3.1.5 Selection of the Model City and its Bases

Skopje city, the capital of the Macedonia, was selected as the model city through a number of consultation with the concerned personnel of the Macedonian side concerning analyses of the present status of air pollution and characteristics of emission sources.

- Skopje city, the center of socio-economy and industries of the Macedonia, suffers from most serious air pollution due to heating during winter because of its topographical and meteorological conditions and also due to automobiles and plant emission gases.

- Automatic continuous monitoring stations owned by metal smelting plant were set in two points in Veles. However, only British samplers unable to cope with emergencies were used in Skopje.

- Veles, Tetovo and Bitola etc. expect a great effect based on the countermeasures in factories which take a leading part. Skopje needs to be covered with overall countermeasures. It is required to construct monitoring system earlier in order to examine the measures.

Discussions were taken place as to whether or not to include Veles city, which had serious air pollution problems as in Skopje, as a model city. However, Veles being 40 km away from Skopje, had different emission source conditions of pollutants. As a result, Veles was not included as a model city. It was decided to take up Veles in recommendations on the construction of a nation-wide air quality monitoring network.

3.2 Determination of Sites for Air Quality Monitoring Station

3.2.1 Distribution Survey of Air Quality in Wide Area

Concentration distributions pattern of SO_2 and NO_2 were comprehended through the measuring results of the simplified sampler.

A total of 100 monitoring points were selected using an 1 km mesh as a reference mesh to evaluate the concentration distribution in the entire Skopje. Simplified samplers were installed at these monitoring points.
The monitoring points were selected based on topographical condition, density of dwelling houses and existing data and information as a reference. At 16 of these 100 monitoring points, simplified samplers were installed near the existing monitoring points of existing samplers for cross-check between these two types of samplers.

Figures 3.9 and 3.10 show the wide-area concentration distributions of SO_2 and NO_2 in the entire area of Skopje.
Generally, the following observation can be made from the wide-area concentration distribution diagrams of SO_2 and NO_2:

- In the NO_2 concentration distribution, the central part of the city showed high concentrations, while high concentrations were also recorded locally in some suburban areas.
- In the SO_2 concentration distribution, the suburbs showed a high concentration level than urban areas differing from the distribution pattern with NO_2.
- Some areas in the mountains on the southern part of the urban area also showed high SO_2 concentrations. Summarizing the above, the impact of mobile sources (vehicles) and area emission sources are large with NO_2. Impacts by other stationary sources added to SO_2.

The simplified sampler that the Study has introduced and the survey methods are useful for grasping a wide concentration distribution for a given period at a low cost. The Macedonian side has already started utilizing it for other research. It is very significant for the Study Team to have already realized some part of the purpose of the Study.
It is expected that the Macedonian side will positively utilize the simplified monitoring method for variety of studies.

SO2 : Average

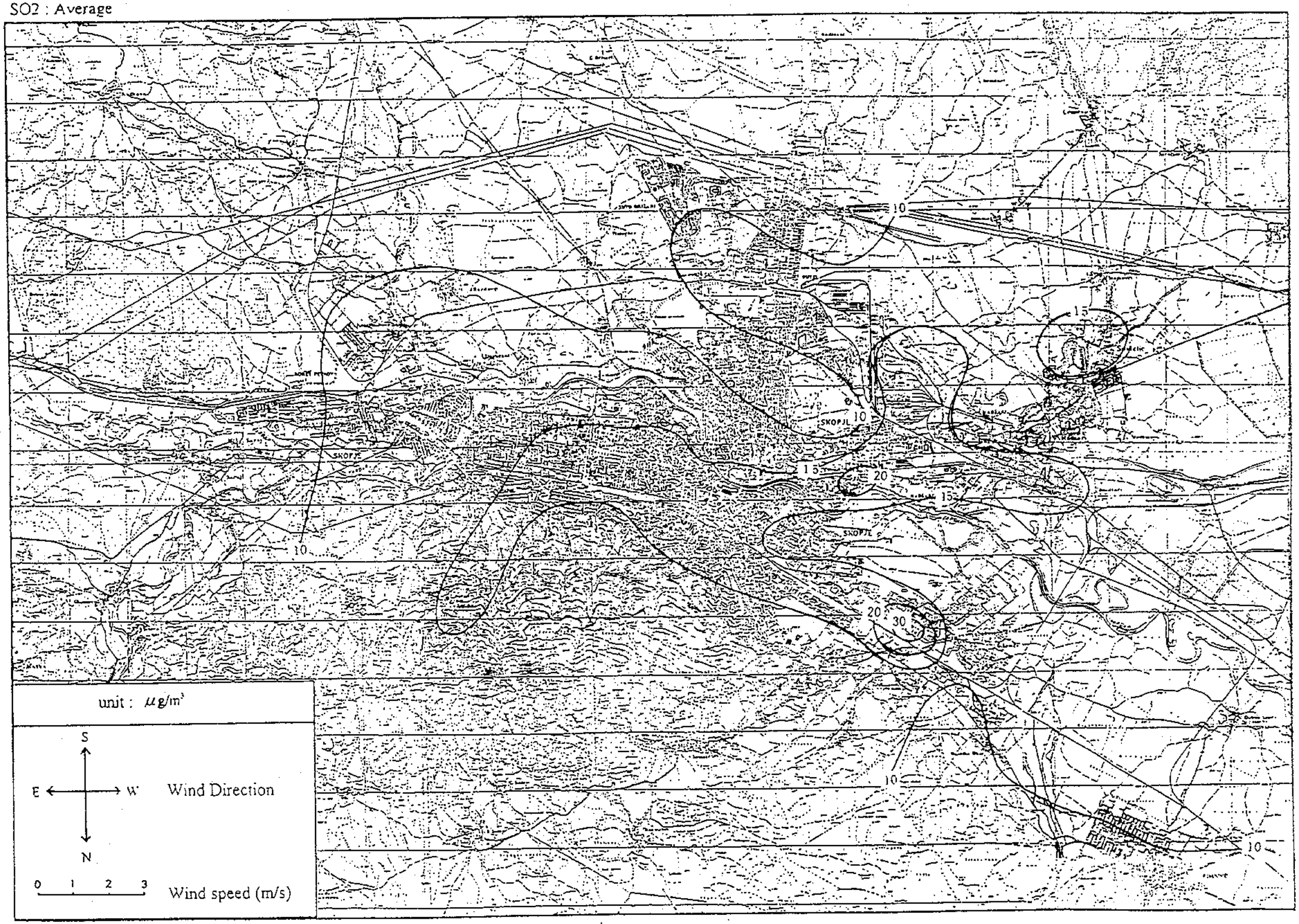


Figure 3.9 (1) The Concentration Distributions of SO_2

SO2 : Run-2

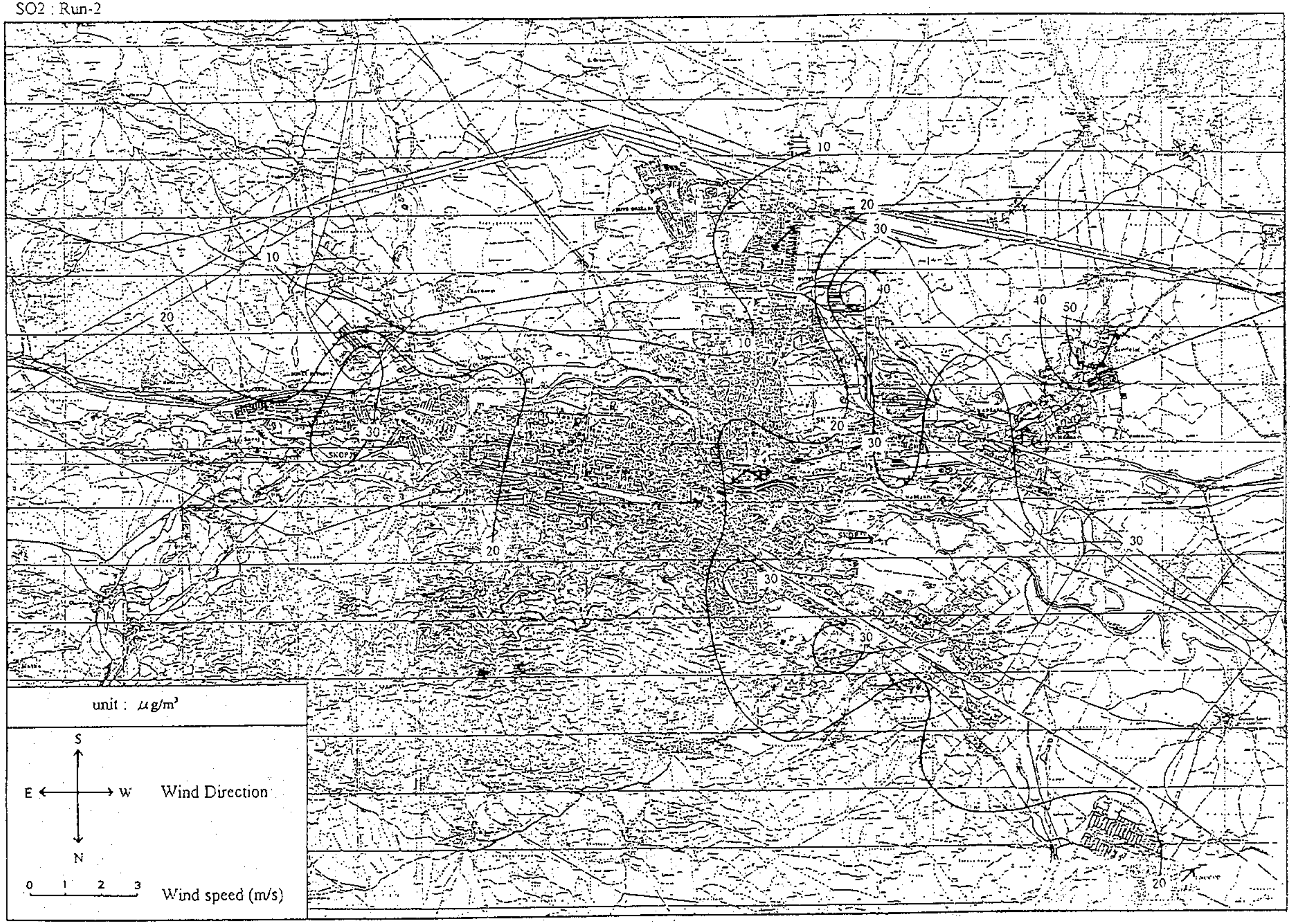


Figure 3.9 (2) The Concentration Distributions of SO_2

NO2 : Average

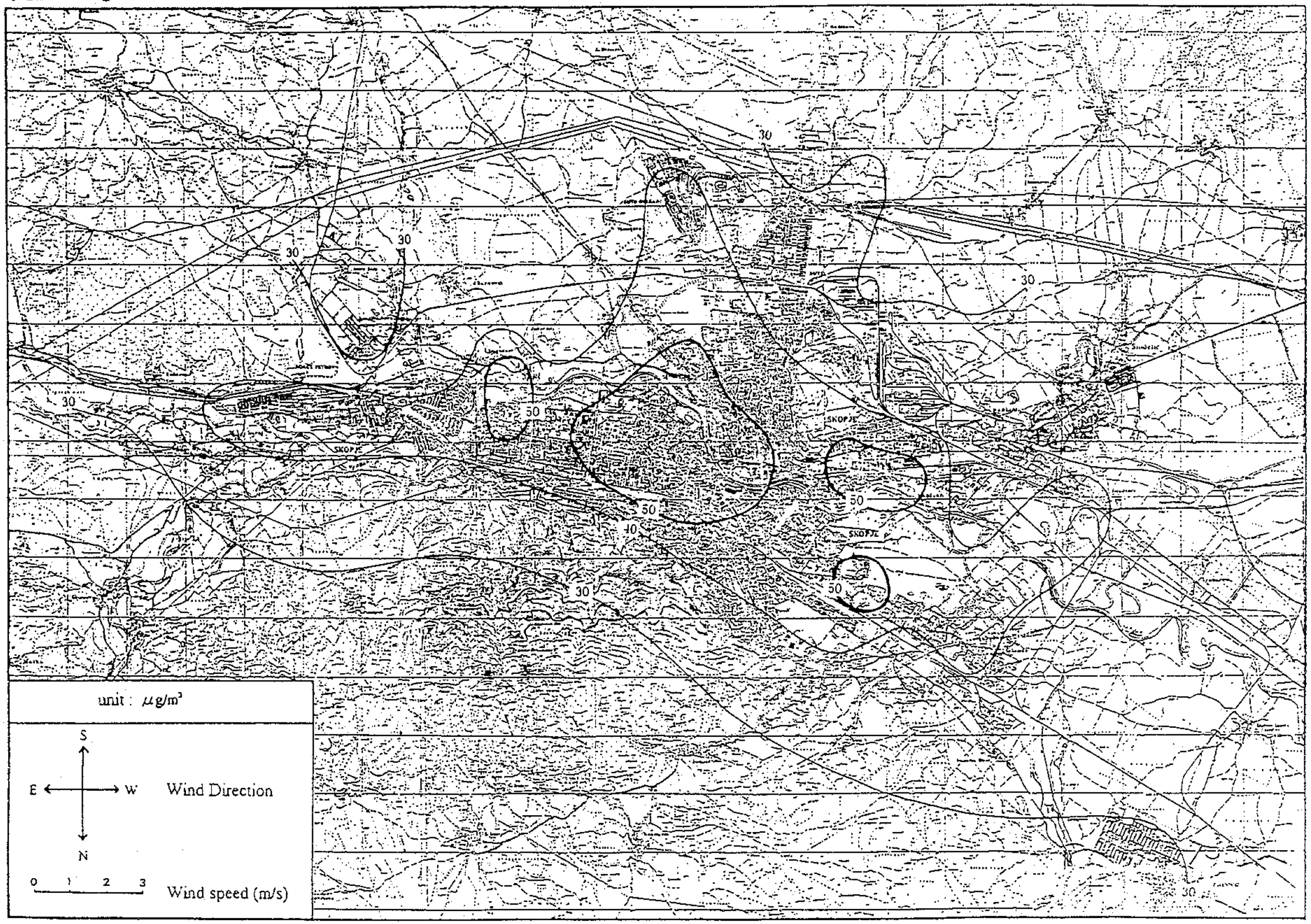


Figure 3.10 (1) The Concentration Distributions of NO2

NO2 : Run-1

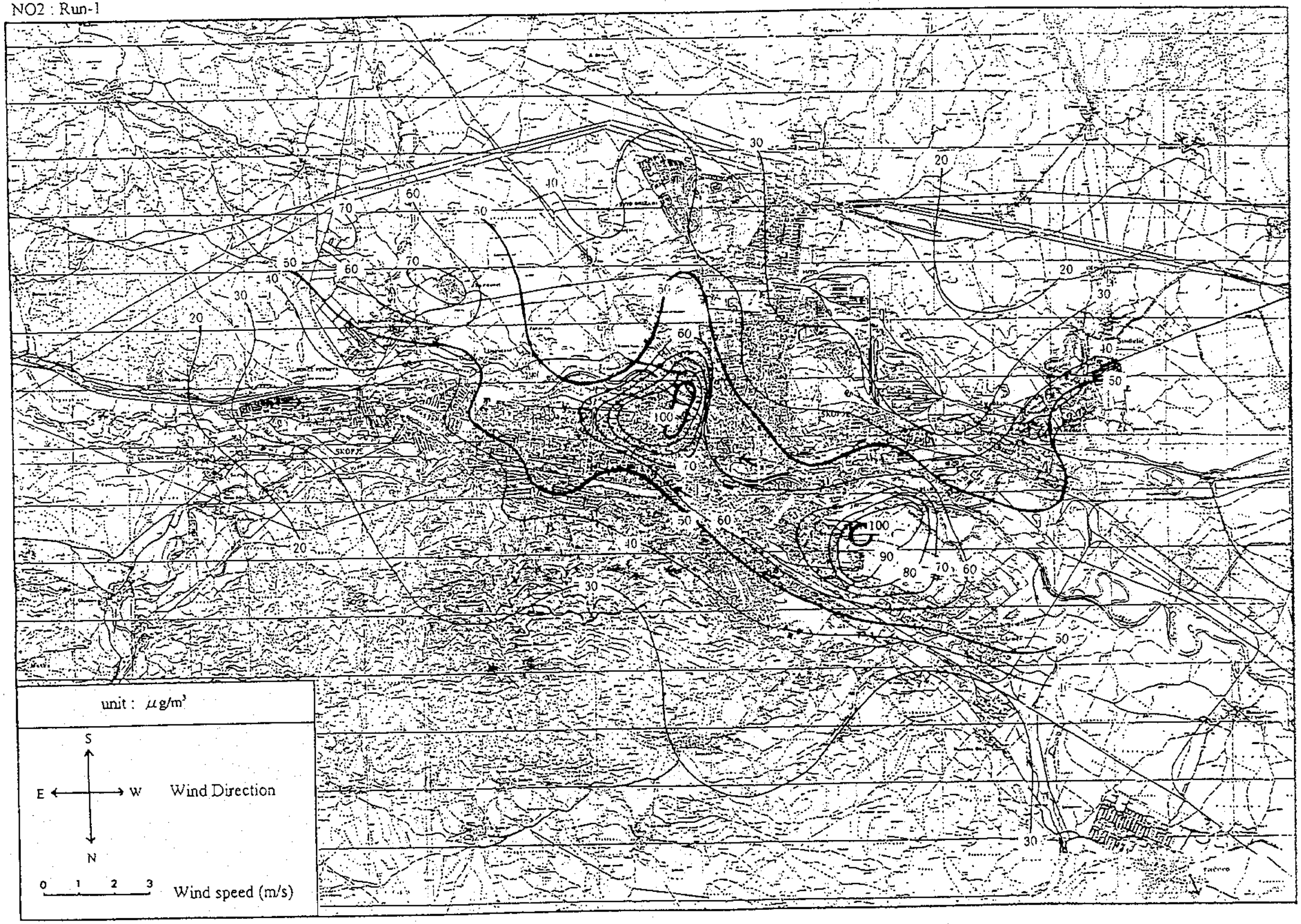


Figure 3.10 (2) The Concentration Distributions of NO_2

3.2.2 Determination of Number of Sites and Location

The Counterpart and the Study Team evaluated locations, meteorology and topographical conditions of emission sources, existing monitoring locations and field survey results of distribution pattern of ambient air concentrations with the simplified samplers. After given due consideration to representative installation positions, four new AQM stations were selected.

<Overview of AQM Stations>

Figure 3.11 shows the locations of the measuring points and AQM stations in Skopje.
The characteristics of AQM stations are outlined below.

Station-1 (Gazi Baba):

This station is located at University of Skopje on top of a hill in Gazi Baba. Emission sources cannot be found nearby. When a northeast wind blows, the steel mill and other factories located about 2 km away from the monitoring station may affect the results. When a west wind blows, the background concentration level may be increased by air from the urban districts. Impact by a number of factories, such as Beer Co., Pivaru, Pharmaceutic Co. Alkaloid, Paper Co. Komuna and Central Heating Plant-EAST located about 1 km southeast to south of the monitoring station, cannot be ignored when stable meteorological conditions prevail in the winter, even though the frequency of the appropriate wind direction that affect the station is low.

Station-2 (Center):

This station is located in the center of Skopje and is called the urban district point. This station has a high probability of showing high concentration levels in ambient air quality in all systems of winds. Stand-alone central heating systems such as that for hotels and boilers in small and medium factories are located nearby. Automobiles are also greatly affecting this station.

Station-3 (Karpos):

This station is located at an intersection of a trunk road at the western edge of Skopje and it can be considered as a location for monitoring automobile emissions. Except for the Central Heating Plant-WEST located about 0.5km to the south, there are almost no factories nearby. Many apartment houses are situated along the trunk road, but they are supplied with heat from the heating plant during the winter.

This location is expected to have large concentration differences depending on systems of windows. This location is affected by air in the urban districts when an east wind blows, while it is affected by heating for many small and medium factories and by individual home heating when a west wind blows. When affected by the Central Heating Plant-WEST, the SO_2 concentration may go up very sharply at this location. The concentration will be lower, however, when a north wind blows.

Station-4 (Lisice):

This station is located at an intersection of a trunk road in the southeastern part of Skopje. This is a station located halfway between an industrial zone and a new town. A cement factory located about 1km south of the monitoring point can be regarded as a major emission source. When a north wind blows in the winter, the Central Heating Plant-EAST is also expected to affect the station. The concentration is forecasted to increase significantly if the station is affected directly by a major emission source.

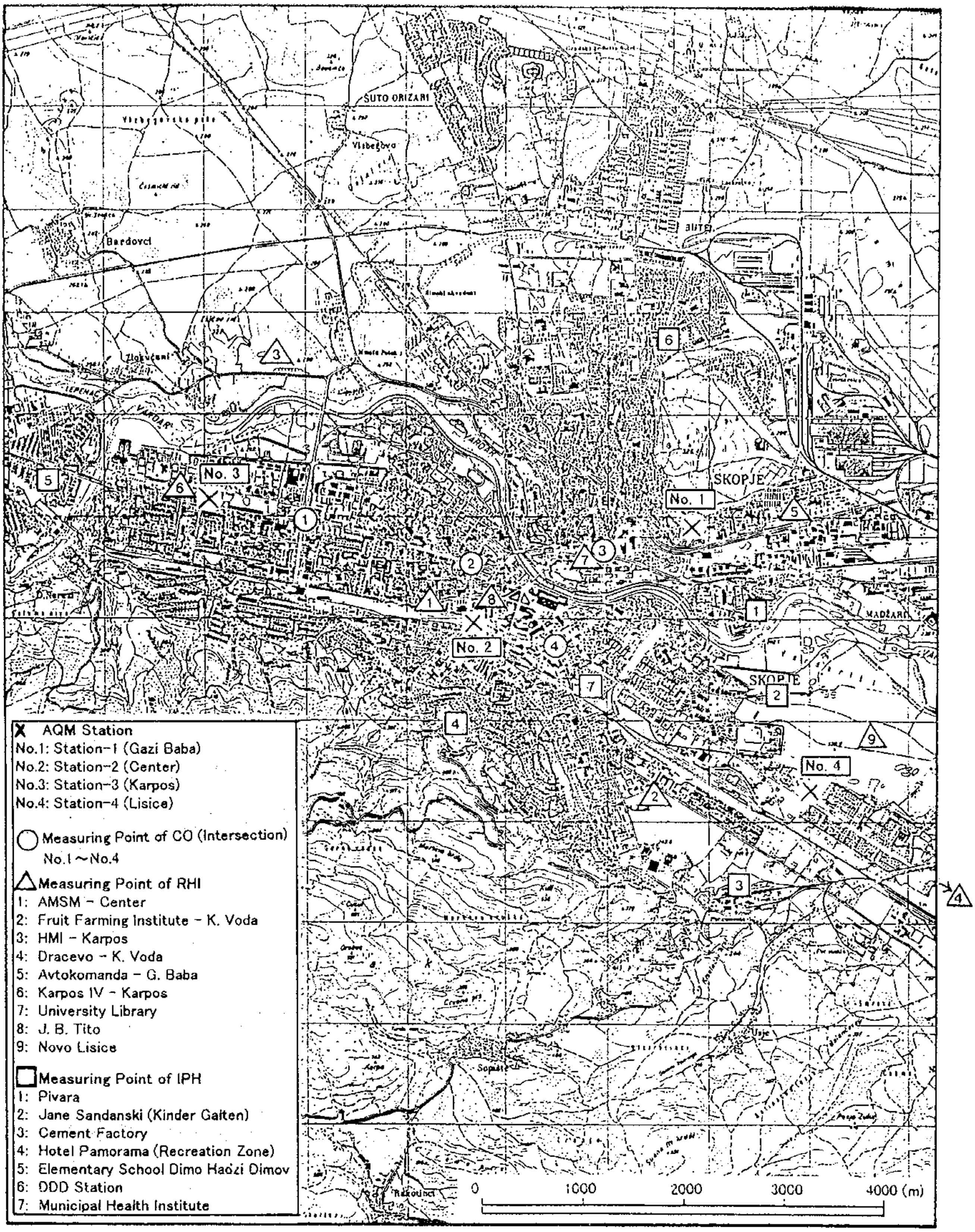


Figure 3.11 Location of the Measuring Points (Existing Sampler) and the New AQM Stations

3.3 Planning of Air Pollution Monitoring Equipment for the Study

3.3.1 Decision on Planning of Air Pollution Monitoring Equipment

(1) Outline of the Development Procedure

The equipment and materials plan necessary to conduct this Study was developed on the basis of the results of collection, readjustment and analysis of existing reference materials and data, in site investigation results, and by performing a diagnosis of the quality and quantity of equipment and materials stored by the Macedonian side.

The development of the equipment and materials plan and procurement procedure is shown in Figure 3.12.

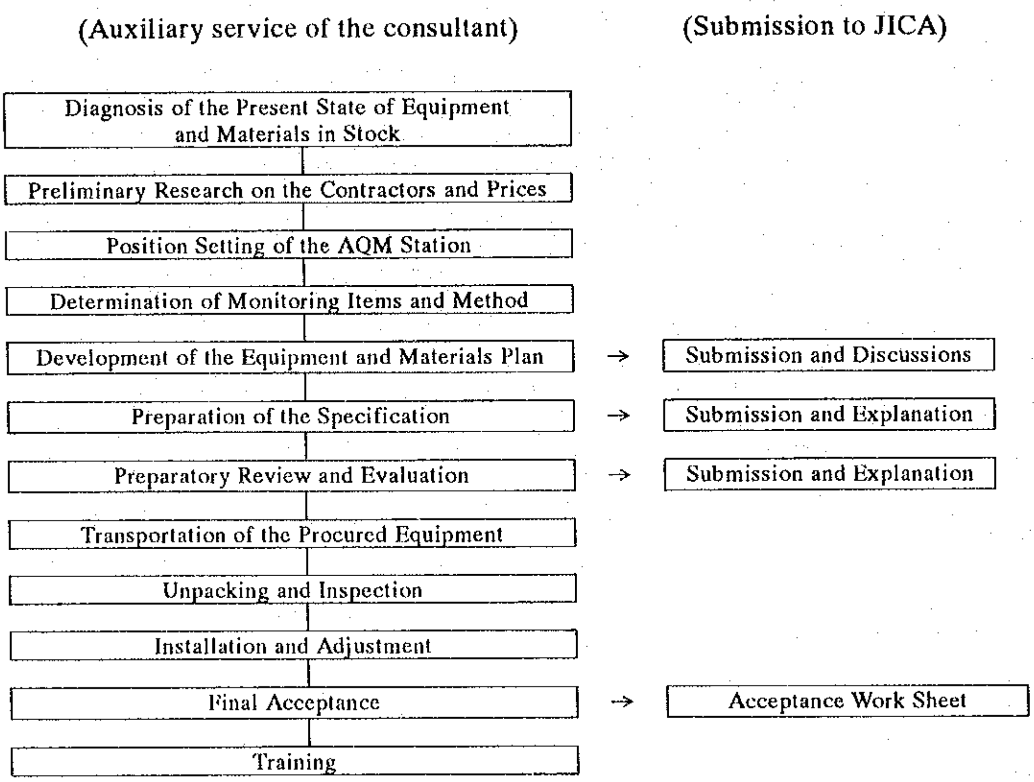


Figure 3.12 Development of the Equipment and Materials Plan and Procurement Procedure

(2) Selection of Measuring Items and Method

Selection of measuring items and method were proceeded for following equipment.

1) AQM Equipment

a) Monitoring Equipment

- AQM Instrument
- Meteorological Instrument
- Data Logger and Telemeter System

b) Equipment for Central Station

c) Equipment for Public Information System

2) Continuous Emission Monitoring (CEM) Equipment

3) Laboratory Equipment

Main measuring items and method of AQM equipment were selected as follows taking accuracy and measured range of equipment into consideration.

SO_2 Analyzer:	Ultraviolet Fluorescence Method
NOx Analyzer:	Chemiluminescence Method
CO Analyzer:	NDIR Gas Filter Correlation Method
O_3 Analyzer:	Ultraviolet Absorption Method
SPM Analyzer:	TEOM Method
Calibrator	Zero Gas Generator, Calibrator, O_3 Generator, others
Wind Direction/Speed:	Ultrasonic Wind Sensor with Heater
Temperature/Humidity:	Pt Sensor, 0 to 100 RH Type Sensor
Solar Radiation Meter:	Pyran Thermocouple
Data Logger:	Data Logger, Computer, Modem, others

The exhaust gas monitoring equipment of the CEM equipment/materials is equivalent to those for environmental application, in which dilution with a stack exhaust gas dilution system was introduced. This method can eliminate the error factor due to drain water in the sample line, which has been a problem with the conventional method.

(3) Decision on Planning of Equipment

A diagram of the monitoring system program is shown in Figure 3.13.

The following points were taken into consideration in selecting the equipment and materials.

- Quick troubles shooting in equipment failures
- High-reliability equipment with fewer failures and easy maintenance and management
- Radio telemetering
- Continuous monitoring system comprising a data transmission system and data processing system

The monitoring equipment (SO_2, NOx and CO) installed in a vehicle to monitor stationary sources can also be used as a mobile monitoring vehicle for environment monitoring.

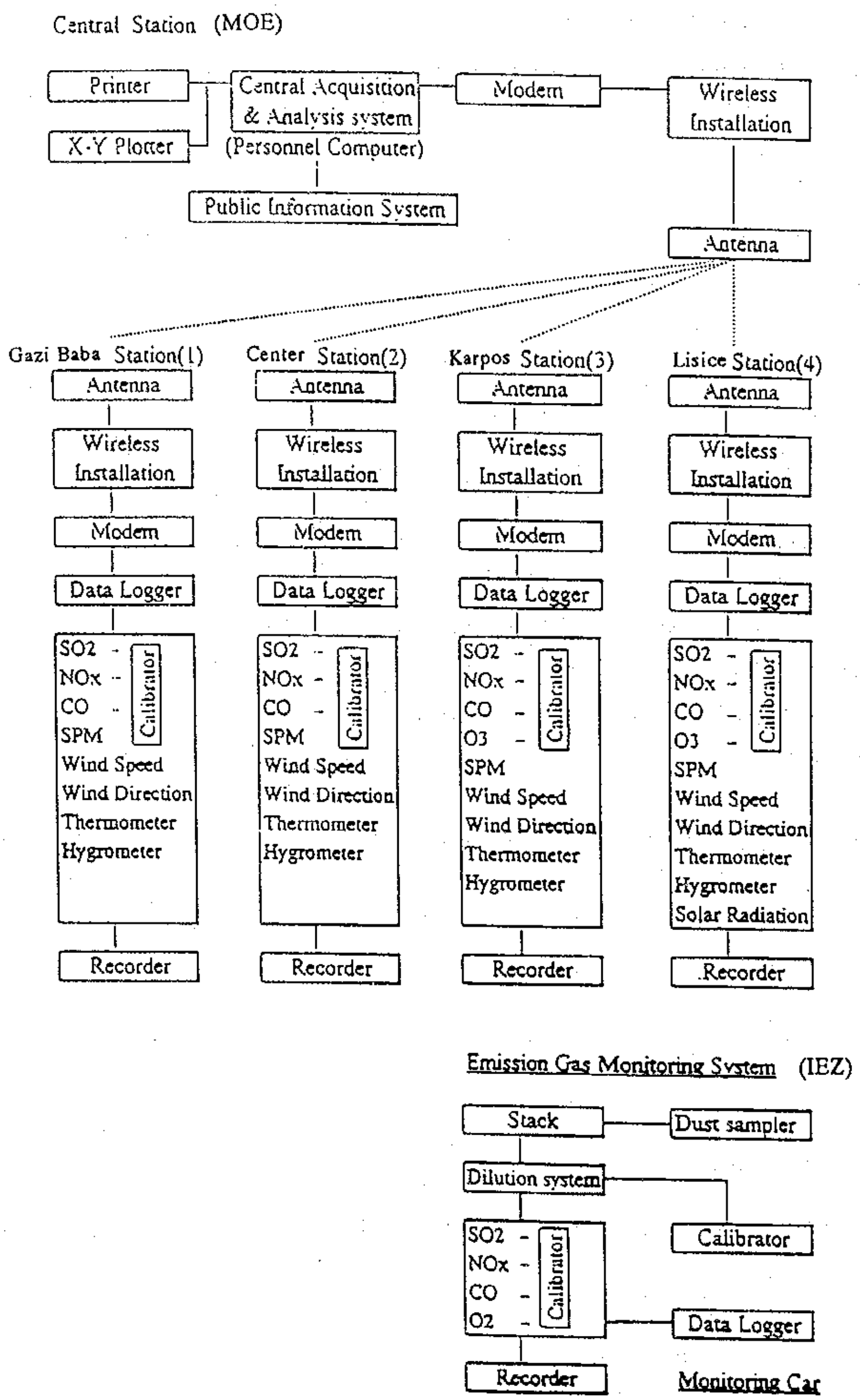


Figure 3.13 Air Pollution Monitoring System

(4) Preparation of Technical Specification of Equipment

A specification prepared was to specifically describe the specification details as follows:

- Nomenclature and Quantity of the Main Body and Consumable Items, Accessories and Spare Parts
- Equipment Monitoring Method and Performances such as the Accuracy, Monitoring Range, etc.
- Output Signal
- Training Concerning Principal Equipment
- Details of the Data Processing Software, etc.

3.3.2 Installation, Adjustment, Inspection and Technology Transfer of Equipment

(1) Installation and Acceptance of the Equipment

1) Installation Procedures and the Time Period for the Equipment and Materials

The installation and adjustment of the principal equipment and materials were started on March 9 and were completed on March 31, 1998.

2) Acceptance of the Equipment and Materials

In addition to checking the quantities, the equipment and materials were checked each time they were installed or adjusted. All the equipment and materials were started up and accepted by the end of March 1998.

(2) Instruction and Technology Transfer of the Equipment

Technical training was provided to the Counterparts and concerned personnel on handling and maintenance of the equipment and materials related to the ambient air quality and stationary source surveys.
The training was given during and after physical installation and adjustment. Also the technology was transferred comprehensively on the entire survey method including monitoring and analysis in form of hands-on work in field surveys and data analysis.

The training on the monitoring equipment included expects such as minor repairs and system management, aside from equipment handling, operation and maintenance.

Chapter 4

Chapter 4 Present State of Air Pollution in Skopje

4.1 Results of Automatic Continuous Monitoring

The analysis for meteorological data as well as ambient air quality data was carried out for the period from April 1998 to January 1999.
The classifications of the seasons are as follows:
Non-heating season: From the beginning of April to the end of September
Heating season: From the beginning of October to the end of March

4.1.1 Meteorological Condition

(1) Surface Meteorology

1) Wind Direction and Speed

The windrose diagrams (non-heating season and heating season) for each monitoring station are shown in Figure 4.1.

a) Station 1 (Gazi Baba)

The monitoring station is set up on the hill of Gazi Baba and the characteristic of the location is that there are no structural obstacles nearby.
Both in the non-heating season and in the heating season, WNW and W winds prevail. Easterly and westerly winds appear in both seasons. As for appearance frequency based on wind scale, it shows high frequency of 1.0 to 1.5 m/s in the non-heating season and of 0.5 to 1.0 m/s in the heating season.

b) Station 2 (Center)

The monitoring station is located in the center of the town area. Although there are high-rise buildings along the trunk road nearby, the south of the station faces a piece of unoccupied vacant land.
It shows similar tendency to Gazi Baba in wind direction and speed.

c) Station 3 (Karpos)

The monitoring station is located almost at the cross junction between trunk roads running in

both the East-West and North-South directions. Although high-rise buildings are to be found along side the trunk roads, there are no big structural obstacles nearby in the area from northeast to the east of the station.
The wind directions are slightly different from other stations. Both in the non-heating season and in the heating season, WSW wind prevails. E wind prevails in the non-heating season. It shows similar tendency to Gazi Baba and Center in wind speed.

d) Station 4 (Lisice)

There are no high-rise buildings near this station that will affect the monitoring process.
Clearly the wind directions are different from other stations. ESE wind prevails in the non-heating season. In the heating season, WNW and ESE winds prevail. Although the wind speed is as weak as other stations, it shows higher appearance frequency than them (over 2.5 m/s).
Upon observation of the general trend, it is found out that W and E winds have high frequencies while there are hardly any signs of N wind. In addition, the wind speed is weak and this is characteristic of Skopje.

Upon observation of the variation of the average wind speed based on time, the wind is strongest from 4:00 to 6:00 p.m. in the non-heating season. In the heating season, the wind tends to be strongest from 0:00 to 3:00 p.m..
As for the variation of the monthly average wind speed, there is a decreasing trend until June. The wind speed does not change greatly after that, but it gets slightly strong in December.

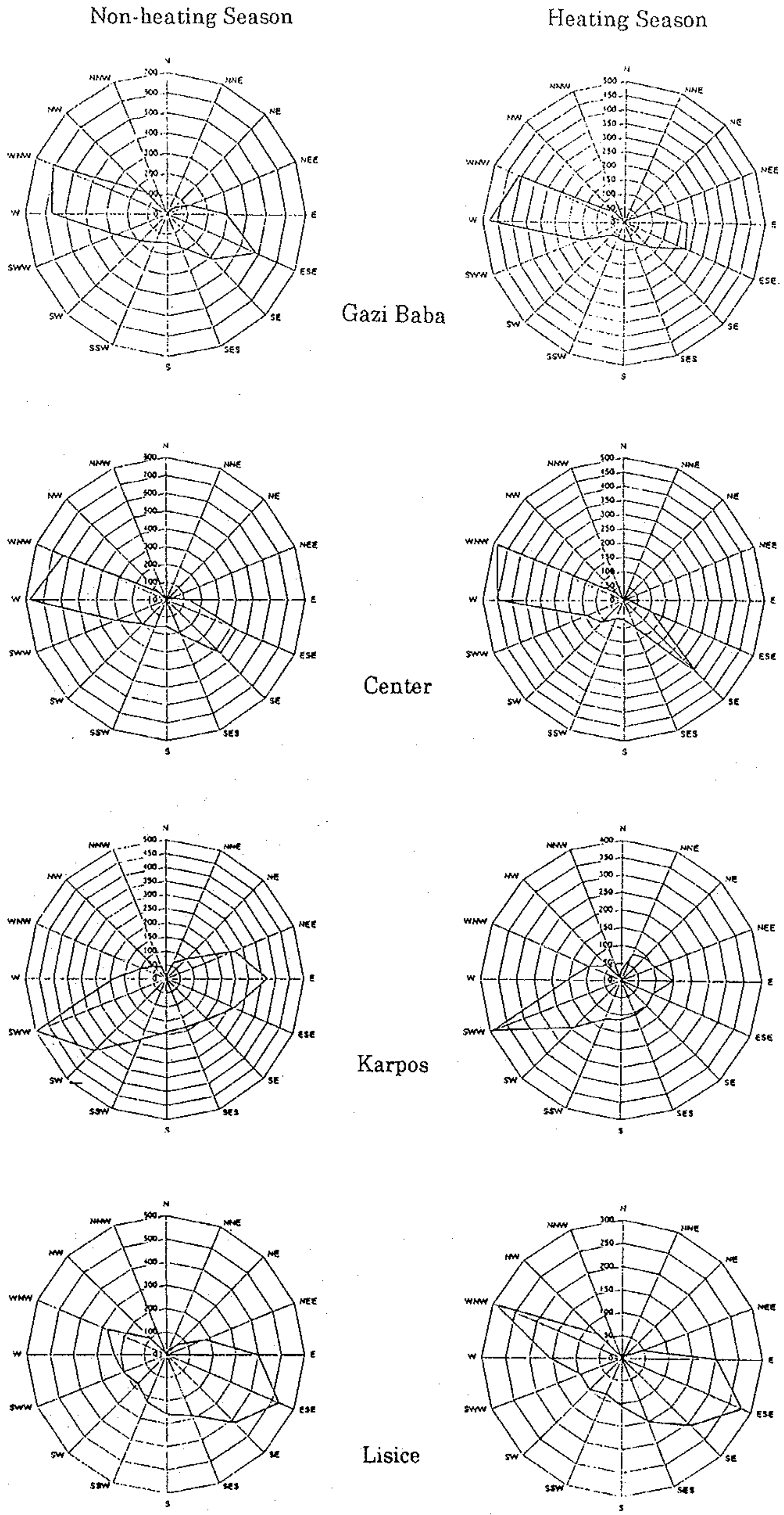


Figure 4.1 Windrose Diagrams in the Heating and the Non-heating Seasons

2) Temperature and Humidity

The characteristic of this diagram is that the fluctuations in the daily average temperature and humidity are the same for every station. In addition, together with temperature increase from May to August, humidity decreased. In August, the average daily temperature is about 30℃ while the humidity is about 40%. The highest hourly value is about 40℃. However, it recorded about -10℃ even in the daytime in the last half of December.

3) Appearance Frequency of Atmospheric Stability Classes

The atmospheric stability is an index for expressing the relative difficulty of atmospheric dispersion. As shown in Table 4.1, the atmospheric stability class is divided into A (strong instability) to G (strong stability) classes according to wind speed, the amount of solar radiation, and depends on the amount of clouds in the night time.

Table 4.1 Classification of Pasquill's Atmospheric Stability Classes

Wind Speed (U) m/s	Solar Radiation (T) kW/m2				Night Cloud Volume		
	T≧0.60	0.60>T ≧0.30	0.30>T ≧0.15	0.15>T	Totally Cloud (8～10)	Upper Cloud (5～10), Middle Cloud and Lower Cloud (5～7)	Cloud Volume (0～4)
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

Remarks

1) Totally clouded corresponds to the middle and lower cloud volume larger than 8.
The upper cloud is of Ci, Cc, and Cs cloud form and cloud of other form correspond to middle/lower cloud.
2) Zero solar radiation corresponds to night time. The start of night time and the last 1 hour period of night is though neutral.
3) Stability classes:
A: Strong Instability B: Instability C: Moderately Instability D: Neutral
E: Moderately Stability F: Stability G: Strong Stability

The heating season, in particular the winter season, shows a tendency to be stable as compared to the non-heating season. In some cases, the stable condition of the atmosphere continued for a few days. The severe air pollution during winter is brought about by such meteorological conditions and the emission of air pollutants from heaters contributes towards air pollution.

The non-heating season, the frequency of strong instability (A) to instability (B) and neutral (D) is becoming higher. This shows the characteristics of Skopje whereby the solar radiation is strong and the wind speed is weak in summer time. As a result, it is a general fact that the frequency of D will rise. On the other hand, the frequency of G (strong stability) is high in the night.

The trend of the concentration of pollutants in the atmosphere being higher in the nighttime than in the daytime can be understood from the classification of atmospheric stability class.

(2) Upper-layer Meteorology

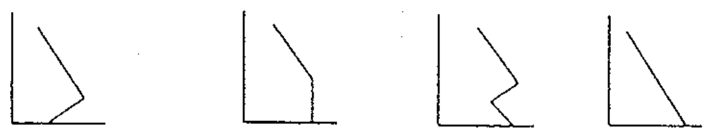
1) Autumn

A summary of the data observed by the Study Team is as follows. In addition, the occurrence of inversion layer is shown in Table 4.2.

Table 4.2 Occurrence of Inversion Layer

Month/day Time	11/19	11/20	11/21	11/22	11/23	11/24	11/25
0 hr	—	—	△	△	○*1△	—	—
6 hr	—	△	△	○	—	—	○
12 hr	—	△	△	△	—	—	—
18 hr	—	△	—	△	—	—	○*2△

*1: until 200m *2: until 300m



- Temperature inversion was observed near the region of 400 to 1,000 m above ground and it was also observed that the lower layer was unstable and the upper layer was stable.
- A drastic change of the vertical distribution of the wind direction at the range of several hundred meters above ground occurred frequently and this shows the unique topological influence of Skopje.
- The wind speed was extremely weak above the ground. The data obtained in the Study shows several cases though the wind speed likely to be weaker with the altitude in general.

2) Winter

The upper-layer meteorological observation from the period of December 1998 to January 1999 is extracted and summarized in Figure 4.2.

During winter, the inversion layer phenomenon occurs very frequently and in some cases, it was found that the phenomenon continued for a few days. The abnormally high concentration for SO_2 and SPM that continued for over a week, having its peak observed on December 30, 1998, is the result of the strong temperature inversion that continued all the day. Under such meteorological conditions, air pollutants emitted from automobiles, factories, heaters etc. accumulate near the ground level of the atmosphere, without dispersing to a wider region and causing severe air pollution. According to the existing data, a similar example of a high concentration level is observed in January 1993.

In many cases, the altitudes for the inversion layer, as measured from the ground level ranges mostly from about a few hundred meters to 1,000 m. The effect of the temperature inversion layer was strong and in some cases, it was found to exceed 4℃/ 100 m. The characteristics for Skopje are that the wind speed is weak, the rate of occurrence of inversion layer is high and the degree of inversion is strong. One of the reasons for this could be due to the geographical conditions whereby there are flat plains in the valley area.

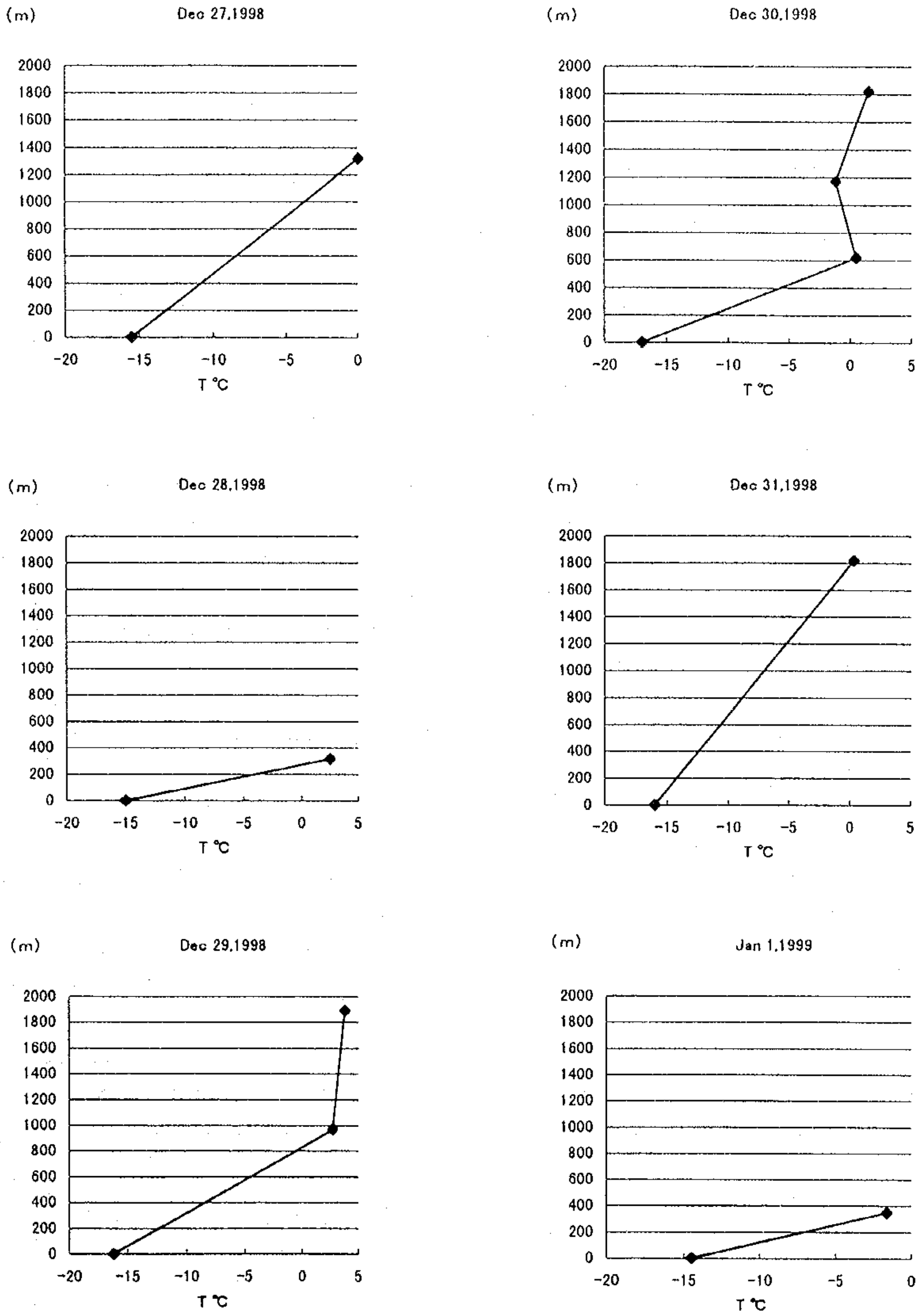


Figure 4.2 The Results of Upper-layer Meteorological Observation
(December 27, 1998 - January 1, 1999)

4.1.2 Ambient Air Quality

(1) AQM Station

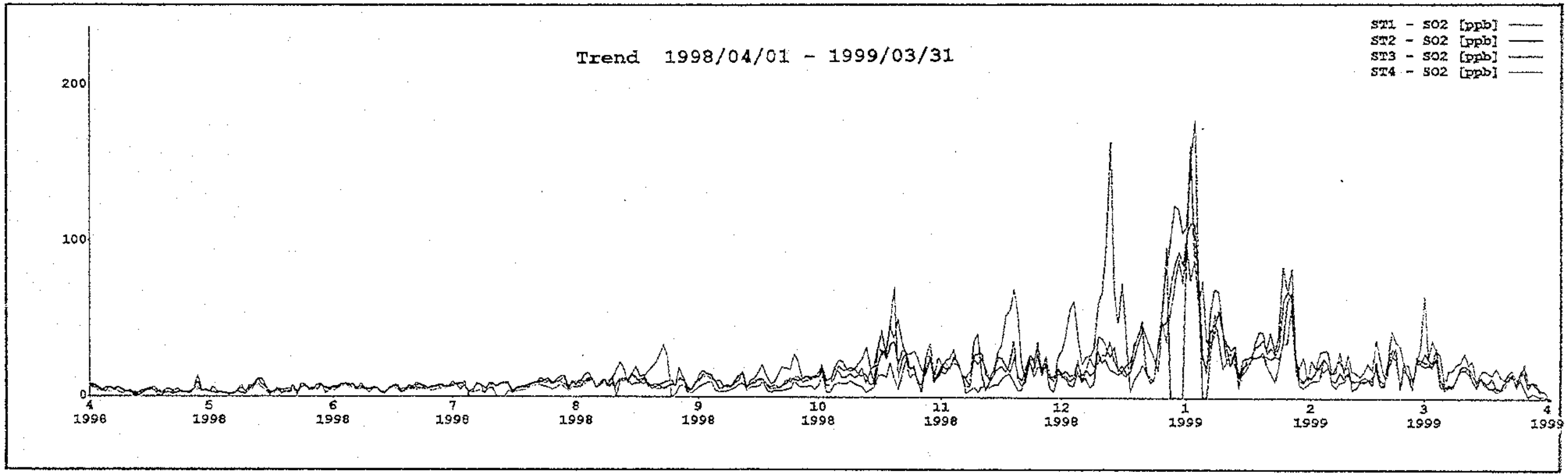
1) Variation in Air Pollutants Concentrations

Figure 4.3 shows variation diagram of daily mean value of ambient air concentration.

- During non-heating season and the season when the air pollutants are more diffused as a result of meteorological reasons, the SO_2 concentration level is not high. SO_2 concentration level is very high in the heating season.
- The values for NO, NO_2, NOx and SPM concentration levels did not show significant fluctuation until early August. It is observed that there is an increasing trend in NO, NOx from the end of September. NO, NO_2 and NOx concentration levels are high in winter.
- Compared with other sites, the NO, NO_2 and NOx concentration levels are low for Gazi Baba (Station 1). In particular, the NO concentration is so low that it is possible to conclude that there is no emission source nearby.
- The difference in concentration levels for SO_2 and SPM as compared among each station is not that significant like that of NOx.

The following facts were found in the fluctuation of pollutant concentration for 1-hour value (Data Book, Figures D4.13 to 4.19).

- The concentration levels for NO, NO_2, NOx, CO and SPM rise in the night, with a slight decrease in midnight and tend to rise again in the early morning. Despite the fact that the number of automobiles are decreasing, the high concentration in the nighttime is still a general phenomenon, and the reason is largely due to meteorological condition. This shows the state of the atmosphere. This can also be understood from the classification of the atmospheric stability class.
- The SO_2 concentration level is high from early morning to noontime, while in the night it is not so high. There are significant changes in the concentration variation for SO_2 as compared to NOx and SPM and this only shows that the emission sources may not necessarily be common after all.
- Even without taking into consideration the concentration variation of the mid-night, the abnormally high concentration period for the winter continually showed a high concentration.



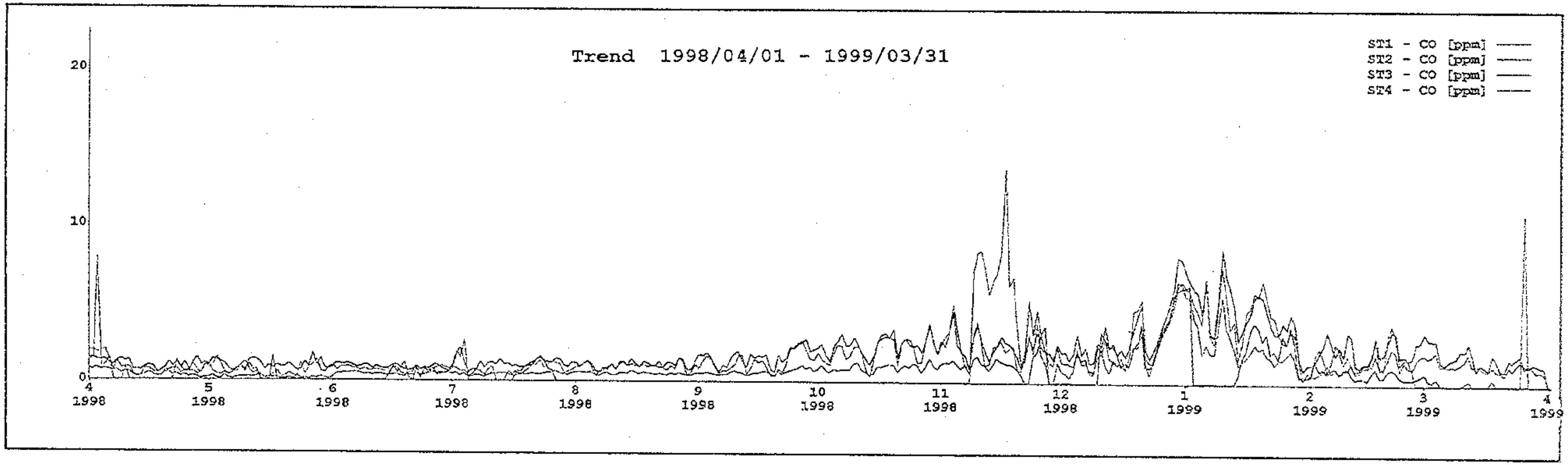


Figure 4.3 (1) Variation of Air Pollution Items (Daily Data)

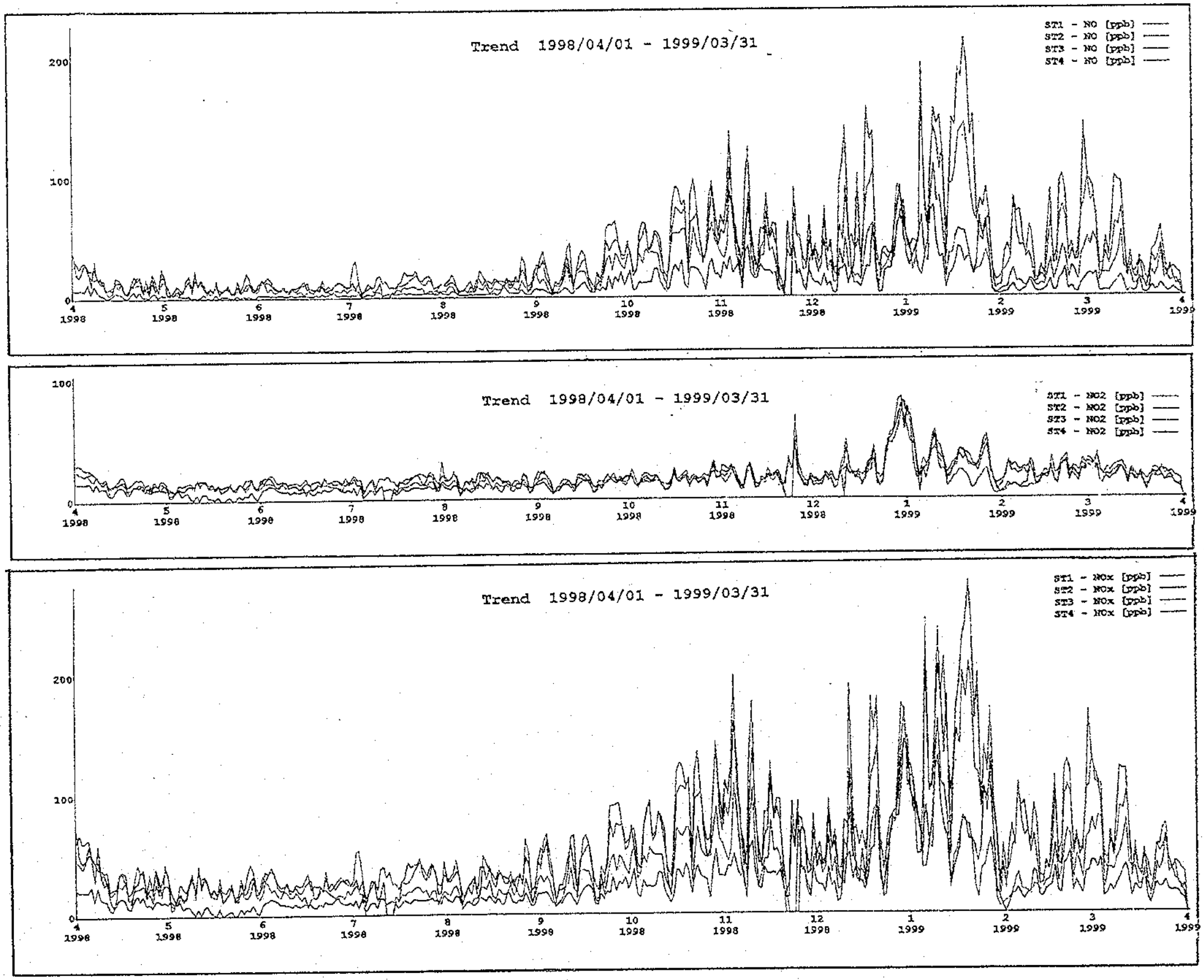
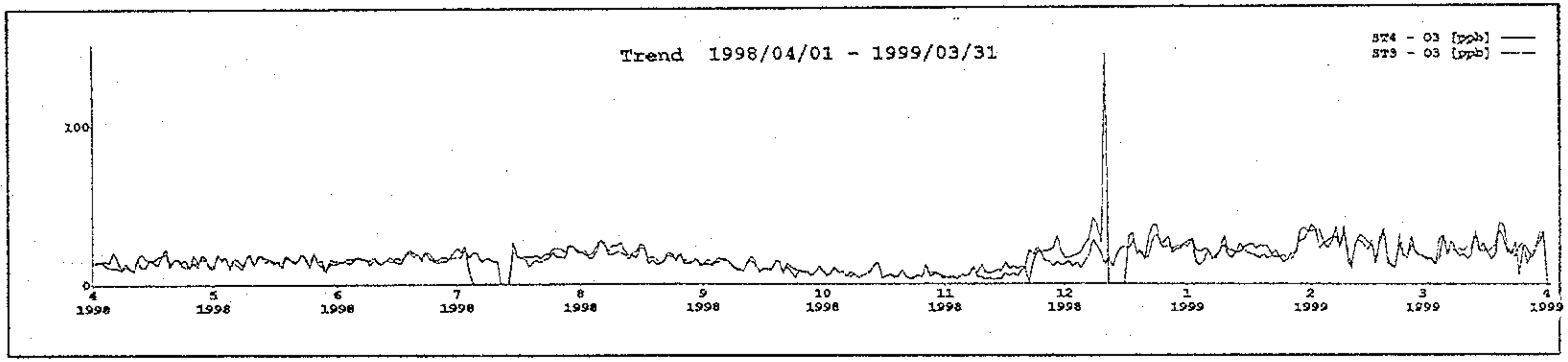


Figure 4.3 (2) Variation of Air Pollution Items (Daily Data)



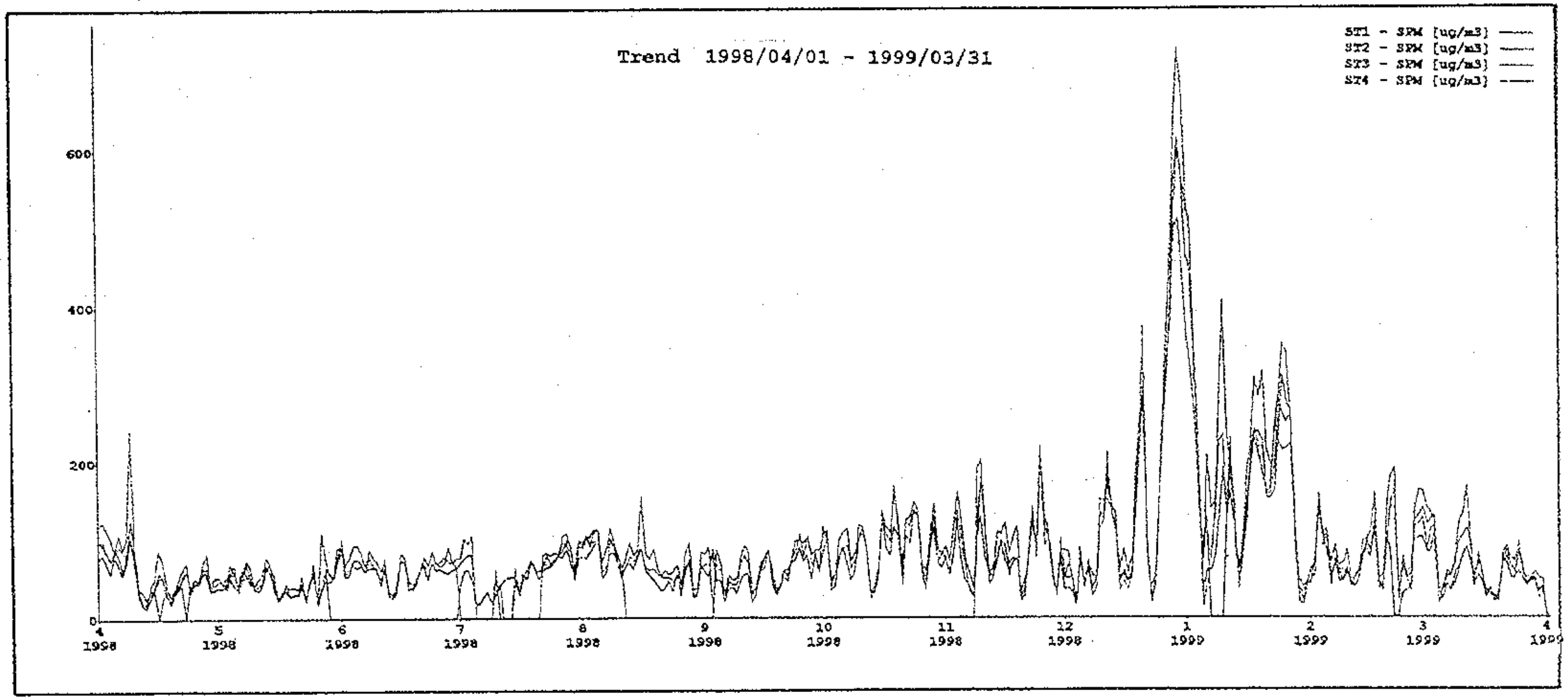


Figure 4.3 (3) Variation of Air Pollution Items (Daily Data)

2) Outline of Data and Comparison with the Air Quality Standard

The outline of automatic monitoring results and the environment standards are shown in Table 4.3.

How to read "kind of value";

Monthly average: Average value of total hourly data for a month

24 hours average (max.): Maximum value of 24-hour average data for a month

1 hour (98%): Concentration from low to 98% level, from the order list of total hourly data for a month

1 hour (max.): Maximum value of total hourly data for a month

a) SO_2

Non-heating Season:
SO_2 concentration level in the air neither exceeds the daily average value nor hourly 98% value as well as hourly maximum set by the standards for any of the monitoring stations. When comparing the concentration level for each monitoring station, the non-heating season shows low concentration and there is not any significant difference.

Heating Season:
In particular the winter season, very often the standards are being exceeded and in some cases, extremely severe air pollution occurred continuously.

Taking into consideration the case for combined pollution with SPM, from the period of the end of December 1998 to the beginning of January 1999, the concentration of SO_2 exceeded the limit for alarm.

Table 4.3 Outline of Automatic Monitoring Results and the Environmental Standards

Components	Kind of Value	Non-Heating Season Gazi Baba	Non-Heating Season Center	Non-Heating Season Karpos	Non-Heating Season Lisice	Heating Season Gazi Baba	Heating Season Center	Heating Season Karpos	Heating Season Lisice	MPC Daily/ for Minute
SO_2 (ppb)	Monthly Ave. (Max)	13	10	11	9	46	42	66	36	56/188
	24 hours Ave.(Max.)	26	19	32	16	161	112	304	100	
	1 hour (98%)	35	22	35	34	165	131	309	115	
	1 hour (Max.)	82	38	46	44	233	204	387	137	
NO_2 (ppb)	Monthly Ave. (Max)	11	19	16	14	33	33	27	29	44/44
	24 hours Ave.(Max.)	17	30	25	32	80	84	78	72	
	1 hour (98%)	30	46	39	45	92	102	97	88	
	1 hour (Max.)	43	63	58	53	122	180	127	109	
NOx (ppb)	Monthly Ave. (Max)	16	46	29	48	76	132	64	135	–/–
	24 hours Ave.(Max.)	31	78	53	93	145	245	171	277	
	1 hour (98%)	58	164	115	198	222	438	222	588	
	1 hour (Max.)	127	254	197	285	655	830	304	999	
CO (ppm)	Monthly Ave. (Max)	0.6	1.5	1.1	1.2	2.8	4.5	5.1	4.0	0.86/2.58
	24 hours Ave.(Max.)	1.0	2.7	2.6	2.6	6.2	8.6	13.6	7.4	
	1 hour (98%)	1.5	5.1	3.1	5.2	8.3	11.3	14.9	11.9	
	1 hour (Max.)	2.2	10.4	5.3	6.5	12.7	13.9	18.4	17.9	
O_3 (ppb)	Monthly Ave. (Max)	–	–	38	33	–	–	26	21	–/63
	24 hours Ave.(Max.)	–	–	53	54	–	–	47	32	
	1 hour (98%)	–	–	85	77	–	–	49	54	
	1 hour (Max.)	–	–	106	95	–	–	70	90	
SPM ($\mu g/m^3$)	Monthly Ave. (Max)	64	87	74	69	182	164	188	213	Black Smoke 50/ 150 Dust 150/ 500
	24 hours Ave.(Max.)	105	244	125	125	614	512	727	600	
	1 hour (98%)	149	209	164	164	653	525	738	646	
	1 hour (Max.)	266	1360	279	340	791	647	887	817	

Note:

(light shading) Exceeding Ambient Air Quality Standard (Black Smoke and Gaseous Components)

(dark shading) Exceeding Ambient Air Quality Standard (Dust)

MPC: Maximum Permitted Concentration

Monthly Average: Average Value of Total Hourly Data for a Month.

Monthly Average (Max): Maximum Value of Monthly Average During a Season Concerned.

24 hours Average: Average Value of Total Hourly Data for a Day.

24 hours Average (Max): Maximum Value of 24-hour Average During a Season Concerned.

1 hour (98%): Maximum Value of Hourly Data (98%) for aMonth During a Season Concerned

1 hour (Max): Maximum Value of Hourly Data (Max) During a Season Concerned.

A comparison between 1 hour value and standard 1 minutu value was made for reference.
Marked data exceed standards even for 1 hour value.

Table 4.3 Outline of Automatic Monitoring Results and the Environmental Standards

Components	Kind of Value	Non-Heating Season				Heating Season				MPC
		Gazi Baba	Center	Karpos	Lisice	Gazi Baba	Center	Karpos	Lisice	Daily/ for Minute
SO_2 (ppb)	Monthly Ave. (Max)	13	10	11	9	46	42	66	36	56 / 188
	24 hours Ave.(Max.)	26	19	32	16	161	112	304	100	
	1 hour (98%)	35	22	35	34	165	131	309	115	
	1 hour (Max.)	82	38	46	44	233	204	387	137	
NO_2 (ppb)	Monthly Ave. (Max)	11	19	16	14	33	33	27	29	44 / 44
	24 hours Ave.(Max.)	17	30	25	32	80	84	78	72	
	1 hour (98%)	30	46	39	45	92	102	97	88	
	1 hour (Max.)	43	63	58	53	122	180	127	109	
NOx (ppb)	Monthly Ave. (Max)	16	46	29	48	76	132	64	135	– / –
	24 hours Ave.(Max.)	31	78	53	93	145	245	171	277	
	1 hour (98%)	58	164	115	198	222	438	222	588	
	1 hour (Max.)	127	254	197	285	655	830	304	999	
CO (ppm)	Monthly Ave. (Max)	0.6	1.5	1.1	1.2	2.8	4.5	5.1	4.0	0.86 / 2.58
	24 hours Ave.(Max.)	1.0	2.7	2.6	2.6	6.2	8.6	13.6	7.4	
	1 hour (98%)	1.5	5.1	3.1	5.2	8.3	11.3	14.9	11.9	
	1 hour (Max.)	2.2	10.4	5.3	6.5	12.7	13.9	18.4	17.9	
O_3 (ppb)	Monthly Ave. (Max)	–	–	38	33	–	–	26	21	– / 63
	24 hours Ave.(Max.)	–	–	53	54	–	–	47	32	
	1 hour (98%)	–	–	85	77	–	–	49	54	
	1 hour (Max.)	–	–	106	95	–	–	70	90	
SPM ($\mu g/m^3$)	Monthly Ave. (Max)	64	87	74	69	182	164	188	213	Black Smoke
	24 hours Ave.(Max.)	105	244	125	125	614	512	727	600	50/ 150
	1 hour (98%)	149	209	164	164	653	525	738	646	Dust
	1 hour (Max.)	266	1360	279	340	791	647	887	817	150/ 500

Note:

[light shading] Exceeding Ambient Air Quality Standard (Black Smoke and Gaseous Components)

[dark shading] Exceeding Ambient Air Quality Standard (Dust)

MPC: Maximum Permitted Concentration

Monthly Average: Average Value of Total Hourly Data for a Month.

Monthly Average (Max): Maximum Value of Monthly Average During a Season Concerned.

24 hours Average: Average Value of Total Hourly Data for a Day.

24 hours Average (Max): Maximum Value of 24-hour Average During a Season Concerned.

1 hour (98%): Maximum Value of Hourly Data (98%) for aMonth During a Season Concerned

1 hour (Max): Maximum Value of Hourly Data (Max) During a Season Concerned.

A comparison between 1 hour value and standard 1 minutu value was made for reference.
Marked data exceed standards even for 1 hour value.

b) NO, NO_2, NOx

During non-heating season about in April, the highest hourly values were recorded for every station well above the ambient standard except Gazi Baba (Station 1). The Same was true for summer time.

During the heating season and in particular, during the winter season, the limits for the standards are frequently being exceeded and like the case of SO_2, there are cases when the environmental standards are being continuously exceeded.

When comparing the NO_2 concentration level for each monitoring station, Center (Station 2) clearly shows the highest value. On the other hand, Gazi Baba tends to show low values as compared to other monitoring stations.

Through all seasons, mostly the causes of NOx can be considered to be due to automobile emission. While it is plausible to conclude that this is reflective of the surrounding areas near each monitoring station.

The ratio of NO_2 to NOx (NO_2/NOx) in the non-heating season and the heating season are shown in Table 4.4.

Table 4.4 Ratio of NO_2 to NOx (April 1998 - January 1999)

	Gazi Baba	Center	Karpos	Lisice
Non-heating Season	0.760	0.488	0.561	0.432
Heating Season	0.497	0.284	0.360	0.266

c) CO

Non-heating Season:

The concentration level of CO in the air exceeds that required by the standard for almost every case except for Gazi Baba.

Heating Season:

The standard has been exceeded for all the cases for all the monitoring stations.

The reason for this is that the standard values set are strict compared with that of the countries in Europe and America or Japanese standards.

Among the four monitoring stations, like in the case for NOx, Center tends to show a slightly higher concentration level.

As for non-heating season, high CO contribution was automobile and it was thought that high CO concentration of Center and Lisice are influenced by such automobile emission than

Station 1.
At Karpos, monthly average of day average maximum was found not so high but one hour 98% and the maximum was high. Karpos may be under the changing influence of emission combined with wind direction.

d) SPM

Non-heating Season:
SPM concentration level in the air exceeds the standard value in most cases in all monitoring stations. High concentration is observed: the highest value of daily average value is 244 $\mu g/m^3$ and the highest hourly value is 1,360 $\mu g/m^3$. Aberrant hourly concentration such as 209 $\mu g/m^3$ in the 98 percentile is not merely resulted from stationary source and exhaust gas from vehicles. It can be resulted from suspended dust. Because of weak wind in Skopje, the atmosphere tends to stay. It is known that this phenomenon makes SPM concentration level high. Dry air is another characteristic of Skopje, and it causes occasional strong wind. It can be guessed through experience that it could raise large amount of sands. Moreover, the automobiles also raise a cloud of dust.

Heating Season:
The standards have been exceeded in all the cases for all the monitoring stations. In particular, the hourly average value for Karpos shows a high value of about 800$\mu g/m^3$ and like the case SO_2, it has brought about severe air pollution.

e) O_3

The O_3 concentrations were monitored at Karpos and Lisice.
The result of both stations resulted almost identical but exceeded the standard from April to August. Since September onwards and until mid-November, the concentration was observed to be decreasing, and after which, the level of concentration for winter was the same as that for summer. In the evening, the level of concentration did not show much decrease, similar to that in the summer.

3) Correlation Analysis of Air Pollutant Concentrations

To understand the emission source characteristics at each AQM station correlation analysis of air pollutant concentrations is used.

a) Correlation Analysis of Pollutants

Non-heating Season:

- NO, NO_2, NO_x and CO show high correlation coefficients in any combination. However, the correlation between NO and NO_2 is not high at Gazi Baba (R=0.465), which is probably resulted from the conversion rate from NO to NO_2.
- The correlation between SPM and the other monitoring parameters are not high. The same tendency can be seen between SO_2 and other monitoring parameters.

Heating Season:

- There is high correlation between SPM and CO, SPM and SO_2 at Gazi Baba and at Center.
- There is high correlation between NO_2 and SO_2 at each station. However, the correlation of NO_2 and NO_x decreases at each station.
- On the whole, the correlation of SPM and the other monitoring parameters tend to increase.

b) Correlation Analysis of Monitoring Stations

- In the non-heating season, the correlation of SO_2 is high between Center and Lisice, where the coefficient is 0.626. In the heating season, however, it is high between Center and Gazi Baba, where the coefficient is 0.804.
- The correlation of NO, NO_2, NO_x are high among Center, Karpos and Lisice. The correlation coefficient of NO_2 is 0.816 between Center and Karpos in the heating season. It seems that these three stations are commonly more influenced by automobiles.
- The correlation of SPM in the heating season is quite high among each station and SPM seems to be a widely spread pollutant.

4) Cross Analysis of Meteorology and Pollutant Concentrations

The purpose of the analysis is to learn the directions of emission sources that affect the stations and the characteristics of the sources.

It is possible to presume the direction of major emission sources by knowing the pollutant concentration of each wind direction.

In general, according to the relationship between wind speed and pollutant concentration, when an influencing emission source is at a high elevation, such as a factory's stack, a high pollutant concentration occurs under a relatively high wind speed condition rather than under mild wind. On the other hand, when the emission source is at a low level, such as vehicles and household heating, a high pollutant concentration occurs under mild wind conditions. The concentration becomes lower when the wind speed increases.

a) Average Pollutant Concentrations by Wind Directions

- SO_2 and SPM concentration distributions by wind direction have common features especially in the heating season. There is a slight difference in that of NOx. The facts above show that the emission sources of SO_2, SPM and NOx are different.
- In the non-heating season, each pollutant shows almost similar distribution pattern among AQM station. However, distribution pattern particularly that of SO_2, differ among AQM station in the heating season. Clearly, characteristics of each point are observed.
- According to SO_2 concentration distribution in winter, some locations may be influenced by stationary emission sources under certain wind direction.
- In Center, the concentrations of SO_2 in the heating season are high with the wind direction of SSE and SE, same as that of SPM.
- Compared with other stations, Karpos (Station-3) had unique characteristic that the distributions of each parameter differed completely.

b) Average Pollutant Concentrations by Wind Speed

Figure 4.4 shows mean concentration by wind speed (Karpos). Distribution of concentration of wind direction that shows maximum concentration is also shown in figures.

In general, air pollutant concentration decreases in negative correlation with wind speed. SO_2, Nox and SPM altogether show negative correlation with wind speed, only in Gazi Baba and Lisice in the heating season. There are various other cases; high concentration can be observed under fixed wind speed etc..

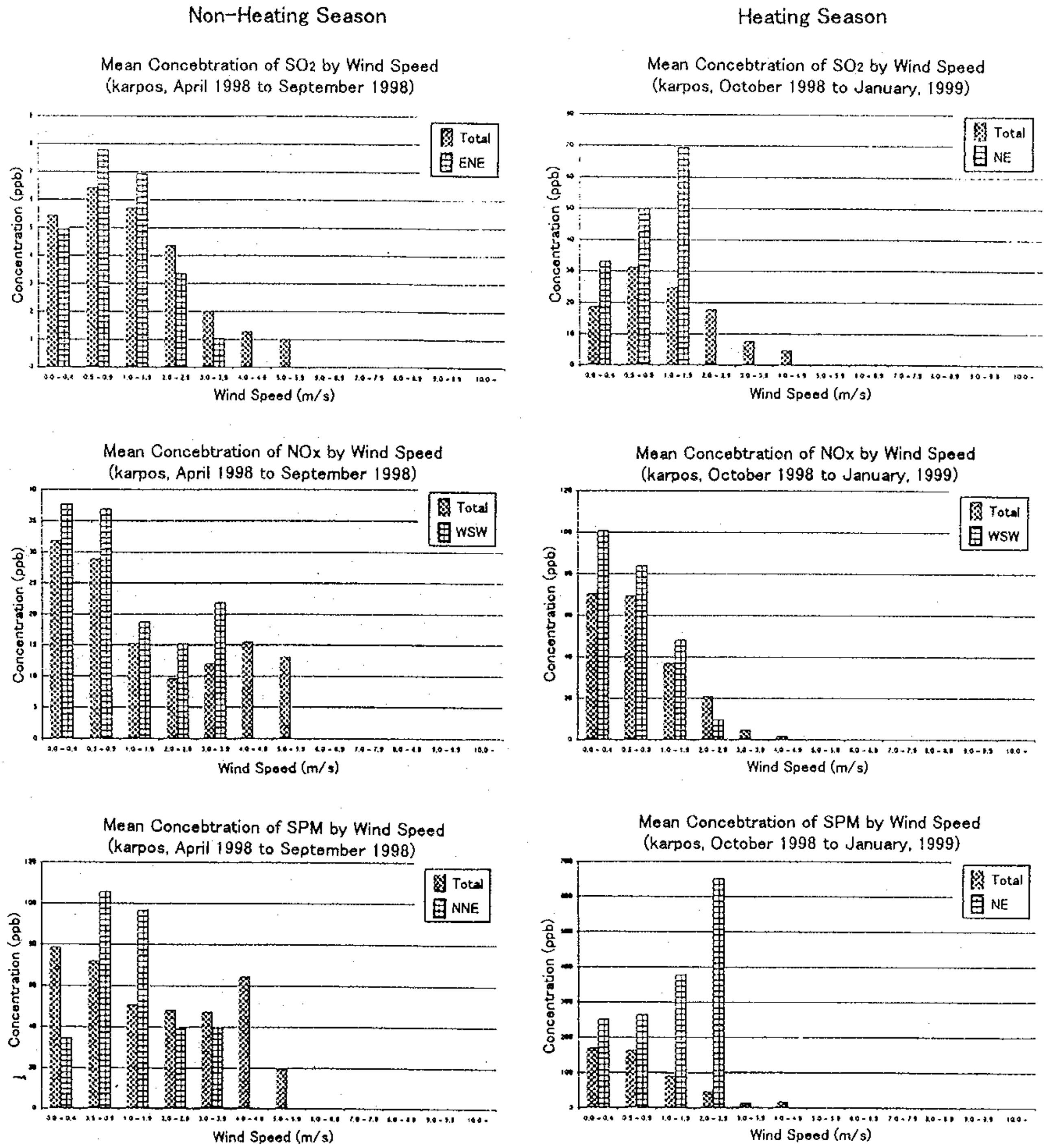


Figure 4.4 Mean Concentration of SO_2, NOx and SPM by Wind Speed (Karpos)

(2) Data of SPM in Ambient Air and Air Emission

1) SPM in Ambient Air

a) Observation by High Volume Sampler

Sampling and components analysis of SPM including heavy metals by a high volume sampler was performed.
In heavy metal components, Pb (less than 0.4μg/m^3) was not exceeded the environmental standard level (0.7μg/m^3). In carbon components, C-ele and C-org levels were the same. C-total dominated about 30% of SPM.

b) Particle Size Distribution by Andersen-type Low-volume Sampler

The Study Team carried out the sampling of particulate matter by size (PM2.5, PM5, PM10) in cooperation with the Counterpart.
The result of carbon analysis is shown in Table 4.5.
XRF analysis is non-distractive and allows the simultaneous multi component analysis but deviation by type is found to be large in terms of sensitivity as well as accuracy. Also analytical method like AAS result applied after acid dissolution often shows wide variance, which necessitates the use of analytical result into careful consideration. Table 4.6 shows effort of XRF analytical data evaluation by grouping the sampling filters (due to small SPM available) and subjecting to acid dissolution and AAS. The analysis data were shown in term of component dissolved in SPM, μg/mg.
The result of AAS analysis clearly showed the high content of Pb and as compared the sample taken near the RHI head office (Sample 1, 2, 3) the sample 4, 5 showed the higher Pb concentration. As for carbon, RWS (Skopje Central Railway Station) point showed higher value of carbon in SPM nearly 40 to 50%. The sample taken at the RHI compared carbon content in SPM size between<2.5μm and that of <10μm showed the higher value of carbon in <2.5μm SPM.

Table 4.5 Results of Carbon Analysis in SPM

(Andersen-type Low Volume Sampler)

Sampling Point	Sampling Date		PM	SPM Conc.	Carbon					
					C-org		C-ele		C-total	
	Date	Year			Conc.	Content	Conc.	Content	Conc.	Content
RHI	December 24-25,	1997	PM10	221	9.2	4.2	24.3	11.0	33.5	15.1
	December 25-26,	1997	PM10	126	7.6	6.1	17.6	14.0	25.3	20.1
	December 26-27,	1997	PM10	371	10.5	2.8	29.3	7.9	39.8	10.7
	January 8-9	1998	PM2.5	163	12.8	7.9	30.8	18.9	43.6	26.8
	January 9-10	1998	PM2.5	166	14.1	8.5	38.3	23.1	52.3	31.6
	January 10-11	1998	PM2.5	13	1.5	11.3	2.6	19.5	4.1	30.8
RWS	February 17-18	1998	PM10	325	38.8	11.9	83.1	25.6	121.9	37.5
	February 18-19	1998	PM10	153	16.5	10.8	47.7	31.0	64.2	41.8
	February 19-20	1998	PM10	130	17.4	13.4	47.3	36.4	64.7	49.8
	February 20-21	1998	PM10	245	29.7	12.1	78.7	32.1	108.4	44.2
	February 21-22	1998	PM10	261	35.4	13.6	86.9	33.3	122.3	46.9

Note: Unit: Conc.: $\mu g/m^3$ Content: %

Content (%): Ratio of component for SPM

December 25-26: It is not 24 hours flow (problem with pump)

Table 4.6 Results of Metal Analysis from Mixed Filter Samples of SPM

(Andersen-type Low Volume Sampler)

Sample No.	Total mass (mg)	Element ($\mu g/m^3$)										
		Na	K	Zn	Mg	Fe	Pb	Mn	Cr	Cu	Ni	Cd
1	13.3	1.128	5.732	0.226	1.977	6.240	1.278	0.748	0.145	0.154	0.172	0.0375
2	8.25	2.624	8.564	0.1576	3.164	7.758	1.273	1.067	0.0958	0.091	0.201	0.071
3	9.44	0.567	5.713	0.1695	1.086	3.072	1.006	0.577	0.0095	0.159	0.147	0.0106
4	3.96	2.487	15.05	0.581	4.90	13.89	7.071	0.795	0.0417	0.53	0.303	0.0353
5	9.79	1.798	8.655	0.398	7.666	21.55	3.473	1.236	0.136	0.408	0.202	0.0215

Note) Sample No.1: RHI, PM10(μm) A

Sample No.2: RHI, PM10(μm) B

Sample No.3: RHI, PM2.5 and PM5.0(μm)

Sample No.4: Kinder Garten, PM10(μm) – near the measuring point of IPH (No.2)

Sample No.5: Railway Station, PM10(μm)

2) Emission Source Data

a) Stationary Sources

Industrial facilities for measurement and observation and the results of measurement are presented in detail in 4.1.3, "Survey of Stationary Air Emission". Dust samples were picked up from stationary souces, which were subject for measurement and observation, and these samples were subjected to component analysis. As for component analysis, the results were shown in exhaust gas measurement results.
In C-ele, as indicated in the private house and Technical High School "Nikola Tesla", concentration was significantly changed with fluctuations of combustion condition. Main component of dust taken from private house using firewood consists of carbon. For C-org, as the blank-filter-paper value was high, it was difficult to analyze.
In addition, dust comprising mainly of carbonic components emitted from private houses during burning of firewood, is one of the main causes of severe SPM pollution during the winter season.

b) Soil

Soil sampling was conducted in four different places where they represent nature of soil in Skopje. The samples were subjected to component analysis including heavy metals after pretreatment.
Although Mn for Bul. Nikola Karev (Sample 2) shows a high value and differences for other components can be detected among all locations, significant trends necessary for explaining the sampling points can not be found.
In order to assess the characteristics of soil components, it is best that measurements be carried out in many points continuously so that data can be accumulated.

(3) Analysis of High Concentration Air Pollution

1) Present Conditions of Air Pollution in Winter

The data from four AQM stations established in Skopje for the Study shows very high concentrations of air pollution by SO_2 and SPM, exceeding MPC by far. Especially, at Karpos station from the end of December 1998 to the beginning of January 1999, the highest of the SO_2 daily average values was 810μg/m^3 and of the SPM daily average values was 726μg/m^3.
Table 4.7 shows the outline of monitoring results of SO_2 and SPM.

Table 4.7 Results of SO_2 and SPM Measurements

Unit: μg/m³

	Kind of Value	Gazi Baba	Center	Karpos	Lisice	MPC
SO_2	Average (24 hours)	420	297	810	260	150
	1 hour	606	531	1,029	356	-
SPM	Average (24 hours)	614	512	726	600	150 *1
	1 hour	791	647	887	816	-
Date for Exceedance of Alarm Criteria	First Stage	Dec. 31, Jan. 1,2	Dec. 29, 30	Jan. 1 to 3	Dec. 29, 31, Jan. 1, 2	1,100 *2
	Second Stage	Dec. 29, 30	-	Dec. 28	Dec. 30	1,400 *2
	Third Stage	-	-	Dec. 29 to 31	-	1,700 *2

Note)

*1 MPC: for Dust: 150 μg/m³, for BS: 50 μg/m³,

*2 Calculation of Alarm Criteria: SO_2 concentration +BS concentration x 2 (μg/m³)

From a topographical point of view, shape of Skopje looks like the Muese Valley in Belgium (in December 1930) and the Donora Valley in USA (in 1948: estimated values of SO_2 concentration: 500 to 2,000 ppb, 1,300 to 5,300μg/m³) where serious air pollution occurred. However, the Skopje Valley is much deeper than these two, and has poorer atmospheric diffusion.

Air pollution in Skopje resembles the London Event in pollution characteristics. In the London Event (December 1952) the number of surplus deaths was 4,000, and the maximum value of SO_2 concentration was 4,000μg/m³. It caused more serious damage than the two valleys shown above.

For example, in Japan, the SO_2 value was recorded as 566 ppb (1,507μg/m³) in Yokkaichi on July 26, 1970, when the number of officially recognized patients of pollution-related disease was 537 (announced by the City of Yokkaichi).

Most of these patients are babies and infants up to nine years of age (37%) and the aged over 60 years old (24%). The Yokkaichi doctor's association at that time assumed that the number of the patients including latent ones would be more than 2,000.

Muese, Donora and London have a similarity with Skopje in that they experienced temperature inversions and extraordinary high concentrations of pollutants. However, the main cause of the former two was, similar to the pollution in Yokkaichi, SO_2 pollution caused by emission from factories. On the other hand, in the case of London, about 60% of air pollution was caused by coal combustion from household heating, which produced dense fog combined with pollution with SPM. The case in London is the most similar to the heavy pollution in Skopje, where firewood is used for household heating.

To take an example of a typical Japanese city, in the city of Nagoya the highest SO_2 daily average values from April 1996 to March 1997 was 19 ppb (approximately 54μg/m³) and that of SPM was 124μg/m³.

2) Analysis of Air Pollution Mechanisms

a) Wind Direction / Speed and Concentration Variation

On the basis of the data from four AQM stations, Figure 4.5 shows the variation of daily average values of SO_2, SPM, and wind direction and speed during two months from December 1998 to January 1999 (the episode).
In seeing the relation between cyclic concentration change and atmospheric factors such as wind direction and speed, it is shown that heavy pollution is often caused when easterly weak wind blew and it is reduced when westerly strong wind rises.

b) Examination of the Mechanisms of Heavy Pollution Episode

i) Characteristics of Weather Conditions

The air pollution which occurred at the episode was as serious as that of January 1993. Based on the observation results and the data collected, Table 4.8 shows a comparison of weather conditions between the episode and January 1993.

Table 4.8 Outline of Weather Conditions When Heavy Concentrations Occur

Item		January 1993	December 1998, January 1999
Wind Direction and Speed (m/s)		0.6 ~ 1.4	E~ESE, 0.7~0.9 (Gazi Baba) SSE~S, 0.7~1.3 (Center) NE, E~ESE, 0.6~1.1 (Karpos) SE~SSE, 0.5~0.8 (Lisice)
Temperature (°C)	Day	-5 ~ 6	-3 ~ -7
	Night	Approx. -10	Approx. -10
	Daily Variation	6 ~ 18	4 ~ 5
Humidity (%)		70 ~ 90	70 ~ 90
Intensity of Inversion (°C/100 m)		1 ~ 3 (Ave. 2°C)	1.2 ~ 5.5 (Ave. 2.5°C)
Surface Layer (m)		-	480 ~ 2,050
Ceiling Height (m)		-	Before high concentration: fare High concentration: fog, visibility 300 m

According to the observation results, wind speed, temperature at night, and humidity were almost at the same level. In this case, it was distinctive that temperature difference between day and night was small, even in the daytime it remained very cold and the intensity of inversion was large. Therefore, it was observed that strong ground inversion was formed throughout the day and night. From the point of air pollution, the weather conditions at the episode was worse than those in January 1993.

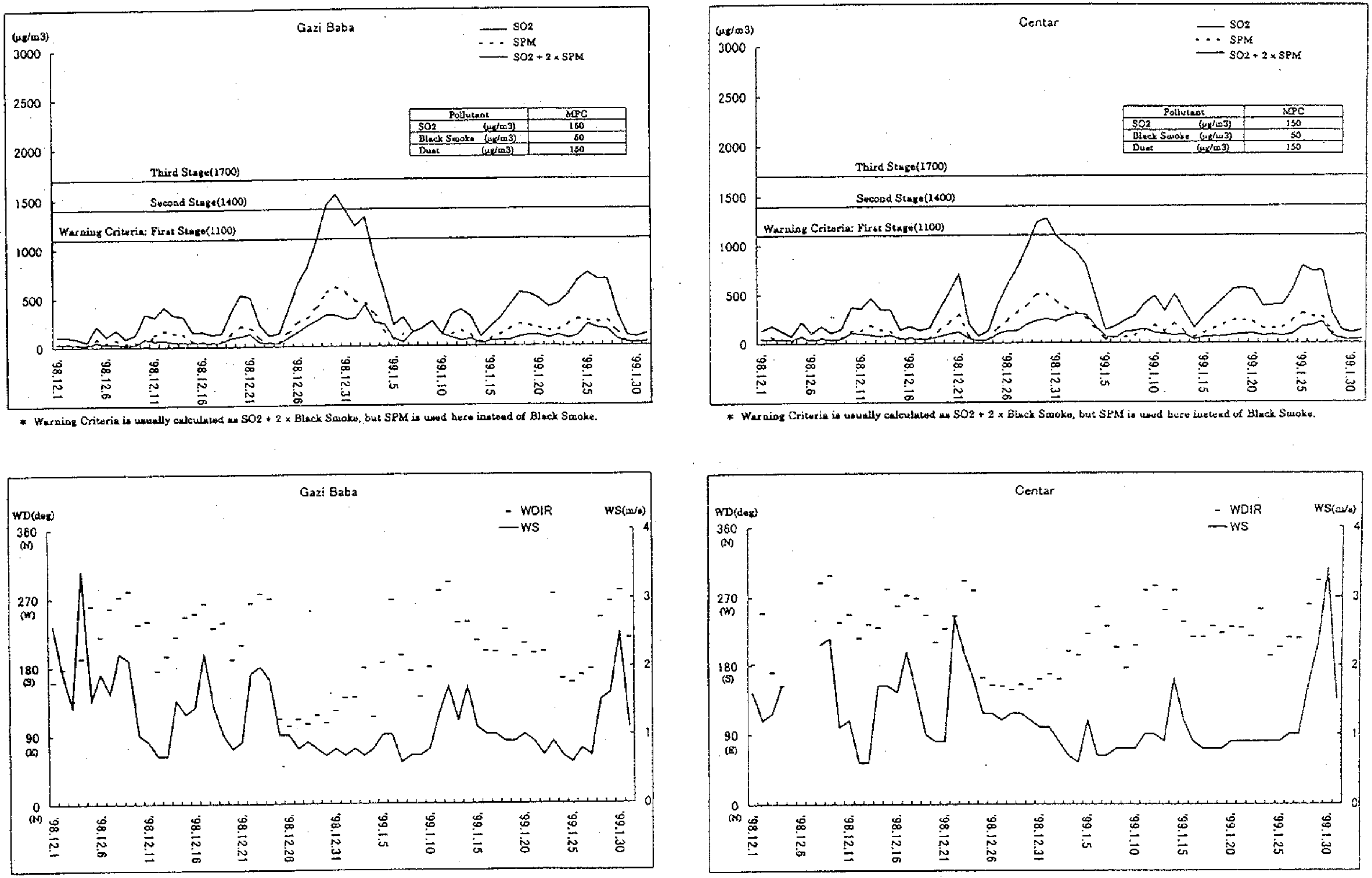


Figure 4.5 (1) Variation Diagram of Daily Average Values of SO2, SPM, and the Wind Direction and Speed
(December 1998 to January 1999)

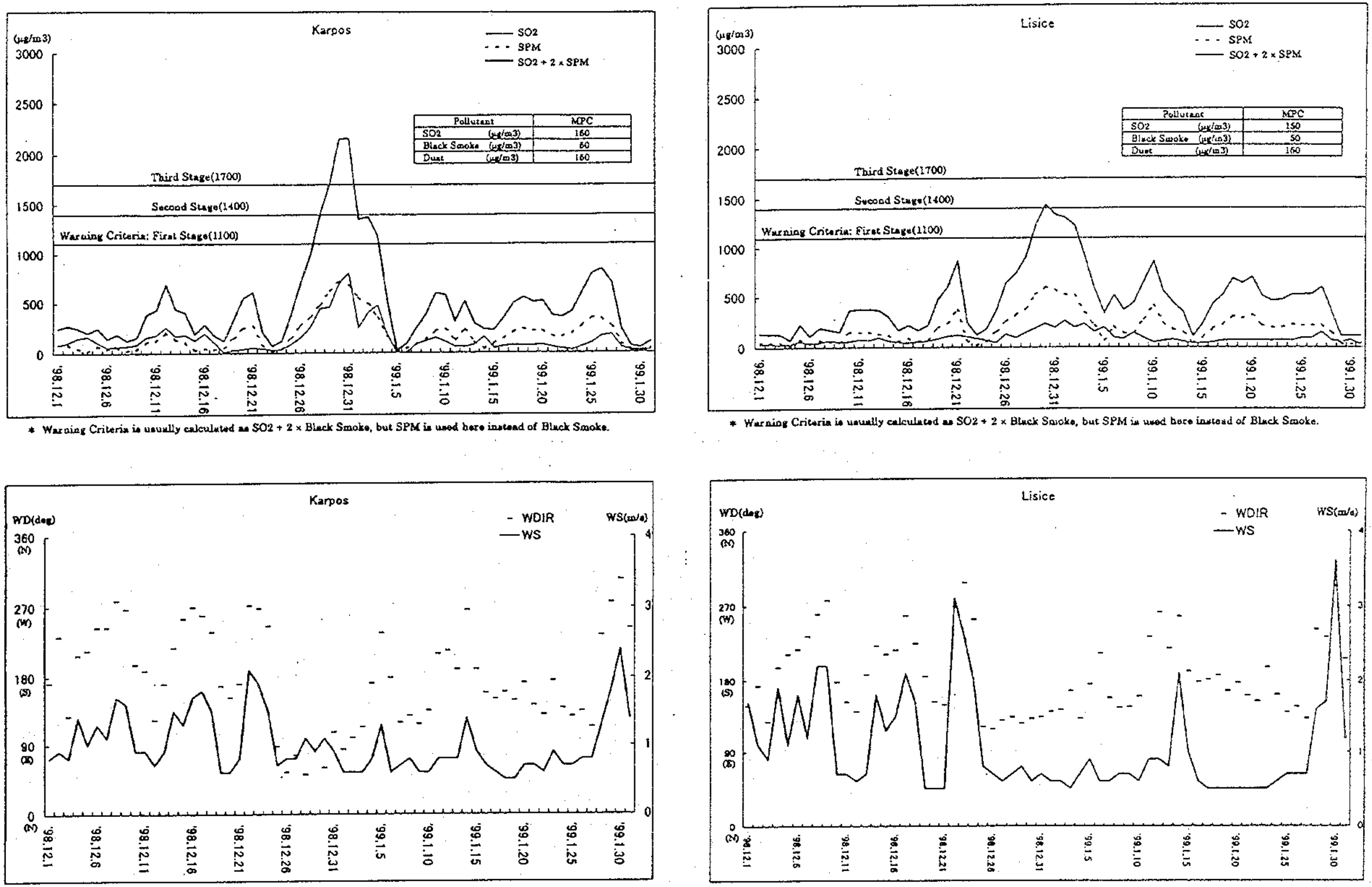


Figure 4.5 (2) Variation Diagram of Daily Average Values of SO2, SPM, and the Wind Direction and Speed (December 1998 to January 1999)

ii) Mechanism of Heavy Pollution Episode

The mechanism of heavy concentration occurrence is as follows.

- First, since around December 25, cold air retained in the basin because cold wave hit from the continent and continued, which formed topographical temperature inversion.
- At the same time, stagnant temperature inversion was formed through the day and the night because of covering by high atmospheric pressure and weak wind.
- Because fair weather continued at night until December 27, the ground was radiantly cooled, and this formed continuous grounding temperature inversion.
- Dense fog occurred on the ground because of the difference in temperature between upper and lower part. Because of dense fog around the ground, sunlight was obstructed while the temperature was raised by sunlight at the mountaintop. Thus, the difference of temperature between upper and lower part was caused.
- Since inversion layer was formed through the day and the night, air pollutant remained and accumulated in the basin among the valley, and it caused unusually heavy concentration.

3) Views for the Measures in Future

The data from AQM stations for about a year, suggest the air pollution problem in the country is focused on two points:

The first one is the occurrence of photochemical smog in summer. The second one is heavy concentrations of pollution combined with SO_2 and SPM in winter. The photochemical smog in summer results from the exhaust gas emitted from old automobiles without emission control, and air pollution in winter is caused by emission from factories, enterprises and heating facilities, and weather conditions.

There are various measures against air pollution, but the serious stagnation in winter should be prioritized.

In Japan, the core tasks for measures against pollution were to reduce SO_2 in industrial regions and to take measures against photochemical smog in urban areas.

To reduce SO_2, two ways were carried out; one is removing SO_2 emitted from the factories by using a desulfurizer and the other is changeover to the fuel with less sulfur content. Judging from its cost and the results, the latter is more effective. That is, some regions were specified first, where the fuel with less sulfur content was used in factories and enterprises. Since the measures obliged to use sulfur free fuel in the season when air pollution became serious, the concentration of SO_2 in the atmosphere decreased drastically. It can be supposed that such measures are the most effective for solving air pollution problem in winter.

To prevent photochemical smog and NOx in summer it is necessary to control emission gas from old automobiles.

As to CO, this depends on measures against exhaust gas emitted from automobiles (shift from old to new).

SPM is produced in the process of burning of coal, oil, and firewood and also by particles from the process of production, secondary produced particles and from running automobiles. As to the measure against SPM, applying electricity and gas to household heating is necessary, as well as the measures stated above.

4.1.3 Results of Stationary Emission Sources Survey

(1) Questionnaire and Visiting Survey

1) Condition of Emission Sources

For obtaining relevant data about the stationary emission sources in Skopje a questionnaire on stationary sources inventory of emission was sent through the MOE to 153 plants in Skopje, answers from almost all companies were obtained. Some of the factories were visited and some additional data were obtained.

On top of that, Figure 4.6 shows the Map of the Region. In this figure, the volumes of fuel consumption for each region (investigated results from the Study) are also shown. In particular, Gazi Baba shows a high volume of fuel consumption and Kisela Voda is next in line.

The main results are as follows:

- As for the boiler, there are many small-scale emission sources, except for the heating plant.
- Heavy oil is mainly used, while coal and firewood are hardly used.
- It seems that the operation rates, which varies among facilities, average 30 to 40 %.
- Most of stacks are as low as about 10 to 20m high. Moreover, an effect of down-draft is not taken into consideration.
- More effort should be made in order to complete emission inventory.

		Cair	Karpos	Center	Gazi Baba	Kisela Voda	Total
Heavy-Oil	Fuels used (in kg/h)	1,269	20,595	14,690	32,622	9,975	79,151
	SO2(kg/h)	35	566	405	900	275	2183
Diesel-Oil	Fuels used (in kg/h)	2,541	934	1,146	28,200	1,025	33,846
	SO2(kg/h)	36	13	16	395	14	474
Total (Fuels used)		3,810	21,529	15,836	60,822	11,000	112,997
Total (SO2)		71	581	421	1295	289	2,657.0

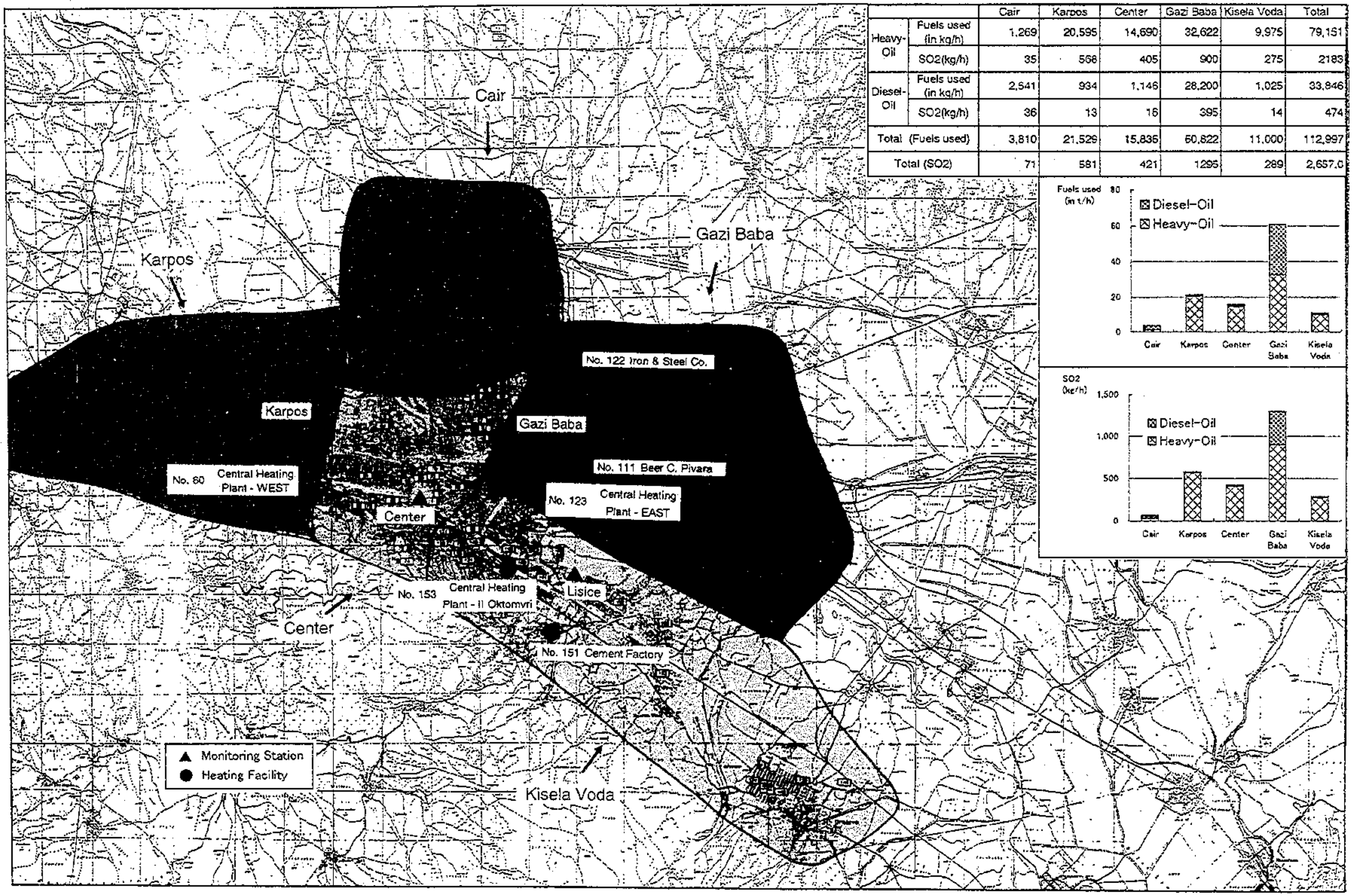


Figure 4.6 Type and Location of Major Stationary Emission Sources and its Emission Intensity by the District

2) Socio-economic Characteristics of Major Emitters

Recoverable socio-economic profile variables are grouped first by municipality and type of surveyed establishment. The data basically refer to the year 1997, in the absence of response to the Questionnaire. In the following Table 4.9, each site was counted separately, therefore the number of surveyed units is more than the number of the 153 establishments involved.

The above statistics reflect some overall characteristics and territorial distributions in the socio-economic conditions of the units surveyed. While eight of the 35 units reporting on rate of operation were bankrupt (23%), the 40% rate of operation for those working was a fairly consistent value throughout the industry section of the Table 4.10 and Figure 4.7. It largely corresponds to representative estimates of actual average industrial operation rates for Skopje in from 1997 to 1998.

Table 4.9 Characteristics of Major Emitters

Municipality: Skopje (Total)

Variable / Type of Unit	Educational	Other Services	Industry	Total
Operation Rate (Average %)**	n. r.	30	40	-
Number of Employees	1,738	5,144	25,732	32,614
Installation Power (MW)*	63.857	74.11	12,566	12,703.967
Kinds of Fuel (% of units)*	Oil (100%)	Oil (100%)	Oil (92%)	Oil (97%)***
Amount of Fuel (Oil) Used (kg/h)*	4,881	28,594	114,566	148,041
Number of Boilers*	157	77	308	542
Number of Stacks*	34	29	117	180
Volume of Emission Gas (Nm^3/h)*	35,943	35,485	2,048,058	2,119,486
Total Volume Flow (Nm^3/h)*	76,020	73,774	3,699,058	3,848,852
Total Number of Surveyed Units	67	41	62	170
Total Number of Responding Units	19	25	42	86
Survey Response Rate (%)	28	61	68	51

Note: * In the absence of response, these data are recovered from other sources of administrative registration.

** Average operation rate of the units responding to the particular survey question.

*** Percent of the units responding to the particular survey question.

Table 4.10 Area Distribution of the Amount of Fuel Oil Used (1997)

Municipality	Cair	Karpos	Center	Gazi Baba	Kisela Voda	Total
Rate (%)	2.6	14.5	11.3	64.3	7.3	100

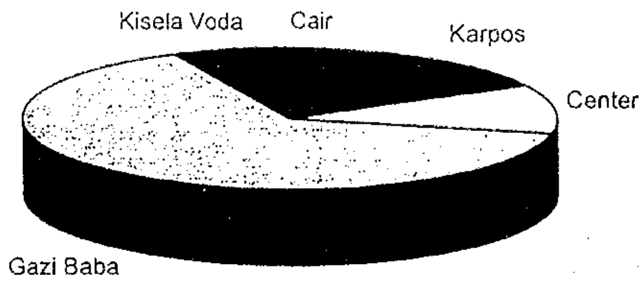


Figure 4.7 Area Distribution of the Amount of Fuel Oil Used (1997)

(2) Combustion Facility and Results of Exhaust Gas Measurements

1) Facilities Surveyed

Heating Facilities: Eight facilities
Facilities for Supporting Survey: Eleven facilities (At the supporting survey were measured in January 1999)
Combustion Facilities: Forty-eight facilities

2) General Comments on the Result from the Survey of Combustion Facilities and Exhaust gas Measurement

The results from the emission measurement of exhaust gases from heating plant facilities in Skopje are given in Table 4.11.
The results from those measurements, together with the results obtained from chemical analysis of metal content in dust samples are given in Data Book. In many cases the concentrations of measured parameters in exhaust gases are exceeded the standards(MPC). There are different sources for this increase of the concentration, but main reasons are:

- The quality of the imported oil is not always satisfactory. The content of sulfur in some cases is over 2 %.
- The combustion facilities are used for a long period (some of them are used more than 20 years). Because of that, in many cases the concentration of oxygen in exhaust gases is very higher (there are cases with more than 10 % O_2).
- Only a few plants have treatment system for exhaust gases and the others are emitted without treatment.

Sixty-seven facilities were measured for pollution sources. The main results are as follows:

- The combustion is extremely air excessive. There is not any idea that the O_2 concentration should be controlled for low NOx and energy conservation.
- Combustion condition is generally well, but there are some which make sparks and uneven combustion.
- At many facilities, the concentration of each component exceeds MPC and there are some cases where CO and dust are emitted, exceeding MPC extremely. There are also a number of cases whereby the concentration of SO_2 exceeds MPC by 2 to 3 times and for the case of NOx, the maximum value also about two times that of MPC.
- Looking at the data for the Beer company which had switch to natural gas for fuel consumption, the concentration levels of all the air pollutants are found to have decreased extremely and the emission of dust and SO_2 can be disregarded in this case.
- Looking at the emitted concentration (emitted volume) of SO_2 from the heating plant, observed during the stage of supporting survey, as compared to the previous stage of the Study when the concentration level was 2,540 to 2,580 mg/m^3, the concentration level decreased to 1,280 to 1,760 mg/m^3. This is due to the active efforts by the heating plant to use good quality heavy oil which is low in sulfur-content.
  In addition, in the case of mixed combustion using heavy oil and natural gas, the SO_2 concentration for natural gas usage decreased and at the same time, there were decreases in the concentration of NOx and CO as well.
- The survey result of questionnaires and visits, as well as that of measurements of stacks and the amount of emitted air pollutants based on regions with Skopje, are calculated. The results are shown in Figure 4.6.

[Recommendation]

In order to cut down on the emission of air pollutants, energy conservation by directly cutting down on the emission of SO_2 is also effective. However, the most effective method of all, is to switch to the use of natural gas. As stated in NEAP, energy conversion to natural gas in its early stage is desirable.

Table 4.11 Result of the Emission Measurement of Exhaust Gases from Heating Plant Factories in Skopje

No	Company	Type of fuel	Type of emitter	Stuck dia., m	Gas temp. °C	Gas velocity m/s	Gas flow, m^3N/h	Dust conc., mg/m^3	Dust emiss. kg/h	SO_2 ppm	SO_2 mg/m^3	NO ppm	NO mg/m^3	NO_2 ppm	NO_2 mg/m^3	NO_x ppm	NO_x mg/m^3	CO ppm	CO mg/m^3	CO_2 %	O_2 %
1	Central Heating Plant – East	Heavy oil	Boiler	2.1	205	-	328204	37.73	12.38	727	2581	210	349.3	16	40.7	226	390.0	202	313	10.6	6.5
2	Central Heating Plant - West	Heavy oil	Boiler 3	2..0 x1.0	216	-	84500	210.0	17.7	864	2571	227	316.3	15	32.0	242	348.3	103	134	13.0	3.7
			Boiler 1	2.0 x1.0	214	-	24333	63.8	1.55	794	2539	223	334.1	10	22.9	233	357.0	100	140	12.1	4.9
3	Techn. school – B. Petrusevski	Heavy oil	Boiler	0.61	211	-	1170	27.47	0.032	740	2574	109	177.6	8	19.9	117	197.5	95	145	11.3	6.2
4	Techn. school - M. Pupim	Light oil	Boiler	0.35	328.5	-	1639	15.5	0.025	250	1399	21	55.1	1	4.0	22	59.1	783	1915	6.7	11.8
5	Tech. school - Nikola Tesla	Coal	Boiler	1.05	65.8	-	5325	217.0	1.16	148	1646	22	114.6	1	8.0	22	122.6	962 0	46763	3.2	17.4
6	Residential heating -	Wood	Boiler	0.2	100.3	-	80	75.2		175	1192	8.5	26.1	2	9.8	10.5	35.9	169 4	5042	3.41	16.8
7	Residential heating	wood	Boiler	0.2	97.3	-	80	46.23		280	3337	17	94.9	2	17.1	19	112.0	159 3	8297	2.3	18.6
MPC** for liquid fuel								50 (150)**	0.5	1700 (<50 MW) 400 (>50MW)						350(<50 MW) 250 (>50MW)			170		
MPC for soild fuel								50	0.5	2000 (<50 MW)						500 (<50MW)			250		
MPC for wood								50 (150)**	0.5	500 1500						500 (<50MW)			250		

*For all waste gases from boilers using liquid fuel values in mg/m^3 are calculated on 3% O_2; for coal 7% O_2; for wood 11 % O_2

**MPC Maximal Permitted Concentration in mg/m^3 .For emission Max. Permitt. Mass Flow is given in kg/h (According to the Macedonian Regulation, Official Lett. 3, p. 37, Jan. 31, 1990)

** MPC of 150 mg/m^3 for dust emission is permitted only is special cases

4.1.4 Survey of Mobile Sources

(1) Traffic Volume and Speed

Mobile source survey was performed in two days: weekday and holiday for 24 hours at 75 points (five areas with 15 intersections/area). The location is shown in S/R (p.4-67), Figure 4.10.

In the survey, wide-scale examinations were carried out on the traffic volume of the whole of Skopje region. Through the survey, better understanding of the traffic conditions in Skopje was obtained.

According to the results of the survey, there are significant differences in the variation patterns of the hourly traffic volumes between that of normal weekday and holidays.

The traffic volume for weekdays shows an increase after 7:00 in the morning and this increase in traffic volume continues until midday, after which, it continues to decrease from midnight to sunrise. On the other hand, the traffic volume for holidays, was found to peak at around 0:00 p. m. and 11:00 p. m., reflecting a distribution pattern consisting of two peak times.

The reason for this could be due to the fact that during holidays, people mostly revolve around leisure and private activities as compared to economic activities on weekdays. Although the daytime traffic volume for weekdays is higher than that for weekends, the difference is not significant.

As for the traffic volume during peak hours, the number of vehicles along major roadways was calculated to be from 3,000 to 8,000 vehicles per hour. There were also cases whereby the number of vehicles at cross-junctions were found to exceed 100,000 vehicles. For example, at measuring point No. 46 the number of vehicles passed in 24 hours on weekday is about 110,000 and during holiday about 95,000. The number of buses (using diesel) at some points is very large (on some crossroads over 5000).

As for the types of vehicles along major roadways, passenger car is the largest in number, followed by bus, small and large truck. When comparing weekdays with holidays, it is observed that more buses are found on weekdays.

On some measuring points the speed of vehicles was found to be very high: more than the limit of 60 km/h.

(2) Air Quality Impact Analysis of Mobile Sources Along Major Roadways

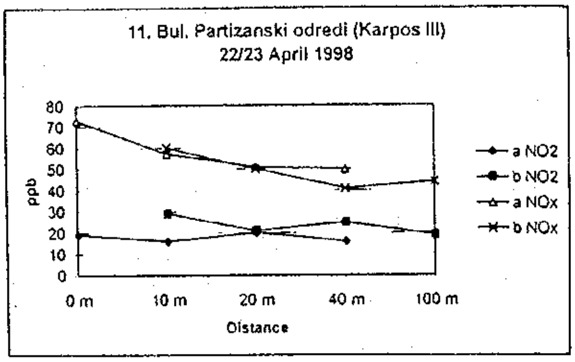
The distance attenuation of concentration of NOx (NO and NO_2) was surveyed by the simplified sampler and portable vane direction anemometer in order to understand the characteristics of NOx pollution by mobile emission along major roadways in Skopje.

Determination of the concentration of NO and NOx was performed by the simplified sampler at six measuring points.

The declining concentrations of NO_2 and NOx in accordance with the distance from edges and intersections on roads are shown in Figure 4.8.

The distribution of NOx shows high concentrations on almost all measuring points.

(Weekdays)



(Holidays)

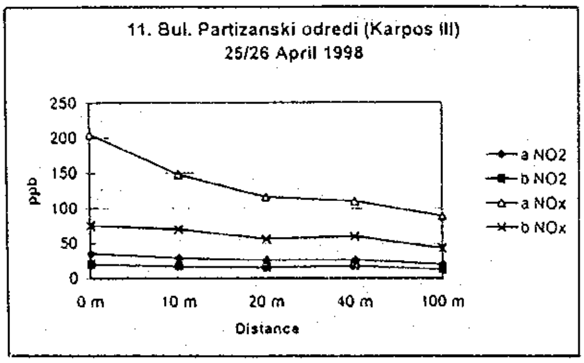


Figure 4.8 Attenuation of Concentrations of NO_2 and NOx by Distance

4.2 Evaluation of the AQM and Existing Data

4.2.1 Evaluation of the Data

Introduction of the AQM system as planned has enabled a real-time understanding of the fluctuation of the concentration over time, thereby assisting the Macedonian Counterpart to achieve its objectives. These objectives include the understanding of the current status of air pollution and implementation of the appropriate countermeasures, development of the monitoring system to serve for review of the counter-measures, as well as development and implementation of regulatory laws, and promotion of the appropriate environmental management aimed at entry in the EU market.

In order to acquire accurate data, the monitoring equipment needs to be incorporated in the traceability system. In addition, the steps involved in the measurement and operation must be minimized to eliminate possible causes of errors. The monitoring system must be maintained thoroughly as a whole, including the screening of measured data.

Evaluation of the data obtained with the AQM system is as follows:

- The monitoring equipment for gaseous materials (SO_2, etc.) is calibrated automatically every day using a standard gas, thereby guaranteeing a degree of traceability basically equivalent to that in Europe and the USA; and
- The SPM meter directly measures the weight of the SPM of 10 μm or less sampled on a filter paper as changes in the frequency, minimizing the intervening error factors.

In this way, the data obtained with the AQM system can be considered as highly reliable if the system is maintained properly. On the other hand, the existing sampler has the following demerits:

- The SO_2 concentration is determined by means of a manual analysis with the prepared standard solution. Many steps are necessary until the data is obtained, resulting in the possibility of hardware and human errors.
- In the case of black smoke, dust collected on the filter paper is measured in the form of scattered light. Consequently, the data obtained refers to the relative concentration, that is to say, the mass is not measured directly. Moreover, the black smoke uses dust as a target and is basically different from the SPM meter. Proper attention must be given to these facts during the evaluation of the data.

The monitoring system with the existing samplers may offer the highly accurate data if proper attention is given to error factors.

The essential points, from a different viewpoint, are summarized below:

a) The comparison with the concentration level at other locations
b) The comparison of fluctuation of the concentration among different components
c) The study of the relationship between the concentration and the meteorological conditions
d) A cross check among monitoring equipment and different monitoring methods
e) Study of the error factors when the data is considered to be incorrect

Concerning a) through c), the central station can conduct the check with ease. It is necessary to screen of the data to exclude any abnormal values.

The past and future data of existing samplers can be used for analysis examining thoroughly the results of various cross-check obtained from this Study.

4.2.2 Method of Data Processing and its Reporting

Automatic continuous monitoring has become possible in Skopje. In order to announce data publicly, validation and evaluation of the monitoring data before hand are necessary.

(1) Validation of the Monitoring Data

To obtain a high credibility of measured value, smooth operation of both measuring system and telemeter system is essential. It is also important to maintain the performance of measuring equipment by careful maintenance system that involves both some cost and labor works. However, even with enough maintenance and control, the occurrence of transmission error due to abnormal noise at recording is still unavoidable. Thus the assurance check of measured value is also necessitated to maintain a high level of credibility.

1) Contents of Definition Work

The data collected in monitoring center is not only applicable as hourly or daily data but also needs to be statistically processed required for each. It is summed up as monthly or yearly data after checking and correcting the abnormal values. It is desirable that the measured values of the year concerned should be published as "National Air Pollution Report (tentative name)" after having been published by each municipality.

a) Daily Confirmation of Measured Value

Daily confirmation is the most basic work, not only making tables using measured data collected by on-line system as hourly data but also verifying the normality of monitoring data collected by processing such as comparing them with reference data set up in each measuring item in advance.

b) Confirmation of Measured Values

Confirmation of measured values is a work to check the validity of measured values by comparing collected values with various information such as reports on maintenance and control execution.

c) Data Screening

Data screening is a work to detect abnormal values, judging from measured values accumulated in the past. The criteria data should be decided after having appreciated fully the distribution of calculation value properties such as hourly value, daily mean value and monthly mean value as well as their relations with various statistics, using the past data as base data. Methods of data screening are shown below.

i) Method of Using Defined Data Obtained by the Station Concerned in the Past

ii) Method of Using Change Volume of Measured Values

It is a method of using periodic change property of measured values, and the changing quantity usually seems to be periodical, related to month or season.

iii) Method of Using Other Items in the Same Station or Same Items of the Adjacent Station

As many patterns of the time change among measured items or adjacent stations have a fixed tendency, screening can be done by setting up the judgment value based on it.

2) Judging and Processing of Abnormal Values

It is necessary to retrieve abnormal values and correct extracted values to accurate ones for keeping the reliability of measured values to be a fixed standard. It is called an abnormal value processing. Basically, an effort should be made to collect measured value as much as possible.

As for the values extracted as abnormal one, they are needed to be searched their causes. It is required to set up unified judging criteria to loose or modify those measured values in each cause so that they may be executed the processing of no correcting, correcting or missing.

The examples of judging and processing of abnormal values are described as follows.

a) Abnormality of Measuring Equipment

When the failure of the equipment is evident, all the measured values are considered to be unknown. However, those values would be modified as the measured data in such cases; sensitivity change is recognized in correcting, zero drift is recognized, abnormality is found in calculation device and modification available in principle, etc..

b) Abnormality of Telemeter System

c) Abnormality by External Causes

The measured values that had been directly influenced by local occurrence sources such as bonfires, burning trashes, parking cars or fire accidents are considered to be valid in principle. However, they may become "unknown values" if the cause is only a temporary one which is regarded as a very limited local pollution.

d) Others

When unnatural measured values appear and its cause is unclear, they are regarded as effective values in principle. However, a note should be put with each unnatural value.

(2) Reporting

1) Outline of the Software for Data Processing

The telemeter system installed in Skopje and the data processing software are outlined below.

a) Data Acquisition Software of the Central Station

The data acquisition software of the central station consists mainly of two software modules as follows:

- Communication of information with each monitoring station for the purpose of recording the data as a database
- Various data processing according to the purpose

b) Data Logger of the AQM Station

The data logger of AQM station records and stores data as the database for each station while transmitting the hour-value data to the data acquisition software of the central station each time communication is made with the central station.

c) Software of the Public Information System

Data indication of street displays for each station can be varied freely as required by the user to indicate the current concentration and its fluctuation by means of various figures, etc..

2) Preparation of Reporting

Atmospheric quality and meteorological data obtained from the AQM station by this study is recorded by the data acquisition software of the central station for processing and subsequent preparation of the report in the form of various tables and figures. These reports are prepared daily, weekly, monthly and yearly, and in arbitrary intervals (every season, etc.). The major content of the report is as follows:

- Statistical processing report; average, maximum, minimum, 50%, 98%, and 99.9% value
- Table of frequency of appearance by wind direction and by wind speed class
- Chart of the hourly, daily and monthly averages of fluctuation (comparison between locations and items, etc.)
- Wind rose
- Bar chart representation of data, etc.