MALAYSIA

AIR QUALITY MANAGEMENT STUDY FOR KELANG VALLEY REGION

FINAL REPORT
VOL.1
SUMMARY

AUGUST 1993

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct a Master Plan Study on Air Quality Management Study for Kelang Valley Region in Malaysia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Malaysia a study team headed by Mr. Makoto Miyakawa, SUURI-KEIKAKU CO., LTD. and composed of members from SUURI-KEIKAKU CO., LTD. and Pacific Consultants International seven times between December 1991 and June 1993.

The team held discussions with the officials concerned of the Government of Malaysia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

August 1993

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

MALAYSIA
AIR QUALITY MANAGEMENT STUDY FOR KELANG VALLEY REGION
SUMMARY

(1) Target Area

Kelang Valley Region

(2) Target Year

The year 2005

(3) Air Quality Target Value

Pollutant	Target Value (annual mean)
SO_2	20 ppb
NO_2	37 ppb
CO	4 ppm

(4) Predicted Air Quality in 2005 (without control Measures)

Pollutant	Maximum Concentration (annual mean)
SO_2	66 ppb
NO_2	63 ppb
CO	11 ppm

(5) Proposed Control Measures

The Table in the last page of the Summary shows the proposed measures and their rough costs.

(6) Evaluation of Proposed Measures

1) Change of Air Pollution Load from 1992 to 2005

(Unit: ton/year)

Pollutant	1992	2005	
		without measures	with measures
SO_x	35,654 (1.0)	51,598 (1.45)	27,055 (0.76)
NO_x	54,454 (1.0)	115,292 (2.12)	85,490 (1.57)
PM	12,605 (1.0)	18,495 (1.47)	11,604 (0.92)
CO	290,407 (1.0)	659,223 (2.27)	321,430 (1.11)
HC	73,445 (1.0)	166,720 (2.27)	103,973 (1.42)

Figures in parentheses are ratio of pollution load between 1992 and 2005.

2) Predicted Air Quality in 2005

Pollutant	Maximum Concentration	Air Quality Target Value
SO_2	19 ppm	20 ppb
NO_2	29 ppm	37 ppb
CO	3 ppm	4 ppm

3) Effectiveness of the Proposed Measures

If the proposed measures are taken as scheduled shown in the Guideline, the air quality in 2005 of SO_2, NO_2 and CO throughout the Kelang Valley Region will be expected to be below the Air Quality Target Values.

Proposed Measures and Their Rough Cost Estimation

Proposed Measures			Cost Estimation
Stationary Sources	Power Station	Fuel conversion from middle fuel oil/coal to natural gas	
	General factories	Fuel conversion from heavy fuel oil to natural gas (Petaling Jaya and Shah Alam)	M$ 2.9 million
		Fuel conversion from heavy fuel oil to light fuel oil(other areas)	
		Use of natural gas for new facilities	
		Combustion management	
		Energy saving	
		Installation of dust collector	M$ 4.0 million
		Extension of stack	M$ 0.2 million
		Replacement of wood combustion boilers	M$ 3.1 million
Motor Vehicles	Light Duty Vehicles	Enforcement of 91/441/EEC for petrol vehicles Shift of diesel taxi to petrol taxi	M$ 1,400/unit
		Introduction of taxi using compressed natural gas	
	Motorcycles	Shift of 2-stroke motorcycles to 4-stroke motorcycles	Cost-up by 10%
		Use of smokeless lube oil for 2-stroke motorcycles	M$ 20/liter
	Fuel Control	Promotion of use of unleaded petrol instead of leaded petrol	
		Decrease of sulphur content in diesel oil to 0.2%	
	Public Transportation System	Complete fulfillment of Transportation Master Plan 2005	
Open Burning		Establishment of solid waste management system	
Institution and Organization	Department of Environment	Strengthening of the capacity	
	Air Quality Monitoring	Establishment of ambient air quality monitoring system - 11 fixed stations - 20 mobile stations	M$ 35.19 million M$ 21.71 million M$ 13.48 million
	Pollution Source Monitoring	Measurement of factory flue gas	
		Measurement of vehicle exhaust gas by chassis dynamometer test	
	Laws	Establishment of Combustion Management System	
		Establishment of Car Inspection System	M$ 9.0 million
	Supporting System	Establishment of a financial support system	
		Conclusion of Pollution Control Agreement	
		Introduction of flextime system	
Air Quality Management Center		Establishment of Comprehensive Air Pollution Control Center - Ambient air quality central monitoring center - Combustion training center - Ambient air quality monitoring training center - Pollution source monitoring center Equipment for factory flue gas measurement Chassis dynamometers 1 unit for petrol vehicles 1 unit for diesel vehicles	M$ 53.9 million M$ 35.2 million M$ 5.7 million M$ 0.76 million M$ 12.24 million M$ 0.24 million M$ 12 million M$ 4 million M$ 8 million

Contents

CHAPTER 1 INTRODUCTION

1.1 Background and Objective of the Study

(1) Background

Kelang Valley Region (2,830 km², about 2.95 million people) consisting of Kuala Lumpur (the capital of Malaysia) and its vicinity has been experiencing worsening air pollution in recent years as a result of the rapid growth of traffic volume, urbanization and industrial activities.

In response to the request by the Government of Malaysia for technical cooperation in conducting Air Quality Management Study for Kelang Valley Region (hereinafter referred to as "the Study") the Government of Japan, through the Japan International Cooperation Agency (hereinafter referred to "JICA") dispatched a Study Team to carry out the Study jointly with the Government of Malaysia in preparing a guideline for Air Quality Management for Kelang Valley Region. The Study commenced on 19th December, 1991 when the Steering Committee was held a meeting and accepted the Inception Report. During the course of the Study, two progress reports, an interim report, and a draft final report were submitted to the Government of Malaysia. This report summarizes the results of the Study.

(2) Objective of the Study

The Study aimed to prepare a guideline for air quality management for Kelang Valley Region with special emphasis on improving air quality monitoring capability, identification of major pollution sources, prediction of future air pollution and feasible control measures. At the same time, the Study was expected to contribute to tangible technology transfer to Malaysian counterparts.

1.2 Outline of the Study

(1) Study Area

The Study area is Kelang Valley Region which is shown in Fig. 1.1. It is approximately 60 km from east to west and 40 km from south to north, consisting of the Federal Territory (Kuala Lumpur) and Klang, Petaling, Gombak and Hulu Langat of Selangor State.

(2) Outline of the Study

A flowchart summarizing the Study methodology is shown in Fig. 1.2. The Study commenced with meteorological observation, air quality monitoring and pollution source investigation. Based on analysis of these measured/surveyed data, an air dispersion simulation model for Kelang Valley Region was developed. Then, based on data on future traffic and energy demand, future pollution load was estimated, and future air pollutant concentration was predicted and measures necessary for preserving comfortable environment in the Region were examined. And finally an guideline for air quality management for Kelang Valley Region was formulated.

(3) Study Schedule

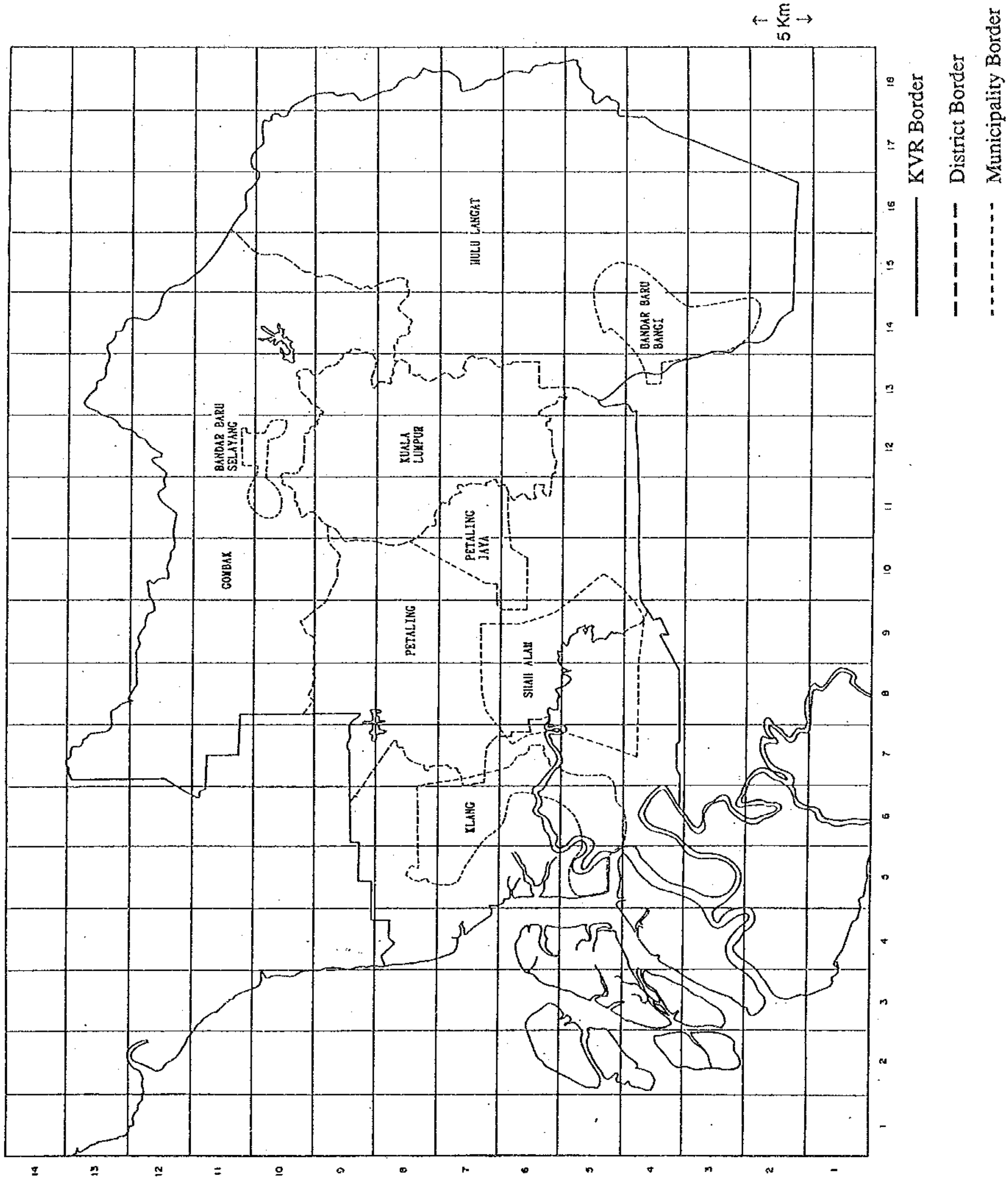
The Study was conducted from December 1991 to August 1993. The Study schedule is shown in Fig. 1.3.

(4) Technology Transfer

The Study team was able to transfer technology to Malaysian counterparts regarding fundamental knowledge of measurement principles, measurement methods and equipment maintenance on meteorological observation, air quality monitoring, exhaust and flue gas measurements and chemical analysis. Technology transfer was also made on analytical study, such as analysis of measured data, estimation of air pollution load, development of air dispersion simulation model, air pollution control measures and air qulity management planning.

During the Study, three Malaysian officers were trained in Japan in areas of air quality monitoring, air dispersion simulation and air quality management.

Fig. 1.1 Study Area



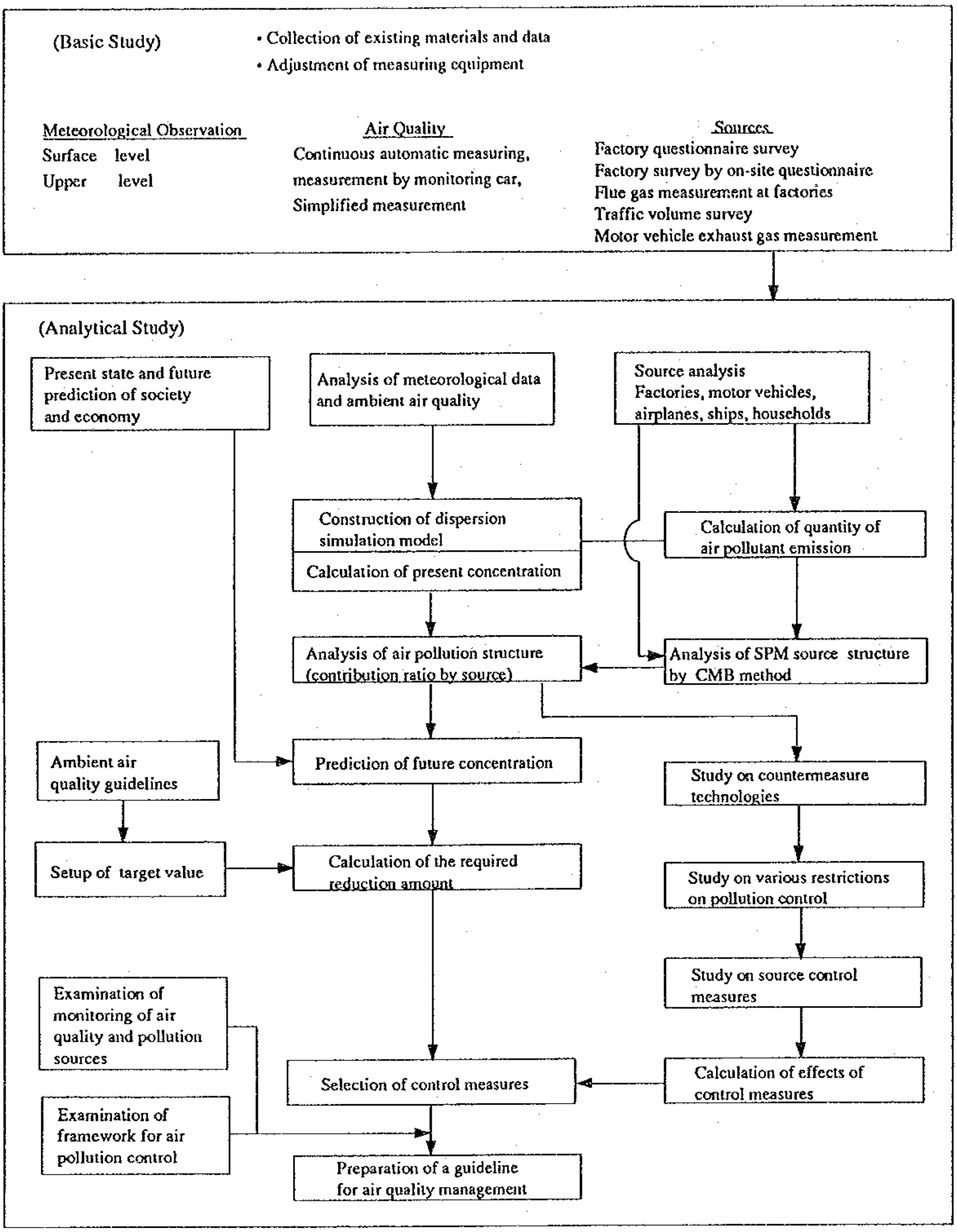


Fig. 1.2 Outline of the Study

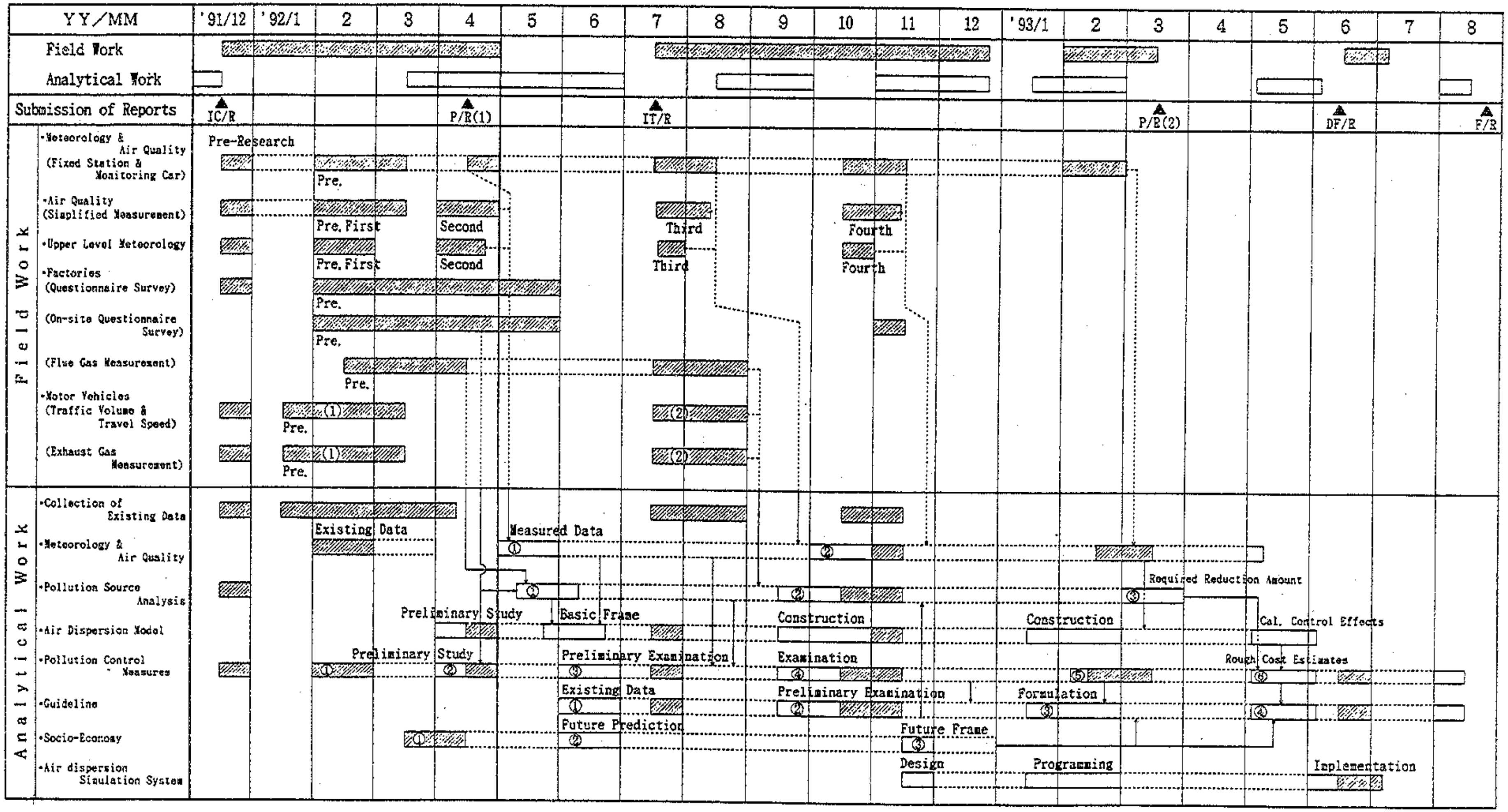


Fig. 1.3 Study Schedule

1.3 Organization for the Study

The Study was carried out jointly by JICA and the Government of Malaysia in cooperation with related agencies.

(1) Malaysian Organization

The Economic Planning Unit of the Prime Minister's Department (EPU) was the main coordinator for the Study, and the main counterpart agency was the Department of Environment, Ministry of Science, Technology and Environment (DOE). Counterpart Team was formed to execute the Study smoothly. Steering Committee and Technical Committee were formed to execute the Study smoothly and to provide advice and consultations. Members of the Steering Committee, Technical Committee and leaders of the Counterpart Team are shown in Tables 1.1, 1.2 and 1.3 respectively.

Table 1.1 Members of the Steering Committee

No.	Name	Department
1.	Abdul Rahman Jamal Director Regional Economics Section (Chairman)	EPU
2.	Hasnol Zam Zam Ahmad (Secretary)	EPU
3.	YM. Tengku Azman bin Tengku Mat	Ministry of Housing & Local Government
4.	R. Letchumanan	Ministry of Energy, Telecommunication and Post
5.	Ismail Mohamad	Ministry of Transport
6.	Leong Chow Peng	MMS
7.	Arisfadilah bin Sariat	EPU
8.	Noor Aini Ahmad	MOSTE
9.	Harvinder Kaur	EPU (Industry)
10.	Abdul Rahman Hj. Ahmad	Health Department, City Hall
11.	YM. Tengku Bakry Shah b. Tengku Johan	DOE
12.	Nor A'zman Rosli	DOE
13.	Mohd. Suhaimi Ahmad	EPU (Energy)
14.	Mohamad Yazi Md. Din	EPU (Energy)
15.	Mohd Fazi Matori	Ministry of Works

Table 1.2 Members of the Technical Committee

No.	Name	Agency
1.	Ir. Tan Meng Leng Deputy Director (Chairman)	DOE
2.	YM Tengku Bakry Shah Tengku Johan (Secretary)	DOE
3.	Mrs. Wan Ramlah Bt. Hj. Wan Ibrahim	DOE
4.	Mr. Ismail Isnin	DOE
5.	Ms. Azuri Azizah Saedon	DOE
6.	Mr. Marzuki B. Mokhtar	DOE
7.	Mr. S. Madhi B. S. Junaidi	DOE
8.	Mr. Masami Mizuguchi	DOE (JICA)
9.	Mr. Terutaka Ishikawa	DOE (JICA)
10.	Mr. Nor A'zman Rosli	DOE
11.	Mr. Hassan Mat	DOE (S'GOR)
12.	Mr. Ahmad Samsudin Che Abas	DOE
13.	Mrs. Wan Noraini Bt. Wan Hamzah	DOE
14.	Ms. Rosnani Bt. Ahmad Kasrin	DOE
15.	Mr. Abdul Rahman B. Hj. Ahmad	CITY HALL
16.	Mr. Dzulfakar B. Maisran	CITY HALL
17.	Mr. Wong Kok Fah	DOC
18.	Mrs. Leong Chow Peng	MMS
19.	Dr. M. Subramaniam	MMS
20.	Mr. Tan Choon Kim	SAMC
21.	Mr. Harjeet Singh	SSS
22.	Mrs. Latifah Bt. Hj. Mohd. Yatim	UPLK
23.	Ass. Prof. Dr. Azizan B. Abu Samah	UM
24.	Mr. Azman Zainal Abidin	UPM
25.	Ms. Lee Tzee Wan	PETRONAS
26.	Mr. Cheah Wai Kong	TNB

Table 1.3 Leaders of the Counterpart Team

1	YM. Tengku Bakry Shah Tengku Johan DOE	Supervision
2	Mrs. Wan Noraini Wan Hamzah DOE	Socio-economic Analysis and Development Plan
3	Mrs. Hajah Rosnani Ibrahim DOE	Guideline
4	Mr. Nor A'zman Rosli DOE	Stationary Source Control
5	Mr. Mohd Izzuddin Abd Ghani DOE	Mobile Source Control
6	Mr. Nor A'zman Rosli DOE	Equipment Management
7	Dr. Azizan Abu Samah UM	Modelling and Simulation
8	Mrs. Rahani Hussin DOE	Pollution Source Investigation
9	Mr. Azman Zainal Abidin UPM	Air Quality Monitoring
10	Mrs. Leong Chow Peng MMS	Meteorological Observation
11	Mr. Lum Koon Woon DOC	Chemical Analysis

(2) Japanese Organization

JICA, the official agency of the technical cooperation, chose Suuri keikaku Co., Ltd. and Pacific Consultants International as the consultants in charge of the Study. JICA formed Advisory Committee to ensure smooth execution of the Study. Members of the Study Team and Advisory Committee are shown in Tables 1.4 and 1.5 respectively.

Table 1.4 Members of the Study Team

1	Mr. Makoto Miyakawa Suuri-Keikaku Co., Ltd.	Overall Supervision/Organization and Institution
2	Mr. Ikuo Inoue Japan Machinery & Metals Inspection Institute	Meteorological Observation
3	Mr. Masanori Fuzikawa Japan Machinery & Metals Inspection Institute	Air Quality Monitoring
4	Mr. Mitsuru Fukuhara Japan Machinery & Metals Inspection Institute	Stationary Source Investigation
5	Mr. Yoichi Enokido Pacific Consultants International	Mobile Source Investigation
6	Mr. Ikushi Okada Japan Machinery & Metals Inspection Institute	Monitoring System
7	Mr. Akeo Fukayama Suuri-Keikaku Co., Ltd.	Meteorology and Air Quality Analysis
8	Mr. Seisuke Suzuki Suuri-Keikaku Co., Ltd.	Pollutant Source Analysis
9	Mr. Haruo Kikuchi Suuri-Keikaku Co., Ltd.	Modeling and Simulation Analysis
10	Mr. Yukihiro Nakano Suuri-Keikaku Co., Ltd.	Air Dispersion Simulation System
11	Mr. Hidenori Kaku Suuri-Keikaku Co., Ltd.	Mobile Source control
12	Mr. Shinzo Hirasawa Suuri-Keikaku Co., Ltd.	Stationary Source control
13	Mr. Norifumi Yamamoto Pacific Consultants International	Air Pollution Control Planning
14	Mr. Fumiaki Onoda Pacific Consultants International	Socio-economic Analysis/Development Plan
15	Mr. Tetsuaki Yokochi Japan Machinery & Metals Inspection Institute	Equipment Management/Chemical Analysis

Table 1.5 Members of the Advisory Committee

1	Dr. Hidetsuru Matsushita Professor, Graduate School of Nutritional and Environmental Science, University of Shizuoka Prefecture	Chairman/Overall Supervision
2	Mr. Susumu Ota Deputy director of Planning and Coordination Division, Planning and Coordination Bureau, Environment Agency	Air Pollution control
3	Mr. Naoya Tsukamoto Global Environment Specialist, Control and Coordination Division, Global Environmental Department, Environment Agency	Atmospheric Environment Analysis
4	Mr. Fumio Ueno Assistant Director, Office of Industrial Development, Industrial Base Division, Department of Commerce, Industry, Labor and Tourism, Hokkaido Government	Pollution Source Measurement

CHAPTER 2 OVERVIEW OF THE STUDY AREA

2.1 Natural Environment

(1) Topography

The Study area, Kelang Valley Region, a basin located in the southwestern part of the Malaysian Peninsula (Fig. 2.1) is surrounded by mountains exceeding 1,500 m height on the east and the Straits of Melaka on the west. The Klang River is the main river, which is joined by many branch rivers and flows into the Straits of Melaka through the Straits of Klang.

(2) Climate

Malaysia experiences a tropical rain forest climate (Af), which is influenced by monsoons from the South China Sea and the Indian Ocean. The Northeast monsoon season from December through February and the Southwest monsoon season from June through August are generally the dry seasons for the western part of Peninsular Malaysia. Two transitional seasons from March through May and September through November are rainy seasons with high humidity .

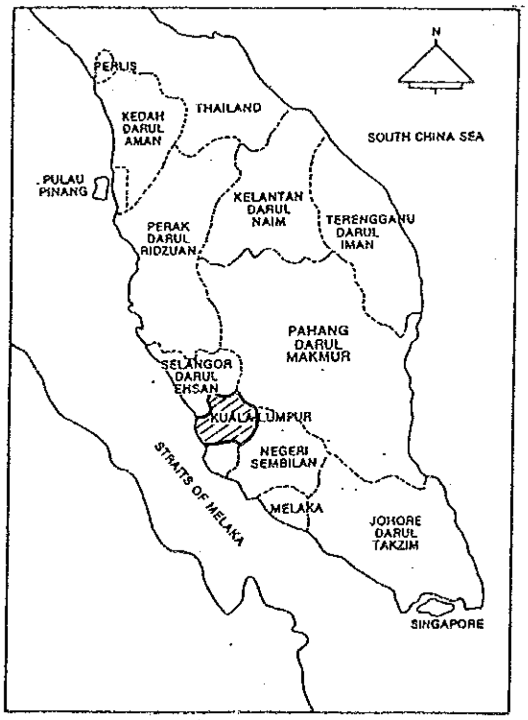


Fig. 2.1 Location of Kelang Valley Region

2.2 Social Environment

(1) Population

According to the latest census carried out in August 1991 and a preliminary count report (PCR) released in March 1992, the total population in Malaysia is 17.57 million. Among them, 2.95 million people (about 17% of the total population) live in the Kelang Valley Region. Our estimation shows a total number of 4.25 million people are expected to live in the Region in 2005. The phenomenon of population sprawling from the Federal Territory of Kuala Lumpur is conspicuous.

(2) Economy and Industry

The Malaysian economy has been expanding rapidly. The average growth rate was 6.7% during the period 1971-1990, and is expected to be 7.0% between 1991-2000. In Kuala Lumpur, the growth of big industries is expected to decline. Future growth will be in the small scale industries, repair and service activities and medium-sized industries with higher employment densities. In Selangor State, industries such as electrical & electronics and machinery & transport equipment are expected to develop rapidly.

(3) Land Use

Kuala Lumpur is the most urbanized area (80% of the total area), followed by Petaling (33%). Agricultural fields occupies the largest area in Klang (47%) whereas forest occupies the largest area in Gombak (55%) and H. Langat (40%).

(4) Transport

Motor vehicles are the major means of land transportation. The total number of registered vehicles in the Federal Territory of Kuala Lumpur and Selangor State is about 1.57 million at the end of 1991 and the percentage of petrol and diesel vehicles were 91% and 9% respectively. As to the percentage of types of vehicles, motorcycle accounts for 44%, followed by motor car at 43%, and they account for 87% of the total vehicles. But introduction of mass transportation system such as LRT and dual truck system of existing railways are expected to start in the near future. For air transport, Subang

International Airport is the only commercial airport in Kelang Valley Region which is being operated at full capacity. The new "Sepang International Airport" will be completed by 1997. Port Klang handles cargo traffic. However, since the port is becoming congested, the west port will be constructed at first in Pulau Lumut during the 6th Malaysian Plan period.

(5) Energy

In Kelang Valley Region, natural gas to households and factories will be supplied in the near future. Several thermal power plants are now under construction or planned by the year 2000.

2.3 Air Pollution Control

(1) Law

The most important law in Malaysia concerning environmental pollution is the Environmental Quality Act, 1974 (amended 1985). This law provides the framework for all states in Malaysia to regulate each environmental policies.

(2) Administrative Organization

The leading administrative organization covering environmental problems in Malaysia is the Department of Environment (DOE). DOE is one of the department in the Ministry of Science, Technology and Environment. DOE is composed of three divisions and ten regional offices (state offices). The main function of the regional offices is to carry out environmental quality monitoring and enforcement of the Environmental Quality Act. Kelang Valley Region is within the jurisdiction of the Selangor/Federal Territory Office.

CHAPTER 3 METEOROLOGY

3.1 Surface Level Meteorology

Outline of the meteorological stations under the Study is shown in Table 3.1 and the locations of the meteorological stations are shown in Fig. 3.1.

Table 3.1 Outline of the Meteorological Stations

Station Name		Observed Items						
		WD	WS	SUN	NETR	TEMP	HUM	RAIN
S-2	UPM	O	O	-	-	O	O	O
S-3	Petaling Jaya	O	O	O	O	-	-	-
S-4	Shah Alam	O	O	-	-	-	-	-
S-5	Klang	O	O	-	-	O	O	O

Abbreviation WD: Wind Direction, WS: Wind Speed
SUN: Solar Radiation, NETR: Net Radiation
TEMP: Temperature, HUM: Relative Humidity
RAIN: Rainfall Amount

In addition to the data above, the meteorological data at Subang (MMS) and Petaling Jaya (MMS) were provided by MMS (Malaysian Meteorological Service).

Characteristic features of the surface level meteorology in Kelang Valley Region are as follows.

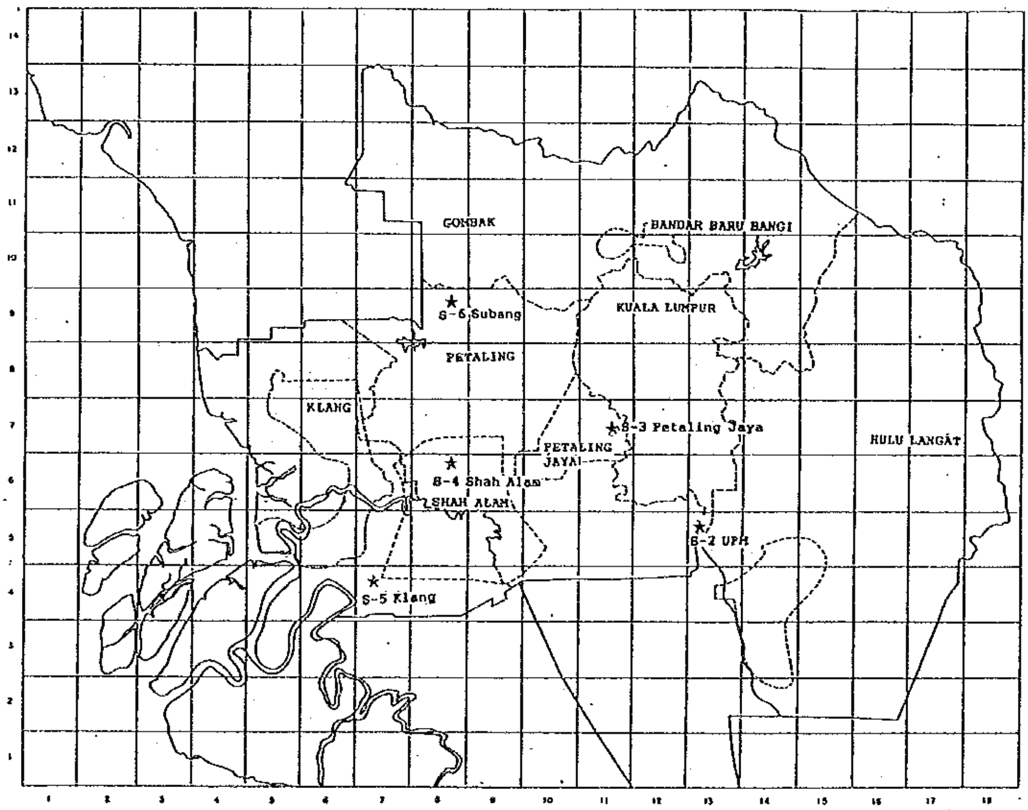
Generally, the wind is weak. At UPM, calm (equal to or below 0.4 m/s wind speed) frequencies are very high and exceed 50%. The histogram of wind speed at UPM is shown in Fig. 3.2. Annual averages of wind speed at all stations are from 0.5 m/s to 1.3 m/s.

Stability index is used to indicate the atmospheric stability. Index 'A' means strong unstable condition and index 'G' means strong stable condition. 'D' class is neutral condition, and is divided into 'DD' (daytime neutral) and 'DN' (nighttime neutral).

A common feature of all stations is the high frequency of unstable class (from A to B) and stable class (G). These conditions are caused by strong radiation and weak wind. The stability index histogram for Petaling Jaya are shown in Fig. 3.3.

Diurnal variations of meteorological parameters show regular patterns. Wind speed, radiation, and temperature all show single peak patterns with the peak occurring during the daytime. The diurnal variation of wind speed at UPM is shown in Fig. 3.4, the diurnal variation of net radiation at Petaling Jaya is shown in Fig. 3.5, and the diurnal variation of temperature at UPM is shown in Fig. 3.6. Relative humidity has a minimum during the daytime. Rainfall occurs mainly in the afternoons and evenings. The diurnal variation of relative humidity and rainfall amount at UPM are shown in Fig. 3.7 and Fig. 3.8.

Wind roses for Shah Alam are shown in Fig. 3.9. N wind direction has high frequencies during the period, but wind speeds are low. In June through August, relatively strong winds are observed in the S and SSW directions. In October, NNW wind direction has high frequency.



Legend

S-2	UPM
S-3	Petaling Jaya
S-4	Shah Alam
S-5	Klang

★ : Meteorological Station

Fig. 3.1 Locations of Meteorological Stations

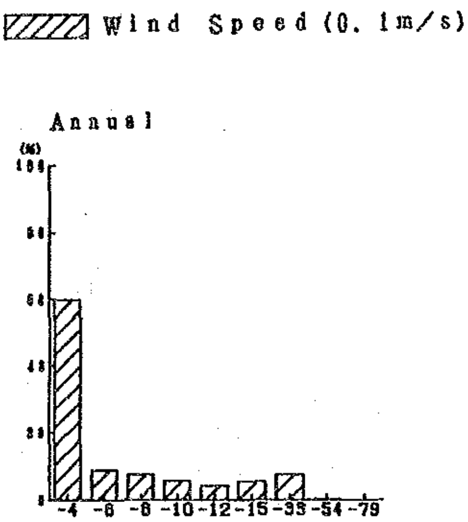


Fig. 3.2 Wind Speed Histogram at UPM
(Mar. 1992 ~ Feb. 1993)

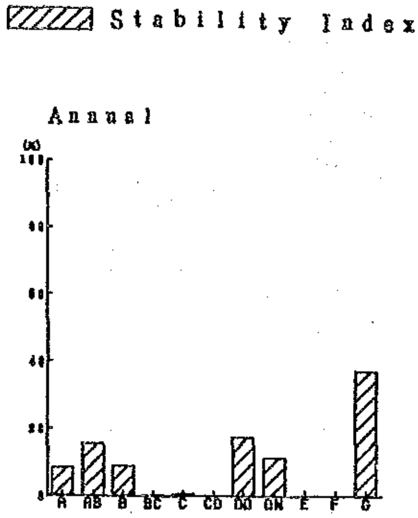


Fig. 3.3 Stability Index Histogram
at Petaling Jaya
(Mar. 1992 ~ Feb. 1993)

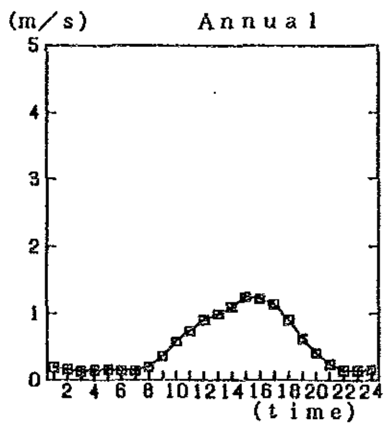


Fig. 3.4 Diurnal Variation of Wind Speed
at UPM
(Mar. 1992 ~ Feb. 1993)

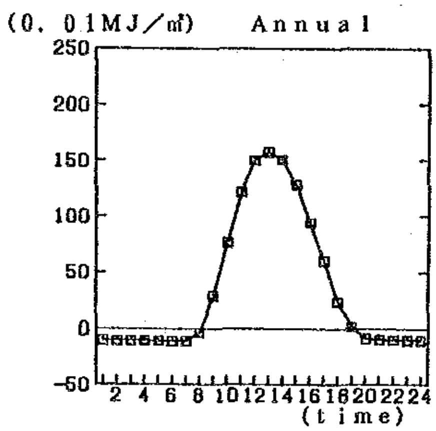


Fig. 3.5 Diurnal Variation of Net Radiation
at Petaling Jaya
(Mar. 1992 ~ Feb. 1993)

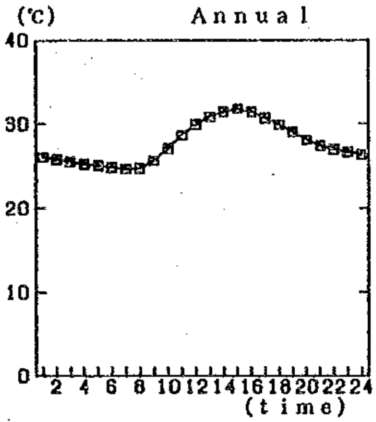


Fig. 3.6 Diurnal Variation of Temperature at UPM
(Mar. 1992 ~ Feb. 1993)

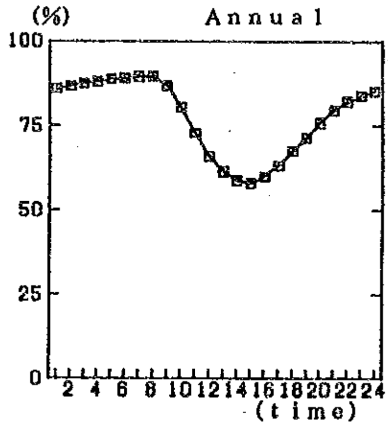


Fig. 3.7 Diurnal Variation of Relative Humidity at UPM
(Mar. 1992 ~ Feb. 1993)

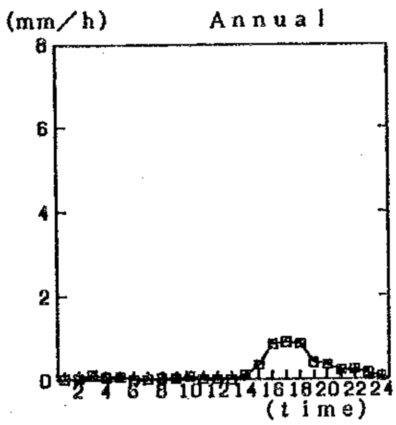


Fig. 3.8 Diurnal Variation of Rainfall Amount at UPM
(Mar. 1992 ~ Feb. 1993)

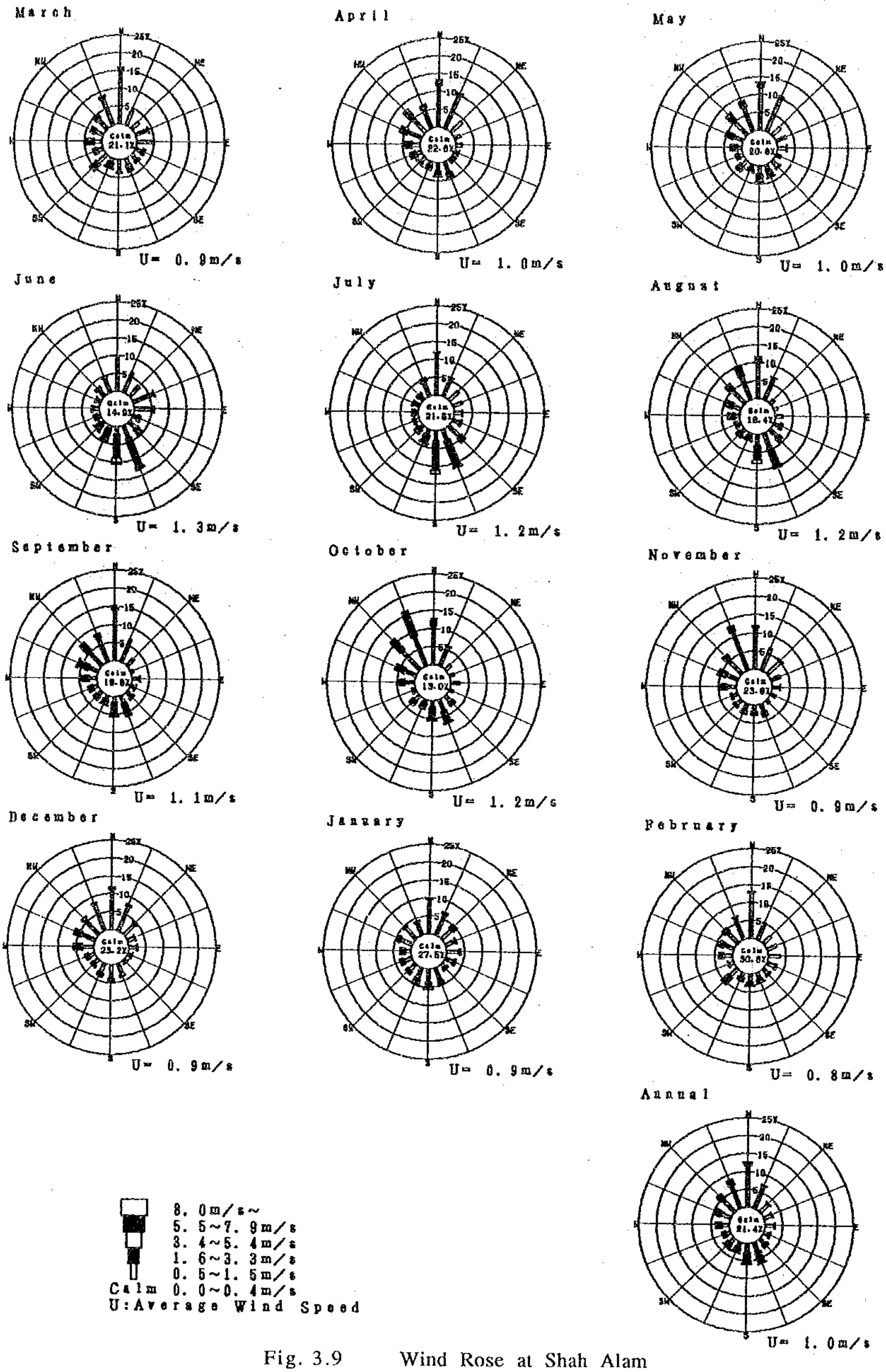


Fig. 3.9 Wind Rose at Shah Alam (Mar. 1992 ~ Feb. 1993)

Monthly changes in wind speed, solar radiation, temperature, relative humidity, and rainfall amount are shown in Fig. 3.10 through Fig. 3.14. The monthly patterns of wind speed, solar radiation, temperature, and relative humidity show no significant change. Generally, rainfall amount is higher in November and December, and lower in June through September.

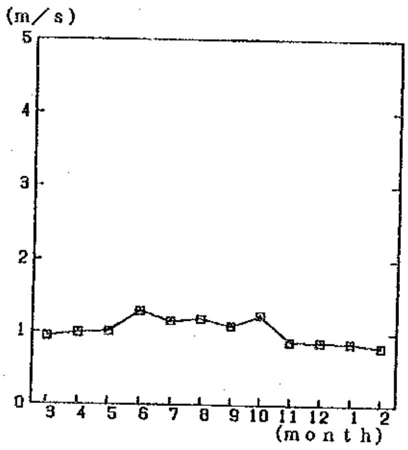


Fig. 3.10 Monthly Change of Wind Speed at Shah Alam (Mar. 1992 ~ Feb. 1993)

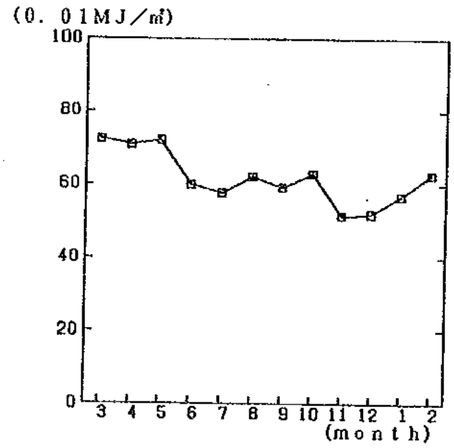


Fig. 3.11 Monthly Change of Solar Radiation at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

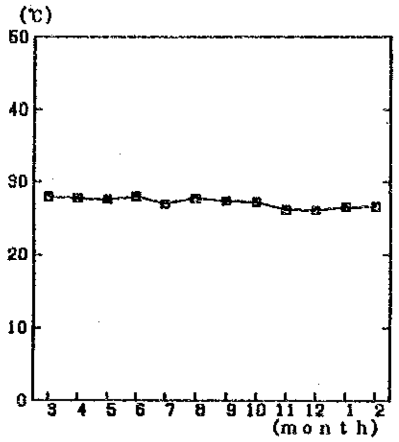


Fig. 3.12 Monthly Change of Temperature at UPM
(Mar. 1992 ~ Feb. 1993)

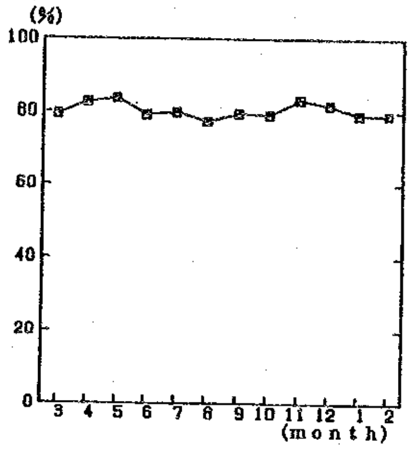


Fig. 3.13 Monthly Change of Relative Humidity at Subang (MMS)
(Mar. 1992 ~ Feb. 1993)

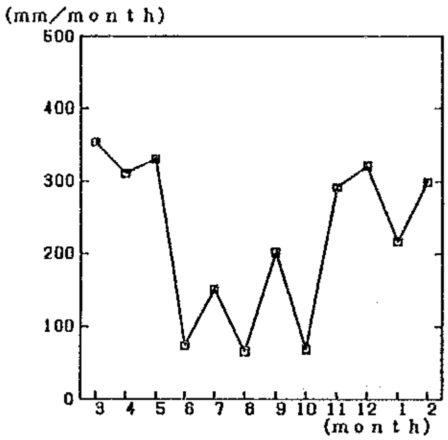


Fig. 3.14 Monthly Change of Rainfall Amount at Petaling Jaya (MMS)
(Mar. 1992 ~ Feb. 1993)

3.2 Upper Level Meteorology

Observations of upper level meteorology were carried out four times at UPM in 1992. Measurement were wind direction, wind speed, and temperature.

Four times of the observation periods are as follows.

1st (February)	20th/February	→	26th/February
2nd (April)	15th/April	→	21st/April
3rd (July & August)	29th/July	→	4th/August
4th (October)	21st/October	→	27th/October

Observations were carried out eight times at 0, 3, 6, 9, 12, 15, 18, 21 o'clock or six times at 6, 9, 12, 15, 18, 21 o'clock a day during the observation periods.

Vertical profiles of wind speed and temperature in April (15th ~ 21st/Apr./1992) are shown in Fig. 3.15. Each observation is expressed by a profile and they are grouped according to the times of the observations.

Vertical profiles of temperature show a common feature. Inversion layers are created during the nighttime and break down during the morning. During the daytime unstable conditions occur at the lower level.

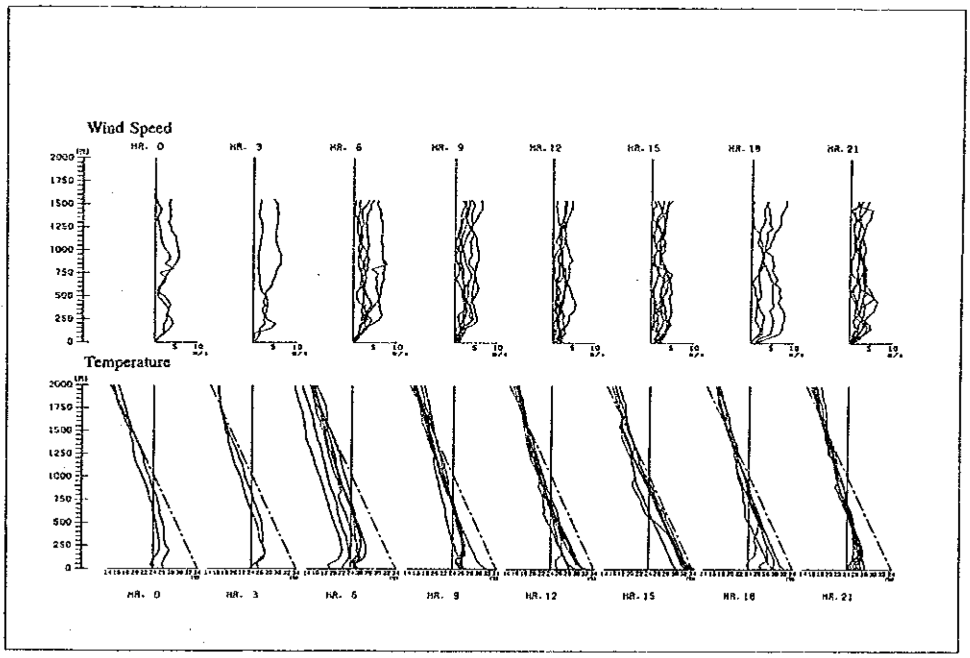


Fig. 3.15 Vertical Profiles of Wind Speed and Temperature at UPM (15th ~ 21st/Apr./1992)

Frequencies of occurrences of surface layer inversions are shown in Tables 3.2 and 3.3. Inversion is defined as temperature increase of more than 0.01 °C per meter with height.

In February, July and August, the frequency of occurrences of surface layer inversions reaches 20%. During the night (from 19:00 to 2:00), the frequency of occurrences exceeds 30%. During the early morning (from 2:00 to 6:00), the frequency of occurrences is more than 25% and two inversion layers reached 150 meters' height.

Table 3.2 Frequency of Occurrences of Surface Layer Inversions in Seasons at UPM (1992)

Height	February	April	July and August	October	Average and Total
50m	15.2% (7)	0.0% (0)	17.8% (8)	4.4% (2)	9.4% (17)
100m	4.3% (2)	0.0% (0)	2.2% (1)	0.0% (0)	1.7% (3)
150m	2.2% (1)	2.3% (1)	0.0% (0)	0.0% (0)	1.1% (2)
Total	(46)	(44)	(45)	(45)	(180)

In parenthesis: Number of Data

Height: Top height of surface inversion layer

Table 3.3 Frequency of Occurrences of Surface Layer Inversions in Time Zones at UPM (1992)

Height	Morning	Afternoon	Night	Early Morning	Average and Total
50m	0.0% (0)	1.2% (1)	33.3% (12)	11.4% (4)	9.4% (17)
100m	0.0% (0)	0.0% (0)	0.0% (0)	8.6% (3)	1.7% (3)
150m	0.0% (0)	0.0% (0)	0.0% (0)	5.7% (2)	1.1% (2)
Total	(27)	(82)	(36)	(35)	(180)

In parenthesis: Number of Data

Height: Top height of surface inversion layer

Time Zones Morning : from 6:00 to 11:00

Afternoon : from 11:00 to 19:00

Night : from 19:00 to 2:00

Early Morning : from 2:00 to 6:00

In the analysis of upper layer inversion, 'target height' was determined by taking into consideration the effective stack height. Then upper layer inversions were classified into three categories. The categories are 'target height inversion (THI)', 'upper height inversion (UHI)', and 'lower height inversion (LHI)'. The target height and target height inversion, upper height inversion, and lower height inversion are illustrated in Fig. 3.16. Target height inversion is said to be the most problematic one and upper height inversion is the second problematic one for air pollution. Lower height inversion does not influence the pollution from the target stack. Inversions which are below twice the target height are tabulated. If the target height is set at 100 meters, then inversions below 200 meters are tabulated.

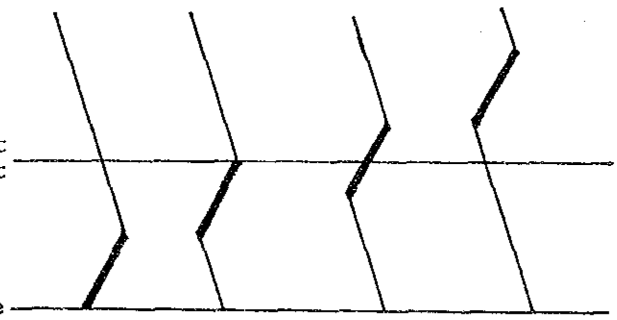


Fig. 3.16 Relations among Target Height and Three Inversion Categories

Frequencies of occurrences of upper layer inversions with target height set at 50 meters are shown in Tables 3.4 and 3.5. Frequency of occurrence of target height inversions in April exceeds 30%. During the early morning, frequency of occurrence of target height inversion is very high and about 49%.

Table 3.4 Frequency of Occurrences of Upper Layer Inversions in Seasons at UPM (1992, Target height: 50 meters)

	February	April	July and August	October	Average and Total
None	67.4% (31)	68.2% (30)	73.3% (33)	88.9% (40)	74.4%(134)
Lower	15.2% (7)	0.0% (0)	17.8% (8)	4.4% (2)	9.4%(17)
Target	17.4% (8)	31.8% (14)	8.9% (4)	6.7% (3)	16.1%(29)
Upper	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0%(0)
Total	(46)	(44)	(45)	(45)	(180)

In parenthesis: Number of Data

Table 3.5 Frequency of Occurrences of Upper Layer Inversions in Time Zones at UPM (1992, Target height: 50 meters)

	Morning	Afternoon	Night	Early Morning	Average and Total
None	81.5% (22)	96.3% (79)	52.8% (19)	40.0% (14)	74.4%(134)
Lower	0.0% (0)	1.2% (1)	33.3% (12)	11.4% (4)	9.4%(17)
Target	18.5% (5)	2.4% (2)	13.9% (5)	48.6% (17)	16.1%(29)
Upper	0.0% (0)	0.0% (0)	0.0% (0)	0.0% (0)	0.0%(0)
Total	(27)	(82)	(36)	(35)	(180)

In parenthesis: Number of Data
Time Zones: Same as Table 3.2.2

3.3 Summary

Meteorological characteristics in Kelang Valley Region based on the analysis conducted are summarized as follows.

Wind speed is very low and therefore pollutants are likely to stagnate in the atmosphere.

Strong stable and strong unstable conditions occur with high frequencies because of weak wind and strong radiation. Pollutants tend to be contained within the lower atmosphere under stable conditions and stirred up to higher levels under unstable conditions.

Diurnal changes of meteorological parameters such as wind speed, radiation, and temperature show single peak pattern. Rainfall mainly occurs in the afternoons and evenings.

Inversion layers are created during the nighttime and break during the morning. Unstable conditions occur at the lower layers during the daytime.

Surface layer inversions occur during the night through the early morning with frequencies of higher than 25%. During the early morning, occurrence of target height inversions with target height set at 50 meters is very high and exceeds 45%. These frequent inversion occurences may affect pollution severely at specific height.

Strong solar radiation and high temperature suggest greater possibilities of photochemical reaction and such conditions could contribute to the formation of NO_2, O_3, and SPM.

Taking into consideration the above meteorological conditions, it is concluded that air pollution in the Kelang Valley Region has the potential of becoming more serious.

CHAPTER 4 AMBIENT AIR QUALITY

4.1 Monitoring of the Ambient Air Quality

(1) Outline of Pollutant Concentration

Ambient air quality was monitored at five fixed stations and thirteen mobile stations. Outline of air quality monitoring is shown in Table 4.1 and the monitoring methods used are shown in Table 4.2. The locations of the monitoring stations for ambient air quality are shown in Fig. 4.1.

In this Chapter, 'Nitrogen Oxides' means NO_2, NOx, and NO, and 'Hydrocarbons' means NMHC, THC, and CH_4. The sum of NO_2 and NO is NOx and the sum of NMHC and CH_4 is THC.

Table 4.1 Outline of Monitoring Stations

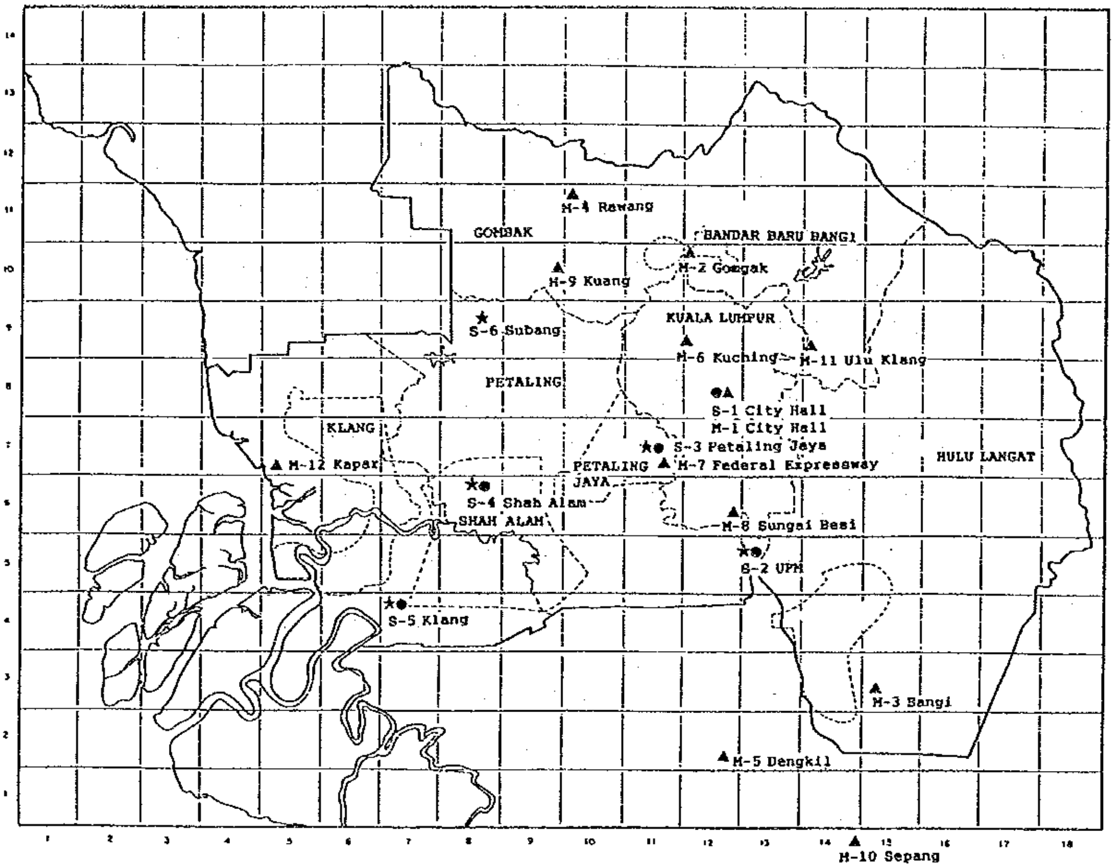
Station Name	Monitoring Items					
	SPM	SO_2	CO	NOxs	O_3	HCs
S-1 City Hall	○	○	○	○	○	-
S-2 UPM	○	○	-	○	○	-
S-3 Petaling Jaya	○	○	○	○	○	○
S-4 Shah Alam	○	○	○	○	○	○
S-5 Klang	○	○	-	○	○	-
M-X (Mobile Stations)	○	○	○	○	○	○

Note NOxs : Nitrogen Oxides(NO_2, NOx, NO)
HCs : Hydrocarbons(NMHC, THC, CH_4)

Table 4.2 Summary of Monitoring Instruments

Monitoring Item	Method
SO_2	Ultraviolet Fluorescence
Nitrogen Oxides	Chemiluminescence
CO	Non-Dispersive Infrared Absorption
SPM	Beta-ray Attenuation
Hydrocarbons	Flame Ionization Detection Gas Chromatography
O_3	Ultraviolet Absorption or Chemiluminescence*

*: City Hall, UPM, Klang



Legend

● : Fixed Station

S-1	City Hall
S-2	UPM
S-3	Petaling Jaya
S-4	Shah Alam
S-5	Klang

▲ : Mobile Station

★ : Meteorological Station

Fig. 4.1 Locations of Monitoring Stations

Averages of major pollutants throughout the measurement periods are summarized in Table 4.3.

Stations which have shown the highest concentration of each pollutant are as follows;

	Fixed Station	Mobile Station
SPM	Shah Alam	Jl. Kuching
SO_2	Petaling Jaya	Sungai Besi
NO_2	City Hall	Sungai Besi
NOx	City Hall	Federal Expressway
CO	Petaling Jaya	City Hall (M)
O_3	Klang	Sungai Besi
NMHC	Petaling Jaya	City Hall

Compliance with the guidelines at fixed stations are shown in Table 4.4.

Remarkables in Table 4.4 are;

- A maximum value and an annual average of PM10 at Shah Alam exceeds the guidelines.
- SO_2 and NO_2 guidelines are satisfied at all fixed stations, but hourly values of SO_2 and NO_2 at City Hall, Petaling Jaya, and Shah Alam reach more than 100 ppb.
- Maximum values of CO eight hour averages exceed the guideline at City Hall and Petaling Jaya.
- Hourly values of O_3 at all stations and eight hour averages of O_3 except UMP exceed the guidelines more than once.

Although the data at the mobile stations are insufficient for accurate evaluation, the hourly maximum value of SO_2 at Bangi, Dengkil, Sungai Besi, and Jl. Kuching, exceeded the guideline. The hourly maximum values of NO_2 at Jl. Kuching and City Hall (M) exceeded 130 ppb.

Health implications of these pollutants are described as follows.

CO combines with hemoglobin to form carboxyhaemoglobin (COHb) in a human body and disturbs the uptake of oxygen into blood. Increase of COHb causes cardiovascular and neurobehavioural effects. The aggravation of symptoms in angina pectoris patients by a certain COHb level is also of great concern as an adverse health effect.

NO_2 has been said to have more effects on a human body than NO. Short-term exposure effects by NO_2 are decrements in pulmonary function, lung function changes of bronchitic subjects, increases of airway reactivity in asthmatic subjects and so on. Studies with animals by long-term exposure show some effects. Effects are caused in lung, spleen, liver, and blood. Structural changes range from a change in cell types in the tracheobronchial and pulmonary regions to emphysema-like effects. NO_2 also increases susceptibility to bacterial infection of lung.

Short-term acute effects by O_3 are notable, beginning with eye irritation, and symptomatic chest and upper respiratory tract effects at higher levels, particularly in susceptible populations. Pulmonary function decrements, cough, and headache can occur in children or asthmatics with O_3 concentrations of around 100 or 200 ppb.

SO_2 and Particulate Matter have synergism effect to human health. Some epidemiological data indicate that SO_2 increases mortality, decrease lung function in sensitive children, and increases respiratory morbidity.

Because Particulate Matter with a diameter below 10 μm can be easily inhaled into lung, PM10 concentration is more important from a health point of view. Some epidemiological data indicate morbidity increase of chronic bronchitis, increase of airway resistance, and increase of mortality in weak and old people. Moreover decline of visibility causes annoyance reaction of the public.

Hydrocarbons are consisted of various chemical compounds and most of hydrocarbons are said not to affect human being or animals with present concentration levels. However, some hydrocarbons like formaldehyde and acrolein stimulate eyes and respiratory organs in a specific working place. Benzene, benzopyrene, and benzoanthracene are said to be carcinogen or mutagen. Moreover NMHC (Non-Methane Hydrocarbon) has high reactivity in O_3 production. NMHC should be controlled to reduce O_3 concentration.

Table 4.3 (1) Average Concentrations of SPM, SO_2, NO_2 and NOx (Mar. 1992 ~ Feb. 1993)

	Monitoring Sites	SPM ($\mu g/m^3$)	SO_2 (ppb)	NO_2 (ppb)	NOx (ppb)
Fixed Station	City Hall	50.7 (6432)	10.4 (3264)	21.7 (6590)	103.3 (6590)
	UPM	24.1 (7114)	8.0 (7363)	8.6 (6005)	18.1 (6005)
	Petaling Jaya	58.8 (7554)	13.3 (8410)	19.3 (8099)	49.4 (8099)
	Shah Alam	67.6 (8227)	7.7 (7990)	15.2 (7832)	31.4 (7832)
	Klang	60.8 (3222)	8.5 (2070)	11.4 (3701)	26.6 (3701)
Mobile Station	City Hall(M)	86.3 (2510)	10.1 (2379)	30.0 (2537)	126.0 (2537)
	Gombak	65.0 (1157)	5.8 (1040)	11.4 (1161)	24.7 (1161)
	Bangi	66.7 (849)	12.4 (790)	9.4 (857)	20.8 (857)
	Dengkil	57.8 (1223)	5.2 (1142)	3.6 (1235)	12.2 (1235)
	Jl.Kuching	92.1 (902)	8.0 (966)	33.1 (971)	103.2 (971)
	Federal Expressway	87.2 (804)	12.1 (801)	32.2 (808)	131.6 (808)
	Sungai Besi	83.3 (935)	13.7 (888)	33.5 (901)	118.2 (901)
	Kuang	47.7 (1126)	4.2 (1139)	7.6 (1134)	23.3 (1134)
	Sepang	33.8 (550)	3.0 (471)	7.8 (597)	23.2 (597)
	Ulu Klang	30.6 (847)	3.2 (838)	9.2 (856)	22.7 (856)
	UTM	47.2 (894)	2.9 (902)	14.4 (903)	40.0 (903)
	Kapar	52.1 (938)	8.3 (637)	5.3 (948)	19.7 (948)

Note : Number of sample data in parentheses.

Table 4.3 (2) Average Concentrations of CO, O_3 and NMHC (Mar. 1992 ~ Feb. 1993)

	Monitoring Sites	CO (ppm)	O_3 (ppb)	NMHC (10ppbC)
Fixed Station	City Hall	2.73 (6880)	9.5 (6344)	—
	UPM	—	10.0 (7196)	—
	Petaling Jaya	2.84 (8384)	9.7 (8126)	79.1 (7546)
	Shah Alam	0.70 (7405)	10.9 (8017)	22.5 (7804)
	Klang	—	12.4 (3679)	—
Mobile Station	City Hall (M)	3.74 (2537)	10.4 (2536)	145.5 (1959)
	Gombak	0.63 (1161)	17.7 (1161)	27.1 (1162)
	Bangi	0.30 (855)	18.3 (857)	119.7 (519)
	Dengkil	0.39 (1242)	13.6 (1234)	140.3 (107)
	Jl. Kuching	2.06 (543)	8.7 (971)	89.6 (401)
	Federal Expressway	2.10 (808)	11.0 (808)	91.7 (811)
	Sungai Besi	2.91 (899)	26.2 (901)	124.9 (905)
	Kuang	—	17.9 (1134)	46.6 (788)
	Sepang	0.64 (602)	12.5 (597)	38.2 (466)
	Ulu Klang	0.40 (287)	16.8 (857)	79.5 (854)
	UTM	1.31 (902)	18.3 (903)	137.0 (892)
	Kapar	0.23 (949)	20.0 (948)	71.8 (834)

Note : Number of sample data in parentheses.

Table 4.4 (1) Compliance with Guidelines on TSP, PM10, and SO_2 (Mar. 1992 ~ Feb. 1993)

Items		TSP		PM10		SO_2	
Guidelines		Yearly 90	Daily 260	Yearly 50	Daily 150	Daily 40	Hourly 130
Unit		(μg/m3)		(μg/m3)		(ppb)	
City Hall	Avg.	61.3		41.5			
	Max.		112.5		76.3	33.5	106
	99%		106.3		72.1	30.5	43
	98%		104.1		70.6	27.3	35
	95%		92.7		62.8	23.9	25
	No.	6432	267	6432	267	114	3264
UPM	Avg.	29.2		19.8			
	Max.		66.3		44.9	31.4	60
	99%		58.0		39.3	17.5	27
	98%		54.6		37.0	14.8	21
	95%		45.7		31.0	13.3	16
	No.	7114	293	7114	293	297	7363
Petaling Jaya	Avg.	71.1		48.2			
	Max.		165.4		112.1	29.5	111
	99%		144.1		97.7	24.9	44
	98%		136.8		92.7	23.9	37
	95%		120.5		81.7	22.1	29
	No.	7554	314	7554	314	351	8410
Shah Alam	Avg.	81.7		55.4 X			
	Max.		253.1		171.6 X	20.1	103
	99%		179.5		121.6	18.0	43
	98%		164.7		111.6	17.0	34
	95%		137.2		93.0	15.6	24
	No.	8227	342	8227	342	333	7990
Klang	Avg.	73.6		49.9			
	Max.		187.8		127.3	22.8	95
	99%		168.1		113.9	18.2	42
	98%		162.3		110.0	15.1	30
	95%		152.6		103.4	13.6	21
	No.	3222	130	3222	130	83	2070

Abbreviations Avg. : Average value
Max. : Maximum value
No. : Number of Data

X: Exceed

Table 4.4 (2) Compliance with Guidelines on CO, NO_2, and O_3

Items		CO		NO_2	O_3	
Guidelines		8 Hours 9	Hourly 30	Hourly 170	8 Hours 60	Hourly 100
Unit		(ppm)		(ppb)	(ppb)	
City Hall	Avg.					
	Max.	10.53 X	15.4	121	118.7 X	267 X
	99%	6.65	9.1	61	59.4	86
	98%	5.86	8.2	53	50.8	70
	95%	5.09	6.6	45	37.3	46
	No.	6871	6880	6590	6244	6344
UPM	Avg.					
	Max.			73	55.8	106 X
	99%			28	39.6	53
	98%			24	36.0	45
	95%			19	29.6	36
	No.			6005	7159	7196
Petaling Jaya	Avg.					
	Max.	10.15 X	15.7	108	80.1 X	128 X
	99%	6.96	8.6	56	54.4	81
	98%	6.30	7.7	51	47.0	66
	95%	5.49	6.3	42	36.6	47
	No.	8397	8384	8099	8129	8126
Shah Alam	Avg.					
	Max.	3.55	5.2	168	93.9 X	158 X
	99%	2.30	3.0	60	64.5 X	88
	98%	1.99	2.6	45	53.8	68
	95%	1.60	2.0	34	39.9	48
	No.	7419	7405	7832	7995	8017
Klang	Avg.					
	Max.			72	68.9 X	132 X
	99%			30	50.9	70
	98%			27	46.3	59
	95%			23	36.9	45
	No.			3701	3641	3679

Abbreviations Avg. : Average value
Max. : Maximum value
No. : Number of Data

X: Exceed

(2) Diurnal Change of Pollutant Concentration

There are typically three main patterns on diurnal changes of pollutant concentrations.

The first one is a 'two peak pattern' with a sharp peak in the morning and a moderate peak in the evening through the night. Most of diurnal changes of CO and Nitrogen Oxides exhibit the two peak patterns and some diurnal changes of SPM and Hydrocarbons also exhibit the two peak patterns. Diurnal changes of Nitrogen Oxides and CO at City Hall are shown in Fig. 4.2 and Fig. 4.3 respectively. Diurnal changes of Hydrocarbons at Petaling Jaya are shown in Fig. 4.4. This two peak pattern is an indication of the influence by motor vehicles.

The second one is a 'single minimum pattern' with the minimum occurring during the daytime. Some monitoring stations exhibit diurnal changes of SPM showing this pattern. It is to be noted that SPM concentration rises up in the evening through the night and the concentration does not decrease till the morning. Diurnal change of SPM at Shah Alam is shown in Fig. 4.5.

The third one is a 'single peak pattern' with the peak in the afternoon. O_3 diurnal changes at all stations show this pattern. This pattern closely follows the daily cycle of insolation. Diurnal change of O_3 at Shah Alam is shown in Fig. 4.6.

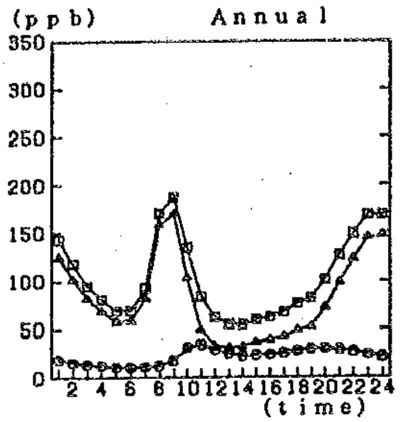


Fig. 4.2 Diurnal Change of Nitrogen Oxides at City Hall (Mar. 1992 ~ Feb. 1993)

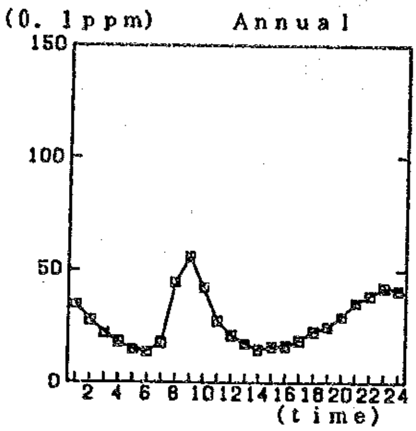


Fig. 4.3 Diurnal Change of CO at City Hall (Mar. 1992 ~ Feb. 1993)

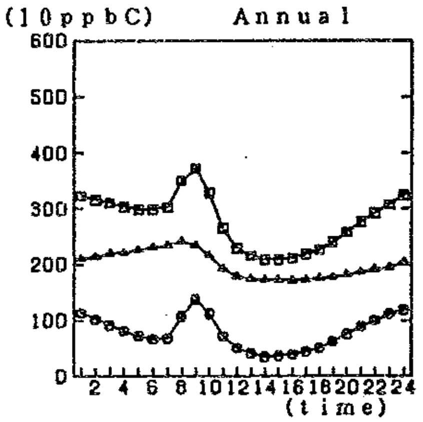


Fig. 4.4 Diurnal Change of Hydrocarbons at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

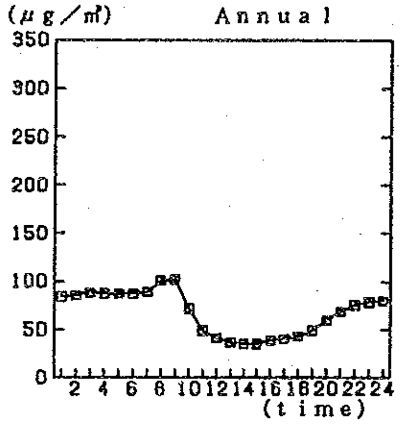


Fig. 4.5 Diurnal Change of SPM at Shah Alam (Mar. 1992 ~ Feb. 1993)

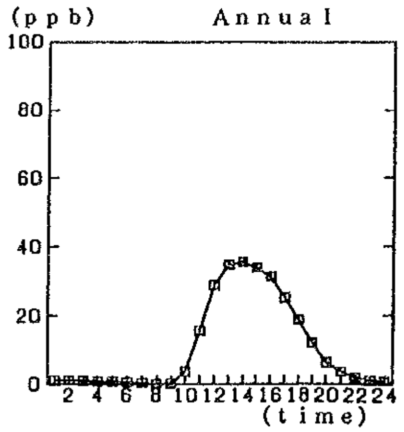


Fig. 4.6 Diurnal Change of O_3 at Shah Alam (Mar. 1992 ~ Feb. 1993)

(3) Relationship of Air Pollutant Concentration to Meteorological Parameters

To analyze the relationships between the pollutant concentrations and the meteorological parameters, the concentrations of the pollutants were averaged by ranks of the meteorological parameters, such as wind direction, wind speed, stability index, and rainfall amount.

In summary, the following characteristics are highlighted.

O_3 concentrations at all stations show high values in the SW through WNW wind directions (Fig. 4.7). The increase of O_3 concentration around 2:00 p.m. coincides with sea breeze.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show a decrease of their concentrations with increase of wind speed. Relationships of CO concentration to wind speed are shown in Fig. 4.8.

Generally, the concentration of pollutant should decrease with increase of wind speed because of dilution. However, O_3 concentrations increase with increase of wind speed (Fig. 4.9). The increase of O_3 concentration coincides with sea breeze and the sea breeze is relatively strong.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show high values with strong stable condition. SPM concentration for different stability index at Shah Alam is shown in Fig. 4.10. If the atmospheric condition is stable, the emission source around the ground level would strongly affect the pollutant concentration.

O_3 concentrations decrease from unstable condition to stable condition. O_3 concentration for different stability index at Shah Alam is shown in Fig. 4.11. Generally, O_3 concentrations are high around 2:00 p.m. when incoming solar radiation is strong, which contributes towards the unstable atmospheric condition.

SPM concentrations show a decreasing trend with increase in rainfall amount. The relationship between SPM concentration and rainfall amount at Petaling Jaya is shown in Fig. 4.12. The wash out effect on particulate matters seems large. However, gaseous pollutants such as SO_2 do not show any clear effect by rainfall.

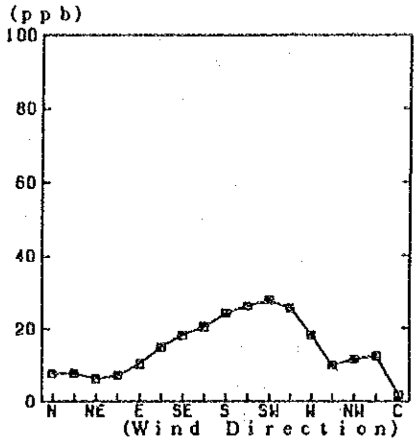


Fig. 4.7 O3 Concentration by Wind Direction at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

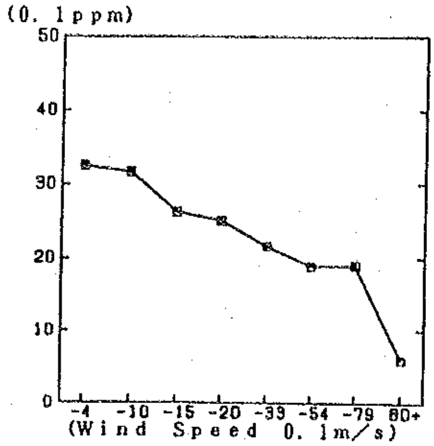


Fig. 4.8 CO Concentration by Wind Speed at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

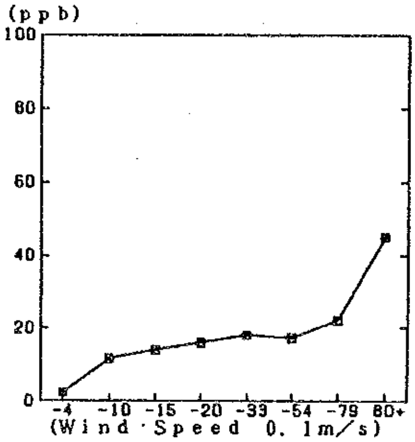


Fig. 4.9 O3 Concentration by Wind Speed at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

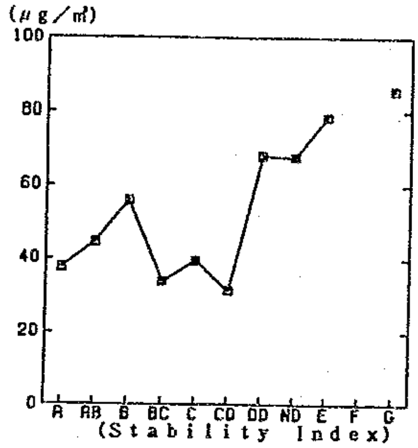


Fig. 4.10 SPM Concentration by Stability Index at Shah Alam (Mar. 1992 ~ Feb. 1993)

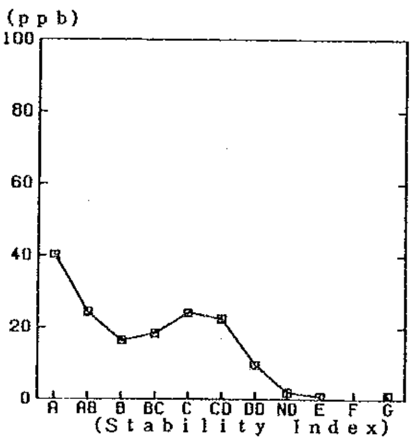


Fig. 4.11 O3 Concentration by Stability Index at Shah Alam (Mar. 1992 ~ Feb. 1993)

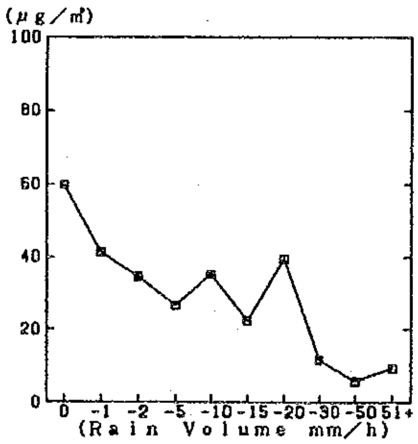


Fig. 4.12 SPM Concentration by Rainfall Amount at Petaling Jaya (Mar. 1992 ~ Feb. 1993)

4.2 Simplified Measurement

4.2.1 Simplified Measurement over a Wide Area

To examine the spatial distribution of the pollutants, contour maps of concentration were produced for the periods as follows;

the first period	:	February	~	March, 1992
the second period	:	March	~	April, 1992
the third period	:	July	~	August, 1992
the fourth period	:	October	~	November, 1992

NO_2 distribution in the first period is shown in Fig. 4.13. Areas of high concentration with more than 20 ppb appear in Kuala Lumpur through Petaling Jaya and Shah Alam through Klang. Areas of high concentration with more than 20 ppb mainly appear in Kuala Lumpur during the second through fourth period. During the second period, areas of high concentration also appear in Gombak.

SO_3 distribution for the second period is shown in Fig. 4.14. Area of high concentration with more than 300 (0.001 mg/day/100 cm^2 Pb) appears in the north part of Kuala Lumpur. The 300 contours in the figure corresponds to 12 ppb (SO_2).

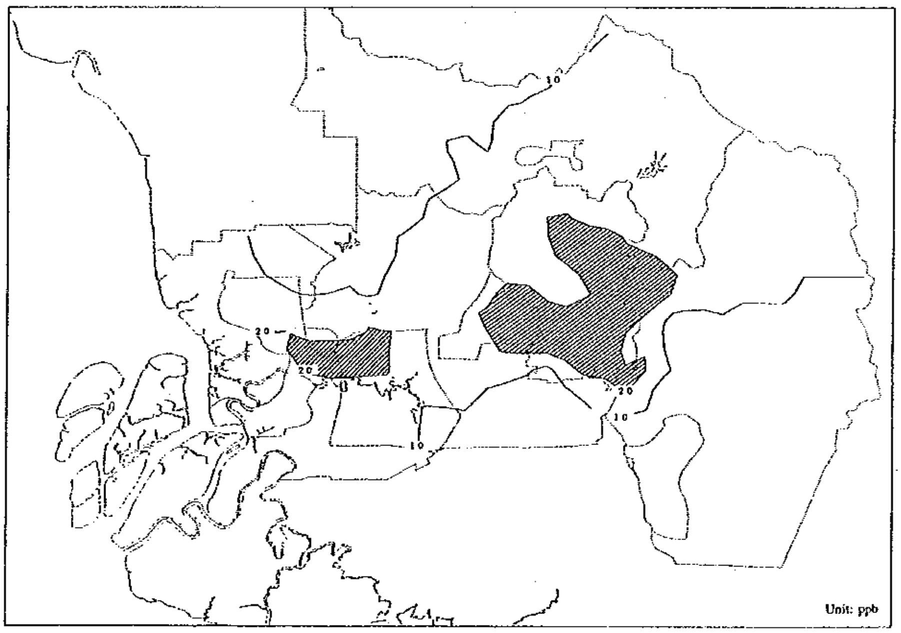


Fig. 4.13 Contour Map of NO_2 by Simplified Measurement over a Wide Area (Feb. ~ Mar. 1992)

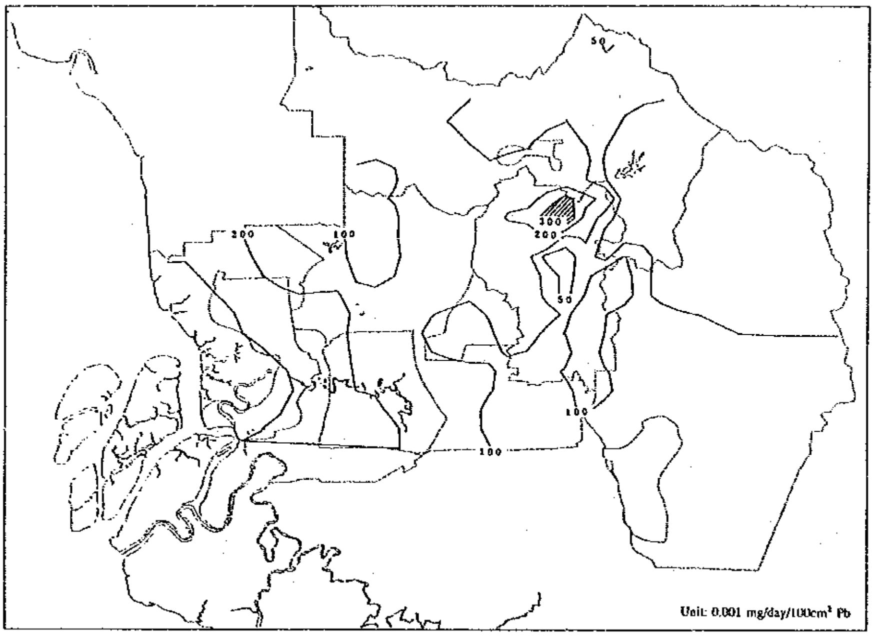


Fig. 4.14 Contour Map of SO_3 by Simplified Measurement over a Wide Area (Mar. ~ Apr. 1992)

4.2.2 Simplified Measurement around Roads

CO profiles around the roads are shown in Fig. 4.15. Concentration decrease with distances from the road.

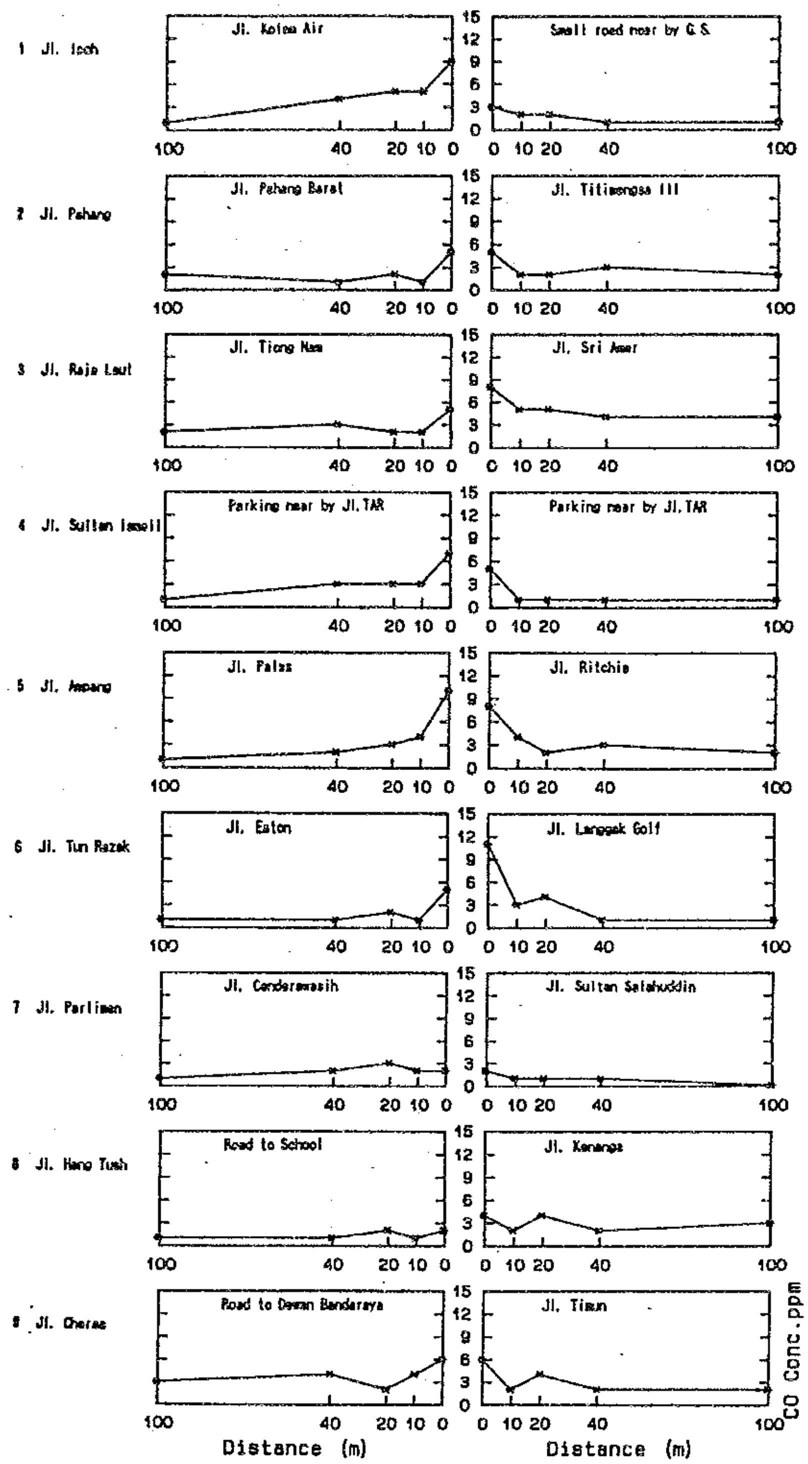


Fig. 4.15 CO Profile by Detector Tube of the First Period (5th ~ 7th/Mar./1992)

4.3 Summary

The characteristics of ambient air quality in Kelang Valley Region as a result of this study is summarized as follows.

Based on the analysis of data from the fixed stations, the status of air pollution in the Kelang Valley Region in 1992 is relatively serious in comparison with the guidelines. Annual average and daily average of PM10 at Shah Alam exceeded the guideline and annual averages of PM10 at Klang and Petaling Jaya were around the guideline level. CO at City Hall and Petaling Jaya exceeded the guideline for 8 hours. O_3 at the all fixed stations exceeded the guideline. The guidelines for SO_2 and NO_2 were satisfied at all the fixed station, but hourly values of SO_2 and NO_2 at City Hall, Petaling Jaya, and Shah Alam exceeded 100 ppb.

Annual average of the each pollutant is the highest at City Hall, Petaling Jaya, or Shah Alam among the fixed stations. The areas around these stations are highly polluted.

Most of diurnal changes of CO and Nitrogen Oxides show the 'two peak pattern'. Diurnal changes of SPM and Hydrocarbons at some stations show the 'two peak pattern'. This 'two peak pattern' is mainly due to the influence of motor vehicles. Diurnal changes of SPM at Shah Alam and some other stations show the 'single minimum pattern'. Diurnal changes of O_3 at all stations show the 'single peak pattern' and this pattern is mainly influenced by the temporal pattern of incoming solar radiation.

The relationship between pollutant concentrations and meteorological parameters reveals the followings.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show a decrease of concentration with increase of wind speed, but O_3 shows the reverse relationships to wind speed.

SPM, CO, Nitrogen Oxides, and Hydrocarbons show high values with strong stable condition, but O_3 concentrations decrease from unstable condition to stable condition.

SPM concentrations show decrease with increase of rainfall amount.

Analysis of SPM concentration shows that SPM concentration is related to low wind speed and high temperature to some extent. NO_2 concentrations are also higher during the high SPM days, but no significant change in NO_2 concentration happened during the haze period in October of 1991.

Analysis of high O_3 concentrations shows that the high O_3 concentration is related to strong solar radiation and high temperature to some extent. NMHC and NO_2 concentrations are also higher during the high O_3 days.

Simplified measurement over a wide area shows the spatial distribution of the pollutants in Kelang Valley Region. Areas of high NO_2 concentration mainly occur in Kuala Lumpur and sometimes in Klang and Gombak districts. Areas of high SO_3 concentration occur in Kuala Lumpur.

Simplified measurement across roads shows the CO profiles.

The results indicate that, air pollution in Kelang Valley Region is relatively serious in 1992 judged from the monitoring data. Moreover, the meteorological conditions such as weak wind, strong solar radiation, and high temperature in the Region have potential to worsen the ambient air quality. Furthermore, the diurnal changes of some pollutants show the influence by motor vehicle even in 1992. Efforts to improve and maintain ambient air quality should be strengthened.

CHAPTER 5 PRESENT STATE OF AIR POLLUTION SOURCES

Investigation of pollution sources is one of the most important tasks in air pollution control planning. Primary purpose of the source investigation in the Study was to estimate quantities of air pollutant emissions to prepare a "source model" as an essential part of the air quality simulation model described in Chapter 6.

The targeted sources and pollutants are shown in Table 5.1. Households include hotels, restaurants and so on. Pollutant emissions unlisted in the Table such as open burning activities, earthworks and nature, were not estimated in the Study. The estimated pollutant emissions are only those emitted from stacks of factories and establishments, ships and households, from tail pipes of motor vehicles and from engines of airplanes. Pollution sources used for air dispersion simulation are factories and establishments, motor vehicles, airplanes and ships.

Table 5.1 Targeted Pollution Sources and Pollutants

Pollution Sources	Pollutants					Source Model
	SOx	NOx	PM (Dust)	CO	HC	
Factories and Establishments	O	O	O			O
Motor Vehicles	O	O	O	O	O	O
Airplanes	O	O	O			O
Ships	O	O	O			O
Households*		O	O			

* Households include hotels, restaurants and so on.

5.1 Factories and Establishments

Based on the questionnaire survey and existing information on factories in DOE, such items as facility type, fuel type, fuel consumption, condition of facility operation, pollution control etc., were collected for 172 major factories on air pollution.

(1) Air Pollution Facilities and Fuel Consumption

The number of factories by industry type is shown in Table 5.2. The majority (55%), belong to industries related to food, wood, rubber and metal products. Two thermal power stations and one cement factory are considered large-scale factories among those surveyed.

Table 5.2 Number of Factories Surveyed by Industry Type

Code	Industry	Number	(%)
101	Food and kindred products	24	14.0
102	Drink feed	1	0.6
103	Tobaccos	1	0.6
104	Textiles	3	1.7
105	Apparel and related products	2	1.2
107	Footgear products	1	0.6
108	Lumber and wood products	15	8.7
109	Furniture and fixtures	1	0.6
110	Pulp, paper and allied products	7	4.1
111	Publishing, printing and allied industries	2	1.2
112	Chemical and allied products	8	4.7
113	Palm oil mill	7	4.1
116	Rubber products	23	13.4
117	Plastic products	4	2.3
118	Ceramic, stone and clay products	2	1.2
119	Glass products	2	1.2
120	Non-ferrous metals and products	2	1.2
121	Iron and steel	6	3.5
122	Fabricated metal products	1	0.6
123	Metal products	15	8.7
124	General machinery and equipment	1	0.6
125	Electrical machinery, equipment and supplies	7	4.1
126	Transportation	1	0.6
128	Other manufacturing industries	24	14.0
129	Electricity supply	2	1.2
131	Hospital	1	0.6
135	Quarry	5	2.9
136	Other establishments	4	2.3
Total		172	100.0

In the 172 factories surveyed, 248 facilities have been emitting pollutants from their stacks. Boilers account for 77% (248 units) of the total number of the facilities in Kelang Valley Region. Other notable facilities are metal heating furnaces, dryers and incinerators.

Most stacks are 50 m meters or less in height. Thermal power plants have reasonably higher stacks. Fuels used in KVR are natural gas, heavy, middle and light fuel oils, wood and palm wastes and coal. Coal is used in thermal power stations and in a cement factory. The coverage rate of fuel consumption in the Study is shown in Table 5.3. Our estimation is considered to be very close to the estimates by Petronas and DOE.

Fuel used by boilers is mainly heavy fuel oil, while most other facilities burn light fuel oil.

Table 5.3 (1) Coverage Rate of Fuel Consumption by Factories

Fuel Type	Consumption surveyed	Consumption in Kelang Valley Region	Coverage(%)
HFO	9,068.5 kl/y		
MFO	50,906.7 kl/y		
LFO	287,837.7 kl/y		
IFO	88,929.1 kl/y		
Other Liquid Fuel	18,908.0 kl/y		
Total of Liquid Fuel	455,650.0 kl/y	453,000.0 kl/y *	100.6
LPG	85,236.0 kl/y	85,000.0 kl/y *	100.3
Palm Waste	187,200.0 t/y	187,200.0 t/y **	100.0
Coal	88,460.0 t/y	90,760.0 t/y **	97.5
Wood	307,197.9 t/y	328,448.0 t/y **	93.5
Electricity	291,375.0 1000kw/y	291,375.0 1000kw/y	100.0

* PETRONAS (1990)
** DOE (1992)

Table 5.3 (2) Coverage Rate of Fuel Consumption by Power Stations

Fuel Type	Consumption surveyed	Consumption in Kelang Valley Region	Coverage(%)
MFO	258,750.0 kl/y	261,473.6 kl/y *	99.0
NG	1,861,109.0 1000M3N/y	1,861,109.0 1000M3N/y *	100.0
Coal	806,400.0 t/y	806,400.0 t/y *	100.0

* TENAGA Nasional Bhd (1992)

(2) Flue Gas Measurement

SOx, NOx, Dust and O_2 in flue gases were measured and analyzed for 36 factories. The main facility measured was boiler (26). Average pollutant concentrations for boilers and furnaces are shown in Table 5.4. The notable differences between the gases from boilers and those from furnaces may be due to the differences in fuels used and combustion control.

Table 5.4 Summary for Flue Gas Measurement Results

Measuring Item	Concentration of emitted		
		Boiler	Furnace
Dust (g/m^3N)	< 0.53	0.24 ~ 0.53	<0.011
SO_2 (ppm)	0 ~ 1790	0 ~ 1790	0 ~ 550
NO_2 (ppm)	0 ~ 315	79 ~ 315	0 ~ 15
O_2 (%)	3.5 ~ 20.4	3.5 ~ 16.1	20.4 ~ 21.0

(3) Fuel Analysis

Various kinds of fuels (53 samples) used in the Region were analyzed for their elemental and physical properties. As for sulphur, heavy fuel oil (HFO) contains 2.51 wt% in average and middle fuel oil (MFO) contains 2.42 wt%. Coal showed slightly lower value of 1.0 and 0.6 wt%. Wood and palm wastes have around 0.2 wt% of sulphur. As for vehicle fuels, petrol and diesel contains 0.003 wt% and 0.323 wt% in average, respectively.

(4) Emission Factor

The air pollutant emission factors for NOx and Dust for air pollution facilities were established on the basis of the results of the flue gas measurements and existing data in USA and Japan (Table 5.5). SOx emission for each facility was calculated from the fuel consumption and sulfur content in the fuel used.

Table 5.5 Emission Factor for NOx and Dust by Facility Type

Facility		Fuel Type	NOx	Ref	DUST	Ref
0101	Boiler	(12)MFO	7.34kg/kl		6.01kg/kl	
		(20)Coal	8.86kg/t	J	0.29kg/t	
		(28)NG	5.84kg/10³m³	J	0.2kg/10³m³	
0102		(11)HFO	1.74kg/kl		12.74kg/kl	
		(12)MFO	1.74kg/kl		12.74kg/kl	
		(13)LFO	1.74kg/kl		12.74kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
		(22A)Palm Waste	3.93kg/t		14.88kg/t	
		(22C)Wood	2.19kg/t		6.95kg/t	
		(29)LPG	2.10kg/kl	J	0.20kg/kl	E
0103		(11)HFO	1.74kg/kl		12.74kg/kl	
		(12)MFO	1.74kg/kl		12.74kg/kl	
		(13)LFO	1.74kg/kl		12.74kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
		(19)Other L.F.	1.74kg/kl		12.74kg/kl	
		(22C)Wood	2.19kg/t		6.95kg/t	
		(29)LPG	2.10kg/kl	J	0.20kg/kl	E
0202	Gas furnace	(29)LPG	1.35kg/kl	E	0.20kg/kl	E
0502	Melting furnace	(29)LPG	1.35kg/kl	E	0.20kg/kl	E
0506	Metal melting furnace	(13)LFO	2.99kg/kl	J	0.59kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0601	Heating furnace	(13)LFO	3.45kg/kl	J	1.26kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0606		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0607	Metal heating furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0611		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0613	Metal forge furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0615		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0821	Combustion furnace	(12)MFO	2.02kg/kl	J	1.53kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0901	Cement kiln	(20)Coal	7.90kg/t		0.54kg/t	
0915	Glass melting furnace	(12)MFO	1.93kg/kl	J	0.18kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	1.74kg/kl		12.74kg/kl	
1001	Reacting furnace	(12)MFO	2.80kg/kl	J	0.59kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1004	Direct heating furnace	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1102	Drying over kiln (drier)	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
1104		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
1106	Dryer	(12)MFO	5.46kg/kl	J	0.30kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(16B)IFO	5.46kg/kl		0.30kg/kl	
		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
1204	Electric furnace	(37)Electricity			0.03kg/10³kw	
1301	Incinerator	(38)G.Waste	0.95kg/t	J	5.46kg/t	J
1303		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(22A)Palm Waste	3.23kg/t		10.68kg/t	
		(22C)Wood	1.54kg/t	J	2.27kg/t	J
		(39)I.Waste	2.59kg/t	J	3.08kg/t	J
1304		(12)MFO	0.38kg/kl		2.08kg/kl	
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(39)I.Waste	2.59kg/kl	J	3.08kg/kl	J
0002	Gas turbine	(28)N.Gas	1.35kg/10³m³N	J	0.08kg/10³m³N	E
0005	Baby cupola	(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
		(21)Coke	0.06kg/t	J	8.32kg/t	J
0006	Glass annealing furnace	(12)MFO	4.33kg/kl	J	0.38kg/kl	J
		(13)LFO	4.33kg/kl	J	0.38kg/kl	J
		(14A)Diesel	1.66kg/kl	J	0.49kg/kl	J
0008	Quarry	(16B)IFO	5.46kg/kl		0.30kg/kl	
		(29)LPG	1.35kg/kl	E	0.20kg/kl	E
		Primary Crushing	-		0.25kg/T	E
		Secondary & Screening	-		0.75kg/t	E
		Screening, Conveying, Handing	-		1.00kg/t	E

Note 1; Reference; E:EPA, J:Japan Environment Agency,
blank:factors obtained from measurement results

Note 2; Emission factors for boilers, incinerators were calculated from the flue gas measurement results.

(5) Air Pollution Load

Air pollution loads from factories were calculated using emission factors, fuel consumption, etc. The results are given in Tables 5.6(1) and 5.6(2) classified according to the facility type. The results indicate that, around 30,000 tons of SOx, 16,000 tons of NOx and 9,000 tons of Dust, were emitted to the atmosphere of KVR in 1992. The major polluter is the thermal power plants which emitted 22% of Dust, 64% of SOx and 81% of NOx. Factories are predominantly located in Shah Alam, Petaling Jaya and Klang.

Table 5.6 (1) Air Pollution Emission by Facility Type (general factories)

Equipment Code & Equipment	Pollutant Amount (ton/y)		
	SOx	NOx	Dust
0102 Boiler	4,015.54	951.15	3,519.81
0103 〃	4,355.36	525.50	2,203.83
0202 Gas furnace	0.00	6.12	0.91
0502 Melting furnace	0.00	3.02	0.45
0506 Metal melting furnace	0.67	0.35	0.07
0601 Heating furnace (reheating furnace) for rolling of metal	3.18	1.95	0.71
0606 〃	815.10	241.19	71.19
0607 Metal heat treating furnace	79.42	23.50	6.94
0611 〃	3.36	0.99	0.29
0613 Metal forge furnace	5.70	1.69	0.50
0615 〃	14.32	4.24	1.25
0821 Combustion furnace	133.42	5.80	4.39
0901 Cement kiln (dry and suspension preheater type)	0.00	698.83	47.77
0915 Glass melting furnace	867.19	24.74	181.14
1001 Reacting furnace	36.62	2.21	0.47
1004 Direct heating furnace	13.86	4.10	1.21
1102 Drying over Kiln (drier)	14.26	4.22	1.25
1104 〃	0.00	62.25	9.22
1106 〃	88.00	12.28	0.93
1204 Electric furnace	0.00	0.00	8.74
1301 Incinerator	0.00	0.62	3.54
1303 〃	261.35	285.34	939.95
1304 〃	3.46	1.02	0.30
0005 Baby cupola	2.28	0.57	0.17
0006 Glass annealing furnace	31.60	24.39	2.14
0008 Other furnace	302.40	93.05	26.63
TOTAL	11,047.09	2,979.12	7,033.80

Table 5.6 (2) Air Pollution Emission by Facility Type (2 power stations)

Equipment Code & Equipment	Pollutant Amount (ton/y)		
	SOx	NOx	Dust
0101 Boiler	19,522.07	10,650.57	1,843.97
0002 Gas turbine	0.00	2,141.10	124.66
TOTAL	19,522.07	12,791.67	1,968.63

5.2 Motor Vehicles

(1) Results of Traffic Volume Survey

Survey on traffic volume was conducted at 50 points on major roads (40) and minor roads (10) in Kelang Valley Region. Regarding the daily traffic volume on weekdays (24 hours), the heaviest traffic was observed at Federal Route 2 (Kota Darul Ehsan) with approximately 386,000 vehicles/day. Traffic volume on Middle Ring Road and roads which run north and south inside the Ring Road was around 100,000 vehicles per day. The average ratio of each type of vehicle to daily traffic volume shows that cars (motor car, van and taxi) accounted for about 70% of the daily total traffic volume on both weekdays and holidays. Motorcycles accounted for 15% on weekdays and 26% on Sundays.

(2) Traffic Volume in Kelang Valley Region

The roads in KVR are classified into major roads and minor ones. Major roads are those with heavy traffic volume, hence emit much pollutants. Minor roads have less heavy traffic and emit less pollutants. Traffic volume on major roads was based on data obtained from the traffic volume survey conducted in the Study and existing data. As for traffic volume on minor roads, daily weekdays traffic volume was estimated based on existing data. The total distance traveled annually is 16 billion kilometers with motor cars accounting for 53% of the total followed by motorcycles (22%) as shown in Table 5.7.

Table 5.7 Annual Distance Traveled by Various Types of Vehicles (1992)

(Unit: million km)

Vehicle Type	Annual Distance Traveled	(%)
Motorcycle	3587.6	(22.2)
Motor Car	8575.6	(53.1)
Van	1122.4	(7.0)
Taxi	844.8	(5.2)
Mini Bus	140.3	(0.9)
Medium/Large Bus	249.3	(1.5)
Small Truck	573.9	(3.6)
Medium/Large Truck	719.9	(4.5)
Lorry/ Trailer	325.5	(2.0)
Total	16139.3	(100.0)

Table 5.8 shows the distance traveled annually in different regions. Kuala Lumpur accounts for 40% of the total distance traveled, followed by Petaling (25%).

Table 5.8 Regional Annual Distance Traveled

Region	Annual Distance Traveled (million km/year)	(%)
Hulu Langat	1864.4	(11.5)
Gombak	2242.2	(13.9)
Kuala Lumpur	6488.2	(40.2)
Petaling	4094.8	(25.4)
Klang	1449.9	(9.0)
Total	16139.5	(100.0)

(3) Average Travel Speed

Travel speed survey was conducted on five routes. Generally at slower speed vehicles emit more HC, CO and SOx, and less NOx. The average speeds of vehicles in four zones, determined from the travel speed survey are listed in Table 5.9.

Zone 1: Inside Inner Ring Road

Zone 2: Zone between Inner Ring Road and Middle Ring Road

Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya

Zone 4 Kelang Valley Region (outside of Kuala Lumpur and Petaling Jaya

Over expressways (Federal Highway, KL-Seremban Expressway and KL-Karal Highway), speeds different from that of general roads were set in Zone 4. Maximum speed of travel for motorcycles was set at 40 km/h.

Table 5.9 Regional Vehicle Average Speed

Unit: km/h

Time zone		Weekdays 07-09	Weekdays 10-15	Weekdays 16-20	Weekdays 21-06	Holidays 07-09	Holidays 10-15	Holidays 16-20	Holidays 21-06
General Roads	Zone 1	20	20	15	20	35	25	25	35
	Zone 2	25	25	20	25	35	30	30	35
	Zone 3	30	35	25	35	45*	40	40	45*
	Zone 4	35	40	35	40	50*	45*	45*	50*
Express Way Zone 4	F.H.	40	50*	40	50*	60*	55*	55*	60*
	KL. S KL. K	50*	65*	50*	65*	65*	55*	55*	60*

* : Motorcycle : 40km/h

Classification of Zone

Zone 1: Inside Inner Ring Road
Zone 2: Zone between Inner Ring Road and Middle Ring Road
Zone 3: Kuala Lumpur (outside of Middle Ring Road) and Petaling Jaya
Zone 4: Kelang Valley Region (outside of Kuala Lumpur and Petaling Jaya)

(4) Exhaust Gas Measurement at Idling State

The measurement of exhaust gas from motor vehicles was conducted with 236 units for CO, NOx and HC while their engine was at idling state. The results are as follows.

1) CO

The average concentration of CO by petrol fueled vehicles (range from 2.4 to 5.1%) was higher than that by diesel vehicles (range from 0 to 0.1%). There was no clear relationship between vehicle age and CO concentration. The CO concentration may depend on the level of maintenance of the vehicle.

2) HC

The notable thing is that the average concentration of HC by motorcycle was very high at 4,060 ppm. It is fifteen times as high as those of taxi and motor car and ten times as high as that of small truck. The HC concentration of diesel vehicles was the lowest at less than 30 ppm. The average HC concentration of LPG vehicles was over 500 ppm, higher than that of petrol vehicles.

3) NOx

The average NOx concentration of diesel vehicles (range from 106 to 273 ppm) was higher than those of petrol and LPG vehicles.

(5) Chassis Dynamometer Test Results

A total of seventeen unleaded petrol fueled vehicles were tested for their exhaust emissions. The results of the tests are as follows.

1) Air Conditioner Off

The test results for the ECE mode for engine capacities of 1500 cc or less grouped into three categories based on year of production are summarized in Table 5.10. Newer model cars seem to emit less CO and HC, more NOx and consume more fuel.

Table 5.10 Average Emission Rates of Motor Car by Model Year (ECE Mode)

Model Year	HC (g/km)	CO (g/km)	NOx (g/km)	Fuel Economy (km/l)	Mileage (km)
- 1985	2.91	21.36	1.23	10.97	374139
1986 - 1991	2.69	9.26	2.70	10.75	64109
1992	2.35	4.98	2.19	10.11	852

2) Effects of air conditioners

Summary of tests on cars with airconditioner on is as follows.

HC: no change
CO: 10 % increase
NOx: 30 % increase
Fuel economy: 10 % decrease

(6) Emission Factor

The quantity of air pollutant emission while a motor vehicle runs 1 km of distance is called emission factor. Emission factors of current motor vehicles were established from the result of the chassis dynamometer tests and published data in the USA and Japan for five pollutants; HC, CO, NOx, SOx and PM. The emission factors for different types of vehicles operating in KVR are given in Table 5.11.

Table 5.11 Current Emission Factors for Motor Vehicles (1992)

(Unit: g/km)

Vehicle Type		Average Speed(km/h) 15	20	25	30	35	40	45	50	55	60	65
Motorcycle	HC	27.18	20.79	17.30	15.12	13.52	12.35					
	CO	44.19	34.03	28.12	24.58	21.98	19.85					
	NOx	0.21	0.19	0.19	0.19	0.20	0.21					
	SOx	0.002	0.002	0.002	0.002	0.002	0.002					
	PM	0.205	0.205	0.205	0.205	0.205	0.205					
Motor Car	HC	3.47	2.57	2.07	1.75	1.50	1.32	1.15	1.02	0.90	0.80	0.73
	CO	36.04	26.44	21.05	17.68	15.16	13.30	11.62	10.27	9.09	8.25	7.58
	NOx	1.51	1.58	1.65	1.74	1.81	1.88	1.93	1.99	2.02	2.07	2.11
	SOx	0.005	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003
	PM	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Van	HC	2.96	2.25	1.83	1.57	1.36	1.19	1.05	0.93	0.83	0.75	0.69
	CO	59.10	43.43	34.60	29.06	24.91	21.86	19.10	16.89	14.97	13.59	12.48
	NOx	2.80	2.89	2.98	3.11	3.22	3.33	3.40	3.49	3.54	3.64	3.70
	SOx	0.119	0.104	0.096	0.089	0.085	0.081	0.080	0.078	0.076	0.074	0.072
	PM	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102	0.102
Taxi	HC	2.57	1.99	1.63	1.40	1.22	1.07	0.95	0.85	0.76	0.69	0.63
	CO	33.48	24.75	19.77	16.59	14.22	12.47	10.90	9.66	8.57	7.80	7.18
	NOx	2.07	2.00	1.95	1.93	1.92	1.93	1.93	1.95	1.97	2.00	2.03
	SOx	0.371	0.323	0.296	0.278	0.263	0.252	0.247	0.240	0.234	0.230	0.226
	PM	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235	0.235
Mini Bus	HC	5.66	4.92	4.30	3.82	3.38	3.05	2.76	2.53	2.31	2.17	2.02
	CO	11.37	9.20	7.62	6.35	5.45	4.72	4.17	3.75	3.45	3.21	3.03
	NOx	4.92	4.44	4.07	3.77	3.55	3.40	3.29	3.22	3.22	3.22	3.29
	SOx	1.518	1.399	1.325	1.274	1.240	1.218	1.195	1.178	1.167	1.155	1.144
	PM	1.603	1.408	1.028	1.028	1.028	1.028	1.028	1.028	1.028	1.028	1.028
Medium/Large Bus	HC	7.60	6.59	5.76	5.09	4.55	4.07	3.68	3.39	3.10	2.91	2.71
	CO	26.68	21.68	17.79	14.87	12.79	11.12	9.73	8.76	8.06	7.50	7.09
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.300	3.041	2.881	2.770	2.696	2.647	2.598	2.561	2.536	2.512	2.487
	PM	4.481	3.935	2.872	2.872	2.872	2.872	2.872	2.872	2.872	2.872	2.872
Small Truck	HC	6.14	4.79	4.05	3.51	3.10	2.73	2.40	2.13	1.89	1.69	1.55
	CO	64.94	51.08	44.22	39.26	35.45	31.64	27.83	24.40	21.73	19.82	18.68
	NOx	2.95	3.10	3.31	3.57	3.82	4.08	4.30	4.52	4.66	4.81	4.92
	SOx	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	PM	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043	0.043
Medium/Large Truck	HC	3.88	3.37	2.94	2.61	2.31	2.08	1.88	1.73	1.58	1.49	1.38
	CO	8.00	6.48	5.35	4.46	3.83	3.32	2.93	2.63	2.42	2.25	2.12
	NOx	6.22	5.61	5.15	4.78	4.49	4.29	4.15	4.07	4.05	4.07	4.17
	SOx	2.201	2.026	1.916	1.852	1.797	1.760	1.733	1.706	1.687	1.678	1.659
	PM	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632	0.632
Lorry/Trailer	HC	5.31	4.60	4.03	3.55	3.18	2.84	2.57	2.37	2.17	2.03	1.89
	CO	18.64	15.14	12.43	10.39	8.93	7.77	6.80	6.12	5.63	5.24	4.95
	NOx	21.06	19.01	17.44	16.18	15.24	14.46	13.98	13.83	13.67	13.83	14.14
	SOx	3.246	2.989	2.827	2.732	2.651	2.597	2.556	2.516	2.489	2.475	2.448
	PM	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389	1.389

(7) Air pollution Load

Based on the traffic volume, the regional average vehicle speed and the average emission rates for each vehicle type and average speed, annual air pollution load in KVR were estimated. The annual air pollution load from motor vehicles is summarized in Table 5.12. The annual total emission is 73,000 tons for HC, 290,000 tons for CO, 36,000 tons for NOx, 3,000 tons for SOx and 3,000 tons for PM. For HC, Motorcycles are the major contributors (70% of the total emission). For CO, motor cars and motorcycles are two major contributors accounting for 47% and 29% respectively. As for NOx, motor cars are the major contributors accounting for 43% of the total. For SOx and PM, medium/large trucks, lorry/trailers and medium/large buses are the major contributors. The contribution to PM emission by diesel vehicles is 59% as shown in Table 5.13.

Table 5.12 Current Pollution Load by Various Types of Vehicles (1992)

(Unit: ton/year)

Vehicle Type	HC	CO	NOx	SOx	PM
Motorcycle	51448 (70.0)	83413 (28.7)	720 (2.0)	7 (0.2)	735 (22.7)
Motor Car	13423 (18.3)	136052 (46.9)	15518 (42.9)	31 (1.0)	369 (11.4)
Van	1543 (2.1)	28586 (9.8)	3633 (10.0)	96 (3.1)	114 (3.5)
Taxi	1114 (1.5)	13259 (4.6)	1640 (4.5)	229 (7.3)	199 (6.1)
Mini Bus	512 (0.7)	854 (0.3)	525 (1.5)	180 (5.8)	152 (4.7)
Medium/Large Bus	1136 (1.6)	3254 (1.1)	3854 (10.6)	678 (21.8)	737 (22.7)
Small Truck	1740 (2.4)	19731 (6.8)	2248 (6.2)	3 (0.1)	25 (0.8)
Medium/Large Truck	1573 (2.1)	2592 (0.9)	3195 (8.8)	1036 (33.2)	456 (14.0)
Lorry/Trailer	956 (1.3)	2666 (0.9)	4879 (13.5)	857 (27.5)	456 (14.1)
Total	73445 (100)	290407 (100)	36212 (100)	3117 (100)	3243 (100)

Figures in parenthesis are percentage values.

Table 5.13 Current PM Emission from Petrol and Diesel Vehicles (1992)

Engine Type	PM Emission (ton/year)	
Petrol	1,327	(40.9)
Diesel	1,914	(59.1)
Total	3,241	(100.0)

Figures in parenthesis are percentage values.

5.3 Airplanes

Subang Airport is located to the west of Kuala Lumpur city and handles both domestic and international flights. The total number of annual flights in 1992 is 96,777 including 44,883 for international flight and 51,934 for domestic flight. The annual total air pollution load from airplanes is 416 tons for SOx, 1,320 tons for NOx and 115 tons for PM.

5.4 Ships

Port Klang is located on west side of Klang Valley Region and handles both import and export commodities. A total number of 5307 ships called at Port Klang in 1990. As for total cargo handling, exports amounted to 8.2 million tons and imports amounted to 13.9 million tons in 1990. The annual total air pollution load from ships is 1,552 tons for SOx, 989 tons for NOx and 200 tons for PM.

5.5 Households

The fuel used by households in Klang Valley Region is mainly LPG. Total LPG consumption by all sources amounted to 286 million liters in 1992 and around 70% (202 million liters) out of 286 million liters were for households including hotels, restaurants, and others. The annual total air pollution load from households including hotels, restaurants, and so on in KVR are 44 tons for Dust and 162 ton s for NOx.

5.6 Total Air Pollution Load

(1) Pollution Load from Various Sources

The annual air pollution loads from various sources are shown in Table 5.14. The annual total air pollution load is 36,000 tons for SOx, 54,000 tons for NOx, 13,000 tons for PM, 290,000 tons for CO and 73,000 tons for HC. As for SOx, factories account for 86% of the total emission. For NOx, motor vehicles are the major pollution source accounting for 67% of the total, followed by factories (29%). As for PM, the major contributor is factories (72%).

Table 5.14 Current Air Pollution Load from Various Sources (1992)

(Unit: ton/year)

	SOx	NOx	PM	CO	HC
Factories					
Power stations	19,522	12,792	1,969	-	-
General factories	11,047	2,979	7,034		
Sub-total	30,569	15,771	9,003	-	-
	(85.7)	(29.0)	(71.4)		
Motor vehicles	3,117	36,212	3,243	290,407	73,445
	(8.7)	(66.5)	(25.7)	(100)	(100)
Airplanes	416	1,320	115	-	-
	(1.2)	(2.4)	(0.9)		
Ships	1,552	989	200	-	-
	(4.4)	(1.8)	(1.6)		
Households	0	162	44	-	-
	(0.0)	(0.3)	(0.4)		
Total	35,654	54,454	12,605	290,407	73,445
	(100)	(100)	(100)	(100)	(100)

Figures in parenthesis are percentage values(%). Air pollutant emission from open burning activities and earthworks are not included in this Table.

(2) Regional Air Pollution Load

The regional air pollution load from factories, motor vehicles, airplanes and ships is shown in Table 5.15. SOx and PM is mainly emitted in Klang. NOx is mainly emitted in Klang and Kuala Lumpur.

Table 5.15 Regional Annual Air Pollution Load from Factories, Motor Vehicles, Airplanes and Ships (1992)

(unit: ton/year)

Pollutant	Region	Factories	Motor Vehicles	Airplanes	Ships	Total
SOx	Hulu Langat	1,184	410			1,594 (4.5)
	Gombak	556	529			1,085 (3.0)
	Kuala Lumpur	641	1,029			1,670 (4.7)
	Petaling	5,558	761	416		6,735 (18.9)
	Klang	22,630	390		1,552	24,572 (68.9)
	Total	30,569	3,119	416	1,552	35,656 (100)
NOx	Hulu Langat	575	4,336			4,911 (9.0)
	Gombak	720	5,445			6,165 (11.4)
	Kuala Lumpur	102	13,518			13,620 (25.1)
	Petaling	765	9,319	1,320		11,404 (21.0)
	Klang	13,609	3,593		989	18,191 (33.5)
	Total	15,771	36,211	1,320	989	54,291 (100)
PM	Hulu Langat	1,924	415			2,339 (18.6)
	Gombak	198	514			712 (5.7)
	Kuala Lumpur	346	1,190			1,536 (12.2)
	Petaling	1,698	759	115		2,572 (20.5)
	Klang	4,836	363		200	5,399 (43.0)
	Total	9,002	3,241	115	200	12,558 (100)

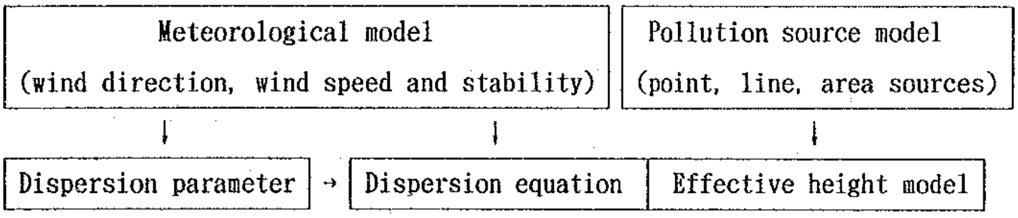
Figures in parenthesis are percentage values.

CHAPTER 6 ANALYSIS OF AIR POLLUTION STRUCTURE BY AIR DISPERSION SIMULATION MODEL

The dispersion simulation model was prepared in order to determine contributions of factories and motor vehicles to the air quality.

6.1 Outline of Air Dispersion Simulation Model

The model consists of sub-models shown below.



(1) Scope of the Dispersion Simulation Model

1) Calculated concentration
Long-term average (annual average) of SO_2, NO_x, NO_2 and CO

2) Sources included
Factories, motor vehicles, airplanes and ships

3) Calculation point
Monitoring station (5 points), and 1 Km mesh points (at the center) in Kelang Valley Region

(2) Meteorological Model

Meteorological data used for dispersion simulation are wind direction, wind speed, and atmospheric stability. In the Study, the Area was divided into two blocks as shown in Fig. 6.1 in view of the topographical state and source distribution. Shah Alam and Petaling Jaja were selected as the the meteorologically representative station for the western block and eastern block respectively. The meteorology of each representative station was applied uniquely to the whole area in the corresponding block. The atmospheric stability during the daytime, was determined using wind speed and solar radiation data, and during the nighttime the wind speed and net radiation data. The wind speed was corrected according to the height of the source concerned.

The meteorological classification of each element is shown below.

Wind direction :	16 directions and calm (≤ 0.4 m/s)
Wind speed :	8 classes
Atmospheric stability :	11 classes

(3) Pollution Source Model

Stacks of factories were handled as point source. Roads on which motor vehicles travel were handled as line source for major roads and as area source for minor roads. As regards airplanes, those staying on ground were handled as area source and those flying up to a height of 500 m above ground as point source. As regards ships, those at anchor in harbor were handled as point source and those cruising as area source.

(4) Effective Stack Height Model

Exhaust gas rises up to a certain height (effective stack height) under the effect of temperature-induced buoyancy and discharge speed. In the Study, this height was calculated using the CONCAWE equation when it is windy and the Briggs equation when it is calm.

(5) Air Dispersion Equation

For the dispersion equation, the plume equation was used when it is windy, and the puff equation when it is calm.

(6) Dispersion Parameter

The dispersion parameters were set by using the Pasquill-Gifford chart for the plume equation and the Turner chart for the puff equation.

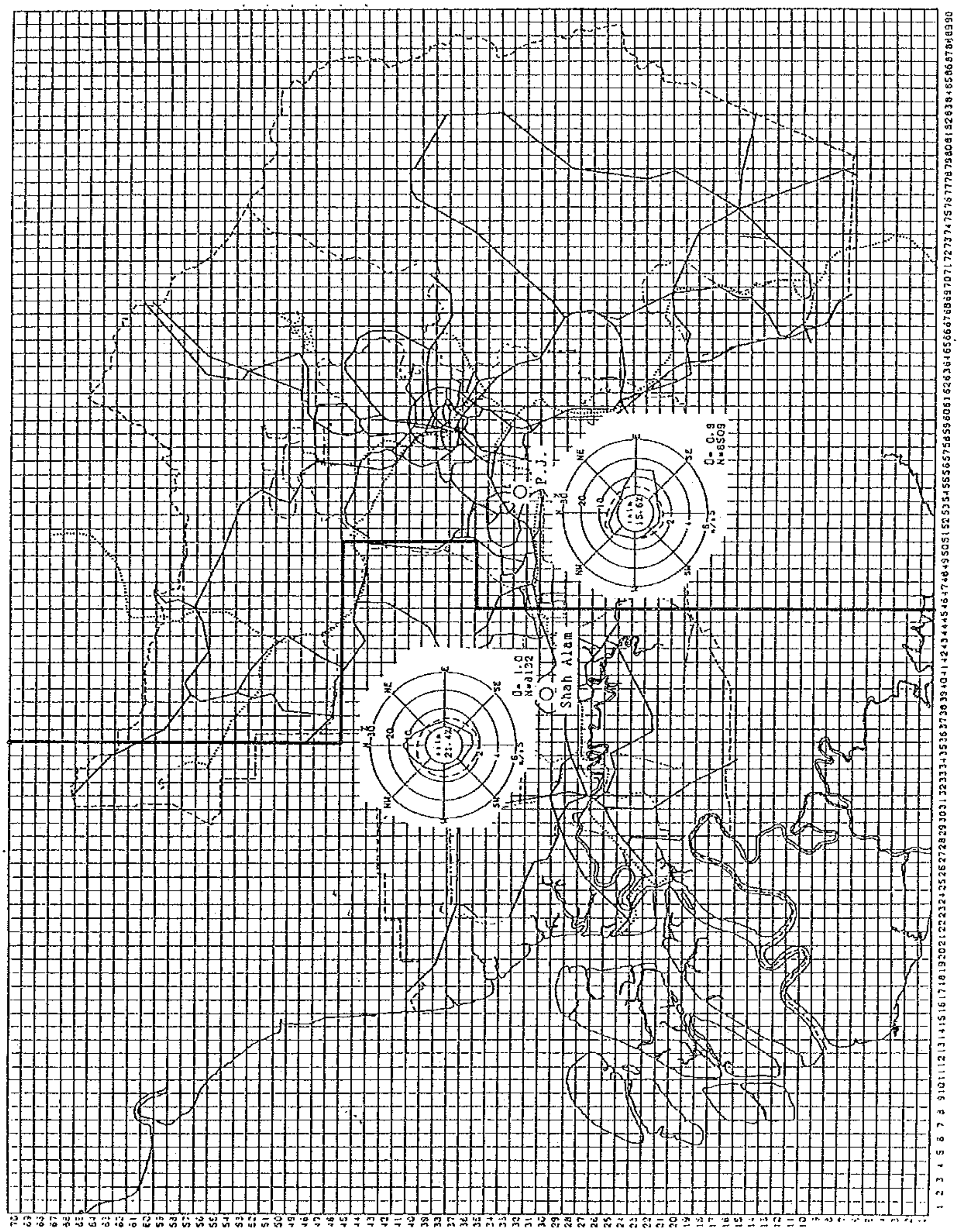
(7) Equation to convert NOx to NO_2

To calculate the NO_2 concentration from the NOx concentration determined from the dispersion simulation, the regression method described below was used.

$[NO_2] = 2.114 \cdot [NOx]^{0.529}$ (unit: ppb)

$[NO_2]$, [NOx] : Long-term average (annual average)

Fig. 6.1 Meteorological Blocks and Representative Meteorological Stations in Kelang Valley Region



Factor: Determined by applying logarithmic liner regression method to data measured at five stations (Fig. 6.2)

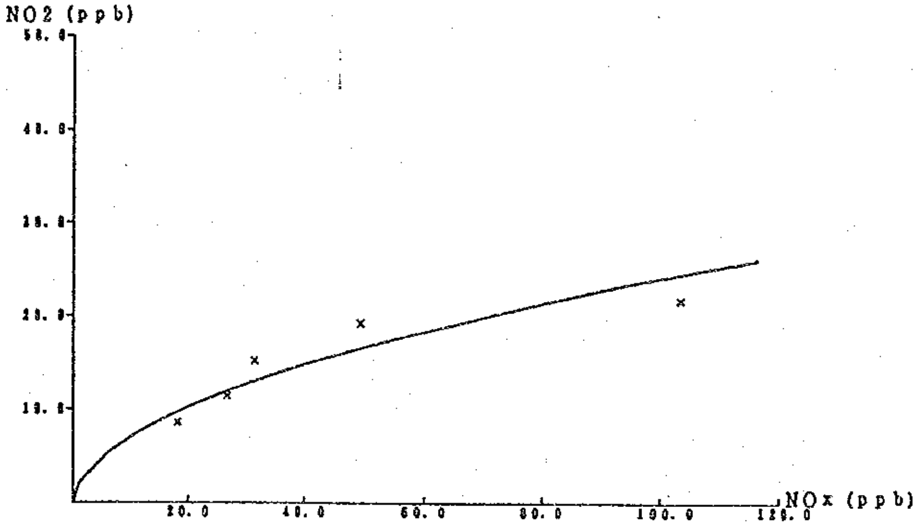


Fig. 6.2 Logarithmic Linear Regression between NO_2 and NOx

6.2 Reproducibility of the Dispersion Simulation Model

The reproducibility for each pollutant was evaluated by means of correlation coefficient. The result shows that SO_2 and NO_2 had a high correlation of more than 0.9 as shown in Table 6.1. Background concentration was defined as the difference between measured and computed values in the Study. Fig 6.3 is the scatter diagram of actual and estimated values for each pollutant.

Table 6.1 Reproducibility of Simulation Model

(March～ May, '92)

Item	Regression Line	Number of Stations for Evaluation	Correlation Coefficient	Coefficient of Variation	Back-ground
SO_2	Y=0.487X+6.43 (ppb)	5	0.903	0.291	3.11 (ppb)
NO_x	Y=0.847X+12.00 (ppb)	5	0.991	0.190	5.91 (ppb)
NO_2	Y=0.737X+4.28 (ppb)	5	0.945	0.193	0.37 (ppb)
CO	Y=0.724X+1.32 (ppm)	3	0.643	0.658	1.02 (ppm)

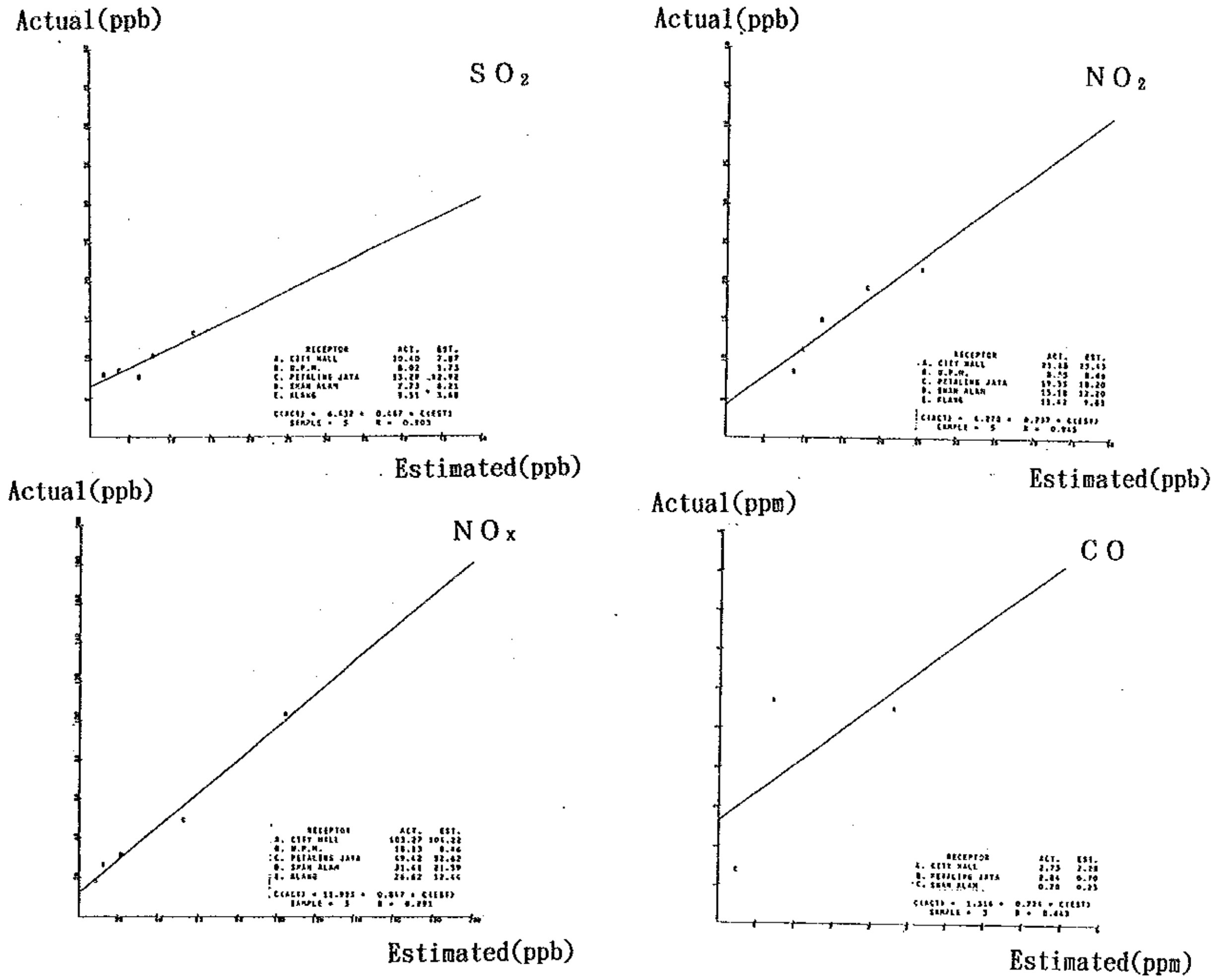


Fig. 6.3 Scatter Diagram of Actual and Estimated Values

6.3 Contribution to Concentration by Sources

The amount and ratio contributed by various sources at each monitoring station and the maximum concentration point are described below:

SO_2: Among the five monitoring stations, Petaling Jaya station (C) shows the highest concentration (16.0 ppb), of which 66% was contributed by factories. Their amount was 10.6 ppb. The maximum concentration point was found in the area of Petaling Jaya, with concentration at 59.7 ppb which is much higher than the air quality target value (20 ppb). The contribution from factories and motor vehicles at the point was 88% and 7% respectively (See Fig. 6.4).

NOx: The air quality target value for nitrogen oxides is specified by NO_2. However, NO emitted from pollution sources is converted into NO_2 through complicated reactions, so the contribution ratio of NOx was calculated in the Study. The calculation result shows high concentration at City Hall station (A), and at the maximum concentration point, principally due to motor vehicles. The contribution from motor vehicles was 8.0 - 104.0 ppb and its ratio 44 - 94%. Though the NOx emission quantity from factories approximately amounted to 30% of the total emission, their contribution was lower because emitted pollutant from stacks are dispersed widely in the atmosphere (See Fig. 6.5).

CO: There is almost no emission of CO from factories. Apart from CO of natural origin, motor vehicles may be considered as the sole source. The calculation result shows high concentration at City Hall station (A) in the center of the City, and maximum concentration point with a value of 3.30 ppm and 4.90 ppm respectively. (See Fig. 6.6)

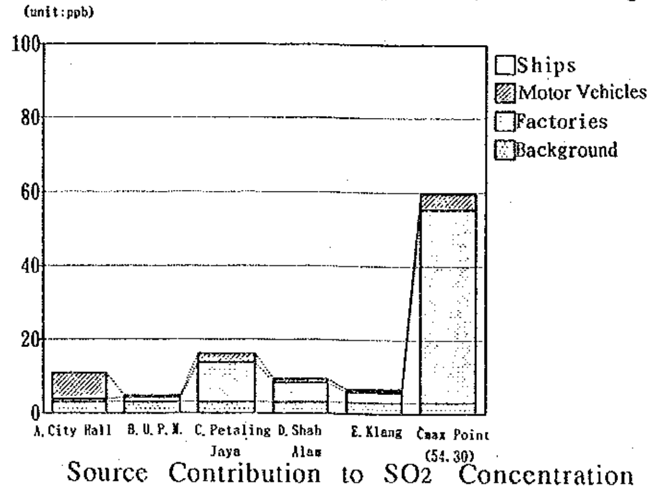


Fig. 6.4 Source Contribution to SO_2 Concentration

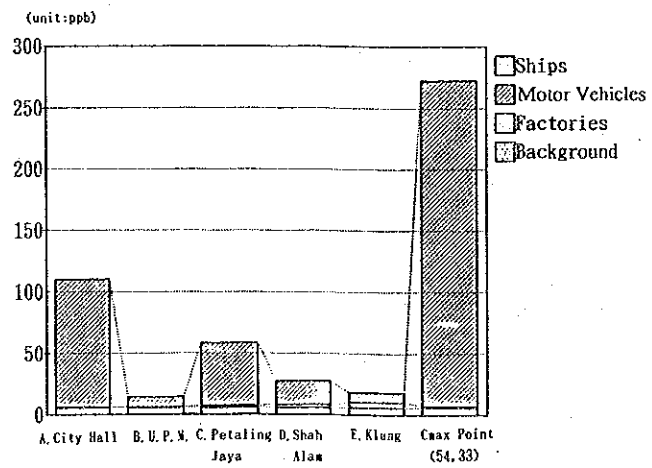


Fig. 6.5 Source Contribution to NOx Concentration

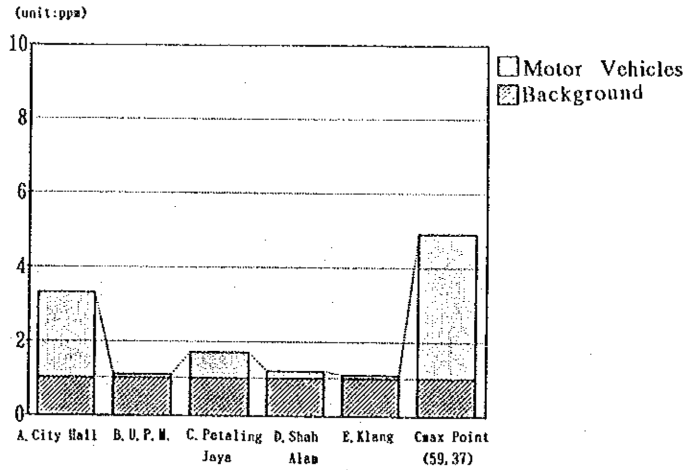


Fig. 6.6 Source Contribution to CO Concentration

6.4 Concentration Distribution

Table 6.2 shows the annual average concentrations of SO_2, NOx, NO_2 and CO at each fixed station and the maximum concentration point. The Maximum concentrations of SO_2, NO_2, and CO exceed the corresponding target values (20 ppb for SO_2, 37 ppb for NO_2 and 4 ppm for CO).

Table 6.2 Current Annual Average Concentration (1992)

Items / Stations	SO_2 (ppb)	NOx (ppb)	NO_2 (ppb)	CO (ppm)
A. City Hall	10.0	110.1	25.4	3.30
B. UPM	4.8	14.4	8.6	1.10
C. Petaling Jaya	16.0	58.5	18.2	1.72
D. Shah Alam	9.3	27.5	12.2	1.25
E. Klang	5.8	18.3	9.8	1.11
Cmax Point Mesh Index	59.7 (54,30)	272.4 (54,33)	41.1 (54,33)	4.92 (59,37)

The regional distribution of concentrations of SO_2, NO_2 and CO obtained through the dispersion simulation are as follows (Fig. 6.7 - 6.9).

SO_2: Concentration is high in the Petaling Jaya area and in areas east of Klang.

NO_2: Concentration is high in Kuala Lumpur and Petaling Jaya areas.

CO: Concentration is high in Kuala Lumpur and Petaling Jaya areas.

× :Cmax Point unit:ppb

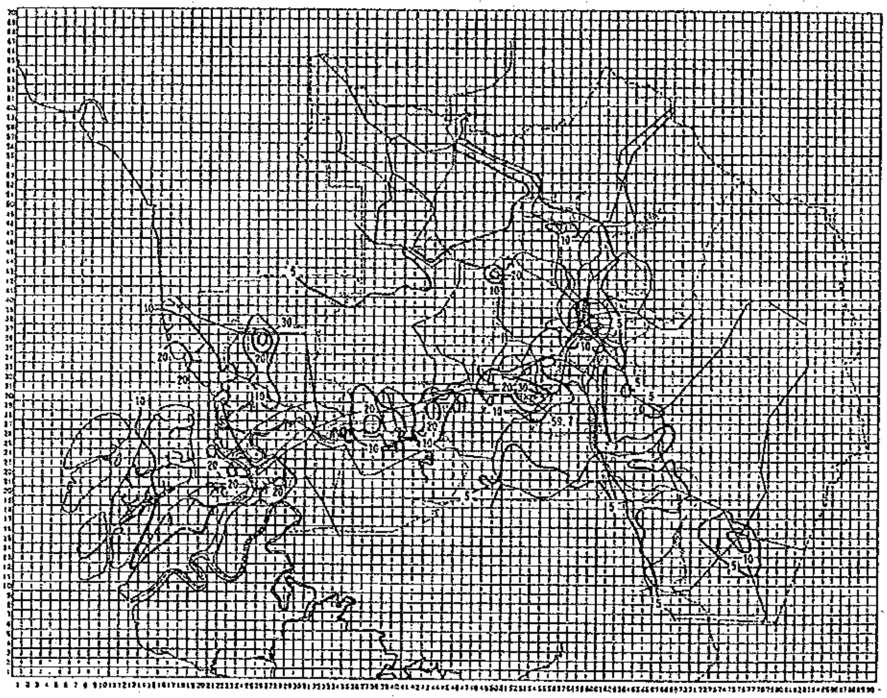


Fig. 6.7 Average Concentration for Isopleths for SO_2

× :Cmax Point unit:ppb

Fig. 6.8 Average Concentration for Isopleths for NO_2

× :Cmax Point unit:ppm

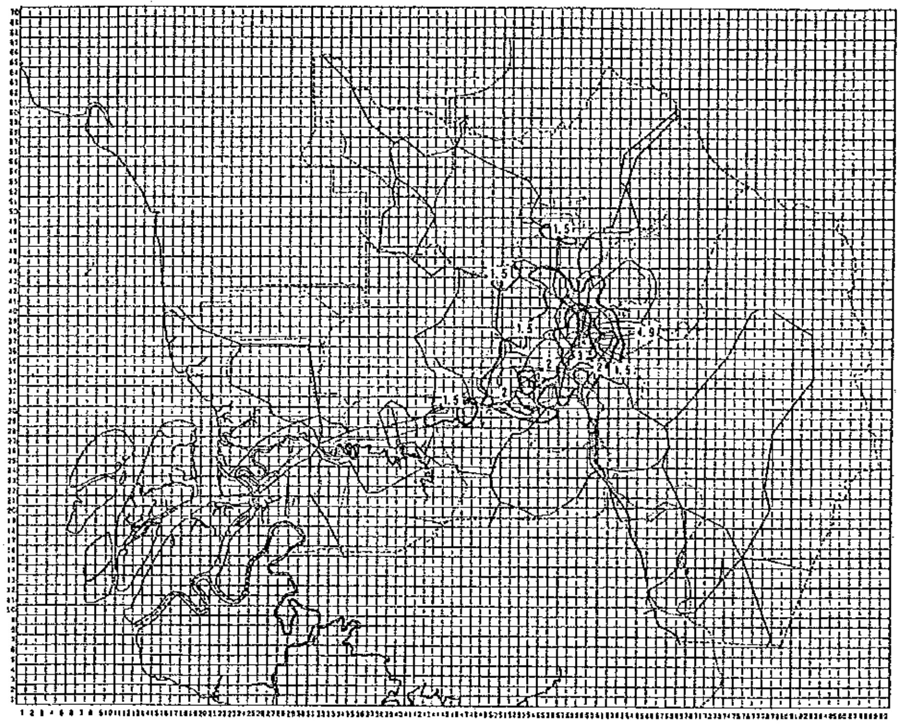


Fig. 6.9 Average Concentration for Isopleths for CO

6.5 Air Dispersion Simulation System

(1) Outline of the Air Dispersion Simulation System

This system can estimate the ambient air quality from existing pollution sources in KVR and also the impact to the ambient air quality by the additional new pollution sources.

The flowchart in Fig. 6.10 outlines the design of the dispersion simulation system.

(2) Function of the System

The dispersion system covers the following items.

- Air pollutants included: SO_2, NOx, NO_2, CO, Dust

- Pollution sources concerned
  New pollution sources will be factories and vehicles.

- Period
  Annual

- Area covered in the estimation
  Kelang Valley Region

The detail of these parameters and equations are shown in Section 6.1.

(3) Simulation Case Study

Since Dispersion Prediction Files for all types of sources are provided for the current (1992) condition and the future (2005) calculated by the Model, the results of the Model and this system can be aggregated together to predict the overall dispersion scenario. The Dispersion Prediction Files of the Model are equipped with options to increase or decrease concentration levels, so that newly implemented control measures can be reflected in the simulation.

This system was implemented in the MMS computer (CONCURRENT Super minicomputer) system.

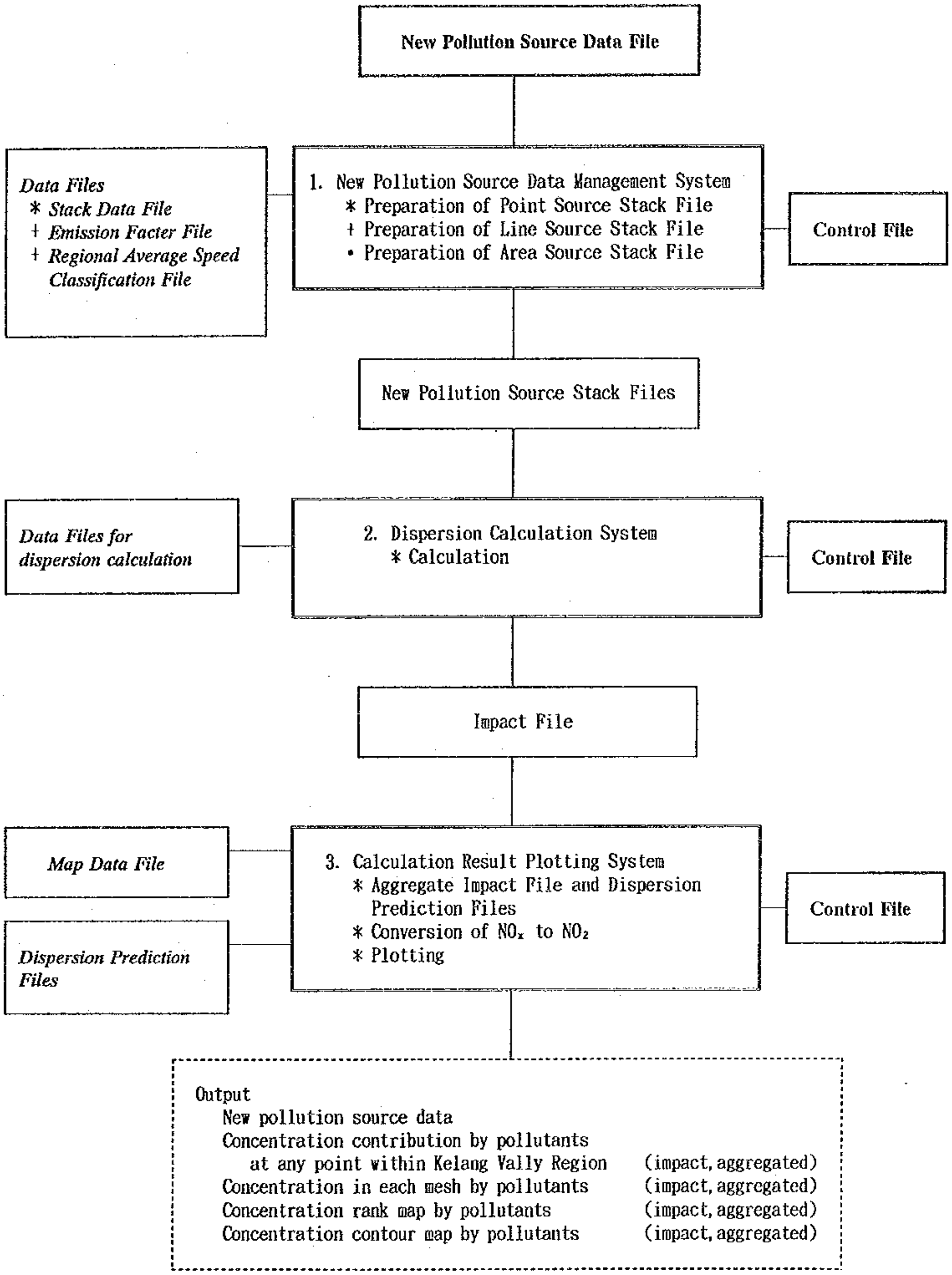


Fig. 6.10 Flowchart of the Air Dispersion Simulation System

CHAPTER 7 CHEMICAL ANALYSIS OF SPM COMPONENT

CMB (Chemical Mass Balance) method is a type of receptor model or statistical model to estimate the contributions from sources to ambient SPM concentration. One special feature of SPM component is the high contribution by natural sources and it is therefore very difficult to establish a completely physical model for estimating SPM due to natural processes. Hence the CMB method provides an alternative way to effectively estimate the contributions by artificial sources and natural processes.

The particles are categorized into primary particles and secondary particles. The primary particles are those emitted in particulate form, but the secondary particles are those emitted in gaseous form and then converted to particulate form. For example, some parts of SO_2 are converted to SO_4 and finally to sulfuric acid or some forms of sulfate. CMB method targets the primary particles and the contributions by the secondary particles are estimated from their chemical components.

SPM component data on emission sources were made based on the analyzed data and the existing information. Eight categories of emission sources assumed are as follows.

1. Sea salt
2. Soil (and road dust)
3. Unleaded petrol combustion
4. Iron and steel industries
5. Wood combustion
6. Fuel oil combustion
7. Diesel oil combustion
8 Cement

CMB method was applied to the ambient SPM component data. The result is summarized in Table 7.1. The general features are as follows.

The contributions by motor vehicles (petrol and diesel) range from about 19% to 44%. The contributions at MMS and City Hall are higher than those at UPM. Contribution by leaded petrol is small judging from Pb, Cl and Br concentrations.

The contributions from wood combustion are 7% to 36%, and ones measured at MMS and UPM are about 15%. About half of organic carbon comes from both vehicle exhaust and wood combustion. Secondary particles converted from organic compounds may be contributing to the rest of organic carbon, and this contribution is estimated to be around 10% of SPM.

The contributions from soil particles depend upon weather and/or season. Those in August and September were about 10%, and those in December, January and March were below 5% at both sites, MMS and UPM.

The contributions by sea salt particles were at most 4%, and the average of all results was 1.8%.

The contributions by fuel oil combustion particles were 1.3% to 6.2% at MMS and 1.0% to 1.7% at UPM, and the average of all results was 2.3%. The contribution at MMS was larger than that at UPM.

The contributions from iron and steel industries were almost below 1%.

The contributions from cement industries were estimated to be 0% to 3.9%. However these estimated values seem to be somewhat disturbed by the contributions from soil particles.

The concentrations by sulfate were almost 2 to 3 $\mu g/m^3$, and the contributions by secondary sulfate to SPM were about 6% on average.

'Others' refers to the contributions excluding the above mentioned primary particles and secondary particles. The greater part of them is water.

Table 7.1 (1) Source Contributions to Ambient SPM

(Unit: ng/m^3, in parenthesis: %)

	M1	M2	M3	M4	Average
Sea Salt	770 (1.4)	1090 (2.5)	650 (1.2)	110 (0.3)	650 (1.3)
Soil	6950 (12.7)	3900 (8.9)	1940 (3.5)	1050 (2.4)	3460 (7.0)
Unleaded Petrol	340 (0.6)	660 (1.5)	580 (1.0)	500 (1.1)	520 (1.1)
Iron & S	230 (0.4)	50 (0.1)	750 (1.3)	270 (0.6)	330 (0.7)
Wood	7070 (12.9)	7850 (17.8)	8720 (15.6)	3590 (8.2)	6810 (13.7)
Fuel Oil	730 (1.3)	1720 (3.9)	2510 (4.5)	2720 (6.2)	1920 (3.9)
Diesel	23290 (42.4)	18740 (42.6)	21650 (38.7)	17590 (40.0)	20320 (40.9)
Cement	990 (1.8)	1200 (2.7)	350 (0.6)	430 (1.0)	740 (1.5)
Sum	40370 (73.5)	35200 (80.0)	37140 (66.3)	26260 (59.7)	34750 (69.9)
Sulfate	1600 (2.9)	1940 (4.4)	3330 (5.9)	1930 (4.4)	2200 (4.4)
Nitrate	0 (0.0)	20 (0.0)	0 (0.0)	50 (0.1)	0 (0.0)
Organic Carbon	8400 (15.3)	4940 (11.2)	5420 (9.7)	4200 (9.5)	5700 (11.5)
Others	4523 (8.2)	1910 (4.3)	10110 (18.1)	11380 (25.9)	7980 (14.2)
Observed	54900	44000	56000	44000	49725

M1: MMS, 17th/August/1992　　M2: MMS, 11th/September/1992

M3: MMS, 28th/December/1992　　M4: MMS, 30th/December/1992

Table 7.1 (2) Source Contributions to Ambient SPM

(Unit: ng/m^3, in parenthesis: %)

	U1	U2	U3	U4	Average
Sea Salt	600 (1.2)	820 (1.4)	150 (0.5)	60 (0.3)	410 (1.0)
Soil	5330 (10.9)	6900 (11.9)	20 (0.1)	50 (0.2)	3070 (7.7)
Unleaded Petrol	110 (0.2)	240 (0.4)	130 (0.4)	80 (0.3)	140 (0.4)
Iron & S	30 (0.1)	140 (0.2)	180 (0.6)	50 (0.2)	100 (0.3)
Wood	5110 (10.4)	10840 (18.8)	4760 (16.4)	1650 (6.9)	5580 (14.0)
Fuel Oil	720 (1.5)	990 (1.7)	500 (1.7)	250 (1.0)	610 (1.5)
Diesel	18430 (37.6)	16530 (28.6)	9660 (33.3)	7830 (32.6)	13120 (32.8)
Cement	390 (0.8)	2240 (3.9)	220 (0.8)	170 (0.7)	860 (2.2)
Sum	30710 (62.7)	38700 (66.9)	15630 (53.9)	10130 (42.2)	23890 (59.8)
Sulfate	1190 (2.4)	2040 (3.5)	1710 (5.9)	2120 (8.8)	1770 (4.4)
Nitrate	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Organic Cargon	6290 (12.8)	10200 (17.6)	2940 (10.2)	1800 (7.5)	5310 (13.3)
Others	10810 (22.1)	6860 (11.9)	8600 (29.7)	9670 (40.3)	8980 (22.5)
Observed	49000	57800	29000	24000	39950

U1: UPM, 17th/August/1992　　U2: UPM, 11th/September/1992

U3: UPM, 28th/December/1992　　U4: UPM, 30th/December/1992

Table 7.1 (3) Source Contributions to Ambient SPM

(Unit: ng/m^3, in parenthesis: %)

	U5	U6	U7	U8	Average
Sea Salt	1540 (3.7)	1170 (2.5)	1030 (2.3)	1380 (3.4)	1280 (2.9)
Soil	1210 (2.9)	1530 (3.3)	1790 (4.1)	2810 (6.9)	1840 (4.2)
Unleaded Petrol	390 (0.9)	130 (0.3)	440 (1.0)	60 (0.2)	260 (0.6)
Iron & S	39 (0.1)	50 (0.1)	310 (0.7)	130 (0.3)	130 (0.3)
Wood	4440 (10.6)	4670 (9.9)	8520 (19.4)	14610 (35.6)	8050 (18.5)
Fuel Oil	0 (0.0)	1240 (2.6)	870 (2.0)	30 (0.1)	530 (1.2)
Diesel	15190 (36.2)	12650 (26.9)	18660 (42.4)	7700 (18.8)	13560 (31.2)
Cement	850 (2.0)	410 (0.9)	530 (1.2)	0 (0.0)	970 (2.2)
Sum	23650 (56.3)	21860 (46.5)	32150 (73.1)	26740 (65.2)	26630 (61.2)
Sulfate	6660 (15.8)	4970 (10.6)	1380 (3.1)	1930 (4.7)	3730 (8.6)
Nitrate	0 (0.0)	0 (0.0)	0 (0.0)	260 (0.6)	0 (0.0)
Organic Carbon	4220 (10.1)	3400 (7.2)	4870 (11.1)	0 (0.0)	2900 (6.7)
Others	7470 (17.8)	16560 (35.2)	4850 (11.0)	10980 (26.8)	10250 (23.6)
Observed	42000	47000	44000	41000	43500

U5: City Hall, 26th/January/1993 U6: Shah Alam, 26th/January/1993

U7: City Hall, 1st/March/1993 U8: Toman Sri Andalas, 2nd/March/1993

Table 7.1 (4) Source Contributions to Ambient SPM

(Unit: ng/m^3, in parenthesis: %)

	Grand Average	
Sea Salt	780	(1.8)
Soil	2790	(6.3)
Unleaded Petrol	310	(0.7)
Iron & Steel	190	(0.4)
Wood	6810	(15.3)
Fuel Oil	1020	(2.3)
Diesel	15660	(35.3)
Cement	860	(1.9)
Sum	28420	(64.0)
Sulfate	2570	(5.8)
Nitrate	0	(0.0)
Organic Carbon	4650	(10.5)
Others	8750	(19.7)
Observed	44390	

CHAPTER 8 PREDICTION OF AIR POLLUTANT CONCENTRATION IN THE FUTURE AND NECESSITY OF REDUCTION OF AIR POLLUTION LOAD

8.1 Target Year

Kelang Valley Region has a Master Plan by the year 2005 to introduce modern public transportation systems such as Light Rapid Train (LRT) System and Mass Rapid Transit (MRT) Railway System. Construction of many new roads and improvement of existing ones are also planned to be completed by that year. When these plans are completed, regional distribution of traffic volume as a major air pollution source will face a remarkable change. So, the year 2005 was chosen as a basis for predicting future air pollution and examining the necessity for reduction of air pollution load.

8.2 Prediction of Future Air Pollution Sources

8.2.1 Prediction Method

(1) Factories and Establishments

1) Prediction Method

a) Power Stations

TNB has a future plan for their power stations until the year 2000. The plan was elongated to 2005 without change in This Study.

b) General Factories

Coal consumption in the cement factory was assumed to increase at a rate of 9.5% per year. Wood waste consumption was assumed to remain at the current amount taking into consideration of the trends in forest preservation. Palm waste consumption was estimated to increase at a rate of 3.3% per year. Future demands for fuel oil and diesel oil were assumed to be identical to those in 1992. LPG demand including natural gas in 2005 was estimated to be 5.13 times of the consumption in 1992.

(2) Motor Vehicles

For motor vehicles, the following assumptions were made:

① The major road network in the future is the same as the current one.
② Traffic volume on all major and minor roads will increase uniformly to 2.27 times.
③ The emission factors are the same as those at present.

(3) Airplanes

Based on the 6th Malaysian Plan, number of flights at Subang Airport in 2005 is estimated to be 105,421.

(4) Ships

The cargo handling amount in the future is expected to be 1.86 times of the current amount.

(5) households

An annual population growth rate of 2.6 % was used.

8.2.2 Total Air Pollution Load

(1) Pollution Load from Various Sources

The air pollution load from various sources are shown in Table 8.1. The total annual air pollution load is 52,000 tons for SOx, 115,000 tons for NOx, 19,000 tons for PM, 659,000 tons for CO and 167,000 tons for HC respectively. For SOx, factories account for 80% of the total emission. For NOx, motor vehicles are the major pollution sources accounting for 71% of the total, followed by factories(26%). For PM, the major contributors are factories (57%) and motor vehicles (40%).

Table 8.1 Future Air Pollution Load from Various Sources (2005) (without control measures)

(Unit: ton/year)

	SOx	NOx	PM	CO	HC
Factories					
Power stations	30,040	26,038	2,423	-	-
General factories	11,283	4,415	8,163		
Sub-total	41,323 (80.1)	30,453 (26.4)	10,586 (57.2)	-	-
Motor vehicles	7,079 (13.7)	82,199 (71.3)	7,359 (39.8)	659,223 (100)	166,720 (100)
Airplanes	360 (0.7)	574 (0.5)	123 (0.7)	-	-
Ships	2,836 (5.5)	1,840 (1.6)	365 (2.0)	-	-
Households	0 (0.0)	226 (0.2)	62 (0.3)	-	-
Total	51,598 (100)	115,292 (100)	18,495 (100)	659,223 (100)	166,720 (100)

Figures in parenthesis are percentage values(%). Air pollutant emission from open burning activities and earthworks are not included, but that from PS-C Power Station outside KVR is included in this Table.

(2) Comparison of Air Pollution Loads between 1992 and 2005

Comparisons of the total annual air pollution loads from various sources between the year 1992 and the year 2005 when no control measures are taken are summarized in Table 8.2. Increase of CO and HC emission is the highest among all the pollutants with a value of 2.27 times, followed by NOx (2.12 times).

Table 8.2 Comparison of Total Annual Air Pollution Loads from All Sources between 1992 and 2005 (without control measures)

	Pollution Load (ton/year)				
Year	SOx	NOx	PM	CO	HC
1992 (A)	35,654	54,454	12,605	290,407	73,455
2005 (B)	51,598	115,292	18,495	659,223	166,720
B/A	1.45	2.12	1.47	2.27	2.27

8.3 Prediction of Pollutant Concentration in the Future

Table 8.3 shows predicted results of future concentration of each pollutant at fixed monitoring stations and the maximum concentration point. The predicted concentrations are 10 to 106% higher than the present level (Table 6.2.2). Figs. 8.1 through 8.3 show predicted concentrations for SO_2, NO_2 and CO respectively. For SO_2, the concentration at City Hall (A) and the maximum point is 20.6 ppb and 65.8 ppb respectively which exceeds the air quality target value (20 ppb). For NO_2, the concentration at City Hall (A) and the maximum point is 39.0 ppb and 63.1 ppb respectively which exceeds the target value (37 ppb).

For CO, the concentration at City Hall (A) and the maximum point is 6.9 ppm and 10.5 ppm respectively which exceeds the target value (4 ppm).

Table 8.3 Predicted Concentration in Future (2005) (without control measures)

Items / Stations	SO_2 (ppb)	NOx (ppb)	NO_2 (ppb)	CO (ppm)
A. City Hall	20.6	246.6	39.0	6.88
B. UPM	6.1	28.5	19.4	1.87
C. Petaling Jaya	19.6	128.1	27.5	3.28
D. Shah Alam	11.0	56.4	17.8	2.21
E. Klang	8.8	33.6	13.6	1.88
Cmax Point	65.8	613.5	63.1	10.52
Mesh Index	(54,30)	(54,33)	(54,33)	(59,37)
Target Value	20	-	37	4

× :Cmax Point unit:ppb

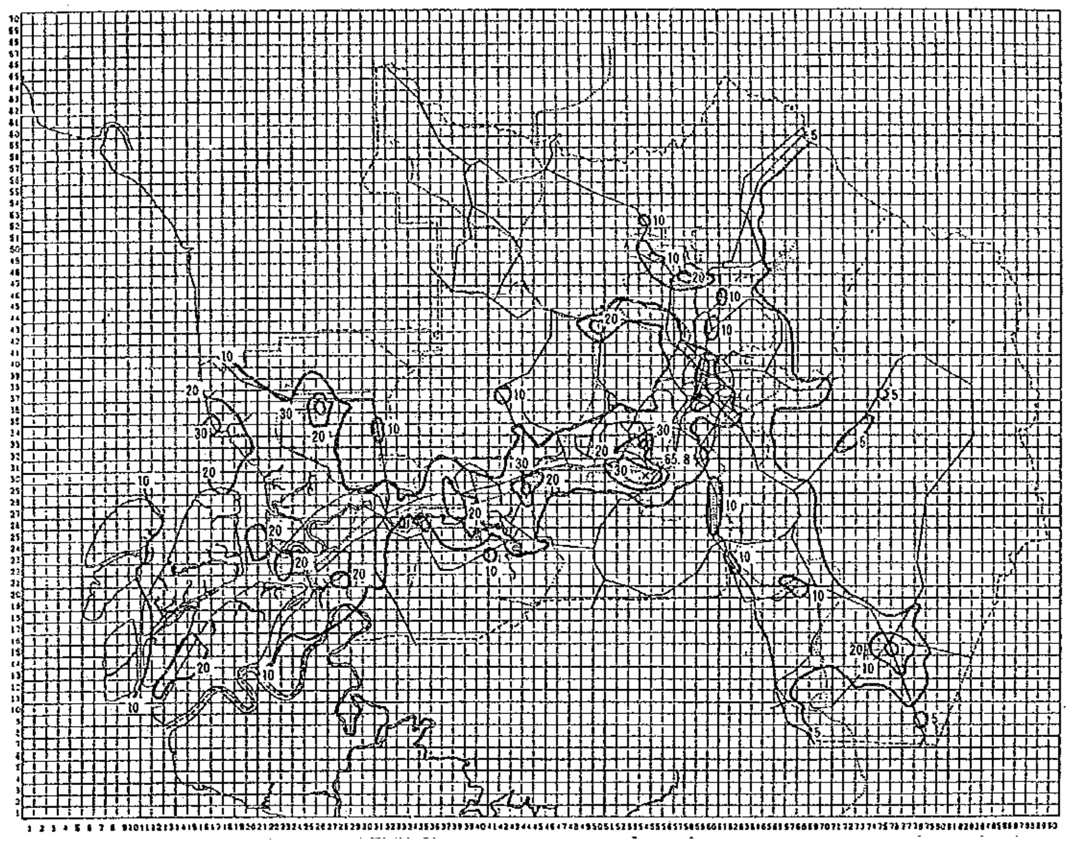
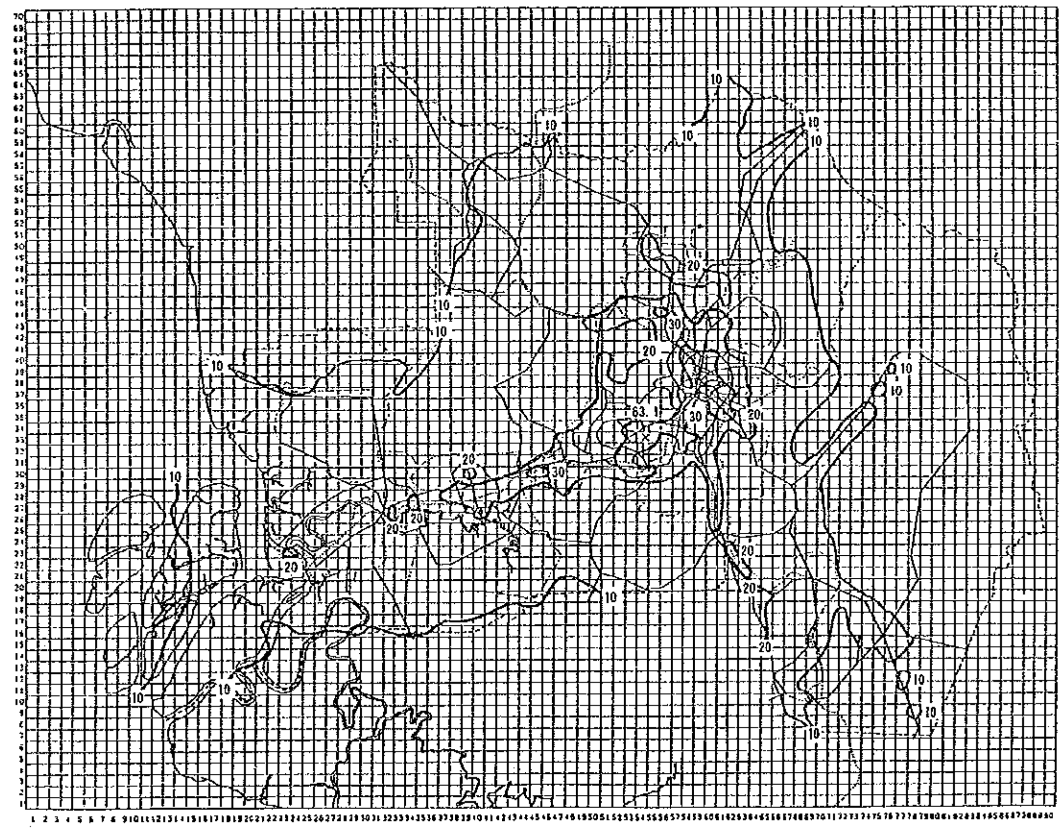


Fig. 8.1 Predicted Average Concentration Isopleths for SO_2 (2005) (without control measures)



x :Cmax Point Unit:ppb

Fig. 8.2 Predicted Average Concentration Isopleths for NO_2 (2005) (without control measures)

Fig. 8.3 Predicted Average Concentration Isopleths for CO (2005)
(without control measures)