5.2.7 Air Pollution Load

Based on the traffic volume, the regional average speed by vehicle type, the average emission rates by vehicle type and average speed, annual distance travelled, fuel consumption, and air pollution load in KVR were estimated.

(1) Distance Travelled Annually

The distance travelled annually by various types of vehicles on different types of roads is shown in Table 5.2.20. The total distance travelled annually in 1992 is 16 billion kilometers with motor cars accounting for 53% of the total followed by motorcycles (22%).

Table 5.2.20 Annual Distance Travelled by Various Types of Vehicles on Different Types of Roads (1992)

(Unit: million km)

Vehicle Type	Major Roads	Minor Roads	Total
Motorcycle	2436.8	1150.8	3587.6 (22.2)
Motor Car	6345.0	2230.6	8575.6 (53.1)
Van	822.3	300.1	1122.4 (7.0)
Taxi	543.6	301.2	844.8 (5.2)
Mini Bus	80.0	60.3	140.3 (0.9)
Medium/Large Bus	173.6	75.7	249.3 (1.5)
Small Truck	423.0	150.9	573.9 (3.6)
Medium/Large Truck	628.2	91.7	719.9 (4.5)
Lorry/ Trailer	256.6	68.9	325.5 (2.0)
Total	11709.1	4430.2	16139.3 (100.0)

Table 5.2.21 shows regional annual distance travelled. As shown in this Table, Kuala Lumpur accounts for 40% of the total distance travelled, followed by Petaling (25%).

Table 5.2.21 Regional Annual Distance Travelled (1992)

Region	Annual Distance Travelled (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)

(2) Fuel Consumption

The annual fuel consumption by vehicle and fuel types is shown in 5.2.22. The annual total consumption is 1,141 x 10^3 kl for petrol and 657 x 10^3 kl for diesel oil. For consumption of petrol, motor cars account for 69% of the total. For diesel oil, medium/large trucks account for 29% of the total, followed by lorry/trailer (24%) and medium/large buses (19%).

Table 5.2.22 Fuel consumption by Various Types of Vehicles (1992)

Fuel	Vehicle Type	Fuel Consumption (1000kl/year)	
Petrol	Motorcycle	142.7	(12.5)
	Motor Car	782.2	(68.5)
	Van	89.0	(7.8)
	Taxi	64.8	(5.7)
	Small Truck	62.7	(5.5)
	Total	1141.4	(100.0)
Diesel	Van	85.1	(13.0)
	Taxi	69.8	(10.6)
	Mini Bus	32.8	(5.0)
	Medium/Large Bus	121.9	(18.5)
	Medium/Large Truck	190.7	(29.0)
	Lorry/Trailer	157.1	(23.9)
	Total	657.4	(100.0)

(3) Air pollution Load

The annual air pollution load in 1992 from motor vehicles is summarized in Table 5.2.23. The annual total emission is 73,000 tons for HC, 290,000 tons for CO, 36,000 tons for NOx, 3,100 tons for SOx and 3,200 tons for PM. For HC, motorcycles are the major contributors (70% of the total emission). Motor cars and motorcycles are the major contributors of CO 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 of PM emission by diesel vehicles is 59% as shown in Table 5.2.24.

Table 5.2.23 Current Pollution Load by Various Types of Vehicles (1992)

(Unit: ton/year)

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

Figures in parenthesis are percentage values.

Table 5.2.24 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.

Regional air pollutant emission from motor vehicles is shown in Table 5.2.25. For all pollutants, Kuala Lumpur accounts for more than 33% of the total emission.

Table 5.2.25 Regional Air Pollution Load from Motor Vehicles (1992)

(ton/year)

Region	HC	C O	NOx	SOx	PM
Hulu Langat	8,034 (10.9)	29,077 (10.0)	4,336 (12.0)	410 (13.1)	415 (12.8)
Gombak	9,300 (12.7)	35,796 (12.3)	5,445 (15.0)	529 (17.0)	514 (15.9)
Kuala Lumpur	33,120 (45.1)	136,058 (46.9)	13,518 (37.3)	1,029 (33.0)	1,190 (36.7)
Petaling	15,775 (21.5)	65,841 (22.7)	9,319 (25.8)	761 (24.4)	759 (23.4)
Klang	7,216 (9.8)	23,634 (8.1)	3,593 (9.9)	390 (12.5)	363 (11.2)
Total	73,445 (100)	290,406 (100)	36,211 (100)	3,119 (100)	3,241 (100)

DOE has its own estimation method for air pollution load from motor vehicles (#5004). The calculation result is summarized in Table 5.2.26. Comparison of the values of DOE and Study Team is made in Table 5.2.27. Both values for each pollutant are considered to be close.

Table 5.2.26 Air Pollution Load from Motor Vehicles Estimated by DOE's Method (1992)

Vehicle Type	No. of Registered Vehicles	0.6	Running hours	Mileage ×1000km/y	Distance Travelled Annualy million km	Fuel Consumption 1000 × ton	Annual Air Pollution Load (ton/year) HC	CO	NOx	SOx	PM
Petrol					15241.3		60255	390079	8870	539	2602
Motor Car	677845	406707	1750	19.32	7849.4	612.25	8878	230818	6306	331	1225
Taxi	6025	3615	3000	96.60	349.2	27.24	395	10269	281	15	54
Bus	516	310	3500	104.65	32.4	-	321	2624	185	5	17
Lorry and Van	75643	45386	3500	48.30	2192.1	170.98	2479	64459	1761	92	342
Motorcycle	712534	427520	1000	11.27	4818.2	-	48182	81909	337	96	964
Diesel					4713.8		2534	16453	24867	3822	966
Motor Car	18635	11181	1750	19.32	216.0	12.24	32	532	135	93	29
Taxi	5811	3487	3000	96.60	336.8	19.09	50	830	210	145	46
Bus	8334	5000	3500	104.65	523.3	59.31	308	1898	3084	451	112
Lorry and Van	125525	75315	3500	48.30	3637.7	412.27	2144	13193	21438	3133	779

Table 5.2.27 Comparison of Estimated Load from Motor Vehicles by DOE and Study Team (1992)

	Total Distance Travelled Annually (million km)	Pollution Load (Ton/year) HC	CO	NOx	SOx	PM
Study Team (A)	16139.3	73455	290407	36212	3117	3243
DOE's Method (B)	19955.1	62789	406532	33737	4361	3568
A/B	0.81	1.17	0.71	1.07	0.71	0.91

5.3 Airplanes

5.3.1 Number of Flights

Subang airport is located to the west of Kuala Lumpur and handles both domestic and international flights. Table 5.3.1 shows the annual number of flights of jet airplanes, calculated from the airport schedule. The number of annual total flights is 96,777.

Table 5.3.1 Number of Annual Flights Classified by Plane Type (1992)

Plane Type	International	Domestic	Total
A310	8,447	-	8,447
A300	5,319	-	5,319
B737	17,207	45,156	62,363
B747	5,527	-	5,527
B757	521	-	521
B767	939	-	939
DC10	4,484	-	4,484
F27	417	-	417
F50	626	3,963	4,589
IL6	313	-	313
L10	521	-	521
L15	209	-	209
TU4	313	-	313
DC8	-	2,816	2,816
Total	44,843	51,934	96,777

5.3.2 Emission Factor

SOx and NOx are the major air pollutants emitted from airplanes. Emission factor for NOx and amount of fuel consumption in Table 5.3.2 were set by plane type and navigation mode from data in Japan (#8008). Emission factor for PM in Table 5.3.3 was set from U.S.EPA report (#5007). In calculating the amount of SOx emitted from airplanes, sulphur content in jet fuel was set at 0.02% (wt%) (#7003).

The navigation mode is shown in Fig. 5.3.1. In the Study, since air pollutant concentration at ground level is calculated by air dispersion simulation model, cruising mode is not included in the calculation and the amount of

air pollutants emitted during approach and climb is calculated up to 500 m above the ground.

Table 5.3.2 NOx Emission Factor and Fuel Consumption Classified by Plane Type

Unit:g/s per engine

Items	Navigation Mode				Aircraft Type
	Idling	Take -off	Ascent	Aproach /Landing	
NO_x	0.21	14.4	9.4	2.44	B737,TU4,
Fuel consumption	153	1,200	975	450	DC8
NO_x	0.085	3.50	3.5	0.81	B757,IL6,
Fuel consumption	115	744	755	465	L15
NO_x	0.83	94.1	52.6	6.51	B747,B767,
Fuel consumption	153	2,650	1,730	640	DC10,A300
Cycle time (min)	20	2	0.4	2.5	-

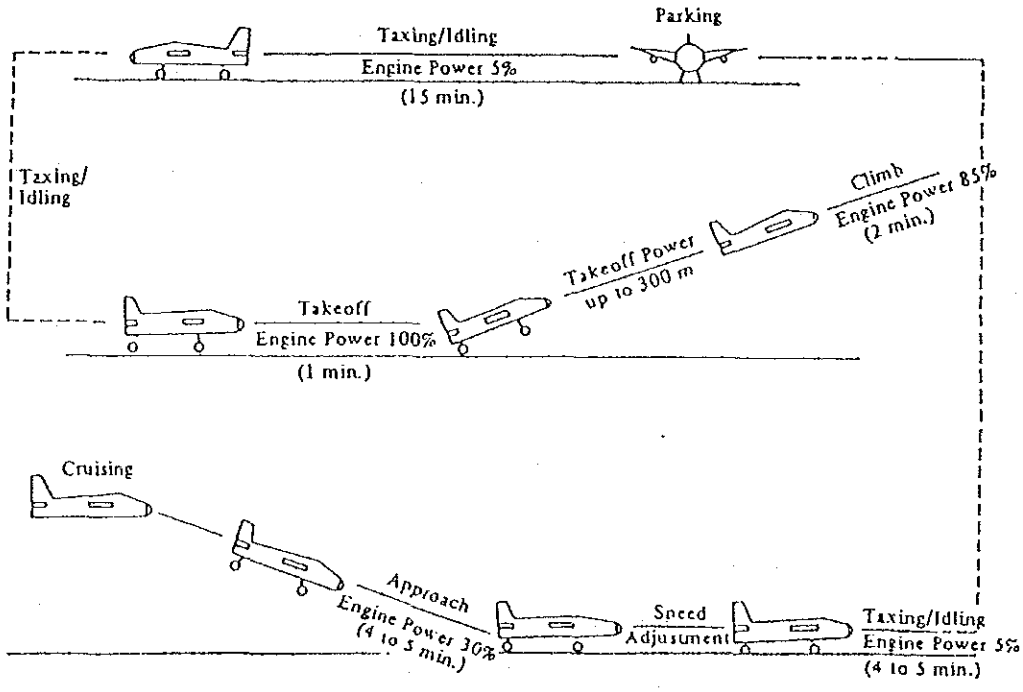


Fig.5.3.1 Airplane Navigation Mode

Table 5.3.3 Emission Factors for Particulate Matter

Plane Type	Emissin Factor (kg/engine)
B737 TU4 DC8	0.19
B757 IL6 L15	0.55
A310 A300 B747 B767 DC10 L10	0.59

Source: U.S.EPA(#5007)

5.3.3 Air Pollution Load

The calculation results of air pollutant amount emitted from airplanes are shown in Table 5.3.4. The annual total air pollution load from airplanes in 1992 is 400 tons for SOx, 1,300 tons for NOx, and 100 tons for PM.

Table 5.3.4 Annual Pollution Load from Airplanes (1992)

Pollutant	Navigation Mode				
	Idling	Take-off	Ascent	Approach /Landing	Total
SOx	172	164	24	55	416
NOx	101	989	115	115	1320
PM	-	-	-	-	115

5.4 Ships

5.4.1 Summary of Estimation Procedure

(1) Ports and Ships

Pollutant emission rates from ships arriving and departing at the Port Klang bay area were estimated by spotting their mooring points and selecting their tonnages and engine operating conditions. The number of ships was obtained from the statistical data compiled by the port authority. Ships were classified according to their types, tonnages, periods of mooring and sailing.

(2) Berths & Ships

Fig. 5.4.1 illustrates the general procedure to estimate emission amounts. Emission factors and methods of estimation were quoted from published data in Japan(#8008)

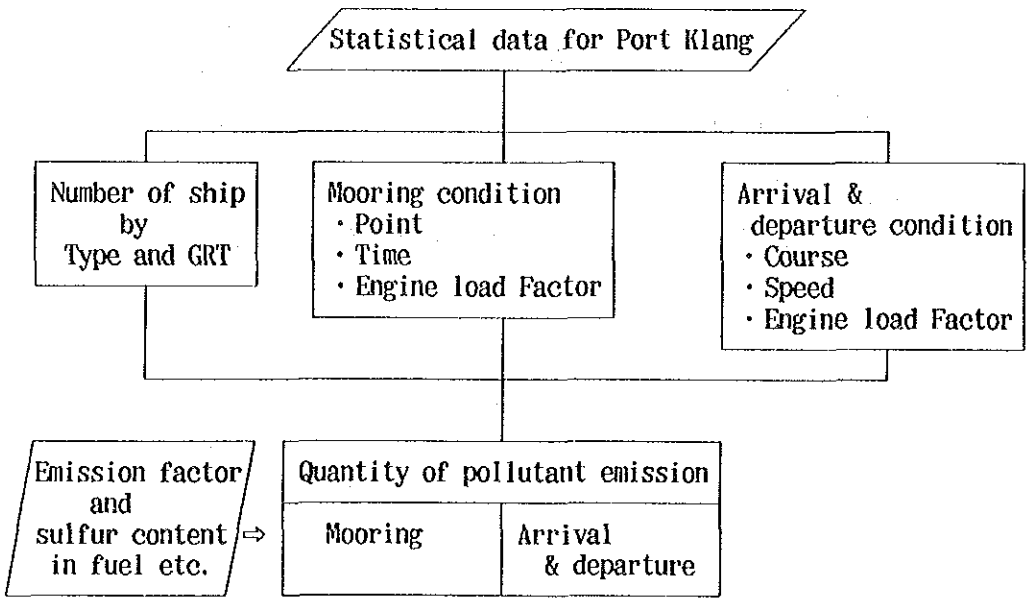


Fig. 5.4.1 Procedure for Estimation of Emission Quantity from Ships

1) Designation of Berths

As shown in Table 5.4.1, berths were classified into three main categories, i.e. South Port, North Port, and Private Port. Code in Table is a berth number taken from the Port Klang brochure (#1030).

Table 5.4.1 Berth Classified

Berth Category	Code
South Port	11 (1-7A)
North Port · Container Terminal · Conventional Traffic Terminal · Liquid Bulk Terminal · Dry Bulk Terminal	 21 (8-11) 22 (12-21) 23 (22-23) 24 (24-25)
Private Port · Electric Power Plant Berth · Junk · Klang Container Terminal	 31 41 42

2) Classification of ships by use and type

Ships were categorized by their usages and types as shown in Table 5.4.2.

Table 5.4.2 Classification of Ships by Usage and Type

Classified by use	Ship type	Classified by use	Ship type
Passenger boat	P.S. boat ①	Cement boat Grain boat Iron ore boat Steel material Coal boat Car carry boat Other	Cargo boat⑤
Ferry boat	Ferry ②		
Full-container Semi-container	Container ③		
LNG boat Tanker LPG boat	Tanker ④	Fishing boat	F.S boat ⑥
		Warship & Other	Others ⑦

3) Classification of GRT (Gross tons) Rank

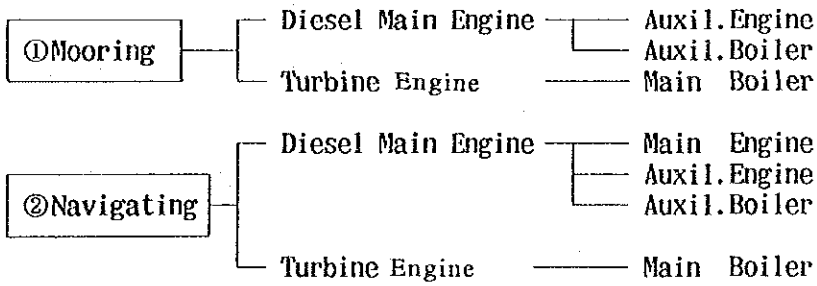
Ships were classified by GRT as shown in Table 5.4.3

Table 5.4.3 Classification of Ships by GRT

Code	GRT rank (ton)~	(ton)	Average (ton)
01	~	499	250
02	500~	999	750
03	1000~	2999	2000
04	3000~	5999	4500
05	6000~	9999	8000
06	10000~	29999	20000
07	30000~	99999	50000

(3) Setting Up Engine Factors for the Estimation of Emission Rate

Engine operating conditions were determined according to the following chart of mooring and navigating.



(4) Navigation Area

Navigation area is shown in Fig. 5.4.2.

5.4.2 Number of Ships Calling at Port Klang

(1) Statistics in 1990

Port Klang is located on the west side of Klang Valley Region and handles both import and export commodities. Table 5.4.4 shows the total number of main ships and their gross tons. As shown in this Table, dry and liquid cargoes account for 80% and 20% of total cargoes, respectively. As to total cargo handled, exports amounted to 8.2 million tons and imports amounted to 13.9 million tons in 1990.

Table 5.4.4 Number of Ships Classified by Type and GRT (1990)

Berth Cat. Code			No. ShiP	Cargo tonnage (10^3 t)		Number of Ships by type				
				Dry Cargo	Liquid Cargo	Ferry	Container	tanker	Dry Bulk	total
South Port		11 (1-7A)	954	1328	1354			477	477	954
North	Cont.T	21 (8-11)	158	352	0		158			158
	Conv.T	22 (12-21)	1462	4698	33	968		10	484	1462
	Liquid	23 (22-23)	474	15	1394			474		474
	Dry B.	24 (24-25)	145	1068	13			5	140	145
Priv	E.P.B	31	214	1656	989			214		214
	Junk	41	16	223	0			16		16
	K.C.T	42	1884	8842	0		1884			1884
Total			5307	18182	3783	484	2526	1196	1101	5307
				21965						

Note : Total number and total GRT of ships at Japanese seaports(1988)

Tokyo	: 58206(Num.)	114.4(10^6 t)	
Muroran	: 8701	27.5	Hokkaido prf.
Tomakomai	: 18045	43.4	Hokkaido prf.

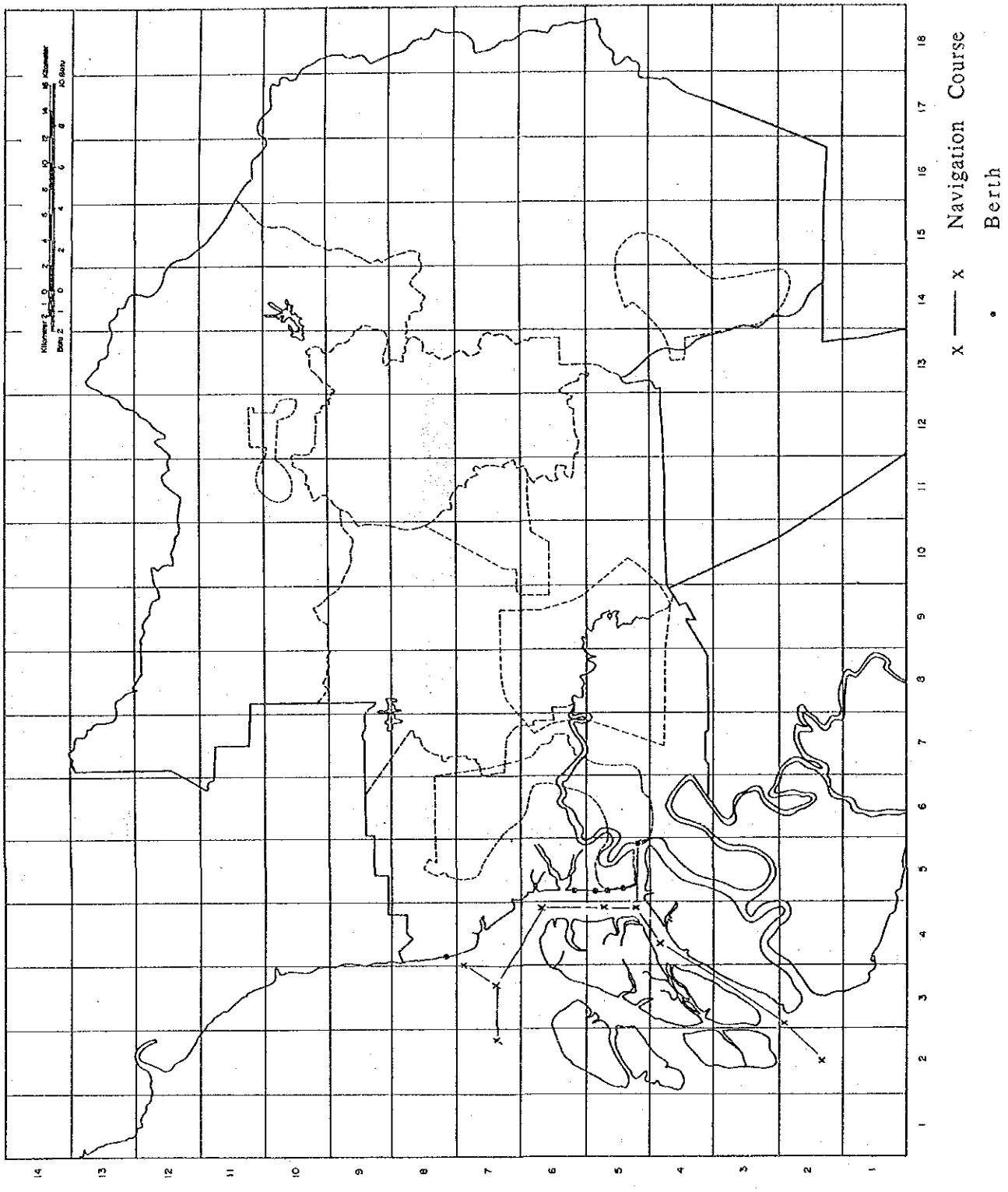


Fig. 5.4.2 Navigation Area

(2) Number of Calling Ships in 1992

Number of ships calling at the port in 1992 was estimated from the predicted cargo handling amounts by Klang Port Authority. The cargo handling amount grows by 30% from 1990 to 1992 (Table 5.4.5).

Table 5.4.5 Cargo Tonnages at Port Klang

(Unit: 10^3 ton/year)

Cargo Year	1989	1990	1991	1992	Note
Container	7279	9137	11650	12664	Growth Rate of 1992/1990 ≒ 1.304
General	11009	12968	14870	16164	
Total	18306	22105	26520	28827	

source: Klang Port Authority Publications

5.4.3 Parameters for Calculating Air Pollutant Emission

(1) Rated Outputs and Fuel Consumptions

Tables 5.4.6 through 5.4.8 give empirical and estimated formula for calculating the rated outputs, fuel consumptions and emission factors.

Table 5.4.6 Rated Outputs of Diesel Engines

Ship Type	Main Diesel Output (PS)	Auxiliary Diesel Output × Number (PS)
Passenger boat	$7.9X^{0.63}$	$1.5X^{0.63} \times 3$
Ferry boat	$4.1X^{0.95}$	$1.4X^{0.70} \times 3$
Container boat	$1.9X^{0.97}$	$2.2X^{0.80} \times 2$
Tanker (oil)	$1.2X^{0.70}$	$1.0X^{0.37} \times 2$
Cargo boat	$1.9X^{0.85}$	$7.7X^{0.60} \times 2$
Fishing boat	$7.3X^{0.50}$	$1.3X^{0.43} \times 3$
Others	$3.3X^{0.81}$	$0.089X \times 2$

Note) X :Gross tonnage

Table 5.4.7 Rated Fuel Consumptions of Boilers

Ship Type	Main Boiler Fuel consumptions (kg/Hour)	Auxiliary Boiler Fuel consumptions (kg/Hour)
Tanker(100,000≦GRT)	$6.4X^{0.58}$	–
Tanker(100,000>GRT)	–	$0.69X^{0.78}$
Except tanker	–	$0.10X^{0.78}$

Table 5.4.8 Emission Factors

Engine Name	Fuel Type	Sul-fur (%)	PM Factor (Kg/t)	NOx Factor (Kg/Kl)
Turbine/Main Boiler	H F D	2.0	4.0	5.0
Main/Auxiliary Diesel				
3,000GRT≦	H F D	2.0	4.0	5.0
3,000GRT>	L F D	1.0	3.0	5.0
Auxiliary Boiler				
3,000GRT≦	H F D	2.0	4.0	5.0
3,000GRT>	L F D	1.0	3.0	5.0

(2) Determination of Diesel Ship Operation Loads

Table 5.4.9 Diesel Power Engines Operation Loads

Ship Type	Non-Cargo operation & Navigating Time		Cargo operation Time		Note
	Auxiliary Diesel	Auxiliary Boiler	Auxiliary Diesel	Auxiliary Boiler	
P.S.B , Ferry Fish B.,Others	0.39 (1)	0.5 (all)	——	——	
Container Boat	0.39 (1)	0.5(all)	——	——	
Tanker (Oil)	0.39 (1)	0.5(all)	0.39 (1)	0.8 (all)	
Cargo Boat	0.39 (1)	0.5(all)	0.33 (2)	0.5 (all)	

Note ( ):Number of Operation engine.

5.4.4 Air Pollution Load

In Table 5.4.10, air pollution load in 1992 from ships calling at Port Klang is given. The annual total air pollution load from ships is 1,600 tons for SOx, 1,000 tons for NOx and 200 tons for PM.

Table 5.4.10 Air Pollution Load from Ships (1992)

		Pollutant Emission and Fuel Consumption			
Port Klang		S OX	N OX	S P M	Fuel Cons.
	Mooring	41.6	29.4	17.8	5945.5
	Navigating	20.4	25.6	5.0	1531.2
	Total (*1)	62.0 (Nm^3/h)	55.0 (Nm^3/h)	22.8 (Kg/h)	7476.7 (kg/h)
Annual Total (*2)		1551.8 (t/y)	989.4 (t/y)	199.7 (t/y)	65495.9 (t/y)

Note) (*1): Average for one hour
(*2): Total annual emission

5.5 Households

5.5.1 Fuel Consumption

The fuel used by households in Kelang Valley Region is mainly LPG. According to the statistics of PETRONAS (#4009), total LPG consumption by all sources amounted to 286 million liters in 1992 and around 70% (202 million) out of 286 million liters were for households including hotels, restaurants, and so on. LPG will be shifted to natural gas gradually in urban districts such as Kuala Lumpur from 1993, because Malaysian Mining Corporation Bhd is planning to supply natural gas to the above region (NEW Straits Times, July 30, 1992).

5.5.2 Emission Factor

Principally, emission factors have to be obtained from as many actual measurements as possible for accuracy. However, since such work for the households was not included in this study, emission factors for households were obtained from existing ones in the USA (#4012): 0.22kg/kl for Dust and 0.8kg/kl for NOx. SOx emission from LPG was not assumed.

5.5.3 Air Pollution Load

The annual total air pollution load from households in KVR 1992 accounts for 44 tons of dust and 162 tons of NOx.

5.6 Summary for Air Pollution Load

(1) Pollution Load from Various Sources

The air pollution load from various sources in 1992 is shown in Table 5.6.1. 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. With 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 (71%).

Table 5.6.1 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 5.6.2. SOx and PM are mainly emitted in Klang. NOx is mainly emitted in Klang and Kuala Lumpur.

Table 5.6.2 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

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

6.1 Outline of the Air Dispersion Simulation Model

6.1.1 Air Dispersion Simulation Model

Simulation model for Kelang Valley Region was developed with information pertinent to emission conditions obtained from analysis of air pollution sources, and the air dispersion field obtained from analysis of meteorological conditions and ambient air quality.

The dispersion simulation model (hereinafter called the "dispersion model") representing the current state of air pollution was prepared according to the procedure shown in Fig. 6.1.1.

6.1.2 Scope of the Dispersion Model

This dispersion model covers the following matters.

(1) Air Pollutants Covered

Sulphur dioxide (SO_2), Nitrogen oxide (NOx),
Nitrogen dioxide (NO_2), Carbon monoxide (CO)

(2) Averaging Time of Concentration

The simulated ambient air quality should be a long-term average concentration taking into consideration the accuracy of the data on air pollution sources, meteorology and air quality.

The annual average concentration was estimated to evaluate the ambient air quality.

(3) Pollution Sources Covered

Factories, motor vehicles, airplanes and ships

(4) Model Evaluation Points

Air quality monitoring stations (five fixed points)

(5) Period

The year 1992

(March 1992 ~ February 1993)

(6) Area

Kelang Valley Region as shown in Fig 6.1.2

Fig. 6.1.1 General Process of Air Quality Simulation

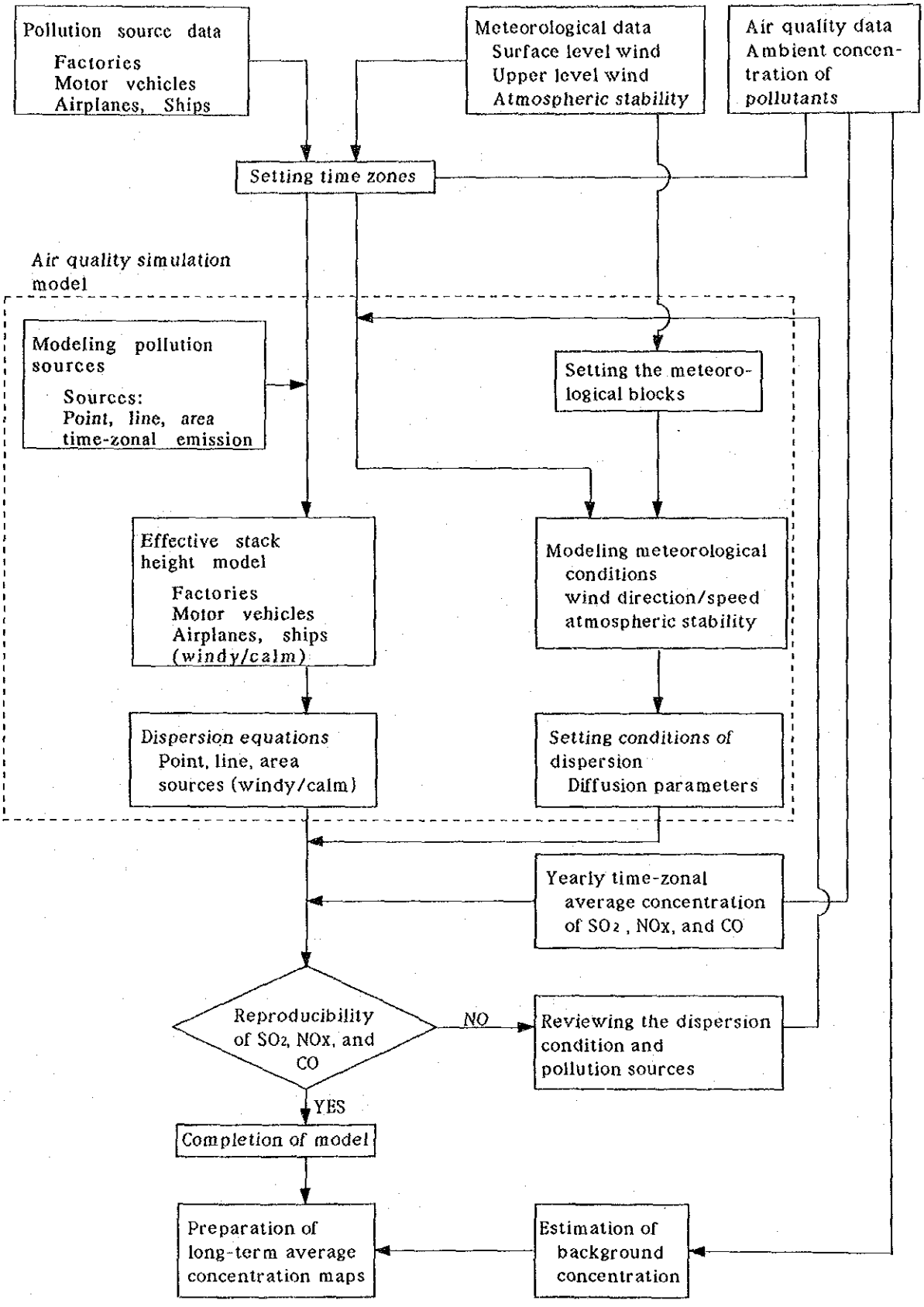
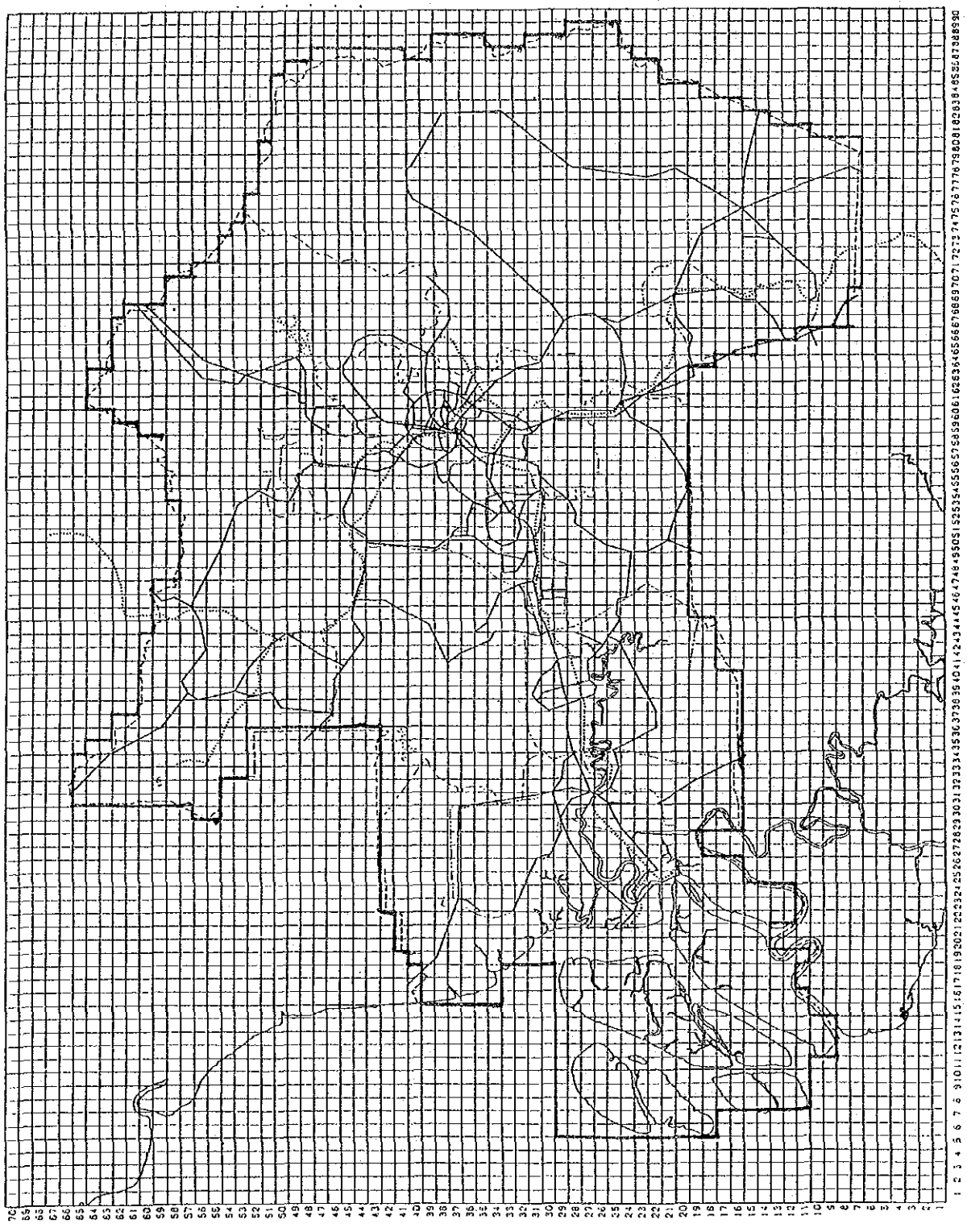


Fig. 6.1.2 Area for Computation of Air Pollutant Concentration for Kelang Valley Region



6.1.3 Classification of Seasons and Time Zones

Because the Kelang Valley Region is subject to monsoons, meteorological conditions differ widely between the monsoon seasons and dry seasons.

So, one year is divided into four seasons in accordance with the monsoon and dry seasons, and different meteorological conditions will be given to them.

Daily time zones were set with reference to hourly changes in factory and motor vehicle activity, meteorological conditions and air quality concentrations.

Classification of seasons and time zones is shown in Table 6.1.1.

Table 6.1.1 Classification of Seasons and Time Zones

Seasons		Time Zones	
Transition I	March~May	Morning	7:00-11:00 a.m.
SW Monsoon	June~August	Noon	12:00 a.m.-7:00 p.m.
Transition II	Sept.~Nov.	Evening	8:00 p.m.-2:00 a.m.
NE Monsoon	Dec.~Feb.	Midnight	2:00-6:00 a.m.

6.1.4 Pollution Source Model

Source model was made while taking their configuration and scale into account. Sources (stack, road, etc.) with large air pollutant emissions were modelled individually and sources consisting of many sources, but with smaller emissions individually were collectively modelled. Sources were modelled as shown in Table 6.1.2.

Table 6.1.2 Type of Pollution Sources

Type of Pollution Sources	Item		Type of Source
Stationary Sources	Factories		Point Source
Mobile Sources	Motor vehicles	Major Roads	Line Source
		Minor Roads	Area Source
	Airplanes	Climb, Approach	Point Source
		Idling, Takeoff	Area Source
	Ships	At harbour	Point Source
		Sailing	Area Source

6.1.5 Meteorological Model

(1) Meteorological Blocks and Representative Meteorology

Meteorological conditions differ from one region to another. Accordingly, the Kelang Valley Region was divided into two blocks as shown in Fig 6.1.3 in view of the topographical state and source distribution.

Shah Alam and Petaling Jaja were the meteorologically representative stations 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.

(2) Meteorological Classification in the Vertical Direction

Generally, the wind speed tends to increase with height from the ground surface. To reflect this trend, the source emission height in the dispersion model was divided into three fields in the vertical direction as shown in Table 6.1.3, and representative meteorological conditions were applied to each field.

The observed wind speed data was used for the lower field, while the wind speed was corrected using the power index P shown in Table 6.1.4 according to the emission height of sources and applied to surface and upper fields respectively.

Table 6.1.3 Vertical Division of Dispersion Field and Corresponding Pollution Sources

Category of Dispersion Field	Pollution Sources
Lower Field	Factories(Stack Height $h_0 \leq 50$m), Motor Vehicles, Ships, Airplanes(Idling/Takeoff)
Middle Field	Factories(Stack Height $50\text{m} < h_0 \leq 100\text{m}$)
Upper Field	Factories(Stack Height $100\text{m} < h_0$)

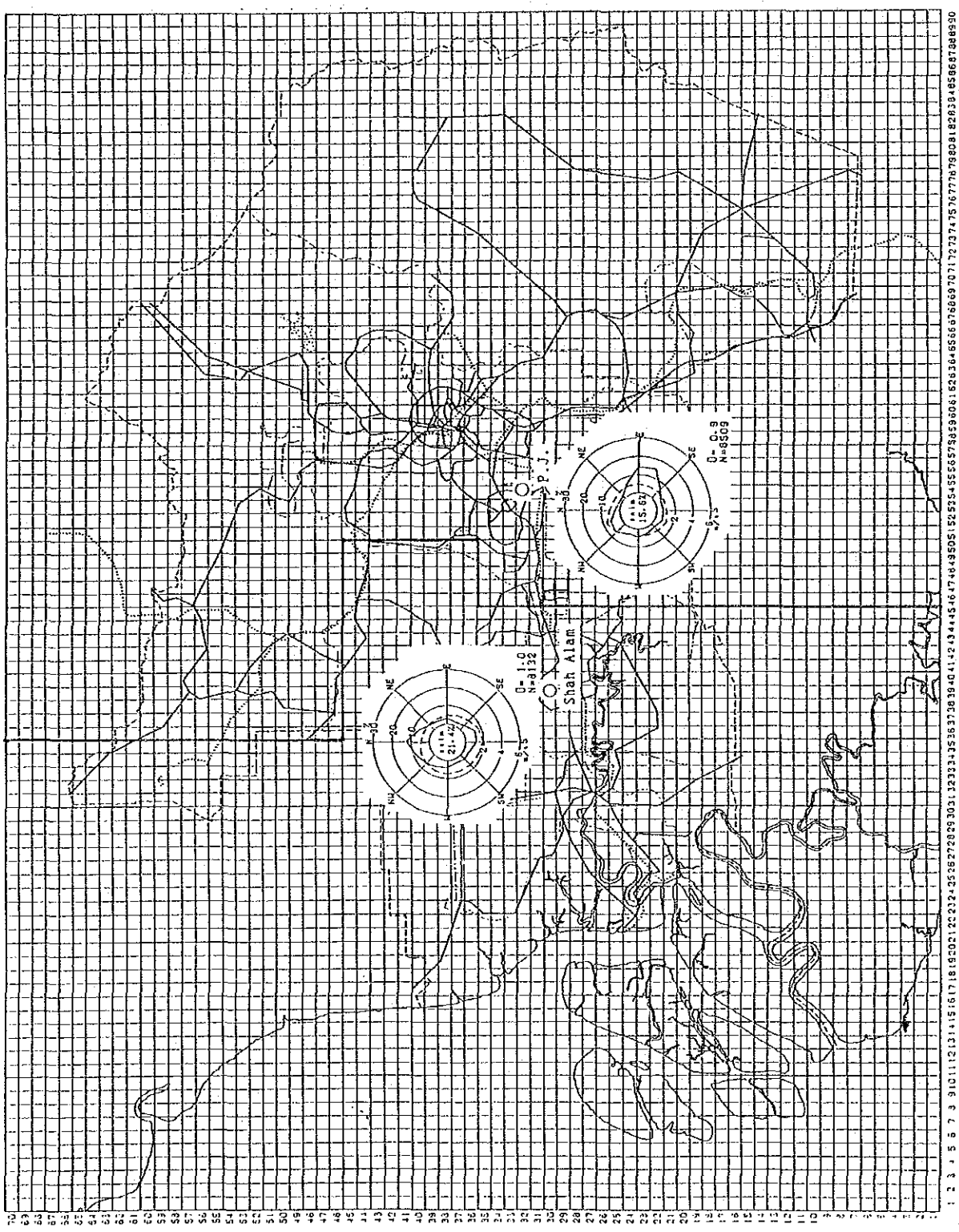
Table 6.1.4 Number of P by Atmospheric Stability

Pasquill's Atmospheric Stability	A	B	C	D	E	F
P	0.10	0.15	0.20	0.25	0.25	0.30

Wind speed estimation formula: $Uz = Us \cdot (Z/Zs)^P$

Uz: estimated wind speed (m/s)
Us: Wind speed on the ground (m/s)
Z: Height of wind speed to be estimated (m)
Zs: Surface wind observation height (m)

Fig. 6.1.3 Meteorological Blocks and Representative Points in Kelang Valley Region



(3) Modelling of Meteorological Conditions

Meteorological conditions were modelled through classification as follows.

- Wind direction: 16 direction and calm($U \leq 0.4$ m/s)
- Wind speed : 8 classes of wind speed as shown in Table 6.1.5
- Air stability : 11 classes of stability categories
  [A (unstable) ~ D (neutral) ~ G (stable)]

Table 6.1.5 Wind Speed Classification

Class	1	2	3	4	5	6	7	8
Wind speed classes (m/s)	0.4 or less	0.5 ~ 0.9	1.0 ~ 1.9	2.0 ~ 2.9	3.0 ~ 3.9	4.0 ~ 5.9	6.0 ~ 7.9	8.0 or more
Wind speed used (m/s)	0	Average wind speed of each class						

6.1.6 Effective Stack Height Calculation Equation

When it was windy, Moses and Carson equation for large scale stack ($Q_H \geq 2 \times 10^6$ Cal/s) and CONCAWE equation from medium to small scale stacks ($Q_H < 2 \times 10^6$ Cal/s) was used to predict the rising height of exhaust gas from the top of a plant stack.

When it was calm, Briggs equation was used.

For pollution sources other than plants, emission height was set as shown in Table 6.1.6 taking their emitting characteristics into consideration.

For climbing and approach/landing of airplanes, point sources were arranged along the route and their height was used as the emission height.

- Moses & Carson Equation

$$\Delta H = (C_1 \cdot V_S \cdot D + C_2 \cdot Q_H^{1/2}) u^{-1}$$

- COMCAWE Equation

$$\Delta H = 0.175 \cdot Q_H^{1/2} u^{-3/4}$$

- Briggs Equation

$$\Delta H = 1.4 \cdot Q_H^{1/4} \cdot (d\theta/dz)^{-3/8}$$

ΔH: The rise of the plume above the stack (m)

C1, C2: Parameters set as follows

Atmospheric stability	C1	C2
From unstable to neutral	0.35	0.171
Stable	-0.04	0.145

VS: Velocity of emitting gas from stack (m/s)

D: Inner diameter at the top of a stack (m)

Q_H: Heat emission due to efflux of stack gases (cal/s)
$= \rho \cdot Q \cdot Cp \cdot \Delta T$

ρ: Density of emitted gases at 0°C (= 1.293×10^3 g/m^3)

Q: Emission rate of gaseous effluent (Nm^3/s)

C_p: Specific heat at constant pressure (0.24 cal/°k•g)

ΔT: Difference between the temperature of emitted gas (Tg) and that of atmosphere (15°C) (°C)

u : Wind speed at the top of stack (m/s)

$d\theta/dz$: Vertical potential temperature gradient of atmosphere (°C/m) (to be set at 0.003 for daytime and 0.010 for nighttime)

Table 6.1.6 Effective Stack Height Model

(Unit : m)

Pollution Sources		Windy	Clam
Motor Vehicles	Urban	5	7
	Suburbs	2	3
Airplanes (Idling, Takeoff)		10	20
Ships		10	20

6.1.7 Air Dispersion Equation

When it was windy (u > 0.9 m/s), Plume equation was applied to predict the long-term average concentration from point source (stack). When it was calm (u ≤ 0.4 m/s), simplified puff equation was applied. Because wind speed is weak in Kelang Valley Region, weak wind puff equation was applied for point source when wind speed was weak (u = 0.5~0.9 m/s).

A integration method of dispersion equation within the range of line length (finite length) was used for the line source, and the same method of the equation within the range of square was used for the area source.

The dispersion equation by source and wind speed is shown in Table 6.1.7.

The detailed explanation of air dispersion equation is given in Section 4.1.1 in the Supporting Report.

Table 6.1.7 Application of Dispersion Equation

Wind Condition / Form of Source	Windy (U ≥ 1.0 m/s)	Weak Windy (0.9 ≥ 0.5 m/s)	Calm (0.4 m/s ≥ U)
Point source	Plume equation	Weak wind puff equation	Simplified puff equation
Line source	Line-source plume equation		Line-source simplified puff equation
Area source	Area-source plume equation		Area-source simplified puff equation

- Plume equation ($2\pi/16$ form)

$$C(x,z) = \frac{1}{\sqrt{2\pi}} \frac{Q_p}{(\pi/8)\cdot x\cdot \sigma_z \cdot U} \cdot \left[\exp\left\{-\frac{(z-H_e)^2}{2\sigma_z^2}\right\} + \exp\left\{-\frac{(z-H_e)^2}{2\sigma_z^2}\right\}\right]$$

- Simplified puff equation

$$C(x,y,z) = \frac{Q_p}{(2\pi)^{3/2}\cdot \gamma} \cdot \left\{\frac{1}{\eta_-^2} + \frac{1}{\eta_+^2}\right\}$$

$$\eta_-^2 = x^2 + y^2 + \frac{a^2}{\gamma^2}(z-H_e)^2$$

$$\eta_+^2 = x^2 + y^2 + \frac{a^2}{\gamma^2}(z+H_e)^2$$

- Weak wind puff equation

$$C(x,y,z) = \frac{1}{\sqrt{2\pi}} \cdot \frac{Q_p}{(\pi/8)\cdot \gamma} \cdot \left\{\frac{1}{\eta_-^2}\cdot \exp\left(-\frac{U^2(z-H_e)^2}{2\gamma^2\eta_-^2}\right) + \frac{1}{\eta_+^2}\exp\left(-\frac{U^2(z+H_e)^2}{2\gamma^2\eta_+^2}\right)\right\}$$

c : concentration of a pollutant (m^3/m^3)

x : downwind distance from the source (m)

y : horizontal distance perpendicular to the x-axis (m)

z : height of the point from the ground where the concentration is to be computed (m)

Q: pollutant emission rate (m^3/s)

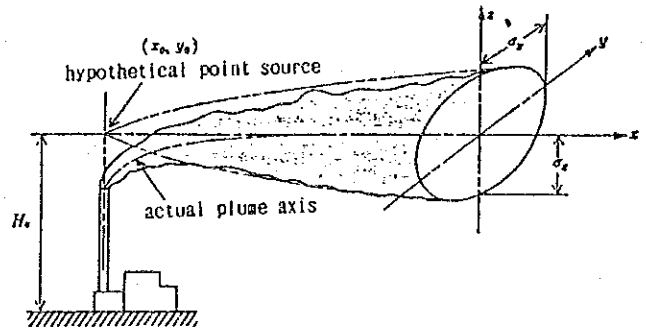
θy: horizontal diffusion parameter evaluated in terms of downwind distance x (m)

σz: vertical diffusion parameter evaluated in terms of downwind distance x (m)

U : wind speed (m/s)

He: effective stack height (m)

α, γ: diffusion parameter by Turner (m)



Coordinate System for Plume Equation

6.1.8 Setting the Diffusion Parameter

Diffusion parameter from Pasquill - Gifford chart shown Fig. 6.1.4, was adjusted so that the calculated concentration fits better to the measured value. The dispersion parameter was set as shown in Table 6.1.8 in correspondence to the atmospheric stability classified based on meteorological observation data.

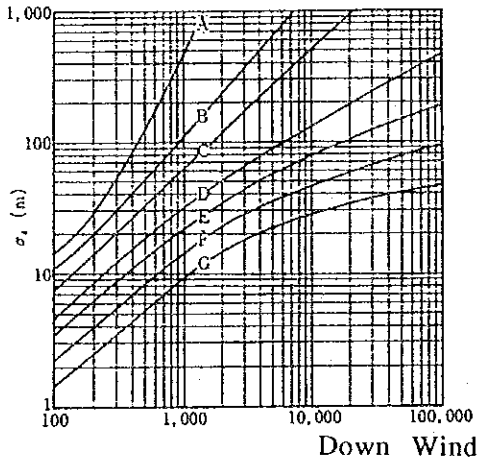


Fig. 6.1.4 Pasquill-Gifford Chart

Table 6.1.8 Diffusion Parameters Set by Atmospheric Stability Class

Classified Atmospheric Stability / Season	Time Zone	Dispersion Field	A	AB	B	BC	C	CD	D (Day-time)	D (Night time)	E	F	G
Transitional	Morning	Lower	A	A	A	B	C	C	C	CD	CD	CD	CD
		Middle	A	AB	B	BC	C	CD	CD	D	D	D	D
		Upper	BC	BC	C	CD	CD	CD	CD	D	D	D	D
	Afternoon	Lower	A	A	A	A	A	A	A	B	B	C	C
		Middle	A	A	B	BC	C	CD	CD	CD	CD	D	D
		Upper	B	B	BC	C	C	C	CD	CD	D	D	D
	Evening	Lower	A	A	AB	B	B	BC	BC	C	C	C	C
		Middle	B	B	BC	C	CD	CD	CD	CD	D	D	D
		Upper	BC	BC	C	CD	CD	CD	CD	D	D	D	D
	Midnight	Lower	B	B	BC	C	CD	CD	CD	D	E	E	E
		Middle	B	B	BC	C	CD	CD	CD	D	E	E	E
		Upper	BC	BC	C	CD	CD	CD	CD	D	E	E	E
SW Monsoon	Morning	Lower	A	A	A	A	B	B	B	C	C	CD	CD
		Middle	A	AB	B	BC	C	CD	CD	CD	CD	CD	CD
		Upper	BC	BC	C	CD	CD	CD	CD	D	D	E	E
	Afternoon	Lower	A	A	A	A	A	A	A	B	B	C	C
		Middle	A	A	B	BC	C	CD	CD	CD	D	D	D
		Upper	B	BC	C	CD	CD	CD	CD	CD	D	D	D
	Evening	Lower	A	A	AB	B	B	BC	BC	C	C	C	C
		Middle	B	B	BC	C	CD	CD	CD	CD	CD	CD	CD
		Upper	BC	BC	C	CD	CD	CD	CD	CD	D	D	D
	Midnight	Lower	B	B	BC	C	CD	CD	CD	D	E	E	E
		Middle	B	B	BC	C	CD	CD	CD	D	E	E	E
		Upper	BC	BC	C	CD	CD	CD	CD	D	E	E	E
Transition	Morning	Lower	A	A	A	B	C	C	C	CD	CD	CD	CD
		Middle	A	AB	B	BC	C	CD	CD	D	D	D	D
		Upper	BC	BC	C	CD	CD	CD	CD	D	D	D	D
	Afternoon	Lower	A	A	A	A	A	A	A	B	B	C	CD
		Middle	A	A	B	BC	C	CD	CD	D	D	D	D
		Upper	B	BC	C	CD	CD	CD	CD	CD	D	D	D
	Evening	Lower	A	A	AB	B	B	BC	BC	C	C	C	CD
		Middle	B	B	BC	C	CD	CD	CD	CD	CD	D	D
		Upper	BC	BC	C	CD	CD	CD	CD	CD	D	D	D
	Midnight	Lower	B	B	BC	C	CD	CD	CD	D	E	E	E
		Middle	B	B	BC	C	CD	CD	CD	D	E	E	E
		Upper	BC	BC	C	CD	CD	CD	CD	D	E	E	E
NE Monsoon	Morning	Lower	A	A	A	B	C	C	CD	D	D	D	D
		Middle	A	AB	B	BC	C	CD	CD	D	D	D	D
		Upper	BC	BC	C	CD	CD	CD	CD	D	D	D	D
	Afternoon	Lower	A	A	A	A	A	A	A	B	B	C	C
		Middle	A	A	B	BC	C	CD	CD	CD	CD	CD	CD
		Upper	B	BC	C	CD	CD	CD	CD	CD	D	D	D
	Evening	Lower	A	A	AB	B	B	BC	BC	C	C	C	C
		Middle	B	B	BC	C	C	CD	CD	CD	CD	CD	CD
		Upper	BC	BC	C	CD	CD	CD	CD	CD	D	D	D
	Midnight	Lower	B	B	BC	C	CD	CD	CD	D	E	E	E
		Middle	B	B	BC	C	CD	CD	CD	D	E	E	E
		Upper	BC	BC	C	CD	CD	CD	CD	D	E	E	E

6.1.9 Equation to Convert NOx to NO2

Conversion of NOx to NO2 concentration was made with a statistical model based on a relationship between measured values of NOx and NO2.

Regression analysis using exponential function was made for annual average of NOx and NO2 at each station from March 1992 to February 1993 as shown in Table 6.1.9. The regression equation is as shown below. This equation was applied for the conversion.

$$[NO_2] = 2.114 \cdot [NO_x]^{0.529}$$

Fig. 6.1.5 shows the scatter diagram of NO2 and NOx concentration and the regression curve obtained from analysis.

Table 6.1.9 Actual Value of NOx and NO2

(Period: Mar., '92 to Feb., '93)

Item	City Hall	UPM	Petaling Jaya	Shah Alam	Klang
NOx (ppb)	103.3	18.1	49.4	31.4	26.6
NO2 (ppb)	21.7	8.6	19.3	15.2	11.4

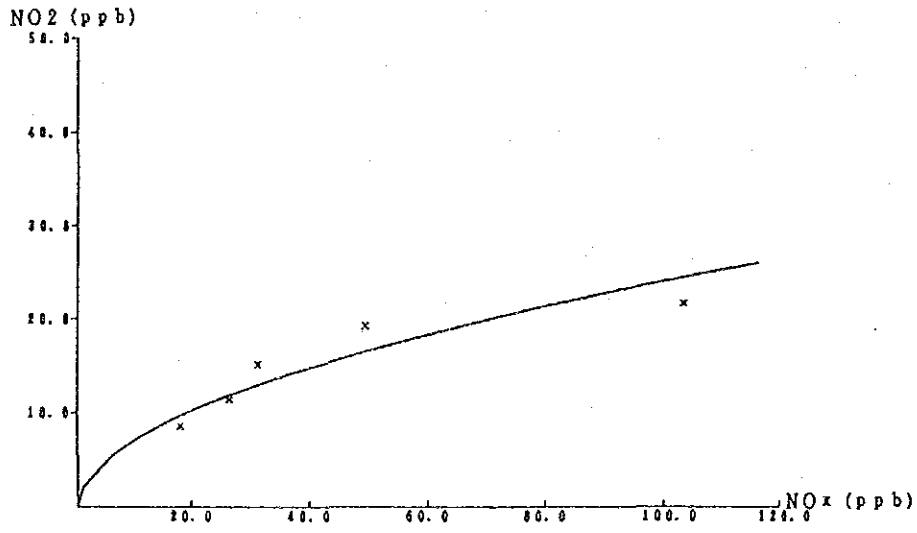


Fig. 6.1.5 Scatter Diagram of Actual Value of NOx and NO2

6.1.10 Calculation of Annual Average Concentration

Annual average of pollutant concentration was calculated by the following equation.

$$C = \Sigma_i \Sigma_j Y_{ij} C_{ij}$$

$$C_{ij} = \Sigma_k \Sigma_l \Sigma_m (R_{ij})_{klm} \cdot C_{klm}$$

C: annual average concentration

Y_{ij}: time ratio of period (i) and time zone (j)

C_{ij}: average concentration of period (i) and time zone (j)

$(R_{ij})_{klm}$: appearance ratio of wind direction (k), wind speed class (l) and atmospheric stability (m) in period (i) and time zone (j)

C_{klm}: calculated concentration of wind direction (k), wind speed class (l) and atmospheric stability (m)

6.2 Calculation Result by the Dispersion Model

Table 6.2.1 shows the annual average for five fixed stations calculated with the dispersion model. The contribution concentration by source is given as well in this Table.

Table 6.2.2 shows reproducibility of the model for each pollutant. The reproducibility for SO_2, NOx and NO_2 is high: the correlation coefficient is 0.9 or more and the coefficient of variation is less than 0.3.

As for CO, these coefficients are insufficient, because data of only three stations was used.

Background concentration was defined as the difference between measured and computed values in this study. The background concentration for each pollutant was appropriate level (Table 6.2.2). In conclusion, the dispersion model is considered to be valid to estimate annual average concentration.

Figs. 6.2.1 through 6.2.4 shows the scatter diagram of measured and calculated values for SO_2, NOx, NO_2 and CO.

Calculation method for correlation coefficient and coefficient variation, setting of background concentration and contribution concentration by source are described in Sections 4.1.2, 4.1.3 and 4.1.4 in the Supporting Report respectively.

Table 6.2.1 Computed Annual Average Concentration by Pollution Source

(Period; Mar. 1992 ~ Feb. 1993)

Item	Pollution Source / Receptor	Total	Factory	Motor Vehicles		Ship	Airplane
				Major Road	Minor Road		
SO_2 (ppb)	A. City Hall	7.9	0.7	6.4	0.7	0.0	0.0
	B. UPM	1.7	1.2	0.3	0.2	0.0	0.0
	C. Petaling Jaya	12.9	10.6	1.8	0.6	0.0	0.0
	D. Shah Alam	6.2	5.2	0.5	0.4	0.1	0.0
	E. Klang	3.7	2.7	0.4	0.2	0.3	0.0
NOx (ppb)	A. City Hall	104.2	0.3	92.3	11.7	0.0	0.0
	B. UPM	8.5	0.5	4.4	3.6	0.0	0.0
	C. Petaling Jaya	52.6	1.4	41.8	9.4	0.0	0.0
	D. Shah Alam	21.6	2.5	11.8	7.3	0.0	0.0
	E. Klang	12.4	4.2	5.1	2.9	0.2	0.0
NO_2 (ppb)	A. City Hall	25.4	-	-	-	-	-
	B. UPM	8.6	-	-	-	-	-
	C. Petaling Jaya	18.2	-	-	-	-	-
	D. Shah Alam	12.2	-	-	-	-	-
	E. Klang	9.8	-	-	-	-	-
CO (ppb)	A. City Hall	2.3	-	2.0	0.3	-	-
	B. UPM	0.1	-	0.0	0.1	-	-
	C. Petaling Jaya	0.7	-	0.6	0.1	-	-
	D. Shah Alam	0.2	-	0.1	0.1	-	-
	E. Klang	0.1	-	0.1	0.0	-	-

Table 6.2.2 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)

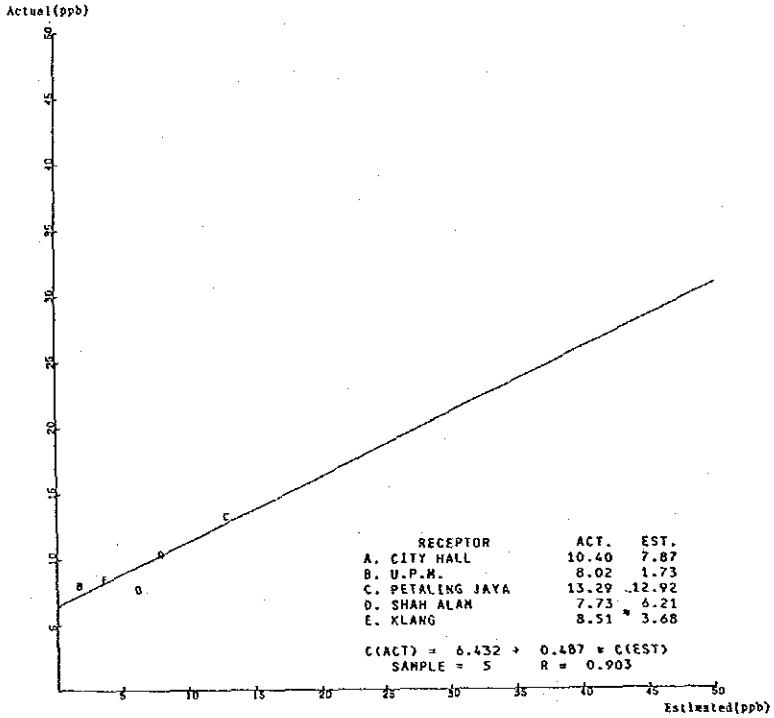


Fig.6.2.1 Scatter Diagram of Actual and Estimated Values of SO_2

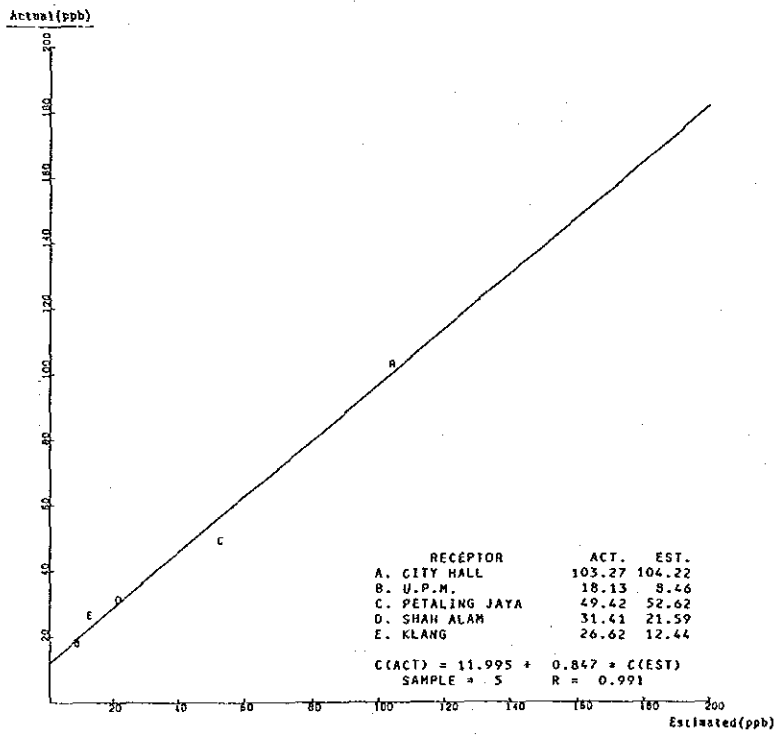


Fig.6.2.2 Scatter Diagram of Actual and Estimated Values of NO_x

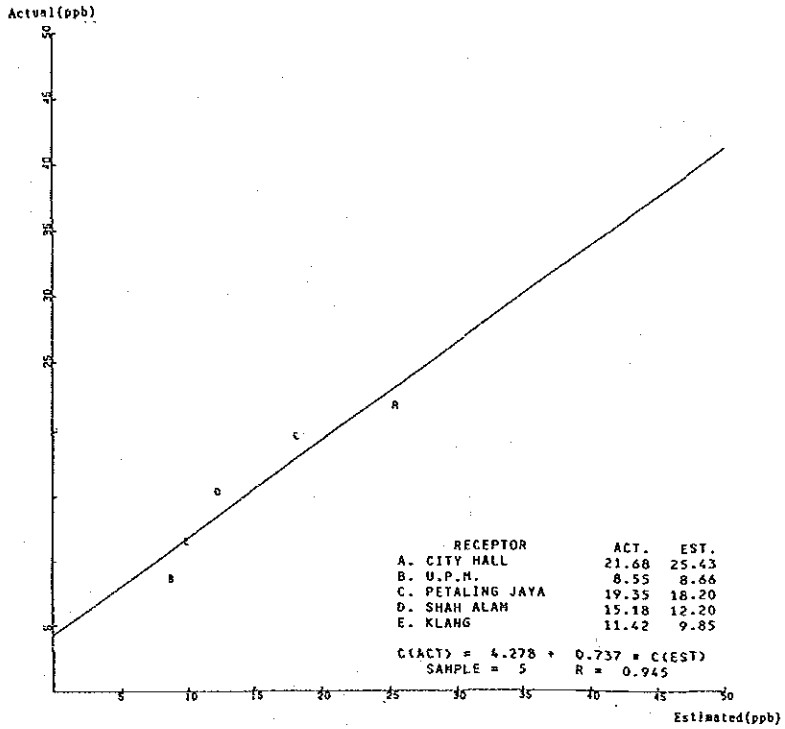


Fig.6.2.3 Scatter Diagram of Actual and Estimated Values of NO_2

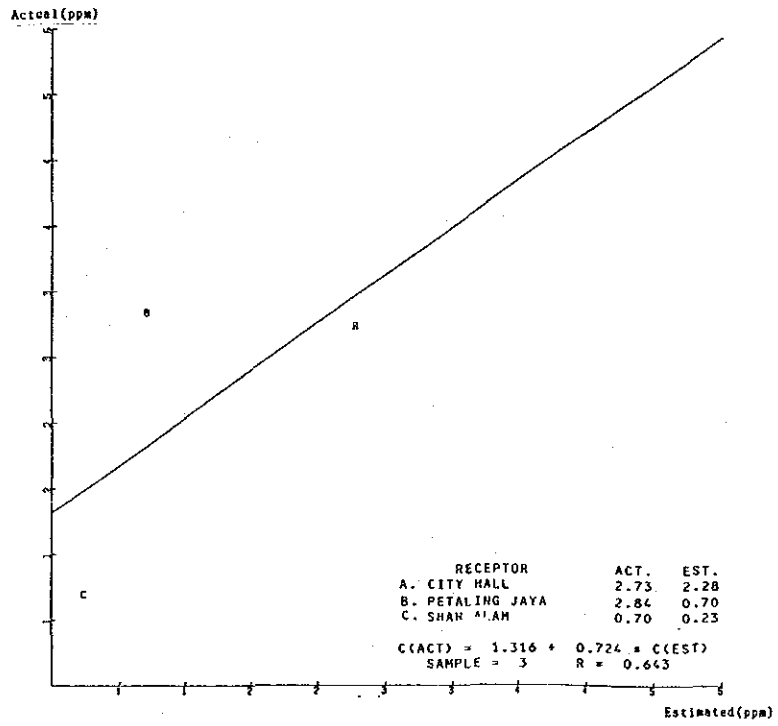


Fig.6.2.4 Scatter Diagram of Actual and Estimated Values of CO

6.3 Analysis of Air Pollution Structure

(1) Contribution Concentration by Air Pollution Sources

Annual average concentrations of SO_2, NOx, NO_2 and CO at each monitoring station and the maximum concentration point in the area were estimated by using the dispersion model described in the previous section. The computed results are shown in Table 6.3.1.

Note that each computed concentration is a sum of individual contribution concentrations of sources and the background concentration.

Concentration not grasped in the Study, concentration by pollutant blowing-back-phenomenon, measurement error, and concentration existing in nature are included in the background concentration.

In the Study, the background concentration was defined as the difference between measured values and computed values shown in Table 6.2.2.

A comparison of annual average concentration to air quality target value is as follows (for air quality target values, see Section 8.4).

SO_2: the maximum concentration exceeds the air quality target value, and the concentration at each monitoring station satisfies the target (20 ppb).

NO_2: the maximum concentration exceeds the target value, and the concentration at each monitoring station satisfies the target (37 ppb).

CO: the maximum concentration point exceeds the target value (4 ppm).

Table 6.3.1 Computed Annual Average Concentration (Mar., '92 ~ Feb., '93)

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)

Contribution concentration by sources at each monitoring station and the maximum concentration point are shown Fig. 6.3.1 - Fig. 6.3.3.

Because contribution concentration by airplanes is so little, their contribution concentration is not shown in these figures.

① SO_2

The contribution ratio of factories to the estimated value is 7 - 88%, and the contribution ratio of motor vehicles is 7 - 71% .

The contribution ratio of factories is higher than that of other sources at all estimated points except City Hall.

② NOx

The contribution ratio of motor vehicles to the estimated value is very high at 44 - 98%. Note that contribution to NO_2 concentration by sources was not calculated because estimated NO_2 concentration was calculated by converting the total NOx concentration to NO_2 concentration.

③ CO

Since only CO emission from motor vehicles was estimated in this study, they occupies all of contribution except background concentration.

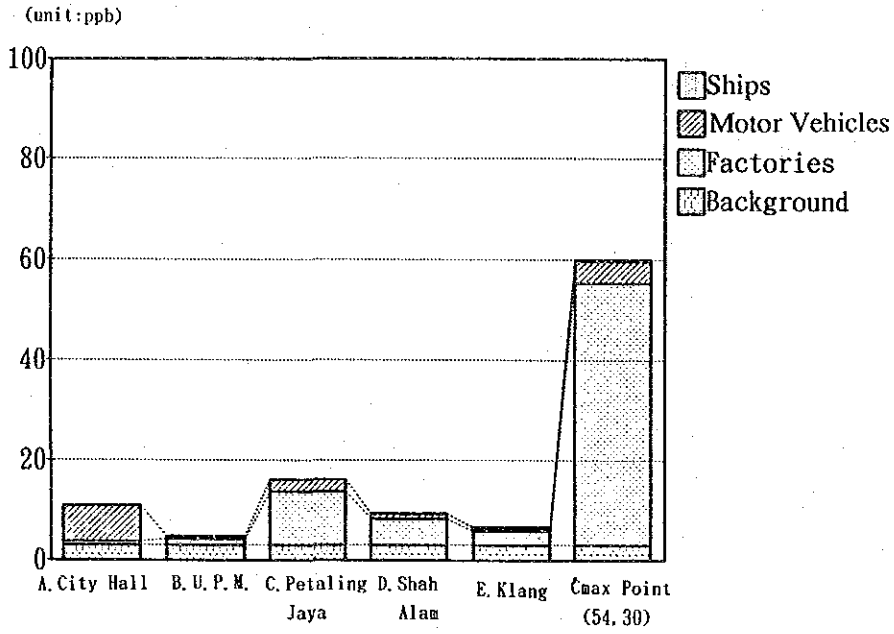


Fig. 6.3.1 Contribution of Sources to SO_2 Concentration (1992)

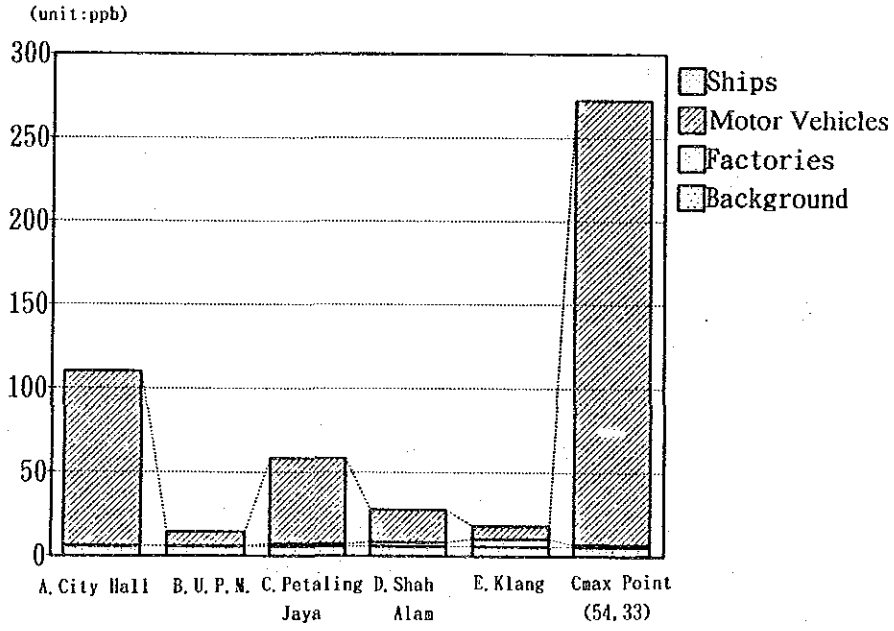


Fig. 6.3.2 Contribution of Sources to NOx Concentration (1992)

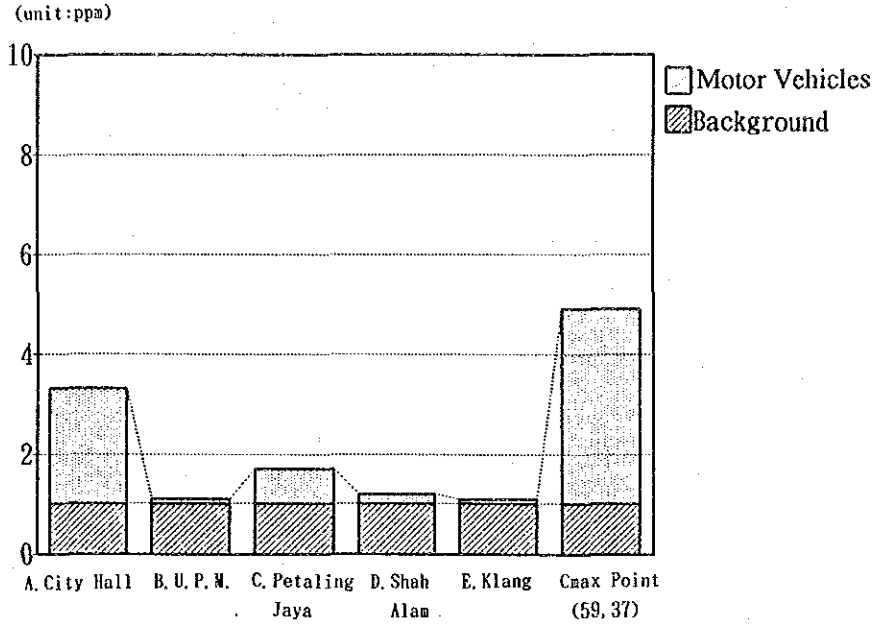


Fig. 6.3.3 Contribution of Sources to CO Concentration (1992)

(2) Estimation of Plane Concentration Distribution

The plane annual average concentration distribution of each pollutant was made using the dispersion model. The results are summarized as follows.

① SO_2

The estimation result of SO_2 plane concentration distribution is shown in Fig. 6.3.4. The concentration of 30 ppb or more distributed in parts of Petaling Jaya and in the east of Port Klang. The maximum concentration was 59.7 ppb in the mesh index (54, 30).

② NOx, NO_2

The estimation result of NOx plane concentration distribution is shown in Fig. 6.3.5. The concentration of 100 ppb or more distributed in parts of Kuala Lumpur and Petaling Jaya. The maximum concentration was 272.4 ppb in the mesh index (54, 33).

The estimation result of NO_2 plane concentration distribution is shown in Fig. 6.3.6. The concentration of 30 ppb or more distributed in the area of

Kuala Lumpur and Petaling Jaya. The maximum concentration was 41.1 ppb in the mesh index (54, 33).

③ CO

The estimation result of CO plane concentration distribution is shown in Fig. 6.3.7. The concentration of 3 ppm or more distributed in parts of Kuala Lumpur and Petaling Jaya. The maximum concentration was 4.9 ppb in the mesh index (59, 37).

The distribution of contribution concentration by pollutant source is given in Section 4.1.1(2) in the Supporting Report.

Fig. 6.3.4 Annual Average Concentration of Isopleths for SO_2 (1992)

(All Sources) X : C max. Point
Unit : ppb

Fig. 6.3.5 Annual Average Concentration of Isopleths for NOx (1992)

(All Sources) X : C max. Point
Unit : ppb

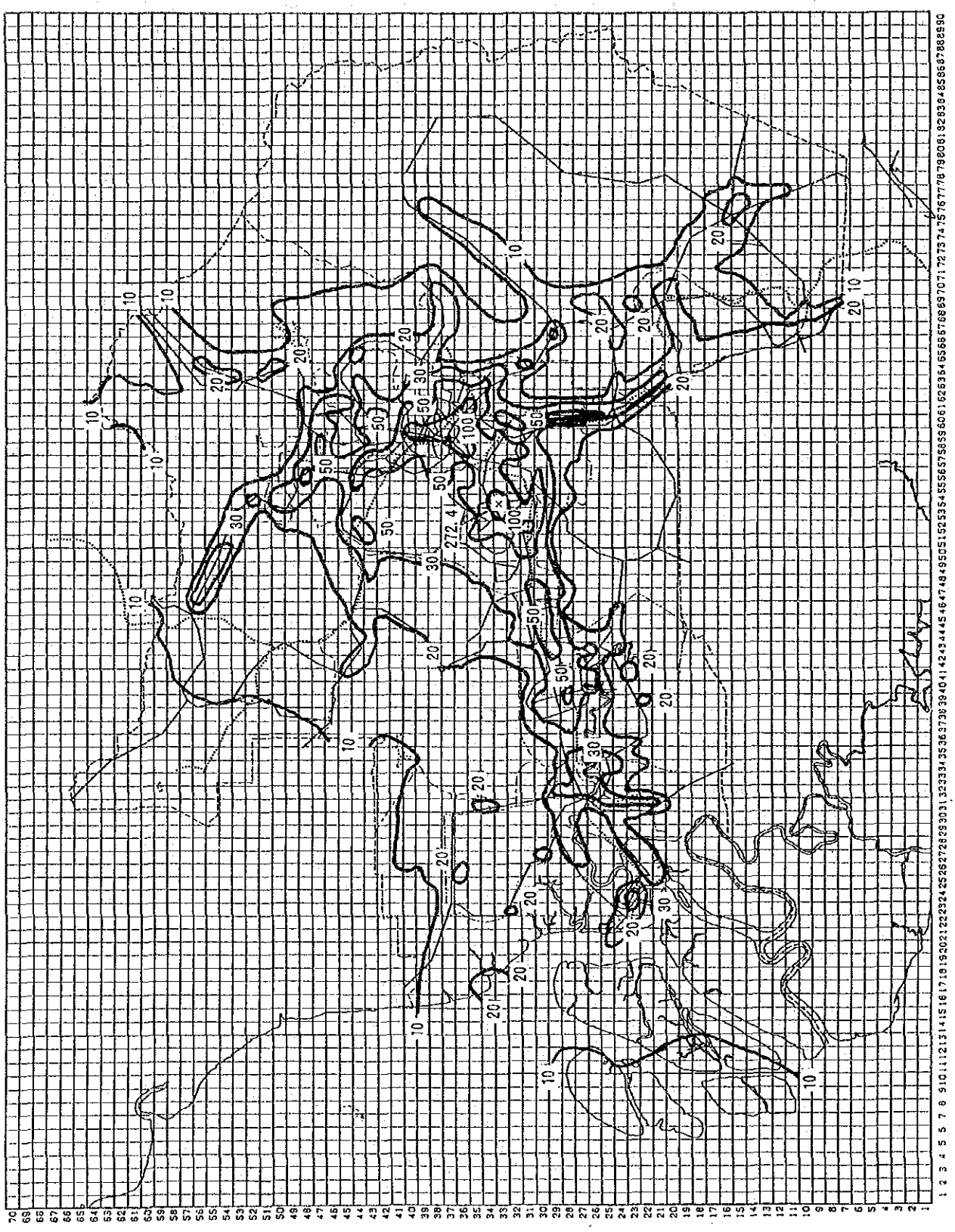


Fig. 6.3.6 Annual Average Concentration of Isoplcths for NO_2 (1992)

(All Sources) X : C max. Point
Unit : p p b

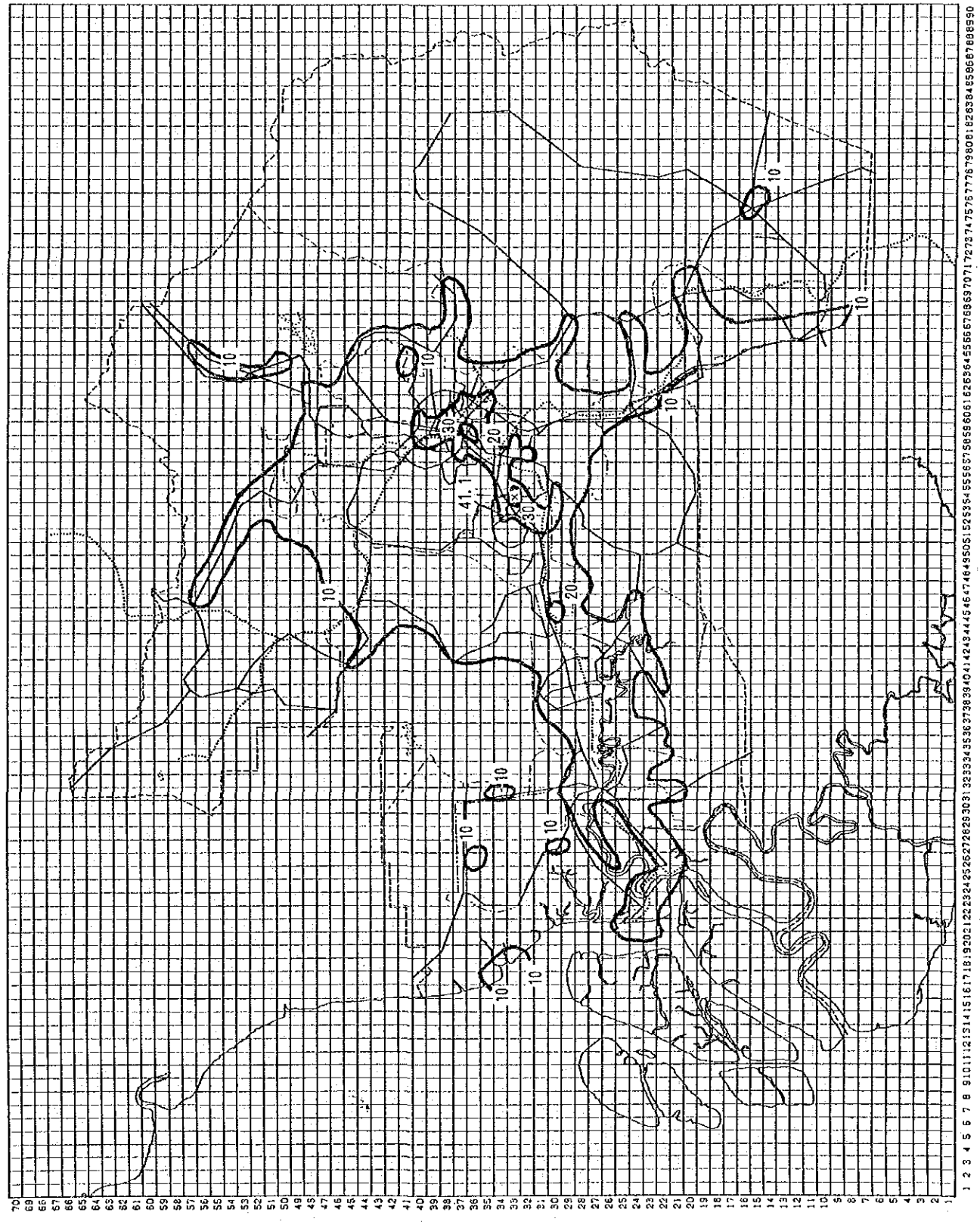
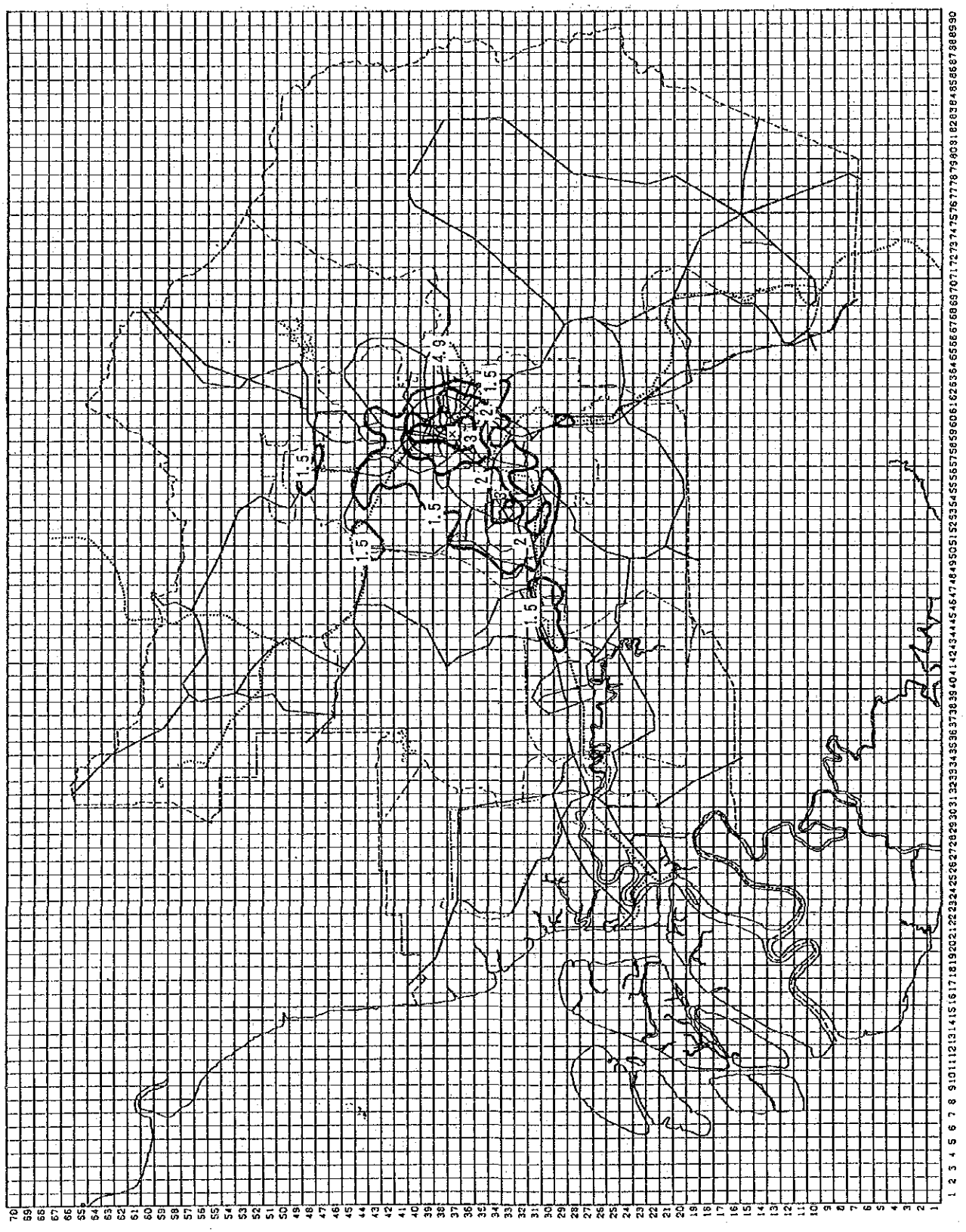


Fig. 6.3.7 Annual Average Concentration of Isopleths for CO (1992)

(All Sources) X : C max. Point
Unit : ppm



6.4 Air Dispersion Simulation System

The air dispersion system was developed using;

a) Meteorological data and air quality data from the stations set up under the Study in the Kelang Valley Region.

b) Meteorological data from MMS

c) Pollution source data surveyed in this Study and from DOE.

This system was implemented in the MMS computer.

6.4.1 Hardware System

This system is CONCURRENT Super minicomputer. The configurations of this system includes Magnetic Tape Drive Units, Hard Disk Units, Floppy Disk Drive Units, Line Printers, Laser Printers, Versatec Plotter and numerous terminals.

6.4.2 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 flow chart in Fig. 6.4.1 shows the outline in the design of the dispersion simulation system.

6.4.3 Input and Output Design

In this system, all types of new pollution sources such as the stacks of factories (point source), vehicles on the major roads (line source) and group of stacks of small factories and/or vehicles on minor roads (area source) are included. All necessary information on these sources is shown later.

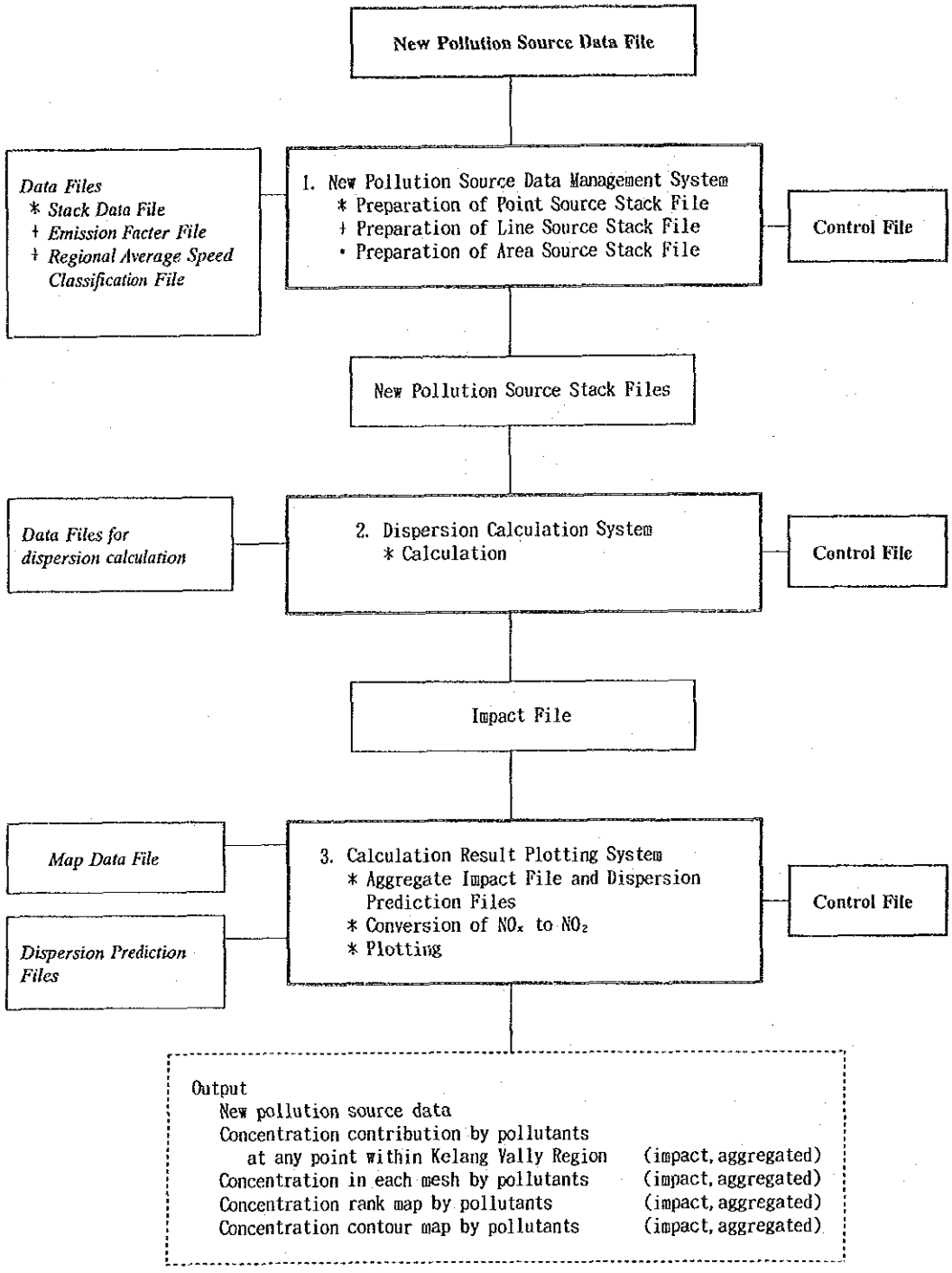


Fig. 6.4.1 Flowchart of the Air Dispersion Simulation System

(1) Stack (point source, area source)

Mesh number where the stack is located (ix,iy)
Location of the stack (X,Y) (m ; distance from the origin to the mesh)
Height of stack from ground (m)
Inner diameter of stack top (m)
Temperature of emitted gas (°C)
Amount of emitted gas (Nm^3/hour)
Effluent velocity (m/s)
Operating month/time
Industry type code
Fuel type code
Annual fuel consumption (ton/year, 10^3 Nm^3/year, 10^3 KW/year)
Hourly fuel consumption (Kg/hour, Nm^3/hour, KW)
Facility code

(2) Vehicles on Road (line source)

Number of link and sub-link
Mesh number of starting point (ix,iy)
Distance of starting point (X,Y) (m ; distance from the origin to the mesh)
Mesh number of ending point (ix,iy)
Distance of ending point (X,Y) (m ; distance from the origin to the mesh)
Zone number
Traffic volume by type and time (number/hour)

(3) Others (area source)

Mesh number of the area (ix,iy)
Annual amount of pollutants (ton/year)

In this system, calculated results are tabulated, and outputs conforming to fixed formats are plotted.

ex. Numerical concentration at each mesh by pollutants
Concentration rank map by pollutants
Concentration contour map by pollutants

An example of Concentration contour map by pollutants is shown in Fig. 6.4.2.

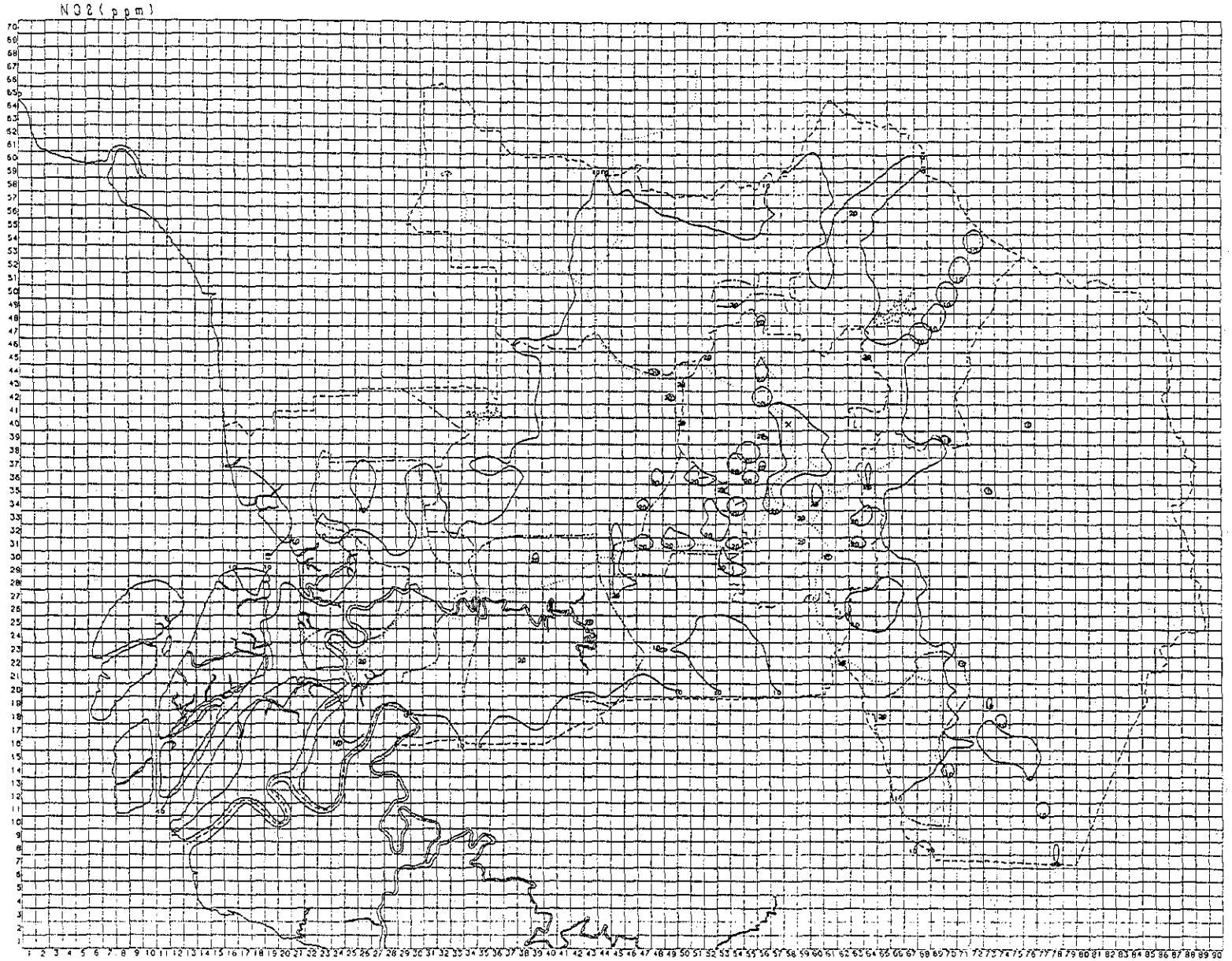


Fig. 6.4.2 An Example of Concentration Contour Map by Pollutants

6.4.4 Function of the System

The dispersion system covers the following items.

(1) Air Pollutants Concerned

Sulphur dioxide (SO_2), Nitrogen oxide (NOx), Carbon monoxide (CO), Dust, Nitrogen dioxide (NO_2)

(2) Pollution Source Concerned

New pollution sources such as factories, vehicles, etc.

(3) Period

Annual

(4) Area Covered in the Estimation

Kelang Valley Region

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

(1) Parameters

Classification of seasons and time zones
Data on coordinates
Geographical data (seashore line, administrative district, etc.)
Meteorological blocks in the horizontal direction
Meteorological classification in the vertical direction
Number of P by atmospheric stability
Classification of wind speed
Modelling of meteorological data
Parameters for Briggs Equation
Diffusion parameters

(2) Equations

Wind speed estimation equation
Effective Stack Height Calculation Equation
(Moses & Carson Equation, CONCAWE Equation, Briggs Equation)
Air Dispersion Equation
(Plume equation, simplified puff equation, weak wind puff equation)
Equation to convert NOx to NO_2
Equation for calculation of annual average concentration

6.4.5 Simulation Case Study

This system, using parameters established in the Model, can simulate impacts of air pollutants emitted from newly constructed factories, roads and so on. Appropriate emission factors of motor vehicles can be selected from those furnished for years of 1992, 1997, and 2005 in the Emission Factor File.

Since Dispersion Prediction Files for each type of source are provided for the current (1992) and the future (2005) conditions calculated on the Model, the results of both the Model and this system can be aggregated together to predict overall concentration. The Dispersion Prediction Files of the Model are equipped with increase or decrease functions. Therefore, newly implemented control measures can be reflected in the simulation.

CHAPTER 7 CHEMICAL ANALYSIS OF SPM COMPONENT

CHAPTER 7 CHEMICAL ANALYSIS OF SPM COMPONENT

7.1 Particulate Matter Component of Emission Source

Particulate matters (PM) from some emission sources were sampled and the chemical components were analyzed for CMB (Chemical Mass Balance) method. Factories, motor vehicles, and soil were investigated as the emission sources. Characteristics of PM sampling from factories and motor vehicles are summarized in Table 7.1.1 and Table 7.1.2. The sampling points of soil are summarized in Table 7.1.3 and Figure 7.1.1.

Table 7.1.1 Particulate Matter Sampling of Factory

Factory Number	Type of Industry	Facility	Fuel
1	Electricity Supply	Boiler	Heavy Oil
2	Chemical and Allied Products	Boiler	Palm Waste
3	Lumber and Wood Products	Boiler	Wood
4	Iron and Steel	Furnace	Electricity
5	Ceramic, Stone, and Clay Products	Kiln & Grinding Mill	Coal

Table 7.1.2 Particulate Matter Sampling of Motor Vehicles

Car No.	Type of Car	Fuel	Used Year
1	Passenger Car	Unleaded Gasoline	3
2	Passenger Car	Leaded Gasoline	10
3	Light Duty Truck	Diesel	6
4	Motorcycle	Leaded Gasoline	5

Table 7.1.3 Sampling Locations of Soil

Point No.	Location	Remarks
1	Beside Federal Route 2	Near to P.J. Hilton Hotel
2	Along Jalan Syed Putra	Beside Kelang River
3	In the Park Bukit Nanas	Among trees
4	Along KL-Seremban Expressway	Residential Area

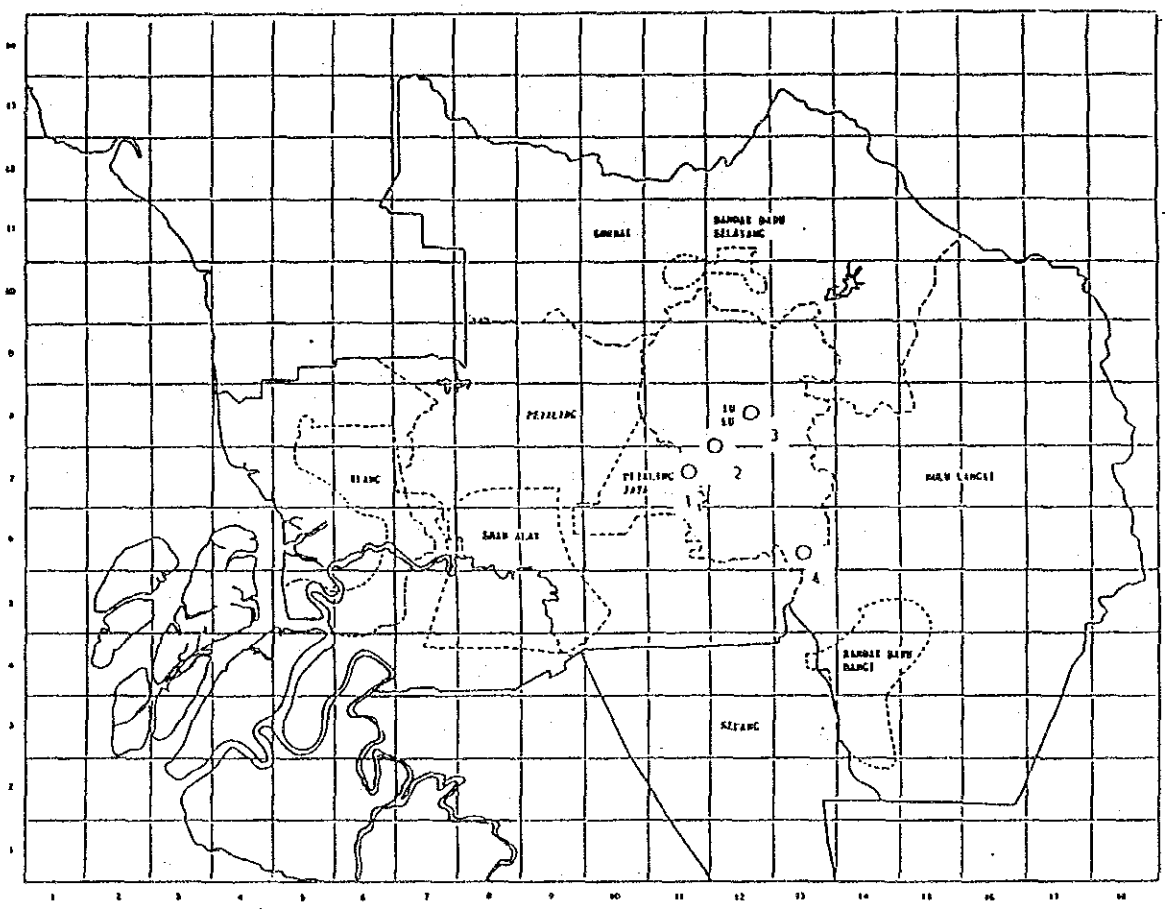


Fig. 7.1.1 Sampling Locations of Soil

The chemical components of PM samples from the factories are summarized in Table 7.1.4. The features of the components from the factories are as follows.

- A portion of K is high from the palm waste and wood burning boilers.
- Portions of Zn and Fe are high from the metal melting furnace.
- A portion of Ca is high from the kiln and grinding mill of the cement factory.

The chemical components of the motor vehicle PM samples are summarized in Table 7.1.5. A portion of Pb is higher in PM from the motor vehicles with leaded petrol than in the ones from the mortor vehicles with unleaded petrol.

The chemical components of the soil samples are summarized in Table 7.1.6. Deposit on the ground surface and subsurface soil are sampled at each point. A portion of Ca is rather high at point 1 and 2 and Sn portion is high at point 4.

Table 7.1.4 Chemical Component Fractions of PM Samples from Factories

unit: fractions in 100 weight parts

Factory Number	1	2	3	4	5
Na	0.127	0.376	0.813	0.186	0.
K	0.0255	15.8	12.3	0.	0.
Ca	0.0535	0.792	0.583	2.08	47.14
Al	0.00669	1.41	0.325	0.297	0.830
Sn	0.	0.00102	0.	0.0391	0.
Zn	0.00611	0.106	0.0692	19.1	0.0605
Fe	0.436	1.10	0.276	27.9	0.567
Mn	0.00449	0.0416	0.149	2.40	0.0331
Ni	0.0710	0.00255	0.	2.19	0.0122
Cr	0.0109	0.0286	0.388	0.104	0.00567
V	0.368	0.0108	0.0125	0.	0.00268
Pb	0.	0.0142	0.0396	2.19	0.0122

(See Table 7.1.1)

Table 7.1.5 Chemical Component Fractions of PM Samples from Motor Vehicles

unit: fractions in 100 weight parts

Car Number	1	2	3	4
Na	3.28	1.53	1.83	6.31
K	3.82	1.91	2.30	10.4
Ca	2.87	1.33	0.168	3.38
Al	0.	0.	0.0387	0.
Sn	0.	0.	0.	0.0
Zn	0.462	0.186	0.181	0.
Fe	0.154	0.326	0.481	0.
Mn	1.21	1.58	0.	0.
Ni	2.33	3.12	0.0226	0.
Cr	0.0692	0.163	0.	0.
V	0.	0.	0.	0.
Pb	7.35	42.1	0.152	44.8

(See Table 7.1.2)

Table 7.1.6 (1) Chemical Component Fractions of Soil Samples (Deposit)

Unit: μg/g

Sampling Point No.	1-A		2-A		3-A		4-A	
Na	570.	(5)	1700.	(2)	4600.	(3)	7200	(2)
Al	53000.	(2)	53000.	(6)	87000.	(6)	120000.	(6)
Cl	260.	(23)	200.	(40)	<100.		300.	(40)
K	4000.	(34)	12000.	(14)	23000.	(9)	21000.	(14)
Ca	94000.	(4)	73000.	(5)	8600.	(18)	8100.	(20)
Sc	10.	(2)	9.9	(1)	23.	(2)	7.9	(2)
Ti	3800	(5)	4300.	(7)	5700.	(5)	5500.	(8)
V	43.	(7)	52.	(5)	160.	(3)	76.	(7)
Cr	45	(10)	70.	(4)	150.	(3)	32.	(21)
Mn	300.	(18)	530.	(12)	450.	(11)	810.	(11)
Fe	36000.	(2)	24000.	(1)	60000.	(2)	17000.	(2)
Co	2.3	(7)	5.7	(3)	4.5	(4)	4.3	(6)
Ni	19.	(23)	19.	(21)	50.	(20)	10.	(40)
Cu	<90.		200.	(40)	<100.		<100.	
Zn	120.	(7)	510.	(3)	110.	(14)	150.	(7)
As	50.	(2)	69.	(2)	15.	(3)	130.	(2)
Se	17.	(6)	6.3	(4)	4.9	(8)	22.	(6)
Br	20.	(3)	41.	(2)	26.	(4)	9.5	(5)
Rb	40.	(7)	130.	(3)	170.	(3)	300.	(2)
Mo	7.	(29)	8.5	(24)	9.2	(16)	28.	(24)
Ag	1.	(29)	5.2	(8)	<0.4		<0.3	
Cd	<2.		<2.		10.	(20)	<2.	
Sn	270.	(7)	120.	(12)	69.	(23)	680.	(4)
Sb	1.6	(4)	2.5	(4)	1.5	(3)	1.7	(5)
I	<6.		<6.		<8.		<9	
Cs	5.2	(2)	16.	(1)	19.	(1)	23.	(1)
Ba	170.	(17)	330.	(8)	460.	(7)	440.	(7)
La	24.	(2)	19.	(2)	13.	(2)	33.	(3)
Ce	58.	(5)	55.	(5)	100.	(5)	98.	(4)
Sm	3.8	(5)	3.6	(5)	1.9	(4)	10.	(7)
Eu	0.46	(10)	0.66	(6)	0.80	(8)	0.64	(6)
Yb	7.3	(4)	4.7	(7)	5.3	(10)	17.	(7)
Lu	0.94	(4)	0.65	(5)	0.78	(4)	2.3	(4)
Hf	25.	(2)	12.	(2)	5.9	(2)	28.	(2)
Ta	22.	(2)	7.8	(3)	5.1	(3)	31.	(2)
W	22.	(4)	17.	(6)	8.6	(12)	56.	(3)
Hg	0.67	(18)	1.6	(11)	0.2	(40)	<0.1	
Th	85.	(4)	29.	(4)	33.	(3)	45.	(4)
U	9.9	(3)	11.	(4)	3.8	(5)	38.	(2)

(See Table 7.1.3 and Fig. 7.1.1)

Table 7.1.6 (2) Chemical Component Franctions of Soil Samples (Subsurface)

Unit: μg/g

Sampling Point No.	1-B		2-B		3-B		4-B	
Na	4600.	(2)	5200.	(2)	5200.	(2)	1100.	(4)
Al	120000.	(6)	92000.	(2)	130000.	(3)	83000.	(2)
Cl	100.	(40)	200.	(40)	<100.		200.	(40)
K	15000.	(15)	20000.	(40)	28000.	(9)	10000.	(40)
Ca	56000.	(6)	7000.	(40)	2000.	(40)	9200.	(15)
Sc	5.2	(2)	7.9	(2)	20.	(2)	13.	(2)
Ti	4300.	(7)	6400.	(4)	9500.	(5)	4300.	(9)
V	39.	(10)	88.	(3)	140.	(3)	39.	(8)
Cr	46.	(5)	120.	(4)	130.	(3)	55.	(5)
Mn	78.	(5)	340.	(15)	420.	(14)	750.	(10)
Fe	17000.	(2)	45000.	(1)	46000.	(2)	24000.	(2)
Co	2.3	(4)	5.9	(3)	4.9	(2)	9.2	(3)
Ni	10.	(40)	34.	(16)	37.	(16)	20.	(40)
Cu	<100.		<100.		<100.		<100.	
Zn	270.	(4)	1500.	(2)	460.	(5)	260.	(6)
As	140.	(3)	110.	(3)	49.	(2)	270.	(3)
Se	4.9	(6)	9.6	(6)	5.6	(6)	24.	(7)
Br	5.9	(7)	92.	(3)	19.	(4)	6.3	(7)
Rb	120.	(3)	190.	(2)	220.	(2)	240.	(2)
Mo	12.	(16)	24.	(17)	14.	(21)	13.	(18)
Ag	0.6	(43)	0.9	(40)	<0.4		<0.4	
Cd	<2.		<2.		<2.		<2.	
Sn	140.	(9)	220.	(7)	50.	(40)	530.	(5)
Sb	8.4	(4)	8.9	(3)	4.1	(2)	3.8	(6)
I	30.	(30)	10.	(40)	30.	(36)	10.	(40)
Cs	8.6	(1)	14.	(1)	20.	(1)	24.	(1)
Ba	270.	(8)	680.	(7)	680.	(6)	410.	(12)
La	21.	(2)	35.	(2)	31.	(2)	43.	(3)
Ce	53.	(5)	100.	(5)	130.	(5)	120.	(5)
Sm	5.3	(7)	8.1	(7)	4.8	(4)	8.3	(8)
Eu	0.39	(8)	0.69	(7)	1.1	(6)	1.2	(6)
Yb	4.3	(7)	7.0	(8)	5.2	(9)	12.	(8)
Lu	0.59	(5)	0.95	(4)	0.71	(5)	1.5	(4)
Hf	13.	(2)	18.	(1)	7.3	(1)	20.	(2)
Ta	6.6	(2)	12.	(2)	6.3	(3)	33.	(2)
W	14.	(5)	24.	(5)	15.	(5)	93.	(3)
Hg	<0.07		0.3	(40)	<0.1		0.32	(24)
Th	27.	(3)	43.	(6)	34.	(4)	47.	(2)
U	19.	(1)	29.	(2)	13.	(3)	20.	(3)

(See Table 7.1.3 and Fig. 7.1.1)

7.2 SPM Components of Ambient Air

7.2.1 Outline of SPM Sampling

Four samples each at UPM and MMS, two at City Hall, and one each at Shah Alam and Tomen Sri Andalas were chemically analyzed. Descriptions of the twelve observations are summarized in Tables 7.2.1 through 7.2.6.

Table 7.2.1 First SPM Samples at MMS and UPM

	MMS (M1)	UPM (U1)
Date	17th/August/1992	17th/August/1992
Sampling Time	From 9:00 17/Aug./92 To 9:00 18/Aug./92	From 9:00 17/Aug./92 To 9:00 18/Aug./92
Weather	Hazy	Clear (generally)
Temperature	27.8°C	28.6°C
Humidity	76.7%	77.0%
Flow Rate	Initial 1132.80 l/min Final 1132.80 l/min	Initial 400.0 l/min Final 388.0 l/min
Weight of Filter	Before 4453.9 mg After 4543.4 mg	Before 973.6 mg After 1001.4 mg

Table 7.2.2 Second SPM Samples at MMS and UPM

	MMS (M2)	UPM (U2)
Date	11th/September/1992	11th September/1992
Sampling Time	From 9:00 11/Sep./92 To 9:00 12/Sep./92	From 9:00 11/Sep./92 To 9:00 12/Sep./92
Weather	Hazy	Clear
Temperature	26.9°C	28.6°C
Humidity	77.0%	73.0%
Flow Rate	Initial 1132.80 l/min Final 1132.80 l/min	Initial 410.0 l/min Final 400.0 l/min
Weight of Filter	Before 4468.8 mg After 4540.5 mg	Before 968.2 mg After 1001.9 mg

Table 7.2.3 Third SPM Samples at MMS and UPM

	MMS (M3)	UPM (U3)
Date	28th/December/1992	28th/December/1992
Sampling Time	From 9:00 28/Dec./92 To 9:00 29/Dec./92	From 9:00 28/Dec./92 To 9:00 29/Dec./92
Weather	Thunderstorm with rain	Clear
Temperature	31.1°C	26.2°C
Humidity	85.5%	90%
Flow Rate	Initial 1132.80 l/min Final 1132.80 l/min	Initial 430. l/min Final 415. l/min
Weight of Filter	Before 4456.9 mg After 4548.4 mg	Before 961.1 mg After 978.7 mg

Table 7.2.4 Fourth SPM Samples at MMS and UPM

	MMS (M4)	UPM (U4)
Date	30th/December/1992	30th/December/1992
Sampling Time	From 9:00 30/Dec./92 To 9:00 31/Dec./92	From 9:00 30/Dec./92 To 9:00 31/Dec./92
Weather	Rain	Clear
Temperature	31.7°C	26.7°C
Humidity	83.5%	87%
Flow Rate	Initial 1132.80 l/min Final 1132.80 l/min	Initial 430.0 l/min Final 410.0 l/min
Weight of Filter	Before 4432.0 mg After 4503.3 mg	Before 948.9 mg After 963.1 mg

Table 7.2.5 First SPM Samples at City Hall and Shah Alam

	City Hall (U5)	Shah Alam (U6)
Date	26th/January/1993	26th/January/1993
Sampling Time	From 10:15 26/Jan./93 To 9:00 27/Jan./93	From 11:50 27/Jan./93 To 10:40 28/Jan./93
Weather	Clear	Clear
Temperature	30.0°C	30.0°C
Humidity	64%	64%
Flow Rate	Initial 425 l/min Final 425 l/min	Initial 425 l/min Final 425 l/min
Weight of Filter	Before 947.6 mg After 973.2 mg	Before 949.1 mg After 978.1 mg

Table 7.2.6 Second SPM Samples at City Hall and First SPM Samples at Toman Sri Andals

	City Hall (U7)	Toman Sri Andals (U8)
Date	1st/March/1993	2nd/March/1993
Sampling Time	From 11:10 1/Mar./93 To 10:23 2/Mar./93	From 11:35 2/Mar./93 To 10:35 3/Mar./93
Weather	Clear	Clear
Temperature	27.4°C	28.9°C
Humidity	81%	89%
Flow Rate	Initial 425 l/min Final 425 l/min	Initial 425 l/min Final 425 l/min
Weight of Filter	Before 955.4 mg After 981.6 mg	Before 952.0 mg After 976.0 mg

7.2.2 SPM Components of Ambient Air

Concentrations of SPM components are summarized in Tables 7.2.7, 7.2.8, and 7.2.9. The characteristics of the results are as follows.

(1) Carbon

Carbon constituted about 34 to 57% of SPM. The ratio of organic carbon was rather high. It is very important to understand the reasons for the high values. Possible sources are motor vehicles, wood combustion, open burning and so on.

(2) SO_4^{2-}(Sulfate)

Sulfate concentrations of these samples are mostly below 3 $\mu g/m^3$ and not high except two values, 7.3 and 5.5 $\mu g/m^3$. The difference between the two sites, MMS and UPM, is small. This means that the secondary sulfate photo-chemically converted from SO2 was dominant in the Region. The value, 7.3 $\mu g/m^3$, observed at City Hall on 1st January 1993 was rather high, and the value at Shah Alam on the next day was not low. The values at other sites must have been similarly high on these days.

(3) NO_3^- (Nitrate)

Nitrate concentrations were below 1 $\mu g/m^3$. This concentration was low, because nitrate exists mostly in the gas-phase at high temperature.

(4) Source Tracer Elements

Al, Ca, and Fe are good tracer elements for soil particles. These analytical values of Al are not reliable because of the background by the quartz fiber filter. Concentration levels of these elements, Al, Ca, and Fe, are not very high. Rare earth elements, Sc, La, Ce and Sm, are also good tracers for soil particles.

It is possible to apply C, Pb, and Br for the tracer elements for exhaust gas from motor vehicles. Pb and Br are good tracer elements for leaded petrol exhaust particles. For diesel exhaust particles, C, especially Cel, elemental carbon, is a good tracer. Pb concentrations at MMS were more than two-times higher than those at UPM. Two sites, MMS and City Hall, were approximately at the same concentration level. Br concentrations were higher than the average concentration in Japan.

It is possible to apply K and C for the tracer elements of wood combustion particles. Wood combustion particles contain highly concentrated organic carbon (Cor) and water-soluble K. K concentrations were from 140 to 920 ng/m^3, and these values were often higher than those in Japan. One of the possibilities is the effect of wood combustion.

V and Ni are good tracer elements for fuel oil combustion particles. V concentrations were several ng/m^3 to about 10 ng/m^3. These values are not so high.

Na is a tracer element for sea salt. Cr, Mn, and Zn are tracer elements for steel factories.

Finally, sixteen elements such as Na, K, Ca, Sc, V, Cr, Mn, Fe, Zn, Br, La, Ce, Sm, Pb, Cel, and Cor were used for CMB method.

Table 7.2.7 (1) Component of Ambient SPM

(Unit: ng/m^3)

Sampling Point	MMS (92. Aug. 17)	MMS (92. Sep. 11)	MMS (92. Dec. 28)	MMS (92. Dec. 30)
Na	300. (6)	400. (5)	260. (7)	69. (23)
Al	3100. (10)	1200. (10)	<3000. (20)	<3000.
Cl	160. (25)	300. (13)	370. (15)	280. (13)
K	750. (9)	790 (8)	610. (40)	300. (29)
Ca	790. (3)	780. (3)	540. (10)	480. (15)
Sc	0.11 (8)	0.046(11)	0.028(29)	0.032(15)
Ti	100. (34)	<70.	80. (18)	<70.
V	7.3 (10)	11. (9)	15. (9)	13. (8)
Cr	2.6 (14)	3. (26)	1. (47)	2.6 (15)
Mn	6.5 (15)	10. (25)	11. (20)	4. (30)
Fe	450. (11)	200. (21)	330. (9)	200. (17)
Co	2.3 (5)	1.2 (7)	0.1 (2)	<0.09
Ni	3. (40)	<2.	5.8 (3)	5.5 (21)
Cu	30. (40)	<10.	<30. (5)	<30.
Zn	90. (3)	31. (6)	220. (2)	76. (3)
As	6.7 (3)	7.7 (3)	7.1 (23)	5.8 (3)
Se	0.6 (30)	0.4 (40)	1.9	1.3 (6)
Br	44. (2)	36. (2)	77. (32)	35. (2)
Rb	5.1 (20)	4.5 (22)	2.8 (40)	2.6 (17)
Sn	<20.	<20.	<10. (19)	<0.5
Sb	4.0 (2)	6.4 (2)	3.4 (14)	3.3 (2)
I	3.7 (15)	10. (9)	2. (22)	3. (45)
Cs	0.30.(20)	0.3 (32)	0.22	0.2 (28)
Ba	20. (43)	10. (46)	61.	24. (17)
La	0.35 (14)	0.29 (21)	0.24 (31)	0.09 (49)
Ce	0.7 (31)	0.4 (48)	<0.1	<0.2
Sm	<0.03	0.05 (32)	0.06	<0.001
Eu	<0.07	<0.03	<0.03	<0.003
Yb	<0.06	0.1 (39)	<0.05 (40)	<0.05
Lu	<0.005	0.03 (34)	<0.004	<0.003
Hf	<0.007	<0.03	<0.08 (37)	<0.08
Ta	<0.06	0.05	0.06 (17)	0.05 (40)
W	<0.1	0.3 (40)	<0.2 (34)	<0.2
Pb	160. (5)	320. (3)	200. (4)	225. (5)
Th	0.30 (9)	0.12.(24)	0.12 (17)	0.13 (19)
SPM	54900.	44000.	56000.	44000.

in parenthesis: error in %

Table 7.2.7 (2) Component of Ambient SPM

(Unit: ng/m^3)

Sampling Point	UPM (92. Aug. 17)	UPM (92. Sep. 11)	UPM (92. Dec. 28)	UPM (92. Dec. 30)
Na	230. (6)	330. (5)	74. (22)	30. (35)
Al	300. (30)	100. (30)	<3000.	<2000.
Cl	310. (9)	70. (32)	<50.	<10.
K	650. (6)	920. (6)	410. (6)	140. (12)
Ca	420 (3)	1400. (2)	210. (16)	240. (13)
Sc	0.082(4)	0.085(8)	<0.004	<0.001
Ti	<50.	80. (40)	<60.	<40.
V	6.1 (7)	8.8 (9)	4. (36)	2. (45)
Cr	1. (34)	2.2 (17)	<1.	<0.6
Mn	3.7 (11)	7.9 (9)	6.0 (17)	2.
Fe	280. (10)	350. (6)	120. (20)	60. (25)
Co	0.59 (16)	0.76 (8)	<0.1	<0.07
Ni	3. (28)	2. (48)	<0.8	<0.5
Cu	20. (40)	40. (40)	<30.	20. (40)
Zn	27. (5)	58. (3)	45. (6)	15. (8)
As	12. (3)	11. (4)	6.5 (2)	3.9 (2)
Se	0.4 (26)	0.99 (11)	0.95 (10)	0.65 (8)
Br	16. (2)	41. (2)	9.5 (3)	4.6 (3)
Rb	3.7 (18)	4.2 (16)	2. (25)	1. (30)
Sn	<8.	<10.	<6.	<3.
Sb	1.2 (4)	7.9 (3)	1.1 (4)	0.59 (4)
I	6.5 (11)	10. (10)	<2.	1. (40)
Cs	0.25 (17)	0.35 (13)	0.17 (17)	0.078(21)
Ba	10. (40)	<10.	<6.	<4.
La	0.24 (19)	0.33 (13)	<0.1	<0.06
Ce	0.66 (19)	0.69 (13)	<0.3	<0.2
Sm	<0.02	0.060(18)	<0.03	<0.02
Eu	<0.02	<0.02	<0.04	<0.03
Yb	<0.02	<0.05	<0.04	<0.03
Lu	<0.006	0.018(23)	<0.007	<0.002
Hf	<0.04	<0.06	<0.07	<0.04
Ta	<0.03	<0.04	<0.03	<0.006
W	0.2 (26)	0.4 (32)	<0.1	<0.07
Pb	72. (5)	120. (5)	77.1 (5)	51.3 (6)
Th	0.20 (11)	0.24 (9)	<0.05	<0.03
SPM	49000.	57800.	29000.	24000.

in parenthesis: error in %

Table 7.2.7 (3) Component of Ambient SPM

(Unit: ng/m^3)

Sampling Point No.	City Hall (93. Jan. 26)	Shah Alam (93. Jan. 27)	City Hall (93. Mar. 1)	Toman Sri Andals (93. Mar. 2)
Na	500. (6)	390. (4)	370. (4)	490. (3)
Al	<2000.	<2000.	300. (49)	<200.
Cl	<30.	<10.	40. (34)	450 (6)
K	400. (29)	400. (31)	400. (17)	620. (19)
Ca	500. (21)	410. (8)	780. (48)	710. (6)
Sc	0.014(16)	0.027(10)	0.025(12)	0.055(9)
Ti	30. (40)	50. (46)	<20.	50. (40)
V	2. (29)	7.0 (11)	7.4 (5)	5.0 (8)
Cr	1. (31)	1. (34)	1.7 (12)	1.6 (19)
Mn	4. (26)	4. (30)	9.4 (18)	5. (31)
Fe	160. (11)	150. (11)	290. (6)	240. (9)
Co	<0.07	<0.07	<0.07	<0.07
Ni	3.0 (20)	2. (34)	2. (40)	<0.8
Cu	<9.	10. (35)	<6.	<4.
Zn	21. (7)	22. (5)	81. (3)	48. (5)
As	2.3 (3)	5.1 (4)	2.9 (5)	5.7 (5)
Se	0.29 (21)	0.50 (10)	0.37 (24)	2.3 (6)
Br	28. (2)	20. (3)	55. (2)	90. (2)
Rb	1.5 (23)	2.2 (17)	2.4 (16)	3.9 (9)
Sn	7. (36)	4. (40)	<6.	<7.
Sb	1.5 (2)	3.6 (2)	7.0 (2)	11 (2)
I	2. (35)	4.3 (12)	2.4 (23)	3. (28)
Cs	0.11 (17)	0.17 (11)	0.12 (17)	0.22 (10)
Ba	19. (19)	<5.	31. (12)	<9.
La	<0.1	<0.05	0.20 (22)	0.22 (19)
Ce	<0.2	<0.2	0.21 (25)	0.43 (24)
Sm	<0.06	<0.02	<0.02	<0.02
Eu	<0.03	<0.01	<0.01	<0.02
Yb	<0.01	<0.01	0.03 (49)	0.05 (38)
Lu	<0.002	<0.002	<0.01	<0.01
Hf	<0.04	<0.04	<0.005	<0.02
Ta	<0.02	<0.03	<0.03	<0.03
W	<0.1	<0.2	0.1 (40)	0.4 (40)
Pb	183. (3)	64.4 (6)	169. (4)	37.5 (5)
Th	0.05 (30)	0.05 (31)	0.08 (26)	0.14 (11)
SPM	42000.	47000.	44000.	41000.

in parenthesis: error in %

Table 7.2.8 (1) Carbon Concentration of Ambient SPM

	MMS (92. Aug. 17)	MMS (92. Sep. 11)	MMS (92. Dec. 28)	MMS (92. Dec. 30)
Ct	30.7 (56%)	24.6 (56%)	28.0 (50%)	19.8 (45%)
Cel	16.4 (30%)	13.8 (31%)	16.0 (29%)	12.0 (27%)
Cor	14.3 (25%)	10.8 (25%)	12.0 (21%)	7.8 (18%)
SPM	54.9	44.0	56.0	44.0

Table 7.2.8 (2) Carbon Concentration of Ambient SPM

	UPM (92. Aug. 17)	UPM (92. Sep. 11)	UPM (92. Dec. 28)	UPM (92. Dec. 30)
Ct	23.6 (48%)	30.1 (52%)	13.6 (47%)	8.8 (37%)
Cel	12.9 (26%)	12.8 (22%)	7.3 (25%)	5.4 (23%)
Cor	10.7 (22%)	17.3 (30%)	6.3 (22%)	3.4 (14%)
SPM	49.0	57.8	29.0	24.0

Table 7.2.8 (3) Carbon Concentration of Ambient SPM

	City Hall (93. Jan. 26)	Shah Alam (93. Jan. 27)	City Hall (93. Mar. 1)	Toman Sri Andals (93. Mar. 2)
Ct	19.0 (45%)	16.2 (34%)	25.0 (57%)	15.3 (37%)
Cel	11.0 (26%)	9.2 (20%)	14.0 (32%)	8.1 (20%)
Cor	8.0 (19%)	7.0 (15%)	11.0 (25%)	7.2 (18%)
SPM	42.0	47.0	44.0	41.0

(Unit: $\mu g/m^3$, in parenthesis: %)
Ct: Carbon Total,
Cel; Elemental Carbon
Cor: Organic Carbon

Table 7.2.9 (1) Concentrations of Ion Species in Ambient SPM

	MMS (92. Aug. 17)	MMS (92. Sep. 11)	MMS (92. Dec. 28)	MMS (92. Dec. 30)
NO_3^-	0.61 (1.1%)	0.56 (1.3%)	0.58 (1.0%)	0.69 (1.6%)
SO_4^{2-}	2.72 (5.0%)	2.66 (6.0%)	4.16 (7.4%)	2.57 (5.8%)
NH_4^+	0.41 (0.7%)	0.34 (0.8%)	1.08 (1.9%)	0.57 (1.3%)
SPM	54.9	44.0	56.0	44.0

Table 7.2.9 (2) Concentrations of Ion Species in Ambient SPM

	UPM (92. Aug. 17)	UPM (92. Sep. 11)	UPM (92. Dec. 28)	UPM (92. Dec. 30)
NO_3^-	0.42 (0.9%	0.32 (0.6%)	0.08 (0.3%)	0.0 (0.0%)
SO_4^{2-}	1.97 (4.0%)	2.80 (4.8%)	2.07 (7.1%)	2.41(10.0%)
NH_4^+	0.29 (0.6%)	0.26 (0.4%)	0.42 (1.4%)	0.50 (2.1%)
SPM	49.0	57.8	29.0	24.0

Table 7.2.9 (3) Concentrations of Ion Species in Ambient SPM

	City Hall (93. Jan. 26)	Shah Alam (93. Jan. 27)	City Hall (93. Mar. 1)	Toman Sri Andals (93. Mar. 2)
NO_3^-	0.54 (1.3%)	0.18 (0.4%)	0.28 (0.6%)	0.54 (1.3%)
SO_4^{2-}	7.32(17.4%)	5.52(12.0%)	2.13 (4.8%)	2.31 (5.6%)
NH_4^+	1.09 (2.6%)	1.61 (3.4%)	0.37 (0.8%)	0.32 (0.8%)
SPM	42.0	47.0	44.0	41.0

(Unit: μg/m3, in parenthesis: %)

7.3 SPM Component Analysis by CMB Method

7.3.1 Outline of CMB Method

CMB (Chemical Mass Balance) method is a type of receptor model or statistical model to estimate the contributions from sources to ambient SPM concentration. The sources of SPM are divided into artificial sources and natural ones. The former includes the different kinds of factories, various types of motor vehicles, ships, airplanes etc. The latter includes soil particles, sea salt particles, and others. 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.

The mathematical formulation of CMB method is explained as follows. The receptor model for estimating the contributions by pollution sources is based on the law of conservation of mass. For example, assuming that (p) numbers of emission sources exist and suppose no interaction follows where mass change occurs, SPM concentration (C) measured at the receptor is obtained by taking the sum of contributions (Sj) of each emission source as in equation (1).

$$C = \sum_{j=1}^{p} Sj \qquad (1)$$

Similarly, concentration (Ci) of component (i) in the SPM is expressed by equation (2). Here (aij) is the mass fraction of source contribution (j) possessing component (i) at the receptor.

$$Ci = \sum_{j=1}^{p} aij\ Sj \qquad (2)$$

Assuming that (n) numbers of components are analyzed at the sources and receptors, then an equation is set up for each component. If the number (n) is greater than or equal to a number (p), we could obtain the answer by solving the set of p linear equations.

When the number (n) is greater than (p), a set of maximum accurate values is obtained by minimizing the value (χ^2) expressed in equation (3).

$$\chi^2 = \sum_{i=1}^{n} \frac{(Ci - \sum_{j=1}^{p} aij\ Sj)^2}{wi^{-2}} \qquad (3)$$

Here (wi) are the weights according to the extent of errors in measurement.

Equation (4) is the matrix form expression of equation (2).

$$\not{c} = A\$ \qquad (4)$$

Here ($\not{c}$) is n-dimensional vector of component concentration, and (A) is n by p matrix of mass fraction of sources, and ($) is n-dimensional vector of contributions by sources.

Generally, the solution by the least squares method is as follows.

$$\$ = ({}^tAWA)^{-1}\,{}^tAW\not{c} \qquad (5)$$

Here, (W) is a diagonal matrix with diagonal components of wi^2. Errors of estimations for the source contributions depend on the way the weights (wi) are chosen.

7.3.2 Analytical Results by CMB Method

SPM component data on emission sources were made based on the analyzed data in section 7.1 and 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 in Section 7.2. The result is summarized in Table 7.3.1. 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 parts of organic carbon comes from both vehicle exhaust particles and wood combustion particles. Secondary particles converted from organic compounds may be contributing to the rest of particulate 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% at both sites, MMS and UPM. On the other hand, those were below 5% in December, January and March.

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 those is water.

Table 7.3.1 (1) Source Contributions to Ambient SPM

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

	MMS (92. Aug. 17)	MMS (92. Sep. 11)	MMS (92. Dec. 28)	MMS (92. Dec. 30)	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)
Un. Petrol	340 (0.6)	660 (1.5)	580 (1.0)	500 (1.1)	520 (1.1)
Iron & Steel	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 C.	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

Un. Petrol: Unleaded Petrol Organic C.: Organic Carbon

Table 7.3.1 (2) Source Contributions to Ambient SPM

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

	UPM (92. Aug. 17)	UPM (92. Sep. 11)	UPM (92. Dec. 28)	UPM (92. Dec. 30)	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)
Un. Petrol	110 (0.2)	240 (0.4)	130 (0.4)	80 (0.3)	140 (0.4)
Iron & Steel	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 C.	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

Un. Petrol: Unleaded Petrol Organic C.: Organic Carbon

Table 7.3.1 (3) Source Contributions to Ambient SPM

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

	City Hall (93. Jan. 26)	Shah Alam (93. Jan. 27)	City Hall (93. Mar. 1)	Toman Sri Andals (93. Mar. 2)	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)
Un. Petrol	390 (0.9)	130 (0.3)	440 (1.0)	60 (0.2)	260 (0.6)
Iron & Steel	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 C.	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

Un. Petrol: Unleaded Petrol Organic C.: Organic Carbon

Table 7.3.1 (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 LOADS

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

This chapter examines the necessity of reducing air pollution load for SOx, NOx and CO, in the future by predicting air pollutant concentration in the Kelang Valley Region.

8.1 Target Year

Malaysia has rapidly developed its economy, social infrastructure and regional development plans. With regard to traffic and transportation in the Kelang Valley Region, there is a major plan to introduce such modern public transportation systems as the Light Rapid Train (LRT) System and Mass Rapid Transit (MRT) Railway System by the year 2005. Construction of a number of new roads and improvement of existing ones are also slated to be completed by that year. Regional distribution of traffic volume as a major air pollution source will see a remarkable change upon the completion of these plans. Accordingly, the year 2005 was chosen as a basis for predicting future air pollution and examining the necessity of reducing air pollution load.

8.2 Prediction Conditions and Air Pollution Load

8.2.1 Factories and Establishments

(1) Prediction Method

Major stationary sources of air pollution in the Kelang Valley Region are boilers in both power stations and other factories. These boilers use fuel oil, diesel oil, coal, wood waste, palm waste, LPG and natural gas. Although current information on fuel consumption in the Kelang Valley Region is available from the questionnaire survey, future demand has to be estimated. Items to be considered to estimate future demand are listed below.

1) Power Stations

TNB has the future plan for the power stations, the major emission source, up to 2000. The plan was extended to 2005 without modification in the Study.

2) General Factories

a) Coal

Coal consumption in the cement factory was assumed to increase at a rate of 9.5% per year as shown in JACTIM report (#4021).

b) Wood Waste

Wood waste was estimated to be consumed at rates equivalent to current amounts in consideration of forest preservation trends.

c) Palm Waste

Palm waste consumption was estimated to increase at a rate of 3.3% per year based on the PORIM report (#4019).

d) Petroleum and Gas

Future demand for fuel oil and diesel oil are assumed to be the same as that in 1992. LPG demand was estimated by referring to PETRONAS (#4009) and JICA (#1032) predictions and multiplying consumption in 1992 by an expansion factor of 5.13 for the year 2005 (refer to Section 3.1.5 in the Supporting Report).

(2) Estimation Results

Table 8.2.1 gives the estimated demand for petroleum and gas fuels from general factories (all factories excluding power stations) in the Kelang Valley Region in the year 2005.

Table 8.2.1 Future Consumption of Petroleum and Gas Fuels by General Factories in KVR in 2005

(Unit : million liters)

Fuel Type	1992	2005	(2005/1992)
LPG	85	436	5.13
Fuel oil	190	190	1.0
Diesel oil	265	265	1.0

(3) Emission Factor

The emission factors used for estimating future air pollution loads from factories are same as the current ones. Most of them were selected from published sources in the USA and Japan. Although actual measurement data is better for estimating air pollution loads, presently conditions are not suited to carry out measurements at air pollution facilities in KVR. Emission factors occasionally differ from place to place depending on the types of facilities and fuels. Therefore, in the future, emission factors for

KVR have to be established based on actual measurement and be corrected regularly.

(4) Air Pollution Load

Table 8.2.2 shows the future fuel demand from factories in the Kelang Valley Region calculated from the growth rates in Section 8.2.1(1). Table 8.2.3 shows air pollution loads from factories in 1992 and 2005. Annual total emission in 2005 is 10,600 tons for Dust, 30,500 tons for NOx and 41,300 tons for SOx. Growth of pollutant emissions from power stations from 1992 to 2005 is remarkable: 23% for Dust, 104% for NOx and 54% for SOx. Currently 78% of the 9,003 ton/year of Dust emitted from factories in the region are from general factories other than power stations. Power stations' share in Dust emission will drop slightly from 78% in 1992 to 77% in 2005. But the share of NOx emissions from power stations will increase from 81% in 1992 to 86%. Clearly, NOx control is necessary for the power plant flue gases. Power stations will emit around 73% of SOx in 2005. This is the result of HFO burning in the boilers by No. 1 boiler and the commission in 1995 and 1996 of new PS-A.

Table 8.2.2 Future Fuel Demand by Factories in KVR (2005)

		1992	2005
General Factories	Fuel oil	190	190
	Diesel oil	265	265
	LPG	85	436
	Wood waste	307	307
	Palm waste	187	267
	Coal	89	198
Power Stations	Fuel oil	258,750	258,750
	Natural gas	1,861,110	2,786,986
	Coal	806,400	1,937,376

Unit Petroleum and gas : million liter/yr
Solid fuel : ton/yr

Table 8.2.3 Future Pollutant Emission from Factories in KVR (2005)

(unit : ton/year)

Year		SOx	NOx	Dust
1992	Power Stations	19,522 (63.9)	12,792 (81.1)	1,969 (21.9)
	General Factories	11,047 (36.1)	2,979 (18.9)	7,034 (78.1)
	Total	30,569 (100)	15,771 (100)	9,003 (100)
2005 Uncon-trolled	Power Stations	30,040 (72.7)	26,038 (85.5)	2,423 (22.9)
	General Factories	11,283 (27.3)	4,415 (14.5)	8,163 (77.1)
	Total	41,323 (100)	30,453 (100)	10,586 (100)

Figures in parenthesis are percentage values (%).

8.2.2 Motor Vehicles

Since the introduction of mass transportation systems will reduce traffic volume and construction of new roads will relieve traffic congestion, they themselves are powerful air pollution control measures. So, the following assumptions were made on motor vehicles to examine the necessity of reducing of air pollution loads in KVR to observe the air quality guidelines (air quality target values, see Section 8.4) and to evaluate the effect of introduction of mass transportation systems and improvement of road network on air pollution.

① The major road network in the future will be the same as the current one.
② Traffic volume on all major and minor roads will increase uniformly at a given rate.
③ The emission factors are the same as those at present.

(1) Traffic Volume

A study conducted by JICA (#6008), estimated the total number of daily trips at 44.515 million in 1985 and 83.33 million in 1995 for an annual growth rate of 6.5%. Assuming that traffic volume will increase by the same rate (6.5% per year) from 1992 to 2005, traffic volume will become 2.27 times of that in 1992.

(2) Major Road Network and Emission Factors

The current major road network (Fig. 5.2.5) and current vehicular emission factors (Tables 5.2.19) were used for estimating air pollution loads in the future.

(3) Air Pollution Load

The total air pollution load of HC, CO, NOx and SOx from motor vehicles will reach 2.27 times of the current load if no control measures are taken on traffic volume and vehicular exhaust gas, as shown in Table 8.2.4. The annual total air pollution load is 167,000 tons for HC, 659,000 tons for CO, 82,000 tons for NOx, 7,100 tons for SOx and 7,400 tons for PM.

Table 8.2.4 Future Air Pollution Loads from Motor Vehicles (2005)

(Unit: ton/year)

Pollutant	HC	CO	NOx	SOx	PM
Total Emission	166,720	659,223	82,199	7,079	7,359

8.2.3 Airplanes

(1) Number of Flights

A new international airport in Sepang (Sepang International Airport) is being planned under the sixth Malaysian Plan. Upon its opening the Subang International Airport will be mainly used for domestic flights.

The sixth Malaysian Plan estimates the number of flights at Subang Airport 99,985 in the year 2000. At that rate, the number of flights in the year 2005 is estimated at 105,421, as shown in Table 8.2.5.

Table 8.2.5 Annual Number of Flights at Subang Airport by Plane Type in 2005

Plane	Type: Domestic
B-737	99,233
DC-8	6,188
Total	105,421

(2) Air Pollution Load

Pollutant emissions from airplanes in various navigation modes are shown in Table 8.2.6. The annual total air pollution load is 360 tons for SOx, 570 tons for NOx and 120 tons for PM.

Table 8.2.6 Annual Air Pollution Load from Airplanes in Various Navigation Modes in 2005

Pollutant	Navigation Mode				Total
	Idling	Takeoff	Ascent	Approach /Landing	
SOx	164	129	21	47	360
NOx	56	386	50	82	574
PM	-	-	-	-	123

8.2.4 Ships

(1) Prediction Method

Estimates on future shipping are based on the report, 'On the Wave of a New Dynamism ...', published by the Klang Port Authority (KPA).

1) Ports and Facilities to be Developed

West Port, which will become Port Klang's new gateway, promises to provide ample opportunities for the business community. It will be built on the 49 sq.km island called Pulau Lumut and will be the focus of development well into the 21st century. Five multi-purpose berths, 16 general cargo/container berths, two liquid bulk and two dry bulk berths, and other supporting facilities are to be built.

2) Designation of Berths

As shown in Table 8.2.7, berths are classified into main four categories, i.e., South Port, North Port, Private Port, and West Port.

Table 8.2.7 Berth Classification

Berth Category	Code
South Port	11 (1-7A)
North Port	
· Container Terminal	21 (8-11)
· Conventional Traffic Terminal	22 (12-21)
· Liquid Bulk Terminal	23 (22-23)
· Dry Bulk Terminal	24 (24-25)
Private Port	
· Electric Power Plant Berth	31
· Junk	41
· Klang Container Terminal	42
West Port	
· Cargo/Container Terminal	51
· Multi purpose Facilities	52
· Liquid Bulk Terminal	53
· Dry Bulk Terminal	54
· Support Facilities	55

3) Number of Ships Calling at Port in 2005

The number of ships in 2005 were estimated from future plans prepared by KPA and figures based on 1990 data. The multiplying factor is 2.42, as seen in Table 8.2.8.

Table 8.2.8 Sea Transport at Port Klang

Cargo Year	1990	1992	2000	2005	Note
Container	9137	12664	24377	32813	Growth Rate of 2005/1990 ≒ 2.420
General	12968	16164	19430	20678	
Total	22105	28827	43807	53491	

source: Klang Port Authority Reports

(2) Air Pollution Load

Table 8.2.9 shows the amount of air pollutants emitted from ships at Port Klang. The annual total air pollution load from ships is 2,800 tons for SOx, 1,800 tons for NOx and 370 tons for PM.

Table 8.2.9 Future Air Pollutant Emission from Ships (2005)

Port Klang		Pollutant Emission and Fuel Consumption			
		SOx	NOx	SPM	Fuel Cons.
	Mooring	76.1	54.7	32.6	10866.1
	Navigating	37.2	47.3	9.1	2793.0
	Total (*1)	113.3 (Nm^3/h)	102.3 (Nm^3/h)	41.7 (Kg/h)	13659.1 (kg/h)
Annual Total (*2)		2835.7 (t/y)	1840.3 (t/y)	365.3 (t/y)	114805.9 (t/y)

Note) (*1): Average for one hour
(*2): Total annual emission

8.2.5 Households

According to our estimation, the number of population in Kelang Valley will increase at an annual rate of 2.6% (Table 2.2.2). Consequently, around 282 millions of LPG will be consumed by households, including hotels and restaurants, in the year 2005. Dust and NOx emissions will be 62 tons/yr and 226 tons/yr, respectively in 2005.

As mentioned in Section 5.5.1, natural gas will be supplied to Kuala Lumpur and other areas. It is difficult to estimate natural gas consumption in the region as it will be left to individuals discretion whether to use it or not. The amount of LPG was substituted for this purpose.

Household emissions of Dust and NOx in the year 2005 are only 0.5 and 0.6% respectively of overall emissions in the region.

8.2.6 Total Air Pollution Load

(1) Pollution Load from Various Sources

The air pollution load from various sources are shown in Table 8.2.10. The total annual air pollution load is 52,000 tons for SOx, 115,000 tons for NOx, 18,000 tons for PM, 659,000 tons for CO and 167,000 tons for HC, respectively. Factories account for 80% of the total SOx emission. Motor vehicles are the major pollution sources of NOx accounting for 71% of the total, followed by factories (26%). For PM, the major contributors are factories (57%) and motor vehicles (40%).

Table 8.2.10 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	30,453	10,586	-	-
	(80.1)	(26.4)	(57.2)		
Motor vehicles	7,079	82,199	7,359	659,223	166,720
	(13.7)	(71.3)	(39.8)	(100)	(100)
Airplanes	360	574	123	-	-
	(0.7)	(0.5)	(0.7)		
Ships	2,836	1,840	365	-	-
	(5.5)	(1.6)	(2.0)		
Households	0	226	62	-	-
	(0.0)	(0.2)	(0.3)		
Total	51,598	115,292	18,495	659,223	166,720
	(100)	(100)	(100)	(100)	(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) Regional Air Pollution Load

The regional air pollution load from factories, motor vehicles, airplanes and ships is shown in Table 8.2.11. SOx and PM are mainly emitted in Klang. NOx is mainly emitted in Klang and Kuala Lumpur.

Table 8.2.11 Regional Annual Pollution Load from Factories, Motor Vehicles, Airplanes and Ships (2005) (without control measures)

(unit: ton/year)

Pollutant	Region	Factories	Motor Vehicles	Airplanes	Ships	Total
SOx	Hulu Langat	1,349	931			2,280 (4.4)
	Gombak	556	1,200			1,756 (3.4)
	Kuala Lumpur	641	2,335			2,976 (5.8)
	Petaling	5,558	1,728	360		7,646 (14.8)
	Klang	33,218	885		2,836	36,939 (71.6)
	Total	41,322	7,079	360	2,836	51,597 (100)
NOx	Hulu Langat	801	9,844			10,645 (9.3)
	Gombak	1,576	12,360			13,936 (12.2)
	Kuala Lumpur	102	30,686			30,788 (26.9)
	Petaling	884	21,154	574		22,612 (19.7)
	Klang	26,622	8,155		1,840	36,617 (31.9)
	Total	29,985	82,199	574	1,840	114,598 (100)
PM	Hulu Langat	2,603	943			3,546 (19.3)
	Gombak	257	1,166			1,423 (7.7)
	Kuala Lumpur	346	2,701			3,047 (16.6)
	Petaling	1,711	1,724	123		3,558 (19.3)
	Klang	5,640	824		365	6,829 (37.1)
	Total	10,557	7,358	123	365	18,403 (100)

Figures in parenthesis are percentage values.

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

Table 8.2.12 compares the total annual air pollution loads from various sources between the year 1992 and the year 2005 when no control measures are taken. The growth rates of the air pollutants from 1992 to 2005 are between 1.45 and 2.27. The growth rate for CO and HC and NOx is the highest among all the pollutants, with a value of 2.27 times, followed by that of NOx (2.12).

Table 8.2.12 Comparison of Total Annual Air pollution Loads from All Sources between 1992 and 2005 (without control measures)

Year	Pollution Load (ton/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 Future Concentration Distribution

8.3.1 Prediction of Concentration at Monitoring Stations and the Maximum Concentration Point

Table 8.3.1 shows predicted results of future concentration of each pollutant at monitoring stations and the maximum point using the sources described in the previous section. Note that the background concentration contained in the predicted value is the same as the present (Table 6.2.2).

A comparison of the results of these concentrations with the target value (see Section 8.4) is as follows. SO_2 maximum concentration and the concentration at City Hall exceed the target concentration (20 ppb).

NO_2 maximum concentration and the concentration at City Hall and Petaling Jaya exceed the target value (37 ppb).

CO maximum concentration and the concentration at City Hall exceed the target value (4 ppm).

Table 8.3.1 Computed Future Annual Average Concentrations (2005) (without control measures)

Items / Stations	SO2 (ppb)	NOx (ppb)	NO2 (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

Fig. 8.3.1 - Fig. 8.3.3 show contribution concentration by source at each monitoring point. The contribution concentration of airplanes is excluded as in the present situation.

(1) SO2

The contribution ratio of factories to the predicted value is 7 - 80% while that of motor vehicles is 14 - 79%, which is approximately equivalent to present trends.

(2) NOx

The contribution ratio of motor vehicles to the predicted value is 54 - 98%. As in the present situation, motor vehicles account for more than half of the contribution in all stations and the maximum concentration point.

(3) CO

As in the present situation, the predicted CO value covers motor vehicles only as a source. Therefore, the concentration excluding background concentration is accounted for in its entirety by motor vehicles.

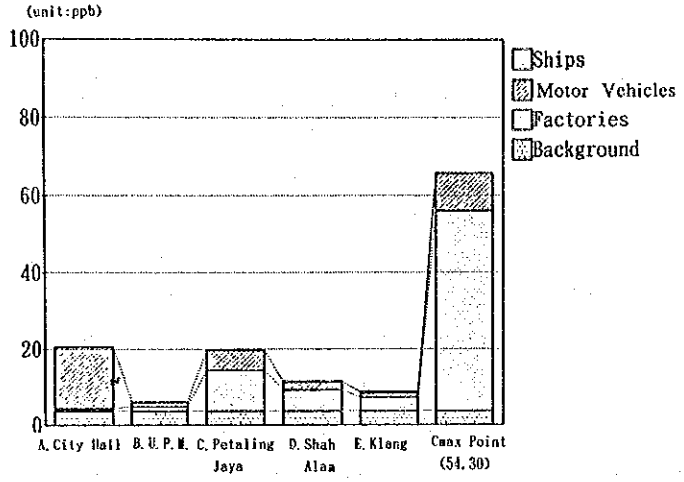


Fig. 8.3.1 Contribution of Sources to SO_2 Concentration (2005) (without control measures)

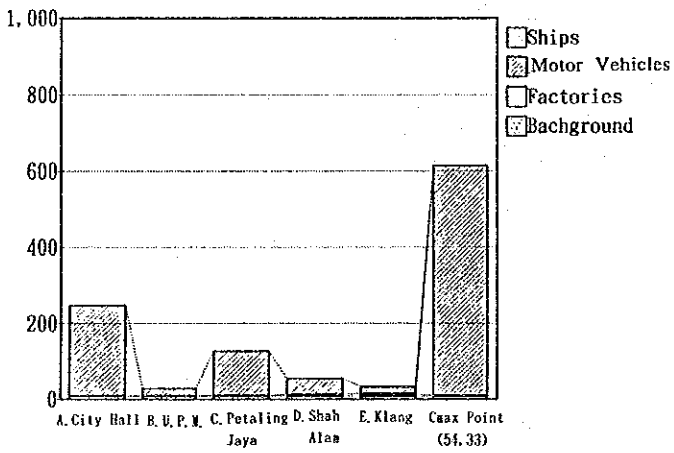


Fig. 8.3.2 Contribution of Sources to NOx Concentration(2005) (without control measures)

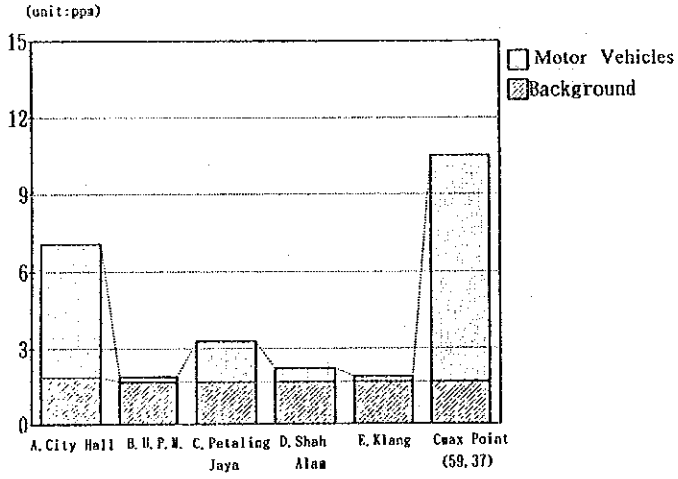


Fig. 8.3.3 Contribution of Sources to CO Concentration (without control measures)

8.3.2 Prediction of Plane Concentration Distribution

The plane distribution of air pollutant concentration in the future was predicted using sources described in the previous section. The result is described below. The contribution concentration distribution by source is described in Section 4.1.1 in the Supporting Report.

(1) SO_2

Fig. 8.3.4 shows the result of predictions on SO_2 plane concentration distribution in the future. A concentration of 30 ppb or more is distributed in parts of Petaling Jaya, Shah Alam and around Port Klang. Areas exceeding the target value are shown in Fig. 11.15(1).

The maximum concentration of 65.8 ppb, which highly exceeds the target value (20 ppb), appears in the mesh index (54, 30) similarly to the present situation.

(2) NOx and NO_2

Fig. 8.3.5 shows the result of predictions on NOx plane concentration distribution in the future. A concentration of 200 ppb or more is distributed in parts of Kuala Lumpur, Petaling Jaya, and Shah Alam. Areas exceeding the target value are shown in Fig. 11.15(2).

The maximum concentration of 613.5 ppb appears in the mesh index (54, 33), similarly to the present situation. Fig. 8.3.6 shows the result of predictions on NO_2 plane concentration distribution in the future. A concentration of 30 ppb or more is distributed in parts of Kuala Lumpur, Petaling Jaya, and Shah Alam.

The maximum concentration of 63.1 ppb, which exceeds the target value, (37 ppb) appears in the mesh index (54, 33), similarly to the present situation.

(3) CO

Fig. 8.3.7 shows the result of predictions on CO plane concentration distribution in the future. The concentration of 7 ppm or more is distributed in a center area of Kuala Lumpur, and the maximum concentration of 10.5 ppm, which exceeds the target value (4 ppm), appears in the mesh index (59, 37), similarly to the present situation. Areas exceeding the target value are shown in Fig. 11.15(3).

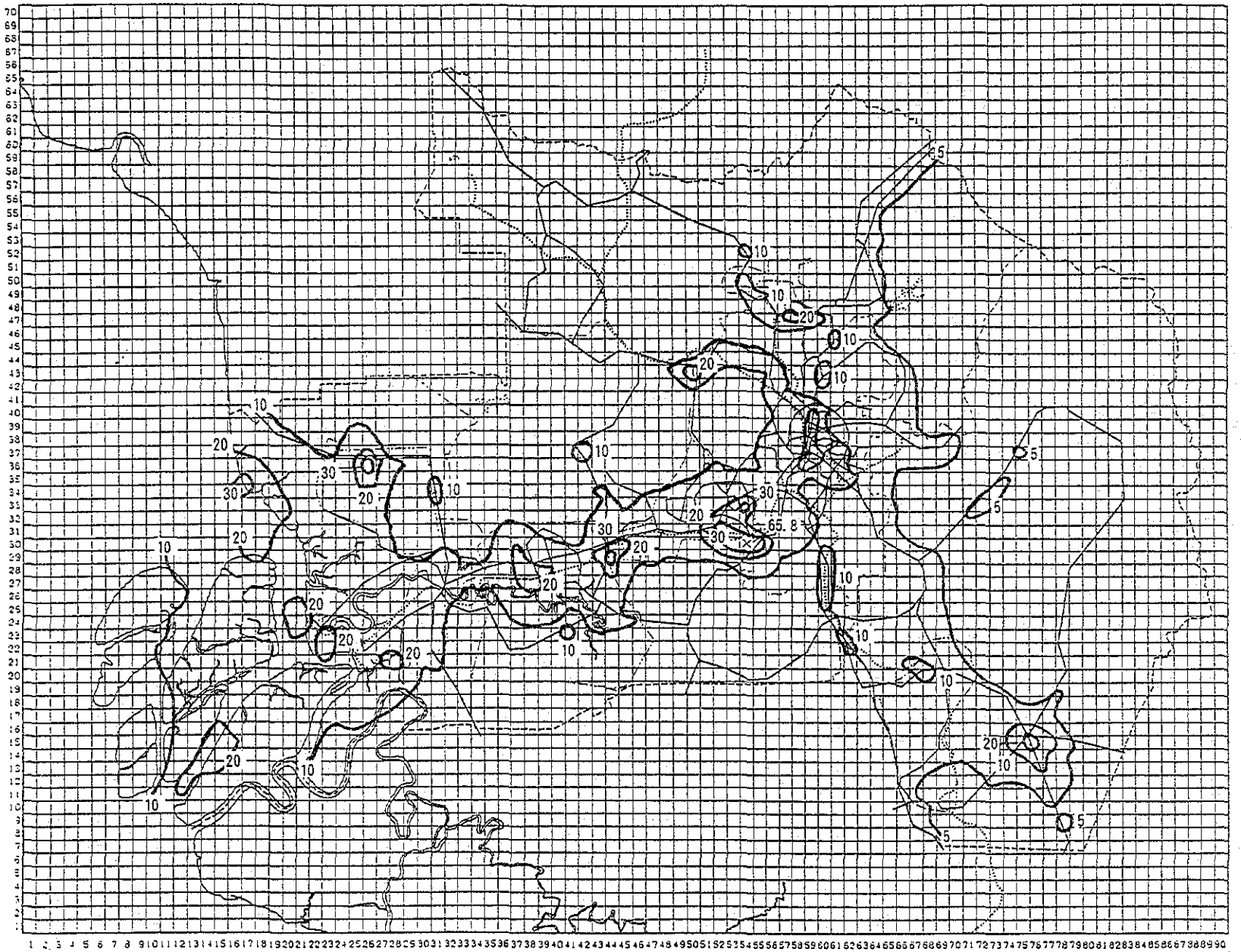


Fig. 8.3.4 Annual Average Concentration Isopleth for SO_2 (All Sources) (2005) (without control measures)

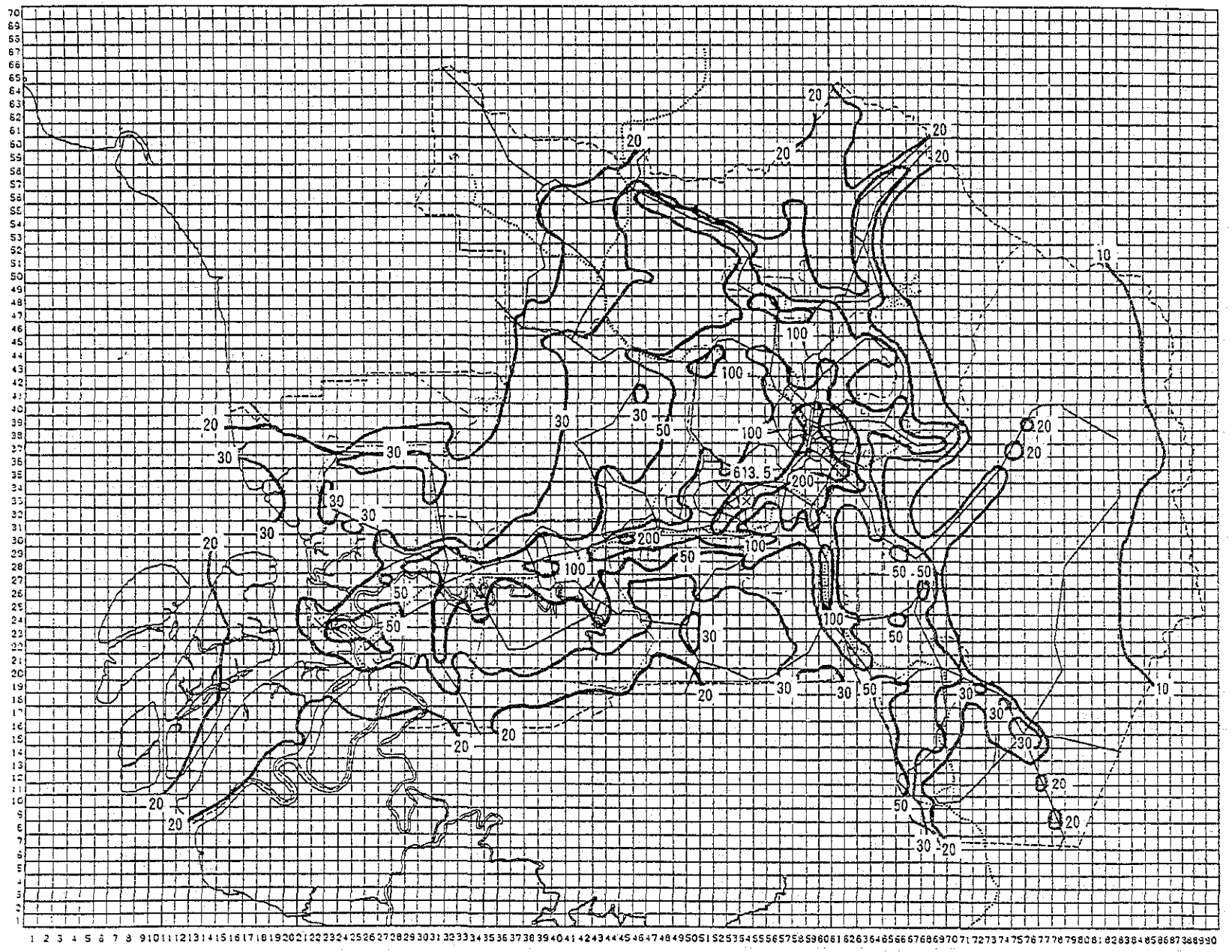


Fig. 8.3.5 Annual Average Concentration Isopleth for NOx (All Sources) (2005) (without control measures)

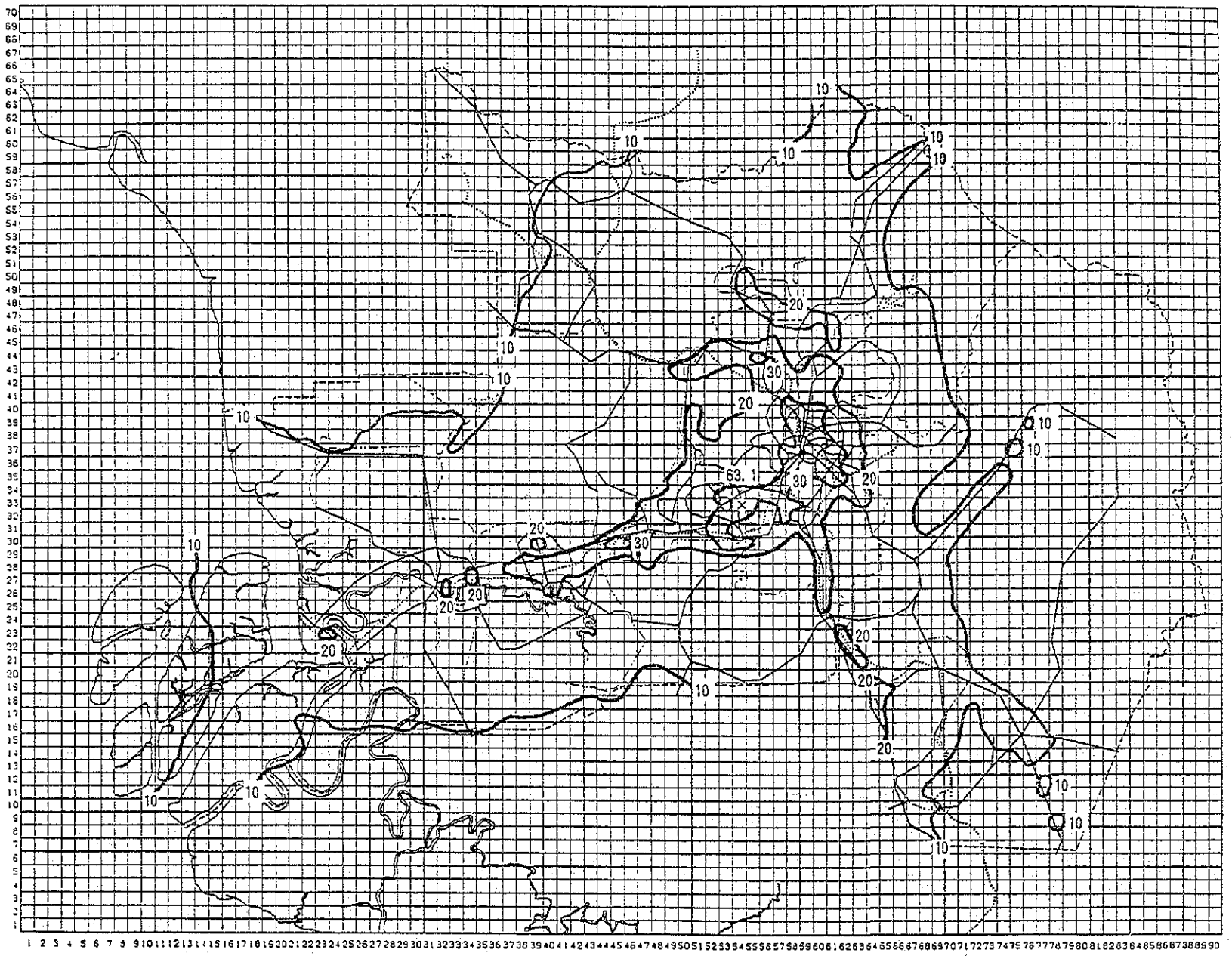


Fig. 8.3.6 Annual Average Concentration Isopleth for NO_2 (All Sources) (2005) (without control measures)

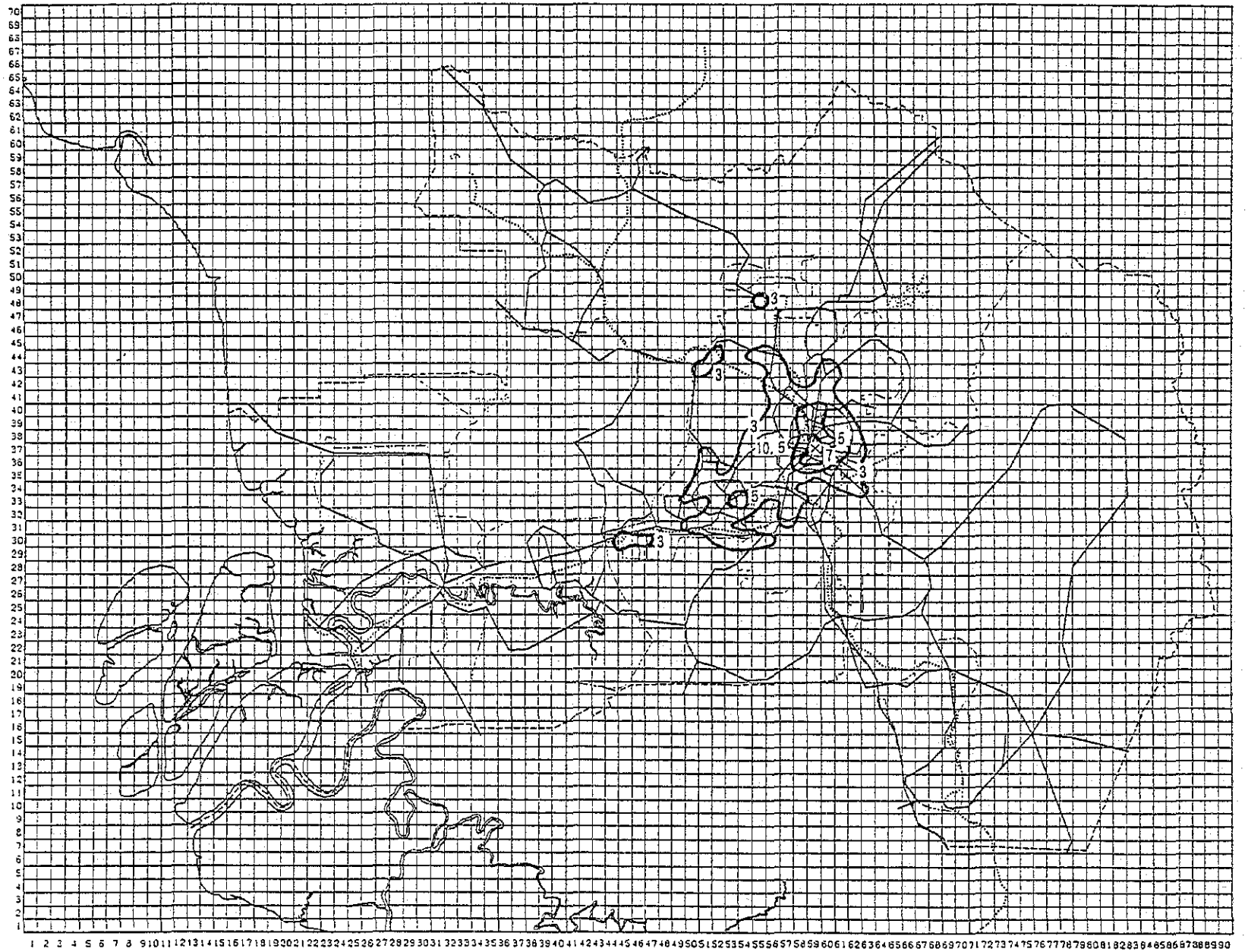


Fig. 8.3.7 Annual Average Concentration Isopleth for CO (All Sources) (2005) (without control measures)