19	1	2670	5665	784	236	1223
S	0	17400	869	4624	5627	0.27	53	21	4329	143	0	26	51
Cl	0	745	60	1460	3413	1.96	71	47	457	521	0	297	67
K	1	1040	386	570	2584	0.55	22	39	46	124	18	279	42
Ca	0	4420	309	1035	827	0.23	136	2	371	144	37	230	116
Ti	0	184	35	156	221	1.16	3	0	38	64	23	1	27
V	1	36	2	26	31	0.73	0	0	24	0	1	0	1
Cr	0	94	18	1346	3009	14.32	61	1	151	1119	6	1	8
Mn	1	60	3	71	104	1.19	33	0	4	23	4	1	7
Fe	1	2090	188	2356	3422	1.13	264	1	465	1172	179	31	245
Ni	0	0	0	59	135	0.00	7	0	2	50	0	0	1
Cu	0	0	0	165	374	0.00	5	1	21	138	0	0	0
Zn	1	794	40	217	335	0.27	60	3	39	74	1	18	21
As	0	21	1	11	12	0.51	0	0	8	2	0	0	0
Br	0	368	15	278	379	0.90	0	0	14	1	0	3	260
Pb	1	1240	62	1028	1157	0.83	17	3	144	111	1	3	749
SPM	1	101000	6040	94717	80800	0.94	2142	157	34935	17757	1798	29612	8317

(Note) ¹1: 1-employed as Tracer element

Table 4.2.4-3(2) Result of CMB analysis for each Run (2)

(a) Winter-Run 1

(Conc.=ng/m³)

Element	Fit*	Observed conc.		Calculated conc.		Ratio Calc/Obs	Concentration originated in each emission source						
		Conc.	Error	Conc.	Error		Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road
C	1	18100	905	18537	16397	1.02	245	79	6056	25	120	10761	1261
Na	1	546	27	1171	1111	2.14	15	261	630	40	7	62	154
Al	1	1020	51	917	1040	0.90	22	10	186	38	326	153	182
Si	0			5214	7393	0.00	15	15	2330	1513	760	149	432
S	0	12900	645	4153	4263	0.32	41	261	3779	38	0	16	18
Cl	0	694	35	1390	1988	2.00	55	586	399	139	0	187	24
K	1	1390	431	788	1550	0.57	17	490	41	33	18	176	15
Ca	0	2380	214	710	493	0.30	104	22	324	39	35	145	41
Ti	0	82	29	87	106	1.06	2	2	34	17	22	0	9
V	1	35	2	22	23	0.64	0	0	21	0	0	0	0
Cr	0	22	9	503	1301	22.89	47	13	131	299	5	1	3
Mn	1	35	2	42	49	1.20	25	1	4	6	4	0	3
Fe	1	1120	89	1212	1548	1.08	203	11	406	313	174	19	87
Ni	0	0	0	21	58	0.00	5	0	2	13	0	0	0
Cu	0	0	0	68	163	0.00	4	8	18	37	0	0	0
Zn	1	347	17	162	176	0.47	46	42	34	20	1	12	7
As	0	17	1	8	8	0.49	0	0	7	1	0	0	0
Br	0	82	4	108	137	1.32	0	2	12	0	0	2	92
Pb	1	521	26	469	447	0.90	13	33	126	30	1	2	265
SPM	0	65200	3260	62214	47945	0.95	1646	1971	30491	4743	1743	18630	2940

(b) Winter-Run 2

Element	Fit*	Observed conc.		Calculated conc.		Ratio Calc/Obs	Concentration originated in each emission source						
		Conc.	Error	Conc.	Error		Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road
C	1	16900	799	16363	15031	1.02	180	38	4418	49	255	10047	1376
Na	1	481	29	920	1025	1.91	11	126	460	80	16	68	163
Al	1	1550	77	1270	1626	0.82	16	5	135	76	696	143	199
Si	0			6357	9701	0.00	11	7	1700	3005	1624	139	472
S	0	11200	561	3024	3485	0.27	30	126	2757	76	1	15	20
Cl	0	1200	60	1093	1971	0.91	40	284	291	276	0	175	26
K	1	1660	431	563	1492	0.34	12	231	30	66	37	165	16
Ca	0	3470	243	655	491	0.19	76	11	236	77	76	136	43
Ti	0	83	30	119	148	1.35	2	1	24	34	47	0	10
V	1	25	1	17	19	0.69	0	0	15	0	1	0	0
Cr	0	0	0	75	173	0.00	3	1	10	59	1	0	0
Mn	1	37	2	44	59	1.19	18	0	3	12	8	0	3
Fe	1	1390	111	1555	2052	1.12	149	5	296	621	371	18	93
Ni	0	0	0	32	77	0.00	4	0	1	26	0	0	0
Cu	0	0	0	94	214	0.00	3	4	13	73	1	0	0
Zn	1	374	19	139	191	0.37	34	20	25	39	1	11	8
As	0	24	1	7	7	0.28	0	0	5	1	0	0	0
Br	0	59	3	112	153	1.90	0	1	9	0	0	2	100
Pb	1	534	27	458	495	0.88	9	16	92	59	1	2	289
SPM	0	70000	3500	58211	46897	0.83	1204	956	22243	9419	3725	17458	3203

(Note) *1: 1=employed as Tracer element

Table 4.2.4-4 Result of CMB analysis summarized for each season

(a) Autumn (Conc.=ng/m³)

Element	Fit ^a	Observed conc.		Calculated conc.		Concentration originated in each emission source							
		Conc.	Error	Conc.	Error	Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road	
C	1	19000	1000	19900	19300	300	100	5800	100	400	11100	2100	
Na	1	646	75	1379	1446	21	279	600	130	25	64	259	
Al	1	2340	120	1890	2420	30	10	180	120	1080	160	310	
S	0	12900	700	4100	4400	100	300	3600	100	1	20	30	
Cl	0	827	69	1766	2881	77	628	350	449	1	193	40	
K	1	1160	400	960	2140	20	520	40	110	60	180	20	
Ca	0	4690	360	940	710	150	20	310	120	120	150	70	
Ti	0	183	38	182	229	3	2	32	55	73	0	16	
V	1	30	2	23	24	0	0	20	0	2	0	1	
Cr	0	8	2	120	282	7	2	18	96	2	0	0	
Mn	1	63	3	76	97	35	1	3	20	12	0	4	
Fe	1	2120	200	2440	3280	280	10	300	1010	580	20	150	
Zn	1	628	33	233	295	65	45	33	64	2	12	12	
As	0	16	1	9	10	0	0	7	2	0	0	0	
Br	0	220	11	171	255	0	2	12	1	0	2	154	
Pb	1	815	44	717	811	18	35	120	96	2	2	445	
SPM	0	93700	4754	78747	66421	2309	2112	29038	15294	6796	19261	4934	
Detected number (Max=3)						3	3	3	3	3	3	3	3
Relative Contribution of each source (%)				81.0		2.5	2.3	31.0	16.3	6.2	29.6	5.3	

(b) Winter

Element	Fit ^a	Observed conc.		Calculated conc.		Concentration originated in each emission source							
		Conc.	Error	Conc.	Error	Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road	
C	1	17100	900	17500	15700	200	100	5200	40	200	10400	1300	
Na	1	514	28	1045	1069	13	194	545	60	12	60	151	
Al	1	1290	70	1090	1360	20	10	160	60	510	150	190	
S	0	12100	600	3600	3900	40	200	3300	100	1	20	20	
Cl	0	947	49	1241	1980	47	435	345	208	0	181	25	
K	1	1530	430	680	1520	10	360	40	50	30	170	20	
Ca	0	2930	230	680	490	90	20	280	60	00	140	40	
Ti	0	85	30	103	129	2	2	29	26	35	0	10	
V	1	30	2	20	21	0	0	18	0	1	0	0	
Cr	0	2	1	63	153	4	1	11	45	1	0	0	
Mn	1	36	2	43	54	22	1	3	9	6	0	3	
Fe	1	1260	100	1380	1820	180	10	350	470	270	20	90	
Zn	1	361	18	150	184	40	31	30	30	1	11	8	
As	0	21	1	8	8	0	0	6	1	0	0	0	
Br	0	71	4	110	145	0	1	11	0	0	2	96	
Pb	1	528	27	468	471	11	24	109	44	1	2	277	
SPM	0	67660	3382	60213	47424	1425	1463	26367	7081	2734	18069	3074	
Detected number (Max=2)						2	2	2	2	2	2	2	2
Relative Contribution of each source (%)				89.1		2.1	2.2	39.0	10.5	1.0	26.7	4.5	

(c) Autumn and Winter

Element	Fit ^a	Observed conc.		Calculated conc.		Concentration originated in each emission source							
		Conc.	Error	Conc.	Error	Steel	Incinerator	Oil	Sandblast	Soil	Wood	Road	
C	1	18600	1000	18900	17900	300	100	5600	100	300	10800	1800	
Na	1	593	61	1246	1308	18	245	578	102	20	63	220	
Al	1	1920	100	1570	2070	30	10	170	100	850	150	260	
S	0	12600	600	3900	4200	50	200	3500	100	1	20	30	
Cl	0	875	62	1556	2559	65	551	366	352	0	188	34	
K	1	1310	410	850	1920	20	460	40	80	50	180	20	
Ca	0	3980	310	840	630	120	20	300	100	90	150	60	
Ti	0	114	35	150	195	3	2	31	43	58	0	13	
V	1	30	2	22	23	0	0	19	0	1	0	0	
Cr	0	7	1	97	239	6	2	12	76	1	0	0	
Mn	1	52	3	63	83	30	1	3	15	9	0	4	
Fe	1	1780	170	2010	2790	240	10	370	790	460	20	120	
Zn	1	521	28	200	257	55	39	31	50	2	12	10	
As	0	18	1	9	9	0	0	7	1	0	0	0	
Br	0	160	9	146	218	0	2	11	1	0	2	131	
Pb	1	700	39	618	696	15	31	115	75	1	2	378	
SPM	0	83260	4259	71333	69554	1955	1852	27969	12009	4571	18786	4190	
Detected number (Max=5)						5	5	6	5	5	5	5	5
Relative Contribution of each source (%)				85.7		2.3	2.2	33.6	14.4	5.5	22.6	5.0	

(Note) ^a1: 1=employed as Tracer element

4.2.5 Comparison of surveyed and existing data

Characteristics in the variations of the pollutant concentration discussed in the section 4.2.1 are based on the AQCC data measured at Fatemi and Bazar. As they are the monitoring stations established for the purpose of observation of air pollution caused by exhaust gas of motor vehicles, they are placed along streets as roadside stations (There are, however, some residential areas around the station at Fatemi.). Therefore, these data indicate the concentration just in the neighborhood of the roadside and they should not be regarded as representing the air pollution of entire Tehran. On the other hand, the simplified measurements of the pollutants were made by the JICA study team in order to know the concentrations which are not directly affected by car emissions. Consequently, the sampling points of this measurement are placed away from busy streets as the general monitoring station is, so that their data will represent the normal ambient air quality in Tehran. Unfortunately, because the measurement was made temporarily in a short period, the data were not enough for evaluation of the general condition of air pollution. It is, however, worth comparing between the AQCC data and the JICA's simplified measurement data for comprehensive understanding of air pollution in Tehran.

The data of the pollutant concentration measured by AQCC and the JICA study team in October, 1996 are compared with each other. Because the data for comparison must be measured in the same period, only the data obtained during the field survey by the JICA team are available. Details of these data are summarized below.

① Period of measurements

October 8 - 16, 1996

② Pollutants for comparison

CO : Hourly average

NO₂ : Daily average

SO₂ : 3-day average

③ Measuring site of which the data are used for comparison

The monitoring station at Fatemi is located in a small area within the intersection of busy streets. On the other hand, sampling points of the JICA team are selected away from busy streets to avoid the effects of car emissions.

Table 4.2.5-1 Measuring site of which the data used for comparison

Item	AQCC Monitoring station	JICA Sampling points
CO	Fatemi	No. 1~13
NO ₂		No. 1~31
SO ₂		No. 1~31

note: The location of these points are shown in the map (Fig.3.2.1-1, Fig.3.4.2-1).

④ Method of measurement

Table 4.2.5-2 Comparison of method of measurement

Item	Method	AQCC	JICA
CO	Sampling	Air is pulled directly into the continuous CO analyzer.	Airbag sampling
	Detection	Analysis by NDIR	Analysis by NDIR
	Output	1 hour average of instant values	1 hour average
NO ₂	Sampling	Air is pulled directly into the continuous NOx analyzer.	Passive sampling on TEA coated filter
	Detection	Chemiluminescence method	Extraction with water, Spectrophotometric analysis
	Output	1 hour average of instant values	24 hour average
SO ₂	Sampling	Air is pulled directly into the continuous SO ₂ analyzer.	Passive sampling on TEA coated filter
	Detection	Ultraviolet fluorometry	Extraction with water, Ion chromatography analysis
	Output	1 hour average of instant values	72 hour (in summer) average 96 hour (in winter) average

note ; NDIR : non-dispersive infrared gas analyzer

TEA : Triethanolamine

See section 3.4.2 for details of the JICA measurements.

AQCC monitoring is made automatically. On the other hand, members of JICA team had to collect the samplers (for NO₂ and SO₂) and the air bags (for CO and HC) which had to be replaced by new ones. Interval of replacement is one hour for CO, 24 hours for NO₂, 72 hours for SO₂, and as for HC, the air bags are replaced 24 times or 6 times a day. In general, the CO data obtained by AQCC and JICA are recognized to show the satisfactory agreement. As for NO₂ and SO₂, the manufacturer of the sampler employed by the JICA verified that the data obtained by the direct sampling (AQCC) and the passive sampling (JICA) coincide with each other. Accordingly, it is considered that there is no problem in comparison between the data measured by AQCC and JICA.

(1) CO

Diurnal variations of the CO concentration in autumn measured at the JICA points and Fatemi are shown in Fig.4.2.3-1(1) - (5) and Fig.4.2.5-1, respectively. Generally speaking, AQCC and JICA data show the same pattern in the diurnal variation. Especially, the variations at No.131 (MOT Office building) and at Fatemi are similar to each other each day. Most of them but for Friday (11, October) have two peaks in a day. The first one appears in the morning (7 - 8h) and the second one appears in the evening (18 - 20h). However, there is the big difference in concentration between Fatemi and the JICA points. The daily maximum concentrations at almost all the JICA points are on the level of 6 - 14ppm. On the other hand, those at Fatemi are 20 - 30ppm. These facts suggest that the level of the CO concentration is highly dependent on the distance from the 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.

(2) NO₂

The variations of the daily mean concentrations of NO₂ in autumn measured at the JICA points and at Fatemi are shown in Fig.4.2.3-5(1) and Fig. 4.2.5-2, respectively. On the whole, the variations at the JICA sampling points are characterized by fall of the concentration on Thursday-Friday and Friday-Saturday.

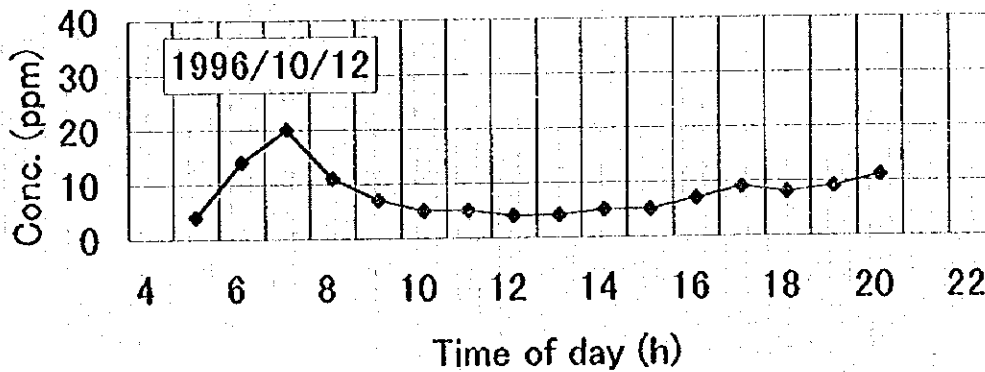
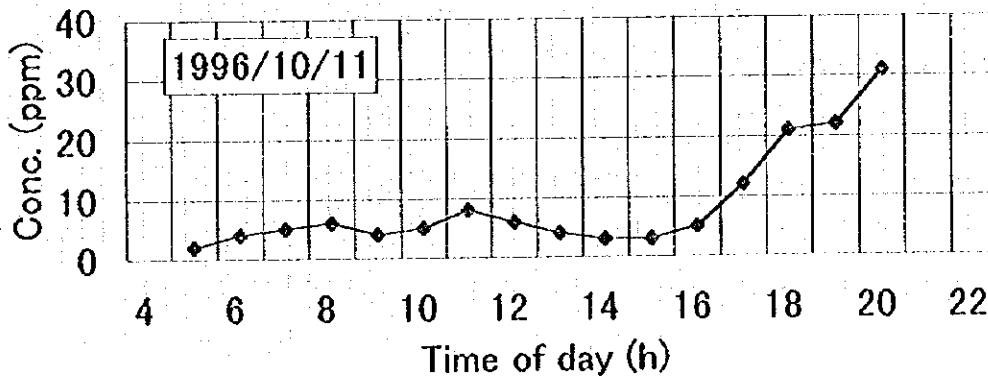
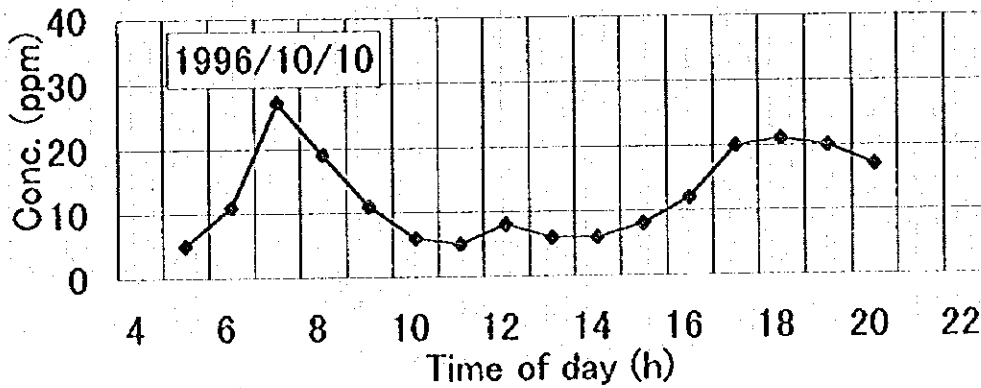
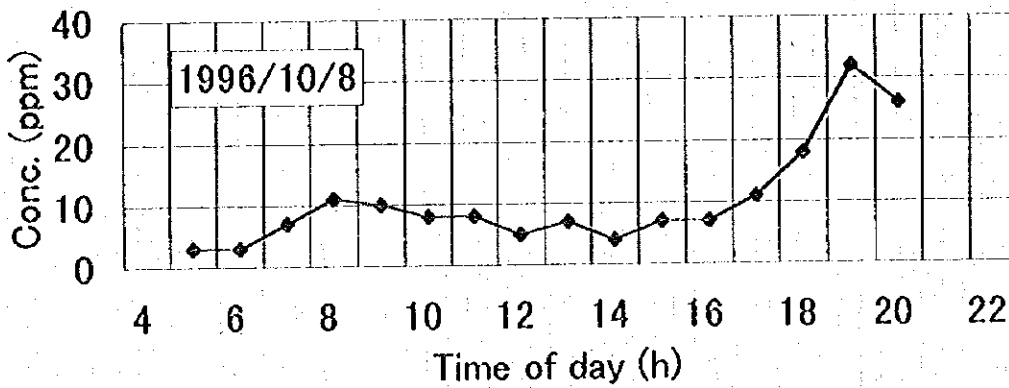


Fig. 4.2.5-1 Diurnal variation of CO concentration at Fatemi station based on hourly average (October 8, 10, 11, 12 1996, corresponding period with additional measurement)

On the other hand, the concentration at Fatemi has the minimum on Saturday-Sunday, and the next minimum on Friday-Saturday. Though it is difficult to explain appropriately these features using only the existing materials, the difference appears to come from some local conditions, because the similar pattern is seen at No.2 - 6 of the JICA points located around Fatemi, while the concentration at Fatemi is lower than those at the JICA points. NO_2 is the secondary product of the chemical reaction between NO and O_3 , and the process takes time to progress. It is therefore considered that the NO_2 concentration is determined by a balance of the mass produced and transported. The production of NO_2 depends on the concentrations of NO and O_3 which are affected by car emissions and solar radiation, while transportation is controlled by the wind. Because the car emission is not the only factor that contributes to the NO_2 concentration, the NO_2 concentration at the road side is not necessarily high.

(3) SO_2

The variations of the 3 day mean concentrations of SO_2 in autumn measured at the JICA points and at Fatemi are shown in Fig.4.2.3-7(1) and Fig. 4.2.5-3, respectively. The data for comparison are the 3day averages for the period of October 9, 14h - October 12, 13h and October 12, 14h~October 15, 13h. Friday is included in the former period. There is, however, no ground for setting the period for the average at 3 days, except for the reason that sampling for longer than 72 hours is required for the SO_2 analysis.

No suggestive difference is observed in the average of the 31 JICA points between the former and the latter period. According to the data at Fatemi, the concentration in the former period is higher than that in the latter period. Probably, it is not worthy to mention the difference between these periods, except description on the difference in the concentrations among the measuring points. The concentration at Fatemi is 33ppb and 24ppb in the respective periods. Such a high concentration is observed only at No.8 of the JICA point located in the neighborhood of a major street. The concentrations at the other JICA points hardly reach 20 ppb and their average is around 11ppb. The SO_2 concentration at Fatemi in the intersection, however, is 2 to 3 times as high as the concentration at the JICA points away from busy roads, suggesting that the SO_2 concentration may depend on the distance from a street and the traffic volume.

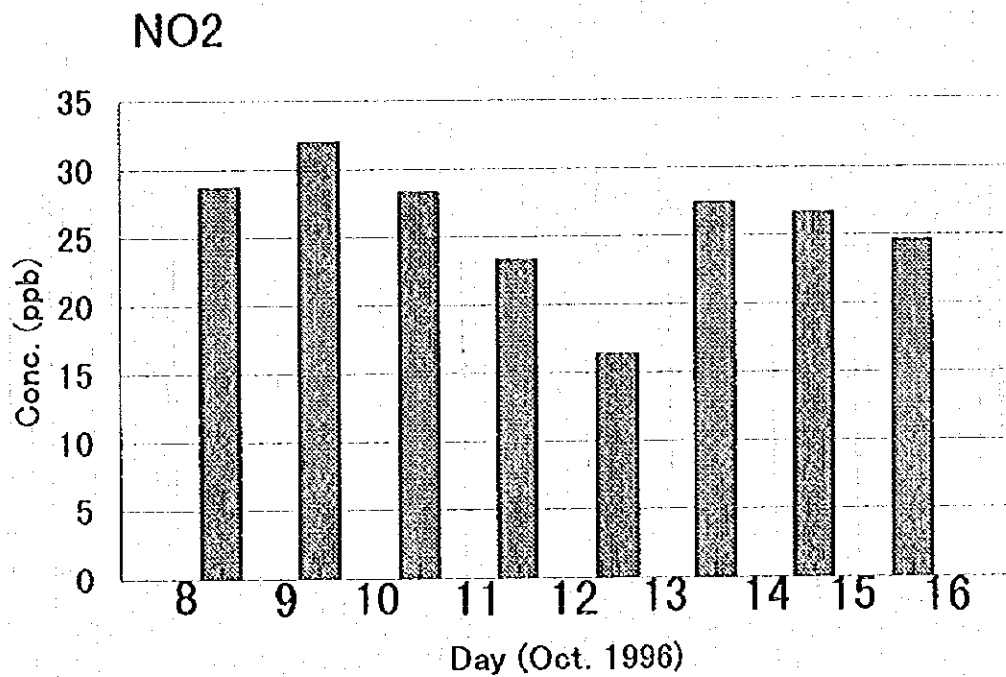


Fig. 4.2.5-2 Daily variation of NO₂ concentration at Fatemi station based on hourly average. (October 8~15 1996, corresponding period with simplified measurement)

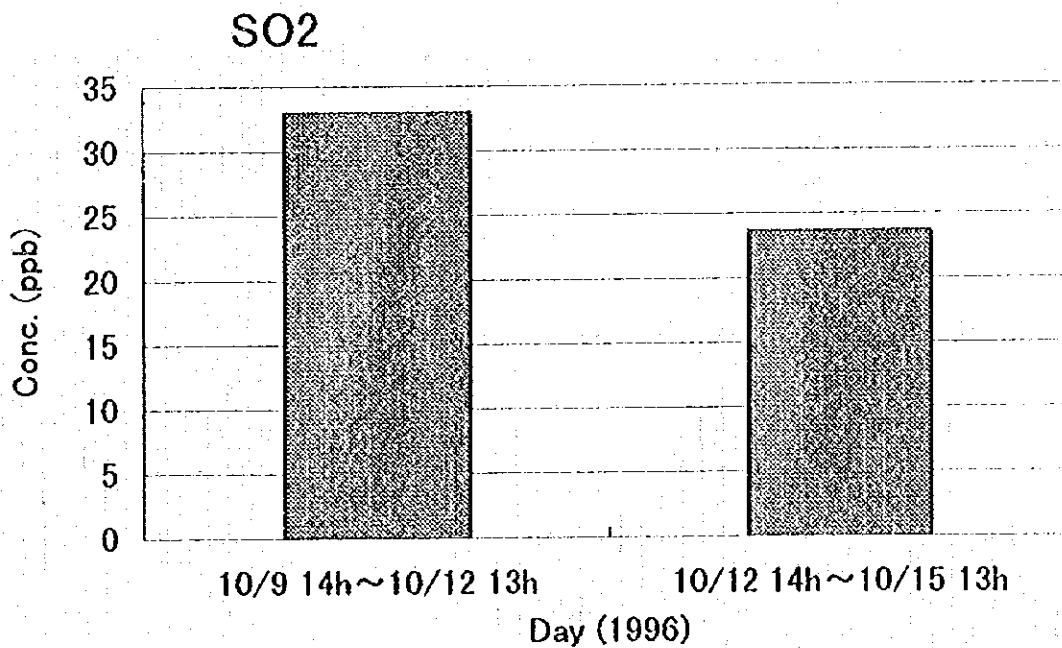


Fig. 4.2.5-3 3 days average of SO₂ concentration at Fatemi station based on hourly average (October 9~12, 12~15 1996, corresponding period with simplified measurement)

4.2.6 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 SO₂, NO, NO₂, NO_x, CO, O₃, 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 4.2.6-1. The annual averages of the several pollutant concentrations (SO₂ and PM10) at these stations are higher than the WHO air quality guideline. For example, the SO₂ 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 SO₂, O₃ and PM10 are higher at Bazar.

Table 4.2.6-1 Annual average concentration of pollutants and environmental standards

	SO ₂	NO	NO ₂	NO _x	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 : SO₂, NO, NO₂, NO_x, O₃ ; ppb CO, THC ; ppm (The original concentrations in $\mu\text{g}/\text{m}^3$ are converted into the value in ppb or ppm under the condition of Tehran (20°C, 880hPa)).

PM10 ; $\mu\text{g}/\text{m}^3$

- 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 $10\ \mu\text{m}$. However, the exclusion method of the large particles ($>10\ \mu\text{m}$) is different. As a result of that difference, PM10 includes some particles somewhat larger than $10\ \mu\text{m}$ 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 SO₂, NO₂, and O₃ 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.

(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 NO₂ concentration distributions is that the concentration in the center part of MOT is slightly higher than that of the outskirts of MOT. And the SO₂ 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 SO₂, NO₂ 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 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.

4.3 Analysis of field survey in the vehicle sector

4.3.1 Road network in MOT

The Tehran Comprehensive Traffic and Transportation Studies (TCTTS) has made a database of roads within GTA for the purpose of a traffic demand and distribution simulation. On the basis of the database, the road network within GTA is shown as Fig.4.3.1-1.

Fig.4.3.1-2 (1), (2), (3) made on the basis of the database indicate emergence frequency of road widths, length of links, number of lanes in GTA respectively. As shown in the figure, the most frequent class of each item is 6m-9m for road widths, 2 for the number of lanes, 100m-200m for length of links, and total length of road networks in GTA calculated by summing up length of all links included in the data base is 5013.42km.

Road classification made by TCTTS is shown in Table4.3.1-1



Fig.4.3.1-1 Road network in GTA

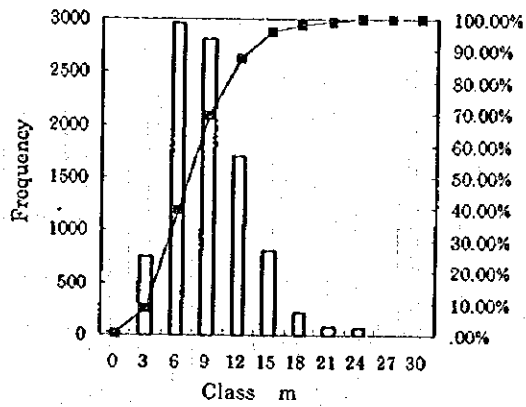


Fig.4.3.1-2(1) Emergence frequency of road width within GTA

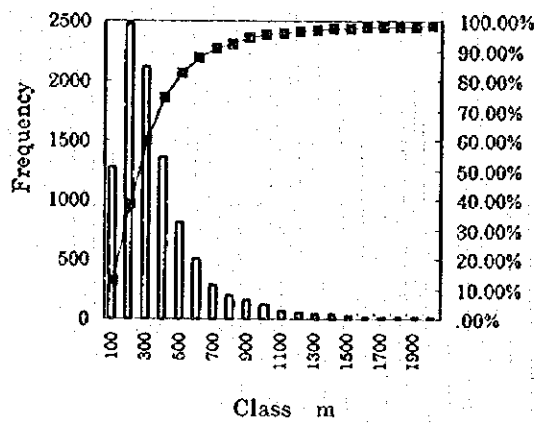


Fig.4.3.1-2(2) Emergence frequency of link length within GTA

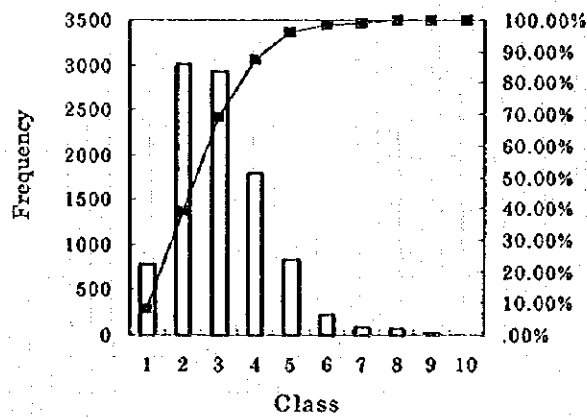


Fig.4.3.1-2(3) Emergence frequency of lane number within GTA

Table 4.3.1-1 Classification of roads within GTA

Road Classification Characteristics	FREEWAY, AUTOBARN, MOTORWAY INTRA CITY HIGHWAY	EXPRESSWAY INTRA CITY HIGHWAY
Function	-	-
Speed limit	110 km/hr	80 km/hr
Number of lanes	2-3 lanes	2-3 lanes
Min. width of lane	-	-
Min. width of road	According to regulation	15 m
Intersection	Not flat	Not flat
Max. between intersections	2000 m (minimum)	1000-2000 m
U turn	-	-
Parking along the Road	Not allowed at all	Not allowed at all
Traffic light	Not existed	Not existed
Pedestrian	Not allowed	Not allowed
Motorcycle	Not allowed	Not allowed
Bicycle	Not allowed	Not allowed
Separator	Axial refuse with 2-m width (minimum)	Axial refuse with 2 m width (minimum)

Road Classification Characteristics	COLLECTOR FEEDER	LOCAL STREET (LOCAL) ACCESS
Function	-	-
Speed limit	50 km/hr	30 km/hr
Number of lanes	2-3 lanes	1-2 lanes
Min. width of lane	6 m (for each direction)	2.75 m (1 lane)
Min. width of road	18 m	10 m
Intersection	Flat	Flat
Max. between intersections	200 m	100 m
U turn	Possible	Possible
Parking along the Road	limited	Allowed
Traffic light	On intersections with main roads	-
Pedestrian	Side walks	Side walks
Motorcycle	Permitted	Permitted
Bicycle	Permitted	Permitted
Separator	Axial line (painting)	-

Road Classification Characteristics	MAJOR ARTERIAL	MINOR ARTERIAL
Function	Connection (express ways and collectors)	Connection (free ways and collector streets)
Speed limit	50 km/hr	50 km/hr
Number of lanes	-	3 lanes
Min. width of lane	3 meter Express lanes, 3 meter side lanes	3 3-meter lanes
Min. width of road	45 (m) minimum	20 (m) minimum
Intersection	Flat	Flat
Max. between intersections	500-1000 m	300-500 m
U turn	-	-
Parking along the Road	Possible	Possible
Traffic light	Exists	Exists
Pedestrian	-	-
Motorcycle	Allowed	Allowed
Bicycle	(On side lanes) Allowed	Allowed
Separator	Axial refuse	Color painting or axial refuse

SOURCE: The Studies under the time of Journey Volume-Delay Function Project (ICTIS, 1991)

4.3.2 Vehicle fleet in MOT

On the basis of the statistical database made by the Center for Computer Service, Municipality of Tehran, the numbers of registered vehicles classified by car type and registered year is described in Table 4.3.2-1. Blank columns in this Table mean lack of data in the corresponding year. As shown in the Table, 1,376,188 vehicles were registered in MOT. Some parts of these vehicles were already scrapped but there are no methods to grasp their accurate numbers. The attention therefore should be drawn to this point when the numbers of registered vehicles are discussed.

Table 4.3.2-1 Numbers of registered vehicles classified by car type and age

Year \ Car	Passenger Car	Van	Mini Bus	Bus	Mini Truck	Truck	Total
1967-1971	83970	25992	2743	5679	1823	13514	133721
1972-1976	225020	76109	5010	2920	1230	12768	323057
1977-1981	199269	52286	4643	2947	219	13768	273122
1982-1986	98979	33627	1450	1586	57	10880	146579
1987-1991	46487	13068	3893	852	50	6945	71295
1991	4375	.....	3265	1330	150	5422	14542
1992	230398	15056	3786	1331	552	32704	283827
1993	73168	.....	.....	.....	.....	.....	73168
1994	56877	.....	.....	.....	.....	.....	56877
Total	1018543	216138	24790	16645	4081	95991	1376188

Fig. 4.3.2-1 indicates a distribution ratio of each vehicle type. As shown in the Figure, passenger cars account for 74% of all vehicles registered in MOT.

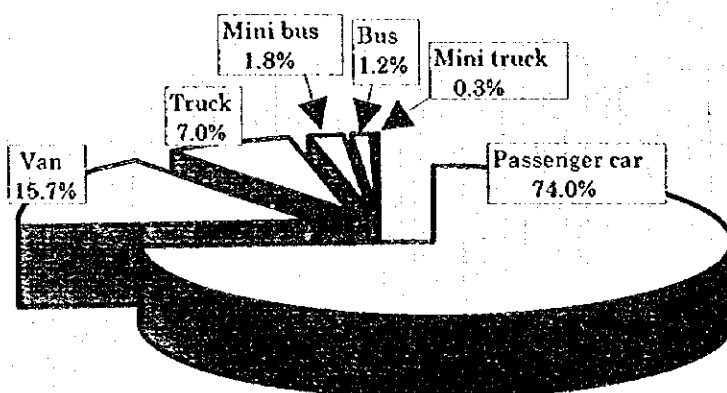


Fig. 4.3.2-1 Share of each type of vehicle registered in MOT

Table 4.3.2-2 indicates the numbers of registered passenger cars, trucks, and buses, and corresponding share of each type of vehicles in Tehran, Tokyo and other countries. This Table makes it clear that passenger cars have a large share and buses have a small share in industrial countries and that the opposite relation prevails in developing countries. Public transportation means like railways, subways, streetcars etc., play an important role in industrial countries, while the bus is less important. In Tehran, the share of a passenger car is much higher than in other countries where a bus has a large share. This means that passenger car plays an important role in daily transportation of citizens in Tehran. This is the reason why CO and HC produced by gasoline-fueled vehicles cause serious problems in Tehran.

Table 4.3.2-2 Comparison of component ratio of three types of vehicles

Countries	Year	Passenger car	Truck	Bus	Total	*
Tehran	1992	1,468,006	100,072	41,435	1,609,513	249
		% 91.2	6.2	2.6	100.0	
Tokyo	1993	2,913,000	1,106,000	16,000	4,035,000	246
		% 72.2	27.4	0.4	100.0	
Japan	1993	41,061,000	20,552,000	247,000	61,860,000	329
		% 66.4	33.2	0.4	100.0	
Indonesia	1990	1,313,000	1,024,000	469,000	2,806,000	7
		% 46.8	36.5	16.7	100.0	
Iraq	1989	672,000	321,000	47,000	1,040,000	186
		% 64.6	30.9	4.5	100.0	
Singapore	1993	306,000	126,000	10,000	442,000	107
		% 69.2	28.5	2.3	100.0	
Hong kong	1993	316,000	131,000	16,000	463,000	52
		% 68.3	28.3	3.5	100.0	
Malaysia	1992	2,148,000	442,000	30,000	2,620,000	112
		% 82.0	16.9	1.1	100.0	
India	1991	2,282,000	1,411,000	333,000	4,026,000	3
		% 56.7	35.0	8.3	100.0	
USA	1992	144,213,000	45,504,000	645,000	190,362,000	565
		% 75.8	23.9	0.3	100.0	
Canada	1992	13,322,000	3,624,000	64,000	17,010,000	488
		% 78.3	21.3	0.4	100.0	
Mexico	1992	7,497,000	3,501,000	106,000	11,104,000	89
		% 67.5	31.5	1.0	100.0	
UK	1993	20,344,000	3,884,000	107,000	24,335,000	362
		% 83.6	16.0	0.4	100.0	
Italy	1991	28,200,000	2,443,000	78,000	30,721,000	496
		% 91.8	8.0	0.3	100.0	
German	1992	37,579,000	1,938,000	86,000	39,603,000	473
		% 94.9	4.9	0.2	100.0	
Swiss	1993	3,138,000	272,000	14,000	3,424,000	449
		% 91.6	7.9	0.4	100.0	

* : Registered number of passenger car per 1000 people

Source : World statistics 1996, Management and Coordination Agency, Japan