

Chapter 5

6-11-10

Chapter 5 Prediction of Air Quality by Air Quality Simulation Model

5.1 Outline of the Air Quality Models

5.1.1 Objective

The Study area for this project is the entire country of Macedonia. However, for the modeling effort, the simulation modeling has been limited to one city. The city selected for the simulation modeling is Skopje with some 60-70 major and mid-size point sources which contribute to the air pollution problem.

Air simulation modeling provides a rational (scientifically-based) method for estimating source contributions, which can then be used to determine the effectiveness of emission reduction alternatives in meeting Macedonian ambient air quality objectives. The method can also be applied numerous times to answer "what if" question for future year emission changes. In the Study the objectives were to develop an example modeling approach and methodology which could be used by Macedonian counterparts;

- as a basis upon which further refinements to modeling could be developed,
- to examine control strategy effectiveness in meeting air quality objectives,
- to develop similar approaches for other cities within Macedonia.

To meet these objectives, air quality modeling study was performed for Skopje, for a base year (1998), one future-year (2008) without additional control measures, and one future-year (2008) with implementation of control measures.

5.1.2 Modeling Approach

Two general classes of air quality models were used in the Study. An air quality dispersion model which simulates the dispersion of air pollutants once they are released into the environment by simulating all of the physical process which take place in the atmosphere (dispersion, transport, deposition, chemical transformation). By simulating these physical processes for all sources of pollutants the model can detail emission source contributions. However, the model is dependent upon reliable measures of emissions and meteorology. Emission estimates are usually reasonably known for CO, SO₂ and NO₂, but are often poorly known for SPM. To strengthen the conclusions regarding SPM source contribution from the dispersion model a receptor

model is used to confirm/support the conclusion. A receptor model examines ambient measurement of SPM for their chemical constituents and compares observed chemical composition to those of emission source profiles to establish source contribution. To successfully apply the method with a high degree of confidence requires many ambient measurement samples and their subsequent chemical analysis and emission source profile information.

(1) Dispersion Modeling Approach

1) Long-term Modeling

To simulate the annual average concentration for the pollutants of; sulfur dioxide (SO₂), suspended particulate matter (SPM), carbon monoxide (CO) and nitrogen dioxide (NO₂). Four candidate air quality dispersion models were considered for this Study. These were ISC3, AERMOD, SHORTZ and CALPUFF. The Industrial Source Complex 3 (ISC3) is the current USEPA recommended guideline model for modeling complex industrial source settings and has undergone extensive model evaluation. It is capable of modeling areas of up to 50 km between source and receptor. In addition, the model has been optimized for running in long-term mode. Hence, the ISC3-LT (long-term version) was selected for the annual average modeling (Ref. 5-1).

a) The ISC Long-term Dispersion Model Equations

The ISC Long-term Model uses input meteorological data that have been summarized into joint frequencies of occurrence for particular wind speed classes, wind direction sectors, and stability categories. These summaries, called STAR summaries for STability ARray, may include frequency distributions over a monthly, seasonal or annual basis. The long-term model has the option of calculating concentration or dry deposition values for each separate STAR summary input and/or for the combined period covered by all available STAR summaries. Since the wind direction input is the frequency of occurrence over a sector, with no information on the distribution of winds within the sector, the ISC Long-term Model uses a Gaussian sector-average plume equation as the basis for modeling pollutant emissions on a long-term basis.

i) Point Source Emissions

<The Gaussian Sector Average Equation>

In the long-term model, the area surrounding a continuous source of pollutants is divided into sectors of equal angular width corresponding to the sectors of the

seasonal and annual frequency distributions of wind direction, wind speed, and stability. Seasonal or annual emissions from the source are partitioned among the sectors according to the frequencies of wind blowing toward the sectors. The concentration fields calculated for each source are translated to a common coordinate system and summed to obtain the total due to all sources.

For a single stack, the mean seasonal concentration is given by:

$$\chi_1 = \frac{K}{\sqrt{2\pi} R \Delta\theta'} \sum_{i,j,k} \frac{QfSVD}{u_s \sigma_z} \quad (1-1)$$

where,

- K: units scaling coefficient to convert calculated concentrations to desired units (default value of 1×10^6 for Q in g/s and concentration in $\mu\text{g}/\text{m}^3$)
- Q: pollutant emission rate (mass per unit time), for the i^{th} wind speed category, the k^{th} stability category and the l^{th} season
- f: frequency of occurrence of the i^{th} wind speed category, the j^{th} wind direction category and the k^{th} stability category for the l^{th} season
- θ' : the sector width in radians
- R: radial distance from lateral virtual point source (building downwash) to the receptor = $[(x+x_y)^2 + y^2]^{1/2}$ (m)
- x: downwind distance from source center to receptor, measured along the plume axis (m)
- y: lateral distance from the plume axis to the receptor (m)
- x_y : lateral virtual distance, equals zero for point sources without building downwash, and for downwash sources that do not experience lateral dispersion enhancement (m)
- S: a smoothing function similar to that of the Air Quality Dispersion Model (AQDM)
- u_s : mean wind speed (m/sec) at stack height for the i^{th} wind speed category and k^{th} stability category
- σ_z : standard deviation of the vertical concentration distribution (m) for the k^{th} stability category
- V: the Vertical Term for the i^{th} wind speed category, k^{th} stability category and l^{th} season

D: the Decay Term for the i^{th} wind speed category and k^{th} stability category

The mean annual concentration at the point is calculated from the seasonal concentrations using the expression:

$$\chi_a = 0.25 \sum_{i=1}^4 \chi_i \quad (1-2)$$

ii) Non-point Source Emissions

The ISC Long-term Area Source Model is based on the numerical integration algorithm for modeling area sources used by the ISC Short-term Model for each combination of wind speed class, stability category and wind direction sector in the STAR meteorological frequency summary, the ISC Long-term Model calculates a sector average concentration by integrating the results from the ISC Short-term Model area source algorithm across the sector. A trapezoidal integration is used, as follows:

$$\bar{\chi}_i = \frac{\int f(\theta) \chi(\theta) d\theta}{S} = \frac{1}{N} \left[\sum_{j=1}^{N-1} f_{ij} \chi(\theta_{ij}) + \frac{(f_{i1} \chi(\theta_{i1}) + f_{iN} \chi(\theta_{iN}))}{2} \right] + \varepsilon(\theta) \quad (1-3)$$

$$\varepsilon(\theta) = \frac{\bar{\chi}_{\text{NEW}} - \bar{\chi}_{\text{OLD}}}{\bar{\chi}_{\text{mid}}} ; \quad \bar{\chi}_{\text{mid}} = \frac{\bar{\chi}_{\text{NEW}} + \bar{\chi}_{\text{OLD}}}{2} \quad (1-4)$$

where,

$\bar{\chi}_i$: the sector average concentration value for the i^{th} sector

S: the sector width

f_{ij} : the frequency of occurrence for the j^{th} wind direction in the i^{th} sector

$\varepsilon(\theta)$: the error term - a criterion of $\varepsilon(\theta) < 2$ percent is used to check for convergence of the sector average calculation

$\chi(\theta_{ij})$: the concentration value, based on the numerical integration algorithm for the j^{th} wind direction in the i^{th} sector

θ_{ij} : the j^{th} wind direction in the i^{th} sector, $j = 1$ and N correspond to the two boundaries of the sector

2) Short-term Modeling

Another goal for the modeling was to simulate hourly SO₂ concentrations for a typical SO₂ episode of 3-4 day duration. Two candidate models were considered for this effort; the Urban Airshed Model (UAM) and CALPUFF modeling systems.

The CALPUFF model was selected as the preferred modeling approach for this location (Ref. 5-2).

a) The CULPUFF Model Equation

CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, subgrid scale terrain interactions as well as longer range effects such as pollutant removal (wet scavenging and dry deposition), chemical transformation, vertical wind shear, overwater transport and coastal interaction effects. It can accommodate arbitrarily-varying point source and gridded area source emissions.

The basic equation for the contribution of a puff at a receptor is:

$$C = \frac{Q}{2\pi\sigma_x\sigma_y} g \exp\left[-d_a^2 / (2\sigma_x^2)\right] \exp\left[-d_c^2 / (2\sigma_y^2)\right] \quad (2-1)$$

$$g = \frac{2}{(2\pi)^{1/2}\sigma_z} \sum_{n=-\infty}^{\infty} \exp\left[-(H_e + 2nh)^2 / (2\sigma_z^2)\right] \quad (2-2)$$

where,

- C: the ground-level concentration (g/m³)
- Q: the pollutant mass (g) in the puff
- σ_x : the standard deviation (m) of the Gaussian distribution in the along-wind direction
- σ_y : the standard deviation (m) of the Gaussian distribution in the cross-wind direction
- σ_z : the standard deviation (m) of the Gaussian distribution in the vertical direction
- d_a : the distance (m) from the puff center to the receptor in the along-wind direction

- dc: the distance (m) from the puff center to the receptor in the cross-wind direction
- g: the vertical term (m) of the Gaussian equation
- He: the effective height (m) above the ground of the puff center
- h: the mixed-layer height (m)

The summation in the vertical term, g, accounts for multiple reflections off the mixing lid and the ground. It reduces to the uniformly mixed limit of $1/h$ for $\sigma_z > 1.6 h$. In general, puffs within the convective boundary layer meet this criterion within a few hours after release.

For a horizontally symmetric puff, with $\sigma_x = \sigma_y$, Eqn. (2-1) reduces to:

$$C(s) = \frac{Q(s)}{2\pi\sigma_y^2(s)} g(s) \exp\left[-R^2(s) / (2\sigma_y^2(s))\right] \quad (2-3)$$

where,

- R: the distance (m) from the center of the puff to the receptor
- s: the distance (m) traveled by the puff

The distance dependence of the variables in Eqn. (2-3) is indicated (e.g., $C(s)$, $\sigma_y(s)$, etc.). Integrating Eqn. (2-3) over the distance of puff travel, ds, during the sampling step, dt, yields the time averaged concentration, \bar{C} .

$$\bar{C} = \frac{1}{ds} \int_{s_0}^{s_0+ds} \frac{Q(s)}{2\pi\sigma_y^2(s)} g(s) \exp\left[-R^2(s) / 2\sigma_y^2(s)\right] ds \quad (2-4)$$

where,

- s_0 : the value of s at the beginning of the sampling step

The major feature and options of the CALPUFF model are summarized in Table 5.1 in Supporting Report (S/R), pp.5-9 to 5-10, and summary of input data used by CALPUFF are shown in Table 5.2 in S/R, p.5-11.

b) Related Models

The CALMET meteorological model consists of a diagnostic wind field module and micrometeorological modules for overwater and overland boundary layers. When using large domains, the user has the option to adjust input winds to a Lambert Conformal Projection coordinate system to account for Earth's curvature. The diagnostic wind field module uses a two step approach to the computation of the wind fields (Douglas and Kessler, 1988). In the first step, an initial-guess wind field is adjusted for kinematic effects of terrain, slope flows, and terrain blocking effects to produce a Step one wind field. The second step consists of an objective analysis procedure to introduce observational data into the Step one wind field to produce a final wind field. An option is provided to allow gridded prognostic wind fields to be used by CALMET, which may better represent regional flows and certain aspects of sea breeze circulations and slope/valley circulations. Wind fields generated by the CSUMM prognostic wind field module can be input to CALMET as either the initial guess field or the Step one wind field (Ref. 5-3).

The major features and options of the meteorological model are summarized in Table 5.3 in S/R p.5-13.

(2) Receptor Modeling

Receptor models are generally contrasted with dispersion models which use estimates of pollutant emissions rates, meteorological transport, and chemical transformation mechanisms to estimate the contribution of each source to receptor concentrations. The two types of models are complementary, with each type having strengths which compensate for the weaknesses of the other. Receptor models use the chemical and physical characteristics of gases and particles measured at source and receptor to both identify the presence of and to quantify source contributions to receptor concentrations.

The modeling techniques include relatively simple techniques such as the use of "tracers of opportunity" such as lead (Pb), an indicator of mobile source contributions, and fluoride (F), an indicator of aluminum smelting. More complex multivariate statistical such as factor analysis and principal component analysis can be applied for relatively large and detailed databases (e.g., 50 or more samples with several dozen chemical parameters) with quite limited knowledge of emission source characteristics. The most robust methods are based on the use of multivariate statistical methods that attempt to "fit" known emission source profiles to observed SPM composition.

The most widely used of these is the Chemical Mass Balance model (CMB). Because of the limited number of samples and chemical constituents collected during 1998 and the limited number of source profiles only the CMB approach with observed concentrations and standard source profiles (e.g., those used or developed in previous receptor modeling studies) is used in the Study (Ref. 5-4).

The information required by and produced by the CMB model is shown in Figure 5.1 in S/R p.5-15.

The CMB consists of the following set of equations:

$$C_i = F_{i1}S_1 + F_{i2}S_2 + \dots + F_{ij}S_j + \dots + F_{iJ}S_J \quad i=1..I, j=1..J$$

where,

C_i : Concentration of species i measured at a receptor site

F_{ij} : Fraction of species i in emissions from source j

S_j : Estimate of the contribution of source j

I : Number of chemical species

J : Number of source types

5.1.3 Modeling Domain for Dispersion Models

The modeling domain is superimposed on a map of Macedonia as shown in Figure 5.1. The domain is a rectangular grid 60 km in the east-west direction and 40 km in the north-south direction. The four corners of the modeling domain are specified in the Gauss-Krieger coordinate system.

The modeling domain of 2400 km² covers all of Greater Skopje and also includes a small area of Serbia just to the northwest of Skopje.

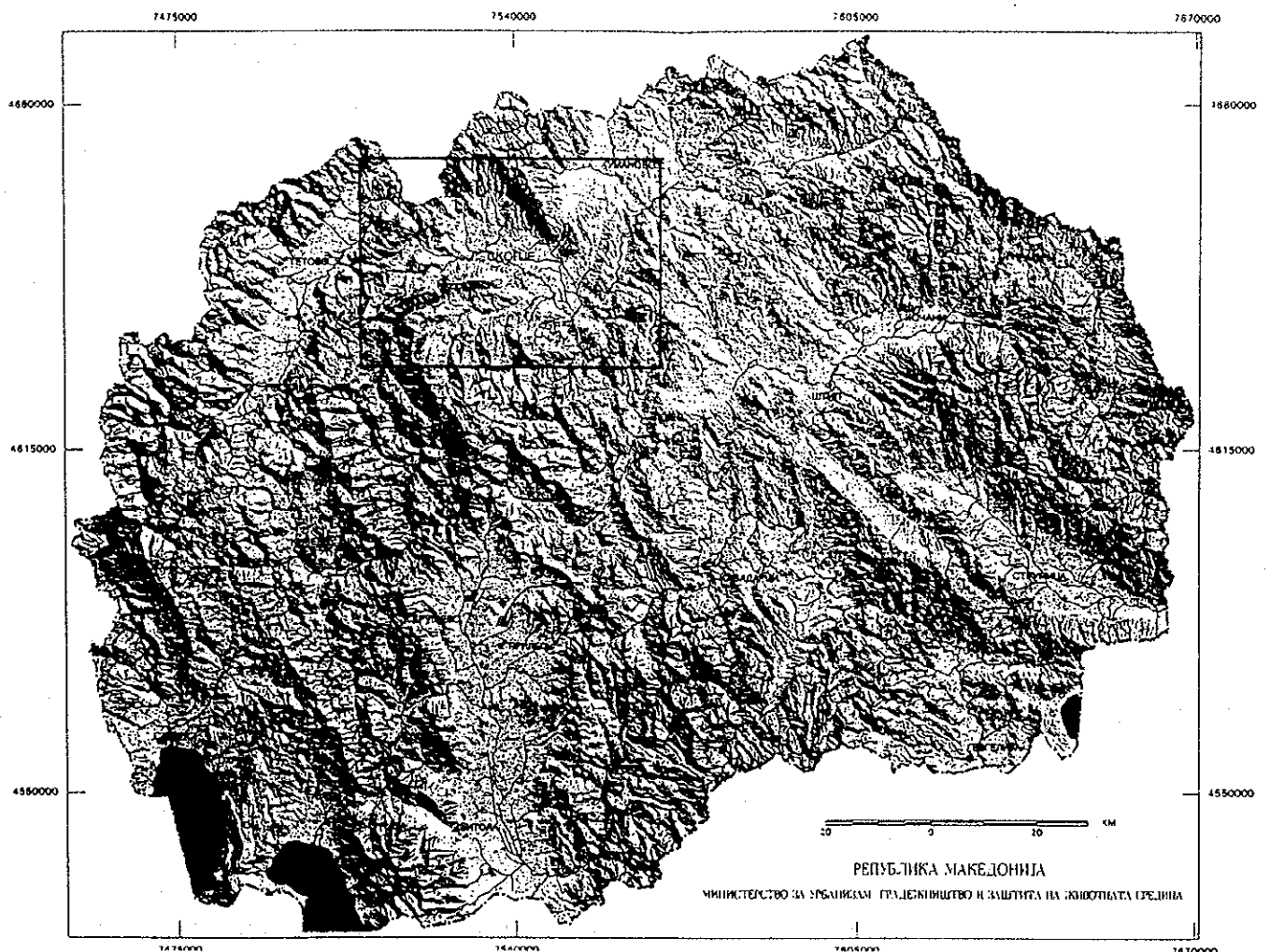


Figure 5.1 Location of the Modeling Domain for Skopje, Macedonia
(Gauss-Krieger Coordinate System) 60 km x 40 km

5.2 Long-term Dispersion Model (ISC3LT)

5.2.1 Modeling Inputs

(1) Input Data

US-EPA ISC3LT (version 96113) was run in long-term mode (to determine annual average). The model was run with four seasonal modes to account for variations in seasonal temperatures and mixing heights. Emission source strength changes were model for two seasons (October 1 to March 31 - heating season) and (April 1 to September 30 - non-heating season) to reflect the strong seasonal change in emissions

from the heating plants.

To perform long-term dispersion modeling, a complete year of hourly meteorological data is needed in order to prepare a joint frequency distribution of wind speed and direction by stability class. The complete meteorological data set includes measurements of hourly stability classification, vertical temperature gradient, wind speed and direction. The most complete data available for the Study was for calendar year 1996. To determine daytime atmospheric stability, solar insolation data is needed in conjunction with wind speed to determine stability.

1) Stability Classification

The MHK Zletovo Metallurgical and Chemical Company collect the most complete data set of hourly solar radiation in Veles. To determine if the Veles site could reasonably be used in place of data from Skopje an assessment was performed. Correlation between the Veles solar radiation data and the limited solar radiation data collected by the RHI show relatively good correlation (see Figure 5.3 in S/R, p.5-18).

In addition, no hourly solar radiation data was available from Veles after October 15. Because of the low solar elevation angle during this time daytime hours were assumed to be weakly unstable (stability class C), however wind speed adjustments to stability was included. Because no measure of vertical temperature gradient is available and hourly nighttime cloud cover data is only partially available cloud cover was conservatively assumed clear at night. This somewhat biases nighttime hours to slightly greater frequency of E (moderate stability) and F (strong stability) stability's, however wind speed adjustments to stability is included.

2) Wind Data

Hourly wind speed and direction from the 10 m above ground level the RHI anemometer from 1996 was used to prepare climatological average wind flow patterns. Plots of annual wind rose (the annual average prevailing wind direction as northwest to west in approximate orientation to the River Vardar and along the axis of the Skopje Valley) and two seasonal wind roses are shown in Figures D5.1 to D5.3 in Data Book. The prevailing wind directions during the October to March heating season (Figure D5.2) and non-heating season (Figure D5.3) are similar except that during the heating season calm conditions (wind speed < 1 m/s) occur almost twice as frequently.

3) Joint Frequency Distribution

A joint frequency distribution was prepared using the one year of complete meteorological data from 1996 using hourly wind data from the RHI and associated stability class. Four sets of joint frequency distributions were prepared, one for each season.

4) Temperatures

Seasonal average temperatures for each stability class were used as input to the model. Values used are based on the ten-year record (1987-1996) from the RHI. Values are shown in Table 5.1.

Table 5.1 Seasonal Temperatures by Stability Class for ISC3LT

Season	(Unit: °C)					
	Stability Class					
	A	B	C	D	E	F
Winter (Jan-Mar)	8.6	8.6	8.6	3.9	-0.5	-0.5
Spring (Apr-Jun)	23.3	23.3	23.3	17.0	10.5	10.5
Summer (Jul-Sept)	29.8	29.8	29.8	22.6	15.6	15.6
Fall (Oct-Dec)	11.8	11.8	11.8	7.2	3.3	3.3

5) Mixing Heights

The upper-air sounding data for Skopje is only made once per day at 01:00 a.m. local standard time. The ISC3LT model needs at a minimum specification of the afternoon mixing height (near the time of maximum mixing height) and the morning mixing height (near the time of the minimum mixing height). No historical data are available for these measurements in Skopje and the nearest upper-air site is more than 500 km away and not representative of Skopje. Therefore, a site in the United States with similar meteorological and topographical setting was identified as a surrogate for Skopje. Based on a review of local climatology the city identified with the most similarities in climate and topographical setting was Boise, Idaho (Ref. 5-5). Seasonal mixing heights are shown in Table 5.2.

Table 5.2 Mean Mixing Heights by Season for Boise, Idaho and Used as Surrogate Mixing Heights for Skopje, Macedonia (Holzworth, 1972)

Season Time	Winter (m)	Spring (m)	Summer (m)	Fall (m)
Morning	407	424	193	279
Afternoon	754	2329	2540	1409

6) Terrain Inputs

The ISCLT model does not need gridded terrain inputs when the dry deposition option is not used. Relative release heights above local terrain height are specified on input for each emission source location.

7) Emission Inputs

All sources are modeled as point or area sources. Emission rates are modeled using annual average emission rate estimate for 1996. Seasonal adjustments are made for the heating plants facilities. Annual average emission rates for major and medium size stationary sources were developed based on survey response answers from the Questionnaire on Stationary Source Emission Inventory as distributed by the Ministry of Environment (MOE). Emissions were adjusted for operating schedules as specified in the inventory. These ranged from 8-hour operations to 24-hour operating periods. Table 5.3 identifies the number of stacks modeled as point sources and the total annual average emission rates for chemical specie.

Table 5.3 Annual Average Emission Rates for Major and Medium Size Stationary Point Sources Used in the ISC3LT Modeling

Pollutant	Number of Point Sources Modeled	Annual Average Emission Rate (g/s)
SO ₂	68	625
NO ₂	71	173
SPM	68	17.4
CO	68	226

Other emission source types such as residential heating, mobile sources, small combustion sources (<200 kg/h fuel combustion rate) and construction activity were modeled as area sources. Data for school heating and administrative buildings were explicitly modeled based on reported source size and location. Other area emission

sources were unavailable at the present time and emission rates were estimated based on per capita emission factors from emission inventories for countries near Macedonia, supplemented by US emission ratios (as European data did not have SPM emissions). The information used to estimate these emissions was the CORINAIR94 emission inventory from Greece, Croatia, Austria and Italy and CORINAIR90 emissions for the same four countries plus Slovenia and Bulgaria. These area source pollutants were assumed to be 75% emitted during the daytime and 25% at night.

Table 5.4 shows the annual average emission density for each area source air pollutant as modeled. Table 5.5 shows the total annual average emissions for each pollutant by major source categories. Mobile source fraction is from the Macedonia National Environmental Action Plan (Ref. 2-5).

Table 5.4 Annual Average Emission Density for Area Sources in Skopje, Macedonia as Used in the ISC3LT Modeling

Pollutant	Emission Density (gm/s-km ²)
SO ₂	6.84
NO ₂	5.13
CO	20.5
SPM	10.3

Table 5.5 Annual Average Emissions and Distribution by Major Source Categories for Four Air Pollution in Skopje, Macedonia

Source Type	SO ₂ t/yr (%)	NO ₂ t/yr (%)	CO t/yr (%)	SPM t/yr (%)
Heating Plants	5,840 (22.5)	1,460 (14.3)	548 (2.1)	182 (1.8)
Combustion Sources	13,870 (53.5)	4,015 (39.3)	6,570 (25.2)	365 (3.7)
Mobile Sources	88.6 (0.4)	2,600 (25.5)	16,400 (62.8)	410* (4.1)
Area Sources	6,116 (23.6)	2,130 (20.9)	2,580 (9.9)	9,080 (90.4)
Total	25,915 (100)	10,205 (100)	26,098 (100)	10,037 (100)

8) Other Modeling Options

<No wet or dry deposition>

- Use urban dispersion curves – Skopje is a city with many tall structures which act to enhance atmospheric dispersion

- Use final plume rise, stack-tip downwash, buoyancy-induced dispersion
- Use default wind speed profile exponents; and
- Use urban vertical potential temperature gradients
- No building downwash
- Decay-half life (4-hours for SO₂)

(2) Receptor Placement

Receptors were placed in a uniform Cartesian gridded array covering the entire modeling domain at 1,000 m horizontal resolution. Discrete receptors were placed at the nine RHI and seven IPH existing measurement points.

5.2.2 Output Results and Model Verification

(1) Air Quality Data for Model Verification - Present Air Quality

1) Model Verification

Modeling results are compared with the annual average monitored results for SO₂ and SPM using data converted from Black Smoke (BS) to SPM for the 1996. Comparisons between modeled and observed are shown for each measurement point for SO₂ and SPM in Tables D5.1 and D5.2 in Data Book. The difference between the values predicted and observed is examined from the survey results. According to the results from questionnaire and visiting research, the average operation rate of factories is presently 30 to 40% of the maximum working. Emissions with maximum working were used for modeling input, therefore the overestimation of SO₂ emissions was found to be clear. Moreover, according to the results from comparison of measurement values for SPM and BS, which is obtained in the Study, it was proved that the values of BS showed only about a half of that of SPM. Therefore, it is understandable that the values predicted and observed will approximate much more with consideration on the facts above.

Figures 5.2 to 5.5 show the spatial distribution within the modeling domain of annual average SO₂, SPM, NO₂ and CO.

a) SO₂ Dispersion

For SO₂ the concentration pattern is consistent with patterns developed from monitored data (Republic of Macedonia, 1996) with the exception of the two highest concentrations; i) the highest simulated concentration located near Zelezara,

Valavnica which is dominated by emissions from the Clinic Center at Vodnjanska 17 and, ii) the second highest simulated concentration located near n. Lisice ul. Mihail Glinka 4, prof. Durnev which is dominated by emissions from OHIS Prvomajska bb (chemical plant). Further investigation is needed to verify the plants stack parameters and actual annual average operating emissions.

b) SPM Dispersion

For SPM the concentration pattern is very similar to the pattern developed from monitored data (Republic of Macedonia, 1996) although the spatial area exceeding $40 \mu\text{g}/\text{m}^3$ is larger for the modeled concentration.

c) NO₂ Dispersion

Figure 5.4 shows the spatial concentration pattern for NO₂ that is consistent with four recently installed continuous NO₂ monitors (Gazi Baba, Center, Karps, Lisice) which show a monthly average range of 9 to $45 \mu\text{g}/\text{m}^3$ for the three months from April to June 1998.

d) CO Dispersion

Figure 5.5, which shows the annual average concentration for CO, appears to be well below observed concentration levels. This is probably reflective of a severe underestimation in the CO mobile source emission inventory and not including any ambient background concentration.

2) Source Contribution

Table 5.9 in S/R (pp.5-28 to 5-29) shows the source contribution by source type for the discrete receptor locations (16 measurement points) for each pollutant source type.

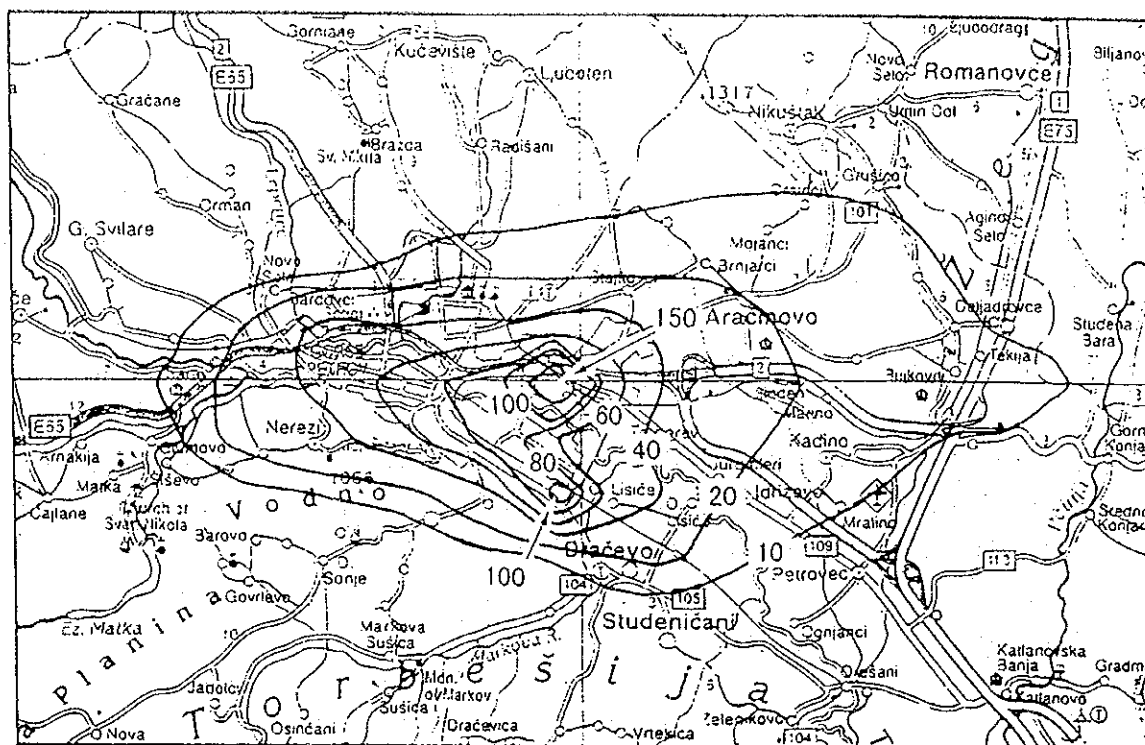


Figure 5.2 ISC3LT 1996 Annual Average SO₂ Concentration (µg/m³)

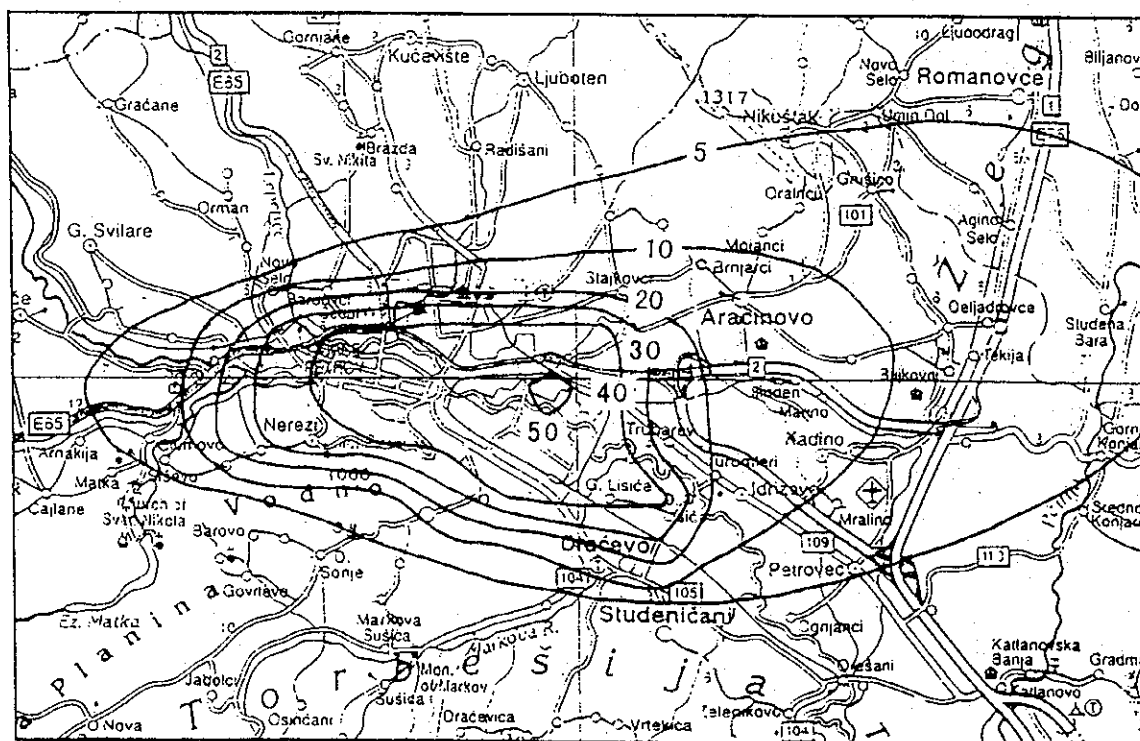


Figure 5.3 ISC3LT 1996 Annual Average SPM Concentration (µg/m³)

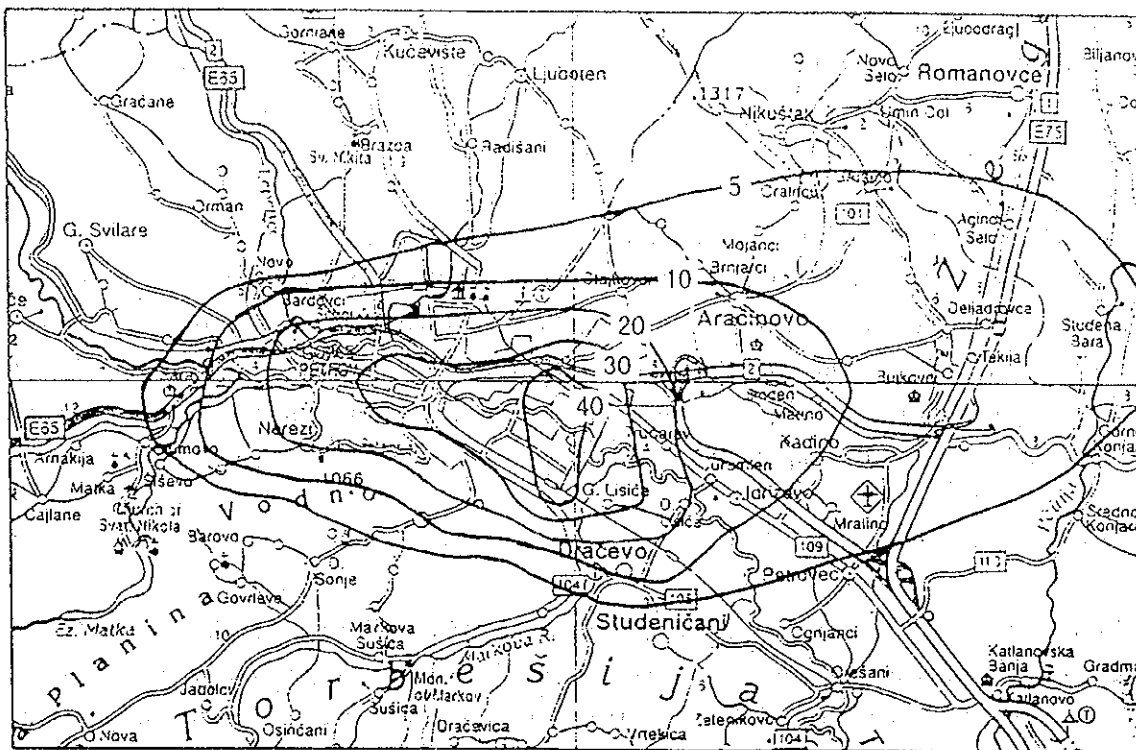


Figure 5.4 ISC3LT 1996 Annual Average NO₂ Concentration (µg/m³)

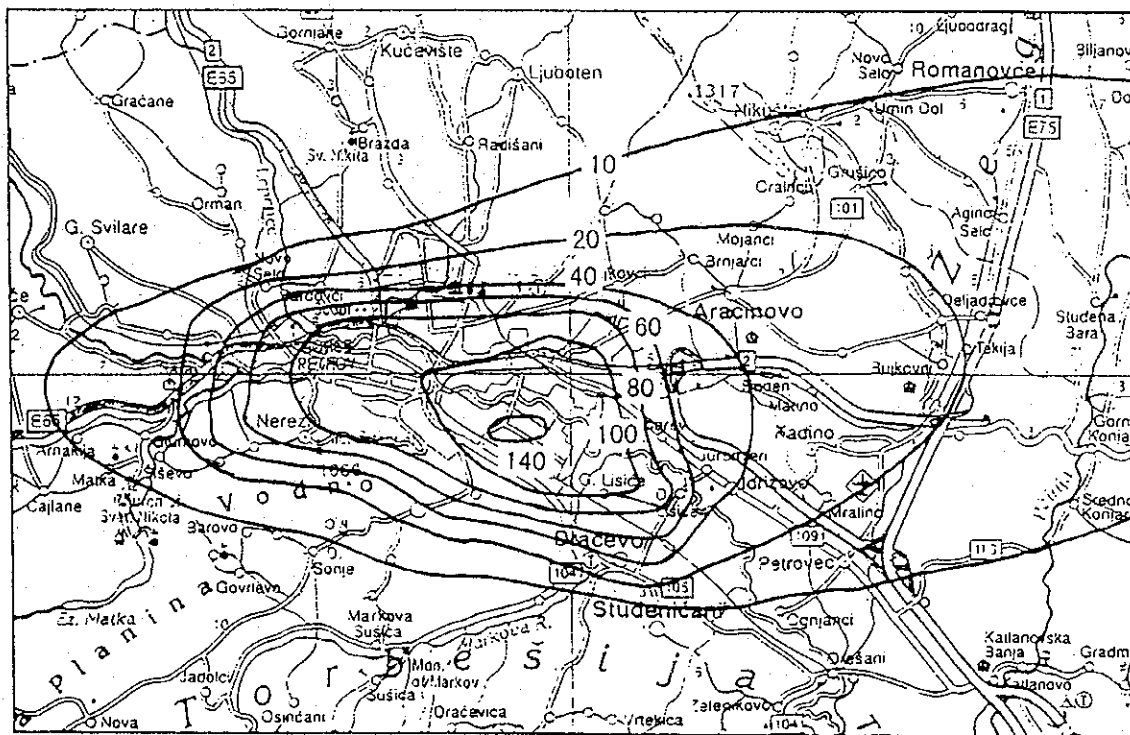


Figure 5.5 ISC3LT 1996 Annual Average CO Concentration (µg/m³)

(2) Future Year and Emission Control Strategy Modeling Results – ISC3LT

1) Future Scenario

Model inputs for the future year simulation are identical to base year modeling effort with the exception of changes to the emission inputs. For the future year (2008) each stationary point source was increased by 20% to reflect additional industrial growth, while area sources remained constant. The control strategy was to switch from oil to natural gas for all of Skopje heating plants. Emissions from the heating facilities were reduced by 80% under this control scenario.

2) Modeling Results

Figures 5.6 to 5.9 show the annual average spatial distribution of SO₂, SPM, NO₂ and CO with the implementation of the control strategy. For all pollutants, including SO₂, the change in emissions resulted in little change to the annual average concentrations. This is because the heating plants contribute little to the overall SPM, NO₂, and CO emissions.

Additionally, these sources only operate for half the year and are emitted from relatively tall stacks. This enables pollutants to be widely distributed.

3) Source Contribution

Table 5.10 in S/R (pp.5-33 to 5-34) shows the source contribution by source type for the monitoring locations for each pollutant source type for the future year with the control strategy. As shown in the table, the source contribution from the heating facilities for SO₂ is much smaller in 2008 than for 1996 with the control strategy implemented, however the 20% growth for other combustion sources erodes the benefit of the control strategy, with a net result of little change in the modeled SO₂ concentration.

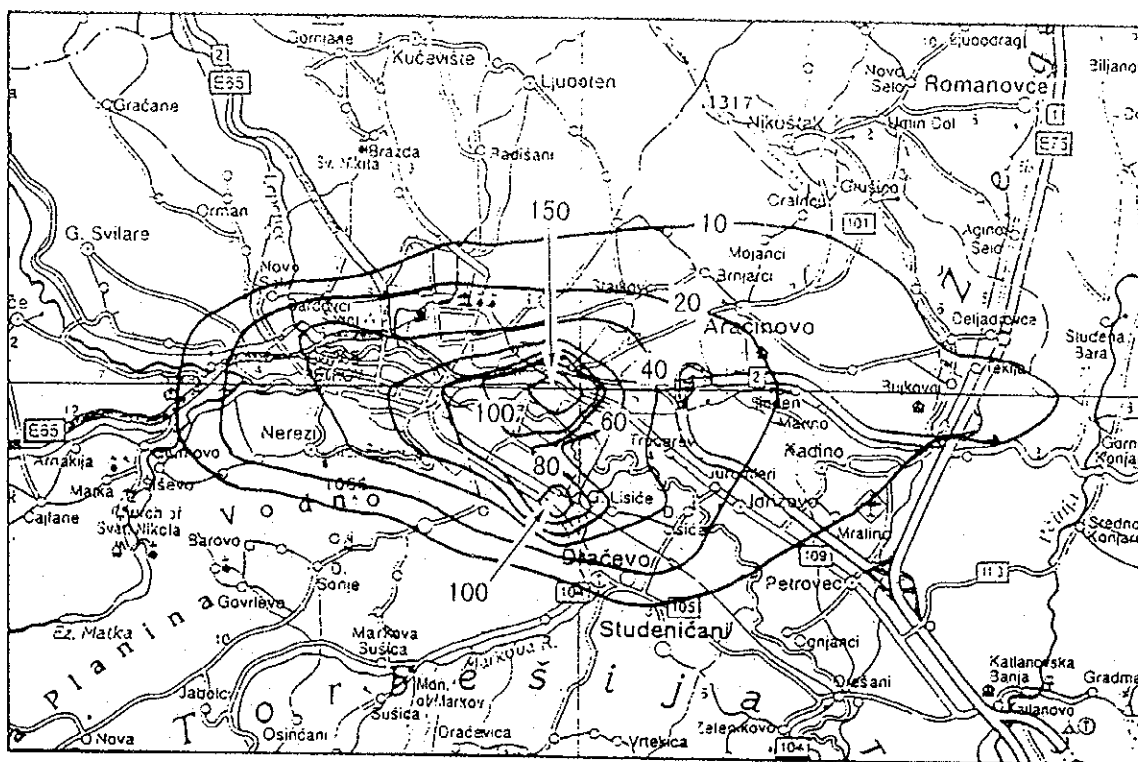


Figure 5.6 ISC3LT Annual Average SO_2 Concentration ($\mu\text{g}/\text{m}^3$) for 2008 with Control for Skopje

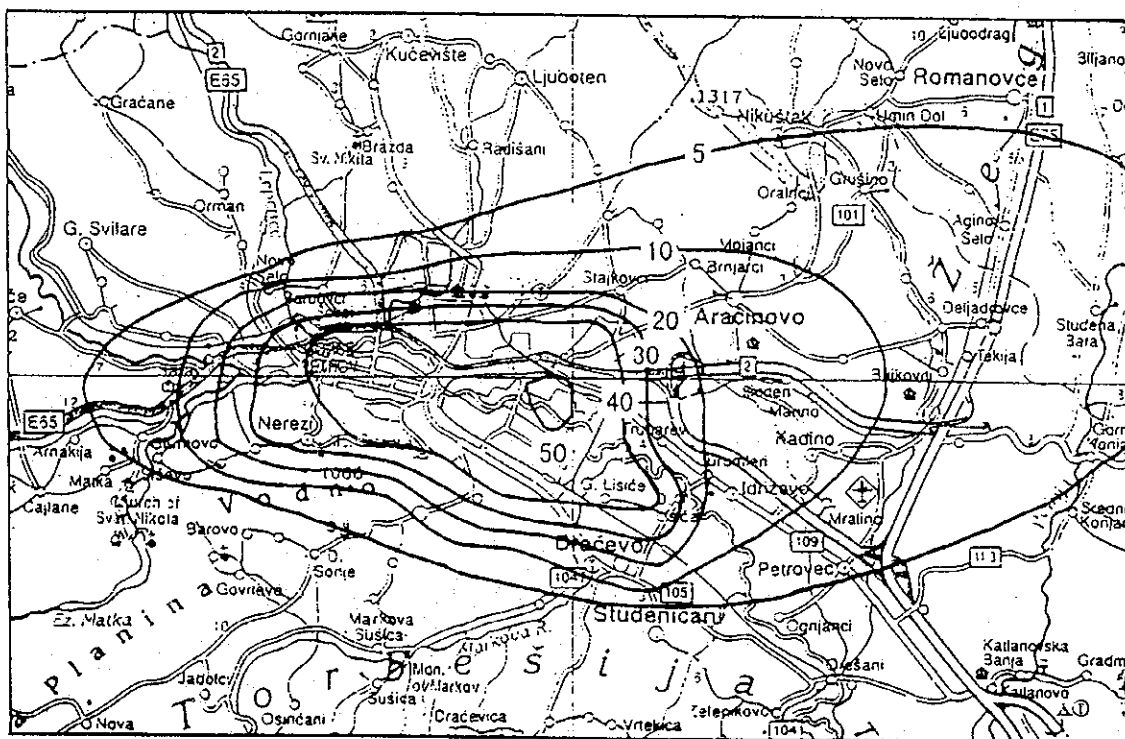


Figure 5.7 ISC3LT Annual Average SPM Concentration ($\mu\text{g}/\text{m}^3$) for 2008 with Control for Skopje

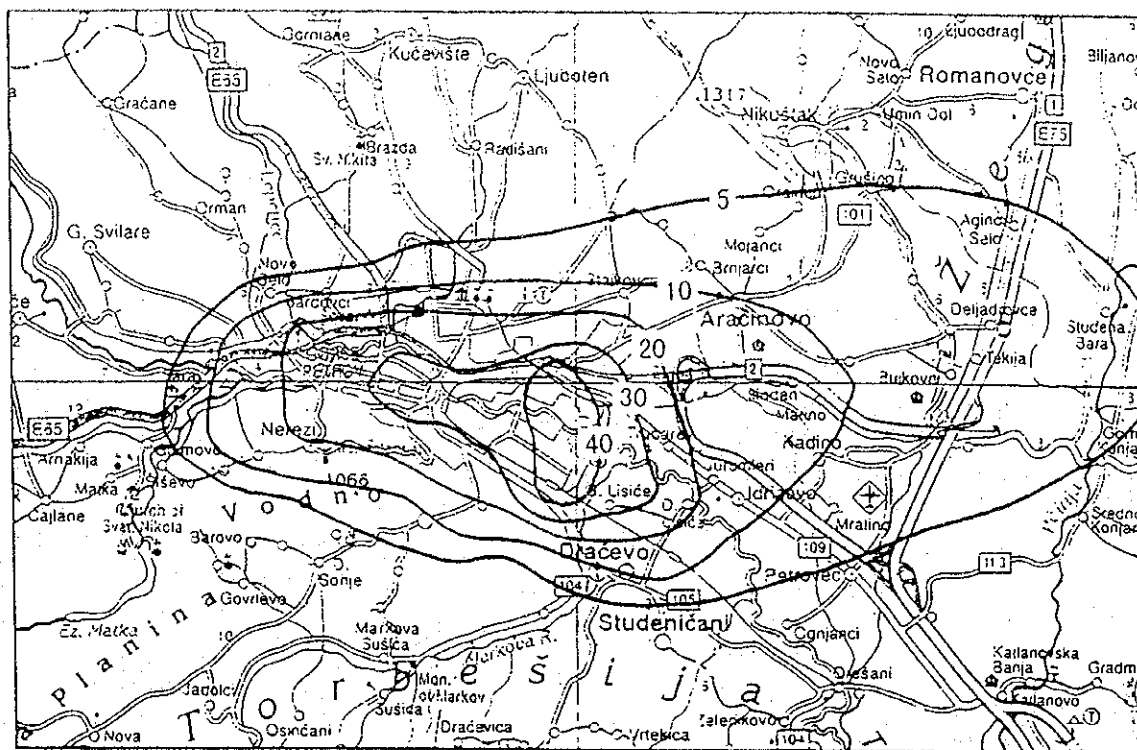


Figure 5.8 ISC3LT Annual Average NO₂ Concentration (µg/m³) for 2008 with Control for Skopje

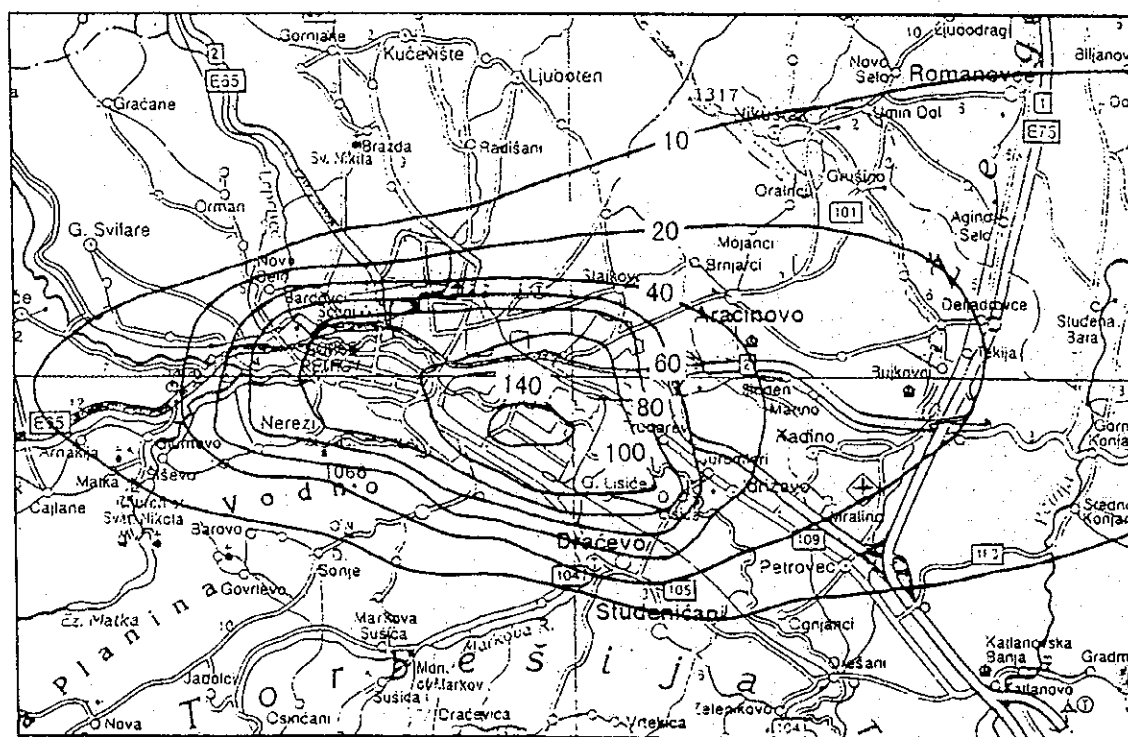


Figure 5.9 ISC3LT Annual Average CO Concentration (µg/m³) for 2008 with Control for Skopje

5.3 Short-term Dispersion Model (CALPUFF)

The CALPUFF modeling system was run in episodic mode to simulate hourly and daily average SO₂ concentration within 60x40 km modeling domain which encompasses all of Skopje. The time period for modeling was from 9:00 p.m. on January 13 to 0:00 a.m. on January 15, 1998. This time period was selected from three episodes where 24-hour SO₂ concentrations exceeded 50 µg/m³ from the winter of 1997 and 1998; from December 11 to 13 (1997), from January 14 to 16 (1998), and from February 11 to 13 (1998). Hourly emission rates and meteorological data were input to the model on an hourly basis to reflect dynamic changes that occur during a typical episode.

5.3.1 Modeling Option and Development of Model Inputs

(1) CALMET

CALMET is a diagnostic meteorological model which includes a wind field module which contains an objective analysis scheme and parameterized treatments of slope flows, kinematic terrain effects, terrain blocking effects, and a divergence minimization procedure, and a micrometeorological model for overland and overwater boundary layers.

(2) CALPUFF

CALPUFF uses the three dimensional meteorological fields developed by the CALMET model. Another key feature used in this application is the module for treatment of complex terrain effects. The model produces hourly averaged concentrations (µg/m³) at both gridded and discrete receptors. Results presented are for 24-hour averages.

1) Emission Inputs

All sources were modeled as point, area or volume sources. Heating season operating emission rates were used for major and medium size stationary sources as reported in the survey response answers from the Questionnaire on Stationary Source Emission Inventory as distributed by the MOE. These facilities were modeled as point sources. Emissions were prepared in spreadsheet format for SO₂ in a format for direct input to

the ISC3 model. Input locations for the major and medium size point sources are specified in local Gauss-Krieger coordinate system, along with the emission rate in g/s, and stack parameters stack height, stack temperature, stack exit velocity, stack diameter. Emissions were adjusted for operating schedules as specified in the inventory. These ranged from 24-hour operations to 8-hour operating periods.

Table 5.6 identifies the heating season operating emission rates by source category.

Table 5.6 Operating SO₂ Emission Rates for Major and Medium Size Stationary Point Sources Used in the CALPUFF Modeling

Source Category	Operating Emission Rate (g/s)
Heating Plants	370
Combustion Sources	439
Area Sources	150
Total	959

2) Modeling Options

- Vertical distribution in the near-field is Gaussian
- ISC-type terrain adjustment
- No sub-grid-scale terrain adjustment
- Near-field puffs modeled as elongated slugs
- Transitional plume-rise modeled, stack-tip downwash included
- Puff-splitting allowed
- No chemical transformation of SO₂ to the sulfate aerosol was performed
- Vertical wind shear modeled above stack top
- No wet or dry deposition
- Used urban dispersion curves for grid-cell locations in urban locations, elsewhere rural dispersion curves were applied
- Buoyancy-induced dispersion included
- Partial plume penetration
- Minimum wind speed (m/s) for non-calm conditions was set at 0.5 m/s
- If puffs stay within the modeling domain after being split initially, they are allowed to split again around sunset before nocturnal shear develops. The time for this resplitting is at 1,600 during this winter episode.

3) Modeling Grid

The same vertical and horizontal grid used in CALMET (meteorological grid) will also

be applied in the CALPUFF (computational grid) application. In addition, the sampling (receptor) grid will be at 1 km resolution which is identical to the computational grid.

4) Receptor Placement

Receptors were placed in a uniform Cartesian gridded array covering the entire modeling domain at 1,000 m horizontal resolution. Discrete receptors were placed at the nine RHI and seven IPH existing measurement points. The local Gauss-Krieger coordinates were determined from location maps provided by the Macedonian side.

5.3.2 Output Results and Model Verification

(1) Air Quality Data for Model Verification

1) Modeling Result of Present Air Quality

In the Study reported operating emissions were used to model SO₂ concentrations within Skopje. Because the emissions modeled are based on operating rates more likely characteristic of near peak emission rates, it is likely the model will overpredict the observed concentrations. Day-specific hourly emission rates based on fuel consumption or power produce for the 15-20 highest SO₂ emission sources would likely significantly improve model performance. Modeling results are compared with monitored 24-hour SO₂ concentrations in Table 5.12 in S/R (p.5-39) for both January 14 and 15, 1998.

2) Source Contribution

Figures 5.10 and 5.11 show the spatial distribution of the 24-hour SO₂ modeled concentrations for January 14 and 15, 1998. Table 5.13 in S/R (pp. 5-41 to 5-42) shows the source contribution by source type for the discrete receptors (16 measurement points) on January 14 and 15, 1998. These results show that for the two points with the highest SO₂ concentration (HMI-Karpos and Hotel Panorama) that the major source contribution was from combustion sources other than the heating plants. Areawide emissions of SO₂ appear to contribute from 20 to 60% of the modeled concentration. Hourly-specific emissions, from sources other than the heating facility, would likely lower overall concentrations significantly. The areawide patterns are shown in Figures 5.10 and 5.11.

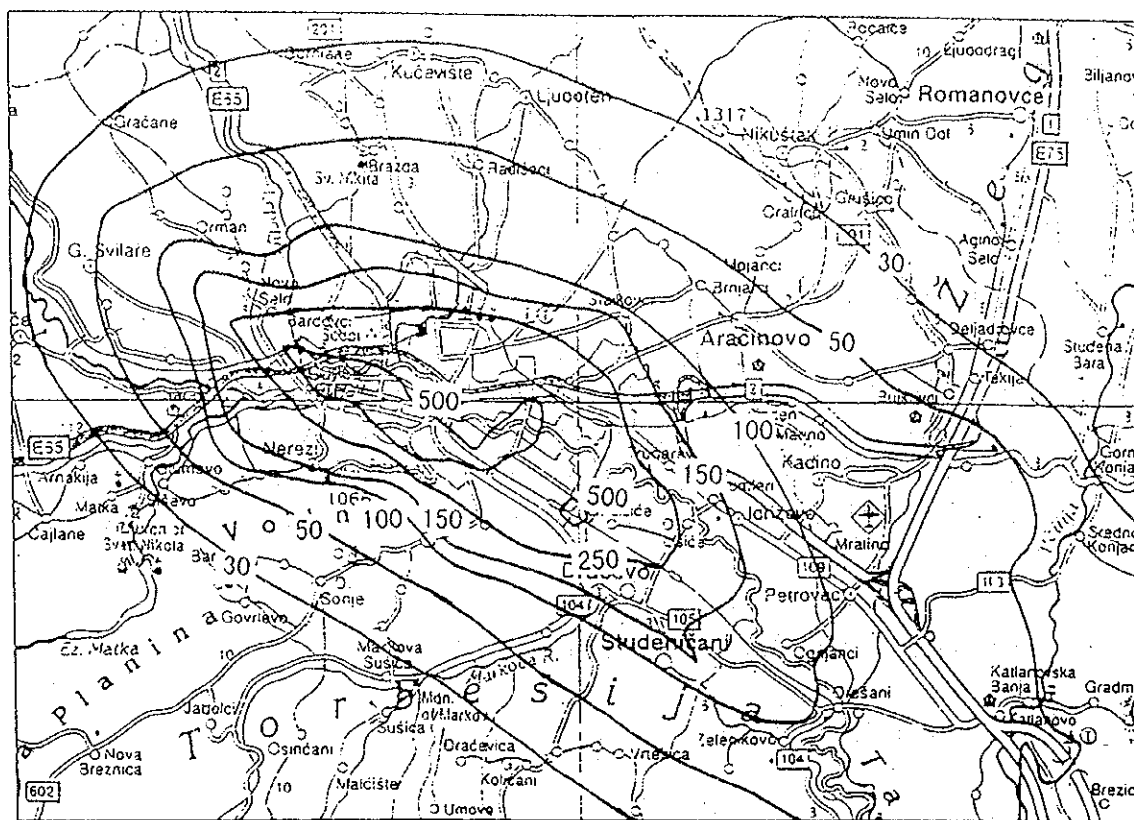


Figure 5.10 24-hour Average Spatial Distribution of SO₂ for January 14, 1998

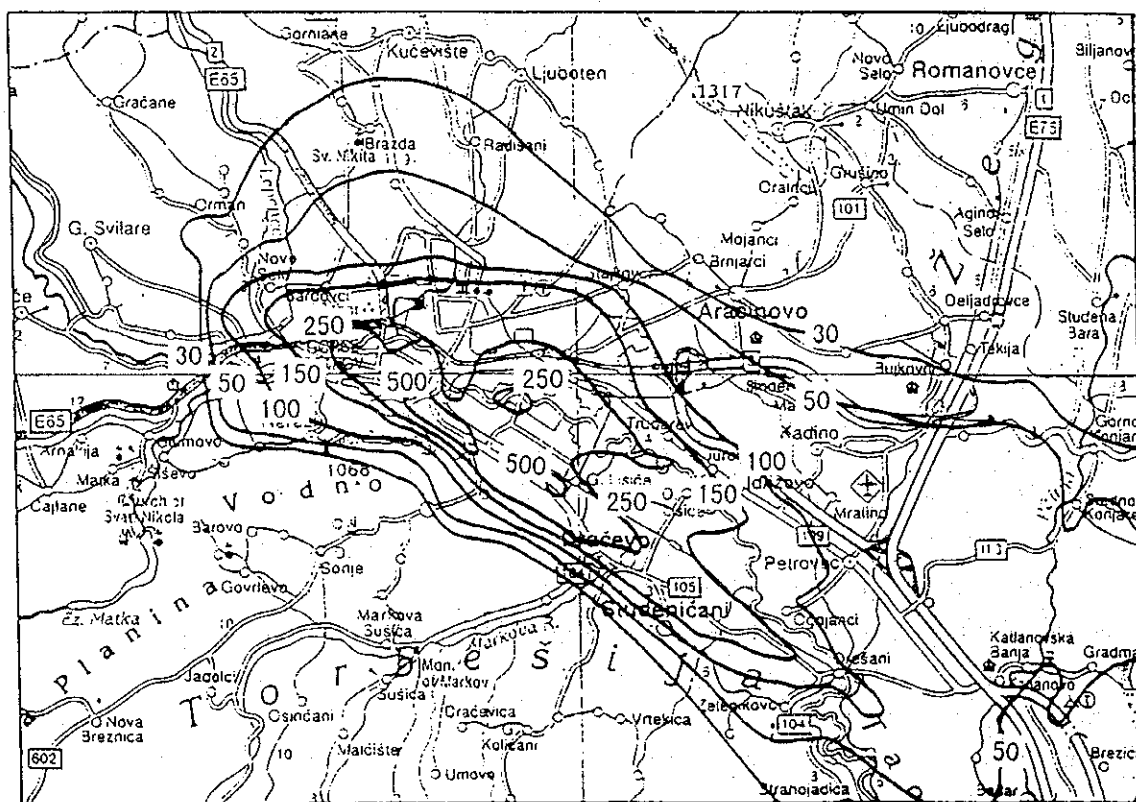


Figure 5.11 24-hour Average Spatial Distribution of SO₂ for January 15, 1998

(2) Future Year and Emission Control Scenario Modeling Results - CALPUFF

1) Future Scenario

Model inputs of CALPUFF for the future year simulation are identical with ISC3LT.

2) Modeling Results and Source Contribution

Figures 5.12 and 5.13 show the 24-hour average spatial distribution of SO₂ for January 14 and 15 with implementation of the control strategy. Table 5.14 in S/R (pp. 5-45 to 5-46) shows the source contribution by source type for the discrete receptors (16 measurement points) for both days of the future-year with the control strategy implemented. Because the peak modeled SO₂ point (Hotel Panorama) had almost no contribution from the heating plants the control strategy shows a net increase from the base year because of the growth in emissions from combustion sources. On the other hand, the measurement point that saw the biggest net reduction in average concentration of 313 µg/m³ was Karpos IV because almost three-quarters of the concentration in the base year is attributable to emissions from the heating plants.

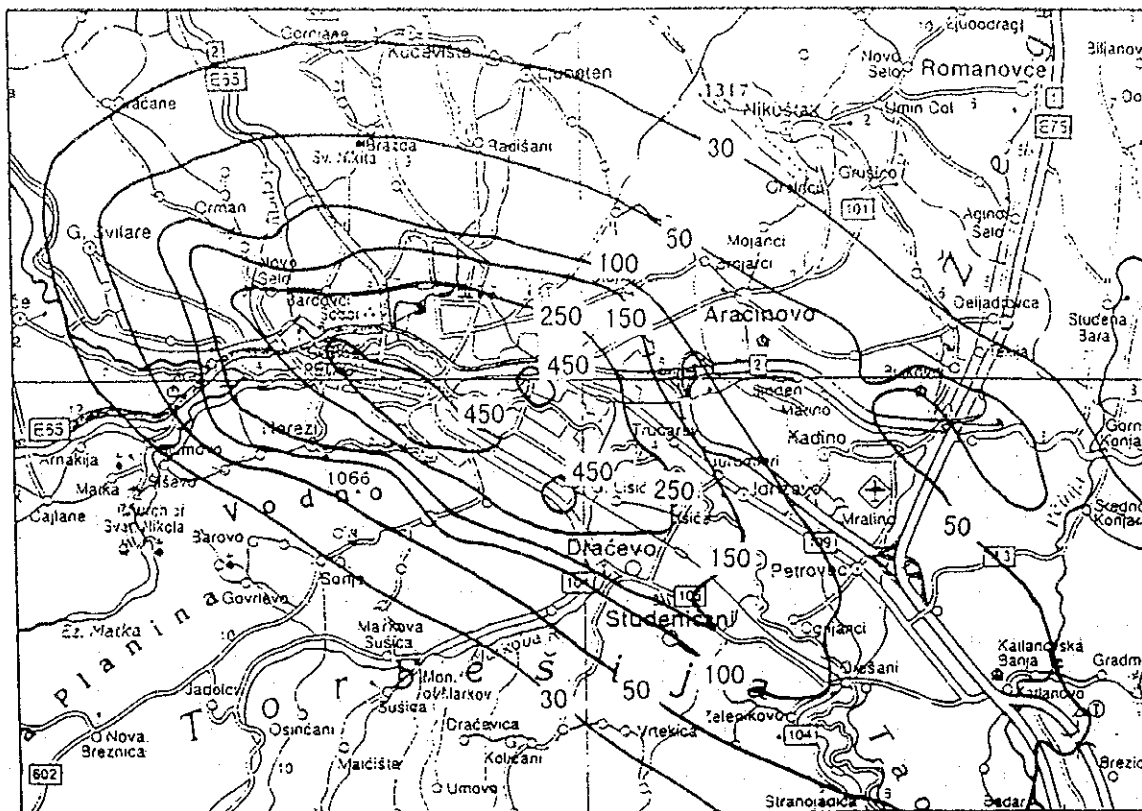


Figure 5.12 24-hour Average Spatial Distribution of SO₂ for January 14, 2008

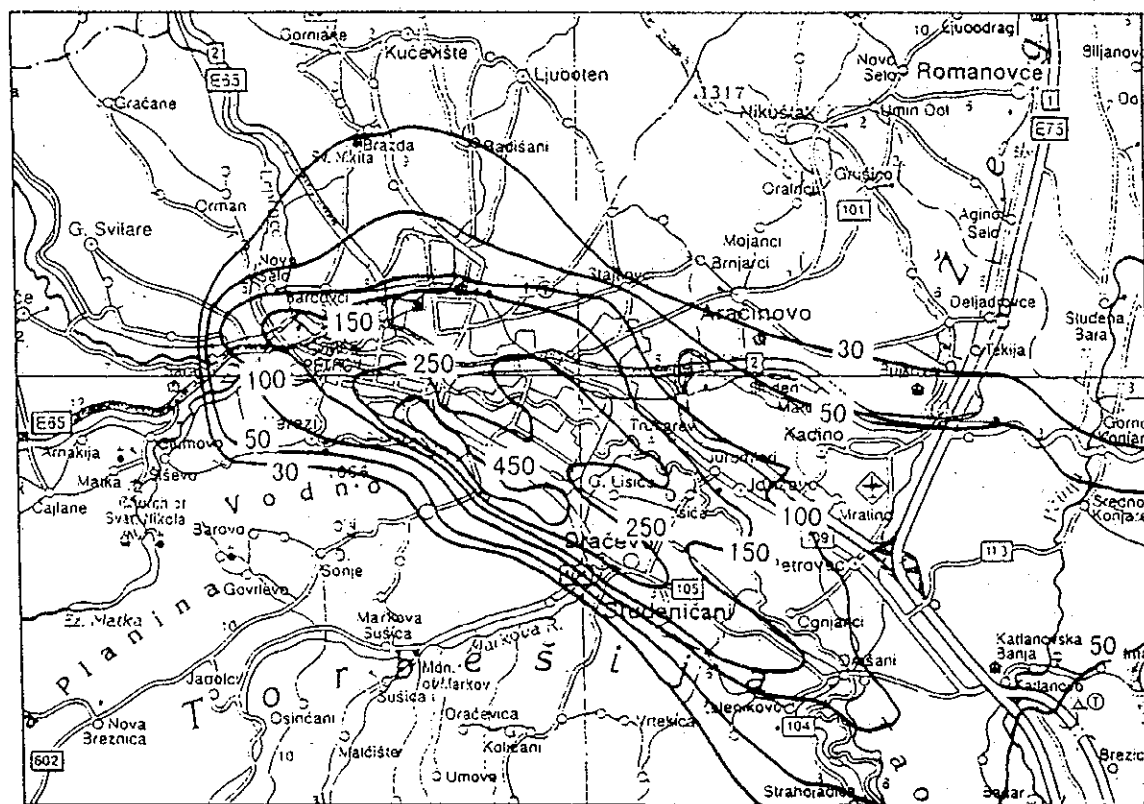


Figure 5.13 24-hour Average Spatial Distribution of SO₂ for January 15, 2008

5.4 Receptor Modeling of Suspended Particulate Matter

5.4.1 Aerosol Characterization Measurements

(1) Sampling of Aerosol

During the period from December 1997 through February 1998, supplemental measurements of fine particle concentrations were conducted in Skopje using the Anderson multistage impactor.

Samples were collected at the Republic Hydrometeorology Institute (RHI), underneath the RailWay Station (RWS) overpass, and in a residential area (Majcin Dom). The primary purpose of this sampling program was to provide aerosol characterization data for the assessment of source contributions to fine particulate matter concentrations.

(2) Analysis of Aerosol

Filters were analyzed gravimetrically for total mass accumulated, and were also subjected to elemental analysis by X-ray fluorescence (XRF). The results of this measurement exercise were mixed. Subjectively good agreement was observed between the time periods for which high mass concentrations were observed and concurrent SO₂ and black smoke measurements by the RHI. However, some compromised the value of the Anderson data. Many elements' observed concentrations are at or below the level of uncertainty in measurements, and it also cannot be assumed that ratios of elemental concentrations on a filter are accurate. Thus the elemental concentrations must be considered to be dimensionless values for purposes of analysis, and cannot be used in direct source apportionment calculations using existing source profiles and receptor modeling techniques.

Despite the limitations on interpretation of the elemental and mass measurements, it was possible to identify several consistent patterns in elemental ratios (and presumably, source contributions) using both graphical and statistical analyses.

5.4.2 Principal Component Analysis (PCA)

(1) Theory of PCA

PCA has been applied in many studies with a fair-to-good degree of success to reveal sources, especially of urban aerosols. PCA is a statistical technique for examining the variance in a multivariate data set by identifying characteristic, recurring and independent modes of variation in a large data set. It is based on the assumption that

the variables can be represented as linear combinations of a set of mutually independent factors. The objective in PCA is to find a minimum number of factors that explain most of the variance of the system. In theory, the variance explained by each factor remains large for the several factors associated with important sources and drops sharply beyond.

(2) The Source of Targets for PCA

To estimate the sources of the trace elements measured at the three points (RHI, M. Dom and RWS) the Study Team performed PCA with the help of the Easy Factor Analysis (EFA Version 2.5) program package (Fuerst, 1988). Some of the problems encountered in the Study were lack of source profiles specific to the area and the limited sample size. The atmosphere in a less-industrialized city and in rural areas is expected to be less complex relative to urban atmospheres of most industrialized nations. Hence PCA can be applied, at least qualitatively, to determine sources of pollution impacting the points under study even in the absence of source profiles specific to the area. Because PCA works through the identification of variability of multiple factors in a dataset, the measurements were conducted at the three points (RHI, M. Dom, and RWS) to attempt to collect samples that were higher or lower in contributions from different known source types. Anticipated source types included mobile sources (the RWS data were specifically collected under the underpass to achieve maximum impact from exhaust and road dust), heating sources (district heating plants and residential and combustion of oil, as well as woodburning), and industrial sources (cement plants and metallurgy).

(3) Chosen Elements for PCA

Fifteen elements (Na, Mg, Al, Si, S, Cl, K, Ca, Ti, V, Mn, Fe, Zn, Br, Pb) were initially chosen for analysis with PCA. Uncertainties of the other elements reported by XRF were consistently larger than their reported values, and could not be used. With this set of 15 elements, PCA was unable to resolve or separate the sources. This was suspected to be due to the large measurement uncertainties associated with some of these elements (Na, Mg and Ti) leading to unstable results. PCA was performed again on using the data for the remaining twelve elements. A total of 56 samples collected between December 25, 1997 to February 21, 1998 were used for the analysis. The results are summarized below.

(4) Correction Coefficient of the Elements

The matrix for linear correlation coefficients for the 56 samples is given in Table 5.7.

For 'n' =56, correlation coefficient (r) greater than 0.35 in this matrix indicate a statistically significant (p=0.01) relationship. However, only a 'r' value greater than 0.7 would indicate that at least 50% of the variability can be explained by a linear association between the two variables. Good correlation is observed between S, Cl, K, Ca and Fe, suggesting that these elements were carried together in the same air mass, either because they arise from a single type of source, or because the spatial and temporal distributions of emissions from contributing source types are similar in Skopje. Particulate sulfur is expected to be primarily the result of secondary sulfate, whose origin is SO₂ from the combustion of fuel oil. Potassium (K) is known to be more abundant in smoke from woodburning. These two findings suggest that the correlation of S and K arise from stagnation conditions in cold weather, resulting in an accumulation in the atmosphere over Skopje of concentrations of heating source emissions over a long enough time period for some fraction of the SO₂ to oxidize to sulfate (one to two days). Ca and Fe are not commonly associated with heating sources, and thus may represent another source of fine particles that accumulate during stagnation (cement manufacturing is a possibility here).

Table 5.7 Correlation Matrix Describing the Correlations Between the Measured Variables

	Al	Si	S	Cl	K	Ca	V	Mn	Fe	Zn	Br	Pb
Al	1.00	0.78	0.73	0.48	0.73	0.47	0.79	0.66	0.66	0.55	0.35	0.38
Si	0.78	1.00	0.74	0.47	0.80	0.47	0.58	0.61	0.58	0.55	0.18	0.22
S	0.73	0.74	1.00	0.89	0.98	0.89	0.75	0.62	0.86	0.63	0.59	0.59
Cl	0.48	0.47	0.89	1.00	0.90	0.99	0.55	0.34	0.85	0.54	0.72	0.70
K	0.73	0.80	0.98	0.90	1.00	0.90	0.69	0.56	0.86	0.63	0.57	0.58
Ca	0.47	0.47	0.89	0.99	0.90	1.00	0.55	0.36	0.84	0.52	0.69	0.68
V	0.79	0.58	0.75	0.55	0.69	0.55	1.00	0.61	0.74	0.51	0.53	0.54
Mn	0.66	0.61	0.62	0.34	0.56	0.36	0.61	1.00	0.60	0.49	0.38	0.38
Fe	0.66	0.58	0.86	0.85	0.86	0.84	0.74	0.60	1.00	0.71	0.87	0.87
Zn	0.55	0.55	0.63	0.54	0.63	0.52	0.51	0.49	0.71	1.00	0.57	0.70
Br	0.35	0.18	0.59	0.72	0.57	0.69	0.53	0.38	0.87	0.57	1.00	0.98
Pb	0.38	0.22	0.59	0.70	0.58	0.68	0.54	0.38	0.87	0.70	0.98	1.00

There is also a good correlation between Al, Si, K, V, Mn and Fe. Fe, Mn and K are all present in the aluminosilicate phase (e.g., crustal dust or rock). Also, as expected, Br and Pb show a strong correlation, as both are present in fixed ratios in the exhaust of vehicles fueled with leaded gasoline.

(5) Four-factor Solution

Results from the four-factor solution are discussed.

1) Factor 1

Factor 1, which accounts for 25% of the variance of this four-factor solution, has a high loading of Pb, Br and is clearly representing the contributions of mobile sources. It also includes a moderate loading of Fe, but the origin of this is not certain. Some road dust (earth crustal) elements would be expected to be present with vehicle exhaust, but it is also possible that there is a source whose emissions are abundant in Fe near the railway station where the highest Pb and Br concentrations were observed.

2) Factor 2

Factor 2 has strong loadings from Al, Si, K, V, and Mn; and explains 29% of the total variability. This probably represents the crustal component as Al, Si, K, and Mn are all present in the aluminosilicate phase (e.g., crustal dust or rock) and hence can be termed as the 'soil' factor. The sources of this material could be windblown dust, construction dust, or regional background concentrations. The occurrence of V in this grouping is somewhat unusual as V has more commonly been used as an indicator species for fuel oil combustion. Direct collection of source profiles for crustal material in different areas of Skopje would be instructive in determining if there is a separate source of V.

3) Factor 3

Factor 3, with high loadings of S, Cl, K, and Ca is more complex and is harder to interpret. It represents the largest portion of the aerosols (30% of the variance explained by this factor). As previously noted, particulate S is expected to be dominated by secondary sulfate during stagnation events. As aerosol concentrations during such events are likely to be a well-mixed combination of all sources of particulate matter (especially "fine mode" particles smaller than 2.5 microns), this factor is likely to include both combustion sources (S from fuel oil, K and possibly Cl from firewood) and other sources. Ca could be indicating contributions from either crustal material or cement manufacturing.

4) Factor 4

Factor 4 contained only Zn and accounted for about 10% of the variance. Both Zn and

Sb have been reported to be relatively abundant in the emissions from municipal waste incineration. This factor could indicate contributions due to burning household refuse, or commercial facility waste incineration. Emissions from this source are not identified in the emission inventory, but should be investigated.

Table 5.8 gives the results of the four-factor solution.

Table 5.8 Principal Component Analysis of Elemental Concentrations in Skopje

	Rotated Factor Loadings				Communality
	Factor 1	Factor 2	Factor 3	Factor 4	
Al	0.10	0.85	0.30	0.21	86.08
Si	-0.16	0.70	0.44	0.46	92.17
S	0.27	0.55	0.75	0.19	97.11
Cl	0.43	0.18	0.87	0.11	99.07
K	0.22	0.50	0.79	0.26	99.73
Ca	0.41	0.19	0.88	0.08	98.27
V	0.38	0.79	0.30	-0.05	85.45
Mn	0.24	0.82	0.06	0.16	76.03
Fe	0.65	0.47	0.54	0.21	96.87
Zn	0.47	0.32	0.22	0.76	95.43
Br	0.91	0.16	0.34	0.07	97.01
Pb	0.91	0.16	0.30	0.22	98.81

In summary, the PCA results indicate that four source groupings can be observed as contributors to SPM concentrations in Skopje. The specific source categories that are apparent, based on knowledge of elemental abundances in emissions, include mobile sources, earth crustal material, heating with fuel oil and firewood, and potentially refuse incineration. The elements providing the most useful information in identifying the principal components included Pb, Br, Al, Si, K, V, Mn, S, and Zn.

There are clear indications of the importance of heating and mobile source contributions to SPM concentrations in Skopje. In particular, the data collected provide strong evidence of a significant secondary sulfate contribution during stagnation conditions. Elemental ratios and source profiles can be used to determine the actual concentration contributions of these sources, however additional sampling and chemical analyses are needed to provide a dataset that can be used to make this determination. The current dataset, because of the uncertainty in absolute elemental concentrations, can only be used to confirm the existence of anticipated relationships between species.

It is possible that both industrial and refuse incineration emissions are contributing to SPM concentrations in significant amounts, however it is not possible to identify these contributions without additional data. Source profiles for fuel oil combustion and road dust would be useful in allowing those portions of the SPM composition to be separately identified. If additional sampling and aerosol characterization studies are conducted, the results of the current analysis can be used to identify several of the key species that should be included. It would be desirable to include elemental and organic carbon and direct determination of sulfate (as opposed to elemental sulfur), along with the other elements listed here, and others that have proven useful in other studies, but whose sensitivity in this dataset was too low to provide useful data. These species include As, Se, Cr, and Hg.

5.5 Air Pollution Control

5.5.1 Environmental Protection Measures

(1) Measures

1) Structural Measures

Review of alternatives for control technology

For the stationary sources, the applicability of alternatives in control technology currently put into practice will be reviewed. Those appropriate to the kind and scale of the sources will be studied in general terms.

A large portion of the transport measures is common in Skopje and the Country, but consideration of the conversion from buses to the new traffic system is a goal at Skopje.

2) Non-structural Measures

As for factors contributing to the deterioration of environment, factors such as the lack of environment protection equipment at plants and other facilities and incomplete measures can be singled out. Other factors are institutional problems and low awareness of the citizens on environmental problems and lack of fostering of personnel.

Personnel awareness is necessary in the combat against environment pollution. The first step to be taken in this direction is to reinforce awareness and enlightenment of ordinary citizens on environment protection, as well as to foster and retrain leaders so that they are able to perceive and evaluate environmental problems correctly.

Figure 5.14 shows an example of public awareness program. To accomplish this, aggressive measures are needed, such as a training system for those concerned with environmental problems, seminars for various levels of people and school education starting from primary education. In the Country, however, fostering of personnel is still at its initial stage.

Personnel training are not practiced. Only since two years ago, the University of Skopje offered environmental engineering courses, which are lectured by professors in the field of industrial engineering, chemistry, machinery and biology.

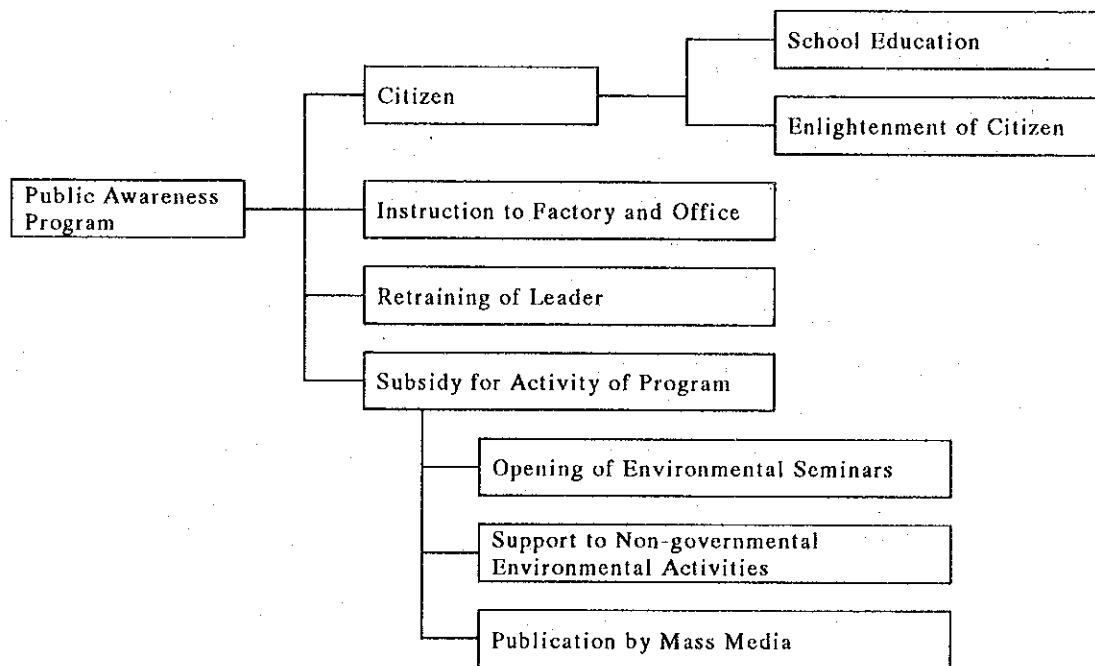


Figure 5.14 An Example of Public Awareness Program

(2) Introduction of Preventive Actions in Japan

The following preventive actions were effective against air pollution under local Japanese conditions:

- a) Environmental Administrative Management and Local Government
Environmental pollution is closely related to the local environment. Therefore, the local government is responsible for the environmental administrative management and authority.
- b) Ordinance of Local Government
An environmental standard is promulgated for the protection of human health from air pollution and for the preservation of the living environment, ensuring for uniformity throughout the Country. Additionally, the emission standard is stipulated to control the amount of smoke and soot dispersing from industrial activities. However, if the preservation of the living environment is not adequate, as judged from natural and social conditions, local ordinances, standards which are more stringent than national standards (override-standards) can be established.
- c) Prompt Relief to Victims
- d) Polluter Pays Principle
 - Pollution-related Health Damage Compensation Law
 - Pollution Control Public Works Cost Allocation Law
- e) Environment Impact Assessment (EIA)
- f) Laws for Optimum Location of Factories
 - Factory Location Law
 - Industrial Relocation Promotion Law
- g) Effort in Greening of Industrial Production System
 - Law Concerning the Improvement of Pollution Prevention System
- h) Qualified Person for Heat Management
 - Law Concerning the Rational Use of Energy in Specified Factories
- i) Legislation of Chemical Substances
 - Drugs, Cosmetics and Medical Instruments Law
 - Agricultural Chemical Control Law
 - Law Concerning Control of Examination and Manufacturing of Chemical Substances
 - Food Hygiene Law
 - Pharmaceutical Affairs Law
- j) Technological Assessment
There are a number of analytical study committees in Japan, which are equivalent to the OTA (Office of Technology Assessment) in the US, for the purpose of technological analysis of environmental preservation and safety technology.
- k) Legislation for Monitoring
 - Industrial Standardization Law
 - Measurement Law

l) Investment in Pollution Control Facility

The cumulative investment for environmental control totaled 9.8 trillion-yen during 20 years from the year of 1970 to 1990 under the various tax-exempt laws for private sectors.

m) Pollution Control Agreement

n) Pollution Control Manager

The Pollution Control Manager System provides for the installation of pollution control systems within factories to meet the regulated levels, which was enforced by reorganization of the pollution-related law.

o) Financial Subsidiary Institution

The installation of pollution controls facilities is difficult for small and medium size industries whose financial bases are not solid enough. In such cases, provincial autonomy establishes a financial subsidiary institution and makes an effort to promote the establishment of the control facility.

5.5.2 Recommendation for Pollution Control for Macedonia

- (1) Revision of monitoring methods for determination of air pollution concentrations which are essential for establishment of environmental standards

The current air pollution prevention law established 13 environmental standards. However, continuous monitoring is applied to only SO₂ and TSP. After cross checking with SO₂ standard gas, the concentration of SO₂ was found lower by 20% than the previously recorded values. Based on this observation, continuous monitoring along with dynamic calibration with standard gas is desirable.

Dynamic calibration was one of the subjects offered in technology transfer during the Site Work I and II. The monitoring instruments provided by the Study were enable to satisfy the EU Directives on air pollution monitoring. Air pollution was understood easier than the previously used monitoring method. By taking advantage of the new monitoring system, the monitoring method should be modified so that prompt response to serious pollution conditions can be achieved by referring to the standards of EU Directives and WHO. It is recommended to establish environmental standards suitable for Macedonia.

(2) Operation and Management of Monitoring System

The Skopje City Assembly established an alarm announcement standard in October, 1990, based on the air pollution prevention law. The announcement of alarm is invoked in case an inversion is produced and continues more than 24 hours with an average wind velocity of less than 2 m/s or that meteorological conditions are predicted to continue for more than 24 hours. Upon collecting these data, it is necessary to establish and operate the monitoring system capable of judging the alarm criteria accurately. The details of monitoring system are summarized in Chapter 6.

(3) Operational Improvement of Environmental Impact Assessments

Because existing data of the Initial Environmental Examination (IEE) and the actual values have not been evaluated, the environmental impact assessment is not performed completely, although EIA is enacted.

It is also recommended not only to screen documents formally but also to establish EIA, including participation and agreement of residents.

- Selection of project type necessary for EIA
- Development of EIA methodology for the development activity impacting the environmental capacity

(4) Establishment of Air Pollution Control Facilities and Tax Incentives

Although a dust collector is installed at both cement and heating plants, the concentration of black soot is high. It is therefore desirable to improve the efficiency of pollution control facilities or to apply more effective new facilities. At the same time the establishment for tax-exempt incentives is also desirable for the installation of the facility. The facility countermeasures for emission sources at the small- and medium- sized industries are not satisfactorily prepared. It is desirable to support and promote these industries for the establishment of air pollution control facilities through long-term, low rate financing and a supplement of interest by a financial subsidiary.

(5) Public Relations to the Citizenry

In order to improve the environmental issues, it is greatly important to spread the

importance of environmental preservation and urge the citizen to awaken to it. The public relations to the citizenry are a means for that purpose, and in many cases, the mass media such as radio, TV, and newspaper are very effective.

The MOE has already announced the conditions of air pollution to the mass media if required, and it is expected that such public relations will be more promoted. For example, opening of web-site via Internet, which has recently become popular, seems to be effective.

Positive actions for public relations are desirable so that the citizens understand the importance of environmental issues properly.

Chapter 6

Chapter 6 Framework of Air Pollution Monitoring System in the Model City

6.1 Necessity of Monitoring System

(1) The Conducted Results from the Study

The Air Quality Monitoring (AQM) system has not existed in Skopje before commencement of the Study, and the samples taken everyday are analyzed once a week. Moreover, only the RHI had the data on the weather such as the wind direction and speed, temperature and humidity, but it was insufficient system for studying the actual conditions of air pollution. Furthermore, it took too much time to get results, so that the measures for emergency did not function well.

The AQM system in Skopje seems to have worked well and to have supplied data of great use on air pollution, for around a year.

In addition, the accumulation and analysis of monitoring data make it possible to clarify the phenomenon of air pollution such as the stagnation episode from December 1998 to January 1999 which have occurred cyclically, and to help the prediction of unusual air pollution and take the necessary actions on the scientific basis in future.

(2) Present Condition of Air Pollution

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 SO₂ 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.

(3) Importance of Monitoring and its Difficulties

The importance of continuous monitoring of air pollution is to obtain basic data and information for the followings:

- Understanding of the level of air pollution and judging whether environmental standards are cleared or not
- Countermeasures in an emergency case

- Prevention of damage to human body

From the results obtained through the Study, the following difficulties are pointed out. In accordance with the "1996 Law on Environment and Nature Protection and Promotion", the MOE acts as executive agency for environmental management.

- a) Organizations which partially monitor the air pollution are the IPH and the RHI and it is difficult to integrate the monitoring data on an administrative basis.
- b) It takes time to find out about the pollution level because of the time taken 24-hour sampling and the subsequent analysis of sample in laboratory. Quick counter-measures in an emergency case can not be taken.
- c) Judgment of short-term pollution can not be made because of no hourly environmental standards.
- d) It was observed that some error factors were included in the existing measuring method based on the results of cross-check.

(4) Necessity of Further Monitoring

Due to installation of AQM system at four stations and one set of mobile monitoring system in the course of the Study, urgently required monitoring systems were mostly set up in the model city. Moreover, in order to solve problems expect c) mentioned above, it is required to provide further monitoring system to measure air pollution in model city considering the results of the Study as well as environmental administration. Concrete items required are as follows.

- To monitor ambient air quality in residential areas, in north and east parts of Skopje, excluded from AQM network.
- To monitor exhaust gas from stationary sources continuously which have large air pollution load in order to take a measure of fuel conversion to low sulfur fuel or cutback in operation of plants.
- To monitor stationary source as well as supplementary ambient air quality using mobile monitoring system.
- To inspect auto-exhaust gas in order to comprehend the actual condition of it which is not monitored at present.
- To establish APMC in order to send all monitored data into the MOE and conduct maintenance and management. To dispose required personnel at the same time.
- To replace the superannuated equipment in the Institute of Environment Zerežala (IEZ), for improve of analytical capability of samples related to air pollution.

6.2 Equipment and Materials Planning

Air pollution monitoring station is categorized into air quality monitoring (AQM) station, road side monitoring station for vehicular exhaust gas, continuous emission monitoring (CEM) station and its supporting mobile monitoring station (these four types can be equipped with automatic continuous monitoring instruments), and various types of sampler. Monitoring with such samplers requires chemical analysis and the laboratory. Enormous amount of data is obtained through monitoring and it is therefore necessary to introduce computer for the processing and storage of data.

There have been drastic developments in existing monitoring system including software for the past decade due to the rapid development in the hardware of monitoring instruments and personal computer and in the communication tools. In order to reduce the management cost of monitoring stations, it is necessary to apply such up-to-date technology as mentioned above to the present and future monitoring system in Macedonia. Overall concept of advanced monitoring and software system is shown in Figure 6.1

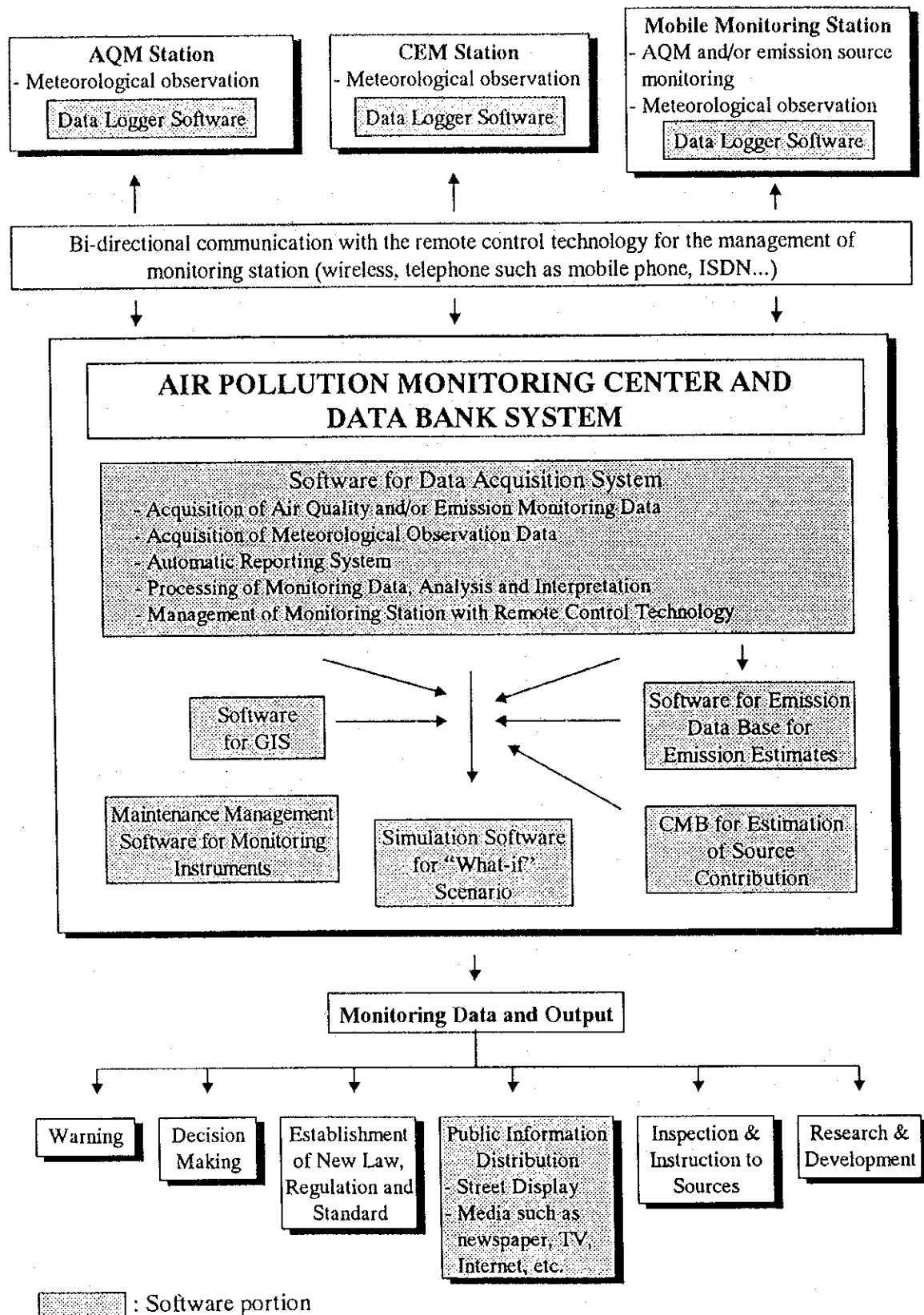


Figure 6.1 Overall Concept of Advanced Monitoring and Software System

6.2.1 Selection of Equipment and Materials

(1) Considerations for Selection of Equipment and Materials

As a result of procurement of equipment and materials necessary for the Study and the Site Works throughout the four seasons, various results and findings were obtained. Considerations for future planning were also identified; for example, the necessity of consideration of the meteorological characteristics for selection of equipment and materials, etc..

1) Consideration of Temperature for Container

The temperature range at Skopje has a variation of 60°C; minus 20°C in winter and often exceeds 40°C in summer. It means that careful consideration must be given to the construction of the container. It is necessary to strengthen the container insulation (thickness: 100 mm or more).

2) Air Conditioner of Container

When the air conditioner fails to operate during the daytime in summer, the interior temperature in the container rises far above the permissible level for the monitoring equipment due to heat generation of the equipment itself and intense solar radiation. Such an excessive temperature rise may result in the failure to obtain the monitoring data and the breakdown of the expensive hardware.

Though the strengthened insulation of the container may delay the temperature rise effectively, it is meaningless without taking a quick action. It is therefore desirable to provide two air conditioners in the AQM station.

3) Selection of Wind Vane Anemometer

Characteristically, the wind speed in winter is extremely low in Skopje which in turn causes severe air pollution. To enable air pollution analysis, it is appropriate to select an ultrasonic wind-vane anemometer which has no driven part and can monitor the breeze accurately.

Consideration should also be given to the low temperature and high humidity in winter. Since freezing on the sensor block of this ultrasonic wind-vane anemometer causes monitoring errors, a type with a built-in heater may be necessary. If a normal breeze wind-vane anemometer is used, measurements may become impossible due to freezing at the drive point.

4) Considerations Concerning Monitoring Range

According to the result of the Study, the air quality concentration undergoes substantial fluctuations according to the time, the day and the season. It is essential that the monitoring equipment has a range sufficiently compatible with large concentration changes.

5) Selection of SPM Meter

Typical monitoring of the SPM includes TEOM and β -ray absorption. Though their detection methods differ, both methods are based on measurement of the SPM mass collected on the filter. This means that the effect of humidity on the filter is one of the probable error factors.

In the case of the TEOM method, the sampling tube and sensor are heated to cope with the effect of humidity. It is not yet confirmed that such heating is sufficiently effective in the low-temperature and high-humidity condition in winter. It is essential to prepare the specification after a thorough study of the SPM meter data.

6) Self-diagnosis and Remote Control Function of the Monitoring Equipment

Although approximately 20 years have passed since the first delivery of the monitoring equipment, its failure rate remains high. In other words, a monitoring equipment with a self-diagnosis function is advantageous for preventing failures before they occur. The personnel and cost required for the maintenance of the AQM system is not insignificant for the MOE, which means that a reduction of the costs is desirable. This can be achieved by controlling the air pollution monitoring station in such a manner that the central station is provided with the remote control function, in addition to data processing, for performing the self-diagnosis and calibration of the monitoring equipment.

(2) Considerations for Development of Equipment and Materials Plan

Proper consideration must be given to the following matters during development of the equipment and materials plan:

- The quantity and location of the air pollution monitoring stations must be determined taking into consideration the monitoring items, so that the maximum effect can be achieved within the limited budget.
- The monitoring equipment and materials must have the monitored items and specifications in compliance with the EU legal system.

6.2.2 Planning on AQM System

(1) Characteristics and Representativeness of Each Monitoring Station

Based on the extensive field survey of concentration distribution pattern of pollutants with the simplified-sampler in Skopje which became a model city, four monitoring points were selected and automatic continuous monitoring instruments were installed. The characteristics of those four monitoring stations are as follows and described in detail in Chapter 3.

- Large emission source is located near this point but influence from local emission source is small
- Medium- and small-sized emission source scattered point in the center of Skopje
- Automobile exhaust gas impacting point
- Intermediate point between industrial area and newly developed residential area

(2) Planning on Number of Monitoring Station and Equipment and Materials

1) Consideration of Effective Monitoring Stationing

Figure 6.2 shows location of the four AQM stations and major stationary emission sources by the District comprising of five prepared based on the questionnaire survey to the factories and field survey in the model city.

According to the Figure, those four monitoring points mentioned above are relatively located in the center of Skopje and do not cover the northern part of city (green colored area) where is mainly residential area. The city, especially residential area is extending to the eastern part of city (red colored area) where construction of residence is under way and is not covered with the present AQM stations. And also the present AQM stations belong to the industrialized or semi-industrialized area. In case of stagnation episode, it is also necessary to monitor the concentration level of air pollution in the residential areas because serious damage to human body is concerned. It is therefore recommended that two more AQM stations be set up in the northern and eastern part of city where are the residential areas.

Further, as judgment criteria for the announcement of alarm at the time of appearance of high concentration of air pollution, it is stipulated that monitoring values at the neighboring monitoring stations covering 4 x 4 km area for each station exceed the standards. In case the model city is divided into areas, whole city area, especially northern and eastern areas of the city can not be covered with the present AQM system. It is therefore desirable that the expansion of monitoring system in the model city includes the residential areas in the north and east of Skopje.

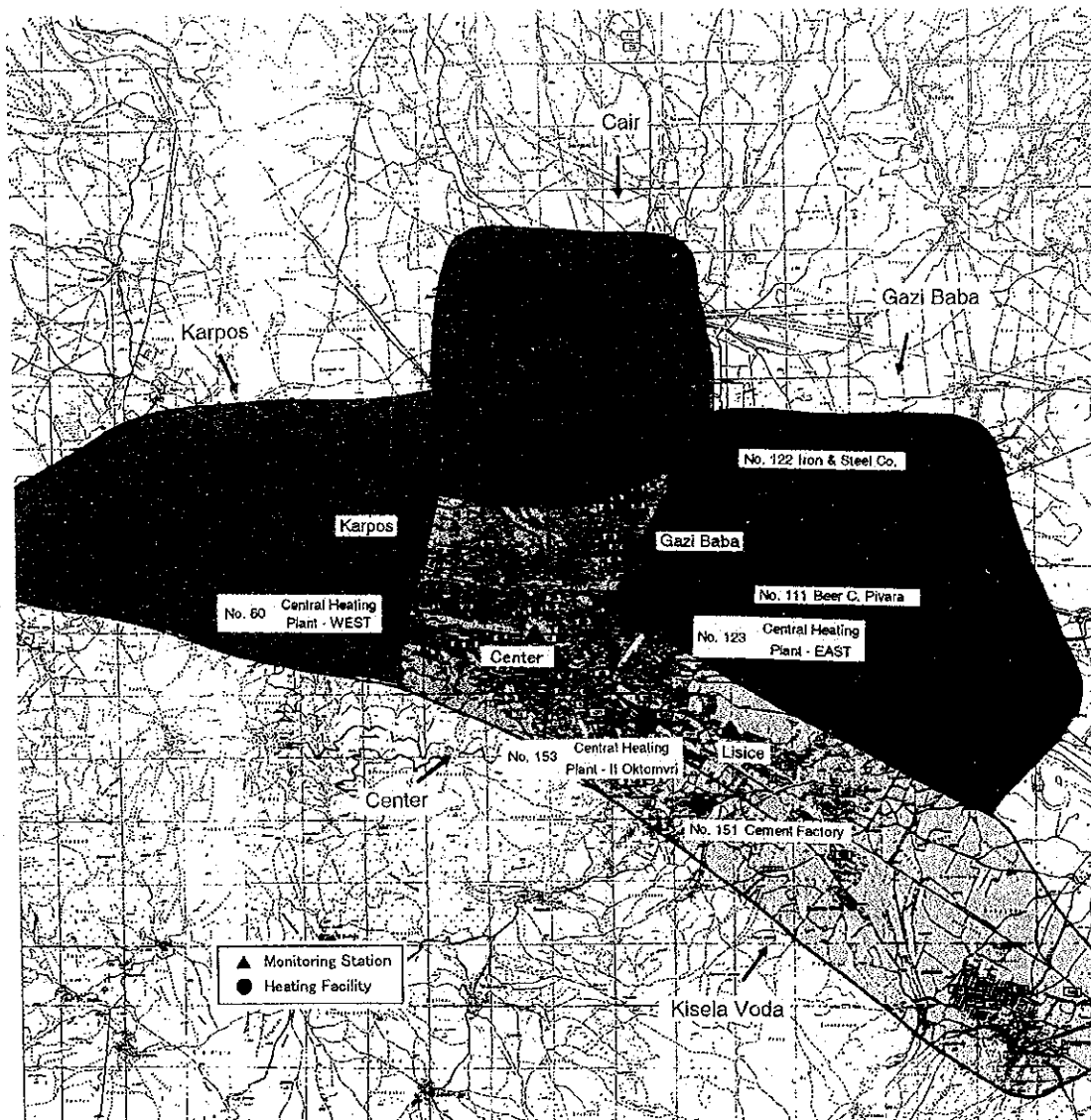


Figure 6.2 Type and Location of Major Stationary Sources and its Emission Intensity by the District

2) Monitoring Equipment and Materials

The monitoring parameters of additional two AQM stations are the same as those of the present monitoring stations. But it was observed in the course of the filed survey that net radiation meter was needed for the evaluation of atmospheric stability in addition to the present equipment items. The detailed equipment list is shown in the S/R (p.6-9).

6.2.3 Planning on CEM System

(1) Monitoring Method

Stationary emission source monitoring is categorized into the spot measurement for a few hours and CEM.

(2) Stationary Emission Source Monitoring

Emission has been monitored in Macedonia with the conventional portable-type exhaust gas measuring instruments. One set of mobile monitoring car stationed in the model city makes it possible to monitor the emission more accurately and frequently. The major pollutants in the model city are SO₂ and SPM. It was observed that the high concentration exceeding the criteria for the alarming announcement appeared during heating season. In order to monitor the amount of emission of pollutants from the stationary emission sources in an emergency case such as the serious stagnation episode and check whether the emission standards are cleared or not, it is recommended that three sets of CEM instruments be installed to the large-scale emission sources in the model city as mentioned below.

(3) Stationary Emission Source and its Parameters to be Monitored in the Model City

Major stationary emission sources and its parameters to be monitored automatically and continuously in the model city are shown in Table 6.1.

Monitoring data are transmitted to the APMC via wireless telemetric system automatically and it is necessary to calibrate the monitoring instruments using standard gases from the APMC with the remote control technology.

Table 6.1 Major Stationary Emission Sources and its Parameters to be Monitored in the Model City

No.	Name of Factory	Type of Combustion	Type of Fuel	Parameter
60	Heating Plant WEST	Boiler 170 W	Heavy oil	Dust, SO ₂ , NO _x and CO
123	Heating Plant EAST	Boiler 294 MW	Heavy oil	Dust, SO ₂ , NO _x and CO
151a	USJE Prvomajiska bb	Cement Kiln	Heavy oil & coal	Dust, SO ₂ and NO _x

As one of countermeasures against air pollution during the first stage or within five years describes in Section 6.5 (p.6-22), a plan of fuel conversion into natural gas for the heating plant is prepared. In case the plan is certainly realized, it is not necessary to monitor the heating plants listed above.

(4) Monitoring Equipment and Materials Planning

The details of equipment and materials to be installed for CEM are shown in the S/R (p.6-11).

6.2.4 Planning on Mobile Monitoring System

In order to monitor the stationary emission source in the model city, a set of mobile monitoring car which is able to measure SO₂, NO_x, CO, dust and velocity of exhaust gas, was provided for Macedonia. There are however more than 500 combustion facilities only in Skopje and also some large stationary emission sources are scattered in Macedonia. It is therefore impossible to monitor all the stationary emission sources with one mobile monitoring car. In order to supplement the insufficient monitoring of stationary emission source in the model city and other cities in Macedonia as well as AQM in uncovered area with the fixed station, it is necessary to station another mobile monitoring car in the model city. The equipment and materials for mobile monitoring are the same as the present mobile monitoring car. The list is summarized in the S/R (p.6-13).

6.2.5 Planning on Auto-exhaust Gas Inspection System

The automobile inspection system exists as an institution but is not enforced actually because no inspection equipment and materials for automobile exhaust gas is equipped. At the initial stage of equipment and materials planning on automobile exhaust gas inspection system, such costly facility and equipment as chassis dynamometer and

Constant Volume Sampler (CVS) which is able to measure the concentration of exhaust gas by driving mode should not be introduced into the inspection system. In order to grasp the present situation of mobile emission, it is recommended that a set of equipment and materials for the inspection of automobile exhaust gas be introduced to APMC in the model city. The equipment and materials to be needed for the inspection are shown in the S/R (p.6-13).

6.2.6 Planning on Data Logging, Acquisition and Processing

It is necessary to introduce computer hardware and software at monitoring station for data logging and the APMC for the acquisition, processing and exporting of air pollution monitoring data in the model city.

(1) Computer Hardware

Computer hardware and its peripherals at the APMC and monitoring station comprise of server, PC, printer, image scanner, XY plotter, etc. for data logging, acquisition and exporting of monitoring data. The details are described in the S/R (p.6-14).

(2) Computer Software

The software which was provided for Macedonia under the Study as well as will be recommended for its expansion of monitoring system in the model city and other cities in Macedonia is summarized in Table 6.2.

The details of functions and features of each software are summarized in the S/R (pp.6-15 to 6-21). Figures 6.3 and 6.4 show the overview of monitoring station and public information distribution system, respectively.

Table 6.2 Present Software and Software Recommended for Expansion in APMC

Software	Present	APMC
Data Logger	○	
Data Acquisition System	○	
Geographical Information System (GIS)	○	*
Maintenance Management of Monitoring Instruments		○
Emission Database		○
Chemical Mass Balance (CMB)	○	
Simulation Model (Air Dispersion)	○	
Public Information Distribution System	○	*

* : Considering the development in technology in future, further expansion or upgrade is recommended.

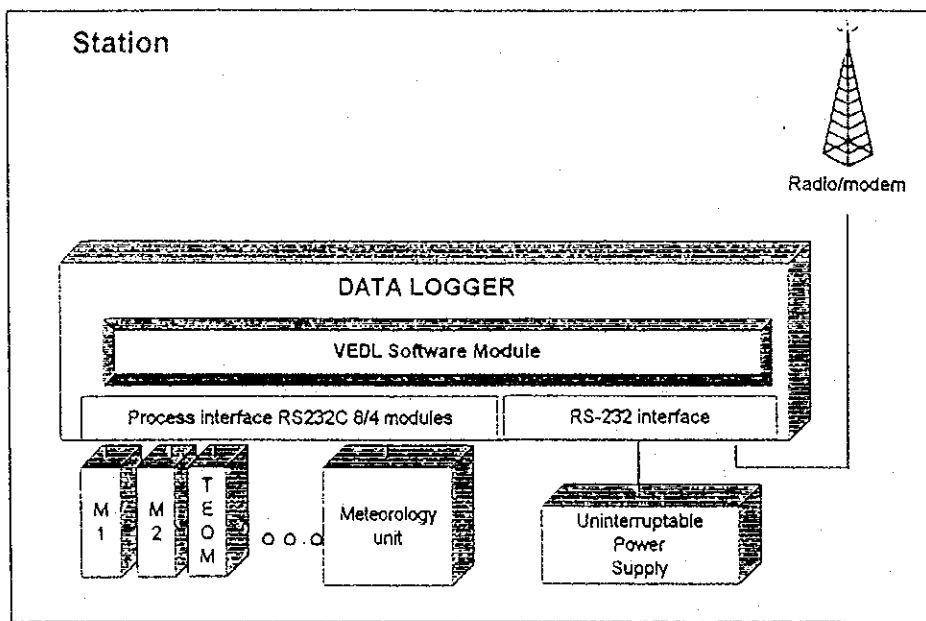


Figure 6.3 Overview of Monitoring Station

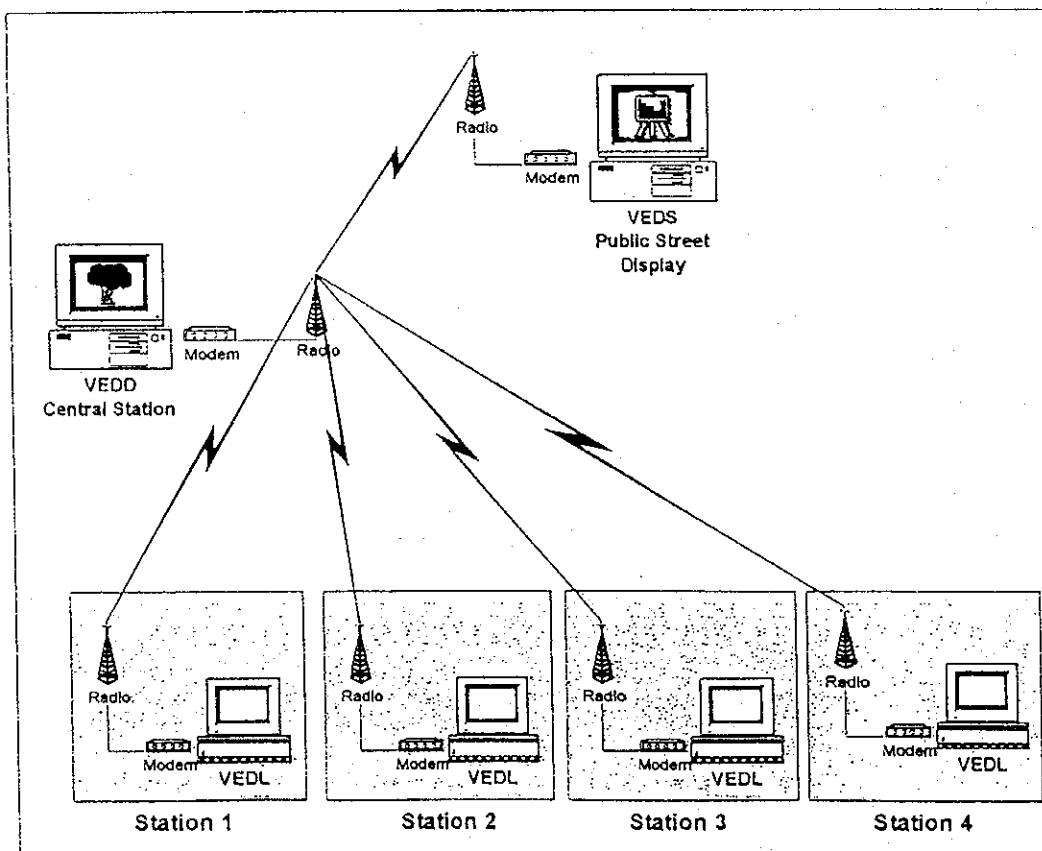


Figure 6.4 Overview of Public Information Distribution System

6.2.7 Planning for APMC

(1) Monitoring Equipment and Materials

Central station for monitoring will be stationed at the APMC. The APMC maintains and manages all the equipment and materials for monitoring and inspection system listed in Sections 6.2.2 (p.6-7), 6.2.3 (p.6-10), 6.2.4 (p.6-11) and 6.2.5 (p.6-11). The present central station at the MOE that provided in the course of the Study will be integrated with the APMC.

(2) Hardware and Software for Data Acquisition and Processing

It is necessary to install hardware such as PC, server and printer and software in order that the APMC manages the monitoring data sent from the monitoring stations for air quality and stationary emission source and mobile monitoring, and the inspection data of automobile exhaust gas. All the data will be stored in the data bank system to be installed in the APMC. The details of hardware and software for data acquisition and processing to be installed at the APMC are described in Section 6.2.6 (p.6-11) and S/R (p.6-13).

6.2.8 Planning for Laboratory of IEZ

It is necessary to take into consideration the purpose of analysis as well as accuracy and detection limits, etc., in the improvement planning for analytical instruments of the IEZ. In addition, the number and performance of equipment and materials should also be decided depending on the number of samples to be treated and analyzed.

Black smoke is monitored for particulate matter but the measurement of Black Smoke is based on the relative method. It is therefore desirable to measure the weight concentration with high volume air sampler and it is recommended that about five units of high volume air sampler (portable type) be introduced for the monitoring of particulate matter in the model city.

Freon was not in problem in the past but tends to be analyzed as a hazardous substance as ozone layer depletion and grovel worming gas at present. It is important to keep in mind that such hazardous substance to be analyzed will increase in future, too. It is therefore necessary to make a plan for the improvement in analytical instruments of the IEZ taking into consideration the requirements and functions to be added in future. At the same time, however, it is also taken into consideration that the introduction of

equipment and materials based on the particular purpose because the present equipment and materials can not satisfy all the requirements and functions in future. Upgrading the functions of the IEZ to the modern state-of-the-art ones in order to produce the highly precise data contributes in the progress for not only the environmental management but also the quality control, and ultimately is connected to the economic and technological development of Macedonia in the future. The function of the IEZ can be categorized into general or routine analysis, research and development, social education, etc..

Equipment and materials to be needed for the improvement of the IEZ at the first and second phase are listed in the S/R (pp.6-23 and 6-24).

6.3 Organization and Institution Planning

(1) Establishment of Air Pollution Monitoring Center (APMC)

According to the "1996 Law on Environment and Nature Protection and Promotion," the MOE became an executing body of environmental administration including the environmental monitoring and policy-making for the prevention of air pollution. In order to monitor the environment effectively and to solve the various problems mentioned above under the newly established MOE, it is recommended that the APMC be established in Environmental Consulting Center of the MOE. Figure 6.5 shows an example of organization chart of the APMC and the following works are expected to be assigned. In addition, in case the nationwide monitoring network is established, the APMC will also become the center.

- AQM, data collection and its screening
- Continuous Emission Monitoring (CEM), data collection and its screening
- Judging whether the standards are cleared or not
- Data collection related to emission source and meteorology
- Management of monitoring data in data bank
- Maintenance and management of monitoring instruments

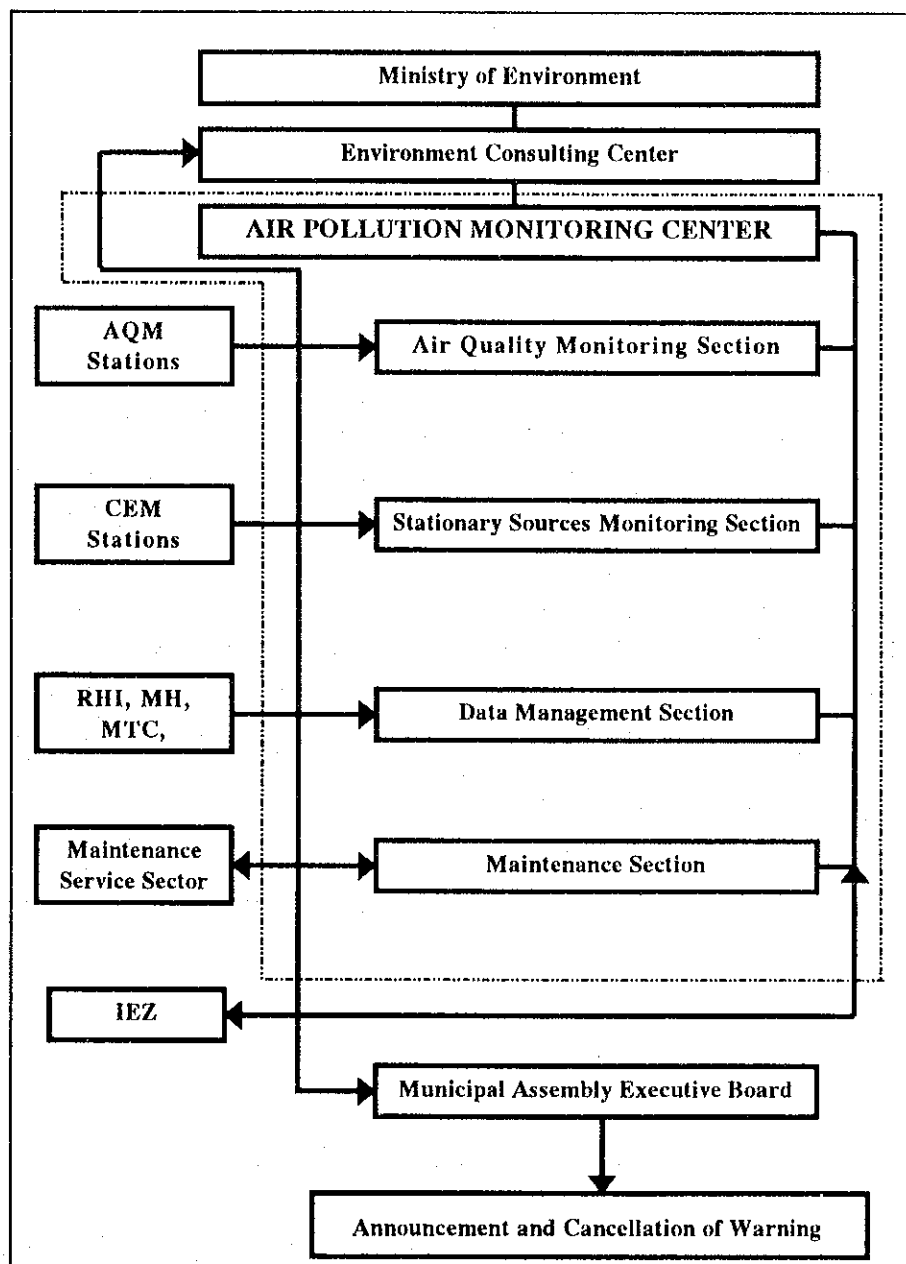


Figure 6.5 Organization Chart of Air Pollution Monitoring Center

1) Organization of APMC and Role of Each Section

The APMC comprises of the following four sections:

- AQM Section
- CEM Section
- Data Management Section
- Maintenance Section

Roles of each section are described in S/R (p.6-29).

2) Other Works of APMC

Other works of the APMC include announcement of alarm when high concentration of air pollution appears in winter and conveys the information about suitable countermeasures to the organizations concerned. The establishment of AQM station for air pollution makes it possible to obtain one-hour monitoring in addition to the existing 24-hour monitoring data. The alarm is however announced based not on the short-term evaluated data but on the 24-hour monitoring data. Before the monitoring method for environmental standards is revised, it is necessary to take actions in an emergency case by referring to the evaluation criteria for short-term of WHO.

(2) Personnel Planning

For the effective operation of the APMC, the following administrative officers and engineers are required.

- Two administrative managers
- Six environmental engineers for monitoring, analysis, data management and maintenance
- Two electronics engineers for computation and communication

General office hours of the APMC follow the other administrative conditions. It is however necessary to arrange 24-hour shifting of personnel and provide against an emergency which it is expected that such a serious air pollution as stagnation occurs and that the alarm is announced depending on the meteorological conditions.

(3) Personnel Development Planning

Enough attention should be paid to the operation of the APMC because the newly

established monitoring system differs from the existing one from the technical viewpoint. That is to say, hardware such as monitoring instruments and computer equipped with microchip and software to run the hardware are introduced into the monitoring system. It is difficult to cope with the existing techniques in O & M of monitoring instruments and extensive knowledge about the overall environment is required. It is therefore necessary for the administrative officers and engineers to receive the step-by-step training and re-education for the operation of the APMC.

1) Short-term Training

Short-term training includes the followings:

- Training held by manufacturer at site
- Lecture and training by newly employed researcher or technical adviser such as professor of university

2) Medium- and Long-term Training

Medium- and long-term training include the followings:

- Three to six months training at environmental monitoring institutes
- Training of engineer at environmental department to be established in university after arrangement with the organizations concerned
- Receiving of foreign expert

6.4 Planning on Maintenance and Management

6.4.1 Installation Condition of Monitoring Instruments

At the time of installation of monitoring instruments it is necessary to pay attention to the following local conditions such as vibration, corrosive gas and dust, humidity, fluctuation of voltage and frequency, level, easiness and safety of maintenance works and sampling tube.

6.4.2 Maintenance of Monitoring Station

(1) Difference in Temperature

Measurement errors may be caused inside of the monitoring instruments when the temperature at the time of installation is different from that of calibration period. Thus it is advisable to install the air conditioner in order to minimize the temperature difference between installation and calibration. The precaution shall also be taken to the application of air conditioner in summer because the moisture content in air sample condenses and the condensed water leads to measurement error as the results of lowering the station room temperature compared with the outside temperature. It is therefore necessary to pay full attention to the difference in the temperatures among installation, calibration and operation.

(2) Maintenance of Air Sampling Tube

The fouling and stain inside the air sampling tube often affect the adsorption or disintegration of monitoring pollutants and thereby leads to reading errors. Thus it is necessary to replace or clean the air sampling tube periodically or more frequently per year depending upon the monitoring conditions. It is also important to inspect the leakage at the air sampler connection part.

6.4.3 Maintenance of Monitoring Instruments

For continuous monitoring of air pollutants, automatic air pollution monitoring instruments have to be effectively and reasonably operated with high reliability. Basic maintenance works for monitoring instruments to keep accuracy of value and reliability at high level are summarized in Table 6.3.

Table 6.3 Major Items and Schedule for Maintenance Works

Check	Purpose	Frequency	Content
Daily check	Continuous normal operation of automatic monitoring instruments	Minimum once/week	1. Check of operation status of monitoring instruments 2. Replacement of consumables 3. Calibration 4. Cleaning
Periodical check (Close check) (Check of transmission accuracy)	Functions and prevention of trouble (keep within accuracy standards)	Minimum once/year	1. Inspection of flow path 2. Inspection of detector 3. Inspection of control and transmission systems 4. Inspection of amplifiers and recorders
Emergency check	Rapid and prompt check for trouble shooting when malfunction or breakdown	At the time of emergency	1. Identification of breakdown and its minor repairs 2. Identification of cause and repair by manufacturer
Function test	Prevention of trouble and to secure the continuous maintenance and data evaluation (required thorough comprehension of equipment characteristics)	When purchasing equipment and when necessary	1. Equipment function test (standard gas) 2. Equipment stability test (fluctuation of flow, zero, span drift, etc.) 3. Validation of monitoring data
Calibration with standard gas	Determination of the accuracy range	When necessary	1. Check with standard gas 2. Compile calibration curve

6.4.4 Maintenance Management Software for Monitoring Instruments

Maintenance management software for monitoring instruments is a software which enhances the diagnostic function. When the central station receives the trouble message, trouble shooting will be displayed on the screen. Such maintenance management software is very convenient for getting a simple understanding of trouble shooting. It is therefore recommended that the software be introduced to the expansion of monitoring system in model city and for nationwide system. The major functions are summarized in the S/R (p.6-37).

An example of the menu for maintenance management software is shown in Figure 6.6.

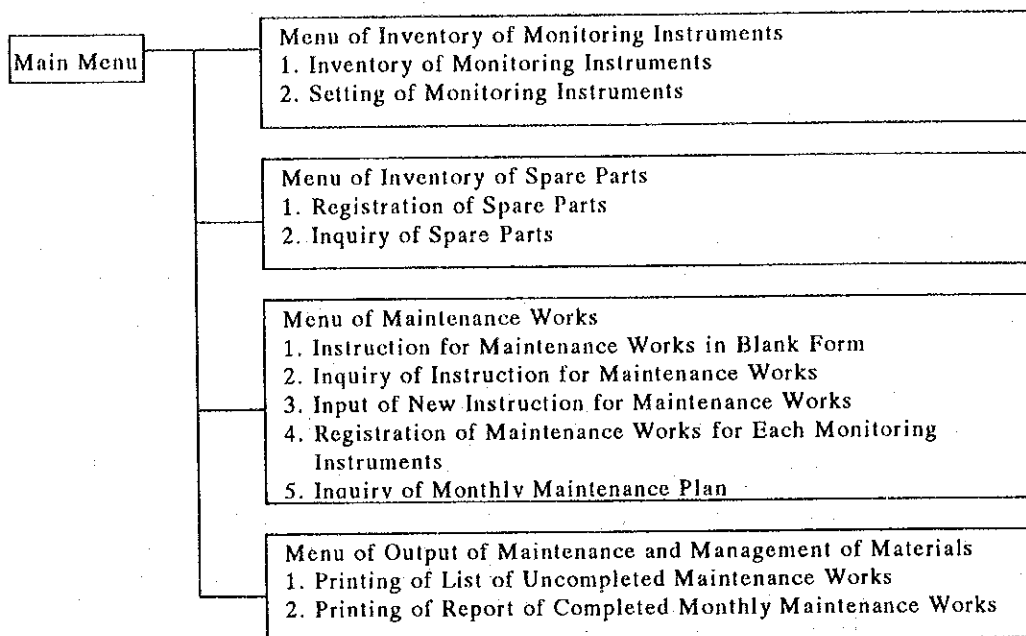


Figure 6.6 Overview of Menu of Maintenance Management Software

6.4.5 Maintenance and Management Planning on Equipment and Materials Procured for the Study

The four AQM stations and a mobile monitoring car in the model city procured and installed for the Study were provided for the Government of Macedonia based on the request after the completion of the Site Work IV in March, 1999. The maintenance and management for the monitoring equipment and materials should be carried out under the responsibility of the MOE. The processing and management of data sent continuously from AQM stations are one of the important jobs. Periodical maintenance makes it possible to use the monitoring equipment and materials up to following seven to ten years approximately.

(1) Personnel

In order to monitor the instantly varying ambient air quality continuously and validate the acquired data at the central station, it is recommended that an administrative officer and an environmental engineer should be posted at the central station. The environmental engineer judges whether the data acquired have abnormality or not and hands over statistically processed data to the administrative officer.

The administrative officer judges whether the processed data clear the environmental standards or not and takes necessary actions if required.

The concentration of SO₂ and SPM in winter and that of O₃ in summer exceeds the environmental standards in the model city. It is therefore necessary to post the full-time personnel for the continuous monitoring of data. It is also necessary for the personnel to have full knowledge of environmental administration, validation of data and monitoring instruments.

Mobile monitoring car is under the management of IEZ. Seven personnel comprising of two environmental engineers, four assistants and a driver are necessary for the emission monitoring and management because additional works at the site such as the preparation of monitoring instruments loaded on the vehicle, connection of sampling probe to the flue duct or stack, etc. are needed.

(2) Maintenance and Management

It is desirable that the specialized engineers of the MOE carry out basically all the maintenance and management works including check, inspection and calibration for AQM stations and monitoring instruments. It is necessary to keep up with the rapid progress in the monitoring instruments, as well as the computer technology of the improved monitoring systems in the developed countries.

Monitoring instruments at AQM stations in the model city are completely different in the structure and principle from the existing monitoring equipment such as British sampler in Macedonia. The present monitoring instruments apply the state-of-the-art electronics and physical technology. Therefore it takes considerable time to acquire the O & M techniques even though the engineer receives training at the manufacturer of monitoring instruments.

Through the daily patrolling and inspection of AQM stations, simple maintenance works were provided by the engineer including the replacement of filter paper, calibration, status check of monitoring instruments, etc. It can be said that the maintenance techniques are now at the initial level.

There are two options to maintain and manage the present AQM stations. The outlines of each option are as follows:

1) Maintenance and Management by the MOE

It is possible to provide a basic maintenance of the monitoring instruments according

to the given specification; monthly replacement of the filter papers of the analyzers for SO₂, CO, NO_x and O₃, replacement of the filter papers of the TEOM on a 2-4 weeks basis depending on the air quality; quarterly replacement of the by-pass filters of the TEOM; replacement of the active coal and the purifier in each analyzer; complete calibration of all analyzers through the solution system once a month. Such a dynamic maintenance requires spare parts for at least one-month continuous operation of the system, which are to be provided by the MOE.

2) Outsourcing to Local Agent

In case all the maintenance and management works of AQM stations are outsourced to the local agent, it is possible firstly to secure the operation of monitoring instruments and the acquisition of monitoring data without the specially high-level techniques by way of completely outsourcing the responsibilities for the maintenance and management of stations to the local agent, and secondly to save the time and manpower for patrolling, trouble shooting, etc..

In order to understand a series of monitoring activities from the operation of monitoring instruments to the validation and evaluation of monitoring data, it is desirable that the MOE itself maintain and manage the monitoring stations. The manpower of the MOE is sufficient for regular maintenance, but for more complex defects such as regular overhauls, it is necessary to collaborate with the local agent depending on the extent of maintenance and trouble in order to operate during long time and to acquire the maintenance techniques little-by-little through the daily maintenance works and co-works with local agent. Once enough knowledge and experiences for a series of monitoring activities including the maintenance of monitoring instruments are acquired, it is possible to make a decision whether the MOE itself maintains and manages the stations or outsource to the local agent, taking into consideration the other factors such as manpower, budget, etc.. In Japanese case, both two options mentioned above can be observed depending on the conditions of municipalities.

An engineer was dispatched only for the purpose of the Study, from the RHI to the MOE for maintenance and management of AQM stations and returned to the RHI in March 1999. It is however desirable that the MOE maintain and manage the present AQM system obtaining the technical cooperation from the engineer from the RHI consecutively.

6.5 Implementation Planning

Implementation schedule for the air pollution monitoring system in the model city is divided into three stages as mentioned below:

(1) Present Stage of Urgently Required Monitoring

It is possible to monitor the followings with the present AQM and mobile monitoring system introduced in the course of the Study:

- Four sets of AQM
- One set of stationary emission source monitoring with mobile monitoring car
- Dust monitoring in ambient air and its component analysis

(2) First Stage of Monitoring Plan within Five Years

- Setting up of additional two AQM stations
- Installation of three CEM stations
- Introduction of a mobile monitoring system
- Introduction of one set of auto-exhaust gas inspection system
- Establishment of the APMC including data bank system
- Improvement in analytical instruments of the IEZ (first phase)

AQM station and mobile monitoring system in the model city will comprise of six stations and two systems in total, respectively. Most of the establishment of monitoring system in the model city will therefore be completed in the first stage of implementation plan.

(3) Second Stage of Monitoring Plan within Ten Years

- Improvement in analytical instruments of the IEZ (second phase)

Table 6.4 shows the implementation schedule on the each stage.

Table 6.4 Implementation Schedule

Stages	Contents
Present stage (urgently required monitoring) The equipment was introduced in the course of the Study	<ul style="list-style-type: none"> - Four stations of AQM - One set of emission monitoring with mobile monitoring car - Dust monitoring in ambient air and its component analysis
First stage (within five years)	<ul style="list-style-type: none"> - Setting up of additional two AQM stations - Installation of three sets of CEM system to three large-scale stationary emission sources - One set of emission monitoring with mobile monitoring car - Introduction of a set of auto-exhaust gas inspection system - Establishment of the APMC including data bank system - Improvement in analytical instruments of the IEZ (first phase)
Second stage (within ten years)	<ul style="list-style-type: none"> - Improvement in analytical instruments of the IEZ (second phase)

6.6 Estimation for Project Expenses

6.6.1 Cost Estimation for Equipment and Materials for model city

Total estimated cost for the establishment of air pollution monitoring system in the model city during both first and second stage would be US\$ 2,090,660 including equipment and materials, annual consumables and spare parts. Table 6.5 shows the summary of cost estimation for air pollution monitoring system in the model city.

The details of cost estimation of each monitoring and inspection system are shown in the S/R (p.6-39).

Table 6.5 Summary of Cost Estimation for Air Pollution Monitoring System in Model City

Unit: US\$

Stage	Item	Cost Estimation			
		Equipment & Materials	Consumables	Spare Parts	Total
1st	AQM	428,200	6,780	12,710	447,690
1st	CEM	312,300	16,800	6,400	335,500
1st	Mobile monitoring	255,100	22,430	1,200	278,730
1st	Auto-exhaust gas inspection	78,500	5,240	3,900	87,640
1st	Software for data acquisition and processing for APMC	148,000	2,500	-	150,500
1st	Improvement in analytical instruments for IEZ (1st phase)	536,940	-	-	536,940
2nd	Improvement in analytical instruments for IEZ (2nd phase)	253,660	-	-	253,660
1st Stage Total		1,759,040	53,750	24,210	1,837,000
2nd Stage Total		253,660	-	-	253,660
Total		2,012,700	53,750	24,210	2,090,660

Lifetime of monitoring instruments is 7 to 10 years approximately and the renewal of present monitoring instruments will be at the time of completion of second stage. It is therefore necessary to secure the budget for renewal about US\$ 150,300 per AQM station, US\$ 8,400 for mobile monitoring car and US\$ 15,000 for APMC.

The estimated cost for the maintenance of air pollution monitoring system in the model city through the outsourcing to the local agent is as follows:

- Consumable:	US\$ 53,750
- Spare parts:	US\$ 24,210
- Fee of service engineer:	US\$ 16,000
- <u>Transportation:</u>	<u>US\$ 16,000</u>
Total	US\$ 109,960

6.6.2 Cost Estimation for Maintenance and Management of Present System

Annual cost for the maintenance and management of present monitoring system comprises of consumables, spare parts and service engineering fee. The annual cost estimation for the consumables and spare parts for the maintenance and management of four AQM stations and a mobile monitoring car is US\$ 26,000 per year approximately. The cost for outsourcing to the local agent is US\$ 32,000 approximately.

- Consumables:	US\$ 16,900
- Spare parts:	US\$ 9,100
- Fee of service engineer:	US\$ 16,000
- <u>Transportation:</u>	<u>US\$ 16,000</u>
Total	US\$ 58,000

6.6.3 Cost Estimation on Each Implementation Schedule

Table 6.6 shows cost estimation on each implementation schedule for establishment of monitoring system.

Table 6.6 Cost Estimation on Each Implementation Schedule

Unit : US\$

Item	Stage & Year	First Stage				
		1	2	3	4	5
Initial investment cost						
AQM system		428,200	-	-	-	-
CEM system		312,300	-	-	-	-
Mobile monitoring		255,100	-	-	-	-
Auto-exhaust gas inspection		78,500	-	-	-	-
Data acquisition and processing for APMC		148,000	-	-	-	-
Subtotal		1,222,100				
Annual O & M Cost						
Spare parts & consumables		77,960	77,960	77,960	77,960	77,960
Fee of service engineer & transportation (outsourcing case)		32,000	32,000	32,000	32,000	32,000
Subtotal		109,960	109,960	109,960	109,960	109,960
Other investment cost						
Improvement in analytical instrument for IEZ		536,940	-	-	-	-
Total		1,869,000	109,960	109,960	109,960	109,960

Item	Stage & Year	Second Stage				
		6	7	8	9	10
Initial investment cost						
AQM system		-	-	300,600	300,600	300,600
CEM system		-	-	-	-	-
Mobile monitoring		-	-	-	-	227,000
Auto-exhaust gas inspection		-	-	-	65,000	-
Data acquisition and processing for APMC		-	-	150,000	-	-
Subtotal				450,600	365,600	527,600
Annual O & M Cost						
Spare parts & consumables		77,960	77,960	77,960	77,960	77,960
Fee of service engineer & transportation (outsourcing case)		32,000	32,000	32,000	32,000	32,000
Subtotal		109,960	109,960	109,960	109,960	109,960
Other investment cost						
Improvement in analytical instrument for IEZ		253,660	-	-	-	-
Total		363,620	109,960	560,560	475,560	637,560

6.7 Procurement Procedure

In order to establish the air pollution monitoring system, the proceeds of any loan of international financial institute may be applicable to the procurement of monitoring equipment and materials. The general procedures are summarized in Figure 6.7. The

details are described in the guidelines being published by each financial institution.

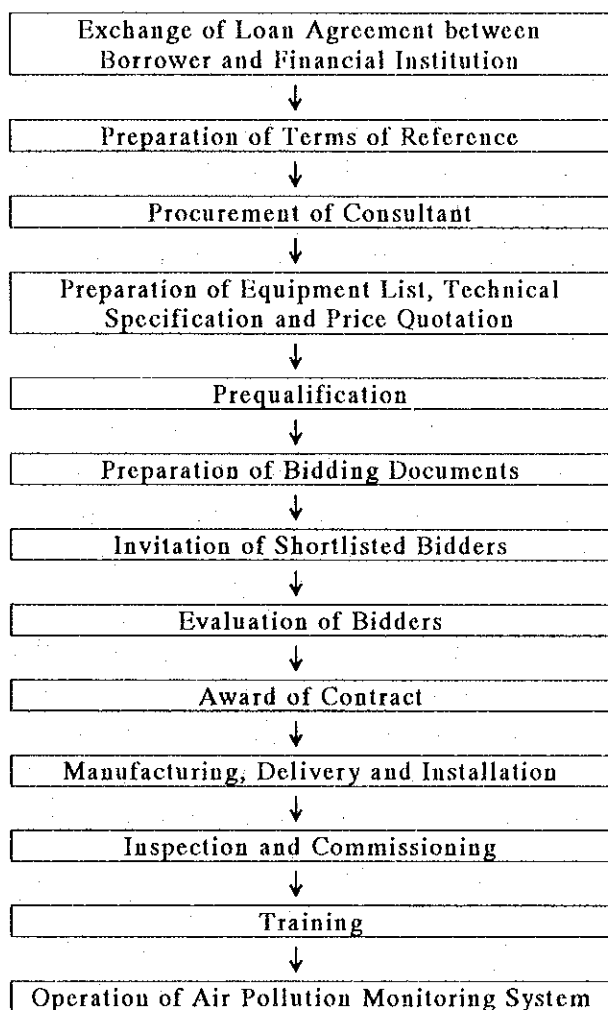


Figure 6.7 General Procurement Procedures under International Financial Institution

- 1) Considerations for Procurement of Equipment and Materials
 - a) Bidding for Procurement

The procured equipment and materials may not be fully utilized if the manufacturer fails to provide the appropriate after-sales service. To ensure effective utilization

over a long period, it is necessary before procurement that measures to prevent the manufacturer from simply selling of spare parts and materials and failing to provide after-sales service be incorporated in the specification. In this context, it is desirable to select a reliable bidder and a technically acceptable method without placing too much emphasis on the price only.

Prospective bidders must initially be pre-qualified to determine whether they are suitably qualified and then they will be requested to submit a proposal for supply of the equipment and materials. The content of the proposals must be reviewed beforehand and a few bidders will be selected. Subsequently, the bidding documents are distributed to the shortlisted bidders, requesting them to submit the technical and /or financial proposal(s) and bid bond. But two-envelope type bidding is desirable.

b) Preparation of Technical Specification

Preparation of a clearly understandable specification is the sole means to prevent trouble with the manufacturer during various procurement processes.

A vague specification may lead to such troubles as difference in the standard or the delivery of a different product due to a difference in the interpretation of the manufacturer.

The specification must be prepared by specifically describing the item, quantity and specification details. The delivery conditions must also be clearly defined upon presentation of the estimate by presenting the specification details to the manufacturer. Even when the specification has been prepared with careful consideration as above described, there are always inquiries from the participants during and after the bid orientation meeting. The executing agency must provide the technical reply to these questions. This requires that the above mentioned agency must have in-depth knowledge of the equipment and materials resulting from a careful study. It is therefore a general practice to have assistance from the consultant, concerning the procurement of the equipment and materials, including preparation of the specification. An example of the specification reviewed during development of the air pollution monitoring equipment and materials plan is shown in the Supporting Report while limiting the description to the principal equipment and materials (SO₂, NO_x, CO, O₃ and SPM meters, ultrasonic wind-vane anemometer and container housing).

c) Presentation of Estimate and Preparation of Estimated Price

The estimate of the air pollution monitoring system includes the local transportation, installation and adjustment and necessary training as well as the equipment and materials itself.

The estimate conditions are summarized roughly as follows:

- Guarantee of spare parts and consumable items for the two-year operation taking into consideration the air pollution and meteorological conditions of Macedonia
- Delivery of equipment and materials at the specified place
- Clear definition of the delivery limit and the installation/adjustment period in the estimate
- Installation work of the equipment/materials including auxiliary works (electricity, fence, etc.)
- The warranty period of equipment/materials is to be one year or more after acceptance
- Training is to be provided twice for the specified principal equipment/materials
- Periodic inspection is to be made twice during the warranty period and once in six months after expiration of the warranty period for the specified equipment/materials
- Clear designation of accessories included in the main body and those not included

Various expenses necessary for the above must be described in the estimate, separately from the price of the main body. It is also necessary to indicate the purchase price of the equipment/materials either on the basis of EX-GODOWN, FOB, or CIF.

The estimated price and bidding documents must be prepared after thorough study on the result of estimate presentation and the previous price by each equipment/material item.

The estimated price is prepared for the purpose of establishing the judgment criteria to enable purchase with advantageous prices as much as possible, as well as review of the project budget. Preparation of the estimated price requires especially careful attention so as not to exert an adverse effect on the subsequent implementation of the bidding, the contract, delivery and inspection.

(3) Bidding

1) Bidding Procedures

International financial institutions consider that, in most cases, International Competitive Bidding (ICB) is the best method for achieving the economical and efficient procurement of equipment and materials. The following methods other than ICB to be followed for the procurement of equipment and materials are generally specified in the loan agreement between the borrower and the financial institution:

- Limited international bidding (LIB)
- Local competitive bidding (LCB) to the local portion
- International shopping

- Direct contracting

2) Prequalification of Bidders

Prequalification is advisable for large or complex works and, exceptionally, for custom-designed equipment and specialized services to ensure, in advance of bidding, that invitations to bid are extended only to those who are capable. Prequalification should be based entirely upon the following capability of prospective bidders to perform the contract satisfactorily:

a) Qualification

- Experience of and past performance on similar contracts
- Capabilities with respect to personnel, equipment and plan
- Financial position

b) Technical Level

In addition, the bidder must have a certain technical level. Evaluation details in the technical level are as follows:

- Installation, adjustment and training plan after delivery
- Details and system of the after-sales service, including maintenance during the warranty period
- System for the supply of parts, etc.
- Countermeasures in case of a failure (the number of days required, the presence of the agent in Macedonia or neighboring countries)
- Details and costs of a maintenance service agreement when this is necessary after expiration of the warranty period
- Technical countermeasures proposed by the contractor for meteorological conditions, etc. at the time of selection of the equipment and materials

3) Two-stage Bidding

In the case turnkey contracts or contracts for large complex works of a special nature, it may be undesirable or impractical to prepare complete technical specifications in advance. In such a case, a two-stage bidding procedure may be used, under which first unpriced technical proposals on the basis of a conceptual design or performance specifications are invited, to be followed by priced bids in the second stage.

4) Bidding Documents

The bidding documents should provide all information necessary to enable a prospective bidder to prepare his bid for the goods and services to be provided. While the detail and complexity of these documents will vary with the size and nature of the proposed bid package and contract, they should generally include the followings:

- Invitation of bid
- Instructions to bidders
- Form of bid
- Form of contract
- Conditions of contract (both general and special)
- Technical specifications
- List of goods or bill of quantities and drawings
- Necessary appendices
- Detailing, for example, the type of security

5) Selection of Successful Bidder

General procedures from the bidding to the award of contract are as follows:

- Opening of bids
- Examination of bids
- Evaluation and comparison of bids
- Preparation of evaluation report
- Award of contract

6) Inspection and Commissioning

a) Factory Inspection

The manufacturer must conduct the performance test before shipment and prepare the test result while making adjustments so that the installed equipment complies with the requirements of the specification. Subsequently, the factory inspection must be made on the principal equipment and materials.

b) Pre-shipment Inspection when Required

c) Unpacking Inspection of Equipment and Materials Delivered at Site

After delivery to the specified place, the equipment and materials must be unpacked and thoroughly checked with regard to quantity and damage of the packaging or equipment/materials caused during transport. The principal items to be checked are the following:

- Check of the quantity of the equipment/materials and the standard accessories, spare parts and additional accessories
- Check of the nameplate which indicates the name, serial number and date of manufacture, the power supply, etc., for the equipment and materials
- Confirmation that the inspection has been completed when an export inspection, etc. is necessary.
- Confirmation of the content and quantity of the necessary items to be submitted, including the operating manual, etc..

The result of the unpacking inspection is summarized on the specified acceptance sheet.

d) Performance Test

After installation of the equipment and materials, an inspection must be made to determine whether or not the performances comply with the specification.

The final acceptance becomes effective when there is no problem with the performance, everything including the system and software is functioning properly, and when the monitoring starts. It is to be noted that the acceptance is rejected, with the requirement that improvement or replacement be made, when the description of the specification or the contents of test result is not complied with. On the other hand, the equipment and materials are judged to be acceptable when their performance, quality, etc., are superior to the performance stipulated in the specification and do not present any practical problem. The acceptance result is summarized on the acceptance sheet.

7) Training

Training for the routine operation, maintenance and trouble shooting should be provided for the operational staff members by the manufacturer, local agent and/or supplier. The training may be categorized into the followings:

- a) Training at the manufacturers premises, prior to installation, when required
- b) Training after installation at the site
 - First training: Mainly concerned with handling of the monitoring equipment
 - Second training: Overall training on maintenance and minor repair of the equipment

and materials

8) Maintenance

The scope of the contract includes the duty of periodical inspections, a total of three times, for a period of 18 months for the specified equipment/materials. It is desirable to conclude the maintenance agreement for the equipment/materials subsequently with the manufacturer or agent.

Considering the maintenance and troubleshooting for the procured monitoring system, it is important factor to select the manufacturer which have the local agent. One of options to maintain the monitoring system after the taking over the equipment and materials is outsourcing to the local agent.

<Supporting Material on AQM Center and CEM Station>

An image of Air Quality Monitoring Center and Continuous Emission Station are given on the next page for a grasp of those systems, which are recommended by the Study.

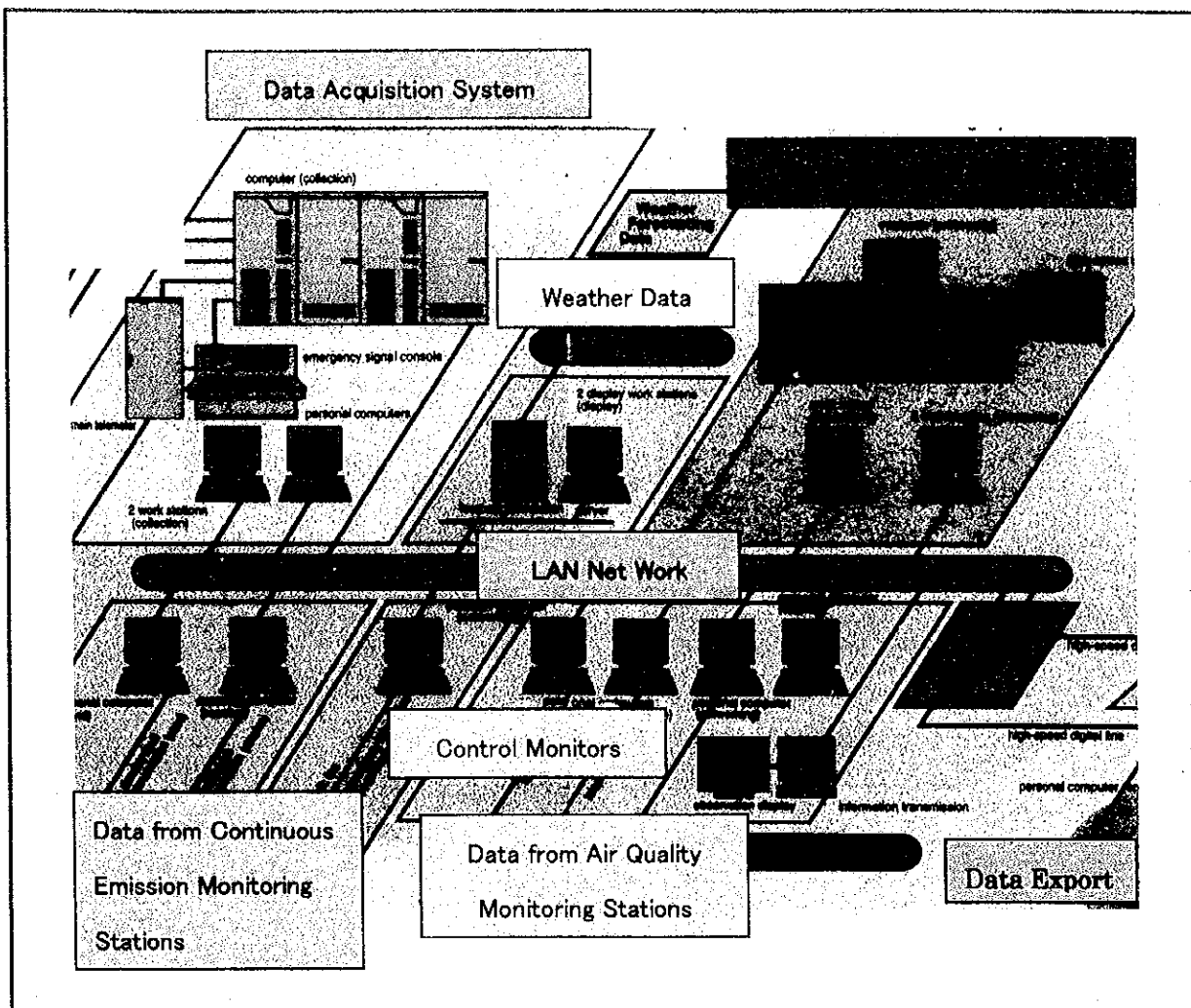


Figure 6.8 An Image of Air Quality Monitoring Center

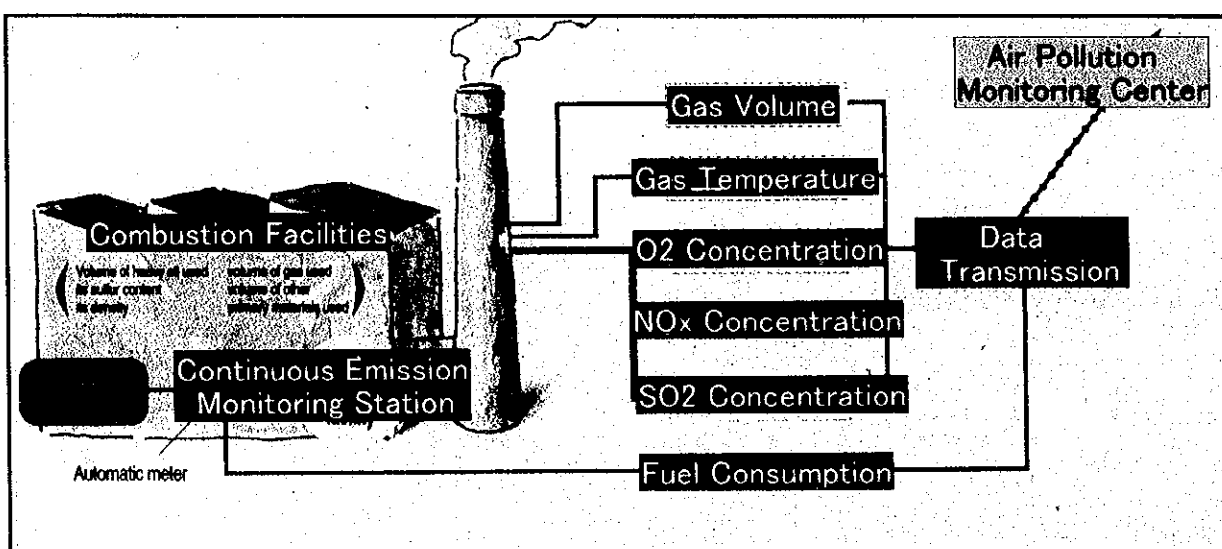


Figure 6.9 An Image of Continuous Emission Monitoring

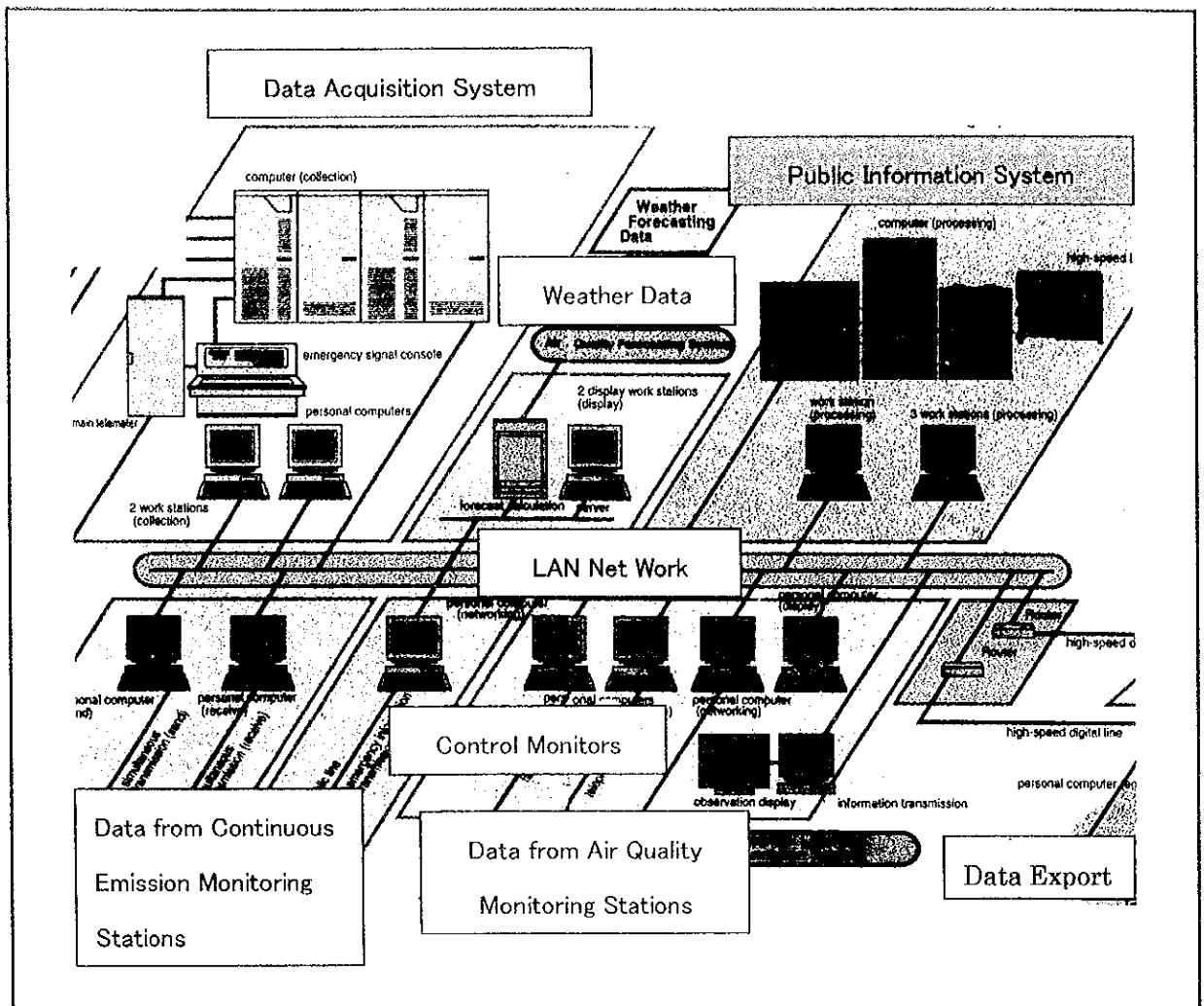


Figure 6.8 An Image of Air Quality Monitoring Center

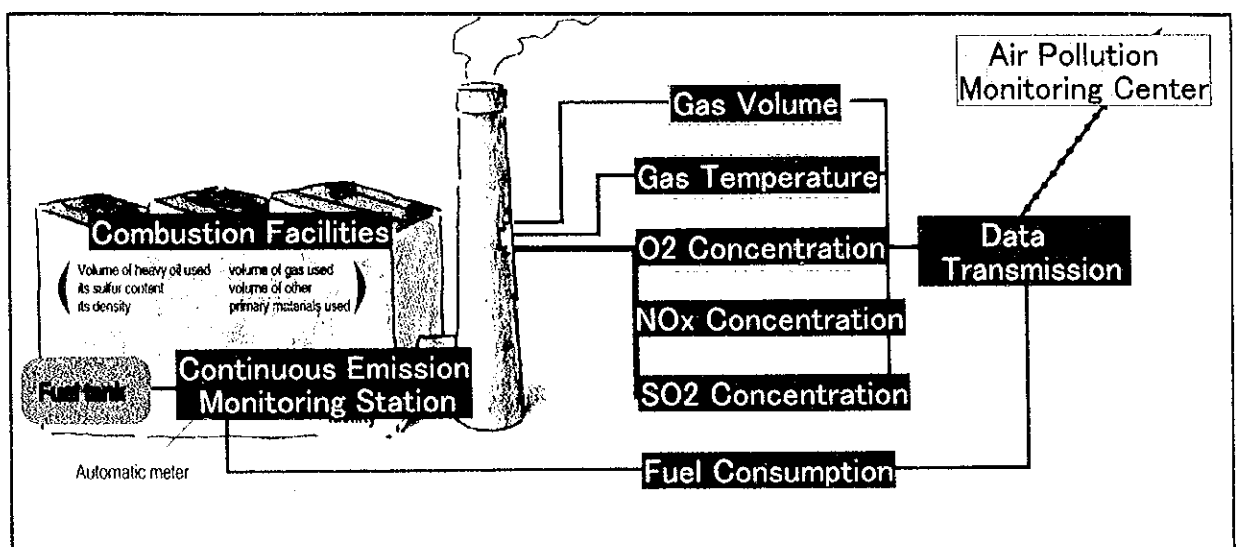


Figure 6.9 An Image of Continuous Emission Monitoring