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Air Quality
Emissions
Exposure
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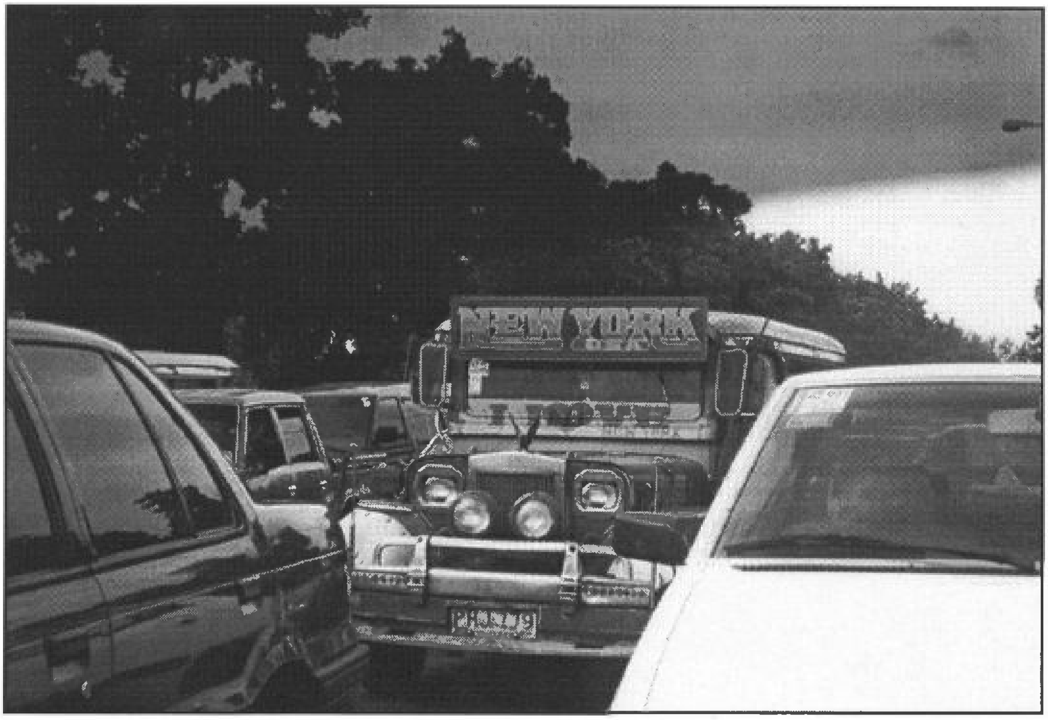
Abatement
Damage
Cost

Urban Air Quality Management Strategy in Asia



METRO MANILA City Specific Report

APPENDICES

Prepared under contract from
The World Bank
Asia Technical Division

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URBAIR

Urban Air Quality Management Strategy in Asia

METRO MANILA

Appendices

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Notice

This report from the URBAIR project conducted under the Metropolitan Environment Improvement Program of the World Bank, ASTEN Division, is the version produced by the project consultants (Norwegian Institute for Air Research and Institute for Environmental Studies in Amsterdam) for the World Bank. The World Bank publishes the official version of this report. The contents is basically the same, but the layout is somewhat different.

This present version of the report is distributed upon request, from NILU, until the official World Bank version is available. The two versions can be used interchangably, as they are basically identical.

Preface

In view of the potential environmental consequences of continuing growth of Asian metropolitan areas, the World Bank and UNDP launched the Metropolitan Environmental Improvement Program (MEIP) in five Asian metropolitan areas - Beijing, Bombay, Colombo, Jakarta, and Metro Manila. In 1993, Kathmandu joined the intercountry program as the sixth MEIP city. The mission of MEIP is to assist Asian urban areas in tackling their rapidly growing environmental problems. Presently, MEIP is supported by the governments of Australia, the Netherlands and Belgium.

Recognizing the growing severity caused by industrial expansion and increasing vehicle population, the World Bank started the Urban Air Quality Improvement (URBAIR) initiative in 1992 as a part of the MEIP. The first phase of URBAIR covered four cities - Bombay, Jakarta, Kathmandu, and Metro Manila. URBAIR is an international collaborative effort involving governments, academia, international organizations, NGOs, and the private sector. The main objective of URBAIR is to help local institutions in these cities to develop action plans which would be an integral part of their air quality management system (AQMS) for the metropolitan regions. The approach used to achieve this objective involves the assessment of air quality and environmental damage (e.g. on health, materials), the assessment of control options, and comparison of costs of damage and costs of control options (cost-benefit or cost-effectiveness analysis). From this, an action plan can be set up containing the selected abatement measures, for implementation within the short/medium/long term.

The preparation of this city-specific report for Metro Manila is based upon the collection of data and specific studies carried out by the local consultants, and upon workshops and fact-finding missions carried out in April and August 1993, and May 1994. The first draft of the report was prepared by Norwegian Institute for Air Research (NILU) and Instituut voor Milieuvraagstukken (IVM, Institute for Environmental Studies) before the first workshop, based upon general and city-specific information available from earlier studies. A second draft report was prepared before the second workshop, with substantial inputs from the local consultants, and with assessment of air quality, damage and control options, and cost analysis carried out by NILU and IES.

This report contains the appendices to the main report.

Acknowledgements are presented in the main report.

Contents

Appendix 1

Air Quality Status, Metro Manila

Contents

Page

Air Quality Status, Metro Manila

1. Description of past and present measurement programs

Stations and parameters

Air quality monitoring in Metro Manila was started in 1971 by the then National Water and Air Pollution Control Commission (NWAPCC). The NWAPCC established six monitoring stations, primarily traffic oriented, and used mechanized samplers for measuring oxidant (ozone), sulphur dioxide, nitrogen dioxide, carbon monoxide, suspended particulates and lead. Monitoring was conducted intermittently on a weekly basis, except at one station where sampling was done daily for an eight-hour period using a mobile and a stationary laboratory.

In 1974, the mechanized equipment was replaced by automatic instruments, also at six traffic oriented, stationary sites. Then, hourly concentrations of carbon monoxide, total hydrocarbons, nitric oxide, nitrogen dioxide, total oxidants, sulphur dioxide and suspended particulates were continuously recorded, along with such meteorological factors as temperature, humidity and wind speed and direction. In addition, a mechanized high-volume sampler was provided at four stations in order to determine the concentration of suspended particulates beyond the measuring range of the automatic dust analyzer. The mechanized high-volume samplers had been operated 24 hours daily but their use was discontinued due to maintenance problems.

By 1978, there was a need for spare electrical parts for the automatic instruments (NPCC, 1978). In 1981 the equipment manufacturer in Japan discontinued manufacturing the types of monitors used in Metro Manila, thus limiting the availability of spare parts. The lack of spare parts and high maintenance costs in the ensuing years forced the National Pollution Control Commission (NPCC) to stop monitoring NO_2, hydrocarbons, and oxidants, leaving only TSP, CO, and SO_2 as the parameters measured. The remaining equipment began to break down in 1983, and in 1984 the number of stations was reduced to three. All monitoring operations were shut down by the end of 1985.

A comparative study made on the automatic instrument and the high-volume sampler for particulate matter showed a significant relationship between the 24-hour average concentrations from the high-volume sampler and the automatic instruments with the high volume sampler giving about 2.6 times higher concentrations (Pecache, G.A., 1979). For other pollutants measured during that period, Dr. Lodge, in reviewing data for the Montgomery report, noted serious problems with the methodology and calibrations for all the pollutants measured with these systems.

DENR-NCR long term monitoring network

The DENR-NCR monitoring resumed again in 1986 using high volume samplers for TSP and manually operated bubblers for SO_2. The sites are variously exposed to road and industrial emissions. The location of the stations is shown in Figure 1, and a complete listing and description of the stations are presented in Table 1 and Table 2.

Both Dr. Mage, a WHO Adviser, and Dr. Lodge in the Montgomery Engineers study, pointed out the problems with the equipment and the operation of the monitoring system. Dr. Mage explained that the orifices for calibrating the high-volume samplers had not been recalibrated for over ten years, and that only two of the high volume samplers operating were flow controlled, i.e. equipped with controllers to maintain a constant flow rate even as the filters load up and become more resistant to airflow. The report (Environmental Management Bureau, 1990) stated that "...manual samplers had to be utilized for sulphur oxides and particulates through improvised monitors using materials from the discarded equipment. The lack of uniformity in the frequency and methods of collection and analysis have limited the amount of data which could be used to completely define the metropolis' air pollution problems".

A tour of several of the existing monitoring stations by project staff confirmed the above. The results of the visits to the monitoring sites indicated poor equipment conditions, and also, except for the Ermita site, inappropriate location to characterize the more severe air pollution conditions resulting from motor vehicle operation in Metro Manila.

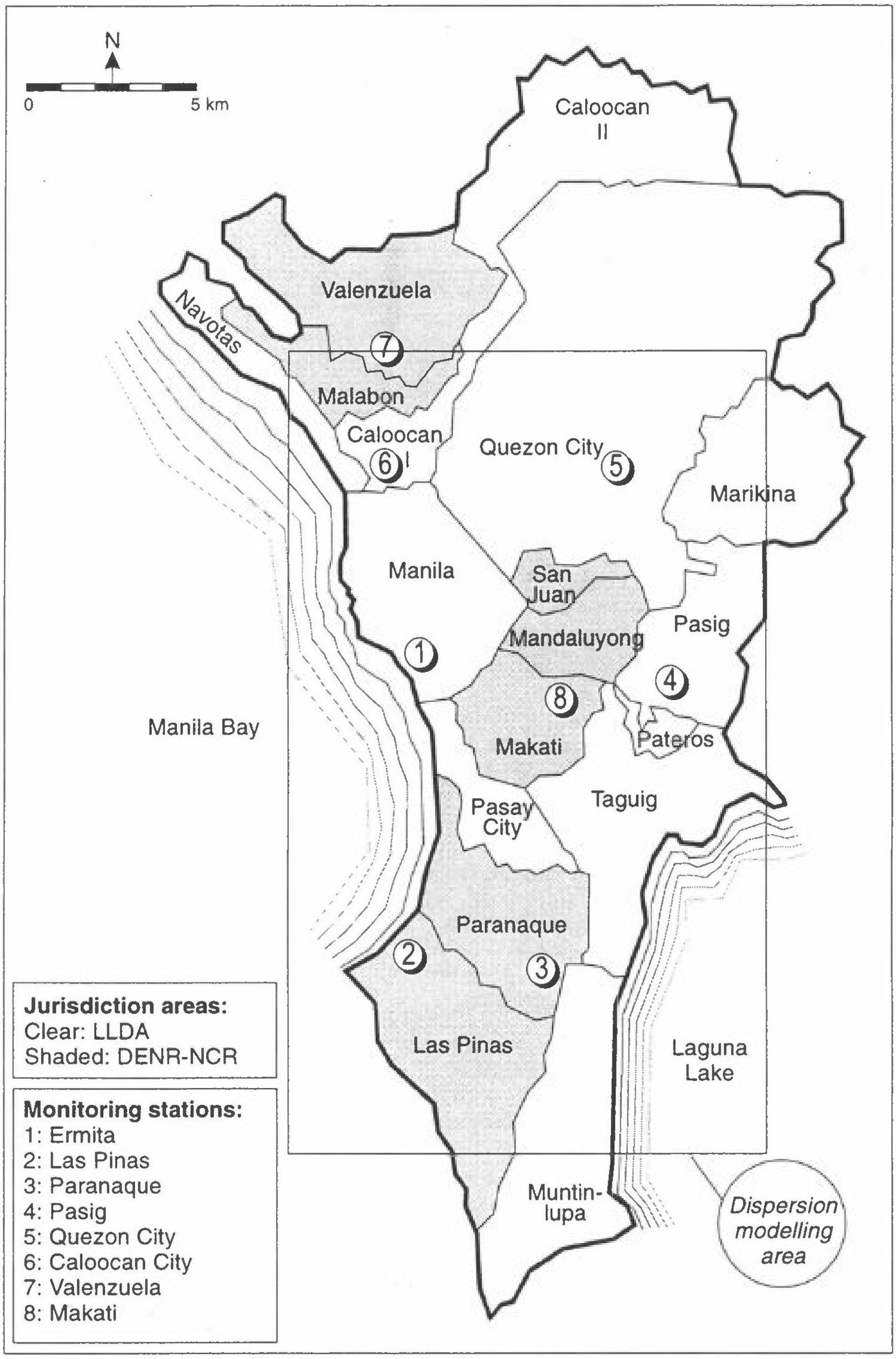

Figure 1: National Capital Region (NCR) of the Philippines.

- *Cities and Municipalities*
- *DENR-NCR and LLDA jurisdiction areas*
- *Monitoring stations*
- *Dispersion modelling area.*

Table 1: Description and classification of the DENR-NCR air quality monitoring network in Manila.

SITE OF SO_2 AND TSP MONITORING STATION				
Stations	Site	Classification of monitoring site	Approx. sampling height above the ground	Sampler
ERMITA	Taft Ave. cor. Pedro Gil St., Ermita, Mla.	Residential, Commercial, Institutional Area & Traffic Oriented	3.0 m	TSP/High-Volume and Midget Impinger/SO_2
LAS PINAS	Casimiro Village, Bo. Pamplona, Las Pinas, MM	Industrial and Residential area	3.0 m	TSP/High-Volume
PARANAQUE	Elorde Sports C.C., Sucat Rd. Paranaque	Industrial and Commercial area	3.5 m	TSP/High-Volume and Midget Impinger/SO_2
PASIG	Valle Verde Phase I Bo. Ugang, Pasig MM	Residential and Industrial Area	3.5 m	TSP/High-Volume and Midget Impinger/SO_2
QUEZON CITY	PAGASA Compund Science Garden, BIR Rd., Quezon City	Institutional Area	3.0 m	TSP/High-Volume and Midget Impinger/SO_2
NAVOTAS	Sampaquita St., Merville Subd. Navotas, MM	Residential Area	3.0 m	TSP/High-Volume
VALENZUELA	Valenzuela Mun. Hall Valenzuela, MM	Industrial and Commercial Area	3.5 m	TSP/High-Volume and Midget Impinger/SO_2
MAKATI:				
a. POBLACION	Palma St., Poblacion Makati, MM	Residential and Industrial Area	3.0 m	Midget Impinger/ SO_2
b. BEL AIR	Bel-Air Park Ph. III Makati, MM	Residential and Industrial Area	3.0 m	TSP/High-Volume and Midget Impinger/ SO_2
c. VIEJO	Gumamela St., Guadalupe Viejo, Makati, MM	Residential and Industrial Area	3.0 m	TSP/High-Volume and Midget Impinger/ SO_2

Table 2: Further DENR/NCR site description (Lesaca, 1994).

	Site description	Nearest road	
		Distance, m	Annual average daily traffic
ERMITA	The site has High Volume and SO_2 sampler, located at Taft Ave. cor. Pedro Gil, Ermita, Manila. It is a Residential, Commercial, Industrial and Traffic Oriented Area. It is on a main road. Other sources nearby: Manila Thermal Plant - 2 km north of station.	5	40 000-50 000
PARANAQUE	The site has High Volume and SO_2 sampler. It is located at Elorde Sports Complex Compound, Sucat Road, Paranaque, MM and it is an Industrial and Commercial Area. it is along a main road. Other sources nearby: Sucat Power Plant - 5 km west of station.	10	30 000-40 000
QUEZON CITY	The site has High Volume and SO_2 sampler, it is located at PAGASA Compound at Science government site (with government office around it) and classified as an industrial area. It is along a main road. No other nearby sources.	30	10 000-15 000
VALENZUELA	The site has High Volume and SO_2 sampler, it is located at the Valenzuela Municipal Hall, Valenzuela, Metro Manila. It is classified as an Industrial and Commercial Area. Nearby souces: Rubber Company - 1 km South East Many small lumber yards - 1 km radius around the station	50	40 000-50 000
MAKATI (Viejo)	The site has High Volume and SO_2 sampler. It is located at Gumamela St., Guadalupe, Viejo, Makati, Metro Manila. It is a Residential and Industrial Area. It is about ten (10) meters from the main road. Other nearby sources: Rockwell Power Plant - 2 km South.	5	<5 000
PASIG	The site has High Volume and SO_2 sampler. The station is located at Velle Verde Phase I, Bo, Ugong, Pasig, Metro Manila and is in a Residential and Industrial Area. About 5 meters from a main road. Other nearby sources: - FR cement (bagging operations) - 1 km east - Resins Inc. - 500 meters east - Union Ajinomoto - 1 km east - Union Glass co - 1 km east - Coca Cola Plant (CO_2) - 1½ km east - Phoenix Steel Co. - 5 km east	5	10 000-15 000
LAS PINAS	The site has a High-Volume and SO_2 sampler which is located at Casimiro Village, Barrio Pamplona, Las Pinas. It is an industrial and residential area. It is about 20 meters from the main road. No other nearby sources.	10	30 000-40 000

ADB/EMB 1991/92 monitoring network

During the Vehicle Emission Control Planning Project in Metro Manila funded by the Asian Development Bank (ADB) a more detailed air quality monitoring study was made in the period 1991-1992. This again was concerned mainly with potential pollution problems associated with vehicle emissions. This project set up five monitoring stations on major streets in Metro Manila. All five stations measured particulate matter and three included lead analyses. One station in Ermita monitored carbon monoxide and nitrogen dioxide continuously. For a short period total oxidants, sulphur dioxide and hydrocarbons were measured. Another station monitored carbon monoxide and nitrogen oxides continuously for a two-month period. This monitoring equipment remains at the Ermita station but is not used except for the carbon monoxide equipment.

This monitoring programme used equipment that would be regarded as "state of the art" for air quality monitoring programmes undertaken in the UK. The equipment types used are summarized in Table 3.

Table 3: Air Quality Monitoring Equipment used for the 1991-1992 survey.

POLLUTANT	EQUIPMENT TYPE
Nitrogen Dioxide	Chemiluminescent Detector
Carbon Monoxide	Non-dispersive Infrared
Hydrocarbons	Flame Ionisation Detector
Particulates (PM_{10})	Beta Radiation Gauge
Lead and TSP	High Volume Sampler

The ADB 1991/92 project team in conjunction with the Environmental Management Bureau and the DENR/NCR staff selected five monitoring sites. Selection criteria included location on major thoroughfares, a geographic distribution and availability of public buildings for actual monitor placement. The following describes these stations and their locations:

Ermita. The project team refurbished the existing DENR/NCR monitoring station on Taft Avenue corner Pedro Gil Street and measured nitrogen oxides and carbon monoxide continuously from August 1991 through December 1991. These monitors were moved to the DENR/NCR office location on Quezon Avenue for the months of January and February, 1992, and were then returned to Ermita. The Ermita station measured total suspended particulate matter and PM_{10} (particulate matter 50 per cent of which has a mass diameter of ten microns or less) on a once-every-three-day basis from August, 1991, until the end of the project sampling period in early March, 1992. There was also measured sulphur dioxide using wet chemistry methods. This station was equipped with a meteorological station measuring wind speed, direction, and air temperature throughout the project period. The Ermita station represented a busy intersection with slow traffic of all types of vehicles.

Asian Development Bank (EDSA). This station started operation in early August 1991, and continued operation through the remaining project monitoring period. It monitored PM_{10} and TSP, and also the meteorological parameters of wind speed, wind direction, and temperature. This station represented an area of high bus and truck traffic near a busy intersection on a major beltway thoroughfare of Metro Manila. The actual sampler was located near the tennis court on Asian Development Bank property along EDSA.

In addition, an Air Quality Index Display Board has been installed on the centre island of EDSA to characterize suspended particulate air quality levels as "good", "fair", or "unhealthful". The PM_{10} sensor, a Horiba Model APDA-350E "beta" instrument located on the ADB property, was designed to send air quality indicator data to the display board receiver by remote control every half hour for display to the public.

Quezon Avenue. At this site PM_{10} was monitored; the monitor was located on a second floor ledge of a government office almost directly across the street from the DENR/NCR office on Quezon Avenue. This site started operation in October, 1991, and continued throughout the project sampling period. Quezon Avenue is an extremely busy street, heavily traversed by Jeepneys. Traffic moves relatively slow in the area of the monitor, and traffic frequently gets tied up at traffic signals. Because the monitor was located on a ledge, there was some concern that it was too sheltered from the street.

Manila Central University Hospital. At this site, located on EDSA near the Monumento Intersection, both PM_{10} and TSP were monitored. The monitor location represented an area of heavy bus and jeepney traffic, and it also is an area of many pedestrians. Numerous pedestrians wait for buses or jeepneys in the area, go to or from the Light Rail Transit station, and use the major shopping areas there.

Start-up of the **San Lorenzo Village** station was delayed due to difficulty in siting: this station therefore operated only for two months of the project sampling period. At this station PM_{10} was monitored on a once-every-three-day basis.

There was also a delay in siting the **Monumento/MCU** station. This station operated only the last month of the project period, with equipment measuring PM_{10} and TSP on a once-every-three-day basis with lead analyses of alternate day TSP filters.

The 1991/92 project sampling station locations and parameters measured are shown in Figure 2.

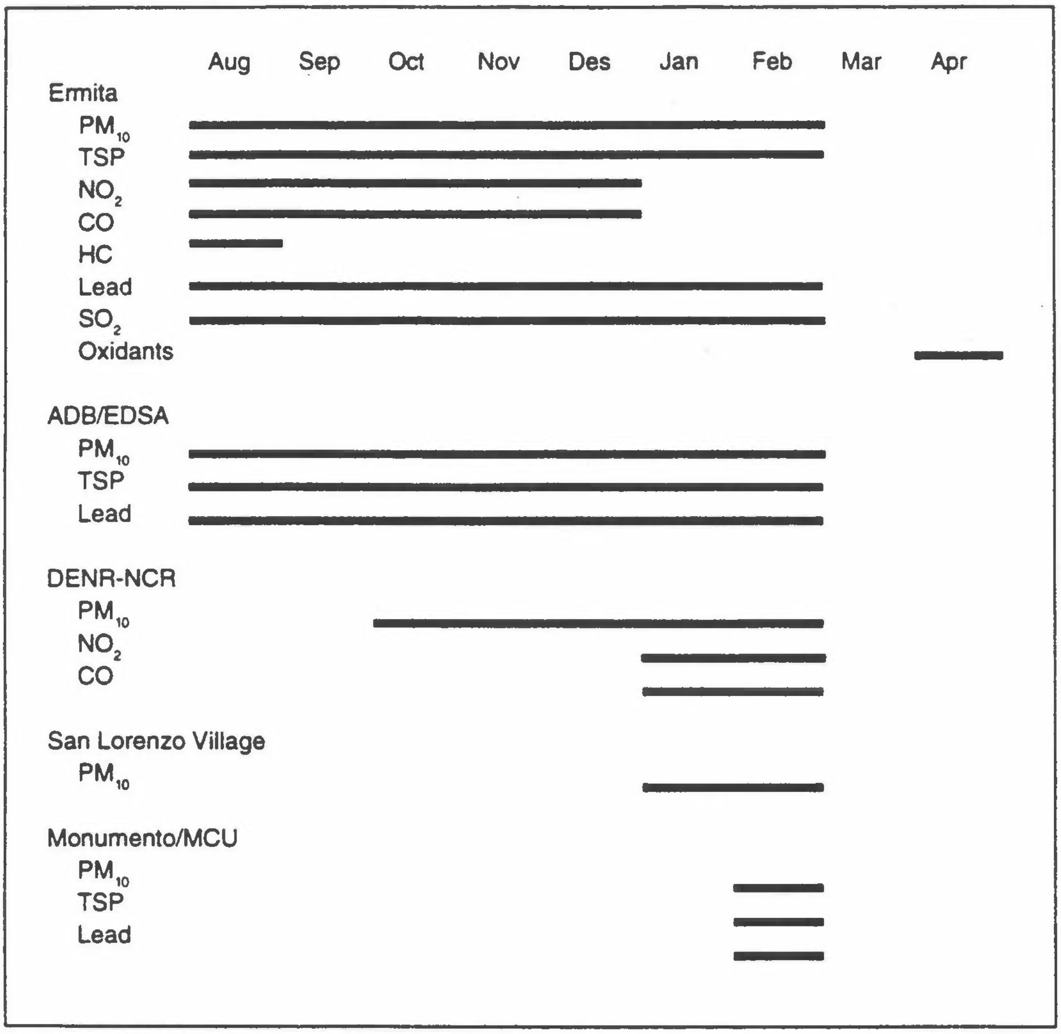

Figure 2: Project Sampling Station Locations and Parameters Measured by Months at Each Location (1991/92).

2. Analysis of measurements

Long term monitoring network

At the DENR-NCR monitoring network in Metro Manila 24-hour samples of TSP and SO_2 are taken. According to the EMB/DENR 1991 data report, the number of samples per month and station varied from 0 to 10. The number of 24-hour samples for the year 1991 varied from 20 (Las Piñas) to 79 (Navotas).

ADB/EMB 1991/1992 monitoring network

This network is described earlier in Figure 2. PM_{10} and TSP were measured on an every third day basis, providing TSP filters for lead analyses on a once every 6 days basis. Nitrogen oxides, carbon monoxide and SO_2 were measured continuously. Total oxidants were sampled continuously at one of the stations for only three days near the end of the overall project period.

Data presented in this report

As several reports have pointed out poor equipment conditions, only recent data (1988-1992) are presented in this report to characterize the over all air pollution situation in Manila.

Total suspended particles (TSP) and PM_{10}

Annual arithmetic averages of total suspended particles in Metro Manila from the DENR-NCR network are shown in Figure 3 (1992) and in Figure 4 (1990-1992). The maximum 24-hour concentrations for the same periods are given in Figure 5 (1992) and in Figure 6 (1990-1992).

In the DENR-NCR network, only the Ermita station represents a high traffic area. Ermita represents an area of a busy intersection with slow traffic of all types of vehicles.

The new Philippine air quality standards for TSP were exceeded at all stations except for the 24-hour maximum value at Navotas in 1992. At the Valenzuela station the annual average values for the years 1989, 1990, 1991 and 1992 were almost 3 times the standard, and the maximum 24-hour value in 1992 was twice the standard.

Figure 7 shows the observed 24-hour TSP concentrations at selected stations for the years 1991 and 1992. Even though very high concentrations are measured throughout the year, there is a tendency for a higher frequency of lower concentrations during the rainy season.

Figure 8 shows the air quality TSP trend for the period 1988-1992 for the stations Ermita, Las Pinas, Paranaque, Pasig, Quezon City and Valenzuela. Except for the Paranaque station, which shows slightly increased annual average values, the TSP levels seem fairly constant at all stations. The levels are well above the new Philippine national ambient air quality guideline. At the Pasig station the maximum 24-hour TSP concentrations have decreased during the last years, but the annual average value has changed very little.

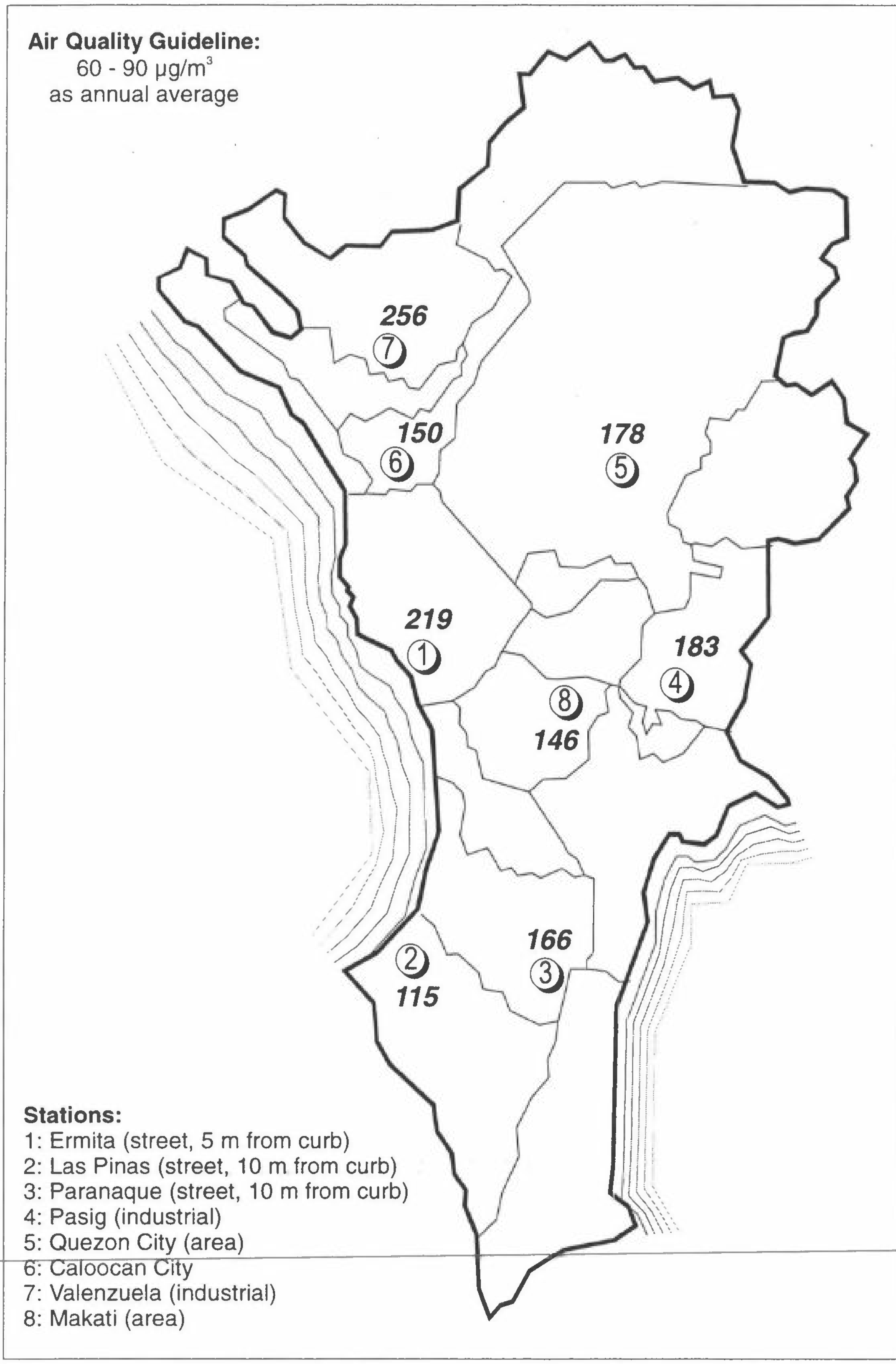

Figure 3: Mean annual TSP concentrations for the year 1992 (µg/m³).

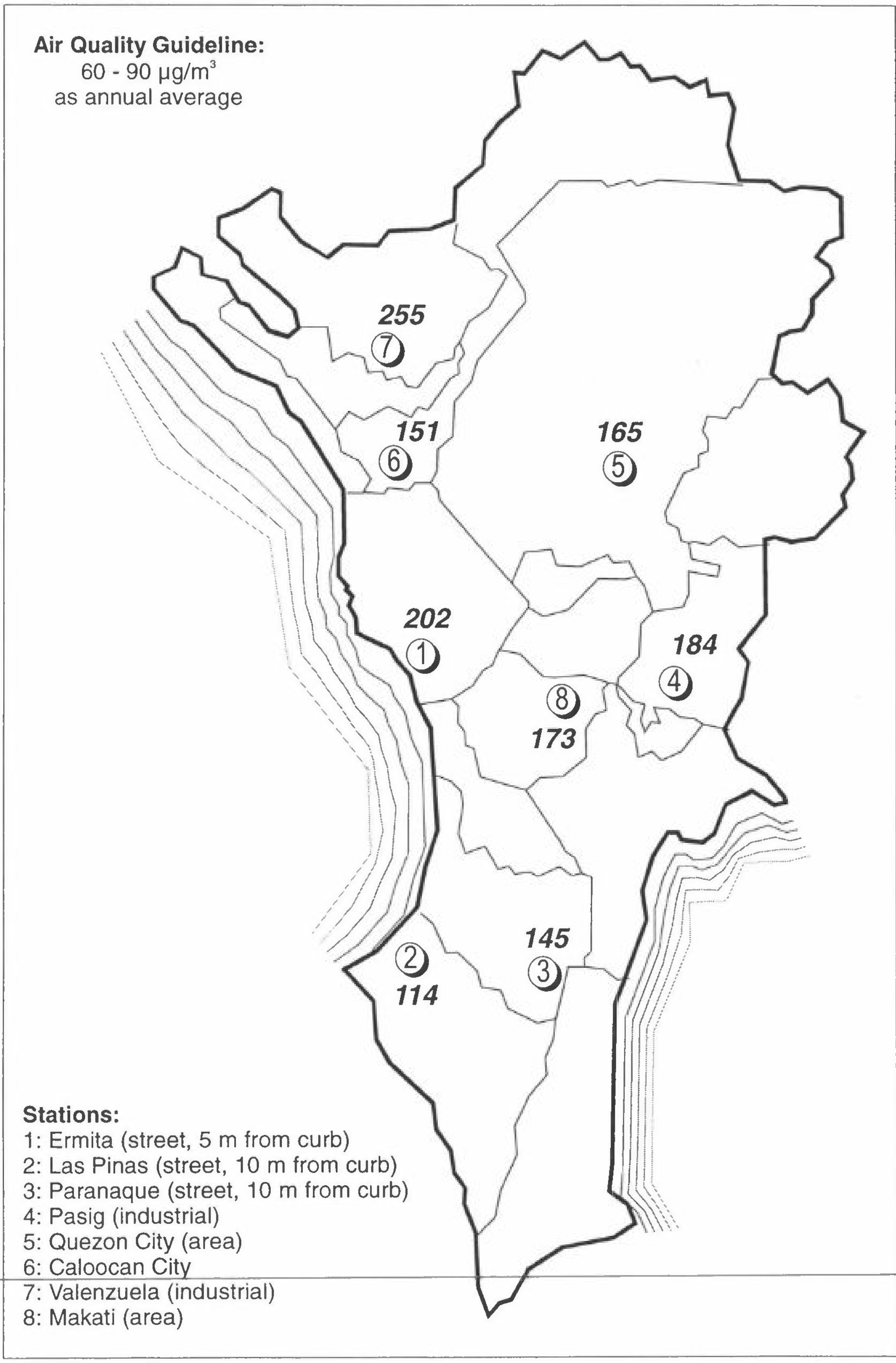

Figure 4: Mean annual TSP concentrations for the three-year period 1990-1992 ($\mu g/m^3$).

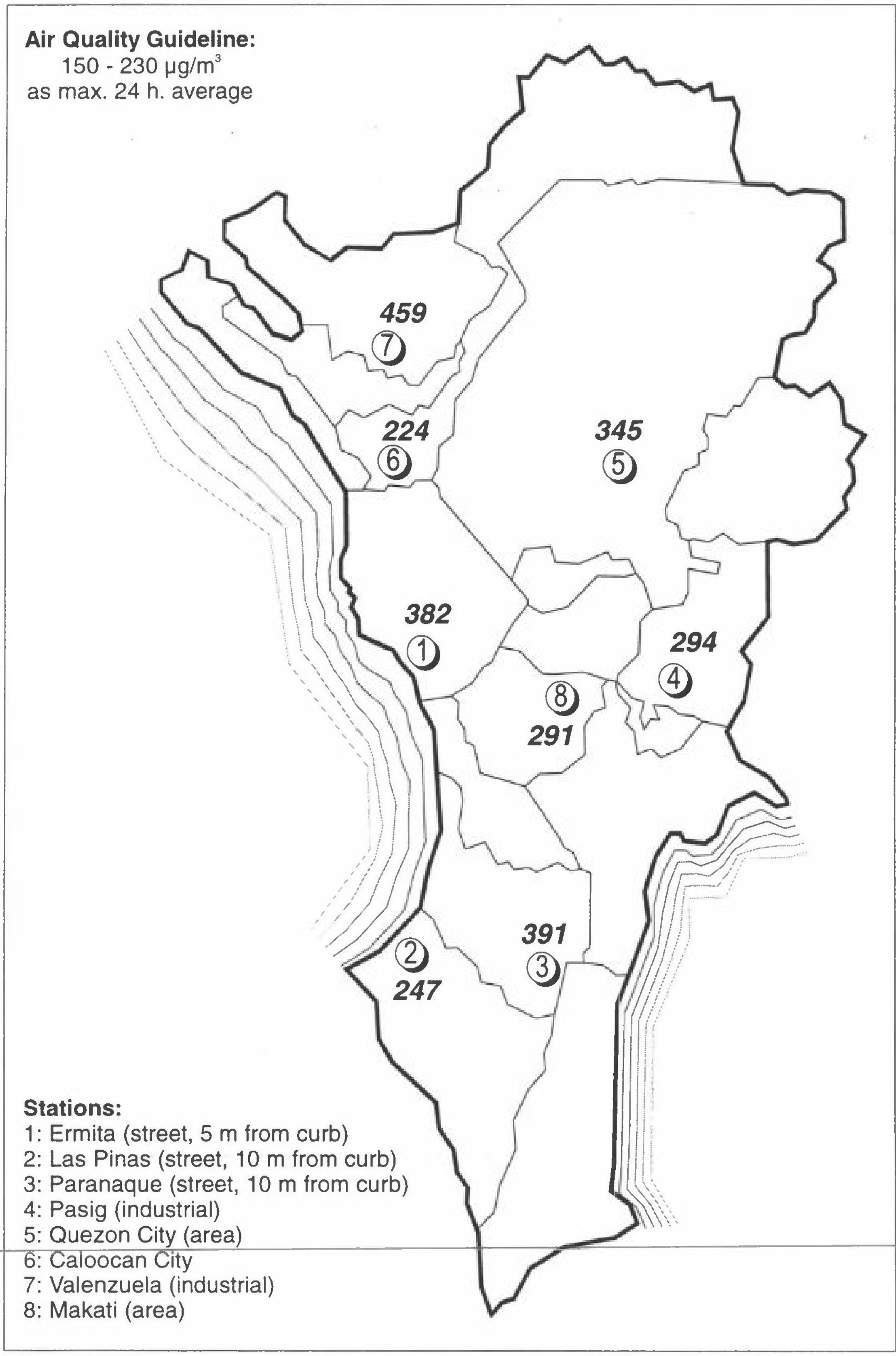

Figure 5: Maximum 24-hour TSP concentrations for the year 1992 (µg/m³).

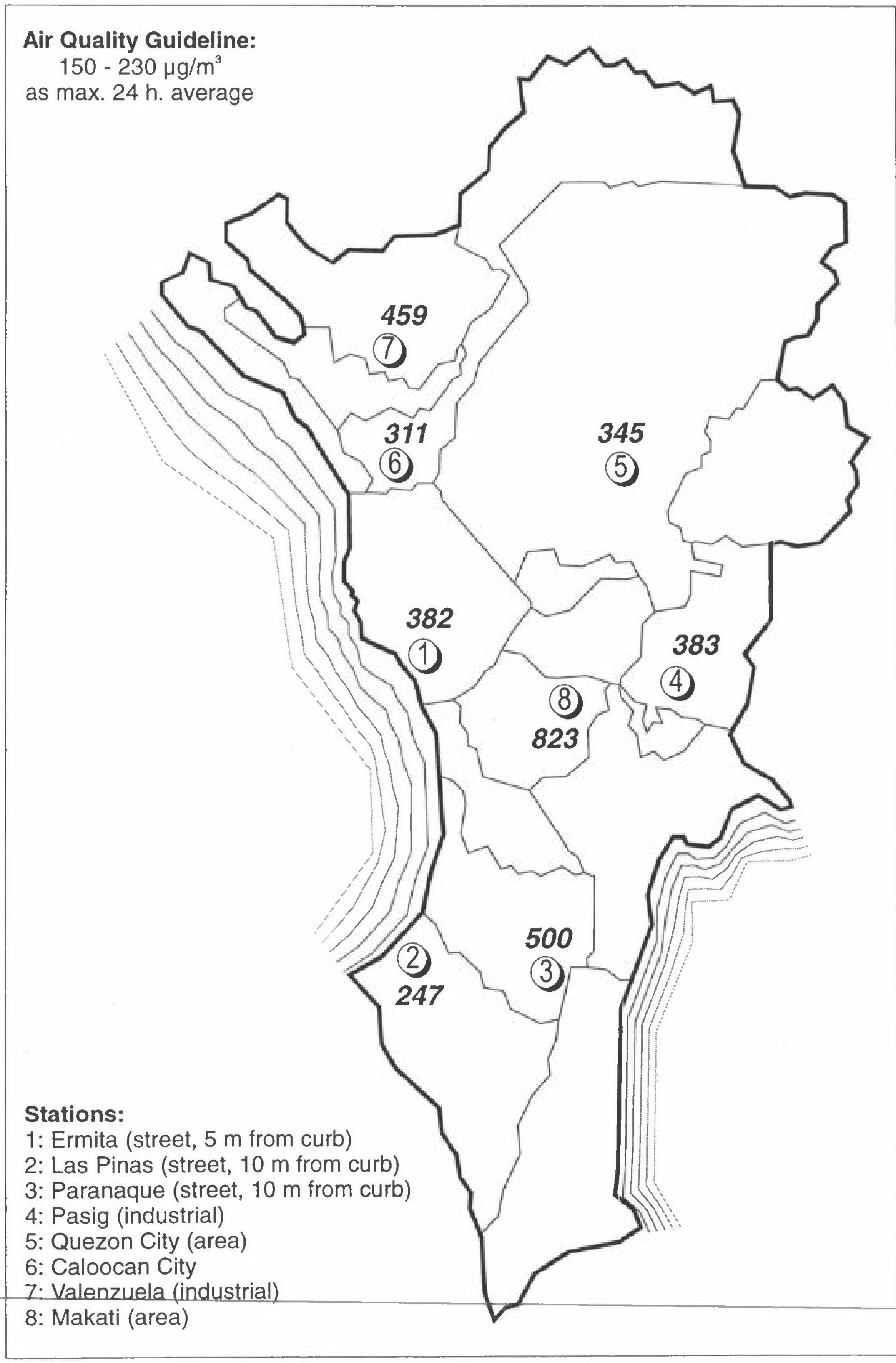

Figure 6: Maximum 24-hour TSP concentrations during the years 1990-1992 (µg/m3).

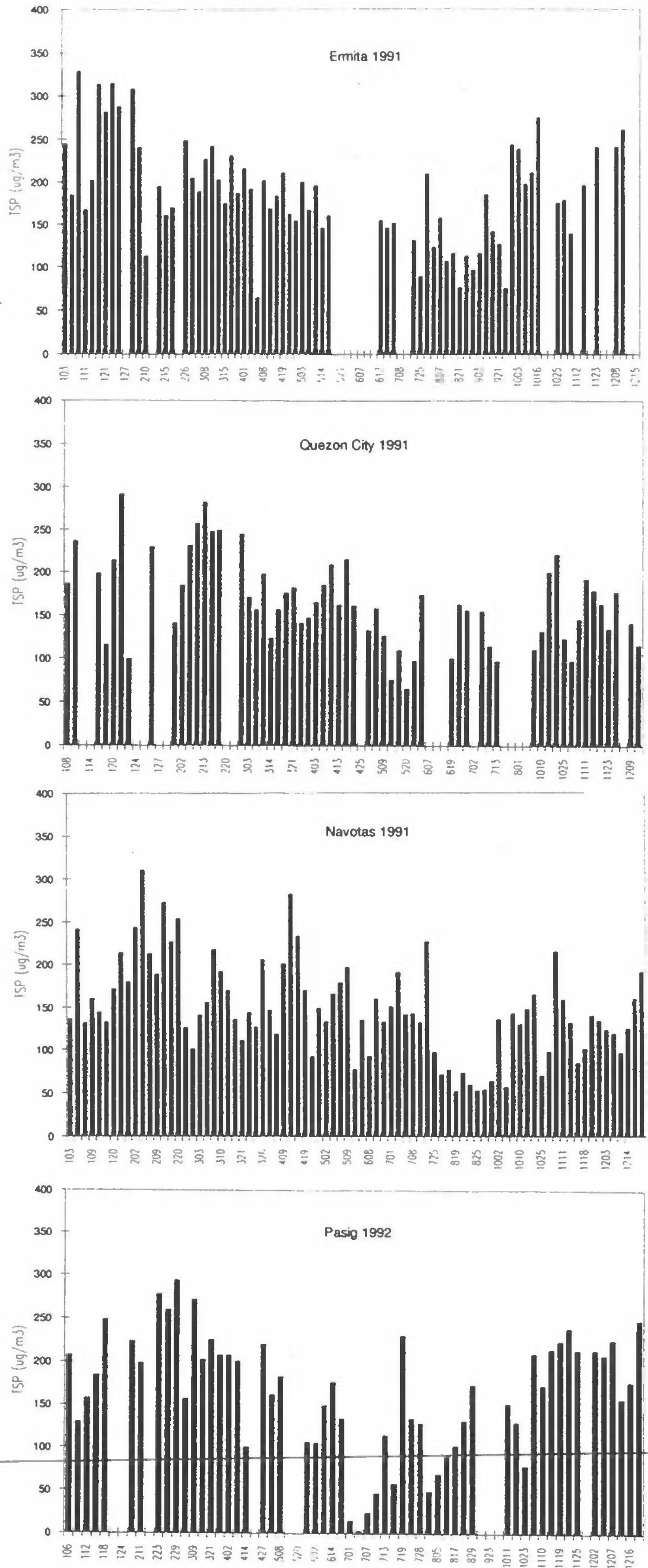

Figure 7: 24-hour TSP concentrations given by month and day for Ermita (1991), Quezon city (1991), Navotas (1991), and Pasig (1992) (µg/m³).

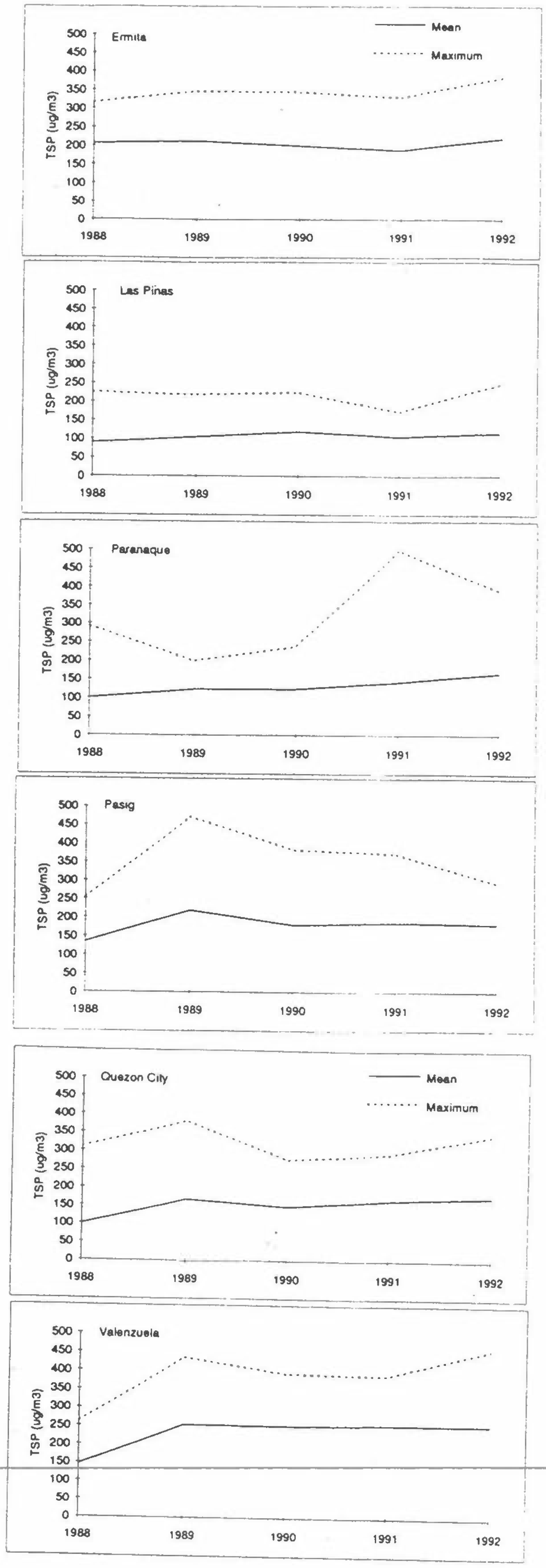

Figure 8: Annual average values and maximum 24-hour TSP concentrations for the years 1988-1992 at 6 stations (μg/m³).

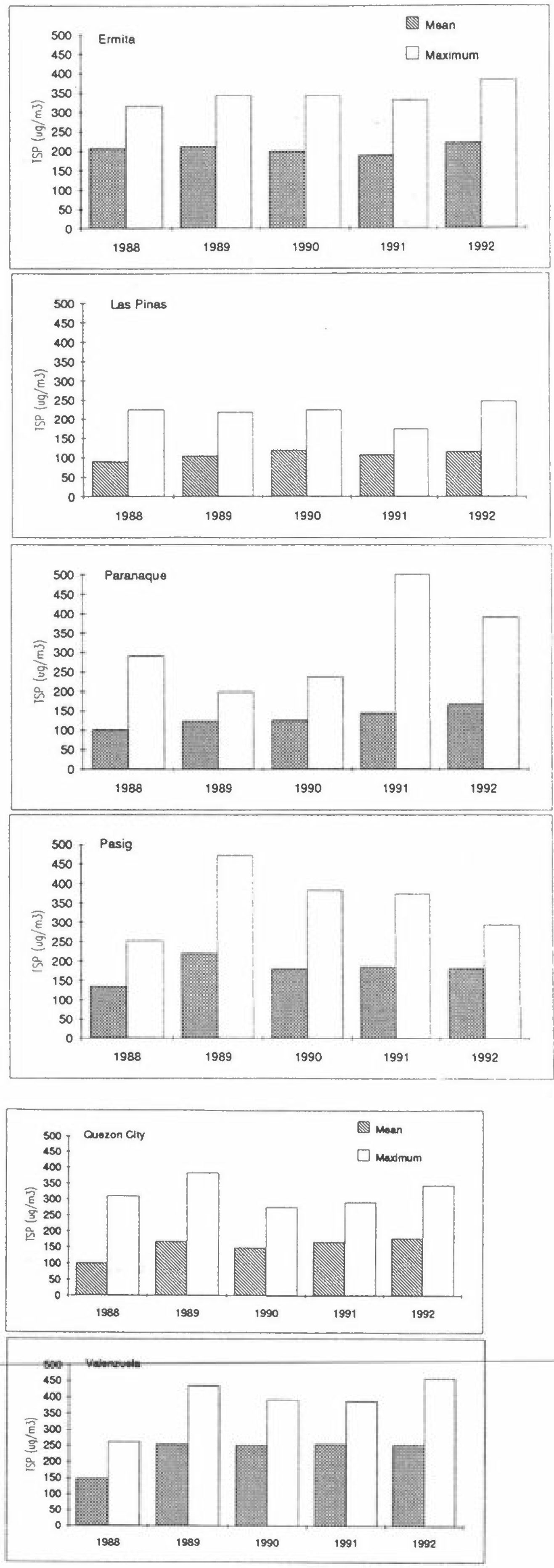

Figure 8: cont.

TSP data from the 1991/92 ADB/EMB project are shown in Table 4. The Ermita station is the same as in the DENR-NCR network, but new measuring equipment was put in. The measurements in the period August 1991-February 1992 showed an annual geometric average of 260 μg/m³, a maximum 24-hour value of 549 μg/m³ and a minimum 24-hour value of 79 μg/m³.

Table 4: TSP concentrations from the 1991/92 ADB/EMB project (μg/m3) (24-hour sampling).

Station	Measurement period	Arithmetric mean value	Geometric mean value	Maximum 24-hour value	Minimum 24-hour value	Number of observations
Ermita	Aug 91-feb 92	256	260	549	79	49
ADB	Aug 91-feb 92	497	480	843	213	47
Monumento	Feb 92	400	413	489	244	5

At the ADB station which represents an area of high bus and truck traffic near a busy intersection on a major highway through Metro Manila, the TSP concentrations were well above the Ermita station level. The geometric mean value was 480 μg/m³ (more than 5 times the standard) and the maximum 24-hour value was 843 μg/m³ (3-4 times the standard).

In the ADB/EMB project also PM_{10} was measured. Results from 5 stations are shown in Table 5. PM_{10} is the mass of particles with diameter less than 10 μm and has direct relevance to possible health effects of particles in the air.

Table 5: PM_{10} concentrations from the 1991/92 ADB/EMB project (μg/m³) (24-hour sampling).

Station	Measurement period	Arithmetric mean value	Geometric mean value	Maximum 24-hour value	Minimum 24-hour value	Number of observations
Ermita	Aug 91-feb 92	144	143	258	54	62
ADB	Aug 91-feb 92	219	212	321	139	47
DENR-NCR	Oct 91-feb 92	227	221	321	142	26
San Lorenzo Village	Jan 92-feb 92	179	185	206	135	10
Monumento	Feb 92	198	201	241	150	5

The results show that the Philippine national ambient air quality guidelines of 60 μg/m³ as an annual geometric mean value and 150 μg/m³ as a 98 percentile 24-hour value were clearly exceeded at all five stations. All of them represent areas with high traffic intensity.

Data from the Ermita, ADB and Monumento stations show that the TSP levels are about twice the PM_{10} levels. This means that about 50% of the particle mass have a diameter above 10 μm.

Lead

In the 1991/92 ADB/EMB project, TSP filters were also analyzed for lead. The results are given in Table 6. The mean values ranged from 1 µg/m3 at the Monumento station to 2.3 µg/m3 at the ADB station. The Philippine national ambient air quality guidelines are 1.5 µg/m3 as a 3-month mean value and 1 µg/m3 as a yearly mean value. These guidelines may be exceeded at all stations, and the ambient concentrations seem to be well above the WHO guideline for 1 year which is 0.5-1 µg/m3.

Table 6: Lead concentrations from the 1991/92 ADB/EMB project (µg/m3) (24-hour TSP-sampling).

Station	Measurement period	Arithmetic mean value	Maximum 24-hour value	Minimum 24-hour value	Number of observations
Ermita	Aug 91-feb 92	1,07	2,18	0,10	36
ADB	Aug 91-feb 92	2,30	5,45	0,44	34
Monumento	Feb 92	1,00	1,44	0,65	4

There are also some lead data available for major thoroughfares in metropolitan Manila for the year 1987 (or may be 1988). Annual arithmetic mean values ranged from 0.26 at the Pasig station to 4.35 µg/m3 at the Valenzuela station. At the Ermita station the annual lead concentration was 0.63 µg/m3 which is well below the 1991/92 value of 1.07 µg/m3.

Sulphur dioxide (SO_2)

Annual arithmetric averages of SO_2 in Metro Manila from the DENR-NCR network are shown in Figure 9 (1992) and in Figure 10 (1990-1992). The maximum 24-hour concentrations for the same periods are given in Figure 11 (1992) and in Figure 12 (1990-1992).

In 1992 the highest values were measured at the Ermita station with an annual average of 0.013 ppm (about 35 µg/m3) and 24-hour maximum value of 0.091 ppm (about 240 µg/m3).

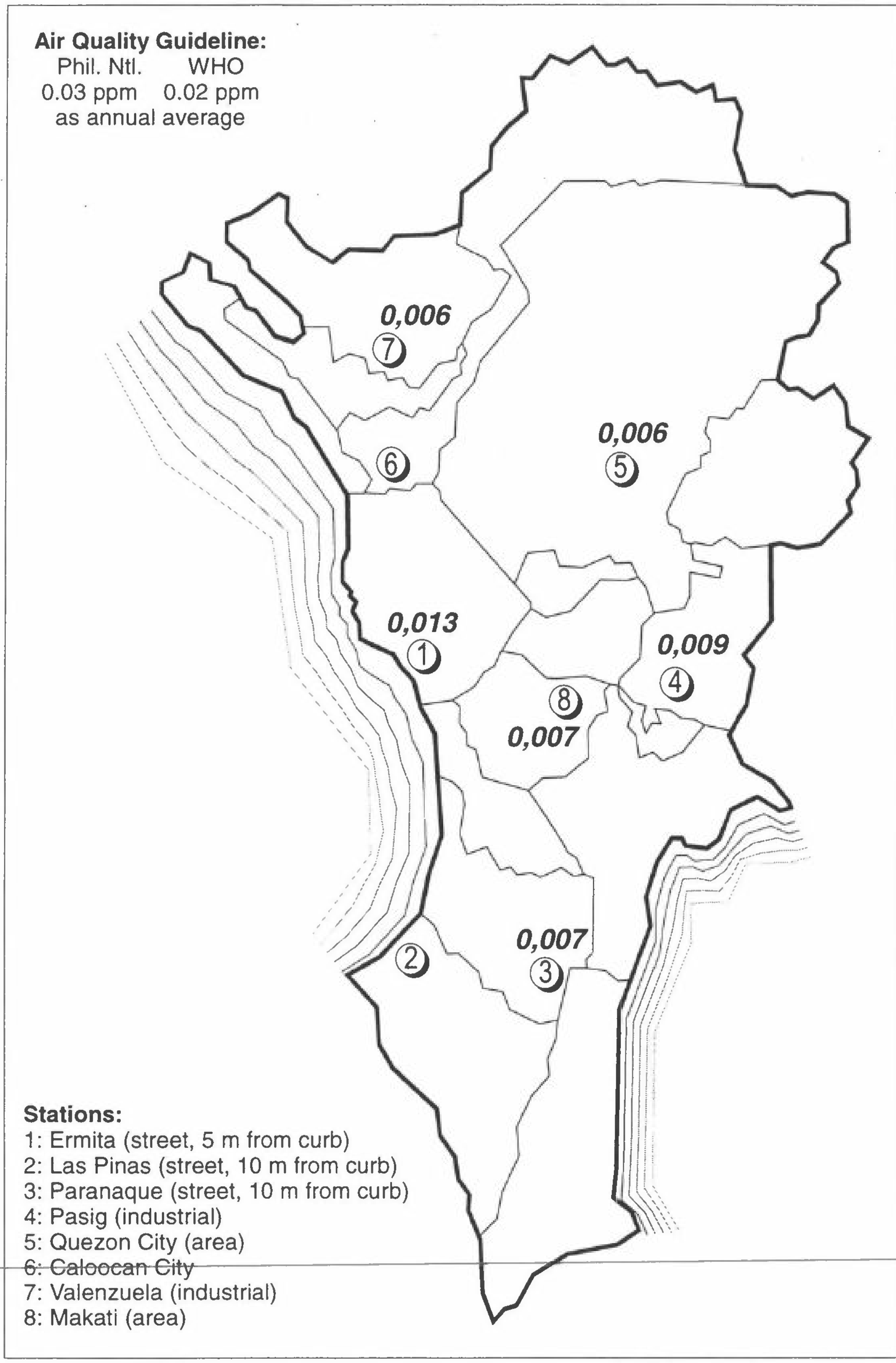

Figure 9: Mean annual SO_2 concentrations for the year 1992 (ppm).

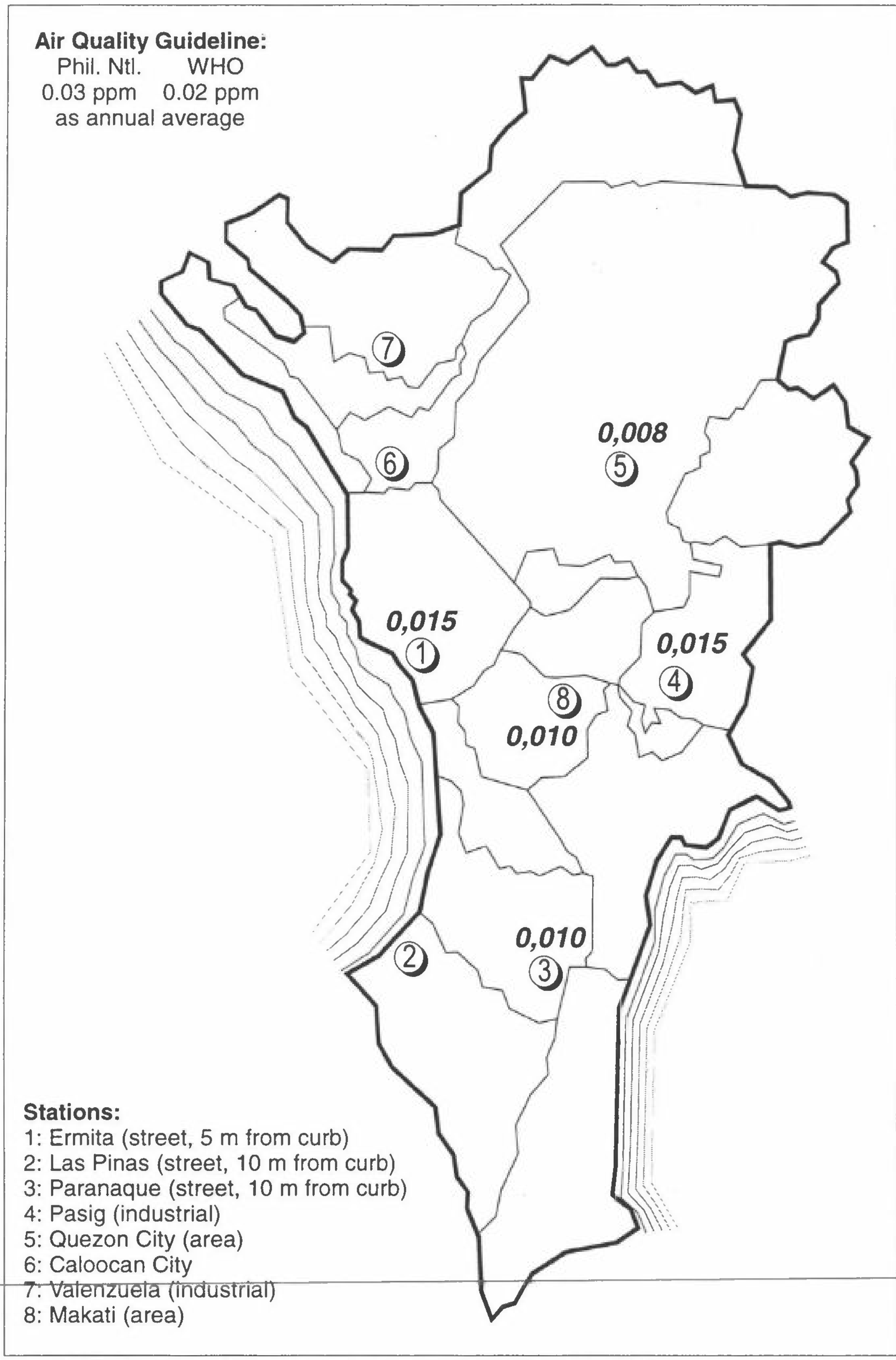

Figure 10: Mean annual SO_2 concentrations for the three-year period 1990-1992 (ppm).

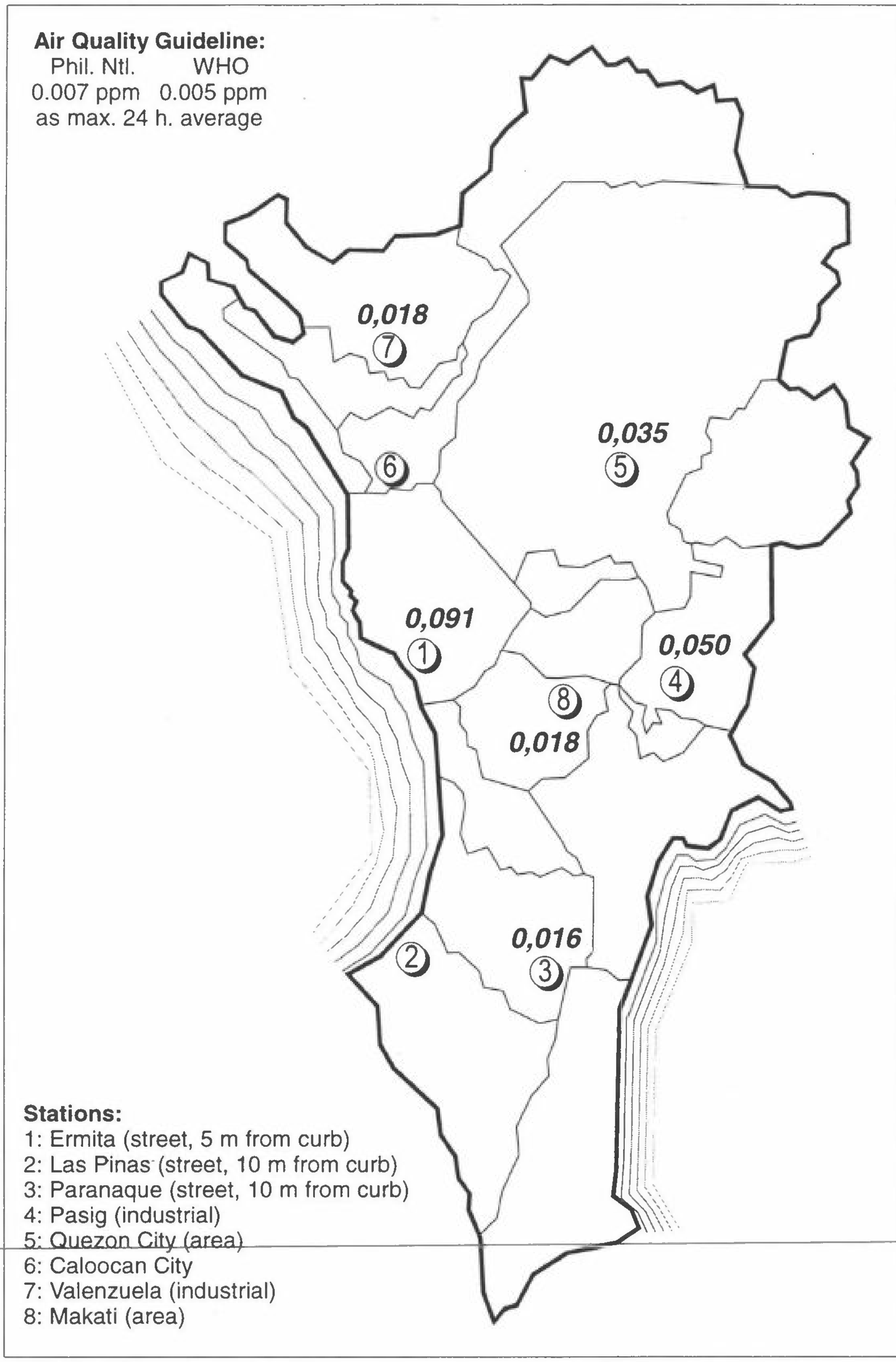

Figure 11: Maximum 24-hour SO_2 concentrations for the year 1992 (ppm).

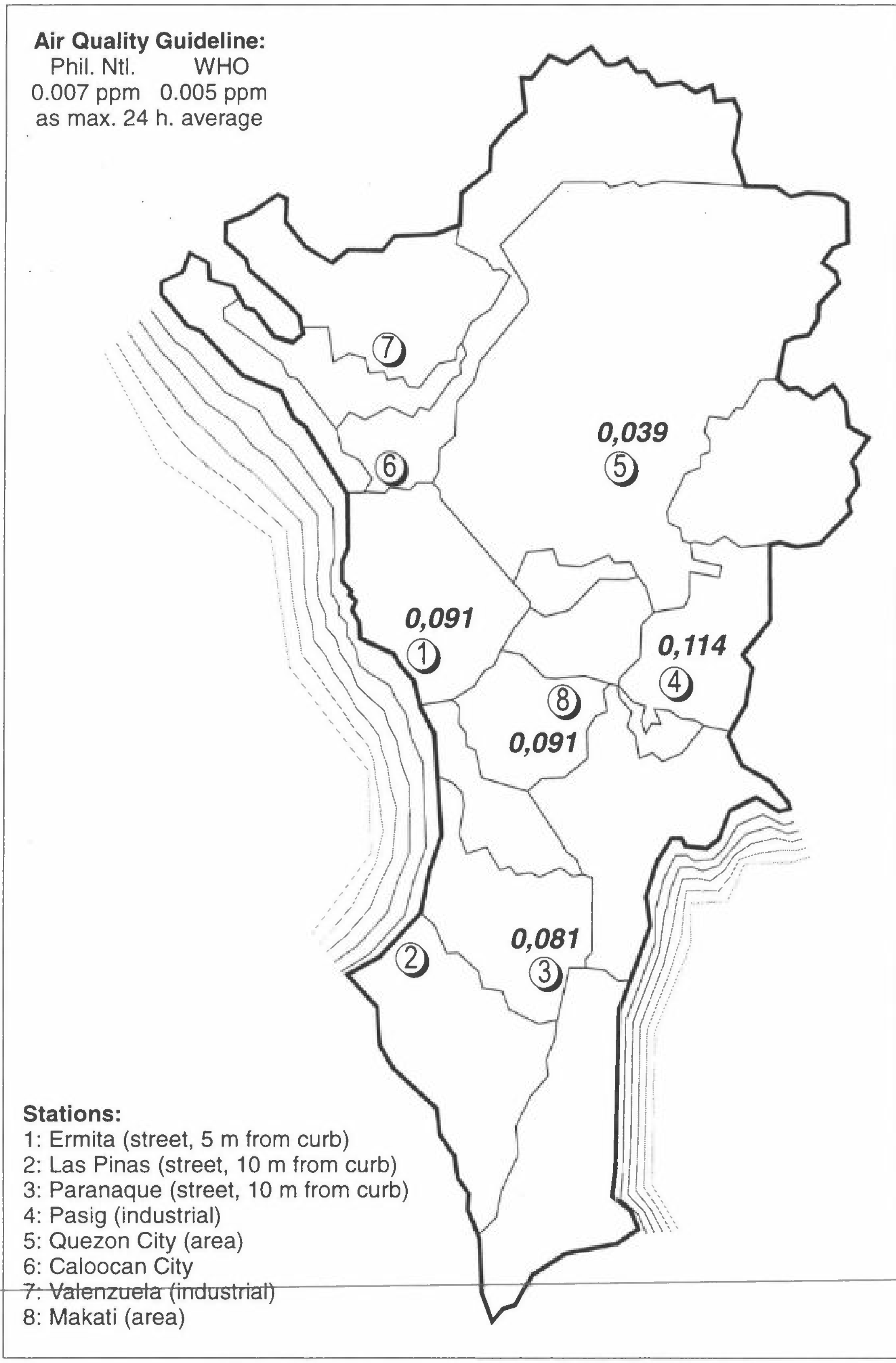

Figure 12: Maximum 24-hour SO_2 concentrations during the years 1990-1992 (ppm).

The maximum 24-hour value at the Ermita station in 1992 was above the Philippine national ambient air quality guideline of 180 $\mu g/m^3$ and well above the WHO standard of 125 $\mu g/m^3$. The annual mean value was below the Philippine and WHO standards.

Figure 13 shows observed 24-hour SO_2 concentrations from selected stations for the years 1991 and 1992. Most of the 24-hour SO_2 concentrations at the Quezon City and Makati stations were very low (below 0.02 ppm). During the months of June, July and August 1992, much higher concentrations were observed at the Ermita station suggesting the influence of a strong source not far away, may be the power station.

Figure 14 shows the SO_2 air quality trend at the stations Ermita, Paranaque, Pasig and Quezon City in the period 1988-1992. The annual average values are well below the new Philippine ambient air quality guideline of 0.003 ppm (80 $\mu g/m^3$), and the measurements show slightly decreased values the last years. The 24-hour guideline of 0.08 ppm (150 $\mu g/m^3$) was exceeded at the Ermita and Pasig stations during the 1988-1992 period, but the 1992 maximum value at the Pasig station was well below the guideline value.

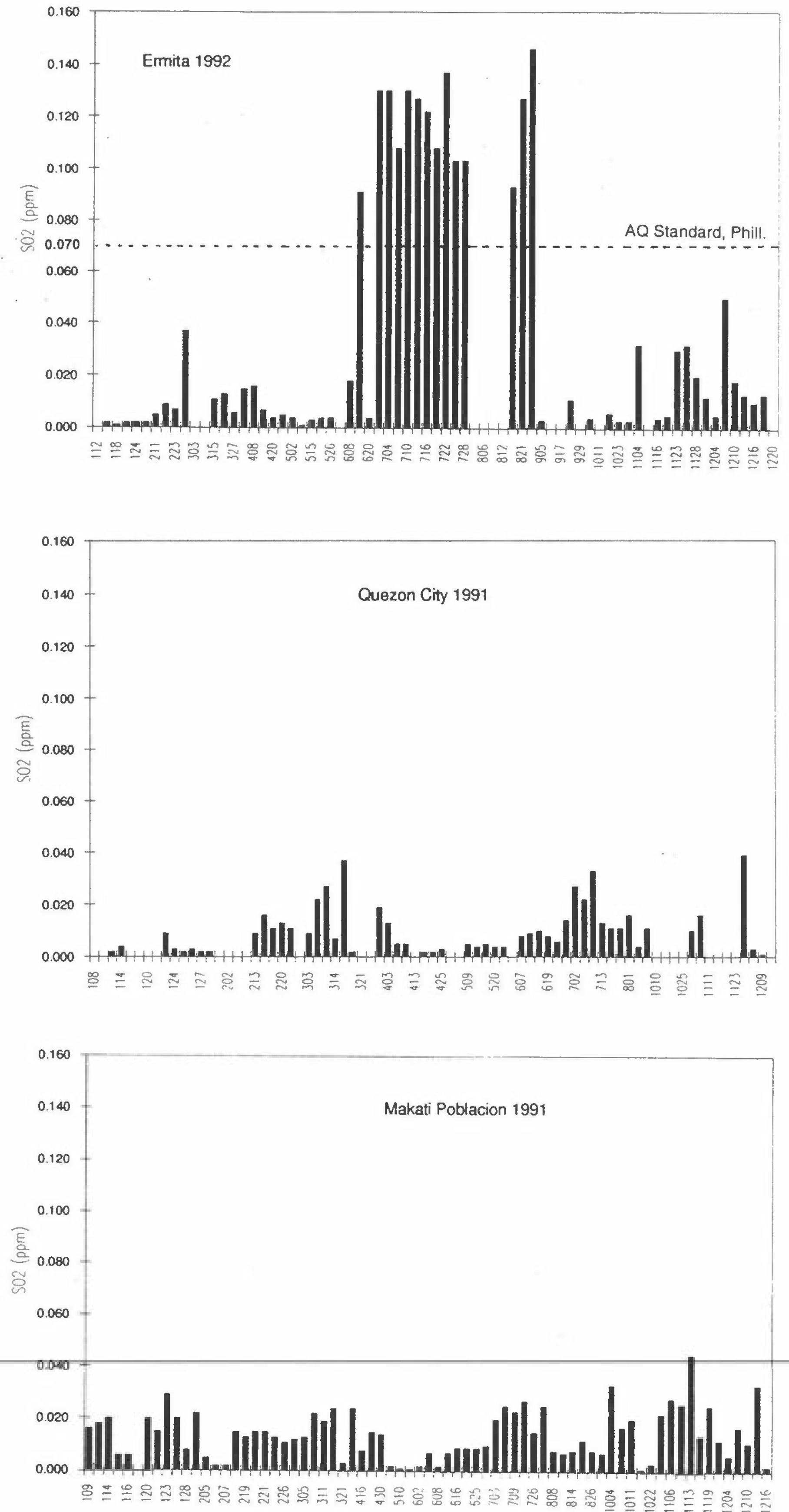

Figure 13: 24-hour SO_2 concentrations given by month and day for Ermita (1992, Quezon City (1992) and Makati Poblacion (1991) (ppm).

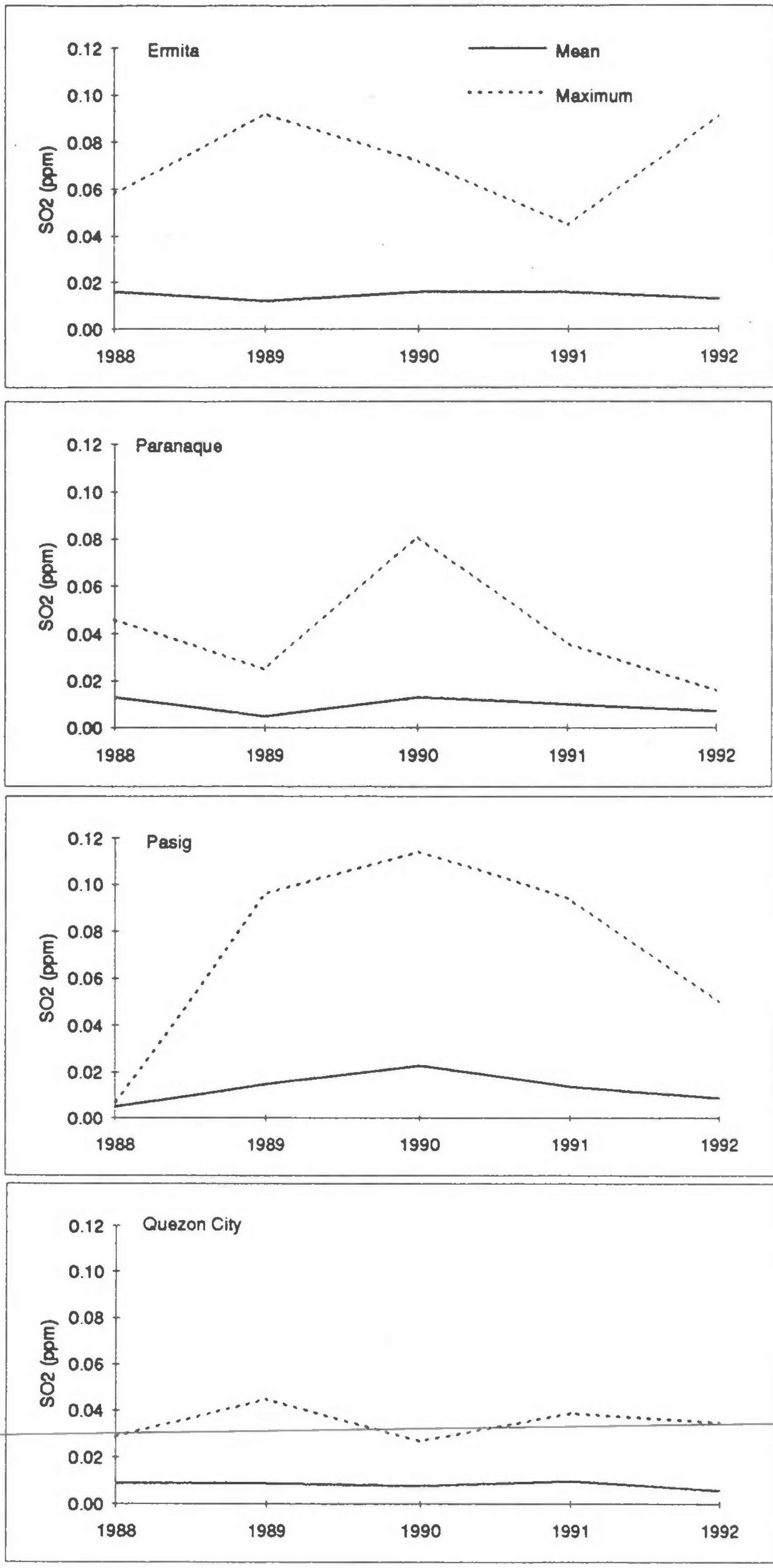

Figure 14: Annual average values and maximum 24-hour SO_2 concentrations for the years 1988-1992 at 4 stations (ppm).

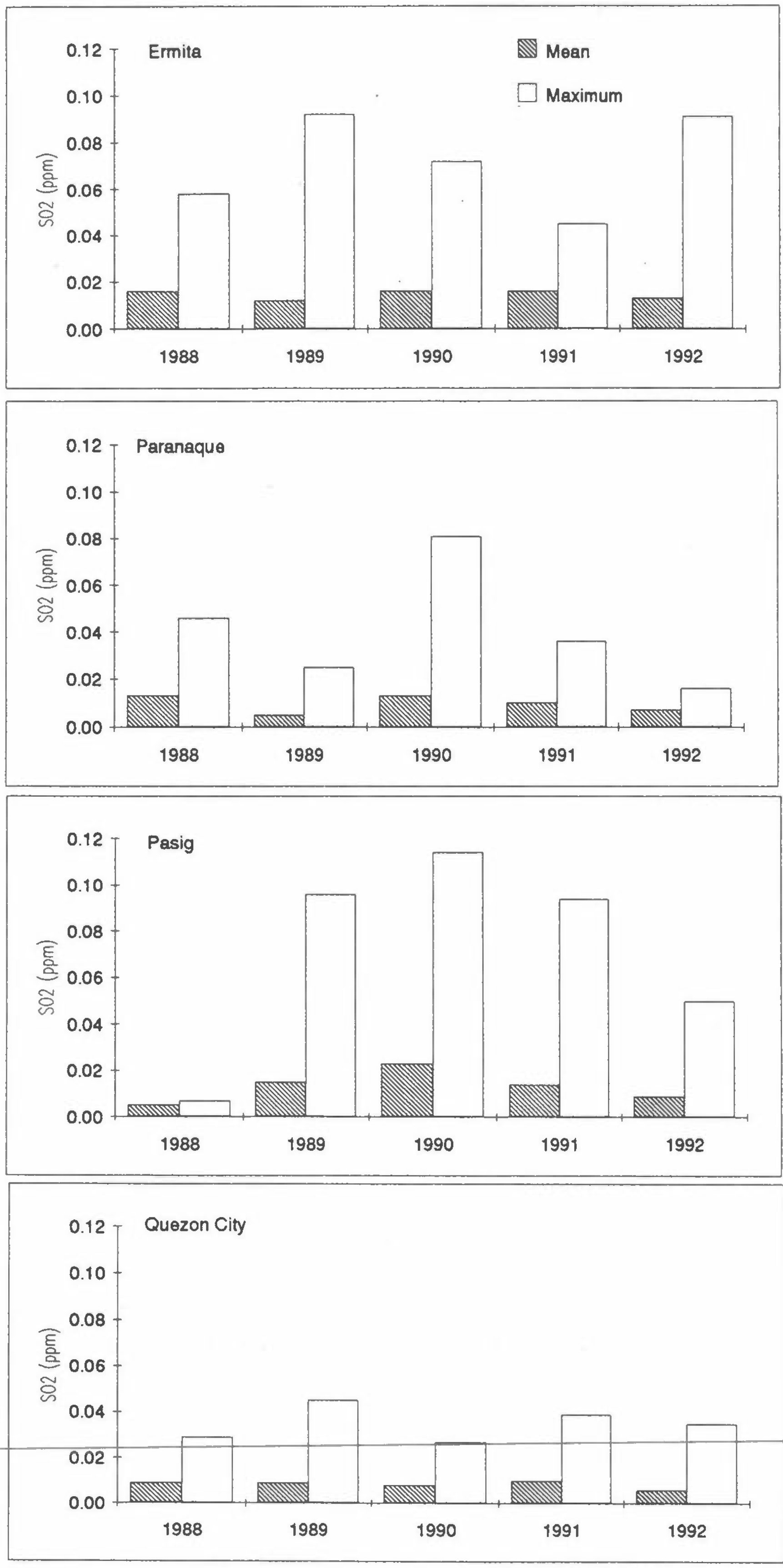

Figure 14: cont.

Carbon monoxide (CO)

CO was monitored in Manila at four sites from 1977 to 1983. Annual mean concentrations were between 1.5 mg/m^3 and 10 mg/m^3. The highest concentrations were measured at the Ermita in 1983.

The only CO measurements since 1983 were during the 1991/92 ADB/EMB project. CO was then measured for five months at Ermita and two months at Quezon Avenue (DENR-NCR). The results of this monitoring are shown in Table 7.

At Ermita the maximum one hour CO value was 20.6 ppm, well below the national standard of 30 ppm. The maximum 8-hour value was 11.3 ppm which is above the standard of 9 ppm. At the Quezon Avenue (DENR-NCR) CO concentrations were lower than at Ermita.

Table 7: Measured average daily maximum one-hour and eight-hour carbon monoxide concentrations. (August 1991-February 1992).

Station and averaging Time	1991 Aug	Sep	Oct	Nov	Dec	1992 Jan	Feb
Ermita							
1-hr (ppm)	20.6	13.7	9.8	6.9	7.3		
8-hr (ppm)	11.3	9.0	6.7	5.1	4.0		
DENR/NCR							
1-hr (ppm)						14.0	14.1
8-hr (ppm)						8.5	7.7

As shown in Figure 15 mean CO concentrations at Ermita in November 1991 ranged from about 0.5 ppm during the night hours to about 3 ppm during rush hour traffic in the morning and afternoon. The monthly mean value in November 1991 seems to be about 2-2.5 ppm.

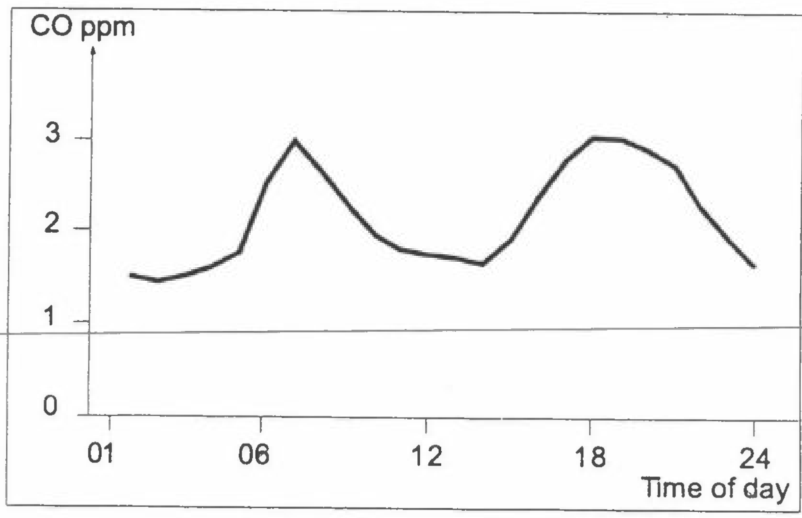

Figure 15: CO diurnal concentration variations, Ermita station, November 1991 (ppm).

Oxides of nitrogen

Oxides of nitrogen include both nitric oxide (NO) and nitrogen dioxide (NO_2).

Until the 1991/92 ADB/EMB project there were no data available on NO_2 air pollution levels in Manila. NO, NO_x and NO_2 were then measured together with CO at the Ermita and Quezon Avenue (DENR-NCR) stations. Table 8 shows maximum one hour and monthly average NO_2 data. The highest values were measured at Ermita in October 1991 with maximum one hour value of 0.240 ppb (about 450 µg/m³) and a monthly value of 0.026 ppb (about 50 µg/m³). The Philippine guideline value is 0.08 ppm/150 µg/m³ for 24 hours. The data does not show if this guideline is exceeded or not.

Table 8: Maximum one-hour and monthly average nitrogen dioxide data (August 1991-January 1992).

Station	1991 Aug	Sep	Oct	Nov	Dec	1992 Jan
Ermita						
1-hr (ppm)	0.044	0.039	0.240	0.110	0.160	
Monthly Ave. (ppm)	0.006	0.007	0.026	0.009	0.050	
DENR/NCR						
1-hr (ppm)						0.240
Monthly Ave. (ppm)						0.016

The daily NO_x, NO and NO_2 concentration variation is shown in Figure 16. As for CO, the highest values were measured during rush hours in the morning and in the afternoon. The lowest values are measured during night hours.

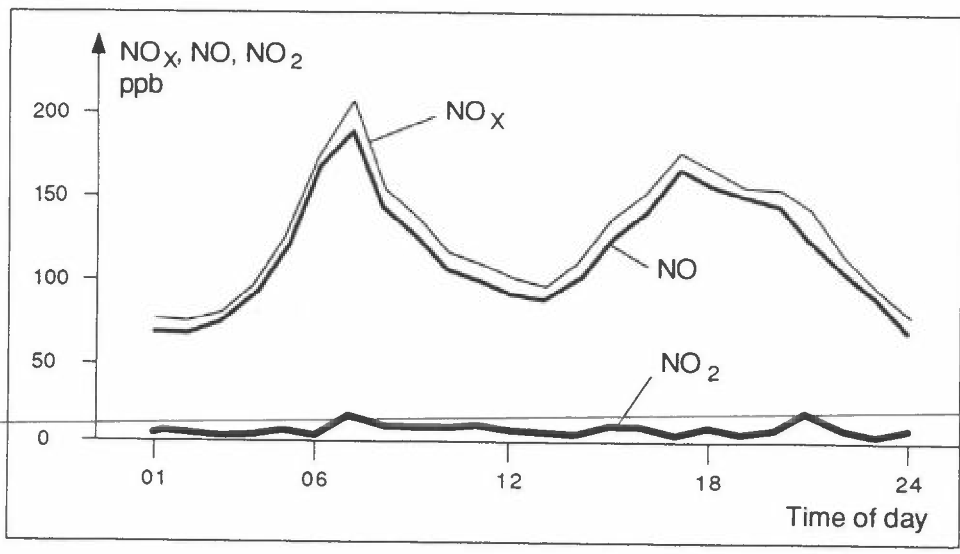

Figure 16: NO_x, NO and NO_2 diurnal concentration variation, Ermita Station. November 1991 (ppb).

NO_2 data are very limited in Manila. Peak concentrations may be well above national and WHO standards, especially in heavily trafficated areas. There is a need for more NO_2 monitoring.

Ozone

O_3 was measured only for three days at Ermita in April 1992 during the 1991/92 ADB/EMB project. The measured levels were below 0.01 ppm. The very low values may be caused by high levels of oxides of nitrogen from the traffic in the area. Chemical reactions between NO and O_3 reduce O_3 and increase NO_2.

More O_3 monitoring is needed, especially in areas well away from heavily trafficated areas.

Appendix 2

Air Quality Guidelines

Air Quality Guidelines

National Ambient Air Quality Standards

In 1992 the Department of Environment and Natural Resources (DENR) has revised and amended the air quality standards of 1978.

The new National ambient air quality guidelines (NAAQG) and standards are given in Table 1.

Table 1: National Ambient Air Quality Guidelines for Criteria Pollutants.

Pollutant	Short term (a)			Long term (b)		
	μg/m3	ppm	Averaging time	μg/m3	ppm	Averaging time
Suspended Particulate Matter (e) - TSP	230 (f)		24 hours	90	-	1 yr. (c)
- PM_{10}	150 (g)		24 hours	60	-	1 yr. (c)
Sulphur Dioxide (e)	180	0.07	24 hours	80	0.03	1 yr.
Nitrogen Dioxide	150	0.08	24 hours	-	-	-
Photochemical Oxidants	140	0.07	1 hour	-	-	-
as Ozone	60	0.03	8 hours	-	-	-
Carbon Monoxide	35 mg/m3	30	1 hour	-	-	-
	10 mg/m3	9	8 hours	-	-	-
Lead (d)	1.5	-	3 months (d)	1.0	-	1 yr

Notes:

a. Maximum limits represented by ninety eight percentile (98%) values not to be exceeded more than once a year.
b. Arithmetic mean.
c. Annual Geometric Mean.
d. Evaluation of this guideline is carried out for 24-hour averaging time and averaged over three moving calendar months. The monitored average value for any three months shall not exceed the guideline value.
e. SO_2 and Suspended Particulates are sampled once every six days when using the manual methods. A minimum number of twelve sampling days per quarter or forty eight sampling days each year is required for these methods. Daily sampling may be done in the future once continuous analyzers are procured and become available.
f. Limits for Total Suspended Particulates with mass median diameter less than 25-50 μm.
g. Provisional limits for Suspended Particulates with mass median diameter less than 10 microns until sufficient monitoring data are gathered to establish a proper guideline.

The national Ambient Air Quality Guidelines in Table 1 are established "for the purpose of protecting the public health and welfare and reducing damage to property, as well as providing an air quality management control strategy for emission limitation from mobile and stationary sources, location of commercial, industrial and residential facilities, and to assist in the promotion and use of an improved transportation system".

The applicable methods for sampling and measurement of the pollutants listed in Table 1 are as follows:

Sulphur Dioxide	Gas Bubbler and Pararosaniline Method (West and Gaeke Method), or Flame Photometric Detector
Nitrogen Dioxide	Gas Bubbler Griess-Saltzman, or Chemiluminescence Method
Ozone	Neutral Buffer Potassium Iodide (NBKI), or Chemiluminescence Method
Total Suspended Particulates (PM_{10})	High volume with 10 micron particle - size inlet: Gravimetric
Carbon Monoxide	Non-dispersive Infra-red Spectrophotometry (NDIR)
Lead	High Volume and Atomic Absorption Spectrophotometry (NDIR)

Other equivalent methods approved by the DENR may be adopted.

WHO Air Quality Guidelines and Standards

WHO Air Quality Guidelines and Standards are listed in Table 2.

The Philippine guidelines for TSP are within the 1979 WHO guideline range. The national PM_{10} guidelines for 24 hours is well above the WHO guidelines. The guidelines for SO_2 are also higher than the WHO guidelines. The NO_2 guideline follows the 1987 WHO guideline. The Philippine guidelines for O_3 are below the WHO values. CO guidelines follow WHO guidelines, while the lead guideline is above the WHO guideline.

Table 2: WHO Air Quality Guidelines/Standards (WHO 1977a, 1977b, 1978, 1979, 1987).

Parameter		10 minutes	15 minutes	30 minutes	1 hour	8 hours	24 hours	1 year	Year of standards
SO_2	µg/m^3	500			350		125[a]	50[a]	1987
SO_2	µg/m^3						100-150	40-60	1979
BS[b]	µg/m^3						125[a]	50[a]	1987
BS[b]	µg/m^3						100-150	40-60	1979
TSP	µg/m^3						120[a]		1987
TSP	µg/m^3						150-230	60-90	1979
TP (PM_{10})	µg/m^3						70[a]		1987
Lead	µg/m^3							0.5-1	1987, 1977[a]
CO	mg/m^3		100	60	30	10			1987
NO_2	µg/m^3				400		150		1987
NO_2	µg/m^3				190-320[c]				1977[b]
O_3	µg/m^3				150-200	100-120			1987
O_3	µg/m^3				100-200				1978

Notes (WHO/UNEP 1992):

a. Guideline values for combined exposure to sulphur dioxide and suspended particulate matter (they may not apply to situations where only one of the components is present).

b. Application of the black smoke value is recommended only in areas where coal smoke from domestic fires is the dominant component of the particulates. It does not necessarily apply where diesel smoke is an important contributor.

c. Not to be exceeded more than once per month.

Suspended particulate matter measurement methods (WHO/UNEP 1992):

BS: Black smoke as concentration of a standard smoke with an equivalent reflectance reduction to that of the atmospheric particles as collected on a filter paper.

TSP: Total suspended particulate matter; the mass of collected particulate matter by gravimetric analysis divided by total volume sampled.

PM_{10}: Particulate matter less than 10 µm in aerodynamic diameter, the mass of particulate matter collected by a sampler having an inlet with 50 per cent penetration at 10 µm aerodynamic diameter determined gravimetrically divided by the total volume sampled.

TP. Thoracic particles (as PM_{10}).

IP: Inhalable particles (as PM_{10}).

National Air Quality Indices

The DENR has also adapted and promulgated national air quality indices.

The following describes the levels of air quality for suspended particulates, sulphur dioxide, photochemical oxidants or ozone and carbon monoxide anywhere in the Philippines.

1 Total Suspended Particulates - (24-hour average):

Good - 0 to 80 µg/m³
Fair - 81 to 230 µg/m³
Poor - 231 to 350 µg/m³

Serious or Alert Conditions:

Very Unhealthful (Alert Level)	350 µg/m³
Hazardous (Warning Level)	600 µg/m³
Extremely Hazardous Emergency Level	900 µg/m³

2: Sulphur Dioxide - (24 hour average):

Good - 0 to 80 µg/m³
Fair - 81 to 180 µg/m³
Poor - 181 to 650 µg/m³

Serious or Alert Conditions:

Very Unhealthful (Alert Level)	650 µg/m³	(0.25 ppm)
Hazardous (Warning Level)	1 570 µg/m³	(0.60 ppm)
Extremely Hazardous (Emergency Level)	2 360 µg/m³	(0.90 ppm)

3 Photochemical Oxidants or Ozone - (1 hr):

Good - 0 to 80 µg/m³
Fair - 81 to 160 µg/m³
Poor - 161 to 350 µg/m³

Serious or Alert Conditions:

Very Unhealthful (Alert Level)	350 µg/m³	(0.18 ppm)
Hazardous (Warning Level)	780 µg/m³	(0.40 ppm)
Extremely Hazardous (Emergency Level)	1 180 µg/m³	(0.60 ppm)

4 Carbon Monoxide - (8-hr average):
Good - 0 to 5 mg/m^3
Fair - 5,1 to 10 mg/m^3
Poor - 10,1 to 17 mg/m^3

Serious or Alert Conditions:

Very Unhealthful (Alert Level)	17 mg/m^3	(15 ppm)
Hazardous (Warning Level)	34 mg/m^3	(30 ppm)
Extremely Hazardous (Emergency Level)	46 mg/m^3	(40 ppm)

During serious or alert conditions different actions are to be taken. All these actions are specified in DENR (1993). A short summary of actions is given below:

- Very unhealthful air quality (alert level):
  - elderly and sick persons should stay indoors and reduce physical activity
  - pedestrians should avoid heavy traffic areas
  - voluntary restrictions on the use of vehicles
  - open burning should be prohibited
  - preparations for reducing industrial emissions.

- Hazardous air quality (warning level):
  - all previous restrictions and in addition
  - the general population should avoid outdoor activity
  - motor vehicles should avoid areas under alert
  - main thoroughfares should be closed for traffic
  - selective curtailment of industrial activities.

- Extremely hazardous air quality (emergency level):
  - all previous restrictions and in addition
  - all persons should remain indoors keeping windows and doors closed
  - use of motor vehicles shall be prohibited except in emergencies
  - major curtailment of all activities in the affected area
  - industrial pollution producing operations shall be curtailed as directed by the Department.

National Ambient Air Quality Standards for Source Specific Air Pollutant from Industrial Sources/Operations

The DENR has also established national ambient standards for source specific pollutants. The discharge of air pollutants that results in peak airborne concentrations (averaging time 5-60 minutes) in excess of the National Ambient Air Quality Standards shown in Table 3 shall not be permitted for any industrial establishment or operation. Sampling shall be done at an elevation of at least 2 meters above the ground level and conducted either at the property line or at a downwind distance of 1.5 to 20 times the stack height, whichever is more stringent.

Table 3: National Ambient Air Quality Standards for Source Specific Air Pollutants from Industrial Sources/Operations.

Pollutants[a]	Concentration[c]		Averaging	Method of Analysis/
	$\mu g/m^3$	ppm	time (min)	Measurement[b]
1. Ammonia	200	0.28	30	Nesselarization
2. Carbon Disulphide	30	0.01	30	Tischer Method
3. Chlorine and Chlorine compounds expressed as Cl_2	100	0.03	5	Methyl Orange
4. Formaldehyd	50	0.04	30	Chromotropic acid method or MBTH-Colorimetricmethod
5. Hydrogen Chloride	200	0.13	30	Volhard Titration with Iodine solution
6. Hydrogen sulphide	100	0.07	30	Methylene Blue
7. Lead	20		30	AAS[b]
8. Nitrogen dioxide	375 260	0.20 0,14	30 60	Griess-Saltzman
9. Phenol	100	0.03	30	4-Aminoantipyrine
10. Sulphur dioxide	170 340	0.06 0.13	30 60	Colorimetric-Pararosaline
11. Suspended Particulate Matter - TSP	300	-	60	Gravimetric
- PM_{10}	200	-	60	Gravimetric

Notes:

a. Pertinent ambient standards for Antimony, Arsenic, Cadmium, Asbestos, Nitric Acid and Sulphuric Acid Mists in the 1978 NPCC Rules and Regulations may be considered as guides in determining compliance.

b. Other equivalent methods approved by the Department may be used.

c. Ninety-eight percentile (98%) values of 30-min. sampling measured at 25°C and one atmosphere pressure.

Appendix 3

Air Pollution Laws and Regulations for the Philippines and Metro Manila

Contents

Air Pollution Laws and Regulations for the Philippines and Metro Manila

1. Introduction

The laws and regulations regarding the control of air pollution in the Philippines and in Metro Manila have been reviewed previously in several reports (e.g. WB/DENR, 199.; WB MEIP, 199.; ADB/DENR, 1992). The actual texts of the laws and regulations have not been available to the authors of this report, except the DENR AD no. 14 of 1993 (see below).

Traffic regulations and enforcement of these are also important for emissions from the road traffic. A summary of these was described in the recent Traffic and Transportation Management Plan (1993-1998).

In addition to these the Anti-Smoke Belching-Campaign which started in 1977 should be mentioned as a specific provision to reduce the particle emissions for diesel vehicles.

2. Summary of existing laws and regulations

- Republic Act No. 3931

  1964: Establishment of the National Water and Air Pollution Control Commission (NWAPCC). The work re. air pollution concentrated first on industrial emissions.

- Presidential Decree (PD) No. 984: Air Quality Standards, etc.

  1976: - Ntl Pollution Control Commission (NPCC, renaming of NWAPCC)

  - Air Quality Standards and Rules

  1978: - Implementing Rules and Regulations

  1993: - DENR Adm. Order (AO) No. 14: The AD 14 is further described below.

  - Revised Air Quality Standards of 1992 revising and amending the Air Quality Standards of 1978

- Presidential Decree No. 1181: Prevention, Control and Abatement of AP from **motor vehicles.**

  1977: - Provisions

  1980: - Implementing rules and regulations

  - Emission standards currently in effect

- Presidential Decree No. 1586: Environmental Impact Assessment System

  1978: - Provisions

  1982: - Implementing Rules and Regulations

  1992: - Revised Rules and Regulations, enforced by EMB

- Executive Order (ED) No. 927:

  1983: Laguna Lake Development Agency (LLDA) vested responsibility to implement and enforce PD 984 in the Laguna Bay Region

- Republic Act 6969:

  1990: Control of toxic substances and hazardous and nuclear wastes

The most important ones, relative to air pollution control in Manila, are the PD 984/DENR AD 14, the PD 1181 (1980 implementing rules and regulations) and the PD 1586 (1992 revision).

3. PD 984/DENR Adm. Order No. 14 (1993)

Revised Air Quality Standards of 1992, Revising and Amending the Air Quality Standards of 1978

Sections 8 and 12 of this order regard Ntl. Ambient Air Quality Guidelines and Air Quality Indices. This is described in Appendix 2 in the present report.

Emissions from stationary sources are treated in other sections, and outlined in the following:

- *Section 4: Ntl. Emission Standards for Smoke and Particulate Matter for Stationary Sources.*

  Visible Smoke emission: Not darker than Shade 1 on the Ringelmann chart. Exceptions for short-term emissions.

  Particulate matter emission limits (mg/N m^3)

	New source	Existing Source	
	1993	After 1978	Before 1978
Fuel burning steam generators[1)]			
a) urban/industrial area	150	300	500
b) other areas	200	300	500
Incinerators	200	300	-
Cement plants (Kilns, etc.)	150	300	500
Smelting furnaces	150	300	500
Other stationary sources	200	300	500

1) 12% CO_2 (volume)

- *Section 5: Ntl. Emission Standards for Source Specific Air Pollutants (NESSAP)*

Emission standards are given for Sb, As, Cd, CO, Cu, HF, Pb, Hg, Ni, NO_x, P_2O_5, Zn, with analytical methods specified.

The NO_x standards are as follows:

NO_x	Maximum emissions (mg/N m³)
Nitric Acid Plants	2,000 (acid+NO_x, calc. as NO_2)
Fuel burning steam generators	
- existing source	1,500 as NO_2
- new source	
coal-fired	1,000 as NO_2
oil-fired	500 as NO_2
Any other source	
- existing source	1,000 as NO_2
- new source	500 as NO_2
Pb Any source	10

- *Section 6: Control of Sulphur Compound Emissions*

Sulphur Contents in Fossil Fuel, Existing Sources:

	Max S (% by weight)			
	Metro Manila		Outside M M	
	July 1993	January 1996	July 1993	January 1996
Fuel oil	3.5	3.0	3.8	3.0
Industrial diesel	0.7	0.5	0.8	0.5
Coal	2.5	1.0	2.5	1.0

These are the initial specifications for 1993-96. After January 1, 1996 all operators shall be required to install appropriate SO_2 control equipment to meet the SO_2 emission limits specified below, unless the above S-in-fuel regulations are revised so as to represent an alternative approach to control the SO_2 emissions.

Emission limits for SO_2 to be met by January 1 1996:

	gm/Nm³, as SO_3	
	New	Existing
Existing sources		
- Sulphuric acid plants	2.0	1.5
- Fuel burning steam generators	1.5	1.0/0.7 [1]
- Other stationary sources	1.0	0.2

1) By January 1, 1994/By January 1, 1996

If these standards are not met by an operator, the following corrective measures may be required:

- To use fuel with a specified sulphur content.

- To erect a stack sufficient to reduce the ground level concentration of SO_2 to below 80 $\mu g/m^3$ (24-hour average) above the background level.

- Alter the process/method of operations.

- *Section 9: Prohibited Acts*

Fugitive particulates:

Prohibition to cause emissions of fugitive particles from any source without taking reasonable precautions, such as:
- dust control during demolition/constructions
- dust control on unpaved road
- use of hoods, fans and filters to contain or vent handling of dusty materials
- covering of open loaded trucks.

Volatile Organic Compounds:

Requirements for handling and disposal, such as:
- maximum tank volume: 150 000 litres, unless leakage of gas is prevented
- max. emissions from ethylene source: 7 kg per day, unless emissions are burned
- max. emissions of organic solvent: 1.5 kg/hour or 7 kg/day from any process.

Nuisance:

Prohibition to cause emissions creating nuisance

Open burning:

Prohibition of any open fire, except, for instance, for:
- cooking
- recreational or ceremonial purposes
- fires for prevention of decease/pests
- disposal of hazardous materials, when no alternative is available, if approved by DENR
- recognized agricultural, forest management practices.

General restrictions, among others:
- The capacities and capabilities of control devices shall not be exceeded.
- No source should be installed if it results, together with the contributions from other sources, in exceeding air quality standards.

- All pollution control devices shall be properly and consistently maintained and operated. No facilities shall be operated without the control equipment in proper operation, except with permission from DENR.
- Erection or alteration/resiting of a chimney shall be applied for, giving the following information:
  . site plan including buildings within 1 000 m from chimney, and height of the highest building within 50 m
  . data on emissions (compounds, amounts and concentrations).

- *Section 10: Source monitoring, Record Keeping, Testing*

  - Any owner/operator may be required to install monitoring equipment, both for emissions and ambient air quality, to keep records and file periodic reports.

  - For each major source, it shall be the responsibility of the owner/operator to do so, without notice from DENR.

  - Analysis and tests to be conducted as specified by DENR.

  - The DENR has the right to inspect.

- *Section 11: Miscellaneous Provisions*

  For stationary fuel-burning equipment, the following applies:

  - Person-in-charge shall be able to inspect smoke plume, without leaving the control room.

  - The following major industries are required to install stack monitoring devices for smoke opacity and SO_2 emissions:
    . Fossil-fuel fired Power Plant (also NO_x)
    . Petroleum Refinery
    . Primary Copper Smelter
    . Steel/Ferro-alloy plants (opacity only)
    The equipment is to be installed within 24 months after the effective date of the regulation.

For miscellaneous equipment, the following applies:

- Reheating furnaces, smoke ovens, baking ovens, coffee heaters, varnish kettles, paint booths and similar equipment shall be so designed that there is no free flow of objectionable gases into the atmosphere. Preventive devices shall be used.

4. PD 1181: Prevention, Control and Abatement of Air Pollution from Motor Vehicles

PD 1181 was passed on 19 August, 1977. The implementing rules and regulation of this PD were published in the official Gazette on 6 October, 1980.

The National Pollution Control Commission was charged with the administration and enforcement of these rules.

Enforcement procedures include the right to apprehend vehicles not complying with the emission standards, after testing the emissions.

The emission standards to be enforced after 1 January, 1981 are as follows:

Vehicle category	Standards
Diesel	
• registered vehicles	Smoke opacity not to exceed 2.5 per m. (light absorption coefficient), at free acceleration test.
• non-registered vehicles, for registration after 1 January, 1982.	Must comply with existing smoke opacity rules of either British, ECE, Australia, USA or this PD 1181 Standard.
• non-registered vehicles with reconditioned engines	Same rule as for registered vehicles
Gasoline	
• registered vehicles	Emission at idle:

Model year	CO %	HC ppm
1976-81	4.5	1 000
1971-75	5.0	1 000
1965-70	5.5	2 000
1964-older	6.0	2 000
2-stroke	6.0	7 800

Vehicle category	Standards
• unregistered vehicles, for registration after 1 January, 1982	Emission limits, for either US 82 (CVS) or ECE test cycle:

Weight GW (kg)	CO g/km	HC g/km
<1 000	25	2.5
1001-1500	30	3.0
1501-3000	35	3.5

These standards imply that the present car fleet in Manila should comply with regulations similar to those of ECE-R15/01 and 74/290/EWG, valid in the European Community between 1975 and 1979.

At present, the following measures are also being undertaken under PD 1181:

- Public Awareness.
  An inter-agency committee chaired by DENR has been created to enhance public awareness of vehicular air pollution. NGO's are co-operating in this task.

- Roadside Inspection and Re-inspection (the Anti Smoke-Belching Campaign) (See below).

- Periodic Inspection
  "AO No. 40-91-005 issued by the Land Transportation Office (LTO) of DOTC, established the New Motor Vehicle Inspection System (NMVIS), under which all new vehicles shall be inspected, to be registered. Due to limited inspection facilities and equipment, the initial implementation of NMVIS is confined to areas where motor vehicle inspection stations are assigned to certain classes or types of motor vehicle."

- Retrofitting. Conversion of vehicle engines to run on less polluting fuels is encouraged (e.g. gasoline-LPG). One taxi fleet has been converted to LPG.

- "Greening of MM". Planting of trees.

- Traffic control. Truck ban and bus lanes (see below).

- Infrastructure approach. Construction of flyovers to enhance traffic flow.

- Voluntary approach. Encouragement to adopt flexible working hours, to relieve rush hour traffic.

5. PD 1586: Environmental Impact Assessment System

The Environmental Impact Assessment System (EIS) was established by PD 1586 on 11 June, 1978. Implementing rules and regulations of the EIS were adopted on 14 December 1981, and amended by the DENR Administrative Order No. 21, series of 1992.

DENR is the leading agency of the EIS. The Environment Management Bureau (EMB) of DENR is responsible for processing the EIS documents on Environmentally Critical Projects (ECP). The DENR Regional Offices shall be responsible for projects that fall within the scope of Environmentally Critical Areas (ECA).

All planned projects within an ECA need an Environmental Compliance Certificate. This is obtained after a review process by DENR/EMB. This review process includes the preparation, by the proponent, of an Environmental Impact Assessment, unless a 1. phase review establishes that the project has no or insignificant impact on the environment. The 1. phase review is based on a specific Project Description (PD) to be prepared by the proponent.

The AO 21/1992 contains an "Annotated Environmental Impact Statement Outline" which is to serve as a general guideline for proponents as to the contents of an EIS.

Summary of the outline is as follows. For the parts regarding air pollution the entire contents of the outline is presented.

1.0 Name and address of project proponent

2.0 Type of project

3.0 Overview Summary

4.0 The project setting
- objective, need, alternatives, associated projects

5.0 The proposal
- general layout, pre-construction details, operation/maintenance

6.0 A brief history of past environmental conditions and a description of the existing environmental and resource use
- climate, terrain, hydrology, oceanography,
- atmosphere:

> The following items should be described in this section:
>
> a. historical trends in air quality of the project area;
>
> b. existing air quality and types and levels of air pollutants already existent in the area of concern; and
>
> c. existing ambient air quality standards and emission standard set by EMB should be appended.

- vegetation, fish and wildlife, land and resource use, socio-economic aspects.

7.0 Future environmental conditions without the project (an average of 5 years projection).

8.0 Prediction and assessment of impacts
- physical/chemical effects
- water, ground water
- atmosphere

i. Air Characteristics
- Changes in air characteristics resulting from the project may have implications from the standpoint of public health, temperature modification, humidity change.
ii. Wind
- Occurrence of wind modification (valley, barrier or funnel effect), creation of localized wind disturbances such as those resulting from the establishment of high rise building complexes and highways.
iii. Inversion
- Development of inversion conditions which result in the entrapment of air remittance causing high impingement concentrations of air pollutants.

9.0 Contingency plans

10.0 Environmental briefing and monitoring

11.0 Mitigation measures

12.0 Residual/unavoidable effects

13.0 Information deficiencies

14.0 Appendices

16.0 Consultation and comments including public recommendations

17.0 Other documents to be attached

The outline indicates that a full description of the effects of the project on air pollution has to be developed, based on necessary collection and compilation of data, measured or calculated.

6. Traffic regulations

Traffic regulations may have a significant effect on air pollution emissions from vehicles, to the extent that they influence the total traffic activity in an area, the traffic count in a particular road section, or the speed and flow of the traffic.

The following regulations may have such effects in Metro Manila:

MMA Ordinance 19 (1991):

- Trucks and buses on major roads 6-9 AM and 4-8 PM
- Designated truck routes during rush hours

MMA Ordinance 78-03-A (1992):

- Towing of illegally parked and stalled vehicles

MMC Ordinance 3 (1989):

- Yellow Lane Rule. Designates and regulates the use of bus and PUJ lanes in main thoroughfares.

MMC Ordinance 6 (1990):

- Prohibiting pedicabs and tricycles on highways and major thoroughfares, and limiting their operation to tertiary roads and within subdivisions.

PD of November 6, 1992:

- Clearing of Obstruction on Sidewalks and other Roadways in order to effect the smooth flow of traffic.
- To identify, develop and use alternative routes to ease the traffic situation in MM.

7. The Anti Smoke-Belching Campaign

This project started in August 1977 with the issuance of PD 1181. The project was first managed by NPCC, then by DENR/NCR, then by a committee of representatives from Metro Manila Authority, Land Transportation Office and the Constabulary Highway Group. After this group disbanded in 1991, DENR/NCR/MVPCC resumed responsibility.

This enforcement activity consists of 1) stopping smoke-belching vehicles and testing their emissions using the Ringelmann Chart as a guide, 2) issuing subpoenas to owners for testing, and 3) confiscating licence plates. Failing in the test results in fines of P200 for the first offence, P500 for the second and P1000 for the third and succeeding offences.

At the peak of the campaign, 18 000 vehicles were apprehended in 1982, but it lost momentum to only about 1 500 vehicles in 1988. After revitalization, again about 18 000 vehicles were apprehended in 1989, and 80% of them reported for testing. 70% of the tested vehicles were then issued a certificate of compliance.

Appendix 4

Emissions of Air Pollutants, Metro Manila

Contents

Emission of Air Pollutants, Metro Manila

1. General description of the city and activities

Manila is the capital of The Republic of the Philippines. It is situated in a plain on the south-western coast of the Luzon Island, around the mouth of the Pasig river in the Manila Bay. The Metropolitan Manila Region (MMR), henceforth to be referred to as the National Capital Region (NCR) covers a total land area of 636 km^2 and consists of 4 cities (Manila, Caloocan, Pasan and Quezon City) and 13 municipalities. Figure 1 shows a map of the NCR area. The population density for the NCR is 12 468 persons per km^2, 60 times denser than the national average. The population is projected to grow at the rate of 2.35% annually during the 1990's, corresponding to a 26% increase during the decade. Table 1 shows the land area, population and population density in the 4 cities and 13 municipalities that comprised the NCR in 1990.

Table 1: Land area, population and population density of the NCR in 1990.

City/ Municipality	Area km^2	Population x 1 000	Population density
1. Manila	38,3	1 599	41 749
2. Caloocan	55,8	761	13 638
3. Pasay City	13,9	367	26 403
4. Quezon City	166,2	1 667	10 030
5. Malabon	23,4	278	11 880
6. Navotas	2,6	187	71 923
7. Makati	29,9	453	15 150
8. Valenzuela	47,0	340	7 234
9. Las Pinas	41,5	297	7 156
10. San Juan	10,4	127	12 211
11. Paranaque	38,3	308	8 042
12. Mandaluyong	26,0	245	9 423
13. Pasig	13,0	397	30 538
14. Taguig	33,7	266	7 893
15. Muntinlupa	46,7	277	5 931
16. Pateros	10,4	51	4 904
17. Marikina	38,9	310	7 969
Total, NCR	636,0	7 930	12 468

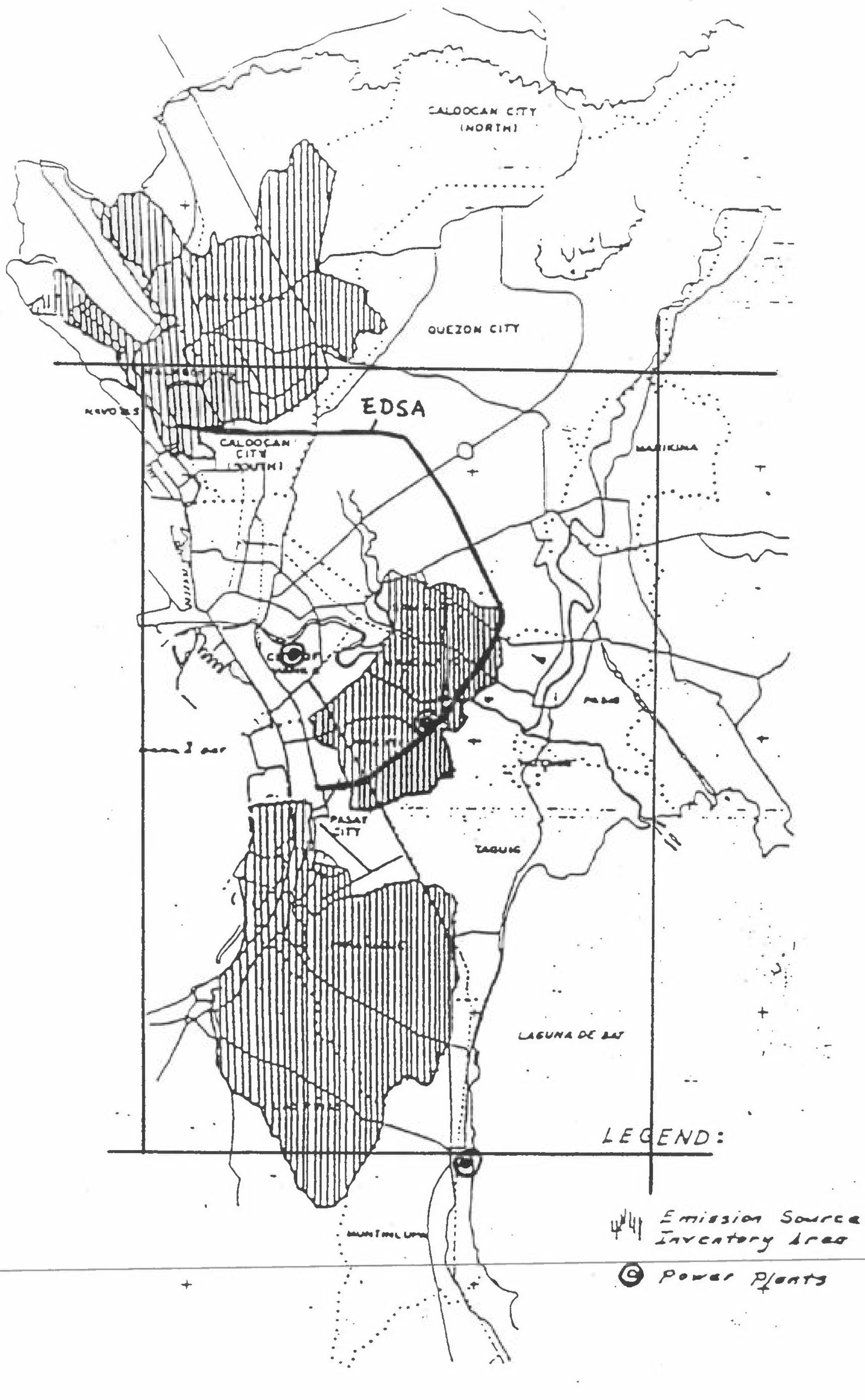

Figure 1: Metro Manila Region with EDSA and the three power stations.

Around Metro Manila runs EDSA, the principal circumferential highway. It is a 12-lane highway running in a demi-circle with a radius of about 7 km. It was built as an outer ring road, but development of city centres such as Makati and Quezon City has changed the structure of the city. Commercial and administrative development has shifted strongly from the Centre to areas outside EDSA, and it has become the spine of the city. At Guadalupe, the busiest point, peak traffic is around 11-12 000 vehicles per hour and daily volumes exceeding 140-150 000 vehicles are observed. Traffic congestion appears regularly along large sections of EDSA. Daily, more than 2 million passengers are passing along EDSA, out of which 1.43 million by bus. With the projected increase in population and traffic it is expected that there will be a total breakdown in the traffic within a few years unless something is done. Several proposals have been made during the last few years: highway improvements, alternative routes and for public transport a Light Rail Transit System (LRT) along EDSA or a transitway system.

About 37% of NCR's total land area is used for housing which includes single family residences, multiple residential units, slums and squatter areas. Generally, poor housing areas with higher density are located around the commercial and tourist areas which provide informal employment opportunities. The better housing areas are located along EDSA at the Southern edge of Quezon City, at Greenhills in San Juan, near Ortigas in Mandaluyong and Pasig and near the Makati Commercial Centre in Makati.

About 8% of the MMR is commercial area. The old commercial areas are located in Ermita, Malate, Quiapo, Divisoria Sta. Cruz and Binondo of Manila. Recent commercial developments occur in Sta. Mesa, (Manila), Cubao, Balintawak, and Monumento (Qezon City), Makati, Greenhills (San Juan), and EDSA-Ortigas-Shaw areas at the confluence of Pasig and Mandalugy. Industrial development took about 15% of the NCR's land in 1990. The factories are concentrated in strategic areas that provide easy access to transportation such as Pasig, Port Area, Paco, Pandacan and Mandaluyong. Other areas of recent industrial concentration are along McArthur Highway, Tandung Sora in the north and along Pasong Tamo and the South Superhighway in the south. Current expansion of industries is now occurring in the municipalities immediately adjacent to the NCR (Laguna, Cavite, Batangas). This is a normal pattern for megacities where new industries are built in areas with lower pollution control than in the Metropolitan Area.

2. Reference map, grid area and population distribution

The region selected for an emission survey and for modelling must be large enough to extend towards localities with negligible emissions, or localities where a constant small value of ground-level emissions can be assumed. For MMR this gives the area stretching to the north beyond Kalookan City, south beyond Muntinlupa, west into Manila Bay, and east towards Laguna de Bay and the eastern borders of Marikina and Quezon City. This covers an area of about 22 x 50 km^2. For emission and model calculations the number of grid squares is of importance for the computer time consumption. For Manila it seems that a grid size of 1 km would be appropriate.

For the calculation of the pollution load in different parts in the NCR, it is essential to have correct data for the population within each km^2 of the area, preferably split into different social classes. This is of importance since a significant part of an emission survey is connected with domestic activities. This may be calculated on the basis of data for the population within subdistricts within the municipalities, a detailed map with the subdistrict borders and some local knowledge. Land Use maps from National Mapping and Resource Information Authority (NAMRIA) could be a good basis for an emission survey.

3. Pollution sources

The main source groups in Manila are:

- Power stations
- Industrial/stationary sources
- Area sources
- Motor vehicles

Several attempts have been made to produce total emission inventories for Metro Manila.

Ayala has made emission calculations for Manila for 1987 and 1990 (Ayala, 1993), and Manins has tried to adjust the figures with additional data (Manins, 1991). The original intention of the inventory by Ayala was to cover the entire Metro Manila Region. However, the emission inventory team had no access to the facility records of stationary sources located in the cities and municipalities of the Laguna de Bay Region which were under the LLDA jurisdiction. Ayala's emission estimates cover thus only the sources in the shaded area of Figure 1.

In order to complete Ayala's emission survey for 1987/88 Manins examined the Metro Manila 1:10 000 Land Use Maps and counted the number of "industry" symbols within each grid cell. The total was 1838 factories. The number of factories registered in the emission data base for the same cells was subtracted from the counts, to give an estimate of the number of factories "missing" from each cell in the data base for Metro Manila. Most of the identified missing factories (1689) are in the Valenzuela-Kalookan city (North) and Makati-Pateros regions, but this number can be only indicative and should be corrected by field survey work.

Ayala calculated emissions of six criteria pollutants for 1987 and 1990: total organic gases (TOG), carbon monoxide (CO), oxides of nitrogen (NO_x), oxides of sulphur (SO_x), particulate matter (PM) and particulate matter less than 10 μ (PM_{10}), as shown in Table 2 for 1990. She also calculated emissions of lead, benzene, ethylene dibromide (EDB), ethylene dichloride (EDC) and asbestos.

Table 2: Summary of emissions from all sources in Metro Manila region, 1990 (Ayala, 1993).

Source	Pollutants, tons per year					
category	TOG	CO	NO_x	SO_x	PM	PM_{10}
Mobile	100 954	572 626	66 216	10 350	13 220	11 450
Power plants	103	684	9 118	68 331	4 850	3 265
Stationary sources	1 713	3 362	4 301	9 762	4 473	4 229
Area sources	5 162	525	276	12	102 386	51 042
Total	107 932	577 197	79 910	88 456	124 929	69 986

Benzene: 4713 tons, EDB 2 tons, EDC 56 tons, Pb 407 tons, asbestos 45 tons.

Table 2 shows that the dominant source of pollutants in Manila is mobile sources for TOC, CO and NO_x. SO_2 is emitted mainly from Power Stations using high-sulphur (3-4% S) fuel, whereas area source resuspension of dust from roads is the main particle source.

Power Stations.

There are three power stations in Metro Manila:

- Sucat (Gardner) Power Station on the edge of Laguna de Bay in Muntinlupa, a four-boiler, two-stack base-load station with a capacity of 150+200+200+300 MW.

- Manila (Tegen) Power Station on Isla de Provisor in the Pasig River, a boiler, two-stack base-load station with a capacity of 2x100 MW.

- Rockwell Power Station south of the Pasig River in Makati, a three-boiler, three-stack base-load station of 3x30 MW.

The positions of the power stations are shown in Figure 1. Table 3 shows emission data and some other data for the power stations.

Table 3: Emissions from the Power Stations in Manila.

Station	Stack height m	Fuel cons. Ml	Emissions (tons/year)				
			TSP	SO_x	NO_x	CO	TOC
1987/88 (Manins)				3% S			
Sucat	122	949	3 796	53 751	6 263	569	28.5
Manila	76	310	1 240	17 558	2 046	186	9.3
Rockwell	79	150	600	8 496	990	90	4.5
Total		1 409	5 636	79 805	9 299	845	42.3
1990 (Ayala)				4% S			
Total			4 850	68 331	9 118	684	102.6

Industrial/stationary sources.

Information about stationary sources is the province of two authorities, National Capital Region, Department of Environment and National Resources (DENR/NCR) and Laguna Lake Development Authority (LLDA). Unfortunately, data from the sources within LLDA have not been available. Of the several hundred emitters in the DENR/NCR database, 149 more significant ones are included in the data base used for model calculations.

Manins has studied the Fuel sales statistics for 1988. When the consumption in the power stations and the stationary sources in the data base is subtracted, 58% of all IFO (Bunker C fuel oil, 4%S) imported to Metro Manila is unaccounted for (or 93% of all non-power station sale). As mentioned above, the stationary sources which fall under the Laguna Lake Development Authority are not included in the data base, but the oil consumption in these will not account for the whole difference.

This is a normal problem when making the first emission estimates for capital cities. Many companies have their main offices in the capital and factories elsewhere in the country, but the sale figures are often assigned to the company address instead of the consumption address. The OEA statistics show that 74% of the IFO sold in the Philippines in 1987 was sold in Metro Manila. Out of the total sale of 3,669 Ml IFO in Manila in 1987, 1409 Ml were used in the power stations. Manins shows that the difference is too big to be accounted for only by the consumption in the stationary sources in the Manila region.

It is clear that the existing basis for emission calculations for Manila is inadequate. The oil companies have to deliver correct data about their customers, including delivery addresses, and the Office of Energy Affairs should have the responsibility for correct sale figures.

Motor vehicles

The estimates of the emissions from motor vehicles in the NCR may be divided as follows: Overall vehicle emissions and spatial distribution of the emissions. The overall vehicle emissions are calculated as the sum

$$Q_{veh,j} = \Sigma N_i * Td_i * Q_{i,j}$$

where

$Q_{veh,j}$ is the total emission of component j (g/year)
N_i is the number of vehicles of category i,
Td_i is an average annual travel distance for the vehicles, (km/year)
$Q_{i,j}$ is emission factor for component j from vehicle category i (g/km)

In earlier emission surveys the only emission factors available have been USEPA factors, as shown in Table 4. It has been pointed out that it is necessary to take local emission measurements from actual Philippine vehicles. Poorly maintained diesel jeepneys and buses are common, no emission controls are used by petrol vehicles, and many motorcycles are used for public transport. In a project initiated by the Asian Development Bank, a measuring program to give a new set of Philippine emission factors has been developed, as shown in Table 5 (Vehicular Emission Control Planning, VECP). These have been applied in the latest emission calculations by Ayala, but the figures she presents do not correspond to the equation above.

Table 4: Emission factors from USEPA (g/km).

	CO	TOC	NO_x	SO_2	TSP
Petrol					
Cars	33.0	3.04	2.70	0.123	0.33
Utility vehicles	33.0	3.04	2.70	0.134	0.33
Truck	117.0	12.20	7.80	0.246	0.68
Mo/Tricycle	17.0	10.10	0.08	0.049	0.21
Diesel					
Cars	1.1	0.20	0.99	0.634	0.45
Utility vehicles	1.1	0.30	0.99	3.380	0.93
Truck	17.8	2.90	13.00	3.380	0.93
Buses	13.2	2.90	13.00	2.535	0.93

*Table 5: Emission factors for vehicles in the Philippines (VECP, 1992).
Unit: gram per kilometre.
Number of vehicles 1990.*

	Number of veh. x 1 000	1 000 km/veh.	CO	HC	NO_x	SO_2	Pb	Particu-late
Gasoline								
Cars	292.6	12	49.5	6.00	2.7	0.011	0.073	0.10
UV	137.4	30	60.0	8.00	3.0	0.014	0.092	0.12
MC	66.6	10	26.0	18.60	0.2	0.004	0.028	2.00
Bus/Truck	6.3	50	36.24	1.68	3.93			0.05
Diesel								
Taxi	14.4	30	1.9	0.65	2.0	0.081		0.60
Jeepny	50.0	50	2.5	0.70	1.4	0.121		0.90
UV	64.3	40	2.5	0.70	1.4	0.115		0.90
Bus/Truck	54.4	50	12.4	3.70	12.5	0.374		1.50

Table 6 shows the results from different emission estimates for Manila. For some components in some vehicle types there are similar values, but in most cases there are substantial differences. The methods should be approximately the same, and the calculations should be based upon the same statistical data. It is of no value to start an argument about the most correct emission figures. For SO_2 the values are based upon different assumptions regarding sulphur content, in other cases the vehicle groups may include different vehicle types. The jeepneys seem to appear like a dark horse in these calculations, in most of the estimates they are included in the Diesel Utility Vehicles. Although buses are very visible sources of pollution, they contribute little to the total emissions.

Table 6: Different emission estimates of vehicle emissions in Manila.

	SO_2				NO_x			
	Manins	Ayala 1987	Ayala 1990	VECP	Manins	Ayala 1987	Ayala 1990	VECP
Gasoline								
Cars	786	750	43		17 239	7 497	11 556	10 440
UV	249	319	64		5 005	3 189	14 641	16 588
Truck	54	12	121		1 721	116	1 276	
Buses		1	7			12	76	
MC/TC	51	130	3		78	1 305	306	147
Sub-tot	1 140	1 212	238		24 042	12 120	27 855	
Diesel								
Cars	206	756	846		321	1 862	956	
Jeepny								4 952
UV	2 516	7 284	6 695		1 965	17 941	7 193	
Truck	6 267	2 289	2 285		24 103	5 639	26 841	41 029
Buses	1 959	329	287		10 353	811	3 371	
MC/TC		64	-			158		
Sub-tot	10 948	10 722	10 113		36 742	26 411	38 361	
Total	12 088	11 934	10 350		60 785	38 531	66 216	73 156

	CO				TSP			
	Manins	Ayala 1987	Ayala 1990	VECP	Manins	Ayala 1987	Ayala 1990	VECP
Gasoline								
Cars	210 694	134 992	213 672	191 399	2 107	750	866	387
UV	61 174	57 414	280 442	277 603	612	319	1 107	2 456
Truck	25 811	2 095	11 770	19 064	150	12	84	1 466
Buses		218	696			1	17	
MC/TC	17 592	73 502	22 025		217	131	1 512	4 923
Sub-tot	315 271	218 221	528 605		3 086	1 212	3 586	
Diesel								
Cars/Taxi	357	672	938		146	1 260	345	
Jeepny				40 701				2 857
UV	2 184	6 475	13 112		893	12 141	5 155	
Truck	33 003	1 908	26 626		1 724	3 816	3 272	
Buses	10 198	293	3 344		719	549	461	
MC/TC		57				107		
Sub-tot	45 742	9 405	44 020		3 482	17 873	9 633	
Total	361 013	227 626	572 626	536 814	6 568	19 084	13 220	12 089

	TOC			
	Manins	Ayala 1987	Ayala 1990	VECP
Gasoline				
Cars	19 409	22 742	30 040	23 200
UV	5 635	9 672	42 049	37 792
Truck	2 691	353	577	
Buses		37	32	
MC/TC	10 452	3 959	15 425	13 638
Sub-tot	38 188	36 763	88 124	
Diesel				
Cars/Taxi	94	94	314	
Jeepny				2 309
UV	596	12 141	3 573	
Truck	5 377	3 816	7 945	12 145
Buses	2 241	549	998	
Sub-tot	8 308	17 872	12 830	
Total	46 495	54 635	100 954	89 084

Spatial distribution of vehicular emissions

For model calculations in an area it is not enough to have figures for the total emission from vehicles, a correct spatial distribution is also necessary. This may be achieved in a three-stage procedure: primary roads, secondary roads and local roads. The co-ordinates for the crossings in the primary road network should be measured on the reference map. Based upon counts of the number of vehicles of different types on the main roads, values for Annual Average Daily Traffic (AADT) may be estimated. It will often be necessary to extrapolate counts from one intersection to the nearest crossings with local experience about the traffic flow. This is a time consuming procedure, but in this way it is possible to calculate the traffic work (vehicle-km) for each vehicle type within each km^2. The next problem is to obtain correct emission factors for the driving conditions on the main roads, but as the first estimate the results of the emission measurement programmes may be used. In this way emission distributions of different pollutants may be calculated.

For the secondary roads it is necessary to measure the length of the primary and secondary roads within each km^2, and subtract the length of the primary roads from the calculations above. Values for the AADT for each vehicle group on the secondary roads should be estimated to give distributions of secondary traffic activity, and from these the emissions may be calculated.

As for the traffic on the local roads, it is necessary to start with figures for the total sale of petrol and diesel in the area. It is normal to assume that there is no net export of gasoline across the borders of the study area. The consumption of petrol and diesel by the traffic on the primary and secondary roads is calculated, and the difference has to be distributed in some way, usually according to the population distribution.

Ayala has estimated the fuel consumption with respect to vehicle type in MMR for 1990 as shown in Table 7. The consumption is distributed according to the number of registered vehicles, without any consideration of different consumption per vehicle. This is obviously not correct, as for instance the MC/TC's, which are 13% of the total number of gasoline vehicles, should account for less than 13% of the fuel consumption.

Table 7: Fuel consumption in MMR, 1990.
Unit: 10^6 litres.

Vehicle type	Gasoline	Diesel
Cars	414.3	50.4
Utility Vehicles	194.5	399.4
Buses	0.5	17.1
Trucks	8.4	136.3
MC/TC	94.3	0
Total	712.0	603.3

In addition to the vehicular emissions in NCR it is important not to forget emissions from the traffic outside the study area, but inside the emission grid. At least the emissions from the main roads should be estimated.

Ayala has also calculated other motor vehicle emissions in addition to the running exhaust emissions: incremental cold start exhaust emissions, incremental hot start exhaust emissions, and the evaporative emissions consisting of hot soak, diurnal and evaporative running losses.

The major road network of Metro Manila (Figure 2) consists of 10 radial and five circumferential roads:

R- 1 Roxas Boulevard
R- 2 Taft Avenue
R- 3 South Superhighway
R- 4 J. P. Rizal Street
R- 5 Shaw Boulevard
R- 6 Ortigas Avenue
R- 7 Quezon Avenue
R- 8 A. Bonifacio Avenue
R- 9 Rizal Avenue
R-10 Honorio Lopez Boulevard
C- 1 Taft Avenue
C- 2 Pres. Quirino Avenue
C- 3 G. Aretana Avenue
C- 4 Epifanio de los Santos Avenue (EDSA)
C- 5 Katipunan (under construction)

Most of the roads are travelled by both gasoline and diesel fuelled vehicles, except for R-2 and R-9 where the Light Railway Transit (LRTA-I) operates. Public transport consists mainly of jeepneys, buses (including mini-buses) and taxis. Motorcycles/tricycles are also used for short distance trips. Private transport is mainly by car and five-seater jeepneys, pick-ups and vans, school and office service buses.

The National Capital Region has about 4 900 km of roads for its interurban travel, classified into 720 km of National Roads, 554 km of Municipal Roads, 1 274 km of City Roads, 318 km of Barangay Roads, and 1 827 km of Private Roads (inside subdivisions).

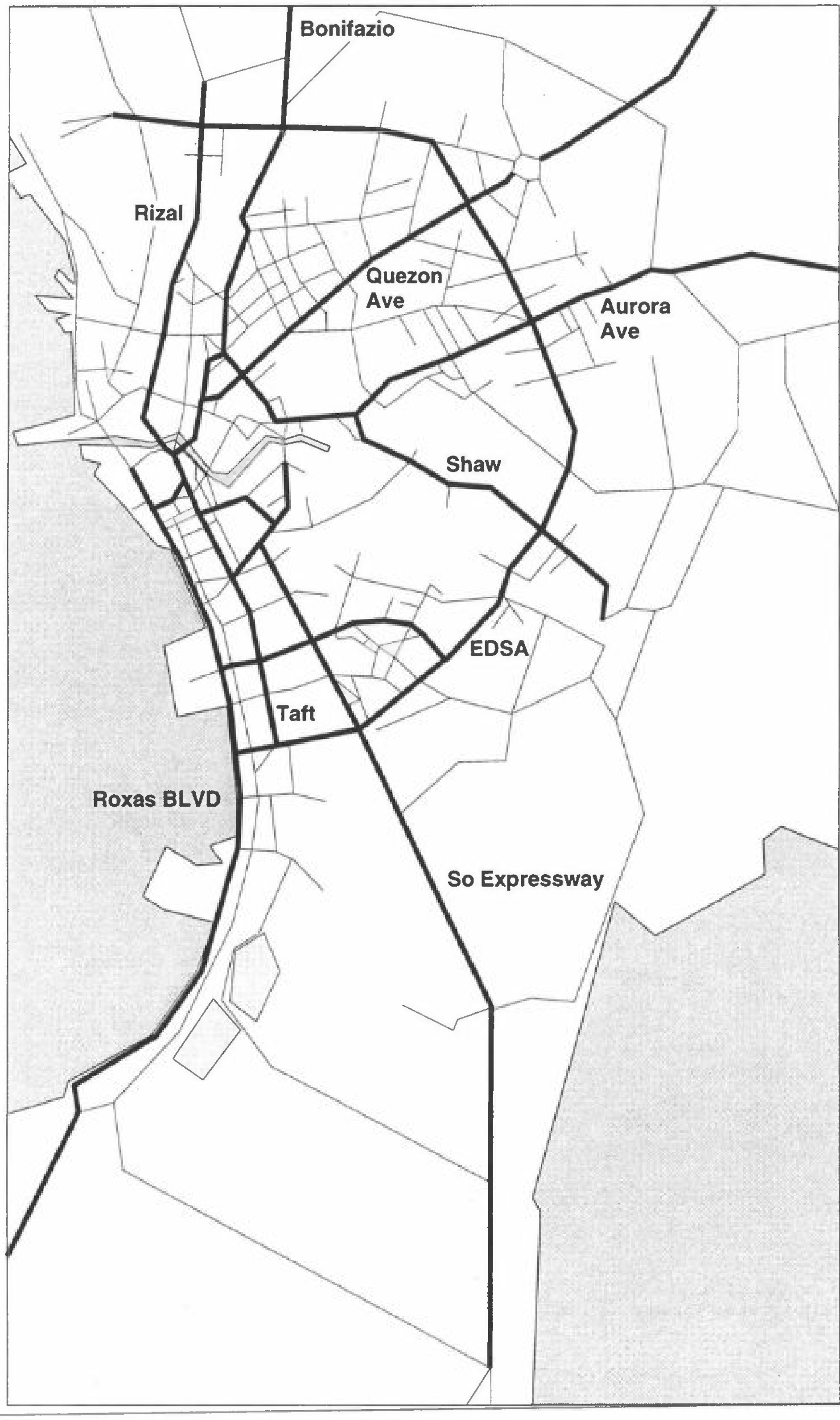

Figure 2: Major Road Corridors in Metro Manila.

Area sources

Area sources are small sources individually emitting relatively insignificant amounts of emissions, but when considered collectively with other similar sources, they become significant. Ayala estimated emissions from 12 different types of area sources as shown in Table 8.

Table 8: Area Source Emissions in Metro Manila Region, 1990 (Ayala, 1993).

	TOG	CO	NO_x	SO_2	PM
Paved Road Travel					80 507
Structural Fires	9.25	113.08	2.57		7
Automobile Fires	0.09	2.87	0.09		2
Road Construction					8 479
Building Construction					13 380
Surface Coatings	381.80				
Adhesive and Sealants	1 332.87				
Dry Cleaning	80.75				
Industrial Degreasing	773.30				
Residential Fuel Combustion	11.61	29.74	145.98	0.18	5
Commercial Aircraft	161.54	378.93	127.17	12.09	4
Gasoline Dispensing Facilities	2 410.92				
Total	5 162.13	524.62	275.81	12.27	102 384

In addition, there will be some emissions from the traffic at the harbour of Manila. No information, however, is available about the consumption of coal in Metro Manila. Emission from residential fuel combustion includes the use of LPG. Normally there should be appreciable emissions from domestic cooking, especially from low-standard dwellings using different cheap fuels. These are not included in official statistics, but has to be taken into account.

For each of the source groups there will be a separate key to distribute the emissions over the area. This may follow the distribution of roads, the number of gasoline stations, the population distribution or even a different distribution key for different regions is possible.

4. Emission survey for Metro Manila, road traffic emissions

This emission survey has been prepared as input for model calculations for the Metro Manila area, as a tool in developing an Air Quality Management Strategy (AQMS) for the area.

An emission inventory should cover source groups such as industrial point sources, small industry and domestic emissions and emissions from main road and local road traffic. Using representative emission factors for each source category will normally give good estimates.

However, this survey is not a complete emission survey for Manila. Many source groups are not included yet, and for others the calculations are based upon secondary information, especially for the spatial distribution. This means that many basic input data are still missing, and we have had to use other data to estimate the distribution.

Information about stationary sources in Metro Manila is divided between two authorities: National Capital Region, Department of Environment and National Resources (DENR/NCR) and Laguna Lake Development Authority (LLDA). Figure 3 shows the two regions within our model area. In the DENR/NCR database there are data for several hundred emitters, but the actual emission data are not available to us.

Map and emission grid

The emission calculations are made for a 1 km^2 grid of 18 x 30, according to "Map of Metro Manila" 1:25 000, and all co-ordinates and references are given relative to this map. The National Capital (NCR) covers a total land area of 636 km^2 and consists of 4 cities (Manila, Caloocan, Pasay and Quezon City) and 13 municipalities. Figure 3 shows the Metro Manila Region and the calculation area. The calculation area covers 540 km^2, of this is about 140 km^2 sea or areas outside NCR. Large (but less inhabited) areas of NCR are situated outside the grid area, mainly the northern part of NCR. Table 9 shows the land area and the population in the regions in 1980, 1990 and 1995.

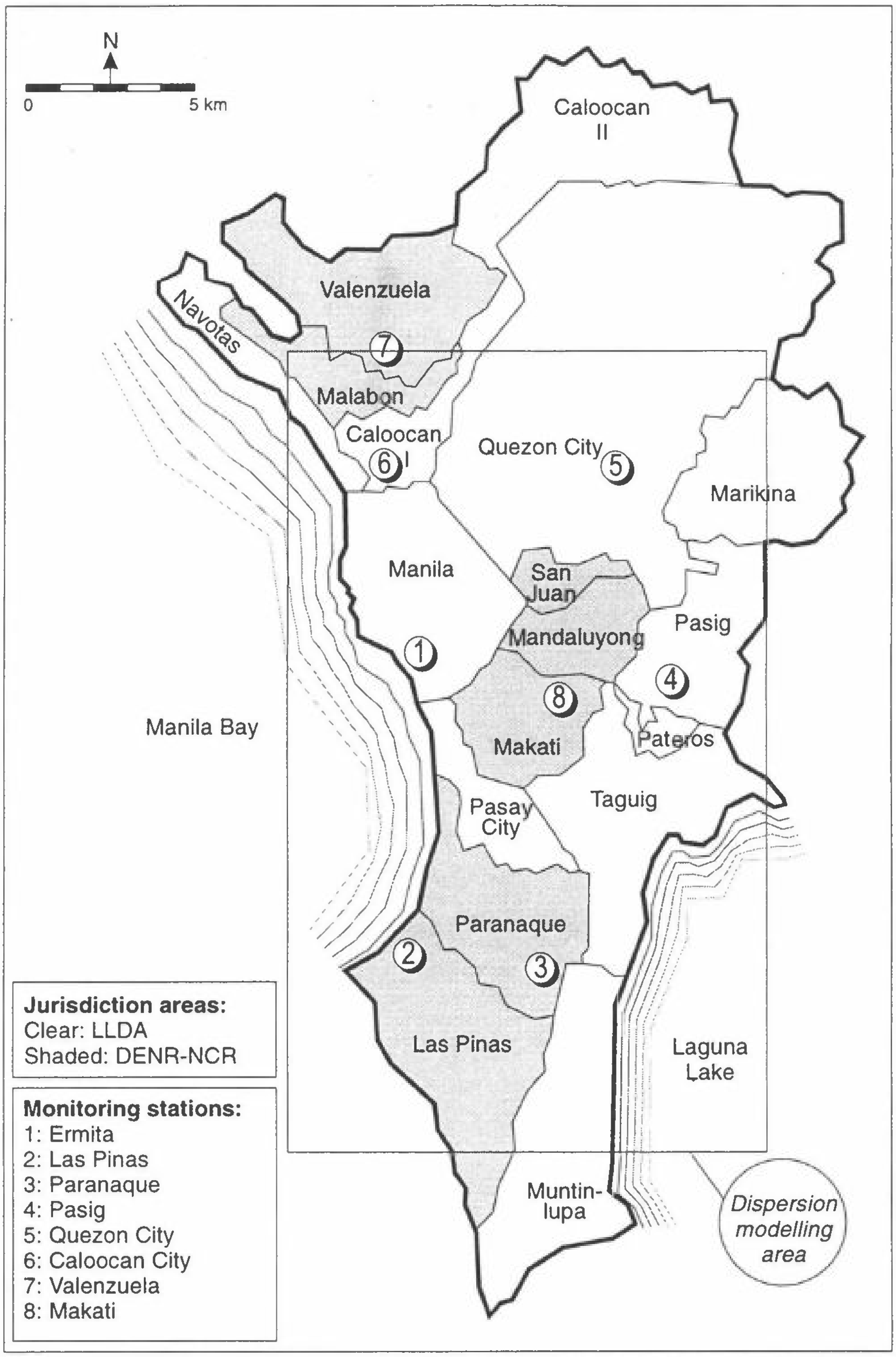

Figure 3: Metro Manila Region and the model calculation area.

Table 9: Area and population in the Manila regions.

Region	Area km²	Cov. %	Inh. 1980 *10³	Inh. 1990 *10³	Inh. 1995 *10³	Baran-gays	Zone
1 Manila	38.3	100	1 630	1 601	1 587	900	1
2 Caloocan City	55.8	50	468	763	975	188	2
3 Pasay City	13.9	100	288	368	417	200	3
4 Quezon City	166.2	90	1 166	1 670	1 999	140	2
5 Malabon	23.4	60	191	280	339	21	3
6 Navotas	2.6	80	126	187	229	14	2
7 Makati	29.9	100	373	453	500	32	2
8 Valenzuela	47.0	10	212	340	430	32	3
9 Las Pinas	41.5	90	136	297	438	20	3
10 San Juan	10.4	100	130	127	125	21	2
11 Paranaque	38.3	100	209	308	375	16	3
12 Mandaluyong	26.0	100	205	248	273	27	2
13 Pasig	13.0	100	269	398	484	30	3
14 Taguig	33.7	100	134	267	376	18	3
15 Muntinlupa	46.7	40	137	278	397	9	3
16 Pateros	10.4	100	40	51	58	10	3
17 Marikina	38.9	70	212	310	376	14	3
Sum	636.0		5 926	7 948	9 378[1]	1 692	

1 The total is reported as 9 205 422, but the sum of the population in all regions gives 9 378 665.

Population distribution

For each region there was estimated a coverage factor to account for the fraction of the population within the grid area. For each km² there was estimated another factor, "built-up-area", to distribute the population within each region, and also to estimate the traffic on minor roads (see later). With more detailed data these factors may be estimated later.

The population in grid (I,J) within region K will be:

$$POP(I,J) = FACT(K)*INH(K)*COV(I,J,K)/(\Sigma COV(I,J,K)),$$

where

FACT(K)	is the coverage factor for region K
INH(K)	is the number of inhabitants in the region K
COV(I,J,K)	is the coverage of grid (I,J) in region K.

Figure 4 and Annex 1 show maps of the population distribution in Manila, 1990. This covers 6 652 600 of the 7 948 000 inhabitants. The highest population density is estimated for grid (2,27), with 76 952 inh/km².

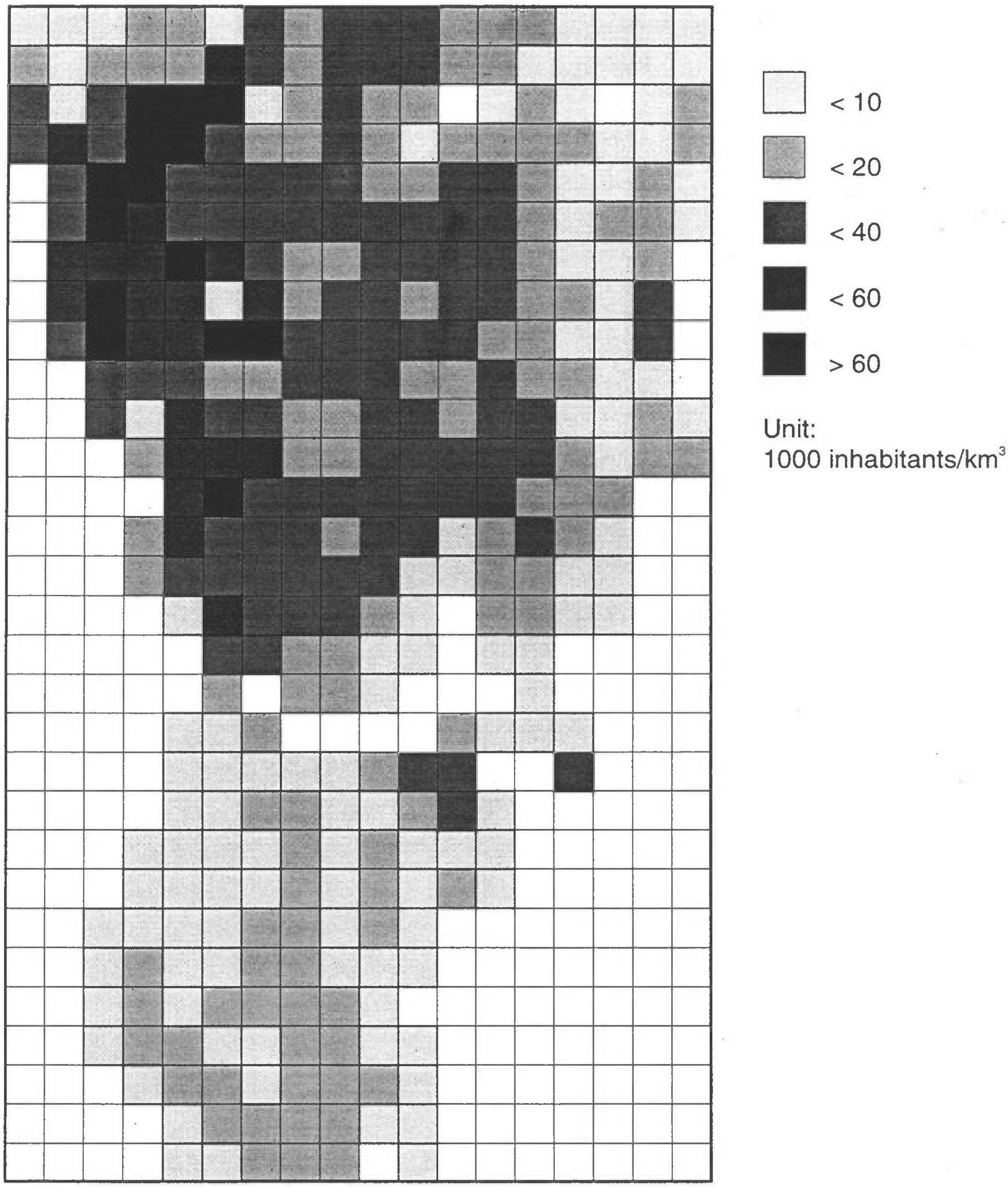

Figure 4: Population distribution in Manila, 1990.

Each region in Manila is divided into a number of "barangays", as shown in Table 9. To give a correct population distribution for Metro Manila, the population in each barangay should be distributed to the grid squares it covers. On the average each barangay is approximately 0.4 km^2, and in this way the errors in the population distribution will be small. For this method it is necessary to have data for the barangay population, and a detailed map with the barangay borders.

The same procedure may be used for other types of data, using demographic or socio-economic parameters. For example the use of different fuels may be a function of social standing.

Emission from traffic

The estimates of the emissions from motor vehicles in the NCR may be divided into two: The overall vehicle emissions and the spatial distribution of the emissions. The overall vehicle emissions are calculated as the sum

$$Q_{veh\ j} = \Sigma N_i * Td_i * Q_{i\ j},$$

where

$Q_{veh\ j}$	is the total emissions of component j (g/year)
N_i	is the number of vehicles of category i
Td_i	is an average annual driving distance (AADD) for the vehicle category,
$Q_{i\ j}$	is average emission factor for component j from vehicle category i (g/km).

Table 10 gives the calculated total traffic activity and fuel consumption for traffic in Manila, based on an assumption of Td_i as shown below:

Table 10: Traffic activity and fuel consumption in Manila.

	No. of veh. *10^3	AADD 10^3 km	Traffic activity 10^9 km/a	Cons. l/km	Fuel cons. 10^6 l
Gasoline					
Cars	292.3	10	2.92	0.10	292
Utility	137.4	26	3.57	0.15	536
MC	66.6	8.5	0.57	0.05	28
Bus/truck	6.3	35	0.22	0.3	66
Sum gasoline	502.6	14.5	7.28	0.127	922
Diesel					
Taxi	14.4	20	0.29	0.10	29
Jeepney	50.0	35	1.75	0.15	262
Utility	64.3	20	1.29	0.15	194
Truck/bus	54.4	35	1.90	0.30	571
Sum diesel	183.1	28.5	5.23	0.202	1 056
Total	685.7	18.2	12.51	0.158	1 979

The fuel sale statistics for Metro Manila for the year 1990 give a total sale of 855 * 10^6 l of gasoline and 1 307 * 10^6 l of diesel oil. This is less gasoline than the consumption calculations above give, and it indicates that either the average mileage of the vehicles or the specific consumption (l/km) is overestimated, or both are.

The total sale of diesel oil is higher than the calculated consumption from the traffic. This is probably explained by the significant amounts of diesel oil used for industrial heating processes.

In the Vehicular Emission Control Planning project, VECP, funded by the Asian Development Bank, a measuring program to give a set of Philippine emission factors was carried out. These are used together with EPA/WHO emission factors to give the emission factors used in the calculations of emissions of NO_x and TSP from traffic in Manila, as shown in Table 11.

Table 11: Emissions of NO_x and TSP from traffic in Manila.

	Traffic activity	NO_x		TSP	
	10^9 km/a	g/km	10^3 t/a	g/km	t/a
Gasoline					
Cars	2.92	2.70	7.89	0.20	584
Utility vehicles	3.57	2.70	9.64	0.33	1 178
MC	0.57	0.07	0.04	0.5	285
Bus/truck	0.22	8.00	1.76	0.68	150
Sum gasoline	7.28	2.65	19.33	0.29	2 197
Diesel					
Taxi	0.29	1.0	0.29	0.6	174
Jeepney	1.75	1.4	2.45	0.9	1 575
Utility vehicles	1.29	1.4	1.81	0.9	1 161
Truck/bus	1.90	13.0	24.70	2.0	3 800
Sum diesel	5.23	5.6	29.25	1.28	6 710
Total	12.51	3.9	48.59	0.70	8 907

On the average, this gives an emission factor of 3.9 g NO_x/km and 0.7 g TSP/km.

Spatial distribution of the traffic emissions

Main roads

For the spatial distribution of the traffic, a main road net for Manila was defined according to a report from the Manila Traffic Management Centre ("MTMC"). For many of the roads the Annual Average Daily Traffic (AADT) was given, for others the data was measured from a map in the report. The road net was not complete and had to be extended and supplemented, mainly for the areas outside EDSA, but also to some extent for the central parts of Manila. For these roads the AADT was estimated by extrapolation or other means.

In this way a main road net for Manila was defined with straight links from one crossing to another, as shown in Figure 5. The total length of the road net is 434.5 km, and the total traffic work on these roads was estimated to 15 418 * 10^6 km/a. This gives an average AADT of about 35 000 cars/day on the main roads. Using the average fuel consumption figure of 0.158 l/km calculated above, this will give a yearly consumption of 889 * 10^6 l of fuel. Annex 2 shows the distribution of the main road traffic activity.

The vehicle composition was given for about 20 counting points in Manila, mainly along the radial and circumferential roads. This is valuable information, but in this study it was not possible to extrapolate these data to the adjacent roads, and we were forced to use composite emission factors based upon the average traffic composition figures (as in Table 11).

Local roads

In addition to the traffic on the main roads there is a considerable amount of traffic activity on the local roads in the area. The average traffic on the main roads was estimated to 35 000 vehicles/day, and for the main road data there seems to be a lower limit of about 10 000. The National Capital Region has a total of about 4 900 km roads for its interurban travel. Most of these will have low traffic, but there will also be roads with heavy traffic, and the emissions are considerable.

To estimate the traffic activity on the small roads, the Metro Manila area was divided into 3 zones: zone 1 is Manila, zone 2 the surrounding regions inside and around EDSA, and zone 3 the regions outside. The zone codes are listed in Table 9. For each km^2 the small road traffic activity was calculated as:

TRAF(I,J) = COV(I,J,K)*TRW(ZONE(K)),

where

COV(I,J,K)	is the coverage of grid (I,J) in region K, defined above
ZONE(K)	is the zone listed in Table 9
TRW(ZONE(K))	is the traffic activity in zone ZONE(K), as listed below: 200 000 vehicle-km in zone 1 130 000 vehicle-km in zone 2 40 000 vehicle-km in zone 3

These estimates of local road traffic activity were set so that the total fuel consumption for road traffic in Manila would correspond to the fuel consumption statistics. The increase from zone 3 towards zone 1 reflects the increase in traffic activity towards the central areas of Metro Manila. The actual ratio of increase was chosen somewhat arbitrarily.

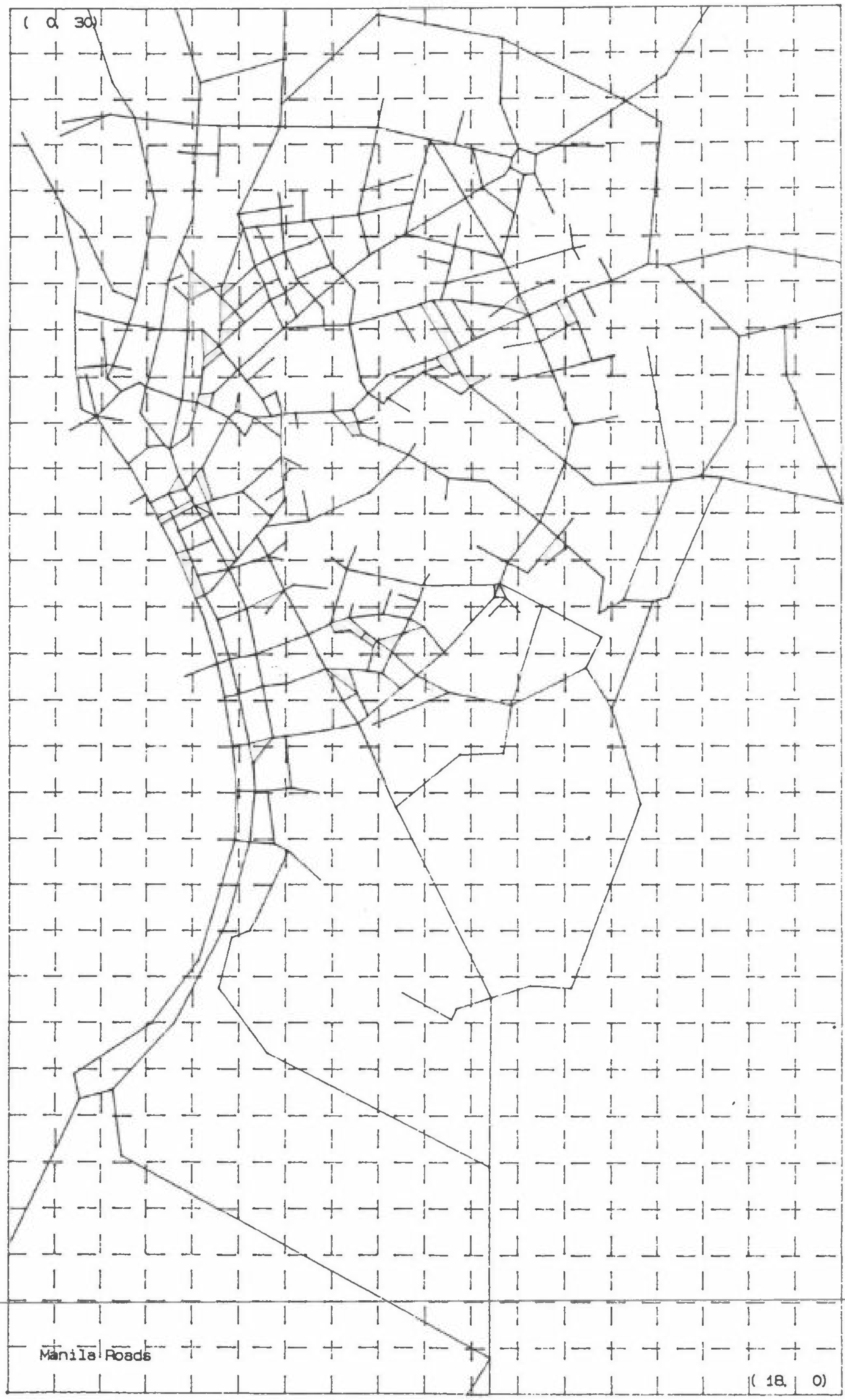

Figure 5: Main road net in Manila.

Based upon these assumptions the traffic activity on the small roads was estimated to 18 706*10^6 veh-km/day or 6.83*10^9 km/a. With the fuel consumption factor of 0.158 l/km calculated in Table 10 this gives a fuel consumption of 1 077*10^6 l/year for the local road traffic. The total fuel consumption is then 889+1 077 (gasoline+diesel) =1 968*10^6 l/year, which corresponds well with the estimated fuel consumption of 1979*10^6 l/year in Table 10.

The estimates for the traffic in Manila give a total of 34 124*10^6 veh-km/day or 12.46*10^9 km/a. Using the average emission factors of 3.9 g NO_x/km and 0.70 g TSP/km as defined above, this gives total emissions from road traffic in Manila shown in Table 12.

Table 12: a) Traffic activity and b) Total emissions from traffic in Metro Manila.

	Traffic activity		Fuel cons.
a)	10^6 veh-km/day	10^9 veh-km/a	10^6 l/a
Main roads	15 418	5 628	889
Local roads	18 706	6 832	1 079
Total	34 124	12 460	1 968

b)	NO_x	TSP
Total emissions from traffic	5.54 t/h	1.00 t/h
	133.1 t/d	23.9 t/d
	48 578 t/a	8 719 t/a

Annex 3 and 4 show maps of average hourly emissions of NO_x and TSP from traffic in Manila 1990.

ANNEX 1: POPULATION DISTRIBUTION

MAP OF POPULATION UNIT: 10 PERSONS

MAX. VALUE IS 7.6953E+04, IN (2 , 27)
SUM= 6.65260E+06 SCALE: 1.0E+01

GRID SIZE 1000 METER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
J=30	900.	600.	1200.	1346.	1831.	823.	.	1156.	2312.	2312.	2312.	1927.	1156.	1156.	771.	771.	385.	632.
J=29	1800.	600.	2700.	1800.	1500.	2546.	771.	1542.	2698.	2312.	2312.	1927.	1542.	771.	385.	385.	385.	1726.
J=28	3840.	900.	300.	.	2244.	1732.	771.	1156.	2698.	1927.	1927.	.	385.	1542.	771.	.	247.	2466.
J=27	3520.	7695.	4039.	4039.	3142.	1542.	1542.	1927.	3083.	1927.	385.	1156.	1542.	1156.	1156.	247.	740.	1973.
J=26	.	3986.	5799.	4039.	1346.	3083.	2698.	3083.	3083.	1542.	1156.	2312.	2312.	1156.	1017.	493.	1973.	986.
J=25	.	3591.	4039.	2465.	771.	3468.	2312.	2312.	3083.	2698.	2698.	2312.	3083.	1542.	740.	1973.	1973.	493.
J=24	2010.	6699.	4689.	1340.	385.	2698.	2312.	1156.	1927.	2312.	2698.	2698.	2312.	1927.	1233.	1726.	2219.	.
J=23	4019.	5359.	5359.	6029.	2010.	.	1927.	1542.	2222.	2539.	1542.	2312.	2312.	1927.	1057.	704.	2465.	.
J=22	4019.	6699.	5359.	5359.	670.	3349.	.	771.	2041.	2426.	2268.	2744.	1927.	1927.	385.	352.	2465.	.
J=21	2679.	6029.	5359.	4689.	6029.	6029.	2679.	.	1056.	2041.	1510.	1127.	2698.	1542.	1542.	704.	352.	.
J=20	.	2679.	2679.	3349.	1340.	1340.	3349.	2010.	1879.	3006.	3006.	1503.	2489.	2818.	352.	704.	1409.	352.
J=19	.	3349.	670.	4689.	2679.	2010.	1340.	1185.	1667.	3006.	3382.	2231.	2465.	2465.	1409.	352.	1057.	1057.
J=18	.	.	1340.	5359.	4689.	5629.	1888.	2427.	2157.	2582.	2475.	2078.	3170.	1761.	1057.	1057.	.	.
J=17	.	.	.	4689.	6029.	3088.	2427.	2427.	1888.	2427.	2696.	809.	1596.	2113.	1761.	704.	.	.
J=16	.	.	1284.	5005.	2140.	.	1618.	2427.	2157.	2157.	270.	539.	1389.	1882.	522.	352.	.	.
J=15	.	.	1284.	2995.	3851.	1712.	1070.	2427.	2427.	1888.	539.	.	1899.	1190.	703.	351.	.	.
J=14	.	.	.	856.	4279.	2995.	266.	1348.	1512.	351.	703.	.	703.	703.	.	.	.	.
J=13	.	.	.	.	1712.	3556.	561.	.	351.	351.	.	.	.	703.	.	.	.	.
J=12	.	.	.	.	1712.	133.	1844.	1416.	398.	664.	266.	1671.	351.	703.	703.	.	.	.
J=11	.	.	.	.	856.	1416.	133.	1195.	1195.	1850.	3256.	3209.	.	.	2459.	.	.	.
J=10	.	.	.	.	268.	133.	266.	266.	1062.	797.	1897.	3646.	703.	.	.	.	.	.
J= 9	.	.	.	.	136.	271.	398.	398.	1062.	929.	1546.	968.	703.	.	.	.	.	.
J= 8	.	.	.	271.	950.	814.	941.	1062.	1195.	664.	1413.	1187.	351.	.	.	.	.	.
J= 7	.	.	.	950.	1357.	814.	268.	1328.	1195.	664.	929.	835.	.	.	.	.	.	.
J= 6	.	.	.	678.	1221.	950.	1085.	1080.	1195.	1328.	929.	.	.	.	.	.	.	.
J= 5	.	.	.	407.	1357.	1357.	950.	950.	1201.	1704.	398.	454.	.	.	.	.	.	.
J= 4	.	.	.	.	407.	1357.	1221.	543.	1083.	1589.	1816.	454.	.	.	.	.	.	.
J= 3	.	.	.	.	.	814.	1085.	1085.	1041.	1362.	681.	454.	.	.	.	.	.	.
J= 2	.	.	.	.	.	136.	407.	1221.	1633.	1362.	.	454.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

ANNEX 2: MAIN ROAD TRAFFIC WORK

MAP OF TRAF. WORK UNIT: 100 CAR-KM/DAY

MAX. VALUE IS 2.6653E+05, IN (8 , 15)
SUM= 1.54178E+07 SCALE: 1.0E+02

GRID SIZE 1000 METER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
J=30	.	114.	12.	315.	.	300.	.	195.	153.	153.	183.	35.	.	.	527.	188.	.	.
J=29	.	.	132.	50.	422.	449.	207.	10.	.	.	121.	94.	129.	433.	500.	.	.	.
J=28	37.	138.	312.	302.	1145.	1156.	851.	974.	947.	510.	326.	97.	825.	491.	87.	.	.	.
J=27	137.	.	71.	110.	846.	586.	.	251.	351.	804.	1132.	1264.	265.	65.	85.	.	.	.
J=26	15.	189.	.	423.	485.	975.	236.	318.	854.	872.	1066.	194.	51.	151.	.	.	.	.
J=25	.	181.	146.	718.	609.	482.	454.	1355.	524.	867.	1592.	366.	383.	561.	330.	153.	152.	152.
J=24	.	226.	335.	771.	935.	600.	1345.	964.	578.	826.	767.	1470.	693.	.	141.	212.	92.	204.
J=23	.	302.	240.	760.	1151.	1008.	.	439.	593.	1058.	221.	1351.	545.	94.	.	232.	269.	.
J=22	.	457.	414.	743.	1824.	912.	712.	1271.	393.	479.	868.	584.	569.	100.	50.	150.	76.	87.
J=21	.	59.	694.	1595.	620.	809.	64.	321.	499.	48.	32.	640.	523.	.	102.	179.	.	163.
J=20	.	.	613.	2168.	659.	1015.	113.	278.	82.	432.	464.	1200.	331.	350.	607.	539.	307.	438.
J=19	.	.	.	1220.	851.	1656.	213.	112.	.	.	455.	1635.	326.	205.	297.	43.	.	.
J=18	.	.	.	591.	1322.	1043.	488.	394.	533.	161.	2068.	230.	641.	565.	341.	.	.	.
J=17	.	.	.	.	1136.	765.	1431.	1268.	1538.	1777.	758.	278.	468.	108.	.	.	.	.
J=16	.	.	.	21.	1288.	430.	966.	1373.	1925.	734.	152.	152.	257.	108.	.	.	.	.
J=15	.	.	.	.	810.	752.	1024.	2665.	254.	4.	284.	3.	40.	149.	.	.	.	.
J=14	.	.	.	.	822.	610.	487.	845.	916.	183.	128.	.	.	157.	.	.	.	.
J=13	.	.	.	.	677.	605.	.	.	1135.	.	.	.	.	79.	.	.	.	.
J=12	.	.	.	.	481.	969.	242.	.	531.	1061.	.	.	39.	79.	.	.	.	.
J=11	.	.	.	.	536.	568.	.	.	.	531.	.	.	79.	.	.	.	.	.
J=10	.	.	.	104.	1002.	127.	.	.	.	1061.	531.	.	39.	.	.	.	.	.
J= 9	.	.	.	595.	533.	106.	.	.	85.	217.	1155.	203.	65.	.	.	.	.	.
J= 8	.	212.	531.	144.	.	830.	415.	.	.	.	830.	.	.	.	.	.	.	.
J= 7	.	368.	178.	.	.	.	415.	830.	415.	.	830.	.	.	.	.	.	.	.
J= 6	27.	54.	543.	.	.	.	.	.	830.	415.	830.	.	.	.	.	.	.	.
J= 5	54.	.	415.	415.	830.	.	.	.	.	.	1244.	.	.	.	.	.	.	.
J= 4	27.	.	.	.	415.	830.	415.	.	.	.	830.	.	.	.	.	.	.	.
J= 3	.	.	.	.	.	.	415.	830.	415.	.	830.	.	.	.	.	.	.	.
J= 2	.	.	.	.	.	.	.	.	830.	415.	830.	.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	170.	1589.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

ANNEX 3: TRAFFIC NO_x EMISSIONS

MAP OF NOx traf UNIT: Kg/h

MAX. VALUE IS 1.0293E+02, IN (8 , 15)

SUM= 9.89485E+03 SCALE: 1.0E-01

GRID SIZE 1000 METER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
J=30	35.	49.	49.	130.	81.	104.	138.	183.	312.	312.	319.	239.	138.	138.	214.	135.	46.	58.
J=29	69.	23.	134.	81.	155.	380.	278.	187.	323.	277.	304.	252.	214.	192.	161.	46.	46.	81.
J=28	193.	66.	268.	484.	679.	635.	288.	363.	541.	348.	306.	22.	236.	298.	112.	.	12.	115.
J=27	216.	288.	155.	440.	610.	458.	184.	288.	450.	416.	307.	430.	246.	153.	158.	12.	35.	92.
J=26	3.	182.	461.	512.	365.	594.	377.	442.	566.	385.	384.	321.	288.	173.	104.	23.	92.	46.
J=25	.	249.	725.	649.	371.	526.	381.	589.	490.	523.	690.	361.	457.	314.	111.	128.	127.	58.
J=24	.	467.	630.	731.	884.	668.	587.	361.	364.	467.	500.	662.	436.	230.	90.	130.	125.	47.
J=23	.	485.	747.	728.	818.	301.	576.	286.	459.	567.	235.	588.	402.	252.	35.	76.	143.	.
J=22	.	382.	718.	724.	904.	833.	786.	662.	506.	571.	661.	596.	362.	254.	58.	46.	98.	20.
J=21	.	14.	436.	644.	489.	325.	153.	420.	507.	426.	284.	286.	443.	184.	208.	64.	12.	38.
J=20	.	.	487.	569.	636.	510.	233.	202.	249.	468.	476.	461.	192.	173.	151.	147.	117.	112.
J=19	.	.	.	420.	749.	866.	602.	210.	230.	369.	520.	619.	156.	128.	114.	22.	35.	35.
J=18	.	.	.	136.	789.	909.	643.	506.	492.	406.	845.	226.	252.	188.	113.	35.	.	.
J=17	.	.	.	35.	550.	418.	745.	707.	677.	825.	636.	202.	235.	94.	58.	23.	.	.
J=16	.	.	.	39.	378.	203.	545.	731.	813.	538.	81.	127.	209.	140.	23.	12.	.	.
J=15	.	.	.	.	210.	289.	409.	1029.	473.	324.	158.	1.	194.	115.	23.	12.	.	.
J=14	.	.	.	.	190.	233.	205.	437.	373.	54.	53.	.	23.	59.	.	.	.	.
J=13	.	.	.	.	156.	209.	.	46.	308.	12.	.	.	.	41.	.	.	.	.
J=12	.	.	.	.	122.	258.	90.	.	122.	245.	.	46.	21.	41.	23.	.	.	.
J=11	.	.	.	.	135.	142.	12.	35.	58.	180.	104.	92.	18.	.	81.	.	.	.
J=10	.	.	.	24.	243.	41.	104.	104.	69.	314.	180.	115.	32.	.	.	.	.	.
J= 9	.	.	.	160.	134.	47.	23.	92.	89.	154.	289.	70.	38.	.	.	.	.	.
J= 8	.	49.	122.	45.	23.	226.	130.	92.	81.	104.	226.	35.	12.	.	.	.	.	.
J= 7	.	85.	64.	81.	69.	81.	188.	295.	153.	92.	203.	23.	.	.	.	.	.	.
J= 6	6.	12.	206.	115.	69.	23.	115.	104.	249.	176.	203.	.	.	.	.	.	.	.
J= 5	12.	.	153.	199.	272.	92.	92.	104.	115.	81.	287.	.	.	.	.	.	.	.
J= 4	6.	.	35.	115.	211.	272.	176.	104.	115.	35.	214.	.	.	.	.	.	.	.
J= 3	.	.	.	35.	115.	104.	142.	283.	176.	92.	214.	.	.	.	.	.	.	.
J= 2	.	.	.	.	69.	92.	92.	81.	260.	130.	214.	.	.	.	.	.	.	.
J= 1	.	.	.	.	12.	35.	104.	92.	69.	39.	389.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

ANNEX 4: TRAFFIC EXHAUST PARTICLE EMISSIONS

MAP OF Part traf UNIT: Kg/h

MAX. VALUE IS 1.4602E+01, IN (8 , 15)
SUM= 1.40374E+03 SCALE: 1.0E-02

GRID SIZE 1000 METER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
J=30	49.	70.	69.	185.	114.	147.	196.	260.	442.	442.	452.	338.	196.	196.	303.	192.	65.	82.
J=29	98.	33.	190.	115.	220.	539.	395.	265.	458.	392.	432.	358.	304.	272.	229.	65.	65.	114.
J=28	274.	94.	380.	687.	963.	901.	409.	515.	768.	494.	434.	32.	335.	422.	159.	.	16.	163.
J=27	306.	409.	219.	624.	865.	650.	262.	409.	638.	590.	435.	610.	348.	218.	224.	16.	49.	131.
J=26	5.	258.	654.	727.	518.	842.	535.	627.	803.	547.	545.	456.	409.	245.	147.	33.	131.	65.
J=25	.	354.	1029.	921.	526.	746.	541.	835.	694.	741.	978.	512.	648.	445.	157.	181.	181.	83.
J=24	.	663.	894.	1037.	1254.	948.	832.	512.	516.	663.	709.	939.	619.	327.	128.	184.	177.	67.
J=23	.	687.	1059.	1033.	1161.	428.	818.	405.	652.	804.	334.	834.	570.	358.	49.	109.	203.	.
J=22	.	542.	1018.	1028.	1283.	1181.	1116.	939.	717.	811.	938.	845.	513.	360.	82.	65.	139.	28.
J=21	.	19.	619.	914.	693.	461.	217.	595.	719.	604.	403.	405.	629.	262.	295.	91.	16.	53.
J=20	.	.	691.	807.	902.	724.	331.	287.	354.	665.	675.	654.	272.	245.	215.	209.	166.	160.
J=19	.	.	.	595.	1063.	1228.	854.	298.	327.	523.	737.	878.	221.	182.	162.	31.	49.	49.
J=18	.	.	.	193.	1119.	1289.	912.	717.	698.	576.	1199.	321.	357.	266.	160.	49.	.	.
J=17	.	.	.	49.	780.	594.	1057.	1003.	961.	1170.	902.	287.	333.	133.	82.	33.	.	.
J=16	.	.	.	56.	536.	288.	774.	1038.	1153.	763.	115.	181.	297.	199.	33.	16.	.	.
J=15	.	.	.	.	298.	409.	580.	1460.	672.	459.	224.	1.	275.	163.	33.	16.	.	.
J=14	.	.	.	.	269.	330.	290.	620.	529.	76.	74.	.	33.	84.	.	.	.	.
J=13	.	.	.	.	221.	296.	.	65.	437.	16.	.	.	.	58.	.	.	.	.
J=12	.	.	.	.	174.	366.	128.	.	174.	347.	.	65.	29.	58.	33.	.	.	.
J=11	.	.	.	.	192.	202.	16.	49.	82.	255.	147.	131.	26.	.	114.	.	.	.
J=10	.	.	.	34.	344.	58.	147.	147.	98.	445.	255.	163.	46.	.	.	.	.	.
J= 9	.	.	.	227.	191.	67.	33.	131.	126.	218.	410.	99.	54.	.	.	.	.	.
J= 8	.	69.	174.	63.	33.	320.	185.	131.	114.	147.	320.	49.	16.	.	.	.	.	.
J= 7	.	120.	91.	114.	98.	114.	266.	418.	217.	131.	288.	33.	.	.	.	.	.	.
J= 6	9.	18.	292.	163.	98.	33.	163.	147.	353.	250.	288.	.	.	.	.	.	.	.
J= 5	18.	.	217.	283.	386.	131.	131.	147.	163.	114.	407.	.	.	.	.	.	.	.
J= 4	9.	.	49.	163.	299.	386.	250.	147.	163.	49.	304.	.	.	.	.	.	.	.
J= 3	.	.	.	49.	163.	147.	201.	402.	250.	131.	304.	.	.	.	.	.	.	.
J= 2	.	.	.	.	98.	131.	131.	114.	369.	185.	304.	.	.	.	.	.	.	.
J= 1	.	.	.	.	16.	49.	147.	131.	98.	56.	552.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18FELT FOR Pa

Appendix 5

Emission Factors, Particles

Contents

Emission Factors, Particles

1. Introduction

Emission factors (emitted amount of pollutant per quantity of combusted fuel, or per km driven, or per produced unit of product) are important input data to emission inventories, which again are essential input to dispersion modelling.

The knowledge of emission factors representative for the present technology level of Asian cities is limited. For the purpose of selecting emission factors for the URBAIR study, references on emission factors were collected from the open literature and from studies and reports from cities in Asia.

This appendix gives a brief background for the selection of emission factors for particles used in the air quality assessment part of URBAIR.

2. Motor vehicles

The selection of emission factors for motor vehicles for use in the URBAIR project to produce emission inventories for South-East Asian cities, was based on the following references:

- WHO (1993)
- US EPA (EPA AP42 report series) (1985)
- Vehicles Emission Control Project (VECP), Manila (Baker, 1993)
- Indonesia (Bosch, 1991)
- Williams et al. (1989)
- Motorcycle emission standard and emission control technology (Weaver and Chan, 1993)

Table 1 gives a summary of emission factors from these references for various vehicle classes. From these, the emission factors given in Table 2 were selected, for use as a basis for URBAIR cities.

Taking into account the typical vehicle/traffic activity composition, the following vehicle classes give the largest contributions to the total exhaust particle emissions from traffic:

- Heavy duty diesel trucks
- Diesel buses
- Utility trucks, diesel
- 2-stroke 2- and 3-wheelers.

Thus, the emission factors for these vehicle classes are the most important ones.

Table 1: Emission factors (g/km) for particle emissions from motor vehicles, relevant as a basis for selection of factors to be used in South-East Asian cities.

Fuel and Vehicle	Particles g/km	Reference
Gasoline		
Passenger cars	0.33	USEPA/WHO
	0.10	VECP, Manila
	0.16	Indonesia (Bosch)
	0.07	Williams
Trucks, utility	0.12	VECP, Manila
	0.33	USEPA
		USEPA
Trucks, heavy duty	0.33	USEPA
3-wheelers, 2 stroke	0.21	USEPA/WHO
MC 2/4 stroke	0.21/	USEPA/WHO
	2.00/	VECP, Manila
	0.21/0.029	Indonesia VWS
	0.28/0.08	Weaver and Chan
Diesel		
Car, taxi	0.6	VECP, Manila
	0.45	USEPA/WHO
	0.37	Williams
Trucks, utility	0.9	VECP, Manila
	0.93	EPA
Trucks, heavy/bus	0.75	WHO
	1.5	VECP, Manila
	0.93	USEPA
	1.2	Bosch
	2.1	Williams

Table 2: Selected emission factors (g/km) for particles from road vehicles used in URBAIR.

Vehicles class	Gasoline	Diesel
Passenger cars/taxies	0.2	0.6
Utility vehicles/light trucks	0.33	0.9
Motorcycles/tricycles	0.5	
Trucks/buses		2.0

Comments

It is clear that there is not a very solid basis in actual measurements on which to estimate particle emission factors for vehicles in South-East Asian cities. The given references represent the best available basis. Comments are given below for each of the vehicle classes.

Gasoline:

Passenger cars:	Fairly new, normally well maintained cars, engine size less than 2.5 l, without 3-way catalyst, running on leaded gasoline (0.2-0.3 g Pb/l), have an emission factor of the order of 0.1 g/km. Older, poorly maintained vehicles may have much larger emissions. The US EPA/WHO factor of 0.33 g/km can be used as an estimate for such vehicles.
Utility trucks:	Although the VECP study (Manila) uses 0.12 g/km, the EPA factor of 0.33 g/km was selected for such vehicles, taking into account generally poor maintenance in South-East Asian cities.
Heavy duty trucks:	Only the USEPA has given an estimate for such vehicles, 0.33 g/km, the same as for passenger cars and utility trucks.
3-wheelers, 2 stroke:	The USEPA and WHO suggest 0.2 g/km for such vehicles.
Motorcycles, 2 stroke:	The Weaver report supports the 0.21 g/km emission factor suggested by USEPA/WHO. In the VECP Manila study a factor of 2 g/km is suggested. This is the same factor as for heavy duty diesel trucks, which seems much too high. Visible smoke emissions from 2-stroke 2- and 3-wheelers is normal in South-East Asian cities. Low-quality oil as well as worn and poorly maintained engines probably both contribute to the large emissions. The data base for selecting a representative emission factor is small. In the data of Weaver and Chan (1993), the highest emission factor is about 0.55 g/km. For URBAIR, we choose a factor of 0.5 g/km. Realizing that this is considerably higher than the factor suggested by US EPA, we also take into consideration the factor 2 g/km used in the VECP study in Manila, which indicates evidence of very large emissions from such vehicles.
Motorcycles, 4-stroke:	The emission factor is much less than for 2-stroke engines. The Weaver report gives 0.08 g/km, while 0.029 g/km is given by the VWS study in Indonesia (Bosch, 1991).

Diesel:

Passenger cars, taxis: The factor of 0,6 g/km given by the VECP Manila is chosen, since it is based on measurements of smoke emission from vehicles in traffic in Manila. The 0,45 g/km of USEPA/WHO was taken to represent typically maintained vehicles in Western Europe and USA, as also measured by Larssen and Heintzenberg (1983) on Norwegian vehicles. This is supported by Williams' factor of 0,37 g/km for Australian vehicles.

Utility trucks: The USEPA and the VECP Manila study give similar emission factors, about 0,9 g/km.

Heavy duty trucks/ buses: The factors in the table range from 0,75 g/km to 2,1 g/km.

It is clear that "smoking" diesel trucks and buses may have emission factors even much larger than 2 g/km. In the COPERT emission data base of the European Union factors as large as 3-5 g/km are used for "dirty" city buses. Likewise, based on relationships between smoke meter reading (e.g. Hartridge smoke units, HSU) and mass emissions, it can be estimated that a diesel truck with a smoke meter reading of 85 HSU, as measured typically on Kathmandu trucks and buses (Rajbahak and Joshi, 1993), corresponds to an emission factor of roughly 8 g/km!

As opposed to this, well maintained heavy duty diesel trucks and buses have an emission factor of 0,7-1 g/km.

As a basis for emission calculations for South-East Asian cities we choose an emission factor of 2 g/km. This corresponds to some 20% of the diesel trucks and buses being "smoke belchers". A larger fraction of "smoke belchers", such as in Kathmandu, will result in a larger emission factor.

3. Fuel combustion

Oil

The particle emission factors suggested by USEPA (AP 42) are taken as a basis for calculating emissions from combustion of oil in South-East Asian cities. The factors are given in Table 3.

Table 3: Emission factors for oil combustion (Ref.: US EPA, AP 42). (kg/m³)

	Emission factor	
	Uncontrolled	Controlled
Utility boilers		
Residual oil[a)]		
Grade 6	1.25(S)+0.38	×0.008 (ESP)
Grade 5	1.25	×0.06 (scrubber)
Grade 4	0,88	×0.2 (multicyclone)
Industrial/commercial boilers		
Residual oil	(as above)	×0.2 (multicyclone)
Distillate oil	0.24	
Residential furnaces		
Distillate oil	0.3	

S: Sulphur content in % by weight

a): Another algorithm for calculating the emission factors is as follows: 7,3xA kg/m³, where A is the ash content of the oil.

4. References

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Appendix 6

Population Exposure Calculations

Population Exposure Calculations

Methodology

An estimate of the exposure of the population of Metro Manila to air pollution concentrations can be arrived at only through application of dispersion models, and on the basis of an emissions survey and the results of air pollution monitoring.

The data base for making an exposure estimate for Metro Manila, under present conditions, is not quite complete. The most important shortcoming is that there are virtually no data on emissions from industrial processes and from refuse burning. Also, the data base on meteorological measurements in Metro Manila is not entirely consistent. There is a substantial data base on air quality measurements. However, more frequent measurements would be desired, and also a more stringent definition and location of measurement sites (city background/street site/industrial hot spot site).

However, the existing data base is sufficient for producing an exposure estimate. We use the survey of emissions from road vehicles ("traffic") as a basis (see Appendix 1). Based on the traffic data supplied, and the population distribution, we consider the spatial distribution of traffic emissions which has been produced, as being of sufficiently good quality. The methodology used is as follows:

1. Emissions of car exhaust were distributed in the km^2 grid net, based on
   - road vehicle and traffic data
   - total fuel consumption
   - population distribution in the km^2 grid net.
2. Annual average concentrations of car exhaust compounds were calculated for each km^2, based on meteorological data for the Port Area met.station (see ch. 2.3 of the main report). These calculated concentrations represent the general "city background" concentrations in each km^2.
3. The car exhaust concentration field was adjusted upwards, applying a factor equal to the ratio between the total emissions of all known area sources (traffic, fuel combustion, construction, refuse burning) and the traffic emissions. A background value of extra-urban pollution concentrations was added:

$$C_{area} = \frac{C(traffic, fuel, refuse, constr.)}{C_{traffic}} + C_{backgr.}$$

   The same factor was applied over the entire area.

4. Each inhabitant is given, as his "exposure value", the concentration calculated for the km^2 grid square where his home is situated. Based on this, a basic exposure curve (number of people exposed to concentrations higher than certain values) is constructed.

5. Measurements at the DENR-NCR sites indicate increased concentrations in **industrial areas** (e.g. Valenzuela, Pasig). Industrial areas are dispersed throughout the Metro Manila region. This additional industrial pollution exposure is accounted for by giving 50% of the people in each concentration interval an added concentration value.

6. The increased concentrations close to the main road system are taken into account in the exposure curve by giving roadside residents, commuters and "workers on the road" (drivers, policemen etc.) an additional concentration value, estimated on the basis of the VECP/ADB measurements at roadside sites.

Calculation of population exposure to air pollution in Metro Manila

The methodology described above is followed and gives the results shown in Table 1.

The table gives:

1. The number of inhabitants living in grid squares with average TSP concentrations (C) within various ranges.

2. The estimation of additional exposure due to industrial emissions and road exposure, and the resulting total exposure.

Table 1: Calculated population exposure to TSP (annual average) in Metro Manila, present conditions (1992).

C traffic $\mu g/m^3$	C area sources[1] + background $\mu g/m^3$	Population exposure, area sources 10^3 inh.	Additional exposure, due to industry[2] 10^3 inh.		Population exposure, area sources + industry 10^3 inh.	Additional exposure due to road side 10^3 inh.	Resulting population exposure[3] 10^3 inh.
	275					A = 65	65
>40	205-225		50		50	B = 300	350
35-40	180-205	210	140	370	670	C/3 = 800	1 470
30-35	160-180	550	370	250	1 030	-D	570
25-30	140-160	1 470	250	240	1 220	-D	760
20-25	115-140	1 010	240	250	750	C/3-D	1 090
15-20	95-115	940	250		460	C/3-D	800
10-15	75- 95	1 000			1 000	-D	540
<10	30- 75	1 470			1 470	-D	1 010
Sum					6 650		6 655

1. Area sources: Traffic + ind./comm. fuel combustion + refuse burning + construction.
   Traffic emissions = 23% of total area source emissions.
2. 25% of inhabitants in each km^2 is given an additional 20 $\mu g/m^3$.
   25% of inhabitants in each km^2 is given an additional 40 $\mu g/m^3$.
3. A: No. of roadside residents = 65 000, exposed to an estimated 275 $\mu g/m^3$
   B: No. of drivers/policemen = 300 000, exposed to an estimated 220 $\mu g/m^3$
   C: No. of road commuters = 2 400 000, exposed to an estimated 185/135/100 $\mu g/m^3$
   (33% of the 2 400 000 in each of the three concentration levels).
   D = (A+B+C)/6:The A, B, and C inhabitants are moved from the lower to the higher exposure classes.

Additional exposure due to roadside exposure (on and near roads) is calculated by the following method:

1. The average on-the-road TSP concentration (annual average) is estimated to be 350 μg/m^3, based on the road and TSP data in Table 2.

2. The following categories of people are given the following exposure:

Drivers/policemen:	Working hours (8 hrs)	:	350 μg/m^3
	Rest of day (16 hrs)	:	150 μg/m^3
	Average	:	220 μg/m^3

Road commuters:

		While commuting (2hrs)	Rest of day (22 hrs)	Average
High exposure	(μg/m^3):	570	150	185
Medium exposure	(μg/m^3):	300	120	135
Low exposure	(μg/m^3):	220	90	100

Residents near roads:

Average road side exposure	350 μg/m^3
Average city background:	150 μg/m^3

The average resident near roads is given the average exposure between road side and city background, i.e. **275 μg/m^3**.

Table 2: Estimated on-the-road TSP concentration (annual average) as a function of AADT (vehicles/day).

AADT on Manila Main Road Network AADT	km	Estimated on-the-road TSP conc. (μg/m^3)
120-140 000	11	570
100-120 000	6	500
80-100 000	16	430
60- 80 000	30	360
40- 60 000	69	290
20- 40 000	120	220
<20 000		150

3. The number of individuals in each category of people exposed to or near the main road network is estimated as described below.

   It is obvious that these are very rough estimates, but they are believed to be of a realistic order of magnitude.

Drivers/policemen

	No. of vehicles	No. of drivers on road daily	No. of persons exposed
Jeepneys	50 000	2	100 000
Buses	5 000	2	10 000
UVs	200 000	0.5	100 000
Trucks	50 000	0.5	25 000
Tricycles	20 000	1	20 000
Total	325 000		255 000

With addition of policemen and other drivers, the no. of "road workers" daily exposed to road concentrations for several hours is estimated to be **300 000**.

Commuters

- No. of person trips daily: 17.7 mill (TTMM, 1993)
- Traffic activity on the main road network: 50% of total
- On the average each person does 3-4 trips per day.

This gives an estimate of **2-3 mill people** commuting on the main road network every day, spending a total of some 1-2 hours per day "on the road".

In the exposure calculation model for Table 2, the figure of 2.4 mill was used as an estimate of the number of road commuters, distributed equally between high, medium and low road exposure, as calculated on the previous page .

Roadside residents

- Length of main roads with AADT <40 000: 130 km
- Length of main roads with residents alongside: 50% of the above, with 50% roadside house coverage
- residents per 10 m roadside.

This gives an estimate of **65 000** roadside residents.

Appendix 7

Spreadsheets for Calculating Effects of Control Measures on Emissions and Exposure

Contents

Spreadsheets for Calculating Effects of Control Measures on Emissions and Exposure

1. Emission spreadsheet

The spreadsheet is shown in Figure 1 and 2. (Examples: TSP and PM_{10} emissions, Metro Manila, Base Case Scenario, 1992.) Figure 3 shows emission contributions for TSP, in absolute and relative terms.

The purpose of the spreadsheet is to calculate modified emission contributions, due to control measures, such as:

- new vehicle technology
- improved emission characteristics, through measures on existing technology
- reduced traffic activity/fuel consumption
- other.

The emissions are calculated separately for large point sources (with tall stacks) and for area sources and smaller distributed point sources. The reason is that air pollution concentrations and population exposures are calculated differently for these two types of source categories.

The columns and rows of the worksheet are as follows:

Columns

a)	q	Emission factor, g/km for vehicles, kg/m^3 or kg/ton for fuel combustion and process emissions. For vehicles, emission factors are given for "existing" and "new" technology.
b)	F, T	Amount of "activity" T (vehicle km) for traffic activity F (m^3 or ton) for fuel consumption in industrial production.
c)	qT, qF	Base case emissions, tons, calculated as product of columns a) and b).
d)	fq, fF, fT, f-	Control measures. Relative reduction of emission factor (fq), amount (fF, fT) or other (f-) resulting from control measures.

TOTAL ANNUAL EMISSIONS, METRO MANILA
TSP, Scenario: 1992

		Emission factor	Amount	Base-case Emissions	Control measures			Modified emissions	Relative emissions per category	Relative emissions total
LARGE POINT SOURCES										
		q (kg/m3)	F (10E3m3)	qF (10E3 tonnes)	fq	fF	f	qF fq fF f (10E3 tonnes)	(dqF fq fFf) (percent)	(dqF fq fFf)tot (percent)
Power plants		1.50	1410	2.12	1.00	1.00	1.00	2.12		100.0
								0.00		0.0
								0.00		0.0
Sum large point sources				2.12				2.12		100.0
Modified emissions/emissions, point sourc.								1.00		
AREA SOURCES AND DISTRIBUTED POINT SOURCES										
Vehicles		q (g/km)	T (10E9 km)	qT (10E3 tonnes)	fq	fT	f	qT fq fTf (10E3 tonnes)	(dqT fq fTf) (percent)	(dqT fq fTf) (percent)
Gasoline exhaust										
Cars	Exist.	0.20	2.92	0.58	1	1	1	0.58	6.6	1.0
	New	0.05	0.00	0.00	1	1	1	0.00	0.0	0.0
UV	Exist.	0.33	3.57	1.18	1	1	1	1.18	13.2	2.0
	New	0.05	0.00	0.00	1	1	1	0.00	0.0	0.0
MC/TC	Exist. 2	0.50	0.57	0.29	1	1	1	0.29	3.2	0.5
	4	0.10	0.00	0.00	1	1	1	0.00	0.0	0.0
	New 2		0.00	0.00	1	1	1	0.00	0.0	0.0
	4		0.00	0.00	1	1	1	0.00	0.0	0.0
Truck/bus	Exist.	0.68	0.22	0.15	1	1	1	0.15	1.7	0.2
	New			0.00	1	1	1	0.00	0.0	0.0
Sum gasoline				2.20				2.20		3.6
Modified emissions/emissions, gasoline								1.00		
Diesel exhaust										
Taxi	Exist.	0.6	0.29	0.17	1	1	1	0.17	2.0	0.3
	New	0.2	0.00	0.00	1	1	1	0.00	0.0	0.0
Jeepney	Exist.	0.9	1.75	1.58	1	1	1	1.58	17.7	2.6
	New	0.5	0.00	0.00	1	1	1	0.00	0.0	0.0
UV	Exist.	0.9	1.29	1.16	1	1	1	1.16	13.0	1.9
	New	0.5	0.00	0.00	1	1	1	0.00	0.0	0.0
Truck/bus	Exist.	2.0	1.90	3.80	1	1	1	3.80	42.7	6.3
	New	0.7	0.00	0.00	1	1	1	0.00	0.0	0.0
Sum diesel				6.71				6.71		11.1
Modified emissions/emissions, diesel								1.00		
Sum total vehicle exhaust				8.91				8.91	100.0	14.7
Modified emissions/emissions, total vehicle exhaust								1.00		
Resuspension		*1.0*	12.51	12.51	1	1	1	12.51		20.7
Sum total vehicles (exh.+resusp.)				21.42				21.42		35.5
Modified emissions/emissions, total vehicles (exh. + resusp.)								1.00		
Fuel combustion		q (kg/m3)	F (10E3m3)	qF (10E3 tonnes)	fq	fF	f	qF fq fF f (10E3 tonnes)	(dqF fq fFf)fuel (percent)	(dqF fq fFf)tot (percent)
BOF										
Ind./commercial		5.10	2820	14.38	1.00	1.00	1.00	14.38	84.7	23.8
DOF										
Ind./comm./domest.		1.40	1820	2.55	1.00	1.00	1.00	2.55	15.0	4.2
Domestic										
Kerosene		0.06	312	0.02	1.00	1.00	1.00	0.02	0.1	0.0
LPG		0.06	682	0.04	1.00	1.00	1.00	0.04	0.2	0.1
Wood				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Coal				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Dung				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Sum domestic				0.06				0.06	0.4	0.1
Modified emissions/emissions, domestic								1.00		
Sum fuel combustion				16.99				16.99	100.0	28.1
Modified emissions/emissions, fuel								1.00		
Industrial processes		q	F	qF	fq	fF	f	qF fq fF f	(dqF fq fFf)ind. (percent)	(dqF fq fFf)tot (percent)
				0	1	1	1	0.00	0.0	0.0
				0	1	1	1	0.00	0.0	0.0
Total				6	1	1	1	6.00	100.0	9.9
Sum industrial processes				6				6.00	100.0	9.9
Modified emissions/emissions, ind. proc.								1.00		
Miscellaneous		q	M	qM	fq	fM	f	qM fq fM f	(dqM fq fMf)misc (percent)	(dqM fq fMf)tot (percent)
Refuse burning				6	1	1	1	6.00	37.5	9.9
Construction				10	1	1	1	10.00	62.5	16.6
Sum miscellaneous				16				16.00	100.0	26.5
Modified emissions/emissions, misc.								1.00		
"Background"				6				6.00		
Unknown										
Sum total area sources, excl. "Backgr."				60.41				60.41		100.00
Modified emissions/emissions, total area sources								1.00		

Figure 1: URBAIR spreadsheet for emission calculations, TSP.*

* In this example of the spreadsheet, the emission factor for resuspension was set to 1.0 g/km, while 2.0 g/km has been assumed to be more realistic, and has been used throughout the URBAIR study. Thus, emission figures in this example spreadsheet deviates from those other places in the Manila report.

TOTAL ANNUAL EMISSIONS, METRO MANILA
PM10, Scenario: 1992

		Emission factor	Amount	Base-case Emissions	Control measures			Modified emissions	Relative emissions per category	Relative emissions total
LARGE POINT SOURCES										
		q	F	qF	fq	fF	f-	qF fq fF f	(dqF fq fFf)	(dqF fq fFf)tot
		(kg/m3)	(10E3m3)	(10E3 tonnes)				(10E3 tonnes)	(percent)	(percent)
Power plants		1.40	1662	2.33	1.00	1.00	1.00	2.33		100.0
								0.00		0.0
								0.00		0.0
Sum large point sources				**2.33**				**2.33**		**100.0**
Modified emissions/emissions, point sourc.								1.00		
AREA SOURCES AND DISTRIBUTED POINT SOURCES										
Vehicles		q	T	qT	fq	fT	f-	qT fq fTf	(dqT fq fTf)	(dqT fq fTf)
		(g/km)	(10E9 km)	(10E3 tonnes)				(10E3 tonnes)	(percent)	(percent)
Gasoline exhaust										
Cars	Exist.	0.20	2.92	0.58	1	1	1	0.58	6.6	1.5
	New	0.05	0.00	0.00	1	1	1	0.00	0.0	0.0
UV	Exist.	0.33	3.57	1.18	1	1	1	1.18	13.2	2.9
	New	0.05	0.00	0.00	1	1	1	0.00	0.0	0.0
MC/TC	Exist. 2	0.50	0.57	0.29	1	1	1	0.29	3.2	0.7
	4	0.10	0.00	0.00	1	1	1	0.00	0.0	0.0
	New 2		0.00	0.00	1	1	1	0.00	0.0	0.0
	4		0.00	0.00	1	1	1	0.00	0.0	0.0
Truck/bus	Exist.	0.68	0.22	0.15	1	1	1	0.15	1.7	0.4
	New			0.00	1	1	1	0.00	0.0	0.0
Sum gasoline				2.20				2.20		5.5
Modified emissions/emissions, gasoline								1.00		
Diesel exhaust										
Taxi	Exist.	0.6	0.29	0.17	1	1	1	0.17	2.0	0.4
	New	0.2	0.00	0.00	1	1	1	0.00	0.0	0.0
Jeepney	Exist.	0.9	1.75	1.58	1	1	1	1.58	17.7	3.9
	New	0.5	0.00	0.00	1	1	1	0.00	0.0	0.0
UV	Exist.	0.9	1.29	1.16	1	1	1	1.16	13.0	2.9
	New	0.5	0.00	0.00	1	1	1	0.00	0.0	0.0
Truck/bus	Exist.	2.0	1.90	3.80	1	1	1	3.80	42.7	9.5
	New	0.7	0.00	0.00	1	1	1	0.00	0.0	0.0
Sum diesel				6.71				6.71		16.7
Modified emissions/emissions, diesel								1.00		
Sum total vehicle exhaust				8.91				8.91	100.0	22.2
Modified emissions/emissions, total vehicle exhaust								1.00		
Resuspension		0.50	12.51	6.26	1	1	1	6.26		15.6
Sum total vehicles (exh.+resusp.)				**15.16**				**15.16**		**37.8**
Modified emissions/emissions, total vehicles (exh. + resusp.)								1.00		
Fuel combustion		q	F	qF	fq	fF	f-	qF fq fF f	(dqF fq fFf)fuel	(dqF fq fFf)tot
		(kg/m3)	(10E3m3)	(10E3 tonnes)				(10E3 tonnes)	(percent)	(percent)
BOF										
Ind./commercial		4.30	2820	12.13	1.00	1.00	1.00	12.13	90.1	30.2
DOF										
Ind./comm./domest.		0.70	1820	1.27	1.00	1.00	1.00	1.27	9.5	3.2
Domestic										
Kerosene		0.06	312	0.02	1.00	1.00	1.00	0.02	0.1	0.0
LPG		0.06	682	0.04	1.00	1.00	1.00	0.04	0.3	0.1
Wood				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Coal				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Dung				0.00	1.00	1.00	1.00	0.00	0.0	0.0
Sum domestic				0.06				0.06	0.4	0.1
Modified emissions/emissions, domestic								1.00		
Sum fuel combustion				**13.46**				**13.46**	100.0	**33.5**
Modified emissions/emissions, fuel								1.00		
Industrial processes		q	F	qF	fq	fF	f-	qF fq fF f	(dqF fq fFf)ind.	(dqF fq fFf)tot
									(percent)	(percent)
				0	1	1	1	0.00	0.0	0.0
				0	1	1	1	0.00	0.0	0.0
Total				3	1	1	1	3.00	100.0	7.5
Sum industrial processes				3				**3.00**	100.0	**7.5**
Modified emissions/emissions, ind. proc.								1.00		
Miscellaneous		q	M	qM	fq	fM	f-	qM fq fM f	(dqM fq fMf)misc	(dqM fq fMf)tot
									(percent)	(percent)
Refuse burning				6	1	1	1	6.00	70.6	15.0
Construction				2.5	1	1	1	2.50	29.4	6.2
Sum miscellaneous				**8.5**				**8.50**	100.0	**21.2**
Modified emissions/emissions, misc.								1.00		
"Background"				6				6.00		
Unknown										
Sum total area sources, excl. "Backgr."				**40.12**				**40.12**		**100.00**
Modified emissions/emissions, total area sources								1.00		

Figure 2: URBAIR spreadsheet for emissions calculations, PM_{10}.

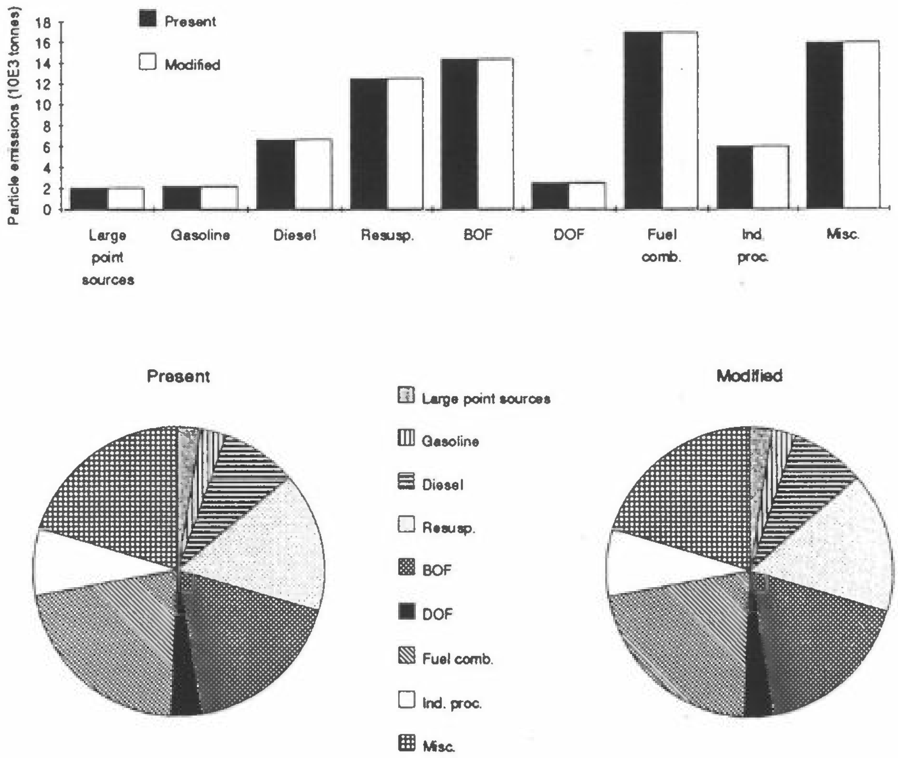

Figure 3: Emission contributions from various source categories.

e) qF fq fF f- Modified emissions, due to control measures.

f) d (qF fq fF f-) Relative emission contributions from each source, per source category:
- vehicles
- fuel combustion
- industrial processes
- miscellaneous

g) d (qF fq fF f-) Relative emission contributions, all categories summed.

Rows

a) Separate rows for each source type and category, "existing" and "new" technology.

b) "Background" : Fictitious emissions, corresponding to an extra-urban background concentration.

c) Modified emission/emissions : Ratio between modified and base case emissions.

2. Exposure calculations

Figure 4 shows the spreadsheet for calculating population exposure to air pollutants. The spreadsheet gives both base case exposure, and modified exposure due to control measures (Example shown: TSP exposure, Metro Manila, base case scenario, 1992).

The exposure calculation takes into account residence exposure due to area distributed emissions, additional exposure due to industrial process emissions, and additional road/roadside exposure. The methodology is described in Appendix 6.

The columns and rows of the spreadsheet are as follows:

Road exposure

a) Categories
- Roadside residents : People living close to the main road system.
- Road workers : Public transport and truck drivers, policemen, etc. spending several hours on the road every day.
- Commuters : People travelling on roads to work, shopping etc., spending 1-2 hours on the road daily.

The number of people in each category is estimated for **base case** and **other scenario ("Modified")**.

b) Concentration — Estimated average concentration that the category is exposed to. Base case.

c) Control measures — Relative reduction of emissions from
- area distributed sources (vehicles - fuel combustion + construction), f1.
- industrial processes, f2.

d) Modified concentrations — Base case concentration x f1 x f2.

e) Exposure — Percent of the total population exposed on the road, for each category
- base case
- other scenario ("Modified").

Residence exposure

a) Base case concentration
- x: Vehicles: Calculated concentration, from traffic emissions
- y: Area distributed sources: $y = x \dfrac{\textit{total area distributed emissions}}{\textit{traffic emissions}} + C_b$

b)
- f1: Relative reduction in area distributed source emissions
- f2: Relative reduction in industrial processes emissions

c) Modified concentrations:
- $z = \left[y - C_b\right] f1 + C_b$

d) Exposure

- o. Exposure due to area distributed sources and background: Percentage of total population with residence in the grids squares with calculated concentration, due to area-distributed sources+background, within the given concentration ranges.
- p,q: Added exposure due to emissions from industrial processes (see Appendix 6).
  p: base case
  q: scenario ("modified"): q=pxf2, i.e. the number of people given extra exposure due to industrial emissions is reduced proportionally to the ind. emission reduction.
- r,s: Added exposure, due to road/roadside exposure. (Values are taken from the "road exposure" table).
  r: base case
  s: scenarios ("modified").
- t,u: Combined exposure, area + industrial + roadside
  t: base case: t = o+p+r
  u: scenario: u = o+q+s
- v,w: Combined exposure as above.

The figures show the cumulative population exposure curves, as follows:

- base case total exposure curve (v vs y)

- for the given scenario:
  - residential exposure curve due to area distributed sources (o vs z)
  - residential exposure curve due to area distributed sources + industrial process emissions (o+q vs z)
  - total exposure curve (w vs z).

The inserted curve shows the details at the high exposure end of the curves.

POPULATION EXPOSURE, METRO MANILA
TSP (Annual average, ug/m3) Scenario: Base Case (1990)

Extra-urban background: 30 (ug/m3)

ROAD EXP.

Category			Conc.	Control measures		Mod. conc.	Exposure, % of total population	
	Base case	Modified		Vehicles + fuel	Industrial processes	Vehicles + fuel + background	Vehicles + fuel + backgr. Base case	Vehicles+ fuel + backgr. Modified
				f1	f2			
Roadside residents:	65000	65000	275	1	1	275	1.0	1.0
"Road workers":	300000	300000	220	1	1	220	4.5	4.5
Commuters C1:	800000	800000	185	1	1	185	12.0	12.0
C2:	800000	800000	135	1	1	135	12.0	12.0
C3:	800000	800000	100	1	1	100	12.0	12.0

RESIDENCE EXP.

Total population:	6655000

Base case concentration		Control measures		Mod. conc.	Exposure, % of total population								
Vehicles	Vehicles + fuel + background	Vehicles + fuel	Industrial processes	Vehicles + fuel + background	Vehicles + fuel + backgr. Base case	Add, due to industrial processes Base case	Modified	Add due to roadside exposure Base case	Modified	Combined Base case	Modified	Combined cumulative Base case	Modified
x	y	f1	f2	z	o	p	q	r	s	t	u	v	w
	250	1	1	250				1.0	1.0	1.0	1.0	1.0	1.0
	225	1	1	225		0	0	0.0	0.0	0.0	0.0	1.0	1.0
40	205	1	1	205	0.0	0.8	0.8	4.5	4.5	5.3	5.3	6.3	6.3
35	180	1	1	180	3.2	6.9	6.9	12.0	12.0	22.1	22.1	28.4	28.4
30	160	1	1	160	8.2	7.3	7.3	-6.9	-6.9	8.6	8.6	37.0	37.0
25	140	1	1	140	22.1	-3.8	-3.8	-6.9	-6.9	11.4	11.4	48.4	48.4
20	115	1	1	115	15.2	-3.9	-3.9	5.1	5.1	16.4	16.4	64.8	64.8
15	95	1	1	95	14.2	-7.3	-7.3	5.1	5.1	12.0	12.0	76.7	76.7
10	75	1	1	75	15.0	0.0	0.0	-6.9	-6.9	8.1	8.1	84.8	84.8
0	30	1	1	30	22.1	0.0	0.0	-6.9	-6.9	15.2	15.2	100.0	100.0

Figure 4: Spreadsheet for population exposure calculations.

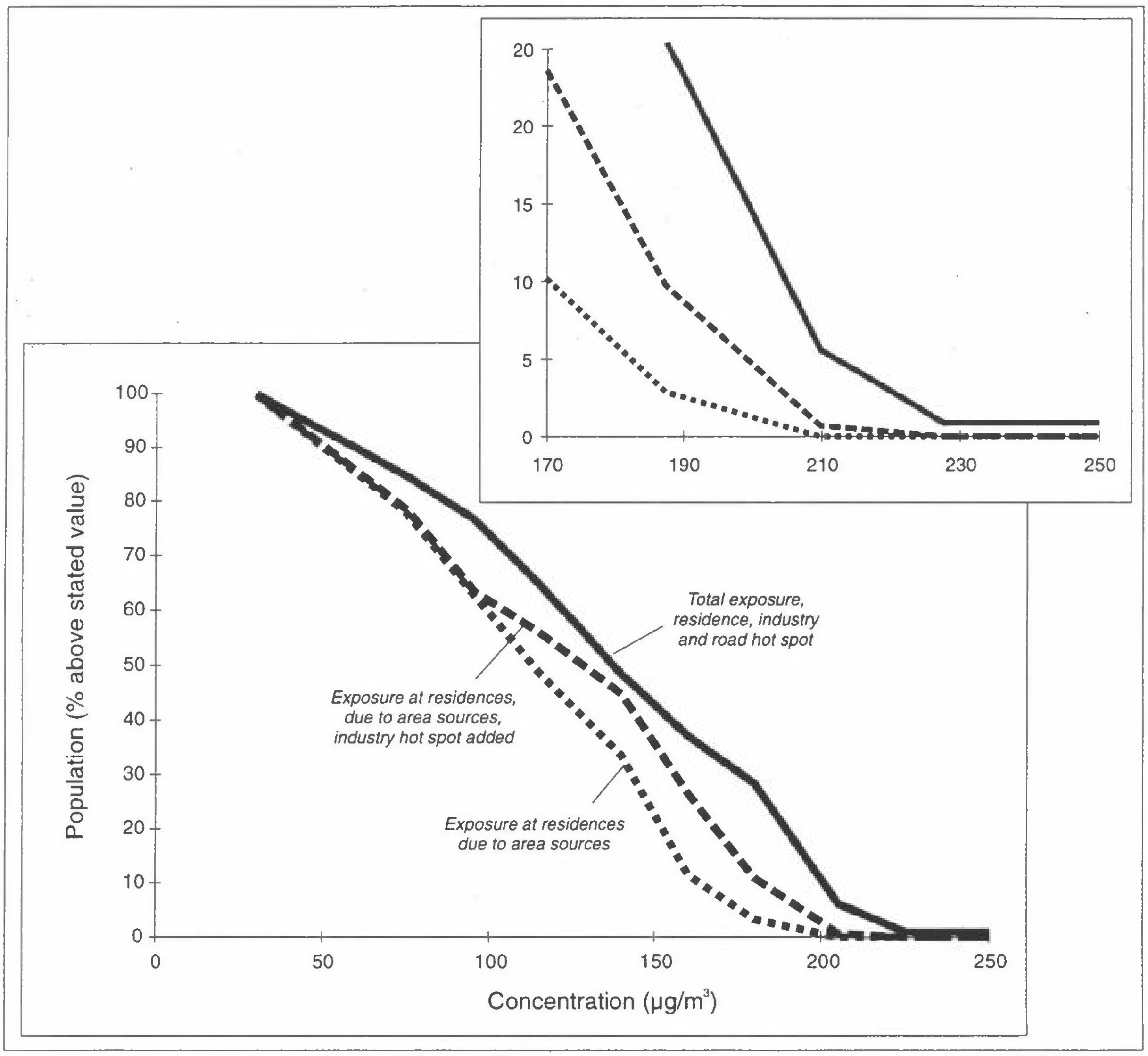

Figure 4: cont.

Appendix 8

Project Descriptions, Local Consultants

Contents

Page

Project Description Regarding Air Quality Assessment

18 May 1993 ANNEX 2

Project Description

This Project Description describes the work to be carried out under the Contract of 30 July 1993 between Norwegian Institute for Air Research (NILU) and the local consultants, Dr. Reynaldo M. Lesaca and Dr. Emmanuel Anglo.

Information shall be collected regarding the items described below. The information to be collected shall go beyond the information contained in the material referenced in the Draft Report from NILU and Institute of Environmental Studies (IES) of the Free University of Amsterdam prepared for the Workshop, and summarized in that report.

Available information shall be collected regarding the following items, and other items of interest for Air Quality Management Strategy Development in Metro Manila:

- Meteorological measurements in and near the city
- Activities/population data for Manila:

Fuel consumption data:	Total fuel consumption - per type (high/low sulphur oil, coal, gas, firewood and other biomass fuels, other) - per sector (industry, commercial, domestic)
Industrial plants:	- Location (on map), type/process, emissions, stack data (height, diameter, effluent velocity and temp.)
Vehicle statistics:	- No. of vehicles in each class (passenger cars, trucks (small, med., large), buses, MC (2 and 3-wheels, 2 and 4 stroke - Age distribution - Average annual driving distance per vehicle class
Traffic data:	Definition of the main road network marked on map. Traffic data for the main roads: - annual average daily traffic (vehicles/day) - traffic speed (average, and in rush hours) - vehicle composition (pass.cars, MCs, trucks/buses)
Population data:	Per city district (as small districts as possible) - total population - age distribution

- Air pollution emissions — Emission inventory data (annual emissions)
  - per compound (SO_2, NO_x, particles (in size fractions: <2 µm, 2-10 µm, >10 µm), (VOC, lead)
  - emissions per sector (industry, transport, domestic, etc.)

- Air pollution data:
  - concentration statistics per monitoring station: annual average, 98-percentile, maximum concentrations (24 hr, 1 hr)
  - trend information
  - methods description, and quality control information on methods

- Dispersion modelling: Reports describing studies and results

- Air pollution laws and regulations: Summary of existing laws and regulations

- Institutions: Description of existing institutions working in, and with responsibilities within, the air pollution sector, regarding:
  - monitoring
  - emission inventories
  - law making
  - enforcement

  The information shall include:
  - the responsibilities and tasks of the institutions
  - authority
  - manpower
  - expertise
  - equipment (monitoring, analysis, data hard/software)
  - funds

It is important that the gathering of information is <u>as complete as possible</u> regarding each of the items, so that we have a basis of data which is as updated and complete as possible. Remember that this updated completed information data base is to form the basis for an action plan regarding Air Quality Management in Metro Manila. Such an action plan will also include the need to collect more data. In that respect, it is very important that the gathering of existing data is <u>complete</u>.

Project description regarding Damage Assessment and Economic Valuation

Project Description

URBAIR

Topics for research

A. Physical Impacts

1. Describe available studies on relations between air pollution and health.

2. Decide on the acceptability of dose - effect relationships from USA (tables 5.7 - 5.9).
   a. Mortality: 10 µg/m^3 TSP leads to 0.682 (range: 0.48-0.89) percentage change in mortality.
   b. Work loss days (WLD): 1 µg/m^3 TSP leads to 0.00145 percentage change in WLD.
   c. Restricted activity days (RAD): 1 µg/m^3 TSP leads to 0.0028 percentage change in RAD per year.
   d. Respiratory hospital diseases (RHD): 1 µg TSP leads to 5.59 (range: 3.44-7.71) cases of RHD per 100,000 persons per year.
   e. Emergency room visits (ERV): 1 µg/m^3 TSP leads to 12.95 (range: 7.1-18.8) cases of ERV per 100,000 persons per year.
   f. Bronchitis (children): 1 µg/m^3 TSP leads to 0.00086 (range: 0.00043-0.00129) change in bronchitis.
   g. Asthma attacks: 1 µg/m^3 TSP leads to 0.0053 (range: 0.0027-0.0079) change in daily asthma attacks per asthmatic person.
   h. Respiratory symptoms days (RSD): 1 µg/m^3 TSP leads to 1.13 (range: 0.90-1.41) RSD per person per year.
   i. Diastolic blood pressure (DBP): change in DBP = 2.74 ($[\text{Pb in blood}]_{new}$ - $[\text{Pb in blood}]_{old}$) with [Pb in blood] is blood lead level (µg/dl).
   j. Coronary heart disease (CHD): change in probability of a CHD event in the following ten years is $[1 + \exp - \{ - 4.996 + 0.030365(DBP_1)\}]^{-1}$ –

$$\{ 1 + \exp - \{ - 4.996 + 0.0030365\ (DBP_2)\ \}\ \}^{-1}$$

   k. Decrement IQ points: IQ decrement = 0.975* change in air lead (µg/m^3).

Calculation example.

Let population be 10 million people.
Let threshold value of TSP be 75 µg/m³ (the WHO standard).
Let the concentration TSP be 317 µg/m³.
--> Concentration - threshold = 317 - 75 = 242 = 24.2 10 µg/m³.
--> Change in mortality = 24.2 * 0.682 = 16.5%.
Let crude mortality be 1% per year.
--> Crude mortality = 100,000 people per year.
--> Change in mortality due to TSP = 16.5% of 100,000 people = 16,500 people per year.

3. For those close -effect relationships that are acceptable, base value must be gathered, e.g.:
   a. crude mortality
   b. present work days lost
   etc.

B. Valuation

1. Mortality.
   a. Willingness to pay.
      In USA research has been carried out on the relation between risks of jobs and wages. It appeared that 1 promille of change in risk of mortality leads to a wage difference of ca. $1000. If this figure is applicable to all persons of a large population (say 10 million), the whole population values 1 promille change in risk of mortality at $1000 * 10 * 10⁶ = $ 10 billion. An increase in risk of 1 promille will lead to ca. 10,000 death cases, so per death case the valuation is $ 1 million. It should be decided if in other countries, e.q. cities, this valuation should be corrected for wage differences (e.g. if the average wage is 40 times lower than in USA, the valuation of 1 death case is $25,000). If this approach is acceptable, the only information needed is average wage.
   b. Production loss.
      If the approach of willingness to pay is not acceptable, the alternative is valuing human life through production loss, i.e. foregone income of the deceased. Again,

the information needed is average wage. Moreover, information is needed on the average number of years that people have a job. However, those without a job should also be assigned a value. An estimate of the income from informal activities can be an indication. Otherwise a value derived from the wages (e.g. half the average wage) can be a (somewhat arbitrary) estimation.

2. Morbidity.
Estimates are needed, for all cases of morbidity, of the duration of the illness, so as to derive an estimation of foregone production due to illness. Just as in the case of mortality (B. 1.b.) wages can be used for valuation of a lost working day. Moreover, the hospital costs and other medical costs are to be estimated. These costs still do not yet include the subjective costs of illness, which can be estimated using the willingness to pay to prevent a day of illness.

3. Willingness to pay to prevent a day of illness.
Valuation in USA, based on surveys among respondents, indicate that the willingness to pay to prevent a day of illness is ca. $15. This amount could, just like the amount of willingness to pay for risk to human health, be corrected for wage differences. The acceptability of such a procedure is, perhaps, somewhat lower.

4. IQ points.
Loss of IQ of children may lead to a lower earning capacity. A USA estimate is ca. $4600 per child, per IQ point, summed over the child's lifetime. If this is acceptable, the figure could be corrected for wage differences between USA and the city.

C. Other impacts

1. Buildings.
An estimate by Jackson et al, (see URBAIR report table 5.18) is that prevented cleaning costs per household per year are $42 for a reduction in TSP concentration: from 235 $\mu g/m^3$ to 115 $\mu g/m^3$. This would imply a benefit of $0.35 per household per $\mu g/m^3$ reduction. This figure could be corrected for wage differences between USA and the city. If that is acceptable, the information needed is the number of households in the city.

2. Monuments.

It is difficult to say which value is attached to monuments, as they are often unique and their value is of a subjective character. Nevertheless, the restoration and cleaning costs of monuments could be an indication of the order of magnitude of damage to monuments. Revenue of tourism might also give a certain indication of the valuation of future damage to monuments.

D. Remark

In most cases, the valuation of damage is not very precise, and certainly not more than an indication of the order of magnitude.

E. Technological Reduction Options

To give a reliable estimate of the costs of technological reduction options, one needs a reliable emission inventory in which is included the currently used technologies and the age and replacement period of the installed equipment. In the absence of this, the study by the city team might wish to concentrate on a case study (e.g. traffic, fertilizer industry, large combustion sources).

The first step is to identify options. Cooperation with IES is possible, once a case study is identified.

The second step is to estimate the costs, i.e. investment costs and O&M (operation and maintenance) costs. Based on the economic lifetime of the invested equipment, the investment costs can be transformed to annual costs, using writing-off procedures. Costs will often depend to a large extent on local conditions. Corrections of the costs are described in chapter 6 of the URBAIR report.

The third step is to estimate the emission reductions of the various reduction options.

The fourth step is to rank the options according to cost-effectiveness. For this purpose the various types of pollution have to be brought under a common denominator. A suggestion could be to calculate a weighed sum of the pollutants, using as weights the amount by which ambient standards are exceeded on average.

The calculation of the cost-effectiveness consists then of the calculation of the ratio of reduction over annual cost (R/C). The options with the highest ration R/C are the most cost-effective ones.

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ABSTRACT
The main report describes the development of an action plan for air quality improvement in Metro Manila, based upon the assessment of emissions and air quality in the metropolitan area, population exposure and health effects (damage), the assessment of costs related to the damage and to a number of proposed abatement measures, and a cost-benefit analysis.

This report contains appendices on air quality measurements, emission factors and inventory, exposure calculations, etc.

NORWEGIAN TITLE

KEYWORDS		
Air Pollution	Management	Metro Manila

ABSTRACT (in Norwegian)

* *Classification*	*A*	*Unclassified (can be ordered from NILU)*
	B	*Restricted distribution*
	C	*Classified (not to be distributed)*