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Urban Air Quality Management Strategy in Asia

Jakarta Report

Edited by
Jitendra J. Shah
Tanvi Nagpal

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Many urban areas in the world are on the threshold of a major environmental crisis in the form of air pollution. The deteriorating air quality in those areas is a result of rapid economic expansion, rise in population, increased industrial emissions and unprecedented growth of passenger vehicles. The impact of air pollution is well known: environmental deterioration, adverse health effects, rising health costs, damage to ecological and cultural properties.

In Jakarta, the main contributor of air pollution is the transport sector, followed by statical emission sources like industrial units and power plants. In addition, there is air pollution emitted from incineration and solid waste disposal, construction industry, and consumption of CFC content products. Fuel quality and engine conditions significantly influence the level of air pollution. To arrest this growing problem, a concerted effort with public involvement is essential. Awareness of the issue, proactive policies, economically affordable standards and technologies and effective enforcement are key elements in an air quality management strategy. Early adoption of policies for environmentally safer technologies can allow developing countries to resolve some of the most difficult problems of industrialization and growth at lower human and economic cost.

URBAIR has assisted the Provincial Government of Jakarta Capital City Region in developing a strategy and action plan for air quality management in Jakarta. It brought together the different stakeholders -- sectoral agencies, private sector, NGOs, academics, research bodies and media -- to formulate a strategy. This Technical Committee deliberated over several months with technical support provided by a team of national and international experts. The resulting action plan is truly impressive and Jakarta is fully committed to its implementation. We will need the support of the international community, as well as public participation, in realizing the goals of the action plan.

I wish to acknowledge with gratitude all those who contributed to the development of the strategy and plan, especially MEIP for facilitating the process.

Vice Governor for The Economic and Development Affair
of the Jakarta Capital City Government

GUBERNUR KEPALA DAERAH KHUSUS IBUKOTA JAKARTA

Ir. Tb. M. Rais

FOREWORD

In view of the potential environmental consequences of continuing growth of Asian metropolitan areas, the World Bank and United Nations Development Programme launched the Metropolitan Environmental Improvement Program (MEIP) in six Asian metropolitan areas: Beijing, Mumbai (Bombay), Colombo, Jakarta, Kathmandu Valley and Metro Manila. The mission of MEIP is to assist Asian urban areas address their environmental problems.

Recognizing the growing severity of air pollution caused by industrial expansion and increasing numbers of vehicles, the World Bank through MEIP started the Urban Air Quality Management Strategy (URBAIR) in 1992. The first phase of URBAIR covered four cities: Mumbai (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 assist local institutions in developing action plans which would be an integral part of the air quality management system for the metropolitan regions. The approach used to achieve this objective involves the assessment of air quality and environmental damage (on health and materials), the assessment of control options, and comparison of costs of damage and costs of control options (cost-benefit or cost-effectiveness analysis).

The preparation of this city-specific report for Jakarta 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 between 1993 and 1995. The Norwegian Institute for Air Research (NILU) and the Institute for Environmental Studies (IES) prepared first drafts of the report, before the first workshops. These were based on general and city-specific information available from earlier studies. Later draft reports were prepared before the second workshop, with substantial inputs from the local consultants, and assessment of air quality, damage and control options, and costs carried out by NILU and IES. The report concludes with an action plan for air pollution abatement produced by the local working groups as a result of the deliberations during the second workshop. NILU/IES carried out cost-benefit analysis of some selected abatement measures, showing the economic viability of many of the technical control options.

It is hoped that this analysis will form the basis for further analysis of data, and formulation of strategies for air pollution control. Local institutions may refer to it as a preliminary strategy and use it in conjunction with the *URBAIR Guidebook* to formulate policy decisions and investment strategies.

Maritta Koch-Weser
Division Chief
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In the World Bank's Environment and Natural Resources Division, Asia Technical Group, URBAIR was managed by Jitendra Shah, Katsunori Suzuki, and Patchamuthu Illangovan, under the advice and guidance of Maritta Koch-Weser, Division Chief, and David Williams, MEIP Project Manager. Colleagues from World Bank Country Departments and Jakarta Resident Mission offered program assistance and comments on the numerous drafts. Management support at the World Bank was provided by Sonia Kapoor, Ronald Waas, and Erika Yanick. Tanvi Nagpal and Sheldon Lippman were responsible for quality assurance, technical accuracy, and final production. Julia Lutz prepared the layout.

Many international institutions including World Health Organization, Japan International Cooperation Agency (JICA), United States Environmental Protection Agency, and United States Asia Environment Partnership provided valuable contribution to the study through participation at URBAIR workshops and with follow-up correspondence and discussions throughout the study.

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ABSTRACT

Severe air pollution is threatening human health and the gains of economic growth in Asia's largest cities. This report aims to assist policy makers in the design and implementation of policies and monitoring and management tools to restore air quality in Jakarta, the booming capital of Indonesia.

Tremendous growth in the human population, numbers of vehicles, and industrial development in the Jabotabek region have led to a significant deterioration in the air quality. Pollutant concentrations near the main roads, especially in the most industrial areas. Total suspended particle (TSP) emissions in Jakarta are estimated at 96,733 tons per year. PM_{10} (particulate matter of 10 microns or less) emissions total 41,369 tons per year, and nitrogen oxide (NO_X) emissions are estimated at 43,031 tons per year. The annual TSP averages in the most polluted areas are 5 to 6 times the national air quality standard. High ozone concentrations, measured 30 to 40 kilometers outside Jakarta, indicate that secondary pollutants have developed as a result of NO_X and VOC emissions in Jakarta.

Using dose-response relationships developed in the United States, this report calculates that PM_{10} emissions caused a total of 4,364 excess deaths, 32 million restricted activity days, 101 million respiratory symptom days, innumerable emergency room visits, asthma attacks, cases of bronchitis in children, and hospital admissions, at a total cost of about US$300,000 (based on Indonesian data) in 1990.

Applying the essential components of an air quality management system to the pollution problem in Jakarta, this report suggests an action plan that lists abatement measures for the short, medium and long terms. Recommended actions fall under two categories: institutional and technical. A single institution with a clear mandate and sufficient resources should be made responsible for air quality management in the city. In addition, data gathering and processing capabilities should be improved throughout the city.

Technically, it is crucial that gross polluters be identified and penalized. Diesel quality should be improved and low-lead or unleaded gasoline be made cheaper than leaded to encourage its use. Clean vehicle emissions standards should be introduced for all vehicle classes. Inspection and maintenance of vehicles is necessary for the enforcement of such standards. The sulfur content of heavy fuel oil should also be reduced. Awareness raising through public and private organizations, including educational institutions, is key to bringing about policy change on matters related to air pollution.

ABBREVIATIONS AND ACRONYMS

AADT	annual average daily traffic
AQG	air quality guidelines
AQMS	air quality management system
BAPEDAL	Environmental Impact Control Board
BKMPD	Regional Investment Board
BLH	Bureau of the Environment
BMG	Meteorological & Geophysical Agency
CHD	coronary heart disease
CNG	compressed natural gas
CO	carbon monoxide
DBP	diastolic blood pressure
DKI KPPL	District of Jakarta Research Centre for Urban Development
DKK	Department of Health
DLLAJR	Road Traffic & Transportation Department
DPU	Department of Public Works
EIA	environmental impact assessment
ERV	emergency room visits
g/l	grams per liter
GEMS	Global Environment Monitoring System
GNP	gross national product
H_2S	hydrogen sulfide
HC	hydrocarbon
Jabotabek	Jakarta, Bogor, Tangerang, and Bekasi
JMG	Jakarta Municipal Government
JUDP III	Third Jakarta Municipal Development Project
IES	Institute for Environmental Studies
KPPL	Urban & Environmental Assessment Office
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MTBE	methyl-tertial-butyl-ether
NILU	Norwegian Institute for Air Research
NGO	nongovernmental organization
NO_X	nitrogen oxide
Pb	lead
PM_{10}	particulate matter of 10 microns or less
ppb	parts per billion
RAD	restricted activity days
RHD	respiratory hospital diseases
RON	research octane number
Rp	Rupiahs
RSD	respiratory symptom days
SO_2	sulfur dioxide
TSP	total suspended particles
$\mu g/m^3$	particulate concentration, in micrograms per cubic meters
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USEPA	United States Environment Protection Agency
VOC	volatile organic compounds
WHO	World Health Organization
WTP	willingness to pay

EXECUTIVE SUMMARY

URBAIR-JAKARTA: Larger and more diverse cities are a sign of Asia's increasingly dynamic economies. Yet this growth has come at a cost. Swelling urban populations and increased concentration of industry and automobile traffic in and around cities has resulted in severe air pollution. Emissions from automobiles and factories; domestic heating, cooking, and refuse burning are threatening the well being of city dwellers, imposing not just a direct economic cost by impacting human health but also threatening long-term productivity. Governments, businesses, and communities face the daunting yet urgent task of improving their environment and preventing further air quality deterioration.

Urban Air Quality Management Strategy or URBAIR, aims to assist in the design and implementation of policies, monitoring, and management tools to restore air quality in the major Asian metropolitan areas. At several workshops and working group meetings, representatives of government, industry and non-government organizations, and international and local experts and researchers reviewed air quality data and designed action plans. These plans take into account economic costs and benefits of air pollution abatement measures. This report focuses on the development of an air quality management system for Jakarta and the action plan that resulted from the development of this strategy.

THE DEVELOPMENT OF JAKARTA

Jakarta's population doubled between 1981 and 1991. In 1995, the metropolitan area's population was 11.5 million. This growth was accompanied by a tremendous rise in the number of vehicles on Jakarta's roads, from approximately 900,000 to 1,700,000. From 1965 to 1990, the growth rate of gross national product per capita (4.5 percent) was among the highest in developing countries. Industrial development in the Jabotabek region, especially along the main highways, has been remarkable.

These developments are reflected in the city's deteriorated air quality. Pollutant concentrations near the main roads and in the northern part of the urban area are sometimes extremely high. The highest values have been measured in the northern part of Jakarta, but many stations seem to be influenced by local sources. The bus terminals in Pulo Gadung and Cililitan both show average total suspended particles (TSP) values above 300 $\mu g/m^3$. Overall, traffic and industries are the main sources of air pollution in Jakarta. Total TSP emissions in Jakarta are estimated at 96,733 tons/year. Particulate matter of 10 microns or less (PM_{10}) emissions total 41,369 tons/year, and nitrogen oxide (NO_x) emissions are estimated at 43,031 tons/year. TSP concentrations are lower in the outskirts, averaging 100–150 $\mu g/m^3$. The annual TSP averages in the most polluted areas are 5–6 times the national air quality guideline. Resuspension from roads, diesel and gasoline vehicle emission, and domestic wood and refuse burning are the main sources of particulate pollution. Drivers, roadside residents and those who live near large sources are most severely affected.

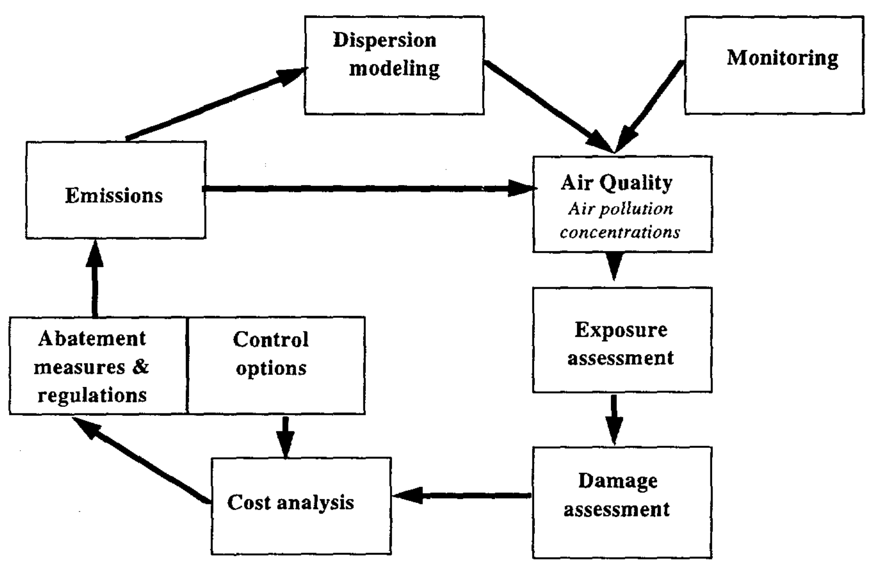
High ozone concentrations, measured 30 to 40 kilometers outside Jakarta, indicate that secondary pollutants have developed as a result of NO_x and VOC emissions in Jakarta. SO_2 pollution is not as serious an issue as particulate pollution.

While attaching an economic value to morbidity and mortality stemming from air pollution can be difficult, there is anecdotal as well as estimated evidence to suggest that the health of Jakarta's residents is under assault. Dose response equations used for valuing health impacts reveal that PM_{10} caused a total of 4,364 excess deaths, 32 million restricted activity days (RAD), 101 million respiratory symptom days (RSD), innumerable emergency room visits, asthma attacks, cases of bronchitis in children, and hospital admissions, at a total cost of about US$300,000 (based on Indonesian data) in 1990.

THE CONCEPT OF AIR QUALITY MANAGEMENT SYSTEM

Assessment and control of pollution form two prongs of an air quality management system (AQMS). These components are inputs into a cost-benefit analysis. Air quality guidelines or standards, and economic objectives and constraints also guide the cost-benefit calculation (See Figure ES.1). An action plan contains the optimum set of short-, medium-, and long-term abatement control measures. Successful, air quality management requires the establishment of an integrated system. Such a system involves:

Figure ES.1: Air Quality Management System



- inventorying air pollution activities and emissions;
- monitoring air pollution and dispersion parameters;
- calculating air pollution concentrations by dispersion models;
- inventorying population, building materials and proposed urban development;
- calculating the effect of abatement/control measures, and
- establishing/improving air pollution regulations.

In order to ensure that an AQMS is having the desired impact, it is also necessary to carry out surveillance and monitoring. This requires the establishment of an Air Quality Information System (AQIS) that can keep the authorities and the general public well informed about the quality of air, assess the results of abatement measures, and provide continuous feedback to the abatement strategy process.

ABATEMENT MEASURES AND ACTION PLAN

Car traffic is the most important source for NO_x and TSP pollution in the urban center. In the industrial area east and north of the city center, industries may be the most notable sources for local air pollution. Measures to reduce air pollution in Jakarta focus on the transport sector. This is because traffic emissions are a clear and major source of air pollution and measures to address other pollution sources could not be substantiated due to lack of data. While pollution control in industrial areas has not been discussed at length, it must also be promoted through enforcement and regulation.

Based on these abatement measures, an action plan was designed through a consultative process that included Jakarta URBAIR working groups, local and international consultants. The measures which stand out from a cost-benefit perspective are introduction of low-lead gasoline and introduction of low-smoke lubricating oil, as noted in Table ES.1

It is proposed that the following technical and policy measures be given priority.

- *Address gross polluters.* Reinforce the anti-smoke belching program. Existing smoke opacity regulations should be more strictly enforced. The success of this action depends upon the routine maintenance and adjustment of engines.
- *Improve diesel quality.* Domestic refineries could be modified to produce low-sulfur diesel (0.2 percent), or it could be imported. Economic instruments such as taxes and subsidies can be used to differentiate fuel price according to quality.

Table ES.1: A summary of technical measures, their effectiveness, annual costs, selected health benefits and total valued benefits

Technical Measures	Avoided emissions (PM_{10}) (tons)	Costs (Annual) (billion Rp)	Mortality benefit (number of cases)	Avoided number of RSD (million)	Avoided health damage (billion Rp) Lowest estimate.
Low -lead and unleaded fuel		50	310		300
Address excessively polluting vehicles	1,000		163	3.8	23.7
Inspection & maintenance scheme	1,300	(max) 67	212	5	31
Low-smoke lubricating oil in two-stroke engines	1,350	2–10	220	5	32
Clean vehicle standards—cars with four-stroke gasoline engines	900	18	147	3.4	21.3
Adopt clean vehicle standards for vehicles with two-stroke engines	2,000	67	325	7.6	47
Improving diesel quality	230		41	1	5.9
LNG to replace 50% of gasoline consumption	650		98	2	14.2

- *Inspection and maintenance of vehicles.* Annual or biannual inspections are necessary to enforce clean vehicle standards. These can be carried out by government or private entities.
- *Clean vehicle emissions standards*: State-of-the-art emissions standards should be set for new gasoline cars, diesel vehicles, and motorcycles. Lead-free gasoline, a requirement for this standard, should be cheaper than leaded gasoline.
- *Cleaner fuel oil*: A reduction in the sulfur content of heavy fuel oil, initially to 2 percent, is a prerequisite.
- *Awareness raising*: Public awareness and participation are key to bringing about policy change. Widespread environmental education promotes understanding of linkages between pollution and health and encourages public involvement. Private sector participation through innovative schemes like accepting delivery only from trucks that meet government emissions standards; Adopt-a-Street campaigns, and air quality monitoring displays should be encouraged. Media can also participate in awareness raising by disseminating air pollution-related data.

RECOMMENDATIONS FOR STRENGTHENING AIR QUALITY MONITORING AND INSTITUTIONS

It is important to ensure that institutions dealing with air quality be strengthened through clearer mandates and enforcing powers. A single coordinating institution with a clear mandate and sufficient resources must be made responsible for air quality management. A comprehensive AQMS can only be based on sound knowledge. In order to improve data, it is recommended that there be continuous, long-term monitoring at 5 or more city background sites, covering areas of typical and maximum concentrations; 1 to 3 traffic exposed sites to monitor street level pollution; and 1 to 5 industrial hot spots, and continuous monitors for PM_{10} , CO, NO_x, SO_2, O_3, depending upon the site. Also, an on-line data retrieval system directly linked to a laboratory database either via modem or fax is recommended for modern surveillance.

Clearly, environmental risks are escalating. If pollution sources are allowed to grow unchecked the economic costs of productivity lost to health problems and congestion will escalate. While working with sparse and often unreliable data, this report sets out a preliminary plan that has the potential to improve air quality and better manage the AQMS in the future.

1. BACKGROUND INFORMATION

SCOPE OF THE STUDY[1]

This city specific report on air quality management for Jakarta was produced as part of the URBAIR program. A major objective of URBAIR is to develop air quality management systems (AQMS) and action plans in Asia's cities.

The AQMS is based on a cost-benefit analysis of proposed actions and measures for air pollution abatement. Costs relate to abatement measures while benefits include a potential reduction in the costs of health damage estimates resulting from air pollution. This study emphasizes the damage to the health of those who are exposed to air pollution. The population exposure is based on measured and calculated concentrations of air pollution through emissions inventories and dispersion modeling .

A general strategy for AQMS is described in the *URBAIR Guidebook on Air Quality Management Strategy*, published by MEIP. Reports based on city specific analysis are produced for each of the four URBAIR/MEIP cities: Jakarta, Greater Mumbai, Metro Manila and the Kathmandu Valley. These four reports outline action plans for air quality improvement, including estimates of cost and benefit figures. The action plans are based on a comprehensive list of proposed measures and actions developed by local working groups in consultation with outside experts.

GENERAL DESCRIPTION OF JAKARTA

Jakarta is situated on the northern coast of Java Island, around the mouth of the Ciliwung river, at about 106° east, and 6° south. It covers an area of approximately 665 square kilometers Along the coast, the landscape is very flat with a mean elevation of seven meters above sea level. The southern area of Jakarta is slightly undulating with ground elevation of approximately 50 meters above sea level. Further south in Bogor outside Jakarta, the mountains are as high as 3,000 meters. There are no natural topographical barriers near Jakarta.

Jakarta is predominately a city of one or two-story buildings, with high-rises concentrated in corridors along the main roads. This may easily change with continued economic development.

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1 Except as indicated, "dollars" refers to 1992–93 U.S. dollars.
Except as indicated, all figures, tables, and textboxes were created by the authors for this report.

The construction of more high-rise buildings may alter the micro-climate at street level. Air pollution from rush-hour traffic is already a problem, and it is likely to worsen in the future.

DKI Jakarta (a commonly used acronym for Daerah Khusus Ibukota Jakarta, or the Special District of the capital city Jakarta) is part of the greater Jabotabek (Jakarta, Bogor, Tangerang and Bekasi) area. At present, there are five mayoralties in Jakarta which are subdivided into 74 subdistricts (kelurahan). Figure 1.1 shows a map of Jakarta. While the work on air pollution concentrates on Jakarta, an emissions survey must account for activities in the surrounding region.

North Jakarta covers the areas along the coast. Despite the risk of floods and poor sanitation, residential developments are common in this area. A new town has emerged around the old international airport at Kemayoran. The areas around Tanjung Priok Harbor have a high population density. Rapid residential development is anticipated here, particularly for middle- and lower-income groups. The eastern part is slowly growing and is dominated by marsh lands and paddy fields with a population density of about 24 inhabitants per hectare.

Central Jakarta is characterized by government offices and related service sectors. Commercial and trading areas are located south of Central Jakarta, along the roads that serve as main transportation axes. The southern part of Central Jakarta has been growing and developing rapidly during the last 20 years, especially as a medium- and high-income residential area. The northern part of Central Jakarta is very densely populated and has up to 500 inhabitants per hectare. A mostly low-income population lives in the *kampong* (low-rise, generally unplanned, mostly low-cost residential areas).

East Jakarta has a lower population density, but new industrial zones in the Bekasi region may encourage development and urban growth. *West Jakarta* has soil, ground water and structural conditions appropriate for residential development. *South Jakarta* has a lower population density. The area has been designated as a ground water percolation area for recharging Jakarta's ground water reserve. The control and management of the greenbelt area competes with the rising demand for housing and commercial use.

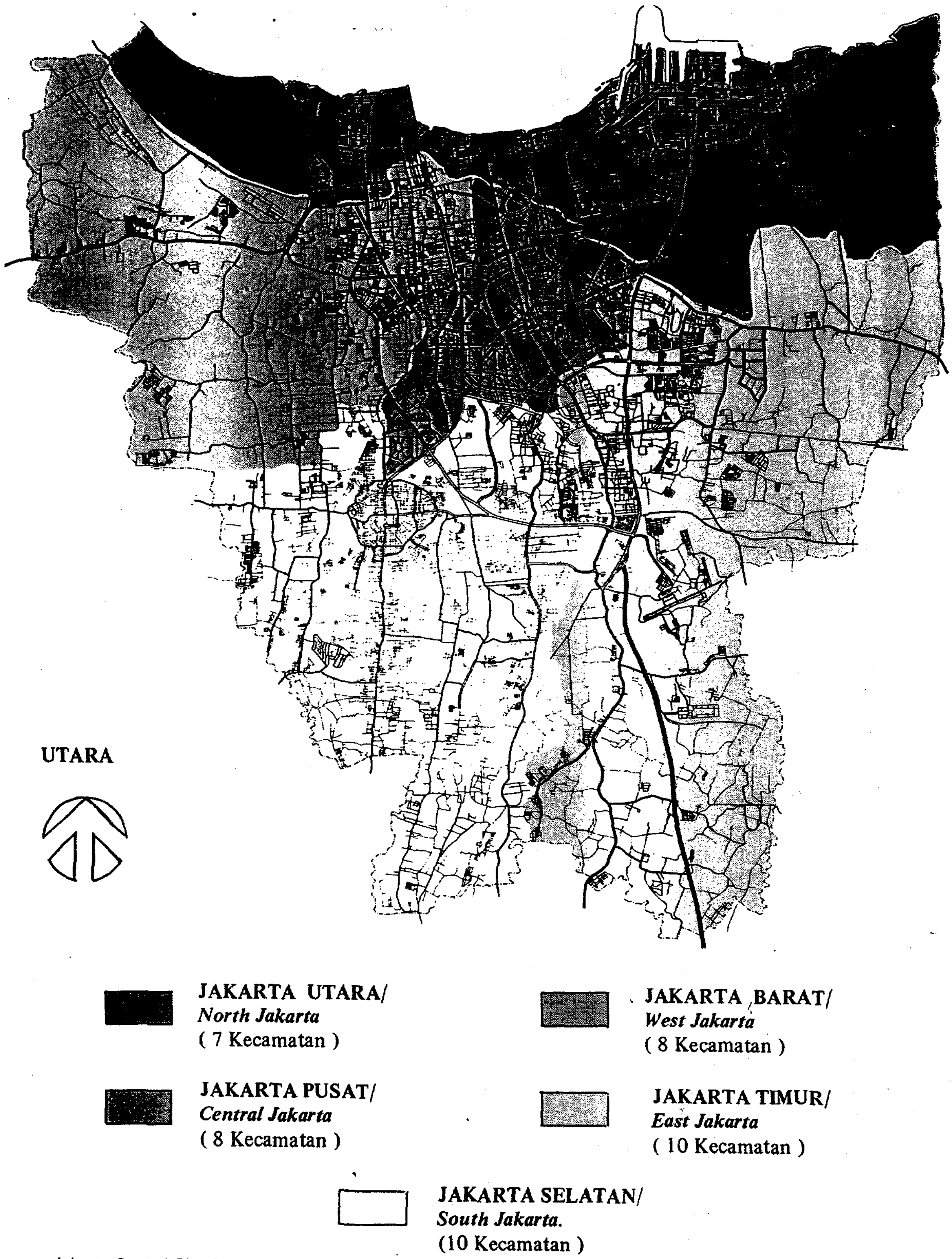
DATA SOURCES

Previous studies

The air pollution situation in Jakarta has been studied by several groups and institutions. Studies that have formed part of the background for URBAIR work include:

- Indonesia: Energy and the Environment (World Bank, 1993);
- Third Jabotabek Urban Development Project (JUDP III), (BAPEDAL, 1994);
- Collection of data for the URBAIR study in Jakarta (Soedomo, 1993);
- List of 100 industries which may qualify for assistance (COWI consultant/World Bank, 1992);
- LLAJR Air Pollution monitoring and control project (Bachrun et al., 1991);

Figure 1.1: DKI Jakarta with 5 mayoralties



Source: Jakarta Capital City Government

- Environmental impacts of energy strategies for Indonesia (BPPT/KFA, 1992);
- Annual report on air quality monitoring and studies (EMC, 1994);
- Air Quality Assessment in Medan (Bosch, 1991); and
- Jakarta in figures (JSO, 1991).

URBAIR data collection

Data on population, pollution sources, dispersion, air quality, and health aspects were collected beginning in March 1992. Dr. Moestikahadi Soedomo and colleagues from the Institute of Technology in Bandung, collected data on air pollution concentrations, fuel and traffic, emissions, and meteorological conditions. Dr. Umar F. Achmadi (Faculty of Public Health), University of Indonesia in Jakarta, collected, evaluated, and summarized data on health statistics and costs related to disease and treatment. Project description for this data is in Appendix 9.

DEVELOPMENT OF JAKARTA, 1981–1992

Figure 1.2 summarizes available data regarding population, vehicles, fuel consumption, air quality, and economic development over the last decade. As can be seen, data are not available on all items for the entire decade. The data shown and summarized here are described in greater detail in subsequent chapters.

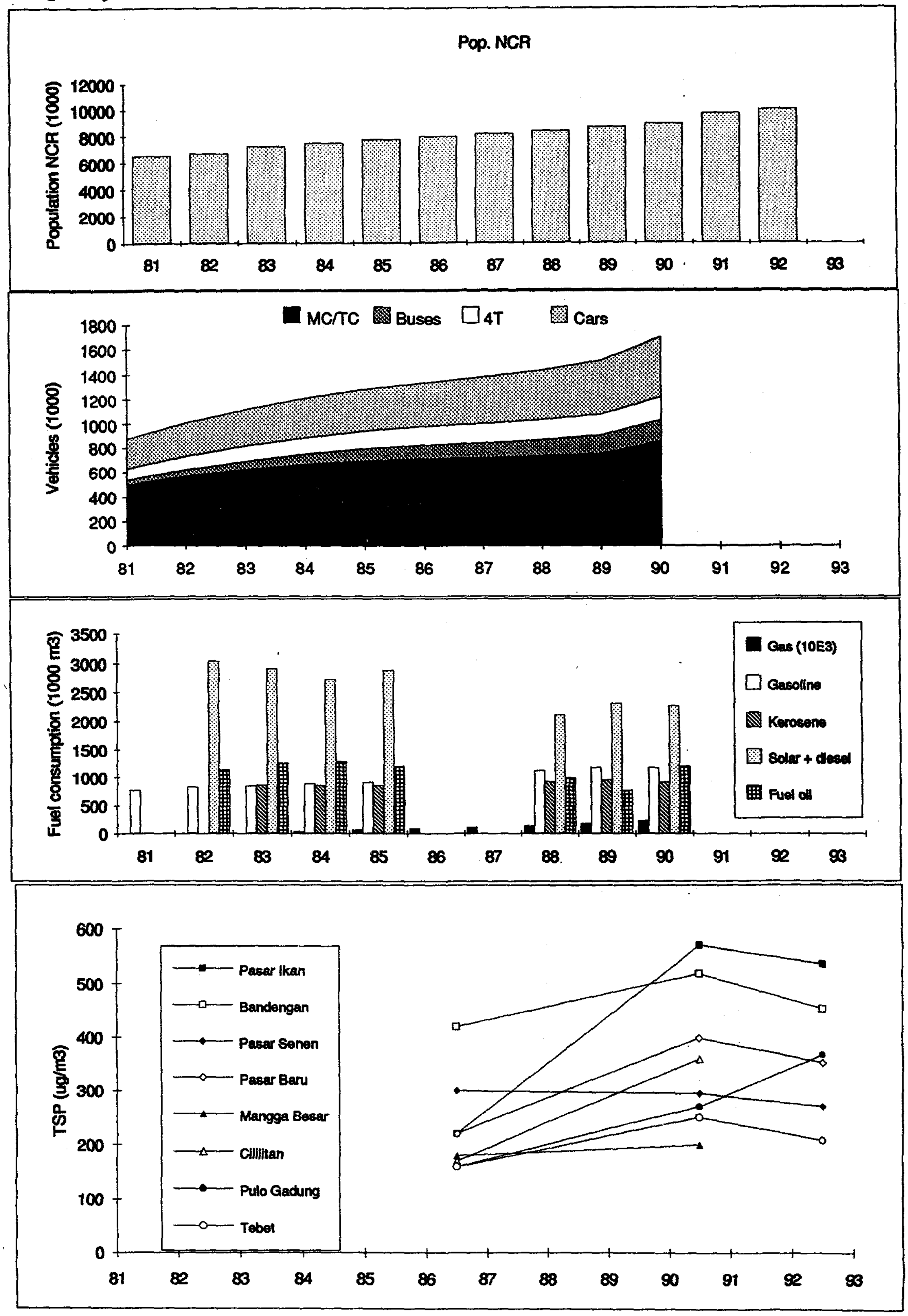
Population has doubled in the last two decades, and there is a significant potential for further growth. This is true for Jakarta and the entire Jabotabek region. The number of cars has also doubled in the last 10 years. Consumption of gasoline has grown with the increased car traffic. The consumption of other fuel types does not show a well-specified trend. Industrial areas have emerged in Pulo Gadung, Cipinang and Mookevart, along the main roads towards Bogor, Bekasi, and Tangerang, respectively. The same regulations apply to all industries in the Jabotabek region. In 1990 the GNP/capita for Indonesia was US$570. Between 1965 and 1990, the growth rate of GNP/capita was 4.5 percent, among the highest in developing countries.

Three agencies have been operating monitoring networks in Jakarta, taking 24-hours samples at different intervals, measuring TSP, SO_2 (sulfur dioxide), NO_x, CO (carbon monoxide) and O_3 (ozone). SO_2 values are low and declining. TSP is the most substantial pollution component in the area. Concentrations of TSP were increasing until 1990, after which the trend has been more variable. The quality of the NO_x measurements seems to vary significantly with yearly differences that are difficult to explain. Results from the new monitoring station at Jl. M.H. Thamrin indicate that the 24-hour NO_x data from other stations may be too low, especially at the more centrally located stations.

POPULATION

The population in Jakarta has increased about 50 percent from 1981 to 1991, and further population growth and economic development can be expected in coming years.

Figure 1.2: Development in Jakarta, 1981–93; population, vehicle fleet, fuel consumption and air quality



Immigrants mainly settle in the southern and eastern parts of Jakarta. Population increase is mainly due to the high birth rate within Jakarta. Table 1.1 shows the age distribution in Jakarta in 1990, indicating a considerable potential for growth.

Table 1.1: Age distribution, 1990

Age	%	Age	%
0–4	12.1	40–44	4.7
5–9	10.4	45–49	3.9
10–14	10.2	50–54	3.0
15–19	9.8	55–59	2.1
20–24	12.2	60–64	1.5
25–29	12.2	65–69	1.0
30–34	9.5	70–74	0.5
35–39	6.3	>75	0.4

VEHICLE FLEET

Jakarta's vehicle fleet is composed of the following:

- passenger cars;
- utility vehicles, pick-ups etc.;
- trucks and buses; and,
- motorcycles and tricycles (Bajaj).

In 1981, 56.6 percent of the vehicles were motorcycles and tricycles, as compared to 50.5 percent in 1990. Of the vehicle fleet in 1990, 9.9 percent were buses, 28 percent were passenger cars, and 11 percent were cargo cars.

Table 1.2 shows the estimated yearly traffic in distance traveled for each of these categories, using gasoline or diesel.

Table 1.2: Estimated traffic in distance traveled for each of the vehicle categories (10^6 km/year)

	Gasoline	Diesel
Passenger cars	5,900	1,500
Utility vehicles	300	300
Trucks and buses	300	850
Motorcycles & tricycles	5,300	-

INDUSTRIAL SOURCES

Jakarta has a large and diversified industrial structure. Although there are various estimates for industrial emissions, they are not sufficiently specific, and further work needs to be done in order to evaluate the impact of industries on air quality.

Table 1.3 shows the number of establishments and the number of employees engaged in production in various industries.

Table 1.3: Number of establishments and persons engaged in production in large and medium factories, 1989

	Establishments	Prod. workers
Food, beverage. & tobacco	222	14,724
Textile	717	87,620
Wood and wood products	131	9,250
Paper and paper products	193	14,684
Industrial chemicals	380	36,022
Nonmetallic minerals	38	8,884
Iron & steel basic industries	17	2,796
Fabricated mineral products	361	54,471
Other manufacture	41	3,745
Total	**2,100**	**232,196**

Source: Jakarta In Figures (1991).

FUEL CONSUMPTION

Data on sales of oil and gas by type of fuel are provided in Table 1.4.

In addition, 56 tons of coal, and 2,560 tons of coke were used by industry in 1989.

Table 1.4: Petroleum products sold in 1990 (Unit: 10^3 m^3.)

	Super 98	Premium	Kerosene	Solar	Diesel	Fuel oil	Gas
Total	105	1,070	915	1,047	295	1,202	226,000
Industry		21	24	441	153	-	63,000
Domestic			896	606	142	1,202	163,000

Source: Jakarta in Figures (1991).

Three electric power stations use gas and diesel oil for generating electricity, with a yearly production of 9 x 10^9 kilowatt-hours in 1990.

2. AIR QUALITY ASSESSMENT

This chapter provides estimates of the population's exposure to area air pollutants, and quantifies the contribution of different pollution sources to this exposure. Population exposure is estimated by describing existing air pollution concentration measurements and their variation in time and space; making an inventory of air pollution sources and their relative contributions; calculating the concentration distributions using dispersion modeling and calculating population exposure by combining spatial distributions of population and concentrations, and incorporating exposure on roads and in industrial areas.

AIR POLLUTION CONCENTRATIONS

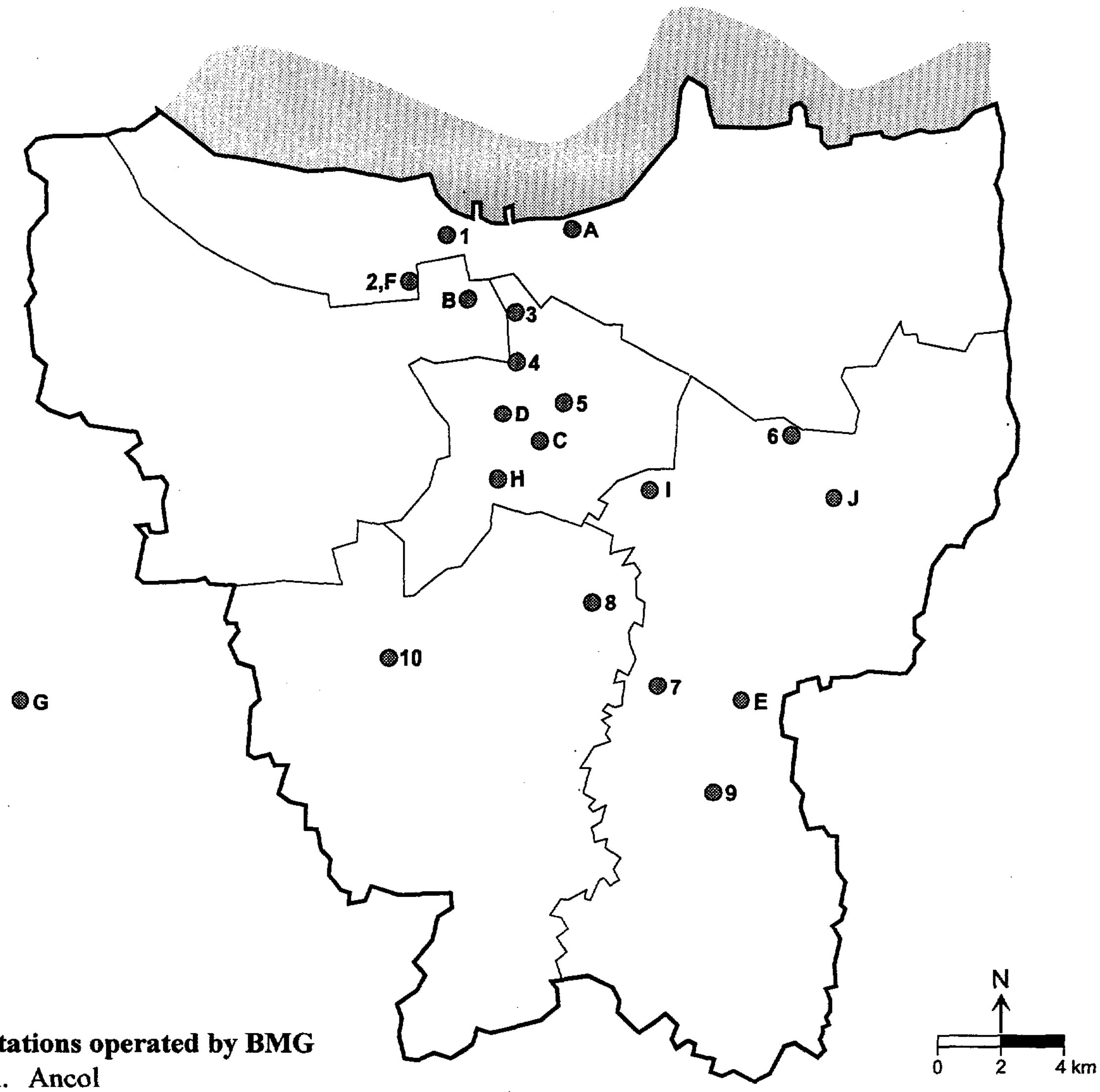
Overview of database

Air pollution measurement programs reveal that Jakarta has a substantial particle pollution problem. TSP air quality guidelines are frequently and spatially extended. According to measurements, the SO_2 pollution problem appears to be less pronounced.

Monitoring networks, and the results of measurements are described in greater detail in Appendix 1. The monitoring networks which have provided data on which our assessments are based are shown in Figure 2.1.

- Seven permanent stations run by BMG (Meteorological and Geophysical Agency). The first BMG station has been in operation since 1976. It is located at the BMG headquarters in Central Jakarta. Six other BMG stations were started in 1980/81, but not operational until the late 1980s. These six stations were restarted in 1991. At the BMG headquarters, TSP, NO_x and SO_2 are measured, while only TSP is measured at the other six BMG stations. At the BMG stations there is one 24-hour measurement every sixth day.
- Two permanent stations run by the Jakarta Municipal Government (JMG), and by the Ministry of Health before 1980. These are part of the United Nations Global Environment Monitoring System (GEMS). At the GEMS sites, TSP, NO_x and SO_2 are monitored every sixth day.

Figure 2.1: Air quality monitoring networks in Jakarta



Stations operated by BMG

A. Ancol
B. Glodok
C. BMG Headquarter
D. T. Monas
E. Halim Perdana
F. Bandengan
G. Ciledug

Stations operated by JMG

H. Jl M.H. Thamrin
I. Kayu Manis
J. Pulo Gadung (PT. JIEP)

Stations operated by DKI KPPL

1. Pasar Ikan
2. Bandengan Utara
3. Mangga Besar
4. Pasar Baru
5. Pasar Senen
6. Pulo Gadung (bus terminal)
7. Cililitan
8. Tebet
9. Pondok Gede
10. Radio Dalam

Note: Positions of Ciledug and Bandengan Utara are uncertain.
Source: Jakarta Capital City Government

- Eight rotational stations run by DKI KPPL[2] (District of Jakarta—Research Centre for Urban Development). Measurements at the KPPL sites are dictated by the availability of equipment and resources. The monitoring stations are operated on a rotational basis. Four stations are operated for eight days and then the equipment is moved to the other four stations. These stations operate for eight months each year. TSP and CO (and sometimes oxidants) are measured at all sites.
- Since April 1992, one-hour averages of SO_2, NO, NO_2, CO and PM_{10} have been measured continuously at Jl M.H. Thamrin in Central Jakarta. This information has not been analyzed in detail here, although reference is made to preliminary findings.

Total suspended particles measurements

Indonesia has adopted the upper limit of World Health Organization air quality guidelines (WHO AQG) as the national standard (see Appendix 2) for TSP. The WHO AQG are 60–90 $\mu g/m^3$ as the long-term (annual) average, and 150–230 $\mu g/m^3$ as short-term (24-hour) average.

As shown in Figure 2.2, and in Appendix 1, these values are clearly exceeded at the measurement stations in Jakarta. The figure shows averages for the period 1986–92. The highest values are measured in the northern part of Jakarta, but many stations seem to be influenced by local sources. The bus terminals in Pulo Gadung and Cililitan both show average values above 300 $\mu g/m^3$. TSP concentrations are lower in the outskirts, averaging 100–150 $\mu g/m^3$. The annual TSP averages in the most polluted areas are 5–6 times the national air quality standard.

Very high, 24-hour average values are recorded at all stations. Except for two extreme values, 864 $\mu g/m^3$ at Bandengan (possibly due to some extreme local sources influence), the maximum values are about 300–450 $\mu g/m^3$, up to twice the AQG value at several stations. Fluctuations in daily measurements reflect variations in meteorological conditions.

While detailed data are not available, it is expected that TSP concentrations are reduced during rainy periods and when the dispersion conditions are good (high wind speed and good vertical mixing). Decreased resuspension from the ground during wet and rainy weather; increased washout of particles during rain, and/or increased wind speed and turbulence with improved dispersion also result in smaller TSP concentrations.

Nitrogen oxides measurements

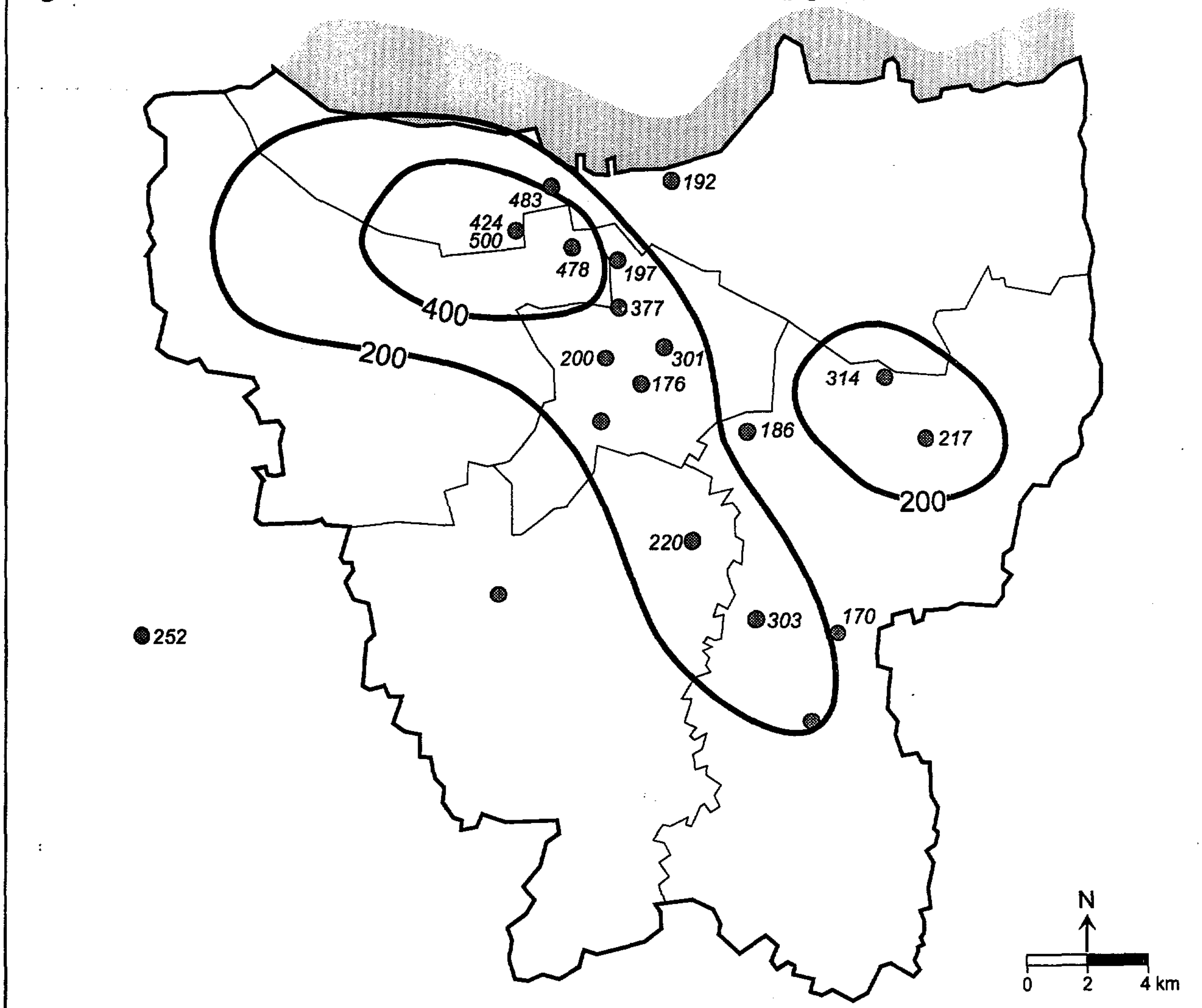
Nitrogen oxides (NO_x)data for KPPL and BMG/health stations are presented in Table 2.1. The JMG (GEMS) reported annual mean NO_x concentrations of 2–4 $\mu g/m^3$, and maximum 24-hour concentrations of 5–10 $\mu g/m^3$ during 1986–1989. These stations primarily reflect suburban ambient air pollution.

Table 2.1: Comparison of annual NO_x averages for 1986–1991 at BMG and Health Air Monitoring Stations

Year	NO_x (parts per billion)		
	BMG-HQ	Health monitoring stations	
		Kayu Manis	Pulo Gadung
1986	60	20	21
1987	130	18	15
1988	140	12	10
1989	140	12	10
1990	40	10	9
1991	29	23	23

[2] The DKI-KPPL was formerly called DKI-P4L.

Figure 2.2: Annual TSP concentrations in Jakarta, 1986–92 (μg/m³)



During 1989 and 1990, the average NO_x concentration at the Bandengan station in the city center was a low 28 μg/m³. NO_x concentration measurements taken at DKI-KPPL stations showed a remarkable decline from 113 μg/m³ in 1983, to 9.4 μg/m³ in 1986. Similarly, maximum 24-hour values fell from 395 μg/m³ to 15 μg/m³. This sudden drop in NO_x concentrations cannot be explained by the available information. It is likely that aside from a possible improvement in air quality, the siting, sampling or instrumentation of the monitoring stations may have had a major influence (WHO/UNEP, 1992). From 1986/1987 to 1990/1991, DKI-KPPL stations reported an increase in NO_x concentrations, while SO_2 levels at the same stations fell considerably in the same period.

From April to June 1992, NO, NO_2 and NO_x data from Jl M.H. Thamrin showed mean values of 64 ppb NO_2 (about 120 μg/m³), and 169 ppb NO_x (about 320 μg/m³). NO_2 daily values ranged from 46 ppb (about 85 μg/m³) to 93 ppb (about 175 μg/m³), higher than the national ambient air quality standard of 150 μg/m³. The highest hourly NO_2 values were not far below the 1-hour proposed national ambient air quality standard of 400 μg/m³.

Measurements of NO_x have probably varied because of changes in measurement techniques. Early results from the BMG sites were high with some monthly averages exceeding 200 µg/m³. At the KPPL sites, the averages for annual measurements of NO_x ranged from about 20 to 160 µg/m³.

At the new station at Jl M.H. Thamrin, the daily averages have a range of 200–500 µg/m³. The values are much closer to those expected at a high traffic density site rather than those recorded at the network sites. These results, however, are from a very limited data set and longer time series are needed for drawing firm conclusions regarding long-term average values and trends.

Ozone measurements

Ozone (O_3) has been measured at eight DKI-KPPL stations. In 1986–1987, annual mean O_3 concentrations ranged from 2 µg/m³ at the Bandengan location to 15 µg/m³ at the Pasar Senen location. The latter had the highest one-hour concentration of 85.8 µg/m³, while the highest one-hour value at Bandengan was only 8.2 µg/m³. Thus, all reported O_3 concentrations in urban Jakarta seem to be well below the proposed national ambient air quality standards.

These measurements of O_3 levels inside the city are lower than expected, especially compared to the NO_x levels. If the O_3 levels are correct, the NO_x levels should be considerably higher than observed at the long-term stations.

On the other hand, high O_3 concentrations (above 200 µg/m³) have recently been measured at the Environment Management Centre outside to the southwest to the city (EMC, 1994). Such high concentrations of oxidants may cause eye irritations or acute health effects. Ultraviolet radiation intensity which contributes to photochemical reactions is high in the daytime, especially in the dry season. Therefore, when the supply of the precursor pollutants, NO_x and VOC, reaches a high level, photochemical oxidants may be formed and transported across a wide area.

The variations in measurements points to the urgent need for a dependable ozone monitoring program in and around Jakarta.

Carbon monoxide measurements

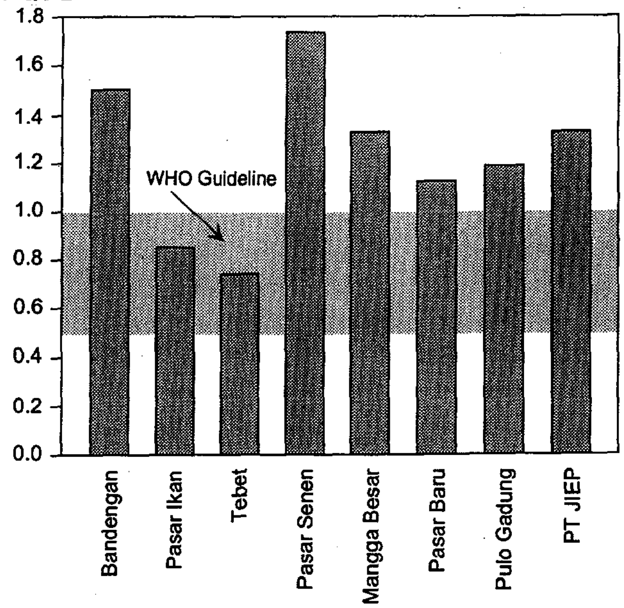
Carbon monoxide (CO) is measured by the DKI-KPPL network. Average CO levels (8 hour) were around 3.5 mg/m³ in a residential area and at a bus terminal (Cililitan site), but reached 27 mg/m³ at the Glodok station in a central commercial area. This value is well above the WHO AQG and the proposed national ambient air quality standard of 10 mg/m³. It indicates that CO is a problem in heavily traffic-exposed areas.

The monitoring station at Jl M.H. Thamrin showed daily CO averages of 2.4–5.1 mg/m³ in April–June 1992 (one sample every 7 days). Hourly values on 25 June varied between 0.5 mg/m³ in the night and 8.2 mg/m³ in the afternoon. The highest 8-hour average this day was 7.1 mg/m³, and the daily average values was 4.9 mg/m³.

The Jl M.H. Thamrin air inlet is 4 meters above ground and about 10 meters from the edge of a highly used traffic circle of about 100-meters diameter. Very high traffic intensity is observed in the circle. Monitoring in a street canyon with heavy traffic probably would give higher CO levels than at the roundabout location. The wind often blows from the station to the traffic circle.

Lead measurements

Figure 2.3: Particulate lead, annual average, Jakarta 1991/92



Vehicle exhaust is the largest cause of lead pollution. Lead is added to gasoline to improve octane. The lead content in gasoline in Indonesia is reported to be 0.44 g/l for 88-octane premium, and 94-octane premix gasoline. Lead-free gasoline was introduced in 1995 at a higher price than leaded gasoline.

The annual WHO AQG for lead averages 0.5–1.0 μg/m³. Figure 2.3 shows the results of measurements for lead in particulate samples from eight KPPL sites in 1991/92. The measurements were made for ten months starting in June 1991 and ending in March 1992, for 24 hours every 8th day.

Average lead concentrations at the DKI-KPPL stations usually range between 0.5–2 μg/m³. Considering the station locations, lead concentrations well above the proposed national standard of 2 μg/m³ for 24-hour average can be expected in areas exposed to heavy traffic.

PM_{10} samples from Jl M.H. Thamrin are analyzed for Pb in Japan. However, no values have been released yet. These values will probably be the best available to evaluate air lead pollution in highly trafficked areas of Jakarta.

AIR POLLUTANT EMISSIONS IN JAKARTA

Total emissions

Data on fuel consumption, traffic and industrial activities were tabulated in the form of an emissions inventory for DKI Jakarta (Table 2.2). Emissions of TSP, PM_{10} and NO_x have been calculated/estimated. Data on industrial activity, emissions and types of vehicles and distances traveled were scarce. Data on power plant emissions were not available. The database and procedures are described in Appendix 4.

Traffic emissions were calculated by using the following method. A main road network for Jakarta was defined from different maps, as shown in Figure 2.4. From a limited set of traffic counts (number of cars per hour), average annual daily traffic (AADT) for some road classes was defined, and data fields with daily traffic was calculated. Traffic counts from 22 different roads (Soedomo, 1993) were used to define a "normalized" traffic composition (Table 2.3). The emission factors used for various modes of transport are shown in Table 2.4.

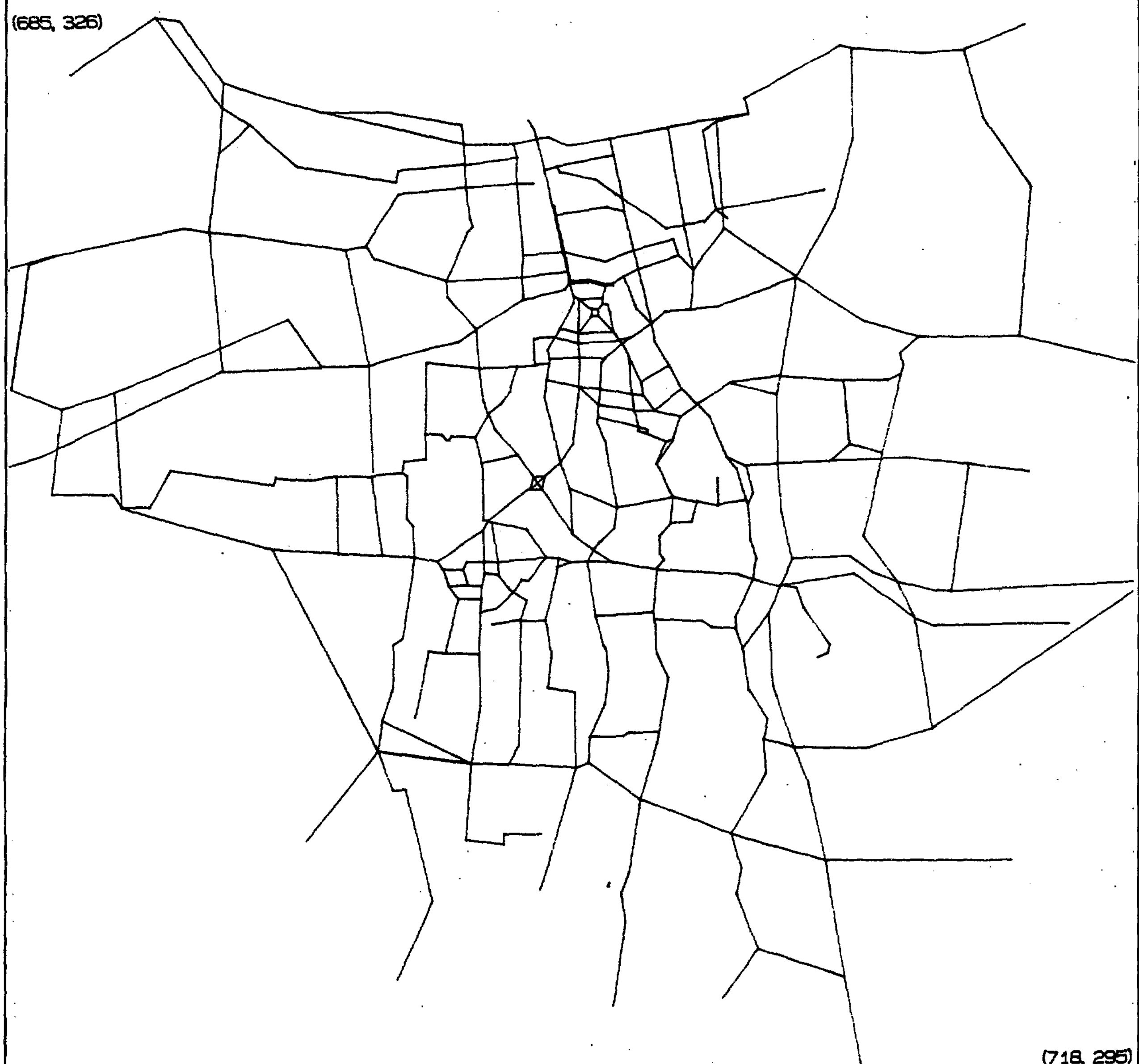
Table 2.2: Estimate of total annual TSP, PM_{10} and NO_x emissions in Jakarta, 1990

Emission sources		TSP	PM_{10} Note	PM_{10}	NO_x
TRANSPORT SECTOR					
Vehicle exhaust					
Gasoline vehicle	Passenger cars	1,132		1,132	15,279
	Pick up etc.	120		120	986
	Truck medium	26		26	304
	Bus	124		124	1,464
	Bajaj	295		295	41
	MC	2,219		2,219	311
Sum *Gasoline vehicle*		3,916		3,916	18,385
Diesel vehicles	Passenger cars	849		849	1,415
	Pick up etc.	329		3,29	511
	Truck medium	308		308	2,002
	Truck heavy	2		2	13
	Bus Coplet etc.	367		367	5,304
	Bus regular	602		602	3,913
Sum *Diesel vehicle*		2,457		2,457	13,158
Sum *Resuspension from roads*		27,832	*d*	6,958	
Sum *Transport Sector*		**34,205**		**13,331**	**31,543**
ENERGY/INDUSTRY SECTOR					
Fuel combustion					
Industrial/commercial.	Distillate fuel	185.4	*b*	92.7	1,483
	Coal	0.4	*b*	0.3	1
	Coke	12.5	*b*	6.2	26
	Gas	3.0		3.0	141
Domestic/small industry	Fuel oil	1,682.8	*a*	1,430.4	2,404
	Distillate fuel	1,617.0	*b*	808.5	2,772
	Gas	7.8		7.8	365
	Open burning	7,027.0		7,027.0	2,635
Sum *Fuel combustion*		10,535.9		9,375.9	9,827
Industrial processes	Food and textile	9,390	*d*	2,348	
	Wood and w. products	2,036	*c*	1,153	
	Paper and p. products	5,211	*c*	2,606	
	Chemicals	3,800	*c*	1,900	
	Non met. min. prod.	1,710	*c*	855	
	Iron and steel	9,450	*c*	4,725	
Sum *industrial processes*		31,867		13,586	
Sum Energy/Industry Sector		**42,403**		**22,962**	**9,827**
OTHER	Airports	26		26	661
	Construction	20,000	*c*	5,000	
	Harbor	100	*b*	50	1,000
Sum Other		**20,126**		**5,076**	**1,661**
TOTAL		**96,734**		**41,369**	**43,031**

Note: Estimates according to existing data for source groups.

a. $PM_{10} = 0.85 \cdot TSP$ (ref. EPA AP42)
b. $PM_{10} = 0.5 \cdot TSP$ (ref. EPA AP42)
c. $PM_{10} = 0.5 \cdot TSP$ (rough estimate)
d. $PM_{10} = 0.25 \cdot TSP$ (rough estimate)

Figure 2.4: Main road network in DKI Jakarta



Source: Jakarta Capital City Government

Some estimates are rough and based on incomplete information. While these figures are often admittedly weak, the emissions inventory may be considered adequate for a first estimate of source contributions and a background for first stage cost-benefit analysis.

Table 2.3: "Normalized traffic composition" for Jakarta

Sedan + Taxi	Pickup	Bus	Microlet + Metro Mini	Truck	Truck Gandeng	MC	Bajaj
.5083	.0524	.0216	.0425	.0138	.0002	.3189	.0423

Table 2.4: Traffic emission factors

	TSP (g/km)	NO_x (g/km)
Gasoline		
Passenger cars	0.2	2.7
Pick-up etc.	0.33	2.7
Truck medium, bus	0.68	8.0
Bajaj, MC	0.50	0.07
Diesel		
Passenger cars	0.6	1.0
Pick-up etc.	0.9	1.0
Truck, bus	2.0	13.0
Bus, Coplet etc.	0.9	13.0

As PM_{10} is the main harmful component in TSP, the exposure calculations are based upon PM_{10} values.

Yearly gasoline consumption (Table 2.5) along with traffic count were also used to estimate AADT, giving a total traffic of 17.2 x 10^9 car-km/yr. From this, average emission factors of 0.35 g/km of TSP and 2.267 g /km of NO_x were used to calculate area emission fields, as shown in Appendix 4.

Resuspended road dust is added to the primary emissions from vehicles. A rough estimate of road dust resuspension based on the following emission factors proposed by USEPA (EPA, AP 42) is:

- local streets (< 500 AADT): 15 g/km;
- collector streets (500–10,000 AADT): 10 g/km;
- major streets (10,000–50,000 AADT): 4.4 g/km;
- freeways/expressways (>50,000 AADT): 0.35 g/km.

These factors are suggested for dry road conditions. Much of the traffic activity in Jakarta takes place on roads with AADT greater than 50,000. Assuming that traffic activity share on road classes is 5 percent (local), 25 percent (collector), 30 percent (major), and 40 percent (freeways), and that the roads are wet 50 percent of the time, EPA emission factors suggest an average factor of somewhat more than 2 g/km.

Table 2.5: Traffic activity and fuel consumption data in Jakarta (1990)

Emission source	Fuel 10^3 m^3/yr.	Traffic 10^6 vehicle- km/yr.
Vehicles		
Gasoline: cars	967.7	5,659
pick-up	66.1	365
truck, bus	40.7	221
Bajaj, MC	100.4	5,027
Diesel: cars	242.0	1,415
pick-up	66.0	365
truck, bus	87.1	155
bus, coplet	73.8	709
Fuel consumption		
Kerosene, solar etc.	1,773.0	
Fuel oil	1,202.0	
Coal, coke	2.6	
Gas	226.0	
Open burning	878.4	

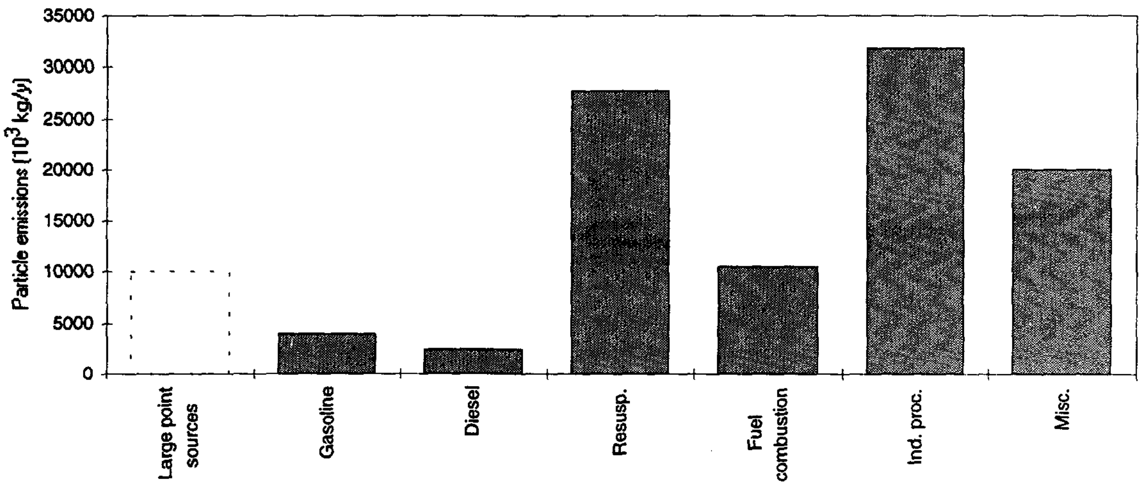
A recent evaluation, based on road measurements of emission rates, supports the EPA emission factors for paved roads, although the study concludes that more investigation is needed (Claiborn et al., 1995).

TSP emission

Total annual emission of TSP is shown in Table 2.2. Figure 2.5 indicates the following four dominant groups of emissions:

- resuspension from road traffic;
- industrial processes;
- open refuse burning; and,
- construction (miscellaneous).

Figure 2.5: Total annual emission of TSP from different groups of sources in 1990 (10^3 kg/yr)



Large point source group resuspension, open refuse burning, and construction are sources that are often omitted in emission estimates. The TSP emission estimate from refuse burning for the Metro Manila study was based on one million households each burning 0.5 kilogram of refuse per day. This is probably an overestimate and will vary with different values for the various regions of the city.

There are many construction activities in Jakarta. Since there were no central measurements of this activity which was judged to be much more than Manila or Mumbai, a total emission of 20,000 tons/year was used. This estimate is based on expert opinion and is twice the value that was estimated for Metro Manila. These emissions were distributed spatially according to the traffic distribution since no other information was available.

Figure 2.6 shows the spatial distribution of TSP emission in Jakarta.

Figure 2.6: Spatial distribution of TSP emission in Jakarta (0.1 kg TSP/hr)

EMISSION OF TSP UNIT: KG/H

MAX. VALUE IS 2.2027E+02. IN (18 . 14)
SUM= 1.10331E+04 SCALE FACTOR: 1.0E-01

SCALE: GRID SIZE 1500 METER

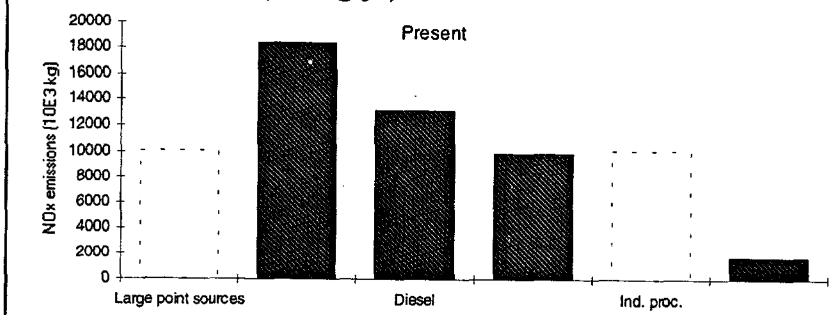
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	.	.	14.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	184.
J=19	.	18.	191.	220.	81.	78.	108.		65.	.	.	.	.	323.	75.	1548.	976.	207.	763.	4.
J=18	24.	41.	39.	43.	23.	234.	479.	284.	1116.	350.	246.	299.	682.	186.	311.	1247.	333.	446.	211.	13.
J=17	28.	118.	135.	166.	216.	331.	245.	393.	394.	720.	684.	428.	300.	649.	906.	362.	133.	844.	16.	188.
J=16	486.	37.	397.	613.	55.	481.	473.	498.	559.	704.	1241.	676.	155.	144.	1083.	264.	15.	926.	160.	227.
J=15	27.	42.	226.	288.	62.	151.	377.	462.	750.	302.	1088.	976.	440.	408.	845.	595.	627.	1105.	1067.	676.
J=14	.	.	91.	148.	292.	331.	530.	519.	594.	460.	787.	759.	577.	751.	1072.	1245.	1433.	2203.	1652.	1555.
J=13	.	.	.	18.	18.	72.	274.	506.	673.	630.	636.	684.	496.	716.	945.	1323.	1564.	1505.	768.	401.
J=12	.	.	.	99.	72.	129.	170.	560.	432.	898.	492.	687.	577.	1033.	1172.	849.	986.	263.	211.	20.
J=11	.	.	.	176.	192.	241.	214.	403.	689.	545.	740.	460.	486.	440.	400.	269.	165.	195.	64.	.
J=10	.	.	.	.	.	111.	110.	376.	724.	485.	695.	755.	590.	716.	855.	519.	553.	238.	73.	.
J= 9	.	.	.	.	.	113.	186.	326.	388.	371.	408.	405.	391.	554.	560.	196.	324.	296.	250.	.
J= 8	.	.	.	.	.	137.	209.	280.	329.	249.	481.	121.	346.	334.	282.	12.	.	.	.	.
J= 7	.	.	.	.	.	.	290.	245.	358.	277.	427.	282.	110.	214.	461.	154.	139.	.	.	.
J= 6	.	.	.	.	.	.	132.	117.	152.	440.	143.	341.	130.	436.	327.	24.	6.	.	.	.
J= 5	.	.	.	.	.	.	.	67.	105.	77.	80.	214.	679.	264.	186.	259.	86.	74.	.	.
J= 4	.	.	.	.	.	.	.	.	.	32.	59.	227.	96.	457.	213.	275.	12.	.	.	.
J= 3	.	.	.	.	.	.	.	.	.	35.	30.	187.	50.	490.	250.	278.	4.	.	.	.
J= 2	.	.	.	.	.	.	.	.	21.	24.	21.	74.	.	799.	22.	275.	4.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	25.	194.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

NO_x emission:

Data on combustion in mobile and stationary sources have been used to estimate the amounts listed in Table 2.2, and shown in Figure 2.7. Mobile sources burning gasoline and diesel fuel are the main source group for NO_x. Emission of NO_x from industrial processes in Jakarta is not known, but is assumed to be small.

Car traffic is the main source of NO_x emission. Process emission from industry is not considered an important source. The spatial distribution of NO_x emission within Jakarta is shown in Figure 2.8.

Figure 2.7: Total annual emission of NO_x from different groups of sources in 1990 (10^3 kg/yr)



Lead emission

The lead (Pb) content in the gasoline consumed in Jakarta in 1990 is calculated in Table 2.6

Measurements have shown that, in the course of urban driving, about 35 percent of

Table 2.6: Lead content in gasoline

Super 98	105×10^3 m^3 x 0.4 kg Pb /m^3	$= 42.0 \times 10^3$ kg
Premium	$1{,}070 \times 10^3$ m^3 x 0.4 kg Pb /m^3	$= 428.0 \times 10^3$ kg
		470.0×10^3 kg

Figure 2.8: Spatial distribution of NO_x emission in Jakarta (0.01 kg NO_2/hr)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20			46.	239.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	106.
J=19	48.	59.	126.	221.	261.	252.	348.	350.	208.	.	.	.	.	1037.	244.	1567.	707.	179.	505.	12.
J=18	80.	133.	129.	140.	74.	266.	569.	919.	2129.	1124.	789.	963.	734.	608.	1019.	2073.	591.	465.	191.	42.
J=17	91.	381.	436.	536.	695.	576.	788.	790.	1278.	1351.	1718.	1376.	972.	1122.	1467.	1167.	435.	773.	52.	603.
J=16	590.	121.	304.	513.	180.	576.	1530.	1610.	1814.	2282.	4009.	2179.	500.	466.	2019.	366.	49.	541.	516.	242.
J=15	89.	136.	242.	440.	200.	494.	1225.	1499.	2420.	980.	3520.	3154.	1429.	832.	1257.	942.	1040.	1117.	1480.	710.
J=14	.	.	293.	475.	938.	1068.	1709.	1686.	1923.	1480.	2544.	2457.	1868.	1447.	1986.	1568.	1683.	1237.	929.	1103.
J=13	.	.	.	61.	61.	235.	888.	1644.	2177.	2049.	2052.	1721.	1605.	1340.	1582.	1820.	1624.	945.	523.	317.
J=12	.	.	.	323.	235.	420.	550.	1821.	1404.	2901.	1594.	2229.	1872.	2846.	2314.	1272.	1711.	846.	679.	65.
J=11	.	.	.	566.	619.	780.	692.	1301.	2225.	1766.	2390.	1496.	1583.	1427.	1295.	872.	539.	634.	209.	.
J=10	.	.	.	.	.	361.	361.	1214.	2333.	1566.	2251.	2445.	1915.	2314.	2752.	1673.	1780.	769.	235.	.
J= 9	.	.	.	.	.	369.	603.	1056.	1256.	1192.	1322.	1312.	1267.	1789.	1311.	635.	1045.	953.	.	.
J= 8	.	.	.	.	.	447.	673.	907.	1066.	802.	1562.	395.	1120.	1081.	906.	38.	.	.	.	.
J= 7	.	.	.	.	.	.	935.	791.	1155.	896.	1379.	910.	360.	694.	1479.	495.		.	.	.
J= 6	.	.	.	.	.	.	426.	383.	493.	445.	466.	1101.	422.	921.	1054.	78.	20.	.	.	.
J= 5	.	.	.	.	.	.	.	219.	340.	250.	261.	691.	729.	852.	602.	833.	277.	238.	.	.
J= 4	.	.	.	.	.	.	.	.	.	103.	193.	735.	313.	497.	201.	884.	39.	.	.	.
J= 3	.	.	.	.	.	.	.	.	54.	113.	97.	603.	163.	602.	317.	892.	15.	.	.	.
J= 2	.	.	.	.	.	.	.	.	69.	79.	70.	237.		622.	72.	884.	13.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	81.	622.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

MAX. VALUE IS
4.0086E+01, IN (11 . 16)
SUM= 2.55184E+03

SCALE FACTOR: 1.0E-02

SCALE: GRID SIZE 1500 METER

the lead is exhausted as particles in the PM_{10} fraction (Haugsbakk and Larssen, 1985). The exhaust system functions as both a temporary and a permanent depository. During accelerations, part of the deposited lead is exhausted as larger particles. It is generally assumed that about 25 percent of the gasoline lead is permanently deposited in the exhaust system. The emission of lead to air in Jakarta is given in Table 2.7. Industrial emissions containing lead should also be taken into account

Table 2.7: Lead emission

In the TSP fraction	353×10^3 kg Pb/year
In the PM_{10} fraction	164×10^3 kg Pb/year

DISPERSION MODEL CALCULATIONS

Dispersion conditions

General description of topography and climate in Indonesia. The atmospheric circulation over Indonesia is affected by the meridian circulation termed Hadley circulation or trade wind. When the sun moves toward the southern hemisphere, the northeast trade wind is attracted to the south (September–February), and moist air from the sea influences Jakarta. When the sun moves toward the northern hemisphere, Jakarta is influenced by dry air (June–August). Normally, Indonesia experiences relatively low wind speeds. In the coastal regions of Indonesia, local land and sea breeze may cause stagnation in the air when they are directed opposite the large- scale wind systems. The dispersion of pollutants may, therefore, vary with season and time of day.

The topography of Indonesia is dominated by the volcanic belt which runs from the western tip of Sumatra to the eastern Irian Jaya, and from the northern tip of Sulawesi to the southern part. In the western and central parts of Java, the topography plays an important effect on the dispersion conditions.

Indonesia's climate belongs to the tropical maritime continent type, one of the most humid regions of the world. The monthly average relative humidity varies between 70–90 percent at an average temperature of 26–28°C.

Topography, climate and dispersion conditions in Jakarta. The area around Jakarta is flat, and no local topography affects the dispersion conditions. The climate is hot and humid. Solar heating during the day and the earth cooling during night produces a local land-sea breeze.

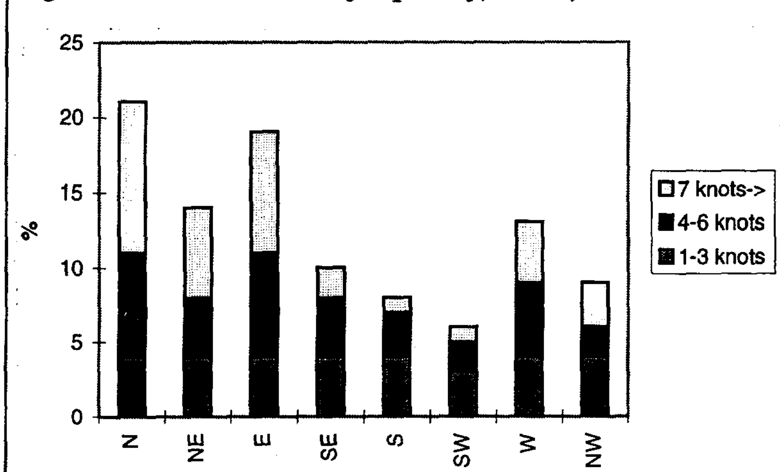
The Agency of Meteorology and Geophysics (BMG) operates six weather stations in the DKI Jakarta and BOTABEK area. The stations measure:

- air temperature;
- air humidity;
- wind speed;
- wind direction;
- cloudiness;
- barometric pressure;
- rainfall; and
- number of rainy days.

Mixing height is derived from upper air measurement (by means of the rawindsonde) from the Soekarno Hatta International Airport. Two-way frequency distribution of wind speed and direction is derived for the six weather stations in the DKI Jakarta area. The wind is categorized into 8 directions and 4 classes of speed (0; 1–3 knots; 4–6 knots; and greater than 6 knots).

Appendix 8 contains a description of dispersion conditions in Jakarta. Yearly data from the BMG weather station have been used to calculate annual average concentrations of NO_x and TSP. Figure 2.9 shows the occurrence of wind for BMG Jakarta. Where stability data were not available for Jakarta, the calculations were performed with neutral conditions. The models use 30°-sector averages, and the frequency distribution with 8 wind sectors is transferred to 30°-sectors.

Figure 2.9: Annual wind frequency, BMG, Jakarta



According to meteorological data (Appendix 8), dispersion conditions in Jakarta are complex, and sharp gradients are found in the wind between the center of the city and the coastline. Thus, it is important to account for the vertical exchange of pollution. There are few high stacks in Jakarta and emissions usually come from low stacks. In such a situation, the spatial distribution of source intensity is nearly proportional to the distribution of concentration values. As an estimate of vertical exchange, neutral stability conditions are used for the mixing layer for the dispersion model.

The influence of low weight level sources is probably overestimated in periods with strong solar radiation and underestimated during nighttime. The annual average concentrations may be somewhat overestimated. More accurate dispersion calculations may be carried out using numerical models describing actual dispersion conditions. It is important to use actually measured input data and to control numerical errors.

This study has used only statistical distributions of meteorological data. Even for long-term calculations, it is necessary to use hourly meteorological data (wind and stability) to create a joint wind speed/direction/stability matrix. The locations of measurement stations need to be reconsidered because the variation in wind roses among these stations is too great.

Adverse meteorological situations in Jakarta. Studies in Jakarta indicate weak and short-lived inversions. During the night, the cooling may produce ground-level inversions that trap the emissions and produce high concentrations. As soon as the sun rises, however, these inversions break up.

High ground-level concentrations may also arise when the local land-sea breeze is opposed to the large-scale wind system. This could happen during the early mornings when the sky is clear, and the airmass in the inland is cooled from below by ground infrared radiation. The airmass tends to follow the topography towards the coast. In the Jakarta area, the wind follows the river valleys from south to north.

The combination of low wind speed and unstable atmospheric conditions in the daytime can lead to high ground-level concentrations near point sources (stack emissions) due to the vertical turbulent motions.

Dispersion model calculations

Model description. The dispersion modeling in the first phase of URBAIR focuses on the calculation of long-term annual average concentrations within 1.5 x 1.5 km^2 grids ("city background" concentrations). Contributions from nearby local sources in specific receptor points such as street sides or industrial hot spots is evaluated separately.

The dispersion model used is a multi-source Gaussian model that treats area, point, and volume sources separately. Such a model is adequate for calculating a first approximation of the contribution from various source groups to long-term average air pollution concentrations.

Meteorological input to the model is represented by a joint wind speed/direction/stability matrix representing the frequency distributions of these parameters for the calculation period. The dispersion conditions are considered to be spatially uniform over the model area. The wind distribution shown in Figure 2.9 is transferred to 30°sectors, and the calculations are made for neutral stability. For point sources, plume rise (Brigg's equations) is taken into account along with the effects of building turbulence and plume downwash. For area sources, the dispersion of the emissions in a square grid is simulated by 100 ground-level point sources equi-spaced over the square, using the actual effective height of the emissions (for the traffic source, a 2-meter emission height is used).The Brookhaven dispersion parameter classification has been used. The actual software package used in the KILDER model system was developed at NILU (Gram and Bøhler, 1993).

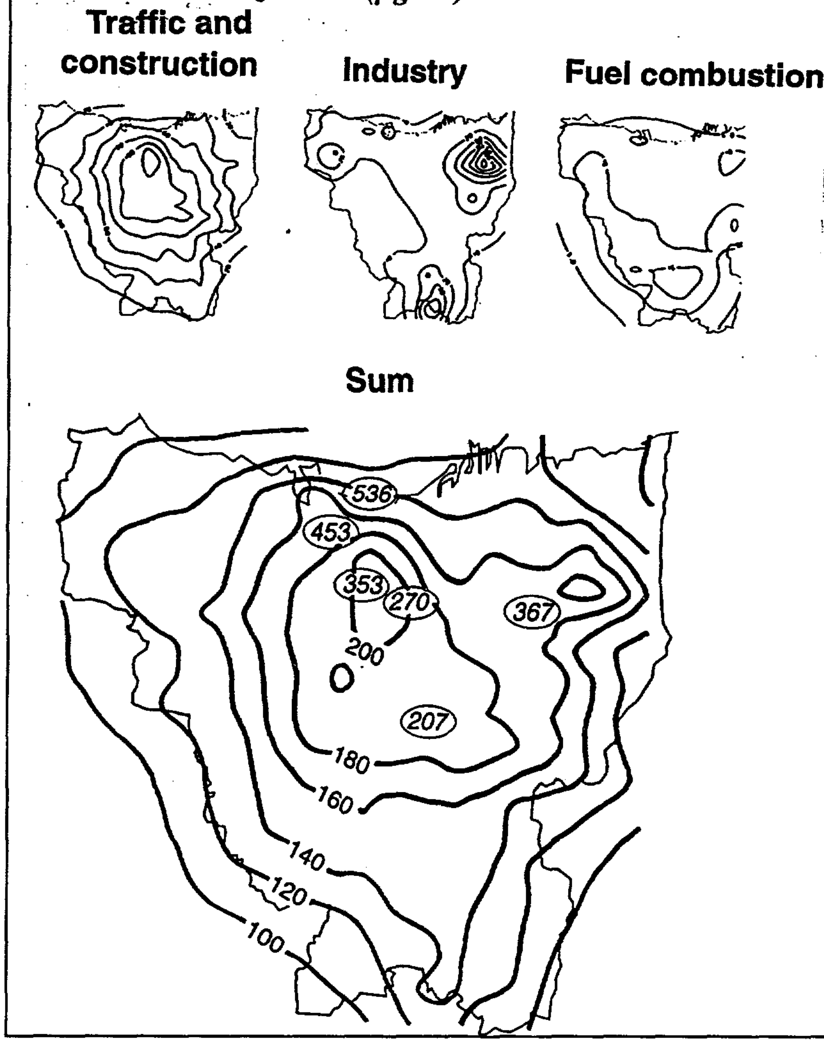
Secondary particle formation, such as secondary sulfate and organic aerosol, is not taken into account in this modeling exercise, which treats only dispersion of primary emission compounds. Further modeling and particle analysis should be done to estimate the extent of secondary particle formation.

TSP. The main contributors of TSP are traffic, industry and domestic burning. Figure 2.10 shows calculated and observed TSP concentrations in Jakarta.

Traffic is the most important source and contributes a maximum of 120 $\mu g/m^3$ in the center of the city. Of this, resuspension contributes 100–110 $\mu g/m^3$. The concentration distribution as a result of industrial emissions shows a maximum of 70 $\mu g/m^3$ over the industrial areas in the eastern part of the city. The emission from domestic burning shows a smaller maximum (10–15 $\mu g/m^3$) in the suburbs as a result of the population distribution and dispersion conditions.

The observed concentrations are inserted in Figure 2.10, showing the total concentrations. An extra-urban background concentration (70 $\mu g/m^3$) has been added. Generally, the calculated values are lower than the observed TSP values, particularly in the northern part of the city, close to the harbor. Some of the measuring stations are located near streets with high traffic intensity. This may explain some of the discrepancy between observed and calculated concentrations. However, in the northern part it is not possible to explain the observed concentrations by the estimated emissions. In order to improve air quality estimates in the maximum zone, it is necessary to know more about the emissions causing such high TSP values. In this area the observed NO_x concentrations are also underestimated.

Figure 2.10: Observed (encircled values) and calculated TSP concentrations in Jakarta (μg/m³)



NO_x. Each source group's contribution to total NO_x concentration is shown in Figure 2.11. An extra-urban background concentration of 15 μg/m³ has been added.

In the central and southern parts of Jakarta, there is a reasonable correspondence between observed and calculated concentrations. In the northern part (close to the harbor) and in the eastern part (close to the industrial area), the calculated emissions are below observed concentrations.

Measurements from the area indicate that NO_2 concentrations are 30–50 percent of the NO_x concentrations, and the proposed NO_2 air quality standard is not exceeded for yearly average values in Jakarta.

The observed ozone concentration in Jakarta is low as a result of the fast chemical reaction with the local NO emission, as shown in the following equation:

$$NO + O_3 \rightarrow NO_2 + O_2$$

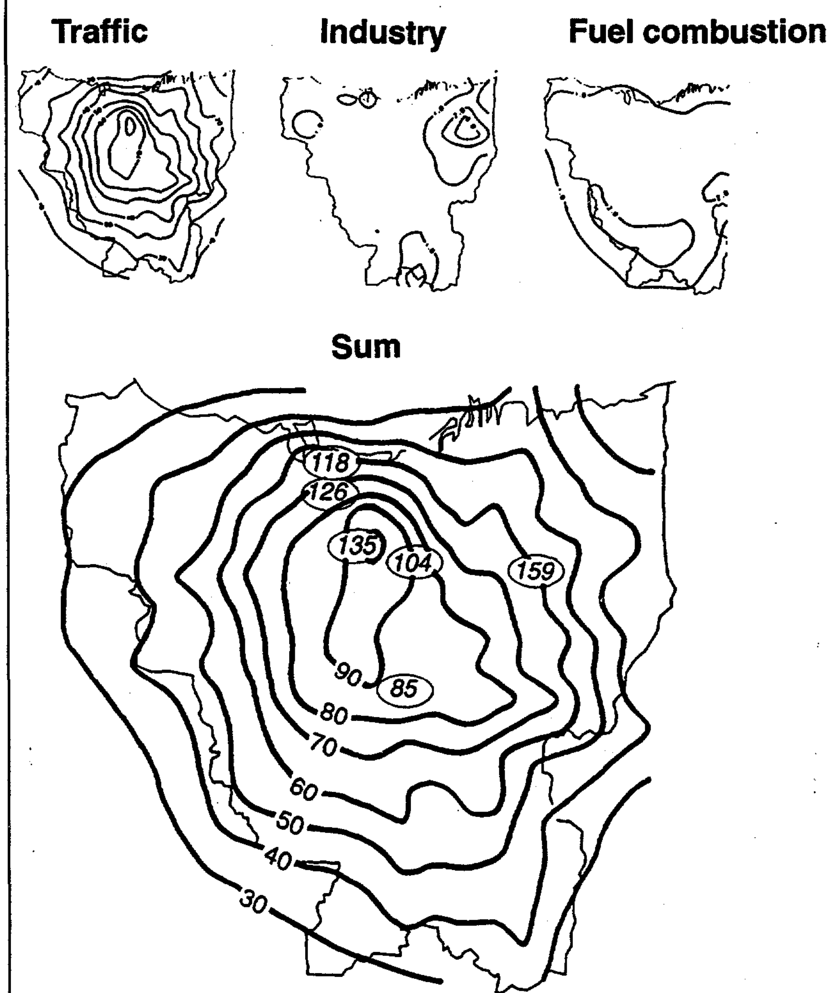
High O_x concentrations measured 30–40 km outside Jakarta area indicate that secondary pollutants develop as a result of NO_x and volatile organic compounds (VOC) emissions in Jakarta. Further investigations are needed to clarify the extent of these pollution problems.

Pollution hot spots

Pollution hot spots are characterized by significant pollution sources that emit large concentrations. Such hot spots are located along the main road system; and near industrial areas with significant emissions, especially through low stacks.

Preliminary calculations of hot spot concentration values indicate that the pollution problem in Jakarta is mainly an urban-scale problem resulting from many distributed sources. Additional pollution along the main roads results from local traffic emissions.

Figure 2.11: Observed (encircled values) and calculated NO_x concentrations in Jakarta ($\mu g\ NO_2/m^3$)



POPULATION EXPOSURE TO AIR POLLUTION IN JAKARTA

Population exposure is defined as the number of persons experiencing modeled pollution compound concentrations within given concentration ranges. The cumulative population exposure distribution gives the percentage of the total population exposed to concentrations above standard values. People are exposed to air pollutants at home, on roads, at work, and other places. In order to correctly map population exposure, data are needed on:

- Concentration distribution, and variation with time in homes (general city air pollution or city background), along the main road network, and near other spots such as industrial areas, and
- Population distribution (residences and workplaces), the number of commuters, and their time-dependent travel habits.

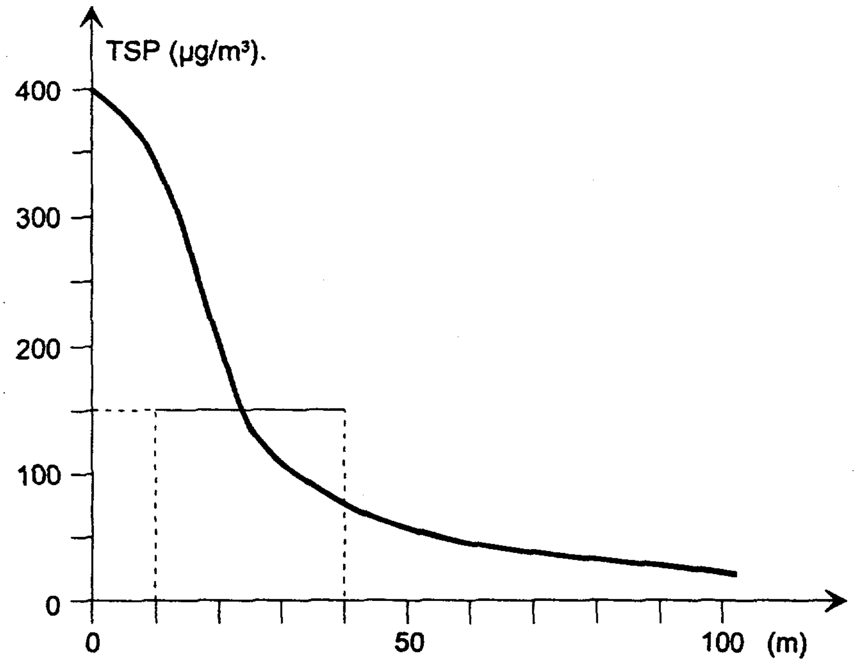
Databases for population exposure calculations are often incomplete. A methodology must be developed for each city based on the available data.

Estimating population exposure in Jakarta

Only exposure to TSP has been calculated for Jakarta. A total NO_x field could not be calculated because of lack of data on NO_x emission from industry. Population exposure was estimated on the assumption that inhabitants in each grid square are exposed to annual average TSP concentrations as shown in Figure 2.10.

The distribution is adjusted upwards to account for all area-distributed sources. TSP concentrations are assumed to decline with increasing distance from the road, as shown in Figure 2.12.

Figure 2.12: Long- term average TSP concentration close to road with high traffic intensity (1 car/sec = 3,600 cars/hour) as an annual average



The results of TSP exposure calculations are shown in Figure 2.13. The deviation from a log-normal distribution may be due to lack of data for various traffic intensities along the main roads in Jakarta.

Values for total exposure and for the effect of a source reduction in pollution on exposure, are given in Table 2.8. This table also shows commuting exposure. It is assumed that 30 percent of the population in each grid square is exposed to road side concentrations for 2 hours each day during commuting. A typical road concentration of 400 µg/m³ is used for calculating the influence on annual average concentration.

Table 2.8: Number of residents in Jakarta exposed to different levels of TSP concentrations outside their homes.

$C\varepsilon\,[C_1$	$C_2\,]$	$N_c > C_2$	ΔN	P	ΔP	Traffic reduction		Industry reduction		Domestic reduction	
µg/m3		µg/m3	inh.	%	%	25%	50%	25%	50%	25%	50%
80.0	90.0	6,458,608	0	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.0	100.0	6,454,574	4,034	99.938	0.062	0.225	0.792	0.062	0.314	0.062	0.062
100.0	110.0	6,400,467	54,107	99.100	0.838	1.458	3.741	0.987	1.257	0.838	0.838
110.0	120.0	6,272,124	128,343	97.113	1.987	3.794	11.120	2.494	3.398	2.190	2.439
120.0	130.0	6,024,203	247,921	93.274	3.839	7.485	19.039	4.437	5.806	3.976	4.065
130.0	140.0	5,668,254	355,949	87.763	5.511	11.207	19.477	6.873	8.571	5.170	5.357
140.0	150.0	5,106,759	561,495	79.069	8.694	13.964	30.877	9.416	9.281	8.973	9.366
150.0	160.0	4,454,121	632,638	68.964	10.105	13.167	10.570	11.598	9.683	10.190	11.491
160.0	170.0	3,835,884	618,237	59.392	9.572	13.172	1.774	7.440	9.383	10.115	8.430
170.0	180.0	3,320,573	515,311	51.413	7.979	23.949	0.059	9.870	11.354	7.511	8.270
180.0	190.0	2,478,595	841,978	38.377	13.037	6.219	0.000	9.175	9.476	12.597	11.305
190.0	200.0	1,446,275	1,032,320	22.393	15.984	1.522	0.000	8.926	18.088	18.792	18.792
200.0	210.0	807,480	638,795	12.502	9.981	0.000	0.000	7.784	4.611	7.083	7.700
210.0	220.0	424,136	383,344	6.567	5.935	0.000	0.000	4.370	3.676	5.935	5.318
220.0	230.0	329,558	94,578	5.103	1.464	0.000	0.000	1.464	0.000	1.464	1.464
230.0	240.0	329,558	0	5.103	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240.0	250.0	329558	0	5.103	0.000	0.000	0.000	0.000	0.000	0.000	0.000
250.0	260.0	329,557	1	5.103	0.000	0.000	0.009	0.000	0.000	0.000	0.000
260.0	270.0	329,276	281	5.098	0.004	0.015	0.049	0.006	0.012	0.004	0.008
270.0	280.0	328,246	1,030	5.082	0.016	0.055	0.226	0.019	0.039	0.016	0.012
280.0	290.0	325,169	3,077	5.035	0.048	0.130	0.473	0.075	0.069	0.048	0.059
290.0	300.0	317,409	7,760	4.915	0.120	0.296	1.034	0.132	0.169	0.132	0.136
300.0	310.0	304,915	12,494	4.721	0.193	0.482	0.640	0.292	0.337	0.194	0.236
310.0	320.0	283,503	21,412	4.390	0.332	0.620	0.119	0.356	0.523	0.358	0.348
320.0	330.0	249,940	33,563	3.870	0.520	1.378	0.001	0.611	0.629	0.509	0.539
330.0	340.0	203,937	46,003	3.158	0.712	0.679	0.000	0.516	0.609	0.684	0.606
340.0	350.0	125,549	78,388	1.944	1.214	0.172	0.000	1.496	1.510	1.425	1.425
350.0	360.0	73,132	52,417	1.132	0.812	0.000	0.000	0.664	0.573	0.600	0.670
360.0	370.0	14,852	58,280	0.230	0.902	0.000	0.000	0.707	0.633	0.902	0.832
370.0	380.0	0	14,852	0.000	0.230	0.000	0.000	0.230	0.000	0.230	0.230
380.0	390.0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
390.0	400.0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

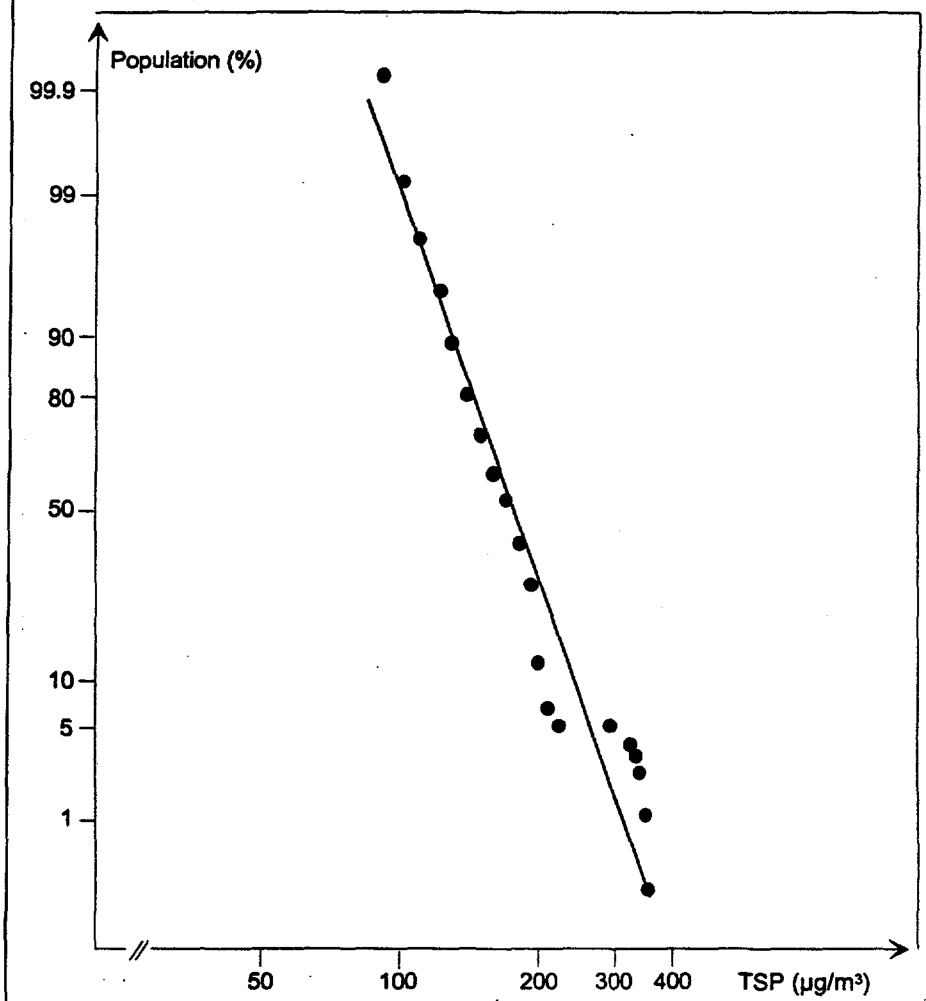
$C\varepsilon\,\lfloor C_1, C_2 \rfloor$: concentration interval $N_C > C_2$: cumulative concentration dist. ΔN: number of people in each pollution

P: cumulative concentration distribution in percent of total population. ΔP: percentage of population in each concentration interval.

Emission reduction: Percentage of population in each concentration interval after emission reduction.

AIR QUALITY ASSESSMENT SUMMARY

Figure 2.13: Percentage of population exposed to annual average TSP-concentrations above different values, as given along the x-axis



Concentrations of TSP have been measured regularly at 17 fixed locations, a few days per month. Some of the stations are located along streets, others in representative regions, and some in industrial areas. This limited data base shows the following:

- TSP is the most important pollutant in Jakarta.
- Observed TSP concentrations frequently exceed AQG. Concentrations near the main roads, and in the northern part of the urban area, are sometimes extremely high.
- Measurements in industrial areas indicate high TSP concentrations.
- High O_3 concentrations, measured 30–40 kilometers outside Jakarta, indicate that secondary pollutants develop as a result of NO_x and VOC emissions in Jakarta. Further investigations are urgently needed to clarify the extent of these pollution problems.

Emission sources. Rough estimates of TSP emission in Jakarta indicate that a considerable part of total emissions comes from car traffic, industrial processes, and open burning. Estimates are based on statistical data on pollution-producing activities, and on emission factors for the Jakarta region. Further investigation is vitally important to improve these rough estimates and to the development of a control strategy.

Road traffic is the main source of NO_x emission. In this study, data to estimate NO_x emission from industry were not available. Industrial process emissions of NO_x should be estimated to get a complete picture. However, these emissions are expected to be less important than traffic emissions.

Population exposure. The number of residents exposed to different TSP or PM_{10} levels is used to calculate health impacts of air pollution. The WHO AQG for particulates is exceeded for all residents in Jakarta. For each square in the grid, the spatial mean concentration is compared to different concentration levels, counting the number of people exposed to concentration above each level. In addition, several people are exposed to sub-grid exposure from main roads, as shown in the lower part of Table 2.8 and the right part of Figure 2.12. These are drivers (8 hours/day), commuters (½–2 hours/day) and roadside residents (24 hours). Due to the lack of industrial NO_x emission data, annual exposure to NO_x is not calculated. The observed NO_x values suggest that either NO_x is not an area problem, or that the measurement or stations are not representative.

Appendix 4 shows discrepancies between different sets of population data. For exposure calculations it is essential to have correct data for the population distribution.

Background for calculating effects of abatement measures. A simplified procedure for calculating emissions and the effects of different control measures on the emissions has been programmed into spreadsheets. These may be used in combination with population fields to prepare first order estimates of the effects of various abatement measures on exposure distribution. The concentration within a grid element $C_s(I, J)$ will be the sum of the contributions from each source group K:

$$C_s(I,J) = B(I,J) + a_K \cdot C_K(I,J),$$

where $B(I,J)$ is a background value, $C_K(I,J)$ is the concentration contribution from source K, and a_K is an emission reduction factor.

From this newly calculated concentration distribution, new exposure calculations should be performed, and from these new effects should be calculated. This may also be programmed into spreadsheets

AIR QUALITY ASSESSMENT

Data shortcomings

Monitoring. Measurements should be carried out to specify the typical chemical composition of the particles at the different stations, particularly in air pollution episodes. The human health impact of high TSP concentrations depends on this composition. The profile of chemical components will also help to identify the main source of particle pollution at the monitoring stations. Microscopic investigation of the particle structure may also give important information. This information is needed to develop a cost-effective control strategy.

The measurement system in Jakarta has the following features and shortcomings:

- collects 24-hour samples of TSP, NO_x and SO_2;
- monitoring network is run by several agencies with different routines for sampling, analysis calibration, and reporting;
- detailed station descriptions are needed to control for local influence;
- few measurements are taken in the other parts of Jakarta, and

- hourly meteorological data (wind, stability etc.) are needed from several places.

The monitoring agencies are operating under considerable financial constraints that impact methodological and manpower capacities. It is nevertheless important to improve air quality monitoring in Jabotabek, as the air entering Jakarta comes from the environs. An improved monitoring system should include:

- at least 5 city background sites, covering areas of typical and maximum concentrations;
- 1–3 traffic exposed sites (to monitor street level pollution);
- 1–5 industrial areas and hot spot sites;
- continuous monitors for PM_{10}, CO, NO_x, SO_2, O_3, depending upon the site;
- an on-line data retrieval system connected to a lab database, via telephone or modem;
- a single agency should be responsible for the monitoring and network control;
- O_3 measurements should be carried out soon in order to determine whether the area has a photochemical air pollution problem and such measurements should be carried out continuously over a one-year period at sites inside and outside Jakarta.

Emissions. Spatial investigations should be planned to specify:

- industrial emissions (questionnaires and measurements),
- open burning,
- resuspension,
- traffic counting, and
- traffic composition.

The Japan International Cooperation Agency (JICA) Integrated Air Pollution Study will continue air pollution studies in the Jabotabek area, including the preparation of an improved emissions inventory. This will include emissions from the point sources, as well as better traffic data.

Proposed actions to improve the air quality assessment in Jakarta are listed in Table 2.9.

Table 2.9: Actions and time schedule for improving air quality assessment

Actions	Time schedule
Air Quality Monitoring	
Design and establish a modified, improved, and extended ambient air monitoring system: • evaluation of sites; number and locations; • selection of parameters, methods, monitors, and operation schedule; • necessary upgrading of laboratory facilities, and manpower capacities.	This activity, part of the JICA study, started in 1995.
Design and establish Quality Control and Quality Assurance Systems	This should start immediately, together with the establishment of an improved monitoring system, and upgraded laboratories.
Design and establish an Air Quality Information System, including • database, • information to - control agencies, l- law makers, - general public.	This should begin as soon as modern, on-line, monitoring stations have been established.
Emissions	
Improve emissions inventory • Produce inventory of industrial emissions (location, process, emissions, stack data), • Improve inventory of road and traffic data, • Improve inventory of domestic emissions • Study resuspension from roads, from other surfaces. Develop an integrated and comprehensive emissions inventory procedure, include emission factor review, update and QA procedures. Cover entire Jabotabek. Improve methods and capacity for emission measurements.	This is a part of the JICA study, started in 1995. Priority: industrial emissions inventory; resuspension from - roads; development of an emissions inventory procedure; collecting traffic data; classifying the road network.
Population exposure	
Assess current modeling tools/methods, and establish appropriate models for control strategy in Jakarta..	Begin immediately by establishing a group which will have long-term responsibility for performing such modeling .

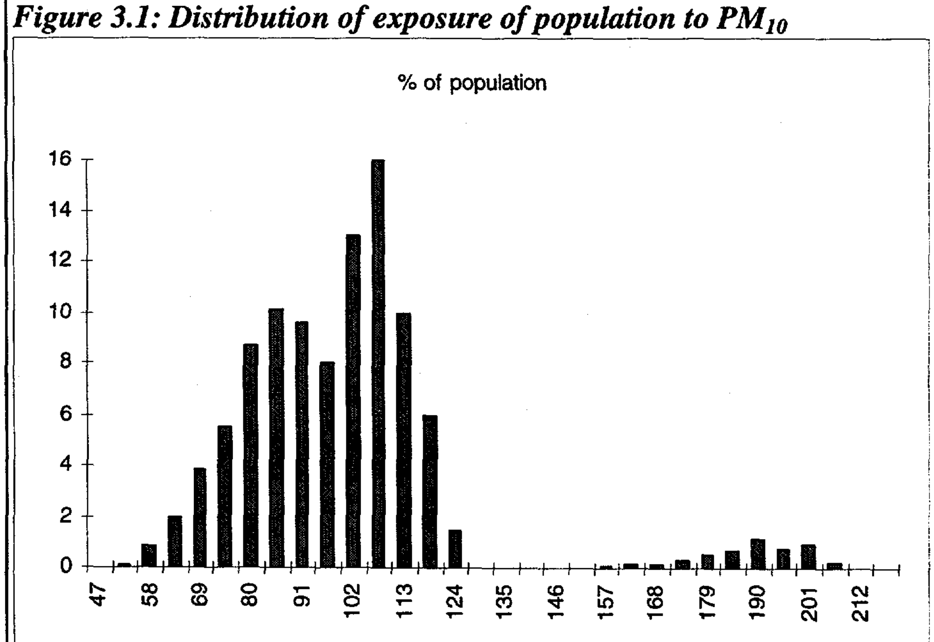
3. HEALTH IMPACTS OF AIR POLLUTION

This chapter presents an overview of the major impacts of air pollution in Jakarta, including an estimation of the monetary value of health damages. Concern about air pollution focuses on the high concentrations of suspended particles and lead, both exceeding national and WHO air quality guidelines (see Chapter 2). Problems arising from SO_2, NO_x, and ozone (photochemical air pollution) do not appear to be as serious. Therefore, this chapter concentrates on PM_{10} and lead.

Health impact estimates are based on air pollution dose-response research conducted in the United States (Ostro, 1994). The methodology for deriving these estimates is described in the *URBAIR Guidebook*. The equations presented here are derived from Ostro's research. Guidelines for acceptable pollution concentrations, "no-damage benchmarks," have been proposed by WHO. Although damage to human health is not the only adverse effect of air pollution, the lack of appropriate data prevented the quantification of other impacts such as a reduction in the economic life of capital goods, tourism, crop production, etc.

Just to give an indication of the possible damage from traffic congestion, let us suppose that one-third of the population (approximately 9.4 million in 1990) loses an average of two hours per day due to traffic congestion for 250 days per year. With an hourly wage rate of Rp840, this results in a damage of approximately Rp1,316 billion.

Figure 3.1: Distribution of exposure of population to PM_{10}



ASSESSING AND VALUING MORTALITY AND MORBIDITY

Health impacts are divided into mortality (excess deaths) and morbidity (excess cases of illness). Mortality and morbidity are derived from air quality data using dose-effect relationships. In principle such relationships are found by statistical comparison of death rates and morbidity in urban areas with different air quality. Ostro (1994) has estimated appropriate dose-effect relations. Admittedly, these dose-effect relations are derived from studies in U.S. cities, and it is speculative to apply them to Jakarta. But until specific dose-effect relations are derived for tropical conditions, these calculations are useful for preliminary analyses. Furthermore, while it is clear that indoor air pollution, such as that caused by cooking, can also damage health, this analysis was limited to outdoor air pollution.

Mortality due to PM_{10}. The relationship between air quality and mortality, where *P* represents the number of people exposed to a specific concentration; *c* stands for crude mortality rate (0.007 in Jakarta); and PM_{10} is the annual average concentration in $\mu g/m^3$, is:

$$Excess\ death = 0.00112 \times ([PM_{10}] - 41) \times P \times c$$

The PM_{10} benchmark is *41*. Above this benchmark mortality increases corresponding to the WHO AQG for long-term annual average concentrations (75 $\mu g/m^3$), taking into account that PM_{10} concentrations are 55 percent of the TSP concentrations.

From this relationship and the data presented in Chapter 2, it can be concluded that the excess mortality due to PM_{10} was about 4,500 cases in a population of 9.4 million. Note that mortality is proportional to the population. If the air quality does not deteriorate, the mortality would still increase with population growth.

Mortality due to lead. Diastolic blood pressure (DBP) plays a role in the dose-effect function of mortality caused by lead. The relationship between lead concentration and change in *DBP* is estimated as:

$$\Delta DBP = 2.74\ (\ln\ [Pb\ in\ blood]_{old} - \ln\ [Pb\ in\ blood]_{new}),$$

where *[Pb in blood]* indicates the concentration of lead in blood ($\mu g/dl$).

The relationship between lead in blood and lead in air is complex, but generally proportional. A good approximation can be made with the following equation:

$$\Delta DBP = 2.74\ (\ln\ [PbA]_{old} - \ln\ [PbA]_{new}),$$

where *[PbA]* indicates the concentration of lead in the air ($\mu g/m^3$).

Evidence of a threshold level of *[PbA]* is scant, and the threshold can be taken as zero. However, as per WHO guidelines, a benchmark of 0.5 $\mu g/m^3$ for $[PbA]_{old}$ can be used. If we fill in the existing lead concentration for $[PbA]_{new}$, the change in *DBP* can be derived. The change in the 12 year probability of death, *Pr(M),* related to the change in blood pressure due to lead is estimated as:

$$Pr\ (M) = (1 + \exp\text{-}[-5.315 + 0.03516\ DBP_{old}])^{-1} - (1 + \exp\text{-}[-5.315 + 0.03516\ DBP_{new}])^{-1}$$

The reference value of DBP_{old} *is* 76, the average value used in the United States.

The average 24-hours concentrations measured in Jakarta vary between 0.5 and 2.0 µg/m^3, but no exact exposure figures could be derived. Therefore, the study used was that by Calkins et al. (1994), who estimated 340 cases of mortality per year due to lead on the basis of the same dose-effect relations.

MORBIDITY

Particulates. Many cases of chronic bronchitis, restricted activity days (RAD), respiratory hospital diseases (RHD), emergency room visits (ERV), bronchitis, asthma attacks and respiratory symptoms days (RSD) can be attributed to particulate pollution.

The following dose-effect relationships, described in greater detail in the *URBAIR Guidebook*, are used:

- Change in RAD per person per year per µg/m^3 PM_{10} is estimated at 0.0575. Using the WHO AQG, the change is $0.0575 \times ([PM_{10}] - 41)$.
- Change in RHD per 100,000 persons is estimated at 1.2 per µg/m^3 PM_{10}. Using the WHO AQG, RHD per 100,000 persons are estimated at $1.2 \times ([PM_{10}] - 41)$.
- Change in the number of ERV per 100,000 persons is estimated at 23.54 per µg/m^3 PM_{10} and the total number of ERV per 100,000 persons at $23.54 \times ([PM_{10}] - 41)$.
- Change in the annual risk of bronchitis in children below 18 years, who comprise 35 percent of the total population (Achmadi, 1994), is estimated as $0.00169 \times ([PM_{10}] - 41)$.
- Change in daily asthma attacks per asthmatic person who total 7 percent of the population (Achmadi, 1994) is estimated at $0.0326 \times ([PM_{10}] - 41)$.
- Number of RSD per person, per year, is estimated at $0.183 \times ([PM_{10}] - 41)$.

The impacts of PM_{10} air pollution, on health in Jakarta are summarized in Table 3.1.

Table 3.1: Impact of PM_{10} air pollution on health, 1990

Type of health impact	Number of cases (thousands)*
Restricted activity days (RAD)	32,001
Emergency room visits (ERV)	131
Bronchitis in children	326
Asthma	1,270
Respiratory symptom days (RSD)	102,000
Respiratory hospital admissions (RHD)	7

* Figures are presented in detail for reasons of consistency, not to suggest large reliability.

Lead. For practical purposes, the WHO AQG for lead exposure thresholds may be used. The major effects of lead are hypertension, coronary heart disease, and decline of intelligence quotient (IQ) in children.

The relationship between a change in the probability of hypertension and a change in air quality is estimated as follows:

$$\Delta H = (1 + \exp - (-2.744 + 0.793 \ln 2[PbA]_1))^{-1} - (1 + \exp - (-2.744 + 0.793 \ln 2[PbA]_2))^{-1}$$

in which $[PbA]_2$ is the ambient lead concentration in the air. As $[PbA]_1$, the WHO AQG of 0.5 µg/m^3 can be used.

The dose-effect relationship of coronary heart disease *(CHD)*, where the increase in the 10 years probability of a case is $\Delta Pr(CHD)$ is:

$$\Delta Pr\,(CHD) = (1 + exp(-(-4.996+0.030365\,DBP_1))^{-1} - (1+exp(-(-4.996+0.030365\,DBP_2))^{-1}$$

The dose-effect relationship used for estimating a decline in children's IQs is:

$$\Delta IQ = 0.975 \times ([PbA]_2 - [PbA]_1),$$

The WHO AQG of 0.5 µg/m³ is used for $[PbA]_1$. Because of lack of exposure figures on lead, we use the results of Calkins et al. (1994), which are based on the same dose-effect relationships. These results are given in Table 3.2.

Table 3.2: Health impact of lead air pollution (1992)

Coronary heart disease	350 cases
Hypertension	62,000 cases
IQ points loss	300,000 points

VALUATION OF HEALTH IMPACTS

Mortality. Placing a monetary value on mortality is debatable. Many argue that such a valuation cannot be made on ethical grounds. By deleting mortality, however, we would seriously underestimate the total damage caused by air pollution. A case (single instance) of mortality can be valued in two ways. The first is based on "willingness to pay," the other on "income potential."

The "willingness to pay" (WTP) approach is described in detail in the *URBAIR Guidebook.* In the United States, a value of about US$3 million per statistical life is often used. Although such a valuation is not readily transferable from one country to another, an approximation can be derived by correcting the U.S. figure by a purchasing power parity factor. The purchasing power parity in Indonesia divided by the purchasing power parity in the United States is factored as 2,120 divided by 21,900 equaling 0.096 (Dikhanov). At an exchange rate of US$1.00 equals Rp2,233, this results in a value of Rp650 million per statistical life in Indonesia.

The second approach is based on income lost due to mortality. The value of a statistical life (VSL) s estimated as the discounted value of expected future income at the average age. If the average age of population is 26 years and the life expectancy at birth is 65 years, the value is:

$$VSL = \sum_{t=0}^{38} w\,/\,(1+d)^t$$

In this equation, *w* equals average annual income, *d* equals discount rate (Shin et al., 1992). In this approach, the value of persons without a salary (e.g. housewives) is the same as the value of those with a salary. If we estimate the daily wage in Jakarta as Rp6,700 (US$3.00) at 200 working days in a year, *w* equals Rp1,340,000. At a discount rate of 5 percent, VSL equals Rp23.45 million.

In both approaches to the valuation of premature death due to PM_{10} air pollution, the cost of air pollution in 1990 ranges from Rp2,836 billion to Rp102 billion.

Morbidity. The *URBAIR Guidebook* presents estimated costs of morbidity (medical treatment, lost earnings) based on U.S. values. In order to obtain city-specific figures, the U.S. estimates were corrected by a factor of 0.096 to reflect the difference in purchasing power. These estimates are supplemented by estimates created specifically for Jakarta (Achmadi, 1994). Both sets of data are presented in Table 3.3.

Table 3.3: Health impacts from PM_{10} and lead and their valuation in Jakarta (1990)

Health impact	Cases	Specific value (US-derived) (Rupiahs)	Total value (US-derived) (million Rp)	Specific value Indonesian Rupiahs	Total value based on Indonesian data. (million Rp)
Impacts from PM_{10}					
Mortality	4,364	650 million	2,836,645	23.45 (million)	102,336
Restricted activity day	32,006,885	12,400	396,885	4,466	142,943
Emergency room visit	131,033	55,300	7,246	11,165	1,463
Bronchitis (children)	326,431	70,000	22,850	22,330	7,289
Asthma attacks	1,270,255	21,400	27,183	11,165	14,182
Respiratory symptoms days	101,865,393	3,200	325,969	4,466	454,931
Hospital admission	6,680	6 million	40,078	335,000	2,238
Total (PM_{10})			*3,656,858*		*725,382*
Impacts from lead (valued)					
Mortality	340	650 million	221,000	23.45 million	7,973
Coronary heart disease	350	47,160	17	11,165	4
Hypertension	62,000	10 million	620,000	3,345,000	207,390
IQ points loss	300,000	980,000	294,000	279,125	83,738
Total (lead)			1,135,000		299,000

CONCLUSIONS

Air pollution damages not just human health but also materials, vegetation and crops, buildings and monuments, ecosystems, and tourism. Lack of data and methodological problems make it very difficult to place a monetary value on much of this loss. In this report, damage to human health is estimated by using U.S.-based dose-effect relationships.

Damage to health consists of mortality and morbidity. Using the human capital approach (i.e. lost earnings due to premature death), the value of a statistical life amounts to Rp23.5 million.

Costs of morbidity are relatively more reliable. They consist of foregone wages and costs of medical treatment. The cost of morbidity due to concentrations of PM_{10} was estimated specifically for Jakarta. This valuation of damage to human health is an underestimation as it does not include the suffering due to illness or premature death.

Table 3.4 presents PM_{10} contributions from various sources and the number of mortality cases and RSD resulting from each of the categories. Total costs are estimated for each category. These figures are approximations based on the Jakarta air quality model. They reflect reduction in health damage, i.e. a benefit, if the emissions from the indicated source were reduced to zero. The health costs are based on Achmadi's 1994 estimates.

The damage due to lead is estimated at Rp291 billion (see Table 3.3). Other health damage (e.g. due to ozone, NO_x, SO_2) could not be estimated due to the lack of exposure figures.

Table 3.4: Air pollution (PM_{10}) impacts attributed to source categories (1990)

Source category	Emissions (tons)	Mortality (cases)	Respiratory symptom days (millions)	Costs (Rp billion)
All sources	42,417	4,364	100.0	725
Gasoline cars (four stroke)	1,284	730	17.0	28
Motorcycles/Bajaj	2,700	1,460	34.0	54
Diesel fueled vehicles	2,363	1,158	27.0	44
Combustion of heavy fuel oil (domestic sources)	1,430	13	0.3	2
Half of process emissions*	7,000	336	8.0	41

* Simplified model used does not allow calculation of total attribution.

Benefits of emissions reduction (Table 3.5) are based on estimates of the total annual TSP, PM_{10}, and NO_x emissions (Table 2.2). These results indicate that reducing emissions from traffic and industry should be the first priority. This does not take into account the costs of abatement.

Table 3.5: An assessment of the benefits of emissions reduction

Source category	Emission reduction (%)	Emission reduction (tons)	Avoided mortality	Avoided RSD (million)	Avoided health costs (Rp billion)	"Marginal" benefits (Rp million per ton reduced)
Traffic	25	5,230	854	20	124	24
Industry (process emissions)	25	3,600	600	14	87	24
Diffuse/domestic	25	3,500	26	0.6	3.8	1

Health impacts and associated costs tend to increase as air quality deteriorates. In addition, with population growth in the city, there is a rise in total costs as the health of more people is put at risk.

4. ABATEMENT MEASURES: EFFECTIVENESS AND COSTS

INTRODUCTION

This chapter presents information about measures for reducing air pollution in Jakarta and for drafting an action plan that would translate these measures into practice. Information is organized by source category: traffic; power plants; fuel combustion other than in power plants; non-combustion sources; construction; and refuse burning.

For the main source categories, characteristics of abatement measures are described in terms of:

- *effectiveness* in emissions reduction and reduced exposure impacts in 1995 (according to the methodology used in Table 3.5); the reference data are mortality (4,500 due to PM_{10}), and number of RSD (100 million);
- *costs* of measures in order to prioritize implementation;
- *benefits* including reduced excess deaths (mortality, reduced number of RSD, and economic benefits);
- *policy instruments and institutions* that may be used to implement the measures; and
- *term* for emissions reduction: short term (2 years), mid-term (2–5 years) , long term (more than 5 years).

The list of measures is derived from the information presented by the local working groups, from the *URBAIR Guidebook* and from earlier plans for addressing pollution in Jakarta. All figures for emissions, costs, and benefits represent annual estimates for 1990, unless otherwise stated.

TRAFFIC

This section describes the effectiveness (abated emissions) and, to the extent possible, the benefits of measures such as:

- introduction of unleaded gasoline;
- implementation of a scheme for inspection and maintenance;
- addressing excessively polluting vehicles;
- improving diesel fuel quality;
- improving quality of lubricating oil in two-stroke engines;

- fuel switching (from diesel/gasoline to LPG/CNG) in the transportation sector; and
- adoption of clean vehicle emissions standards.

Introduction of low-lead or unleaded gasoline

Unleaded gasoline addresses the lead pollution problem and is a prerequisite for the introduction of strict emissions standards. An "intermediate" approach would be to lower the lead content of gasoline.

The introduction of unleaded gasoline requires that vehicles with catalytic converters and a separate fuel distribution system that does not mix leaded with unleaded fuel be simultaneously brought into use. Retailers usually sell both leaded and unleaded fuel. Older engines may require leaded fuel because of the material used for valve seats and/or the high RON-number gasoline

Effectiveness. Emissions decline and are proportionate to the eventual market shares of unleaded and low-lead gasoline. In case of low-lead gasoline, the reduced emissions are proportionate to the lead content.

Costs of the measure. If lead is removed, the gasoline has to be reformulated in order to maintain ignition properties. To obtain gasoline with a sufficiently high RON number, lead may be substituted by oxygenated compounds. MTBE (Methyl tertiary butyl ether) is the preferred substitute. These changes increase production costs, typically by Rp40–60 per liter gasoline, depending on the local market for refinery products, the required gasoline specifications, and the costs of MTBE (Turner et al., 1993). From Table 2.5 it is inferred that about 1 billion liters of gasoline is consumed, leading to a cost estimate of Rp50 billion cost for a 100 percent shift to the use of unleaded gasoline.

Policy instruments and target groups. Officially lowering the allowed content of lead is the most common way of affecting change. In countries where gasoline is taxed, the taxes on unleaded gasoline are lowered and those on leaded gasoline are increased, so that the net yield for the fiscal authority does not change. The petroleum industry and gasoline distribution firms have to produce and distribute the gasoline.

Term. Unleaded fuel can be made available at a large scale within five years. The production of low-lead gasoline is technically simple. A summary of this abatement measure is given in Table 4.1.

Table 4.1: Introduction of low-lead and unleaded fuel

Effectiveness:	Depending on the rate of introduction.
Costs:	Costs at refinery Rp40–60 (per liter unleaded fuel).
Benefits:	Rp300 billion. Reduction in mortality, 340 cases; loss of IQ points (children).
Instruments/institutions:	New regulation; tax differential.
Term:	Two to five years.
Target groups:	Petroleum industry, firms that sell gasoline.

Scheme for inspection and maintenance

Effectiveness. Maladjusted fuel injection systems or carburetors and worn-out motor parts pose a threat to traffic safety. They also increase fuel consumption and costs, and lead to large emissions. Semi-annual inspection and maintenance of vehicles would probably result in substantial reductions in PM_{10} , VOC, and CO. An accurate assessment of emissions reduction associated with an inspection and maintenance scheme requires statistical data on emission characteristics of the Jakarta vehicle fleet relative to its state of maintenance. Such information is not available.

It is assumed that the proposed inspection and maintenance scheme would reduce tail pipe emissions of PM_{10}, VOC, and CO by one-third, as is the case for the World Bank estimate for Manila (Mehta, 1993).

Costs of an inspection and maintenance scheme. Jakarta presently lacks the capacity to test all vehicles for emissions. It is estimated that approximately 650 test units are needed to carry out 33 million tests (a 20-minute, biannual procedure). It is suggested that private firms could share the responsibility (Budirahardjo, 1994)[3]. A similar scheme has been proposed for Manila (Baker et al., 1992). Such a scheme may cost roughly Rp67 billion, or Rp2,200 per test per vehicle owners. A reduction in fuel costs, associated with improved engine performance, would offset the maintenance costs.

Policy instruments and target groups. According to Governor Decrees 122 and 1236 (1990), vehicles must comply with standards and an inspection scheme. Emissions are measured at road-worthiness inspections (Decree of the Minister of Transportation KM 8 of 1989) carried out by the Transport & Highway Department Service (Budirahardjo, 1994).

Term. An inspection and maintenance scheme can be implemented within 5 years. A summary of this measure is given in Table 4.2.

Table 4.2: Implementation of an inspection and maintenance scheme

Effectiveness:	35% reduction, 1,300 tons PM_{10}.
Costs:	Rp67 billion; maintenance costs are expected to be offset by improved fuel efficiency.
Benefits:	Reduced mortality, 212; reduced RSD, 5 million; avoided health costs, Rp30.8 billion; reduction of CO, VOC emissions; safer automobiles (if roadworthiness is included in the scheme).
Instruments/institution:	Implementation of existing rules; arrangement for involvement of private firms.
Term:	Two–five years.
Target groups:	Private sector.

3 The scheme would work in the following way: licensed firms perform inspections; authorities spot-check the firms to ensure that inspections are made properly; approved vehicles get a sticker valid for a specific period; drivers have to show a test report upon request; and vehicles are spot-checked by Transport Authority.

Address excessively polluting vehicles

A fourth of all vehicles are estimated to have excessive emissions. These vehicles are badly maintained, use worn out engines, or have maladjusted engine controls. The extent of emissions reduction, obtained through a strict enforcement of the regulation, is about 1,000 tons (15 percent reduction of traffic-exhaust emissions). A summary of measures for abatement of excessively polluting vehicles is given in Table 4.3.

Table 4.3: Excessively polluting vehicles

Effectiveness:	1,000 tons PM_{10}.
Costs:	Varies depending on implementation.
Benefits:	Reduced mortality, 163; reduced RSD, 4 million; avoided health costs, Rp23.7 billion
Instrument/institution:	Stringent application of existing laws.
Term:	Two to five years.
Target groups:	Traffic authorities, vehicle owners and police.

Improving diesel quality

Diesel's ignition and combustion properties are important parameters for explaining PM_{10} emission from diesel engines (Hutcheson and van Paassen, 1990, Tharby et al., 1992). These properties include: volatility,[4] viscosity,[5] and cetane number.[6] In Jakarta a minimum cetane number of 45 is specified for diesel fuel. In the United States, Western Europe, and Japan the corresponding number varies from 48 to 50.

Diesel quality is also determined by the presence of detergents and dispersants in diesel fuels. These additives keep injection systems clean and have a discernible impact on efficiency (Parkes, 1988).

Effectiveness. An improvement in the properties of diesel fuel, as expressed by a higher cetane number, and the addition of detergents results in a 10 percent reduction in PM_{10} emission or the equivalent of about 230 tons (1990 data).

Reducing the sulfur content leads to a proportional decline in SO_2 emission. PM_{10} emission also decreases because a part of the particulates comes from sulfur in the fuel.

Costs. The cost of improving diesel fuel, especially improving the cetane number, is determined by the oil-product market, the refinery structure (capacity for producing light fuels, visbreaking, hydrotreating etc.), and government involvement in the national market. The latter finally determines the price of fuels at the pump.

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4 Volatility is the ease with which a product begins to vaporize. Volatile substances have relatively high vapor pressures; therefore, they boil at relatively low temperatures.

5 Viscosity is the property of a fluid which determines its rate of flow. As a fluid's temperature increases, its viscosity decreases and it flows more readily.

6 The physico-chemical properties of diesel fuel, as expressed in the cetane number, influence the magnitude of TSP emissions of diesel powered vehicles. The relationship between these properties (such as volatility, viscosity) and the production of TSP in a diesel motor is not straightforward; the characteristics of the diesel motor, its load and its injection timing plan are other important parameters complicating the picture.

The cost of reducing the sulfur content of diesel stems from the requirement for extensive desulfurization at the refinery. The cost of reducing sulfur from 0.7 percent to 0.2 percent is Rp20 per liter. When combusted, the sulfur in diesel fuel forms corrosive sulfuric acid. Therefore, lowering the sulfur content leads to a financial benefit, as there is a parallel reduction in the cost of vehicle maintenance and repair.

Policy instruments and target groups. Recommentations to improve the quality of diesel fuel affect the energy policy of Indonesia and thus both authorities dealing with energy and fuel standards would have to be involved.

Term. The required adjustment of refineries, such as extension of visbreaking capacity, would take about 3-5 years. A summary for abatement measures for improving diesel fuel quality is in Table 4.4.

Table 4.4: Improving diesel fuel quality

Effectiveness:	230 tons PM_{10} (1990).
Costs:	Low.
Benefits:	Reduced mortality, 41; reduced RSD, 1 million; avoided health costs, Rp5.9 billion; reduction of SO_2 emission.
Instruments/institution:	Energy authorities.
Term:	Three–five years.
Target groups:	Petroleum industry.

Introduction of low-smoke lubricating oil for two-stroke, mixed-lubrication engines

Jakarta traffic has a large share of motorcycles and tricycles (locally known as Bajajs) equipped with two-stroke mixed lubrication engines. Exhaust from these vehicles causes about one-third (2,700 tons) of the PM_{10} emission. A substantial fraction of the particles emitted is in the form of droplets of unburned lubrication oil. According to Shell (private communication, 1993), the lubricating oil used in most South-Asian countries is cheap and has poor combustion properties.

Effectiveness. It is assumed that the use of a better lubrication oil would cut the emissions in half (1,350 tons reduction).

Costs. The introduction of these oils is estimated to double the costs of lubricating oil. The annual consumption of these oils is estimated at 2,000–5,000 tons.[7] Low-smoke lubricating oil may cost as much as Rp2–10 billion per year.

Policy instruments and target groups. An economic instrument might be preferred. A summary of this abatement measure is given in Table 4.5.

Table 4.5: Introduction of low-smoke lubricating oil

Effectiveness:	1,350 tons PM_{10} (1990).
Costs:	Rp2–10 billion.
Benefits:	Reduced mortality, 220; reduced RSD, 5 million; avoided health costs ,Rp32 billion.
Instruments/institution:	Regulations.
Term:	Two years.
Target groups:	Petroleum industry.

7 Mileage of motorcycles and tricycles (Bajajs) is estimated at 5.3 billion km. At an average fuel efficiency of 0.02 liter/km, and an average content of 2–5 percent, total annual consumption of lubrication oil ranges from 2,000–5,000 tons.

Fuel switching in the transportation sector

Switching to gaseous fuels such as Liquid Petroleum Gas (LPG) and Condensed Natural Gas (CNG) is another way of reducing PM_{10} emission. In areas where supply of LPG is abundant, it is widely used; fuel taxes favor its use. The use of LPG and CNG requires adapting the engine and its controls. This is economically feasible only when LPG and CNG cost less than gasoline or diesel.

LPG can be used as a clean alternative to both gasoline and diesel. PM_{10} emission from LPG is very low. Currently, the use of LPG as an automotive fuel is prohibited in Indonesia (P.T. Mojopahit, 1991). This prohibition could be reconsidered.

CNG use has been promoted for vehicles other than motorcycles or tricycles (Bajaj). Although it was introduced as an alternative fuel for taxicabs (Blue Bird), it has not been widely accepted. (P.T. Mojopahit, 1991). The investments for engine modification could be paid off within 1–1.5 year. A practical problem with CNG use is the loss of luggage space due to large fuel tank and a reduction in motor power.

Effectiveness. CNG is used as substitute fuel in four-stroke gasoline engines. It is very effective in reducing PM_{10} emission (90 percent reduction). If all gasoline cars had been modified for the use of CNG, emissions would have been 1,300 tons less in 1990 (about 3 percent of the total emissions). Table 4.6 gives the estimated benefits of CNG use.

Table 4.6: Introduction of CNG to replace 50 percent of gasoline consumption (1990 situation), passenger cars

Effectiveness:	650 tons.
Costs:	Costs for vehicle owner depend on the price differential between gasoline and CNG (natural gas is cheaper).
Benefits:	Reduced Mortality, 98; reduced RSD, 2 million; avoided health costs, Rp14,2 billion.
Trade-off:	Increase of emission of methane (greenhouse gas), the main constituent of natural gas.
Instruments/institution:	Regulations and incentives.
Term:	Two–five years.
Target groups	Energy authorities.

Costs. Investment in a taxi with a CNG tank and the modification of fuel-system in 1991 was estimated at Rp1.5 million. Given the fuel prices (gasoline versus CNG) in 1990–1991, costs were negative for taxi owners.

Policy instruments and target groups. The use of CNG for automotive purposes, is an objective of the Indonesian government (Decree of Research and Technology Minister No. 887/M/BPPT/1986).

Adoption of clean vehicle emissions standards

Many countries have adopted standards for permissible emissions from vehicles. These standards require vehicles with four-stroke gasoline engines to be equipped with exhaust gas control devices based on the use of three-way catalysts (closed-loop systems). A few countries, including Austria and Taiwan, have also set standards for motorcycle emissions, requiring that two-stroke engine-powered vehicles be equipped with open-loop catalysts. Such catalysts control VOCs, PM_{10}, and CO emissions, but not NO_x. The catalyst technology uses unleaded gasoline, the sulfur content of which should be less than 500 ppm. Therefore, introducing such standards requires the infrastructure for producing and distributing unleaded gasoline.

Diesel-powered vehicles are also subject to regulations in Jakarta. The emission requirements are met by adjusting the motor design and management plan. Tailpipe emission treatment may also be used. Existing buses can be retrofitted with abatement equipment. If the latter method is to be used, the diesel must be of higher quality than is currently used (sulfur content below 0.02 percent). Such a standard is now being introduced in some parts of the world.

Effectiveness: Closed-loop catalytic treatment of exhaust gases in gasoline engine vehicles (three-way catalysts) reduces exhaust emissions of NO_x, CO, and VOC by about 85 percent. Because unleaded gasoline is required, lead emission is eliminated.

Open-loop catalytic treatment of exhaust gases in two-stroke motorcycles reduces CO, VOC and PM_{10} (oil mist) emissions. There is 90 percent reduction in PM_{10}, otherwise the major source of emissions from two-stroke engines. Alternatively, using well-designed and maintained four-stroke engines leads to similar reduction in PM_{10} emission.

Unleaded gasoline is a prerequisite for the use of catalytic devices for treating exhaust gases. Removing lead from gasoline changes its ignition properties; gasoline has to be reformulated to maintain ignition. This can be done by increasing the content of aromatics[8] in gasoline, or by adding oxygenated compounds such as MTBE (methyl-tertiary-butyl-ether). Aromatics, however, include benzene, a carcinogenic compound. This may result in an environmental hazard, both from benzene exposure due to evaporation of gasoline (during production, storage and handling), and from an increase in the benzene content in exhaust gases (Tims et al., 1981, Tims, 1983). A limit on the benzene content of gasoline may be necessary. A decision on the specification of this limit would be based on current air quality data. Experience in other countries suggests that this issue can be resolved. Catalytic devices are effective in destroying benzene in exhaust gases. This all leads to the expectation that the net result is small—decrease of benzene emission from "clean" cars and (possible) increase of the exhaust emissions of dirty cars using unleaded gasoline.

Unleaded gasoline with a high RON-number[9] is usually produced by adding MTBE, the preferred lead substitute. MTBE must be imported into Indonesia.

Costs. Due to methodological difficulties, it is not possible to calculate the total costs of introducing these standards in Jakarta. However, costs can be estimated on a vehicle-by-vehicle basis.

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8 Aromatics are groups of hydrocarbons of which benzene is the parent. They are called "aromatics" because many of their derivatives have sweet odors. These hydrocarbons are of a relatively high specific gravity and possess good solvent properties. Certain aromatics have valuable anti-knock (octane) characteristics. Typical aromatics are benzene, toulene, xylene.

9 The octane number of gasoline is a measure of its anti-knock value. The higher the octane, the higher is the anti-knock value of gasoline.

The cost of **closed-loop catalytic treatments of exhaust gases** stems from the increased purchasing cost of vehicles. In the United States, this increase averages US$400, ranging from US$300 to US$500 (Wang et al., 1993). While catalytic devices have a minor adverse effect on fuel economy, the associated costs are compensated by an increase in the lifetime of replacement parts such as the exhaust system.

The cost of **open-loop catalytic treatment of exhaust gases** is related to increased equipment costs and decreased fuel costs due to improved engine operation. Taiwan has adopted standards requiring the use of open-loop catalytic devices. The increased cost of US$60–80 is offset by fuel savings (Binnie & Partners, 1992). Total annual costs are estimated at US$75 per vehicle (depreciation plus increased fuel costs). It is assumed that the cost for two-stroke engines or motorcycles is similar to the cost for four-stroke engines.

Other costs include higher price of unleaded gasoline due to increased production cost and modifying pump nozzles. A very rough estimate of the cost is Rp200,000 annually per car (Rp100,000 for the depreciation of the control system and Rp100,000 in increased fuel costs, depending on possible subsidies/levies on gasoline). A summary of measures for adoption of clean vehicle standards is given in Table 4.7, and for motorcycles and tricycles in Table 4.8.

Policy instruments and target groups. The following groups are involved in the introduction of "clean" vehicles:

- firms that import vehicles;
- car and motorcycle industry;
- garages (must acquire the skills for maintenance of clean vehicles);
- petroleum industry and gasoline retailers (introduction of clean cars requires the availability of unleaded gasoline); and vehicle owners (have to pay the price).

Term. In practice, standards can be set only for new cars and motorcycles as it is too expensive to equip existing vehicles with the necessary devices. Practically all vehicles currently sold in the world market are designed to be equipped with catalytic control systems. The effect of these standards will be shown gradually, reflecting the rate of replacement of existing vehicles.

Table 4.7: Adoption of clean vehicle standards. Gasoline passenger cars and vans

Effectiveness:	80% effectiveness per gasoline vehicle (for 1990, 900 tons).
Costs:	Rp200,000 (including costs of unleaded fuel) - order of magnitude! In total Rp18 billion.
Benefits	Reduced mortality, 147; reduced RSD, 3 million; avoided health costs, Rp21 billion (hypothetical situation in 1990); reduction of emissions of CO, NO_x and VOC; the main justification for the introduction of these systems in other countries.
Instruments/institution:	
Term:	Two–five years; the result of such measures becomes clear with the renewal of the car fleet.
Target groups:	Petroleum industry makes unleaded fuel available, vehicle importers, vehicle manufacturers.

Table 4.8: Adoption of clean vehicle standards for motorcycles and Bajajs (two-stroke engines) either requiring catalytic converters or four-stroke engines

Effectiveness:	80% effectiveness per vehicle (in 1990, 2000 tons).
Costs:	Rp170,000 (including costs of unleaded fuel); total Rp67 billion.
Benefits:	Reduced mortality, >325; reduced RSD, >8 million; avoided health costs, Rp47 billion (hypothetical situation in 1990); reduction of emissions of CO, NO_x and VOC; the main justification of introduction of these systems in other countries.
Instruments/institution:	Regulations.
Term:	Two–five years; the result of such measures becomes clear with the renewal of the fleet.
Target groups:	Petroleum industry makes unleaded fuel available, vehicle importers, vehicle manufacturers.

Improvements in abatement, and other propulsion techniques

The United States and European Union are considering the further tightening of standards. Methods to accomplish this include:

- improving current abatement techniques;
- improving inspection and maintenance, as small numbers of maladjusted/worn-out cars cause disproportionately large emissions; and
- enforcing the use of "zero-pollution" vehicles, i.e. electric vehicles in downtown areas.

Although diesel engines emit less CO_2 they are still a bottleneck in decreasing automotive air pollution because exhaust gas treatment similar to that for gasoline cars is not available.

Addressing resuspension emissions

Although resuspension is a high priority issue in Jakarta, there is lack of quantitative information about city-appropriate abatement measures. Future analyses should give priority to measures dealing with resuspension. In general, all methods for reducing entrainment should be evaluated and applied. Controlling resuspension of road dust may be the most cost effective way of reducing TSP exposure.

Improving traffic management

Traffic management includes a variety of measures including: traffic control by police or traffic lights; one-way streets; new roads, and road-pricing systems. One of the main aims of traffic management is to solve congestion problems. Curbside traffic management may improve air quality[10], but it may also increase air pollution because it usually results in the increased use of the transport system. In terms of exposure, traffic management leads to improvement in downtown air quality and reduction in road exposure. In terms of total exposure, however, the net result may be small. Improved traffic management has other environmental benefits such as less noise and congestion. Although more detailed analysis is needed, traffic management appears to be a cost-effective policy.

Constructing and improving mass-transit systems

Mass-transit systems, such as light-rail transport, may solve environmental problems due to traffic and the need to increase transport capacity. Building such systems is a long-term process requiring large investments.

Assessing the costs and effectiveness of measures to improve Jakarta's public transport system, including the construction of mass-transit systems, involves:

- describing a future system appropriate for Jakarta;
- assessing the performance of such system (passenger-kilometers);
- estimating construction costs;
- describing the baseline (future situation without such a system);
- estimating avoided emissions;
- assessing non-environmental benefits; and
- designing a scheme to identify costs and benefits addressing environmental concerns.

The costs of constructing mass-transit systems are high. Projects cannot be justified from an air-pollution point of view alone. However, mass-transit systems have a wide variety of other benefits, including reduction in traffic congestion.

CONTROLLING POLLUTION FROM LARGE POINT SOURCES

Cleaner fuels in existing plants. Power plants are not a large cause of air quality problems in Jakarta. The use of cleaner fuel such as low sulfur oil, cleaner coal, or natural gas may be contemplated. The benefits of such a switch would be a reduction in SO_2 and CO_2.

Fuel combustion other than in power production. PM_{10} emission also results from the combustion of fuel oil in small industries (source category "domestic"). This emission is estimated at 1,700 tons (+1,620 tons from distillate fuel). The damage associated with this emission is low (mortality 13 RSD below one million, health cost below Rp2 billion).

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10 Accelerating vehicles, a prominent feature of congested traffic, emit disproportionately large amounts of pollutants.

Industrial Processes (Non-Combustion Sources)

Lack of data on process emissions estimated at 14,000 tons per year prevents addressing appropriate abatement measures. Rough estimates based on data from large factories producing steel ingots and billets indicate that TSP emission may be reduced by 4,000 tons/year at an investment cost of 10 million dollars (COWI/World Bank, 1992).

Open Burning and Construction

Refuse burning results in an estimated 7,000 tons of PM_{10}. A concrete proposal to address this emission requires more information on the characteristics of the source. PM_{10} emission due to construction is estimated at 10,000 tons, with demolition activities being the main source. There are various ways of controlling this emission, including screens alongside demolition sites, the use of chutes to remove rubble, etc. However, emission details are lacking, and it is not possible to develop a proposal for abatement measures.

Conclusions

There are a number of measures that are appropriate for improving the air quality in Jakarta. An important issue is estimated benefits which translates into reduced health costs and reduced damage costs. Information on the costs and benefits of each measure is needed in order to establish priorities.

Traffic emissions are a major cause of air pollution. Measures that stand out from a cost-benefit point of view are:

- introduction of unleaded gasoline;
- introduction of low-smoke lubricating oil; and
- (further) development of the use of natural gas both for automotive and stationary use.

A similar listing of measures addressing other pollution sources was not possible due to lack of data. This is unfortunate because other sources appear to be more important than traffic, including:

- resuspension of particles, mainly from traffic and roads;
- industrial process emissions; and
- open refuse or biomass burning.

5. ACTION PLAN

The proposed action plan is based on the cost-benefit analysis of various measures that reduce air pollution and resulting damages. This plan is based on available data, the shortcomings of which have been identified throughout this study. Improving the database is necessary in order to extend the action plan to include additional measures.

The "actions" fall into two categories:

1. Technical and other measures that will reduce the exposure and damage; and
2. Improving the database, and the regulatory and institutional basis for establishing an operative AQMS in Jakarta. This includes raising public awareness and promoting public and private sector cooperation. Examples of successful initiatives include the Adopt-a-Street approach in which the private sector becomes responsible for socially responsible environmental management and awareness raising. Environmental education and outreach via television and newspaper are equally important.

ACTIONS TO IMPROVE JAKARTA'S AIR QUALITY AND ITS MANAGEMENT

Actions to improve air quality

Actions and measures have been proposed by the Jakarta URBAIR working groups, through other World Bank studies, and by the URBAIR consultants. Proposed actions and measures are categorized as (1) improved fuel quality, (2) technology improvements, (3) fuel switching, (4) traffic management, and (5) transport demand management.

A proposed action plan of measures which can be introduced in the short term is given in Table 5.1. The calculated benefits of many of the measures are substantial. For some of the measures, such as low-smoke lubricating oil and improving diesel quality, the monetary benefits are higher than the estimated costs. Lowering the lead content in gasoline is an important measure that has already been initiated through legislation. Lead-free gasoline is a prerequisite for clean vehicle standards and is not listed as a separate measure.

Success of these measures requires enforcement. It is important to ensure that technical improvements and adjustments such as repair shop capacity, capability for efficient adjustment of engines, and availability of reasonably priced spare parts are ensured.

The actions incorporate the following measures.

Addressing excessively polluting vehicles:

- strict enforcement of smoke opacity regulation.

Table 5.1: Action plan of abatement measures

Abatement measure	Benefits		Cost of measure	Time frame	
	Avoided emissions, *tons of PM_{10} per year*	Avoided health damage		Introduction of measure	Effect of measure
Vehicles					
Low-lead and unleaded fuel	--	Rp300 billion 340 deaths, loss of IQ points in children	Rp40–60/liter, total Rp50 billion	Immediate	2–5 years
Inspection/ maintenance	1,300	Rp31 billion 212 deaths, 5 million RSD	Rp67 billion	Immediate	2–5 years
Address excessively polluting vehicles	1,000	Rp24 billion 163 deaths, 4 million RSD	Low	Immediate	2 years
Low-smoke lubricating oil, 2-stroke engines	1,350	Rp32 billion 220 deaths, 5 million RSD	Rp2–10 billion	Immediate	2 years
Improving diesel quality	230	Rp6 billion 41 deaths, 1 million RSD	Low	Immediate	2–5 years
CNG to replace 50% of gasoline consumption	650	Rp14 billion 98 deaths, 2 million RSD	Unknown	Short	~5 years
Clean vehicle standards (Passenger cars and MC/Bajaj)	2,900	Rp68 billion 500 deaths 12 million RSD	Rp85 billion	Immediate	5–15 years

- routine maintenance/adjustment of engines.

Improving diesel quality:
- import of quality low-sulfur diesel (0.2 percent);
- modifications in Indonesian refineries; or
- taxes/subsidies to differentiate fuel price according to fuel quality.

Inspection/Maintenance:
- annual (or bi-annual) inspection; and
- establishment of inspection and maintenance stations (government or private).

Clean vehicle emissions standard:
- state-of-the-art vehicle emissions standard for gasoline cars, diesel vehicles and motorcycles; and
- availability of lead-free gasoline at a lower price than leaded gasoline.

Awareness raising:
- public participation in AQMS process to successfully implement environmental education;
- private sector participation in innovative schemes; and
- information dissemination through all media.

Table 5.2 lists abatement measures for which cost-benefit analysis has not been performed. These measures could also be introduced in the short term, and would benefit air quality.

Table 5.2: Additional measures for short- to medium-term introduction

Abatement measure/action		Time frame: Introduction of measure	Time frame: Effect of measure
Vehicles			
Address dilution and adulteration of fuel		Short-term	Short-term
Restrict life time of public UVs and buses		Short-term	Medium-term
Traffic management			
Improve capacity of existing road network	- improve surface - remove obstacles - improve traffic signals	Short-term	Medium-term
Extend/develop road network: Improve/eliminate bottlenecks		Short-/medium-term	Medium-term
Transport demand management			
Improve existing bus system	- improve time schedules - improve junctions/stations - make integrated plan	Short-term	Medium-term
Develop parking policy	- restrictions in central area - parking near mass transit terminals - car-pooling	Short-term	Short-term Short-term Short-term

Actions to improve the AQMS

A successful AQMS requires putting into action the best possible air quality assessment, damage and cost assessment, institutional and regulatory framework, and awareness building among the public and policymakers. A summary of actions to improve the AQMS in Jakarta are listed in Table 5.3.

Table 5.3: Actions to improve air quality assessment in Jakarta

Air Quality Monitoring	• Improve the ambient air, monitoring system, • Upgrade laboratory facilities and man-power capacities, • Establish a quality control system, • Establish database, suitable for providing Air Quality information to the public/control agencies/law makers.
Emissions	• Produce inventory of industrial emissions, • Develop integrated, comprehensive emissions inventory procedure, • Study resuspension from roads.
Population exposure	• Establish appropriate dispersion modeling tools for control strategy in Jakarta.

A COMPREHENSIVE LIST OF PROPOSED MEASURES AND ACTIONS

Table 5.4 presents the proposed action plan with measures to improve the air quality in Jakarta.

Table 5.4: Categorized action list to improve the air quality in Jakarta
S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

WHAT	HOW	WHEN	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
CATEGORY: Improved Fuel Quality							
Address dilution and adulteration of fuel	Improved enforcement existing law	S/M	DOE	10% reduction TSP	-		
Decrease lead-level in leaded gasoline	Mandatory regulation	S/M	DOE, Petrol industry				
Market unleaded gasoline. Evaluate additives.	Voluntary-use tax system	S/M	DOE, Petrol industry	100% reduction of lead			
Phase-out of leaded gasoline. Time schedule.	Mandatory regulation	M/L					
Upgrade diesel-fuel quality (volatility, sulfur)	Alter fuel quality standards	S/M	DOE, Petrol industry	10% reduction TSP			
Decrease maximum allowable S content in fuel oil	Regulation, phased	S/M	DOE			Requires refinery restructure	
CATEGORY: Vehicles (Technology Improvement)							
1. State-of-the-art emission control for new cars, gasoline	Extend present regulations, set time schedule	S/M-L					
2. State-of-the-art emission control for new motorcycles	Extend present regulations, set time schedule	S/M-L					
3. State-of-the-art emission control for new light duty diesel vehicles (cars)	Extend present regulations set time schedule	S/M-L					
4.State-of-the-art emission control for heavy duty diesel vehicles (UV, buses, trucks)	Extend present regulations set time schedule	S/M-L					
5. Vehicles Address highly polluting vehicles:							

Table 5.4: Categorized action list to improve the air quality in Jakarta

S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

WHAT	HOW	WHEN	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
a. Control emissions from diesel UV, trucks	Enforce existing regulation I/M system. The use of diesel particle oxidizers/trups should be evaluated as suggested by Dr. Mike Ruby.	S/S					
b. Restrict life of public utility vehicles/engines and buses	--	S/M					
c. Control emission from gasoline vehicles							
INDUSTRIAL SOURCES Use of emission control equipment Process modifications/improvement	Licensing (emission reg's)/ Charges on emissions/ Promote good environmental practices						

CATEGORY: Fuel Switch							
1. LPG for transport (buses, PUV) CNG for gasoline	Study CNG utilization for transport;	S					
2. Natural Gas in industry	Study possibilities (resources)	S					

Table 5.4: Categorized action list to improve the air quality in Jakarta
S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

WHAT	HOW	WHEN	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
CATEGORY: Traffic management							
Improve traffic flow							
a. Improve existing road network	Place responsibility,	S/S					
b. Extend/develop road network	enforce - Analysis of the situation (bottlenecks, etc.)	S/M					
c. Improve/co-ordinate traffic signal systems	- Support responsible agencies						
d. Segregate mass transport from other modes.							
e. Improve facilities for non-motorized traffic							
Develop network of truck terminals, as part of a scheme for efficient transport of goods.							
CATEGORY:. Transport Demand Management							
Expansion of bus system.	Advocate & Support						
Introduction of light-rail system							
Survey present mass-transit situation, and develop comprehensive/ integrated plan for mass transit in MM, based on existing components: - improve time schedules, coordination - improve junctions/stations, especially where several modes meet.							
Survey new concepts for person transport (APM, guideway bus system, etc.) and evaluate its possible use in Jakarta.							

Table 5.4: Categorized action list to improve the air quality in Jakarta
S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

WHAT	HOW	WHEN	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
Promote non-motorized traffic (NMT) incl. improve/construct facilities, such as lanes and roads for NMT							
Land use planning to reduce transport demand							
Use parking policy to influence traffic mode mix, e.g. - parking restrictions in central areas, - parking facilities near mass transit terminals, - carpool guidance system.							
CATEGORY: . Inventorying/Dispersion Modeling							
Improve emission inventory for DKI Jakarta							
a. Produce inventory of Industrial-emissions (location, pro-process, emissions, stack data)		S/S					
b. Improve inventory of road and traffic data		S/S					
c. Improve inventory of domestic emissions		S/S					
d. Study resuspension - from roads, - from other surfaces		S/M					
Develop an integrated and comprehensive emission inventory procedure, incl. emission factor review, update and QA procedures.		S-M					
Assess current modeling tools/methods, and establish appropriate models for control strategy in DKI Jakarta.							

Table 5.4: Categorized action list to improve the air quality in Jakarta.
S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

WHAT	HOW	WHEN	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
CATEGORY: . Air Quality Monitoring							
Design and set up modified/improved/extended monitoring system		S					
Design and establish Quality Control/Quality Assurance System - evaluation of sites; number and location - selection of methods/parameters/ monitors/frequency of operation.		S					
Establish data base of all DKI Jakarta data regarding - air quality - meteorology (dispersion)							
CATEGORY: . Institutional and regulatory framework							
CATEGORY: Awareness raising							
Promote environmental education, adopt innovative schemes that involve public/private sector participation; involve media in dissemination of air pollution data and awareness issues.		on-going					
CATEGORY: Further studies							
Study resuspension from roads							

6. INSTITUTIONS, FUNCTIONS, AND POLICY PLANS

INSTITUTIONS

Central control

The State Ministry of Environment is the main central body responsible for environmental management and regulation. Environmental legislation began with Decree 02/MENKLH/I/1988, issuing pollution standards for air and water. One Assistant-Minister coordinates mobile source air pollution management with the Ministries of Industry and Health. Another Assistant-Minister coordinates industrial air pollution control together with the Ministries of Industry and the Interior.

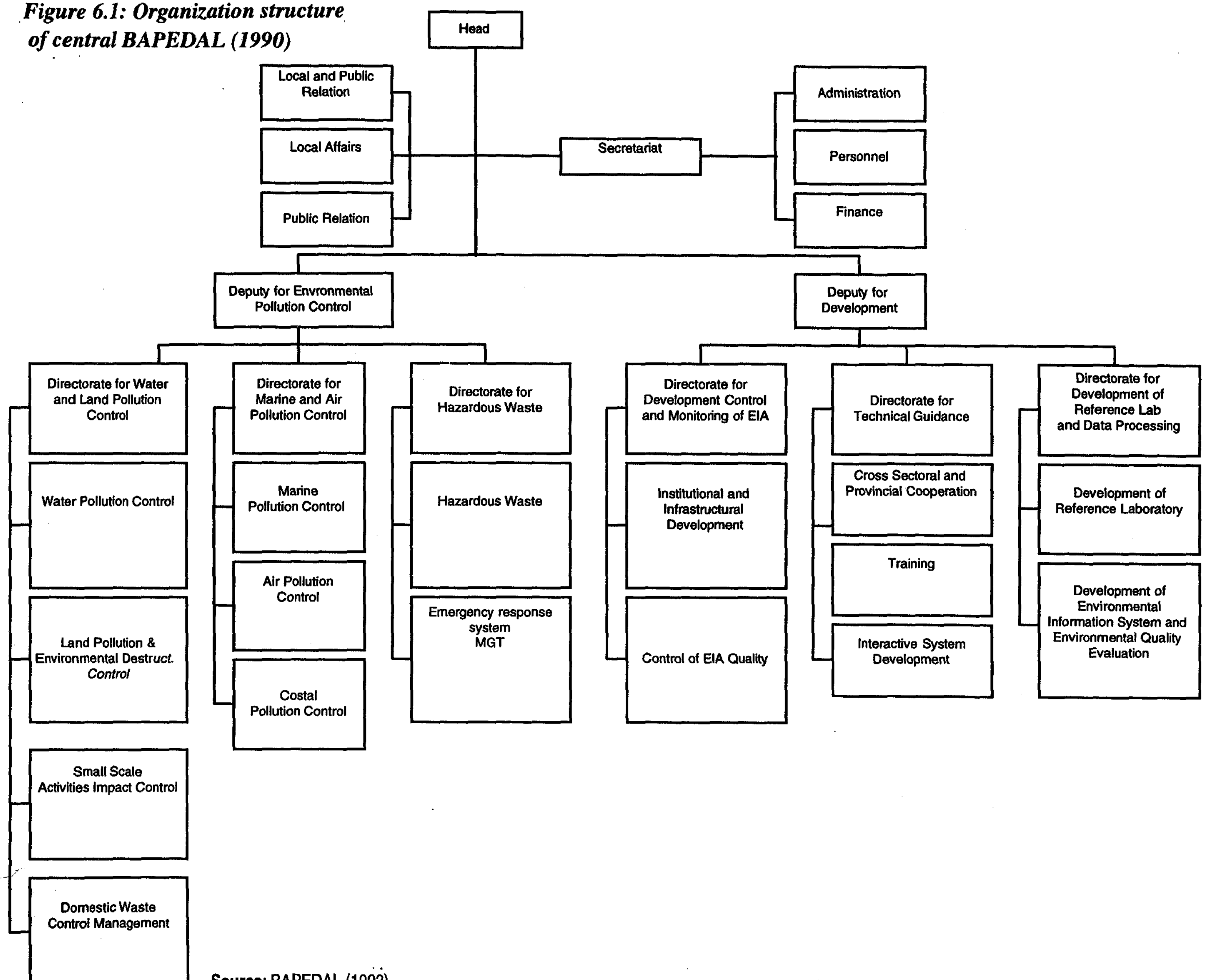
BAPEDAL was established in 1990 as a central control agency for environment in Indonesia. BAPEDAL's organizational structure is shown in Figure 6.1. The World Bank and other consultants have been involved in the BAPEDAL Development Plan to be implemented over six years. Other organizations have proposed the creation of an Environmental Management Centre for research and training, and a Reference Laboratory as part of BAPEDAL.

Bureau of Environment

The Bureau of Environment (BLH) comes under the organizational umbrella of the Assistant of the Secretary for Social Welfare at the Secretariat of the Province. The structure of BLH is complicated and would benefit from simplification. Its mandate includes the following:

- developing implementation and technical guidelines for industrial emissions;
- coordinating the formulation of implementation guidelines of motor vehicle emissions standards;
- public awareness programs focusing on clean air, for example, encouraging people not to use their cars, especially on holidays;
- coordinating an implementation study for staggering working hours and work-days;
- coordinating assessment and program formulation on the age limit for motor vehicles; and
- air quality monitoring program and utilization plan for mobile monitoring equipment.

Figure 6.1: Organization structure of central BAPEDAL (1990)



Source: BAPEDAL (1993).

Road Traffic and Transportation Department

The Road Traffic and Transportation Department (DLLAJR) is in the Jakarta Provincial Government. It is responsible for the control of road traffic and transportation, including road worthiness of motor vehicles and their emissions. Its mandate includes:

- coordinating the checking and enforcement of inspection requirements for motor vehicles with the local government and traffic police;
- integrating the computer system on car registration and inspection;
- assigning private car garages and mechanics to participate in car exhaust inspection and issue pollution-free certificates; and
- leading an information campaign on the use of catalytic converters.

KPPL

KPPL is the regional implementation unit of urban and environmental research and development, directly responsible to the governor of DKI Jakarta. The administrative coordination structure of KPPL DKI Jakarta consists of:

- Head of KPPL DKI Jakarta.
- Administrative Division
  - Sub-division of Correspondence and Personnel,
  - Sub-division of Finance,
  - Sub-division of Equipment and Households.
- Programming and Evaluation Division
  - Data and Information Section,
  - Program Formulation Section,
  - Program Evaluation Section.
- Functional staff include research groups
  - Urban Ecology,
  - Environmental Management,
  - Urban and Environmental Socioeconomy and Socioculture,
  - Urban and Environment legislation,
  - Laboratory Analysis,
  - Librarian,
  - Computer group.

KPPL shares some of the responsibilities for developments in Jakarta, especially on urban and environmental issues. Its responsibilities also include:

- collecting data and information to formulate programs and evaluate their implementation;
- assessing urban ecology, environmental management, socioeconomic, sociocultural and legal aspects of urban and environmental issues;
- carrying out laboratory analysis, and
- technical coordination of the regional government institutions that are involved in the integrated assessment of urban and environmental issues.

KPPL DKI Jakarta has four laboratories. The Physical and Chemical Laboratory analyzes river, ground, sea water, land and sludge, plant, vegetable, and fish samples. Water analysis includes parameters such as conductivity, turbidity, color, temperature, acidity/alkalinity, chloride, ammonia, nitrate, nitrite and total nitrogen, sulfate, sulfide, hydrogen sulfide, fluoride, hardness, suspended solids, total dissolved solids, chemical oxygen demand, biochemical oxygen demand, detergent, cyanide, iron, copper, lead, chromium, nickel, manganese, mercury, cadmium, calcium, magnesium, sodium, potassium, and caloric value.

The Microbiology Laboratory analyzes microbiological parameters including, plankton, benthos, coli form, fecal coli, and tests by using bioassy.

The Air and Sound Laboratory analyzes air quality, emissions, and sound/noise. Analysis of air includes testing for NO_x, NO, SO_2, dust, ozone, H_2S, ammonia, hydrocarbons, CO, CO_2, Wind speed and direction, heavy metals in the dust, and rainfall.

The Toxicology Laboratory performs analysis of organic chemicals, and pesticides, including hazardous materials.

KPPL also conducts physical surveys such as the regular monitoring of river water, and ambient air quality. The results of KPPL surveys have been extensively used by the Regional Administration to establish environmental monitoring policies.

Environmental support network

The Ministry of Environment has developed the university-based Environmental Studies Centers (PSL). The primary objective of PSL is to increase the availability of environmental experts who can advise officials responsible for environmental planning and policy analysis. Another initiative is to encourage the development of environmental NGOs. Many of the larger NGOs belong to WALHI, the umbrella network of environmental NGOs, established in 1980.

FUNCTIONS

The MEIP analysis of key institutions (Bulkin, 1992) provides the overview of institutional functions and linkages in air management shown in Figure 6.2. BAPEDAL is not included yet in the matrix, nor in the matrices for water, waste, etc., indicating that the BAPEDAL is still in the development stage.

The overview of central institutions responsible for air pollution management is based on Figure 6.3.

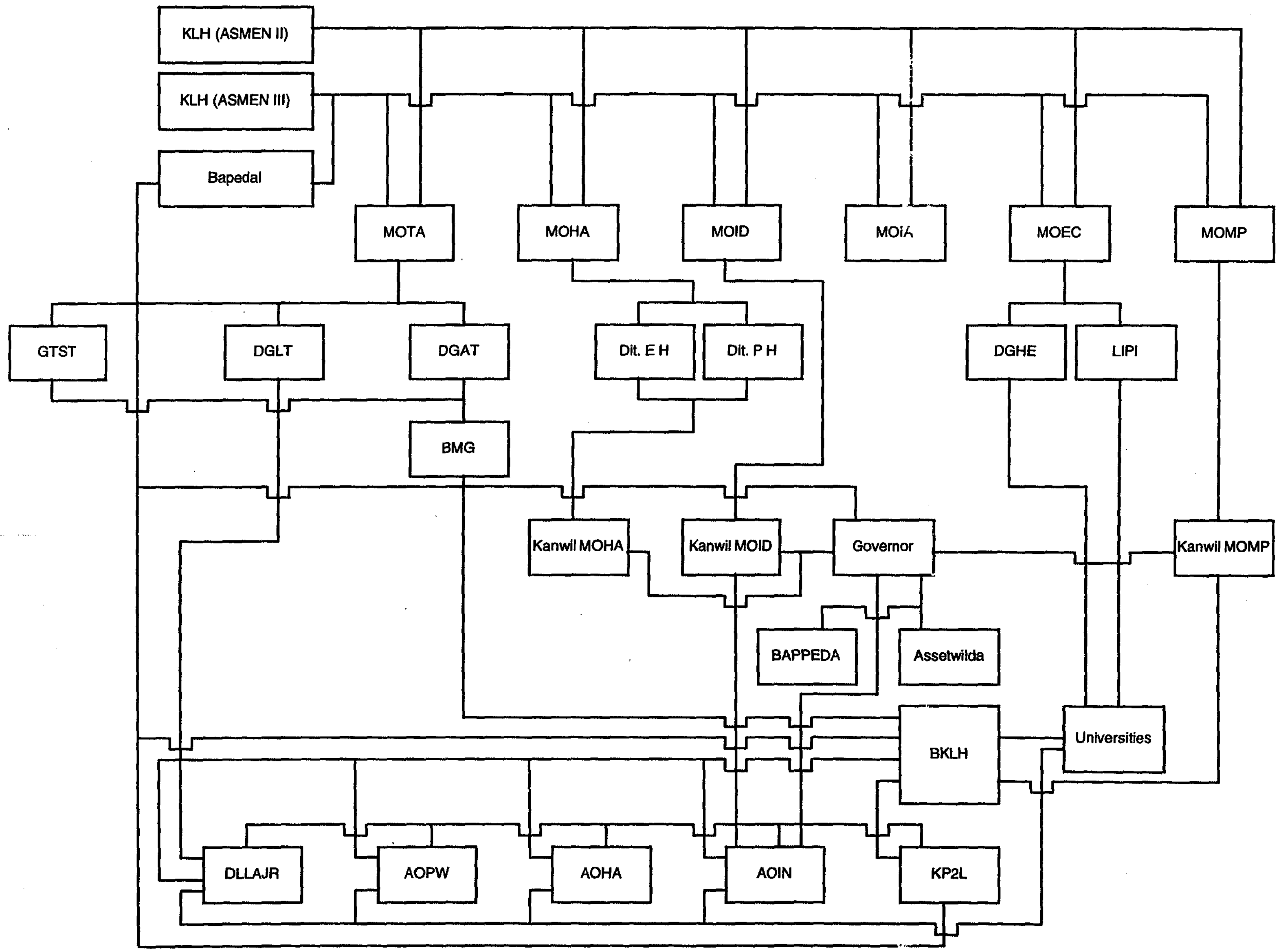
Figure 6.2: Institutional linkages in managing air pollution according to management functions

Management function	Central government: KLH	MOHA	MOPW	MOTA	MOIA
Policy	*	*		*	*
Standard formulation	*		*		*
Planning:					
a. Infrastructure					
b. Services					
Pollution Control:					
a. Permitting	*		*	*	
b. AMDAL	*	*	*	*	
c. Monitoring		*	*	*	
d. Law enforcement	*	*	*	*	

Management function	Provincial government: KPPL	AOH	AOPW	BAPPEDA	GOV	SEKWILDA	BKLH	AOID	BKPMD	DLLAJR
Policy	*	*		*	*	*	*			
Standard formulation	*		*		*					*
Planning:										
a. Infrastructure			*							*
b. Services	*		*	*			*	*		
Pollution control:										
a. Permitting	*		*					*	*	*
b. AMDAL	*						*	*	*	*
c. Monitoring	*	*	*	*	*	*	*	*	*	*
d. Law enforcement					*			*	*	

Source: Bulkin (1992).

Figure 6.3: Diagram of interagency linkages in air quality management



Source: Bulkin (1992).

Monitoring

Central government. Central Ministries of Health, Public Works and Transportation share the responsibilities of monitoring air pollution.

Provincial government. Ten agencies are responsible for air pollution monitoring. BMG, not included in Figure 6.3 should also be on this list.

Actual monitoring in Jakarta is done by JMB (GOV), BMG, and KPPL. The other agencies issue information from the monitoring to public, and to other agencies for the purposes of planning and enforcement.

Permits

Central government. The Ministries of Environment, Public Works, and Transportation are responsible for permitting and licensing air polluting activities.

Provincial government. KPPL, and the Ministries of Public Works and Industry, the Provincial Investment Board, and the Agency of Traffic and Highway Transportation have permitting and licensing functions.

AMDAL environmental impact assessment

The Environmental Impact Assessment (EIA) process for new and existing polluting activities involves the Ministries of Environment, Health, Public Works, and Transportation at the central level; and the Ministry of Industry, Bureau for Population and Environment, Office of Urban and Environment Studies, Traffic and Highway Agency, and the Investment Coordinating Board at the provincial level.

Law enforcement

The Ministries of Environment, Health, Public Works and Transportation have functions regarding law enforcement at the central level. At the provincial level, the Municipal Government, the Ministry of Industry, and the Investment Control Board are responsible for law enforcement.

Emissions standards

The DLLAJR is responsible for vehicle emissions standards in Jakarta. Other institutions involved in the implementation of vehicle emissions include:

- Provincial Planning Board of Jakarta (BAPEDAL),
- Bureau of Environment (BBLH),
- Urban and Environment Assessment Office (KPPL),

- Bureau of Economic Facilities Development (Bangsarekda),
- Bureau of Law Enforcement (Ro Ketertiban),
- Regional Investment Board (BKPMD),
- Department of Health (DKK),
- Department of Industry (Dinas Perindustrian),
- Department of Public Works (DPU),
- Department of City Planning (Dinas Tata Kota),
- Bureau of Legal Affairs (Ro Hukum).

Supervision of the emission parameters evaluation is coordinated by the Urban and Environment Assessment Office. The Bureau of Environment is responsible for coordinating the implementation evaluation. The Bureau of law evaluates regulation.

EXISTING LAWS AND REGULATIONS ON AIR POLLUTION

Air pollution legislation in Indonesia, and in Jakarta, has been described in detail in a report by LLAJR Air Pollution Monitoring and Control Project performed by Institut Teknologi Bandung (Bachrun et al., 1991), by Kozak and Sudarmo (1992), and by Budirahardjo (1994).

In these references, the national air pollution legislation is summarized as follows:

- *Law No. 4/1982 "The Basic Provisions for the Management of the Environment".* This is the umbrella provision for all environmental regulations in Indonesia. Under this law, the KLH (State Ministry for Population and Environment) issued the Ministerial Decree KEP-35/MENKLH/I0/1993, which established national ambient air quality standards and emissions standards for stationary sources. The compounds listed in this decree are SO_2, NO_2, TSP, CO, O_3, HC, Lead, H_2S, and NH_3 and smoke emission (opacity) from diesel vehicles. These standards act as guidelines for the provinces to accept or develop more stringent standards.
- *Government Regulation 29/1986*, specifying the AMDAL process for central ministries to undertake Environmental Impact Analysis on existing and new projects. The AMDAL process is still developing, but is hampered by the lack of trained reviewers and qualified consultants.
- *Decree No. KM-8-1989* of the Minister for Communications addresses *Vehicle emissions standards* in the context of *road worthiness*. This decree limits CO and HC emissions from idling gasoline powered vehicles.
- *Draft Regulation of KLH* has been promulgated as the Decision of the State Minister of Environment no. KEP-35/MENLH/10/1993 on Emissions standards for Motor vehicles (note from S. Hadiwinoto, 1994).
- *Draft Regulation "Government Regulation for the Control of Air Pollution".* Drafted by KLH and an interdepartmental Air Quality Technical Committee. This regulation describes responsibilities for air quality monitoring and data collection, such as emissions inventories, and specifies BAPEDAL as the agency responsible for an air pollution control program. The Regulation also outlines a permit process, and sanctions. The Draft Regulation was expected to be promulgated before the end of 1992.
- *Regulations on tetraethyl lead contents in gasoline*, under the Ministry of Mines and Energy. The lead content has been reduced from 2.5 ml per U.S. gallon in the mid 1980s to 1.5 ml per U.S. gallon (0.449 l) for all gasoline qualities. Production of lead-free gasoline has been discussed.

- *Act number 14 of 1992 on Traffic and Land Transportation* states that all motorized vehicles are subject to testing with respect to emissions and noise.
- *Decree KM 71* of 1993 of the Ministry of Transportation is on the periodical test of motorized vehicles. The responsibility for testing rests with the Provincial Government, and the tests are to be carried out by the Traffic and Transportation Service in the province, or delegated to the Traffic and Transportation Service at local government level.

Regarding air pollution regulations in Jakarta, the above-mentioned references list the following:

- *Governor's Decree No. 382 Year 1977,* on the obligation of companies and entities, engaged in industry within the territory of the Capital City of Jakarta to investigate their wastes to the PPMPL Laboratory or a Laboratory appointed by the authorities.
- *Governor's Decree No. 220 Year 1979,* grants authority to enter industrial companies and entities within the territory of the Capital City of Jakarta for the purpose of inspection and investigation of industrial waste.
- *Governor's Decree No. 587/1988,* issues ambient air quality standards. These are equivalent to the national standards.
- *The Decision of the Governor of DKI Jakarta No. 709 Year 1990,* on the establishment of the coordination team for the enforcement of environmental regulation within the territory of DKI Jakarta.
- *The Decision of the Governor of DKI Jakarta No. 1117 Year 1990,* on the appointment of the Centre for Research and Development of City and Environment (P4L) DKI Jakarta which has the authority to inspect, and to issue the result of laboratory analysis for the purpose of evidence in cases of violation of laws on the regulation on environment in the territory of the DKI Jakarta.
- *Governor's Decree No. 1222/1990,* issues vehicle emissions standards, also equivalent to the national standards. DLLAJR is responsible for vehicle emission testing in Jakarta.
- *Governor's Decree No. 1236/1990* on the implementation of vehicle emission control.
- *Provincial Act No. 5/1984* on a Master Plan of Jakarta up to the year 2005, mentions zoning. Two experiments have so far been carried out. "Three in One" requires that cars, on specified roads, must transport at least three passengers. In a number of places a special bus lane was introduced. The results of the experiments appear to be positive.

Blue Sky Program. The Ministry of Environment launched "Program Langit Biru" (Blue Sky Program) in 1991, to address air pollution problems. For stationary sources, the program gives priority to power plants, cement, paper and pulp, and steel industries. To control air pollution from mobile sources, BAPEDAL plans to control black smoke and switch to unleaded gasoline. The Clean Air Program (Prodasih), announced in 1991, is an effort to increase public awareness of air pollution, and to emphasize the enforcement of Decrees.

Recent publications

Publications describing the institutional environment/air pollution management and control in Indonesia and Jakarta include the following:

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- Kozak, J.H. and R. P. Sudarmo. 1992. "An overview of air pollution in Indonesia." Environmental Management Development/KDH, Jakarta.
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SHORTCOMINGS

Efficient management requires clear lines of authority and responsibilities. Many institutions in Jakarta have overlapping responsibilities for the environment. Institutional shortcomings include the lack of control and law enforcement, and shortage of well-trained personnel and qualified consultants.

Selected reasons for inefficient control and monitoring are as follows:

- functional relationships between agencies are unclear;
- poor communication and cooperation between agencies;
- enforcement agencies often do not refer to reports on pollution problems to take legal action;
- the perception of policies and law enforcement is often not clearly stated;
- socio-cultural obstacles, including the effects of the patrimorial relation of authority, which tends towards serving higher authority rather than the interests of society; and
- obstacles in Government-Private Sector cooperation.

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APPENDIX 1: AIR QUALITY STATUS, JAKARTA

DESCRIPTION OF PAST AND PRESENT MEASUREMENT PROGRAMS

Stations and parameters. In 1991 air quality was measured at 17 stations in Jakarta. 7 stations run by BMG (Meteorological and Geophysical Agency) and two stations run by the Jakarta Municipal Government (JMG) (before 1980 by the Ministry of Health) are permanent. 8 rotational stations are run by DKI-KPPL (District of Jakarta—Research Centre for Urban Development). The temporary nature of the KPPL sites is dictated by the availability of equipment and resources to operate the network.

The location of the stations are shown in Figure 1 and a listing and description of the stations as of 1991 are presented in Table 1.

The first BMG station has been in operation since 1976 and is located at the BMG Headquarters in Central Jakarta. The six other BMG stations were started in 1980/81, but were not operated in the late 1980's. These six stations were restarted in 1991. At the BMG Headquarters TSP, NO_x and SO_2 are measured, while only TSP are measured at the other six BMG stations. At the BMG stations there is one 24 hour measurement every 6th day.

The two stations run by the JMG are part of the United Nations Global Environment Monitoring System (GEMS) since 1979. At the GEMS sites TSP, SO_2 and NO_x are monitored every 6th day.

DKI-KPPL operates 8 air monitoring stations on a rotational basis (i.e. every 8 days, 4 stations are operated and then the equipment is moved to 4 other stations). These stations are only operated 8 months a year. TSP, NO_2, SO_2 and CO (and oxidants on occasions) are measured at all sites.

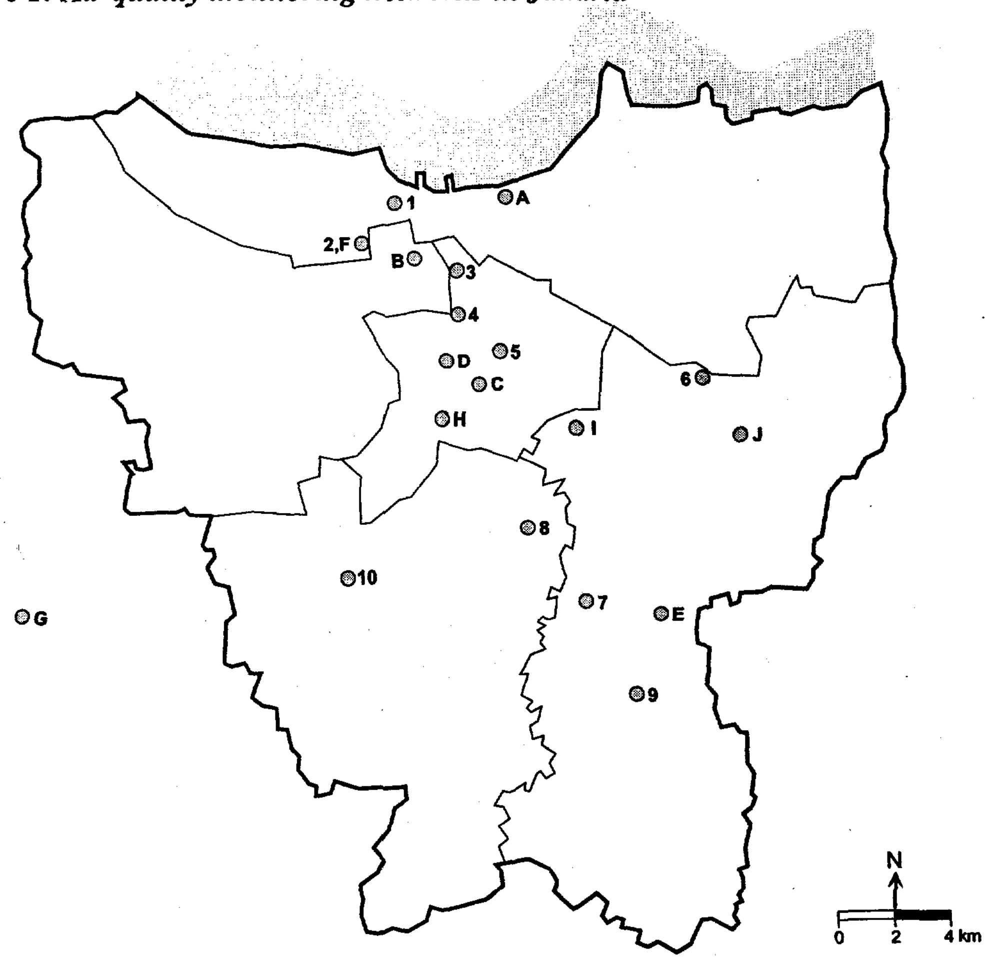
The location of the 8 DKI-KPPL sampling points were originally selected to record air pollution impacts on land use and are therefore not representative for most of the DKI Jakarta, notably the areas with heaviest population concentration and traffic. In the WHO/UNEP 1992 report are three of the DKI-KPPL stations characterized as road side stations (Pasar Baru, Pasar Senen and Mangga Besar) as well as the BMG Headquarters, Monas and Pulo Gadung stations.

Table 1: Air quality monitoring network in Jakarta

Station	Operation started	Period discontinued	Date restarted	Purpose/land use classification	Remarks
BMG Jakarta					
BMG Headquarters	1976			Reference/Standard-C*	Operated 1976-1992, Paramater TSP, NO_x, SO_2, acid rain, turbidity 2 particulate analysis
Ancol	1980	1988-1990	1991 (July)	Urban/recreation - I, C	
Bandengan	1980	1988-1990	1991 (April)	Urban/mixed area, industry - I	
Glodok	1980	1988-1990	1991 (April)	Urban/shopping centre, transportation - C	
Monas	1980	1986-1990	1991 (April)	Urban/regreening, recreation - C*	National Monument Area
Halim Perdana Kusumah	1980	1988-1990	1991(June)	Urban/airport area - C, R	
Ciledug	1981	1988-1990	1991 (June)	Rural area - RA	Meteorological Station Class II
JMB/Ministry of Health					
Kayu Manis	1979			Urban air quality/ residential area - C	TSP, SO_2, NO_x
Pulo Gadung	1979			Urban air quality/ industrial area - I*	TSP, SO_2, NO_x
Jl M. H. Thamrin	1992			Urban/traffic	SO_2, NO, NO_2, CO, PM_{10}, continuously 1 hour
DKI-KPPL					
Pulo Gadung	1983-1990			Urban air quality/ industrial & residential area - I	TSP, SO_2, NO_x, NH_3
Tebet	1983-1990			Residential - R	TSP, SO_2, NO_x, NH_3
Bandengan Utara	1983-1990			Residential & warehouse/urban air quality - I, C	TSP, SO_2, NO_x, NH_3
Cililitan	1983-1990			Urban air quality/bus terminal - C	TSP, SO_2, NO_x, NH_3
Pasar Baru	1983-1990			Urban air quality/ shopping centre - C, R*	TSP, SO_2, NO_x, NH_3
Pasar Ikan	1983-1990			Urban air quality/ residential & warehouse - I, C	TSP, SO_2, NO_x, NH_3
Pasar Senen	1983-1990			Urban air quality/trade centre & residential - C*	TSP, SO_2, NO_x, NH_3
Mangga Besar	1983-1990			Urban air quality/trade centre & residential - C*	TSP, SO_2, NO_x, NH_3

Note: Land use classification -- R, residential; RA, rural area; I, industrial; C, commercial; * roadside station.

Figure 1: Air quality monitoring networks in Jakarta



Stations operated by BMG
A Ancol
B Glodok
C BMG Head Quarter
D Monas
E Halim Perdana
F Bandengan
G Ciledug

Stations operated by JMG
H Jl M.H. Thamrin
I Kayu Manis
J Pulo Gadung

Stations operated by DKI KPPL
1 Pasar Ikan
2 Bandengan Delta
3 Mangga Besar
4 Pasar Baru
5 Pasar Senen
6 Pulo Gadung (bus terminal)
7 Cililitan
8 Tebet
9 Pondok Gede
10 Radio Dalam
11 PT. JIEP

Note: The PT. JIEP and BMG Bandengan stations are not marked on the map because the positions are uncertain.

DKI-KPPL has had continuous instruments for several years, but have only used these for short term special studies. The limited operation is because of the operating/maintenance cost and the availability of calibration gases. DKI-KPPL has received continuous monitoring equipment from Japan for measuring O_3, SO_2, NO_2, and CO, and this equipment has been put into operation at the Jl M.H. Thamrin by JMG (see below).

In addition to the permanent and rotational stations in Jakarta, several short-term air quality monitoring studies have been done in selected cities. Two earlier short-term studies of interest are the transportation study in Jakarta in August–September 1982 by BMG and the Ministry of Communications, and a study in 1984 in 15 centers in Indonesia by BMG, KLH (State Ministry for Population and Environment), Ministry of Health and DKI. In December 1991–February 1992, a transportation related air quality study was done in Jakarta and Bandung by the BAPEDAL (Environmental Impact Management Agency) with the assistance of ITB (Bandung Institute of Technology) and DKI-KPPL.

Measurement and analyses methods. The measurement methods used by the various agencies are based on the WHO methods and are listed in Table 2.

Table 2: Measurement methods used in Indonesia

Parameter	Analyses method
Sulfur dioxide (SO_2)	Pararosaniline method collected in midget impinger.
Carbon monoxide (CO)	Detector tube method (i.e. Draeger tube).
Nitrogen oxides as NO_2	Saltzman method collected in midget impinger.
Oxidant as O_3	NBKI method collected in midget impinger.
Suspended particulates (TSP)	Gravimetric. High-volume sample.

Continuous monitoring methods have been used on a limited basis in the past in Jakarta, but their use has been restricted due to the availability of calibration gases and resource constraints. The recent BAPEDAL study noted above utilized a combination of continuous and wet chemical sampling methods.

Special road side station at Jl M.H. Thamrin. Since April 1992 the JMG has been measuring air pollution from road traffic by a new display monitoring station at Jl M.H. Thamrin. This station is the only one in Indonesia using modern technology and located to record road side air pollution. The pollutants measured are SO_2, NO, NO_2, CO and PM_{10}. For suspended particles, only particles below 10 μm (PM_{10}) in diameter are recorded as opposed to other TSP (total suspended particulates) air concentration data available in Indonesia, which include all particle sizes up to 50–100 μg/m³. The PM_{10} is of special interest when relating health effects to air particle pollution.

Also heavy metals are sampled and analyzed monthly in Japan where the monitoring equipment originates.

ANALYSIS OF MEASUREMENT RESULTS

Long term monitoring networks in Jakarta. At the BMG and JMG stations 24-hour samples are taken every 6 days. TSP, SO_2 and NO_2 are measured at three stations and only TSP at the other six stations. The 8 DKI-KPPL stations are operated every 8 days on a rotational basis and TSP, SO_2, NO_2, CO and O_3 are measured. In general these three agencies use the standard reference methods recommended by the WHO and/or the USEPA. Generally, flow calibration is made on the instruments every 6 months. Calibration procedures for the gaseous sampling (SO_2 and NO_2) would follow the WMO/WHO requirements. A new station at Jl M.H. Thamrin with continuous monitoring equipment was put in operation in April 1992.

Total suspended particulates (TSP). Annual averages of total suspended particulates in Jakarta are shown in Tables 3 and 4. Some results from the new display monitoring station Jl M.H. Thamrin are shown in Table 5.

The results show that TSP is generally very high in all areas. The 1991 value from Glodok (648 μg/m³) exceeds the proposed national ambient air quality annual standard of 90 μg/m³ by as much as a factor of 7. All stations, with the exception of the Halim Perada location, exceed the standard at least by a factor of 2.

Table 3: 1980–1991 Annual average total suspended particulates (μg/m³) in Jakarta for permanent BMG and Health Stations

Location Year	BMG (C)	Ancol (I/C)	Bandengan (Delta) (I)	Glodok (C)	Monas (C)	Halim P. (C/R)	Ciledug (RA)	Kayu Manis* (C)	Pulo Gadung* (I)
1980	197.9	139.2	474.9	508.2	123.9	108.4	-	256.2	177.9
1981	337.0	117.1	409.6	455.9	142.1	98.4	73.0	223.0	164.3
1982	272.2	336.3	512.3	516.9	199.0	129.4	133.5	278.0	223.0
1983	169.5	382.6	606.4	492.1	332.2	144.1	156.0	338.2	310.3
1984	169.7	161.7	447.1	487.8	167.2	160.3	135.5	272.7	151.8
1985	150.5	158.5	468.7	450.3	284.8	120.2	155.1	213.0	184.0
1986	117.7	146.3	540.5	395.9	-	140.0	213.3	191.0	185.0
1987	175.2	169.0	272.8	390.4	-	212.3	266.4	148.0	181.0
1988	228.1	-	-	-	194.0	-	-	188.0	187.0
1989	186.1	-	-	-	-	-	-	238.0	252.0
1990	168.5	-	-	-	-	-	-	188.9	227.0
1991	182.2	261.2	458.8	648.3	205.8	156.4	276.2	159.0	270.0
Average	189.9	231.3	463.7	555.3	206.0	147.8	219.1	224.4	208.9

Note: Land use classification: R--residential area; I--industrial area; C--commercial area; RA--rural area;
* Ministry of Health (JMG) (GEMS).

Table 4: Comparison of annual averages for TSP, SO_2 and NO_x for the periods 1986/1987, 1990/1991 and 1992/1993 for DKI-KPPL monitoring network in Jakarta

Pollutants	TSP (μg/m³)			SO_2 (ppb)			NO_x (ppb)		
Stations	1986/1987	1990/1991	1992/1993	1986/1987	1990/1991	1992/1993	1986/1987	1990/1991	1992/1993
Pasar Ikan (I/C)	220	570	536	8	3	2	9	19	58
Bandengan (I/C)	420	520	453	7.2	5	3	11	15	62
Pasar Senen (C)	300	295	270	5.5	3	1	9	19	51
Pasar Baru (C/R)	220	400	353	6	3	2	2	15	66
Mangga Besar (C)	180	200		7	2.5		9	11	
Cililitan (C)	170	360		5	3		10	17	
Pulo Gadung (I)	160	270	367	6	4	2	9	12	78
Tebet (R)	160	250	207	3.5	5	2	6.5	9.5	42

Note: Land Use Classification:R --residential area; I--industrial area; C:--commercial area.

Table 5: Display monitoring station, JL. Mh. Thamrin. Daily averages, Thursdays, the first two months of monitoring, 1992

Day	SO_2 (ppb)	NO (ppb)	NO_2 (ppb)	NO_x (ppb)	PM_{10} (µg/m³)	CO (ppm)
16 April	14.0	138.0	75.3	213.0	92.8	5.40
23 April	7.3	138.0	46.1	185.0	33.7	5.05
30 April	7.7	105.0	46.0	151.0	67.0	3.43
7 May	7.4	103.0	44.7	147.0	96.5	3.60
14 May	18.4	113.0	83.2	197.0	111.0	4.80
21 May	13.0	85.0	61.0	147.0	79.0	3.00
28 May	12.0	74.0	71.0	145.0	109.0	3.00
04 June	13.1	101.0	61.7	163.0	98.3	3.93
11 June	13.0	71.0	49.7	120.0	106.0	2.42
18 June	13.2	92.5	72.1	164.0	114.0	3.35
25 June	22.1	136.0	92.7	228.0	77.2	4.9
Average	12.8	105.1	64.0	169.1	89.5	3.9

Note: PM_{10} data for 11 June is computed as an interpolation.

Hourly monitor results 25 June 1992

Hour	SO_2 (ppb)	NO (ppb)	NO_2 (ppb)	No_x (ppb)	PM_{10} (µg/m³)	CO (ppm)
1	10	32	32	64	30	1.2
2	9	36	32	68	30	1.3
3	8	16	22	38	30	0.5
4	9	65	23	88	10	1.5
5	11	150	49	199	30	3.6
6	18	230	112	342	65	7.8
7	24	218	145	363	95	8.1
8	21	140	118	258	110	5.0
9	20	164	138	302	65	5.4
10	29	162	162	324	60	6.2
11	40	190	106	296	100	6.3
12	26	192	130	322	70	6.5
13	26	178	157	335	90	6.3
14	42	178	152	330	100	6.4
15	64	204	178	382	100	8.2
16	70	190	106	296	110	7.7
17	27	160	122	282	100	7.7
18	15	190	114	304	100	7.5
19	13	124	86	210	95	4.4
20	15	218	95	313	90	8.2
21	14	128	56	184	150	4.0
22	11	56	31	87	140	1.7
23	1	18	25	43	60	0.8
24	11	28	34	62	25	0.8
Average	22.25	136.13	92.71	228.83	77.29	4.88

Daily (24 hour) average, high and low values, week 22–28 June, 1992

Day	NO_x (= NO_2 + NO), ppb			PM_{10}, µg/m³		
	Average	High	Low	Average	High	Low
Monday 22 /6	196	302	58	116.0	200.0	45.0
Tuesday 23/6	196	302	58	116.0	200.0	45.0
Wednesday 24/6	212	348	84	123.0	200.0	60.0
Thursday 25/6	229	382	38	77.2	150.0	10.0
Friday 26/6	210	363	0	81.0	130.0	40.0
Saturday 27/6	163	275	62	80.0	110.0	40.0
Sunday 28/6	106	168	76	73.7	120.0	30.0

Source: KPPL.

The TSP levels from the DKI-KPPL stations are not directly comparable to the BMG/Health results, because the DKI-KPPL represents different sampling locations and time periods, i.e. dry/wet seasons for each year. But there are similar trends in TSP levels between the three networks. The 1990/91 annual TSP averages in the Pasar Ikan and Bandengan areas exceeded the national ambient air quality standards by about a factor of 6. Also Table 4 shows the increasing average TSP concentrations from 1986/87 to 1990/91 for all stations, except for Pasar Senen which stayed at essentially the same level.

Figure 2 shows annual average TSP concentrations for the period 1980–1991 for some selected stations in the BMG/Health network. The Glodok location (commercial, W. Jakarta) is in the most polluted area and the Halim Perada location (commercial/residential, E. Jakarta) has the lowest concentrations.

Figure 2: Annual average TSP concentrations for the period 1980–1991 for some selected stations (μg/m³)

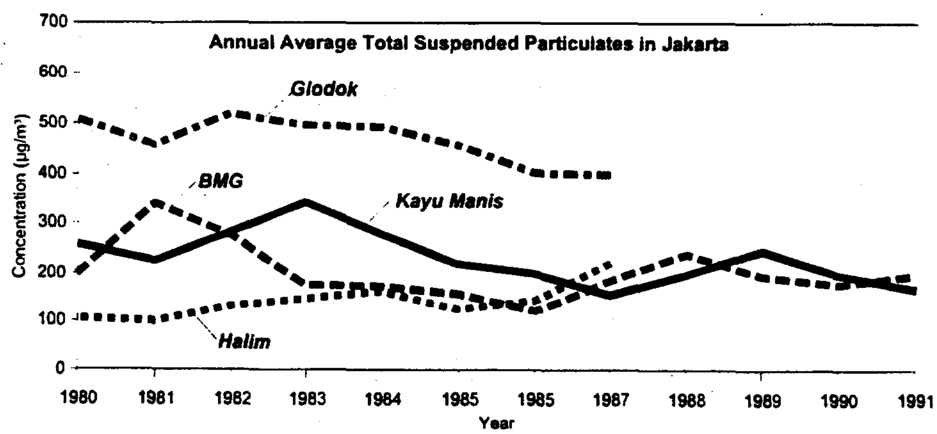


Figure 3 shows TSP isopleths based on the measurements in the years 1980–1985 (Office of State Min. of Population and Environment, 1990). The areas of highest TSP levels are the city Centre and the eastern part of western Jakarta. The TSP levels are much lower in the eastern parts of the city where the GEMS sites are located.

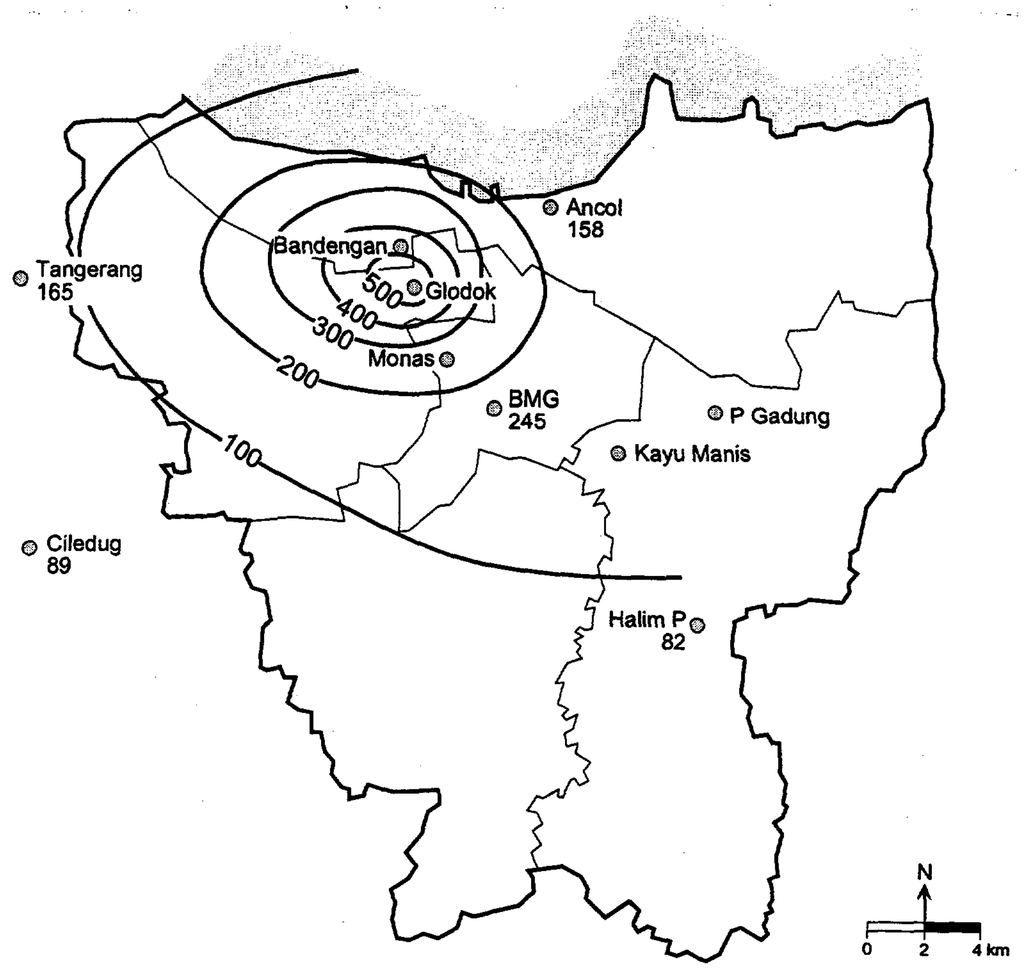
There is limited information on the 24 hour average TSP levels. According to Kozak and Sudarmo (1992) the daily TSP concentrations in Jakarta exceeded the 24 hour TSP air quality guideline on the average 173 days per year over a 7-year period.

The 24-hour mean TSP values from 4 selected stations, Pasar Ikan, Bandengan, Pasar Baru and Pasar Senen for the period 1992/1993 are shown in Figure 4. Most of the 24-hour mean TSP values are well above the proposed national ambient air quality standard of 230 μg/m³. The highest value of 865 μg/m³ was measured at Bandengan on 4 March 1993.

At the new display monitoring station Jl M.H. Thamrin near a roundabout in central Jakarta, PM_{10} is continuously monitored on an hourly basis. PM_{10} is the sum of particles with diameter less than 10 μm and is more related to possible health effects of particles in the air.

PM_{10} daily levels at Jl M.H. Thamrin station in April–June 1992 varied between 34–114 μg/m³ with an average of 90 μg/m³. The WHO 24-hour guideline of 70 μg/m³ was exceeded most of the days. PM_{10} levels are somewhat lower during weekends than during working days.

Figure 3: Suspended particulate matter isopleths 1980–1985



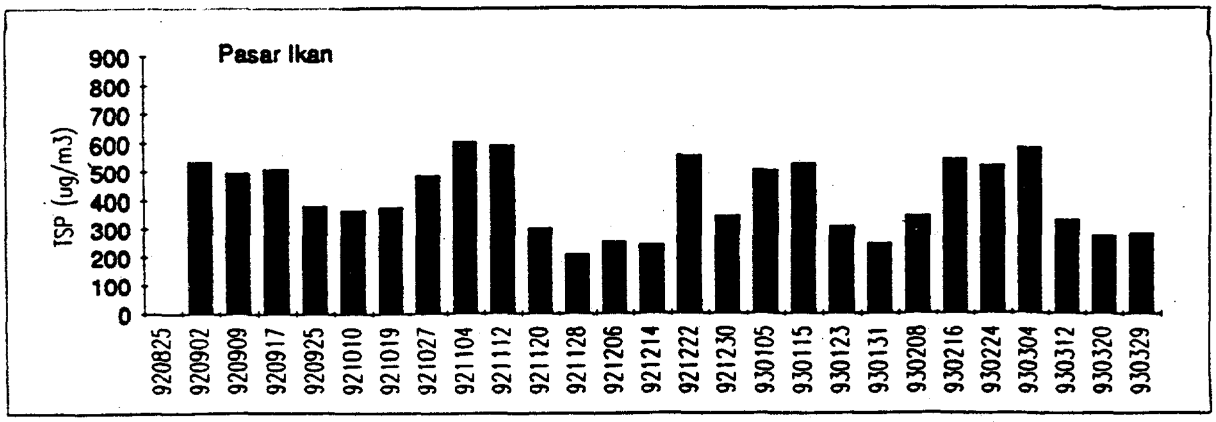
Source: Office of State Ministry of Population and Environment (1990).

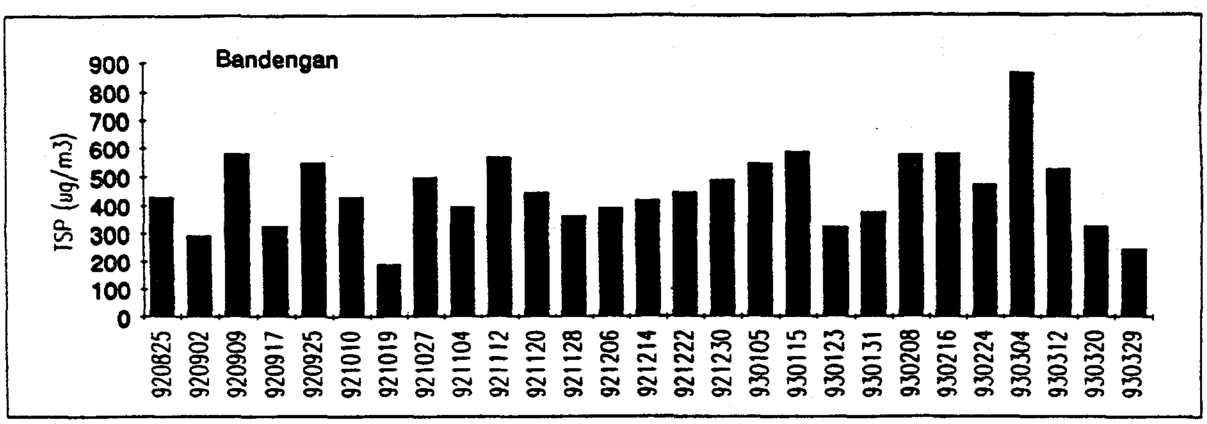
The PM_{10} levels were considerably higher during working hours than during the night, indicating human activities (probably mainly road traffic) to be the main emission source.

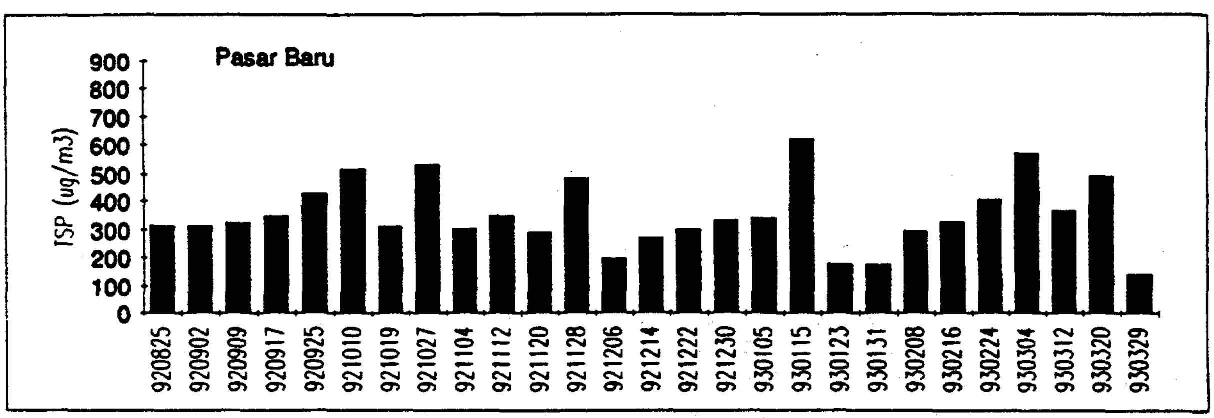
The PM_{10} data from Jl M.H. Thamrin station indicate that PM_{10} levels in Jakarta are very much lower than TSP levels measured at all the other stations. There is no reason to believe that TSP in traffic-exposed central Jakarta areas should be lower than at the TSP stations. If the TSP measurements are correct, the obvious conclusion is that most of the TSP particles have a diameter above 10 µm.

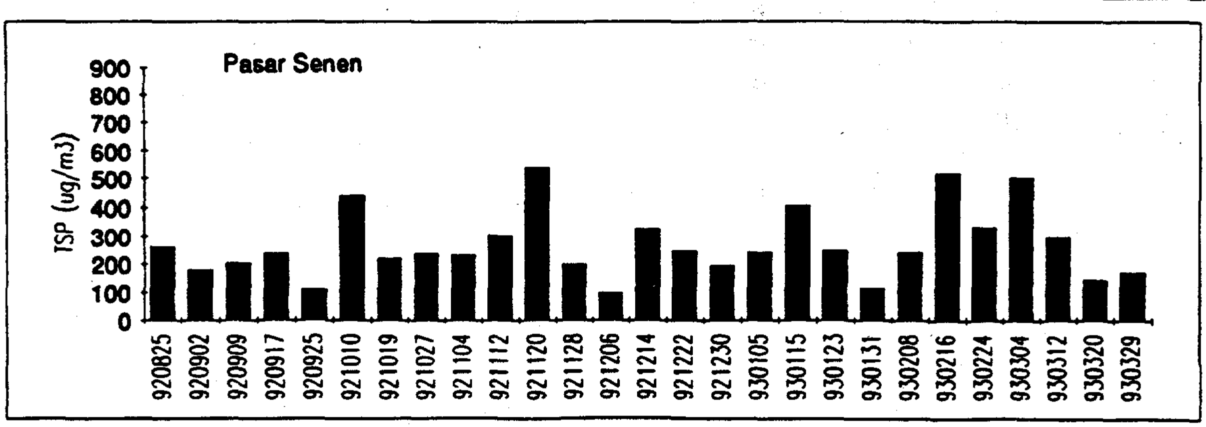
Sulfur dioxide (SO_2). Long-term SO_2 data is available from BMG (one station), JMG (2 stations) and KPPL (8 stations).

Figure 4: 24-hour mean values of TSP at selected sites during the measurement period 1992/1993 ($\mu g/m^3$)









Annual SO_2 averages are shown in Tables 4 and 6. Generally the annual levels are very low, from 5 ppb (14 µg/m³) to less than 0.1 ppb (0.3 µg/m³). The JMG stations Pulo Gadung and Kayu Manis show significantly lower values than all other stations, even in the same areas. According to Kozak and Sudarmo (1992) this could be due to specific sampling location characteristics, but it might be also due to varying sampling and analysis performance by the various agencies. They point out that consistent siting criteria and inter-laboratory comparisons should be considered to resolve these differences.

Table 6: Comparison of annual SO_2 concentrations from 1986–1991, from BMG and Ministry of Health air monitoring stations in Jakarta

Year	SO_2 (ppb)		
		Monitoring stations	
	BMG-HQ	Kayu Manis	Pulo Gadung
1986	2.0	0.1	0.2
1987	1.4	0.1	0.2
1988	1.7	0.5	0.4
1989	1.8	0.1	0.1
1990	4.0	<0.1	<0.1
1991	2.0	<0.1	0.1

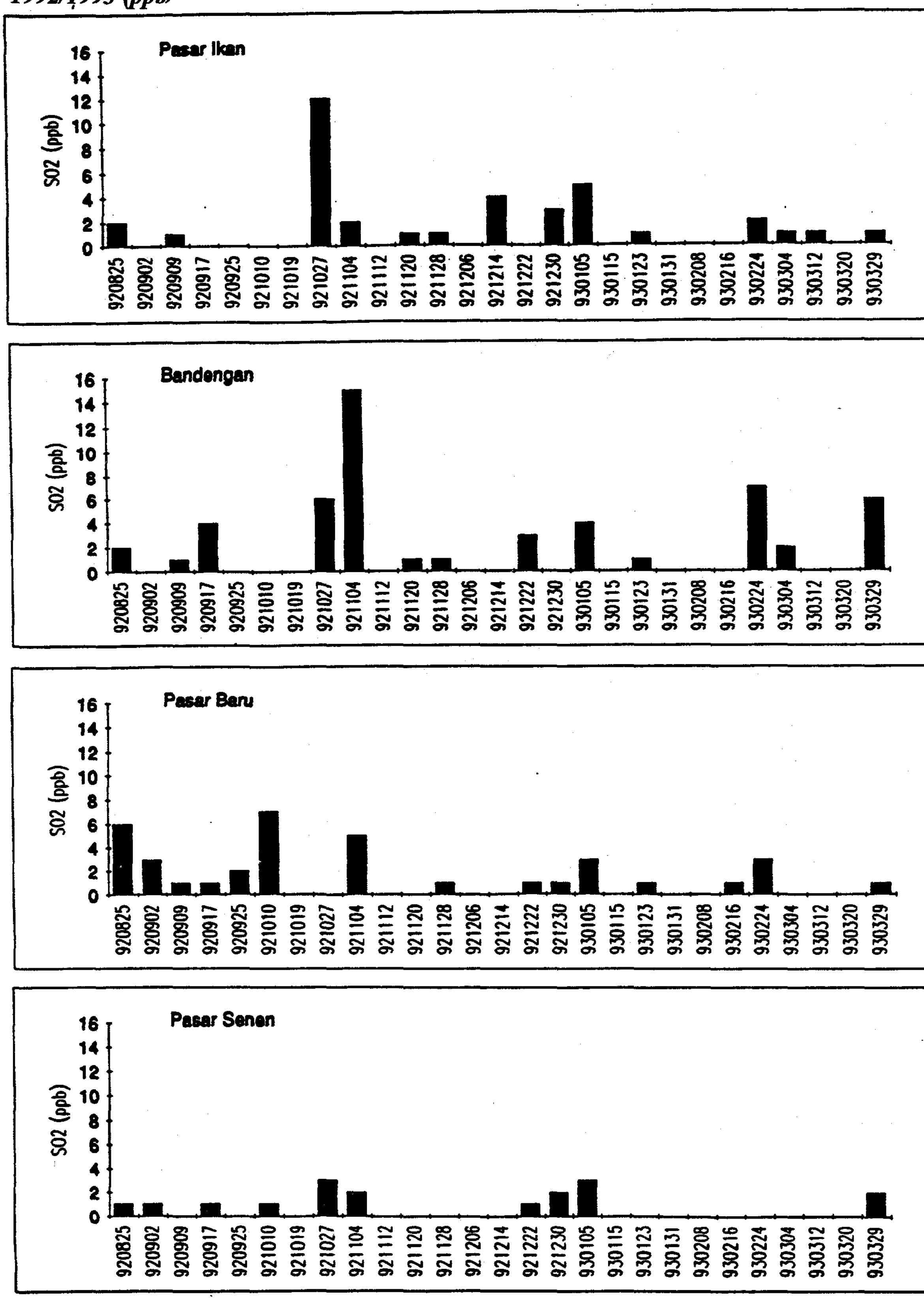
There is little available information on 24-hour average SO_2 values from the BMG/JMG/KPPL networks. In 1983 maximum 24-hour average concentrations of SO_2 were reported to be around 240 µg/m³, but daily averages decreased to 8 µg/m³ in 1986–1989. This remarkable sudden change cannot be explained at this time.

The 24-hour mean SO_2 values from 4 selected stations, Pasar Ikan, Bandengan, Pasar Baru and Pasar Senen for the period 1992/93 are shown in Figure 5. Most of the values are below 5 ppb (14 µg/m³). The highest value was 15 ppb (40 µg/m³).

The available 24-hour data suggest that SO_2 concentrations in Jakarta is *probably* not a serious problem. Large differences in SO_2 concentrations, both in time and between agencies, however, make the question of the reliability of the measurements important.

Recent data from the monitoring station at Jl M.H. Thamrin in April–June 1992 show daily mean values in the range 7.3–22 ppb (about 20–60 µg/m³) with an average of 12.8 ppb (about 35 µg/m³) (see Table 5). Hourly data from June 25 indicate SO_2 levels about 20 µg/m³ in the night and up to almost 200 µg/m³ during the day. The Jl M.H. Thamrin site SO_2 data may indicate that the 24-hour SO_2 data from the other stations are too low. Sampling procedures and analysis methods should be seriously checked.

Figure 5: 24-hour mean values of SO_2 at selected sites during the measurement period 1992/1993 (ppb)



Nitrogen dioxide (NO_2). NO_x data for KPPL and BMG/health stations are presented in Table 4 and Table 7 respectively. NO_X is reported, but the main component would probably be NO (Kozak and Sudarmo, 1992c).

The JMG (GEMS) reported annual mean NO_x concentrations of 2–4 μg/m³, and maximum 24-hour concentrations of 5–10 μg/m³ during 1986–1989. These stations are located away from the city Centre and thus primarily reflect suburban ambient air pollution.

During 1989 and 1990 the average concentration at the Bandengan station in the city Centre was (as low as) 28 μg NO_x/m³.

Table 7: Comparison of annual NO_x averages for 1986–1991 at BMG and Ministry of Health air monitoring stations in Jakarta

	NO_X (ppb)		
		Monitoring stations	
Year	BMG-HQ	Kayu Manis	Pulo Gadung
1986	60	20	21
1987	130	18	15
1988	140	12	10
1989	140	12	10
1990	40	10	9
1991	29	23	23

DKI-KPPL stations show a remarkable fall in NO_x concentrations from 113 μg/m³ in 1983 to 9.4 μg/m³ in 1986, and similarly, maximum 24-hour values fell from 395 μg/m³ to 15 μg/m³. This sudden drop in NO_x concentrations cannot be explained with the available information, but it seems likely that besides a possible improvement in air quality, the siting, sampling or instrumentation of the monitoring stations must have had a major influence (WHO/UNEP, 1992).

The DKI-KPPL stations show an increase again in the NO_x concentrations from 1986/1987 to 1990/1991 at all monitoring stations, while the SO_2 levels at the same stations fell considerably in the same period.

As shown in Table 4, NO_x levels were considerably higher during 1992/1993 than during 1990/1991. The mean values range from about 40 ppb to 80 ppb (80–160 μg/m³). This remarkable difference in NO_x levels from year to year seems difficult to explain.

From April–June 1992 NO, NO_2 and NO_x data from the new monitoring station Jl M.H. Thamrin show mean values of 64 ppb NO_2 (about 120 μg/m³) and 169 ppb NO_x (about 320 μg/m³). NO_2 daily values ranged from 46 ppb (about 85 μg/m³) to 93 ppb (about 175 μg/m³). The highest values are above the proposed Indonesian ambient air quality standard of 150 μg/m³.

Hourly NO_2 values on 25 June 1992 ranged from 22 ppb (about 40 μg/m³) to 178 ppb (about 340 μg/m³). The highest values are not far below the proposed 1-hour national ambient air quality standard of 400 μg/m³.

The results from Jl M.H. Thamrin indicate that NO_2 concentrations in the most heavily trafficked areas in Jakarta may be above the WHO and Indonesian standards.

The Jl M.H. Thamrin NO_2 results indicate, as was the case with SO_2, that the 24-hour NO_x data from the other stations may be too low, especially at the more centrally located stations. Similarly to SO_2, the NO_x sampling procedures and analysis methods should be seriously checked.

Ozone (O_3). O_3 is measured at the 8 DKI-KPPL stations. In 1986–1987 annual mean O_3 concentrations ranged from 2 μg/m³ at the Bandengan location to 15 μg/m³ at the Pasar Senen location. The latter station also had the highest 1-hour concentration with 85.8 μg/m³, while the highest 1-hour value at Bandengan was as low as 8.2 μg/m³. Thus all reported O_3 concentrations in Jakarta seem to be well below the proposed national ambient air quality standards.

The O_3 levels seem to be lower than expected, especially compared to the NO_x levels. If the O_3 levels are correct, the NO_x levels should be considerably higher than observed at the long term stations.

Unfortunately, O_3 is not monitored at the new Jl M.H. Thamrin location. Because of photochemical reactions of NO and O_3 to NO_2 and high observed NO_2 levels one would expect rather low O_3 levels at this site, especially during day time when the traffic volume is high. O_3 measurements with a continuous monitor is recommended at this site.

High O_3 concentrations have been measured outside the city. 100 ppb of oxidant is frequently measured at EMC in Serpong, 30 km southwest from central Jakarta (EMC, 1994).

Carbon monoxide (CO). CO is measured at the DKI-KPPL network. 8-hour average CO levels were found to be around 3.5 mg/m^3 in a residential area and at a bus terminal (Cililitan site), but were up to 27 mg/m^3 at the Glodok station in a city Centre commercial area. This value is well above the WHO guideline and the proposed national ambient air quality standard of 10 mg/m^3, indicating CO to be a problem in heavily traffic-exposed areas.

The new monitoring station at Jl M.H. Thamrin showed daily CO averages between 2.4–5.1 mg/m^3 in April–June 1992 (one sample every 7 days) with an average of 3.9 mg/m^3. Hourly values 25 June varied between 0.5 mg/m^3 in the night and 8.2 mg/m^3 in the afternoon. The highest 8-hour average this day was 7.1 mg/m^3, and the daily average value was 4.9 mg/m^3.

The Jl M.H. Thamrin air inlet is 4 m above ground level, about 10 m from the edge of a traffic circle (diameter of about 100 m). Very high traffic intensity is observed in the circle. Monitoring in a street canyon with heavy traffic would probably give higher CO levels than at the roundabout location. The wind often blows from the station to the traffic circle.

Lead (Pb). Average lead concentrations at the DKI-KPPL stations usually range between 0.5–2 µg/m^3. Considering the locations of the stations, Pb concentrations well above the proposed national ambient air quality standard of 2 µg/m^3 for 24-hour average are to be expected in more heavily traffic-exposed areas.

A study in July 1985 showed monthly Pb concentrations at three sites between 0.3–3.6 µg/m^3. The values were strongly correlated to road traffic volume.

PM_{10} samples from the new road side monitoring station Jl M.H. Thamrin are analyzed for Pb in Japan. However, no values have been released yet. These values will probably be by far the best to evaluate air lead pollution in densely trafficked areas in Jakarta.

The lead content in leaded gasoline in Indonesia is reported to be 0.44 g/l for 88 octane premium and 94 octane premix gasoline. During Summer 1995, unleaded gasoline was introduced in Jakarta, in relatively small amounts.

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APPENDIX 2: AIR QUALITY GUIDELINES

NATIONAL AMBIENT AIR QUALITY STANDARDS

The Air Quality Technical Committee, coordinated by KLH (State Ministry for Population and Development), and with members from the relevant national departments, DKI (District of Jakarta) and selected universities was formed in 1983. This group proposed ambient air quality standards for 9 parameters (KEPMEN, 1988). These standards are listed as "Existing standards" in Table 1.

Table 1: Existing (E) and proposed (P) national ambient air quality standards for Indonesia

Measuring time		30 minutes		1 hour		3 hours		8 hours		24 hours		1 year	
Parameter	**Unit**	**E**	**P**	**E**	**P**	**E**	**P**	**E**	**P**	**E**	**P**	**E**	**P**
SO_2	µg/m³				900					260	300		60
CO	mg/m³				30			22.6	10				
NO_2	µg/m³				400					92.5[a]	150		100
O_3	µg/m³			200	160								
TSP	µg/m³									260	230		90
Lead	µg/m³									6	2		1
HC	µg/m³					160	160						
H_2S	µg/m³	42											
NH_3	µg/m³									1,360			

Note: a) Nitrogen oxides.

The Technical Committee held a series of workshops/meetings at the beginning of August 1990 to consider and evaluate the information provided by EMDI (Environmental Management Development in Indonesia) and the members of the Committee on standards/objectives used by other countries and agencies. The existing National Ambient Air Quality standards from KEPMEN/1988 were used as the starting point for potential revisions, additions or deletions.

Revised National Ambient Air Quality Standards were drafted by the Technical Committee in January 1991, after a review which included documentation from a number of international agencies and jurisdictions. In particular, recent reviews prepared by the World Health Organization (WHO) were considered in detail and modified for the air pollutants SO_2, O_3, CO, TSP and Pb after discussion by the Technical Committee. In October 1991 it was proposed that a standard for hydrocarbons should be added to the list of parameters.

The National Ambient Air Quality Standards proposed in 1991 are also presented in Table 1 together with the existing standards. The primary purpose of the air quality standards is the protection of public health and other environmental receptors, such as vegetation, wildlife, material deterioration etc. against the adverse effects of air pollution. However, it is emphasized that the standards must also consider the prevailing exposure levels and environmental, social, economic and cultural conditions.

The standard measurement methods listed in Table 2 are essentially unchanged from KEPMEN (1988). The main reference for the measurement methods is the WHO document "Selected Methods of Measuring Air Pollutants" (WHO, 1976), which specifies standard methods that are similar to those used by U.S. Environmental Protection Agency.

Table 2: Standard measurement methods for proposed national ambient air quality standards

Parameter	Analysis method	Equipment for analysis	Sampling equipment
Sulfur dioxide	Colorimetric	Spectrometric	Gas sampler
Carbon monoxide	Non-dispersive infrared	Non-dispersive infrared analyzer	CO-analyzer
Nitrogen oxides as NO_2	Colorimetric	Spectrofotometer	Gas sampler
Oxidant as O_3	Colorimetric	Spectrofotometer	Gas sampler
Suspended particles	Gravimetric	Scale	High volume sampler
Lead	- Gravimetric	Scale	High volume sampler
	- Destruction	Atomic absorption	High volume sampler

WHO AIR QUALITY GUIDELINES AND STANDARDS

WHO Air Quality Guidelines and standards are listed in Table 3. For SO_2 the WHO guidelines are much lower than the proposed Indonesian standards for averaging periods 1 hour and 24 hours. The Indonesian CO values for 1 hour and 8 hours are equal to the WHO values. The Indonesian NO_2 1 hour value is the same as the WHO guideline. The proposed Indonesian O_3 1 hour guideline is within the WHO guideline range. The proposed 1 year value for lead is the same as the upper range WHO level. This is also the case for the proposed 24 hours and 1 year Indonesian guidelines for TSP.

Generally, the proposed Indonesian National Ambient Air Quality Guidelines follow the WHO guidelines, except the 1 hour and 24 hours values for SO_2.

No standards are proposed for PM_{10}, i.e. particulate matter less than 10 μm in aerodynamic diameter. This may be because of lack of monitoring equipment.

Table 3: 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 standard
SO_2	µg/m³	500			350		125[a]	50[a]	1987
SO_2	µg/m³						100–150	40–60	1979
BS[b]	µg/m³						125[a]	50[a]	1987
BS[b]	µg/m³						100–150	40–60	1979
TSP	µg/m³						120[a]		1987
TSP	µg/m³						150–230	60–90	1979
PM_{10}	µg/m³						70[a]		1987
Lead	µg/m³							0.5–1	1987, 1977[b]
CO	mg/m³		100	60	30	10			1987
NO_2	µg/m³				400		150		1987
NO_2	µg/m³				190–320[c]				1977[b]
O_3	µg/m³				150–200	100–120			1987
O_3	µg/m³				100–200				1978

Notes:

a) Guideline values for combined exposure to sulfur 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

BS = Black smoke; a 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}).

Source: WHO/UNEP (1992).

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APPENDIX 3: AIR POLLUTION LAWS AND REGULATIONS FOR INDONESIA AND DKI JAKARTA

REGULATIONS AND INSTITUTIONS IN AIR POLLUTION (1994) BY DR. BUDIRAHARDJO

General information. Cities development all over the world give the consequences in transportation problems, due to the economic growth in the cities, causes the additional ownership of the vehicles and the increasing of number of population move to the suburban area for the housing and located in the distance between residential are with the center of the city and also job sites.

Jakarta for example in 1985 was facing 14 million personal trips and based on the study of ARSDS, the projection is increasing to 24.9 million person trips in 2005 where the projected population is 12 million.

The annual increase of cars in Jakarta is around 11.76% in average, and there are a lot of difficulties have faced to implement the limitation number of vehicles owned by citizens. It is understand able that the present traffic condition mostly congested. Will become more critical if the counter measures are not being taken to overcome the situation especially in traffic problems.

The amount of vehicles on the roads and the traffic jam situation which are frequently happen is the source of emission of tail gas will cause the impact of worsening of ambient air quality.

Regulations On Emission Of Exhaust Gas Handling. In the field of traffic and land transportation, there are several regulations, among other:

- Act number 14 of 1992 on: Traffic and Land Transportation, in Chapter 13 article (1) mentions: "Every motorized vehicle, trailler, box car and special vehicle which are on the roads subject to be tested."
  Chapter 13 article (2): The testing as it is mean in the article (1) include the Type Approval and/or Periodic Test.
  In Chapter 50 article (1): "To prevent air pollution and noise pollution form vehicle which might bring impact to the sustainability of Living Environment, every car (vehicle) obligatory to comply to the criteria of standard emission exhaust gas and noise level."

In Chapter 50 article (2): "Every owner, manager of the Public Transportation, obligatory has to prevent the happening of air pollution and noise as what is mean in the article (1), as the results of the operationalization of vehicles."

Government Regulation number 44 of 1993 on Vehicles and drivers, in Chapter 127 article (1) among other mention, "Motorized vehicle has to comply with the requirement of roadworthiness, which includes:

a. Emission of exhaust gas from motorized vehicle, and
b. The noise of main brake.

- In Chapter 127 article (3) mentions: "The criteria of roadworthiness which is mean in the article (1) a and b, will determined by Ministerial Decree who is responsible in the Living Environment after the consultation with Minister of transportation."

  Decree of Ministry of Transportation number KM 71 of 1993 on: The periodical test of Motorized Vehicle.

  In Chapter 2 article (1): Implementation of periodical test of motorized vehicle by mean of:

  a. to guarantee of safety in the technical point of view in the using of motorized vehicle on the road,
  b. to keep sustain environment from the possibility pollution due to the usage of the motorized vehicle on the road, and
  c. To serve the public service to the society.

- In Chapter 3, Periodical test of motorized vehicle is done by Provincial Government and operationally is done by Traffic and Transportation Service in the Province, or can be delegated to Traffic and Transportation Service in Local Government Level.

  In Chapter 12 mentioned, The equipment for testing of exhaust gases, include testing equipment for Carbon Monoxide (CO), Hydrocarbon (HC) and Smoke tester of the exhaust gases.

- Decree of Ministry of Transportation, number KM 8 of 1989, The criteria of standard limitation on the roadworthiness to the production of motorized vehicle, trailler, box car, body construction, truck body and each components, was decided the limit.

  The decision about the exhaust gases, was decided in Chapter 3 and Chapter 4 as follow:

  a. the content of CO and HC at emission of the exhaust motorized vehicle with Premium as the fuel with 87 RON has been decided maximum 4.5% for CO and 1200 ppm for HC;
  b. the content of CO and HC at the emission gas of motorized vehicle in idling condition and during normal atmospheric condition;
  c. The smoke content in the emission gas of motorized vehicle with compression ignition and with diesel fuel it was decided with maximum 50%;
  d. The smoke level of the exhaust gas measured in free speed condition.

- The criteria of noise level of horn belong to the motorized vehicle, was decided in Chapter 7 and Chapter 8 as follow:

  a. the horn noise level of motorized vehicle was decided minimum 90 dB(A) and maximum at 118 dB(A);
  b. The decision of horn noise level of motorized vehicle be measured at the place where there is no noise with the reference noise level at the lower condition in the distant of 2 meters in front of vehicle.

- Governor Jakarta Decree number 1222 of 1990, about "Standard emission of vehicle in Capital City of Jakarta" In the Chapter 4, article (1) mentioned: The Traffic and High Way

Service Department Jakarta is responsible to exercise Verification of vehicle emission in Capital City of Jakarta.
In the article (4) of the same Chapter mentioned: The implementation of emission verification will be done at the same time with roadworthiness test of the vehicle or separately.

- Governor Jakarta Decree number 1236 of 1990 about operating procedure in implementing vehicle emission standard in Capital City of Jakarta.
  In the Chapter 6, article (1) mentioned: The control toward implementation of vehicle emission will be done by related institution, includes:
  - Provincial Planning Board of Jakarta (Bappeda),
  - Bureau of Environment (BBLH),
  - Urban Research and Environment Office (KPPL),
  - Bureau of Economic Facilities Development (Bangsarekda),
  - Bureau of Well-Order (Ro Ketertiban),
  - Regional Investment Board (BKPMD),
  - Department of Health Service (DKK),
  - Department of Industry Service (Dinas Perindustrian),
  - Department of Public Works Service (DPU),
  - Department of City Planning Service (Dinas Tata Kota),
  - Bureau of Law (Ro Hukum).

  In Chapter 7, article (1) mentioned: Evaluation toward the emission standard will be done as follow:

  a. Supervising in the emission parameters evaluation will be coordinated by Urban Research & Environmental Office,
  b. Supervising in the implementation evaluation will be coordinated by Bureau of Environment,
  c. Supervising in the evaluation of regulation affair will be coordinated by Bureau of Law.

Controlling Air Pollution Through Emission Examination

- Procedure and Phasing of emission examination.
  The procedure which guides the air pollution program in administrative border of Jakarta was mentioned in Governor Decree 1222 and 1236 of 1990.
  In these decrees several items have to be underlined are as follow:

  a. the vehicles that have to be examined are all kinds of vehicle which are operated in the public roads in Jakarta includes Public cars, transportation cars, Passenger's cars, Buses, Trucks and Motor Cycles;
  b. every kind of vehicle in point a above, has to comply the standard in the parameters as follow;
  c. Transport & Highway Department Service is responsible in examination of emission in Jakarta, emission worthiness duration minimum three (3) months and maximum six (6) months. The vehicle that fails to comply with emission standard is restricted to be operated in the public roads;
  d. The phasing of implementation of standard emission:
     1) Public enlighting and education,
     2) The choice of appropriate testing equipment,
     3) Planning the needs of facilities,

4) Testing Procedures and Certification,
5) Cooperation with Private Sector,
6) Supervising procedure between related institutions.

The amount of vehicle compulsory to emission exam.

- The amount of vehicles compulsory to be emission examination and roadworthiness test in Jakarta based on the data up to the end of 1990 are given in Table 2.
  - With the assumption of annual increase of vehicles that have to be examined as 8.72%, the projection will be 432,930 vehicles to be tested in the coming 5 (five) years.
  - At the same time based on the assumption of vehicle annual increasing rate is constant follow the rate in the period of 1986–1989, will give the estimation of vehicles which will be examined in 1995 (After stage I 1991–1994) are (as summarized in Table 3).

Table 1: Mandatory standard emission tests

		Standard Emission			
Type of Vehicle	**Fuel**	**CO-%Vol**	**NOx-ppm**	**HC-ppm**	**Smoke-%**
Passenger Car	Petrol	4.50	1,200	1,200	--
	Diesel	--	1,200	1,200	50
	Mixed	4.50	1,200	1,200	50
	CNG	3.00	--	--	--
Trucks, Pickup	Petrol	4.50	1,200	1,200	--
	Diesel	--	1,200	1,200	50
	CNG	3.00	--	--	--
Buses	Petrol	4.50	1,200	1,200	--
	Diesel	--	1,200	1,200	50
	CNG	3.00	--	--	--
Motor Cycles	Petrol	4.50	2,800	2,800	--
	Mixed	4.50	3,600	3,000	--

Table 2: Compulsory vehicle exams

Amount of Vehicle		Vehicle Compulsory Exam		
Type of Vehicle	**Amount**	**Type of Vehicle**	**Amount**	**Exam**
Public car	40,522	Passenger car	35,792	65,809
Private car	553,755	Buses	26,759	21,110
Commercial	174,494	Cargo car	134,719	197,097
Total:	**1,531,645**	**Total:**	**197,270**	**285,016**

Table 3: Projected vehicles to be examined in 1990 and 1995

Type of Vehicle	Annual Increasing Rate (%)	Emission Exam 1990	Emission Exam 1995	Composition (%)
Private cars	5.62	1,107,550	1,455,760	41.4
Cars compulsory to be examined	8.72	285,016	432,930	12.3
Motor Cycles	1.34	1,525,748	1,630,740	46.3
Amount of Vehicles		2,918,341	3,519,430	100.0

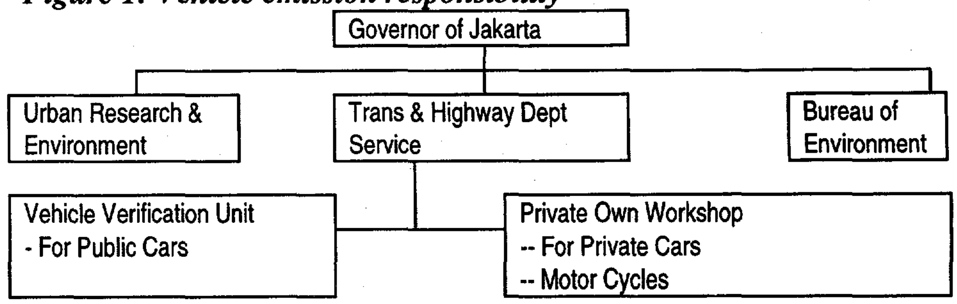
Note: Assumed emission exam two times per year.

Examination of motorized vehicle emission.

- Principally the emission test is one of the component in roadworthiness of the motorized vehicle, based on Decree of Minister of Transportation KM 8 of 1989. Due to the most of vehicles that have to be tested are private cars (87.7%) and motor cycles, this mean that most emission test facilities have to be prepared.
  With the calculation of time needed for administrative affairs, at least 20 minutes for each testing. When the operation time of testing equipment is 6 hours, and 6 days week, and 50 weeks per year (2 weeks for maintenance and calibration), result of calculation is that every testing unit able to perform the testing for 1,800 hours per year or 5,400 cars per year. If the

estimated amount of cars that have to be tested are 33 million in the year of 1995, the need of testing equipment is about 650 units. This means the need of private sector participation.

Figure 1: Vehicle emission responsibility



Supervision of emission test.
- As it was mentioned in the Governor Decree number 1236 of 1990, the institution for vehicle emission test in Jakarta is as follows (Figure 1):
- The related institutions in supervising various activities and each related responsibility of vehicles emission test, was mentioned in the Chapter 2 above.

Air pollution control through traffic & transportation management
- Air pollution control in the urbanized area might be supported by traffic management.
- In the Provincial Government Act number 5 of 1984 about: Master Plan Jakarta up to the year 2005, in the policy guideline of Transportation Sector was mentioned the present of Restricted Zones in the center of the city.
- The limitation of transportation was decided through the zoning.
- The zoning in the center city, which surrounded by the rail way, the transportation limitation might reach up to 75%, this means the residual 25% volume of transportation in this zone.
- Zones surrounded by rail way ring up to inner ring road, the transportation limitation will be 50%.
- Zones in between inner and outer ring road, the limitation will 25%, and zones outside outer ring road the limitation only 5–10%.
- With this limitation of transportation means the amount of operated vehicles on the public road are decreasing, this will reduce amount of pollutant from tail gas of motorized vehicle. Beside the less of amount of vehicles means the average vehicle's speed on the public road also increasing, and resulting less emission gases per unit length of road.
- The experiment of Restricted Area has been exercised by "Three in One", since 20 April 1992, in the Path of Highway Sudirman, Thamrin, Medan Merdeka Barat, and Gatot Subroto from 6:30–10:00 a.m. The private cars pass through the restricted zones have to be three and more passengers.

  The 14 months record on the results of "Three in One" are as follow:
  - private vehicles speed increase by 35%,
  - buses speed increase by 40%,
  - volume of private vehicles increase by 2% but with increasing speed,
  - amount of buses increase by 99% (frequency of trips increase),
  - amount of buses passengers increase by 89%.

- The limitation of the usage of private cars has to be balanced by the public transportation service, as such that the people able to change to the public transportation rather than using their own cars. Special Bus lane has been tried since 1 March 1990 in several path of high way like Thamrin Sudirman from 07.00–09.00 and 16.00–19.00, and gradually will be followed in other high ways like: Sisingamangaraja, Medan Merdeka Barat, Gunung Sahari up to Jatinegara, Kramat Bunder to Suprpto, Pramuka-Pemuda, Panglima Polim Raya and Melawai Raya. In the year 1993 end will be implemented in Gajah Mada-Hayam Wuruk.
- By the Special Bus Lane shows some improvement as follow:
  - average Bus speed increase by 32%,
  - volume of Buses increase by 48%,
  - passengers increase by 42%,
  - amount of buses trips increase from 6 trips/day now up to 7.2 trips/day.
- Mass Rapid Transportation still being considered by Central Government and Government of Jakarta Metropolitan. If the mode of Light Train or Sub Way was chosen, because both facilities are using electricity as power sources, this mean that the solution might bring the decrease of air pollution through Transportation Sector.
- MRT which are present now is fly over rail way from Manggarai Gambir, Rail way ring Kota-Senen-Jatinegara-Manggarai-Tanah Abang-Kota, to and fro. Also electrically and diesel fuel Jabotabek Train. Electric wiring net work has been prepare and ready by now, excluded in Kebayoran Lama-Rangkas Bitung.
- MRT also in the design state from Block M to City, to operate the facilities, an institution should be set up as Authority Agency to manage the facilities.

Conclusion

- The land transportation has contribute dominantly to Air Pollution in the urban area/City as the results of emission gases, while-the amount of vehicles are increasing.
- And for private cars, motor cycles might invite the Private Sector to join with the emission test activities.*
- "Three in One" shows a good result on air pollution abatement and should be broadened in the near future.
- MRT able to be the solution of transportation problem to limit the amount of private cars. and in the long run also MRT in Jabotabek Region.

AIR POLLUTION CONTROL INSTITUTIONS

Dinas Lalu lintas dan Angkutan Jalan Raya (DLLAJR) = Road Traffic and Transportation Department. DLLAJR-DKI is a department of the Jakarta Provincial Government which is responsible for the control of road traffic and transportation, including the road worthiness of the motor vehicles and their emission.

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* According to the Regulation, all cars should undergo emission test. It will be implemented in phases, with cargo and public transportation getting first priority (Hadiwinoto, MEIP).

The organization, tasks and procedures in the DLLAJR are defined in the Perda (Local Regulation) no. 2 / 1985. The head of the DLLAJR reports to the Governor, and he is under the administrative coordination of the Sekretaris Wilayah Daerah (Secretary of the Province).

The main tasks of DLLAJR are to execute/implement the planning, organizing, supervision, and control of the road traffic and transportation which are in the authority of the local/provincial government, and other tasks complying to the acts and regulations, to achieve a safe, orderly, and (smooth) traffic and transportation.

To execute the main tasks, the DLLAJR will:

a) plan the road and transportation network;
b) implement the techniques of traffic and transportation;
c) implement the licensing of traffic and transportation;
d) implement the vehicle inspection;
e) control the traffic, transportation, and motor vehicles;
f) control and ensure the safety of road transportation, terminals and transfer points;
g) plan and construct terminal and transfer points.

The organization of DLLAJR comprises:

a) Head of the DLLAJR,
b) Deputy Head of the DLLAJR,
c) Administration,
d) Accounting,
e) Personnel,
f) Planning and Programming,
g) Traffic Engineering,
h) Transport Services Development,
i) Traffic and Transportation Control,
j) Terminal and Transfer Points Development,
k) Vehicle Inspection,
l) Sub Department at the Municipality level.

Divisions which are related to the air pollution control are:

a) Planning and Programming Division, responsible for data collection, programming, monitoring, evaluation and control, among others traffic counting on roads and intersections for all motor vehicles. Planning and Programming Division also conduct studies on traffic volume control, development of mass transit, the use of compressed natural gas, and development of passenger and goods transport routes.

b) Traffic Engineering, responsible for road marking and signs, parking sites, traffic computers, crossing design, u-turns, medians, pedestrian bridge, etc.

c) Transport Services Development Division, responsible for the development, licensing and control of transport services establishment, among others: licensing for the routes and operations of bus companies, and to implement/enforce the use of natural gas for public transportation.

d) Traffic and Transportation Control Division, responsible for the coordination and formulation of control, enforcement, and information on traffic and transport system, development and supervision of driving-schools, garages/workshops, and emission control at the terminals.

e) Car Inspection Division, responsible for the inspection of motor vehicles. Trucks, buses, and other public transport vehicles get the inspection each six months (twice yearly) including emission control. The inspections are carried out at the inspection office: Pulogadung for bus and passenger cars, and Ujung Menteng for trucks. Also available are on-site inspections as requested by the car pools.

f) The Sub-Departments at the Municipality level are responsible for the orderly functions of the traffic and transportation facilities, such as the control on bus, trucks, taxis, and the local traffic condition.

Badan Pengelola Terminal Angkutan Jalan = Road Transportation Terminal Authority. The Head of the DLLAJ-DKI is an ex-officio head of the BPTAJ, because the functions are very closely related. The main task of BPTAJ is to optimize the capacity and outputs of all the terminal facilities to improve public service.

The organization comprises:

- Head of BPTAJ,
- Deputy Head of BPTAJ,
- Planning and Programming,
- Development and Supervision,
- Construction and Maintenance,
- Security and Enforcement,
- General Affairs,
- Terminal Sites.

The divisions which are closely related to air pollution control are:

- Planning and Programming, which plans the operations and development of the terminals;
- Security and Enforcement, which control the transport services and emission discharge;
- Development and Supervision, which gives the guidelines, motivate, and supervise the transport companies on condition of the vehicles;
- Terminal Sites, which conduct the daily control at the terminals, including the vehicle condition.

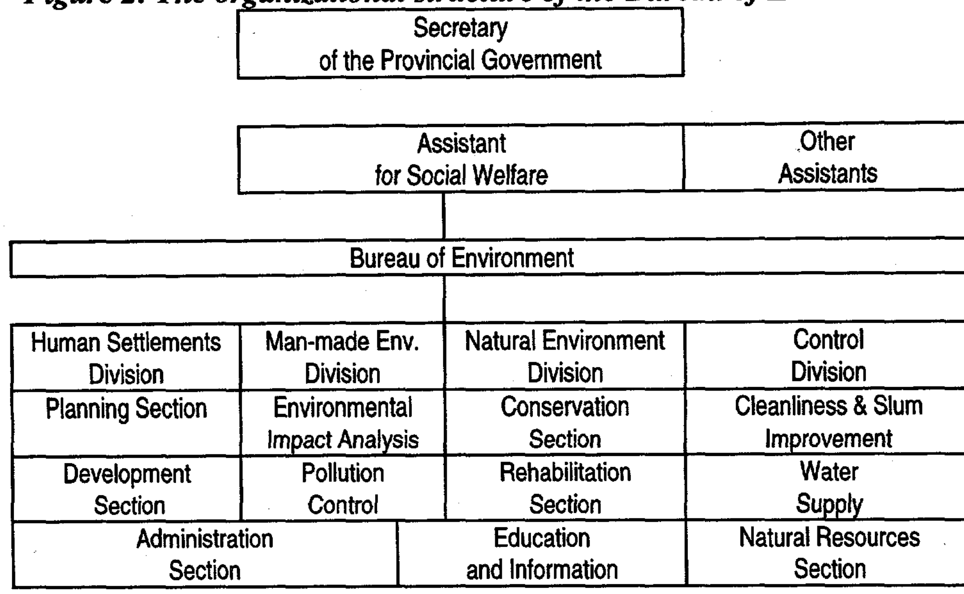
Biro Bina Lingkungan Hidup (BBLH) = Bureau of Environment. BBLH is under the coordination of the Assistant of the Secretary for Social Welfare, at the Secretariat of the Province. Its main task is to prepare policies, coordination, and development on environmental affairs.

To implement the tasks, BBLH will:

a) prepare policies, programs, and guidelines on environmental quality and environmental protection;
b) coordinate, guide, and encourage environmentally sound development;
c) coordinate, plan, and guide development of man-made environment;
d) coordinate, plan, and guide implementation and enforcement of pollution control.

The organization of BBLH comprises:

Figure 2: The organizational structure of the Bureau of Environment



a) Human Settlements Division,
b) Man-made Environment Division,
c) Natural Environment Division,
d) Control Division.

There is no specific division for air pollution control, but it is included in the task of the Man-made Environment Division which is responsible for data collection, planning, programming and development of pollution abatement.

The Pollution Control Section in the Man-made Environment Division is in charge of:
a) data collection, programming, and preparing guidelines for the development of pollution control;
b) coordination for implementation of pollution control.
The structure is rather confusing and needs some adjustment.

Direktorat Jendral Perhubungan Darat (DJPD) = Directorate General for Land Transport. DJPD is a Directorate General under the Ministry of Transportation responsible for road transportation, railway, and ferry. The development of the Urban Mass Transit System (Sarana Angkutan Umum Massal = SAUM) will help reduce the air pollution in urban areas.

Without an adequate mass transit system the growing metropolis will depend only on road transportation, especially private cars. Traffic jams and air pollution has been worsening continuously. A breakthrough is critically needed to reduce traffic jams and air pollution, giving priority to public transport, especially the mass transit system.

APPENDIX 4: EMISSIONS SURVEY FOR JAKARTA

INTRODUCTION

This emissions survey is prepared to serve as input for model calculations for the Jakarta area, as a tool in developing an Air Quality Management Strategy (AQMS) for the area. In order to use it as a tool it is necessary to have correct information about the present emissions situation (amounts and spatial distribution) and the effects of different development strategies. Model calculations together with air quality measurements will give a description of the present situation, and the model may be used later to range the different alternatives for the future.

An emissions inventory should cover source groups as industrial point sources, small industry and domestic emissions and emissions from main road and local road traffic. It is impossible to calculate the emissions from each single source (house, stack, car), but using representative emission factors will normally give very good estimates. The emissions in a city may be organized in three main groups: traffic, industrial and domestic activities. For model calculations it is necessary to calculate both total emissions for each group and the spatial distribution of the emissions.

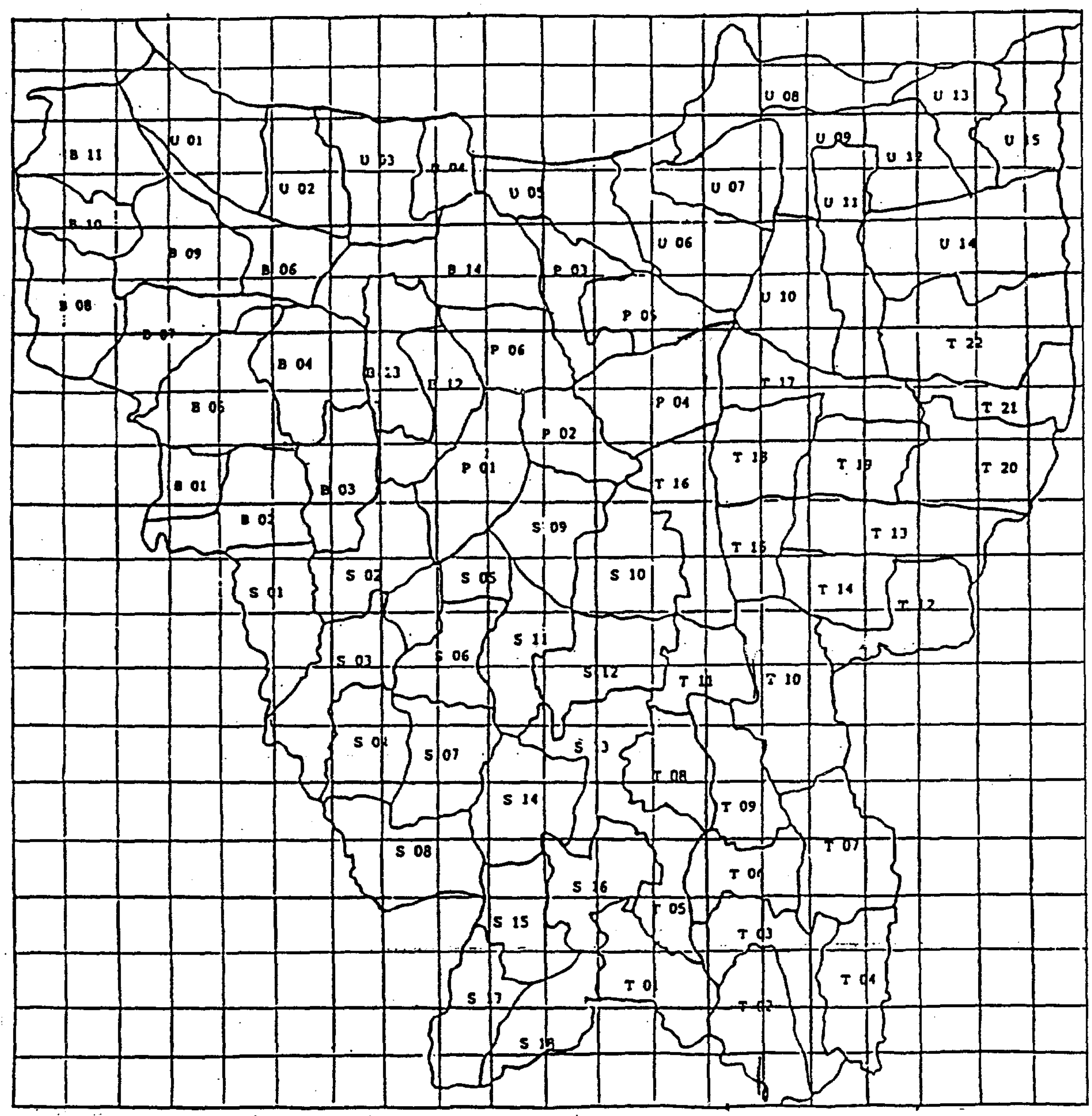
This survey is not a complete emissions survey for Jakarta. It is based upon data which are not satisfactory explained and errors may have been introduced. Many source groups are not included yet, and for other the calculations are based upon secondary information, specially for the spatial distribution. This means that many basic input data are still missing, and we have had to use other data than desired to calculate the distribution.

MAP AND EMISSIONS GRID

The emission calculations were intended to be made for a 1 km^2 grid of 32 x 32, using the UTM net according to "Peta Rubumesi Indonesia" 1:25,000, edition 1990. All road coordinates and references are given relative to these maps.

Figure 1 shows the DKI Jakarta Region and the grid net, which covers 1,024 km^2. DKI Jakarta itself covers about 666 km^2, the rest is areas in Bekasi, Bogor, Tangerang and sea. The district borders in the figure are drawn directly from reduced copies of the maps.

Figure 1:Districts in Jakarta and the Soedomo grid



Note: P: Central Jakarta, S: South Jakarta, T: East Jakarta, U: North Jakarta, B: West Jakarta.
Source: Bachrun (1991).

For this study, basic data for calculating emissions for many source groups were not available in the first phase. For these we had to make use of data from Dr. Soedomos estimates of the emissions in Jakarta (Soedomo, 1992). He uses a grid network of about 1500 x 1500 m^2, and we found it difficult to transform his data to the km^2-grid. Instead it was decided to use the Soedomo grid for the calculations. In the UTM-system this corresponds to a zero-point in the lower left corner with UTM-co-ordinates $(^{6}86, ^{92}95)$.

As air pollution moves across all administrative boundaries, an emissions survey has also to take into account activities in the surroundings of Jakarta, but the most dominant work has to be made for Jakarta itself. Near the border of Jakarta there are industrial activities, mainly along the main roads to the east, south and west of the metropol. The new Jakarta International Airport Soekarno-Hatta is also situated outside the border east of Jakarta, in Tangerang.

POPULATION DISTRIBUTION

Many of the emitting activities in a city are distributed according to the population distribution, and the exposure calculations use the population distribution directly.

The evaluation of the population distribution is based upon data from the census 1990 (Jakarta Statistical Office, JSO, 1991) and the Jakarta maps showing the borders of the different districts and sub-districts. For each sub-district there was evaluated a distribution code to the grid net, and the population within the sub-district allocated to the grid according to this.

This is a method which gives a fairly correct distribution; the more complete the information upon which the distribution code is based, the more correct will the result be. The errors will be of the order of locating some hundreds of inhabitants in one grid instead of the neighboring grid. When the distribution code has been made, it is easy to make new distribution calculations with new population data, e.g. future projections. It is only when there have been (or are planned) major changes within a sub-district that the distribution code has to be revised.

The population in grid (I,J) within sub-district K will be:

$$POP(I,J) = INH(K)*COV(I,J,K),$$

where

- INH(K) is the number of inhabitants in the sub-district K,
- COV(I,J,K) is the coverage of grid (I,J) to sub-district K,
- $\Sigma COV(I,J,K) = 1.0$.

In different data sets for the population of Jakarta the area of each region and sub-region varies, often considerably, from data-source to data-source. It is not known whether this has to do with new administrative borders or different reference maps. Table 1 shows the land area and the population for the districts (kecamatans) in Jakarta according to different sources. There are large differences between the data sets which cannot be explained only by migration or development. To produce a correct population distribution it is necessary to check the background for the input data very strictly. In the calculations we have used data from JSO 1991; for some of the kelurahans we have used areas according to the map and other sources. Figure 2 shows the calculated population distribution for Jakarta 1990.

Table 1: Population in the regions of Jakarta according to different sources

Central Jakarta (Jakarta Pusat)	km^2	kel.	1987	1990	1990 stat
Tanah Abang	9.30	7	229,896	192,152	203,975
Menteng	6.53	5	116,581	90,774	117,415
Senen	4.23	6	134,547	112,589	130,256
Cempaka Putih	4.69	3	84,400	92,497	88,242
Johar Baru	2.38	4	112,850	122,866	106,847
Sawah Besar	6.22	5	152,040	124,482	146,455
Gambir	7.80	6	129,493	112,864	127,021
Kemayoran	8.21	8	206,107	226,528	228,457
Jakarta Pusat	49.36	44	1,165,914	1,074,752	1,148,669

Jakarta East (Jakarta Timur)	km^2	kel.	1987	1990	1990 stat
Pasar Rebo	12.95	5	80,366	119,517	99,431
Cipayung	27.21	8	55,939	100,860	71,449
Ciracas	16.09	5	94,709	157,674	122,372
Kramat Jati	13.34	7	159,711	211,757	175,521
Makasar	21.64	5	117,989	146,532	134,224
Jatinegara	10.64	8	253,682	277,578	266,335
Duren Sawit	23.13	7	205,068	290,246	241,577
Matraman	4.85	6	176,205	165,372	179,595
Pulo Gadung	15.71	7	229,115	279,103	251,313
Cakung	42.43	7	119,112	315,826	191,284
Jakarta Timur	187.99	65	1,491,896	2,064,465	1,733,101

Jakarta West (Jakarta Barat)	km^2	kel.	1987	1990	1990 stat
Kebon Jeruk	17.87	6	144,399	261,605	165,479
Kembangan	24.64	5	81,043	157,233	99,856
Cengkareng	30.10	6	130,868	367,969	178,087
Kalideres	27.39	5	94,147	175,496	102,712
Grogol Petamburan	11.39	6	224,316	242,015	221,188
Palmerah	7.54	5	186,090	217,065	191,625
Tambora	5.48	11	243,242	263,607	266,499
Taman Sari	4.36	8	155,534	130,326	152,205
Jakarta Barat	128.77	52	1,259,639	1,815,316	1,377,651

South Jakarta (Jakarta Selatan)	km^2	kel.	1987	1990	1990 stat
Kebayoran Lama	19.31	6	210,805	260,764	262,722
Pesanggrahan	13.46	5	89,891	153,715	125,705
Pasar Minggu	22.71	7	224,038	231,848	203,519
Jagakarsa	25.51	5	111,812	143,072	127,505
Mampang Prapatan	7.73	5	127,758	148,665	125,242
Pancoran	8.23	6	112,786	141,373	123,333
Kebayoran Baru	12.75	10	199,175	186,865	198,033
Setia Budi	9.05	8		179,405	185,959
Tebet	9.53	7		248,493	273,961
Cilandak	18.35	5	166,550	172,036	147,706
Jakarta Selatan	146.63	64		1,866,236	1,773,685

Table 1 continued: Population in the regions of Jakarta according to different sources

Jakarta North (Jakarta Utara)	km^2	kel.	1987	1990	1990 stat
Penjaringan	35.48	5		155,630	158,798
Pademangan	9.91	3	118,203	90,505	120,317
Tanjung Priok	25.22	7	250,024	277,372	284,654
Koja	11.38	6	226,160	241,833	246,975
Kelapa Gading	16.12	3	59,253	67,305	71,604
Cilicing	43.29	7	161,879	177,214	178,628
Pulau Seribu	11.80	4	14,467	14,246	14,276
Jakarta Utara	153.20	35		1,024,105	1,075,252
Total	665.95	**260**		**7,844,874**	**7,108,358**

Note: kel. -- number of kelurahans.

Sources: for 1987: Bachrun et al. (1991); for 1990: Soedomo (1993); for 1990 stat: JSO (1991).

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

Figure 2: Population in Jakarta 1990 (in hundreds of inhabitants)

MAP FOR INHABITANT UNIT: PERSON
HIGHEST VALUE IS 1.2044E+05, IN (11 , 15)
SUM= 7.10835E+06SCALE: 1.0E+02
GRID SIZE: 1500 METER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	.	.	1.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.	6.
J=19	39.	47.	23.	5.	2.	4.	.	.	.	.	.	.	.	76.	162.	63.	173.	63.	41.	9.
J=18	64.	107.	104.	32.	7.	39.	157.	255.	255.	.	.	195.	139.	426.	822.	673.	398.	217.	28.	10.
J=17	51.	72.	117.	130.	94.	22.	123.	558.	528.	540.	390.	100.	392.	493.	772.	278.	351.	306.	42.	24.
J=16	78.	97.	87.	106.	145.	202.	469.	459.	790.	898.	1045.	397.	147.	147.	131.	137.	39.	39.	39.	29.
J=15	72.	110.	116.	92.	92.	356.	635.	722.	565.	395.	1204.	855.	635.	316.	122.	132.	65.	43.	37.	26.
J=14	43.	105.	84.	69.	111.	193.	370.	828.	651.	228.	813.	895.	638.	356.	199.	151.	96.	45.	35.	90.
J=13	.	.	35.	49.	49.	189.	370.	778.	730.	1098.	489.	486.	499.	636.	392.	231.	252.	127.	104.	97.
J=12	.	.	40.	190.	112.	225.	227.	974.	758.	763.	585.	945.	865.	708.	520.	194.	155.	81.	81.	37.
J=11	.	.	59.	97.	116.	250.	260.	348.	565.	729.	682.	768.	933.	682.	384.	341.	341.	325.	169.	.
J=10	.	.	.	.	.	129.	263.	291.	313.	407.	399.	888.	863.	840.	711.	357.	268.	211.	209.	.
J= 9	.	.	.	.	.	79.	240.	298.	445.	402.	139.	557.	452.	527.	513.	66.	175.	153.	112.	.
J= 8	.	.	.	.	.	29.	303.	159.	380.	396.	118.	672.	319.	425.	369.	66.	31	.	.	.
J= 7	.	.	.	.	.	47.	199.	129.	204.	257.	253.	313.	208.	228.	268.	62.	52	.	.	.
J= 6	.	.	.	.	.	.	82.	123.	258.	213.	200.	228.	304.	255.	272.	177.	63.	16.	.	.
J= 5	.	.	.	.	.	.	.	73.	105.	112.	144.	188.	207.	287.	181.	164.	76.	32.	.	.
J= 4	.	.	.	.	.	.	.	.	23.	25.	67.	155.	237.	252.	49.	82.	60.	32	.	.
J= 3	.	.	.	.	.	.	.	.	.	44.	91.	78.	137.	132.	94.	55.	32.	12	.	.
J= 2	.	.	.	.	.	.	.	.	10.	55.	64.	56.	.	88.	89.	58.	33.	11	.	.
J= 1	.	.	.	.	.	.	.	.	6.	41.	25.	.	.	.	30.	66.	20.	7	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Source: JSO (1991).

EXHAUST EMISSIONS FROM TRAFFIC

Total traffic work. To make an estimate of total traffic work and emissions from traffic a normal approach is to use the number of registered cars of different categories together with an estimate of an average annual driving distance (AADD) for each vehicle category as the basis for the estimates. In many cases, however, AADD is not known and estimates show large differences from city to city.

The following estimate for the annual average daily traffic (AADT) in Jakarta is instead based upon data for the yearly gasoline consumption, 1,175 x $10^3 m^3$ in 1990 (JSO, 1991). Soedomo has reported counts of different vehicle categories for morning (07–09), daytime (12–14) and afternoon (16–18) traffic at 22 different roads in Jakarta (Soedomo, 1993), and from the sum of all counts for each vehicle category an average vehicle distribution is calculated, as shown in Table 2.

Table 2: Distribution of vehicle categories in the urban traffic of Jakarta

Sedan+ Taxi	Pickup	Bus	Microlet + Metro Mini	Truck	Truck Gandeng	MC	Bajaj
.5083	.0524	.0216	.0425	.0138	.0002	.3189	.0423

Note: Values are normalized with respect to the total traffic intensity.

This traffic composition is based upon counts at only a few roads, many of them with restrictions for certain vehicle types. The main road network in Jakarta should be classified into different road classes and for each road class separate vehicle distributions should be calculated. Also, hourly counts should be performed for 24 hours at several (10 or more) roads, in order to study the representativity of short-time counts.

The EPA reports the following fuel consumption for Indonesian vehicles (Bosch, 1991), taken from the Highway Transport Planning Project 1986 (Assumed average speed is 30–40 km/h):

- Car: .171 l/km (80% gasoline/20% diesel).
- Truck:
  - Pickup—.171 l/km (50% gasoline/50% diesel),
  - Medium—.181 l/km (20% gasoline/80% diesel),
  - Heavy—.236 l/km (0% gasoline/100% diesel).
- Bus:
  - General—.191 l/km (0% gasoline/100% diesel),
  - Oplet/Sudaco—.181 l/km (31% gasoline/69% diesel),
- Motorcycle: .020 l/km (100% gasoline/0% diesel),
- Becak: .020 l/km (100% gasoline/0% diesel).

This gives a gasoline consumption for each group as shown in Table 3.

Table 3: Specific gasoline consumption in Jakarta

Vehicle group	Fraction of traffic	Gasoline fraction	Consumption l/km	Consumption l/year*
Sedan/Taxi	.5083	0.8	.171	.06953 AAT
Pickup	.0524	0.5	.181	.00474 AAT
Truck, med.	.0138	0.2	.200	.00055 AAT
Bus, small	.0425	0.31	.181	.00238 AAT
Bajaj/MC	.3612	1.0	.020	.00722 AAT
SUM	0.810		1,175 x 10^6 l**	.08443 AAT

* The total traffic work for the gasoline cars.
** Total annual consumption

Compared with the total gasoline consumption this gives the total traffic work for the gasoline cars.

- AAT = 13,917 x 10^9 car-km/year and the annual average daily gasoline traffic,
- AADT = 38.129 x 10^6 car-km/day.

According to Table 3 the gasoline cars represent 81% of the total traffic work, and this gives a total traffic work of 17.181 x 10^9 car-km/year or 47.073 x 10^6 car-km/day. The validity of this approach is dependent upon correct consumption figures for gasoline, accepted consumption factors, correct statistical data for gasoline/diesel composition for each vehicle group and a traffic composition based upon sufficiently complete traffic counts. As explained, there are however, shortcomings in the data basis that needs to be improved, e.g. more counts and data for traffic compositions.

Following the same procedure for diesel, we get a diesel consumption factor of 0.0336 l/km, which should give a diesel consumption of 110 x 10^3 m^3/year. For the industry there will often be an uncertainty in the data on the consumption of different similar fuel types. Diesel and similar fuels are used both for heating, in industry and in traffic, and the uncertainties may be high. Normally the export/import of gasoline use across city boundaries may be neglected. This means that vehicles filling within the area and driving outside the area compensate for cars driving into the area from outside.

Emission factors. In several recent studies in Indonesia, the emissions from car traffic have been estimated for various areas:

- A joint Indonesian German Energy Strategy Study (BPPT/KFA, 1991). In this study, the emissions from 364 different vehicles were measured under different driving conditions, and overall emission factors were extracted,
- an air quality study in Medan (Bosch, 1991),
- an energy conservation study for Surabaya (IIEC, 1991).

The emission factors used in the studies are listed in Table 4.

The emission factors used in this URBAIR calculation for Jakarta were selected on the basis of following sources of data:

- USEPA emission factors from the AP42 publication.
- Emission factors from the WHO publication: "Assessment of Sources of Air, Water and Land Pollution", Part I: Rapid Inventory Techniques in Environmental Pollution (Geneva, 1993).
- Emission factors for suspended particles from road vehicles described in Appendix 5.

The selected emission factors for road vehicles are shown in Table 5.

Table 4: Emission factors (g/km) for different vehicle classes, used in recent studies in Indonesia

	Passenger cars		Trucks and buses	Small trucks and buses		Motorcycles
	Gasoline	Diesel	diesel	Gasoline	Diesel	
CO						
VWS, 1991	24	5.2	2.5	41	5.3	20/17 (4/2-stroke)
Bosch, 1991	57	3.1	8.8	58		24 (MC + Bajaj)
IIEC, 1991 -uncontrolled (Techn. II)	62	1.9	12	62	1.9	31/26 (4/2-stroke)
- controlled (Techn. IV)	23	1.4	10	23	1.4	22/18 (4/2-stroke)
NO_x						
VWS	6.9	1.3	11	9.1	1.5	0.15/0.08 (4/2-stroke)
Bosch	2.2	1.3	17	2.6		0.18
IIEC -Techn. II	2.0	1.4	20	2.0	1.4	0.2
-Techn. IV	1.0	1.1	13	1.0	1.1	0.4/0.2 (4/2-stroke)
HC						
VWS	2.2	0.5	1.6	3.9	0.5	1.8/9.9 (4/2-stroke)
Bosch	8.5	1.3	3.0	9.7		8.9
IIEC -Techn. II	8.3	0.7	3.7	8.3		8.2/19 (4/2-stroke)
-Techn. IV	3.0	0.6	1.9	3.0	0.6	3.7
Particles (combustion)						
VWS			0.36			0.029/0.21 (4/2-stroke)
Bosch	0.16		1.2			
SO_x						
VWS		0.57	0.85			0.014/0.024 (4/2-stroke)
Bosch	0.13	0.38	1.75			0.019

Note: VWS factors--overall emission factors, Java driving conditions; Bosch factors--urban driving conditions, Medan; IIEC factors --Uncontrolled vehicles (Techn. II), Controlled vehicles (Techn. IV); Factors for various driving speeds were given. Those presented in thistable are for 24 km/h, i.e. urban driving.

Based upon estimates for the total traffic and with emission factors from Table 5, Table 6 shows the emissions of NO_x (as NO_2) and TSP in Jakarta from different vehicles.

Spatial distribution of traffic emissions. To evaluate the spatial distribution of the traffic emissions it is necessary to start with the distribution of the traffic work. This consists of traffic on the main roads and local roads. Normally the traffic work on the local roads is in the order of 15–20% of the total. Due to other driving conditions on the local roads than on the main roads the emissions, particularly of CO, might be much higher.

Table 5: Emission factors used for URBAIR, Jakarta

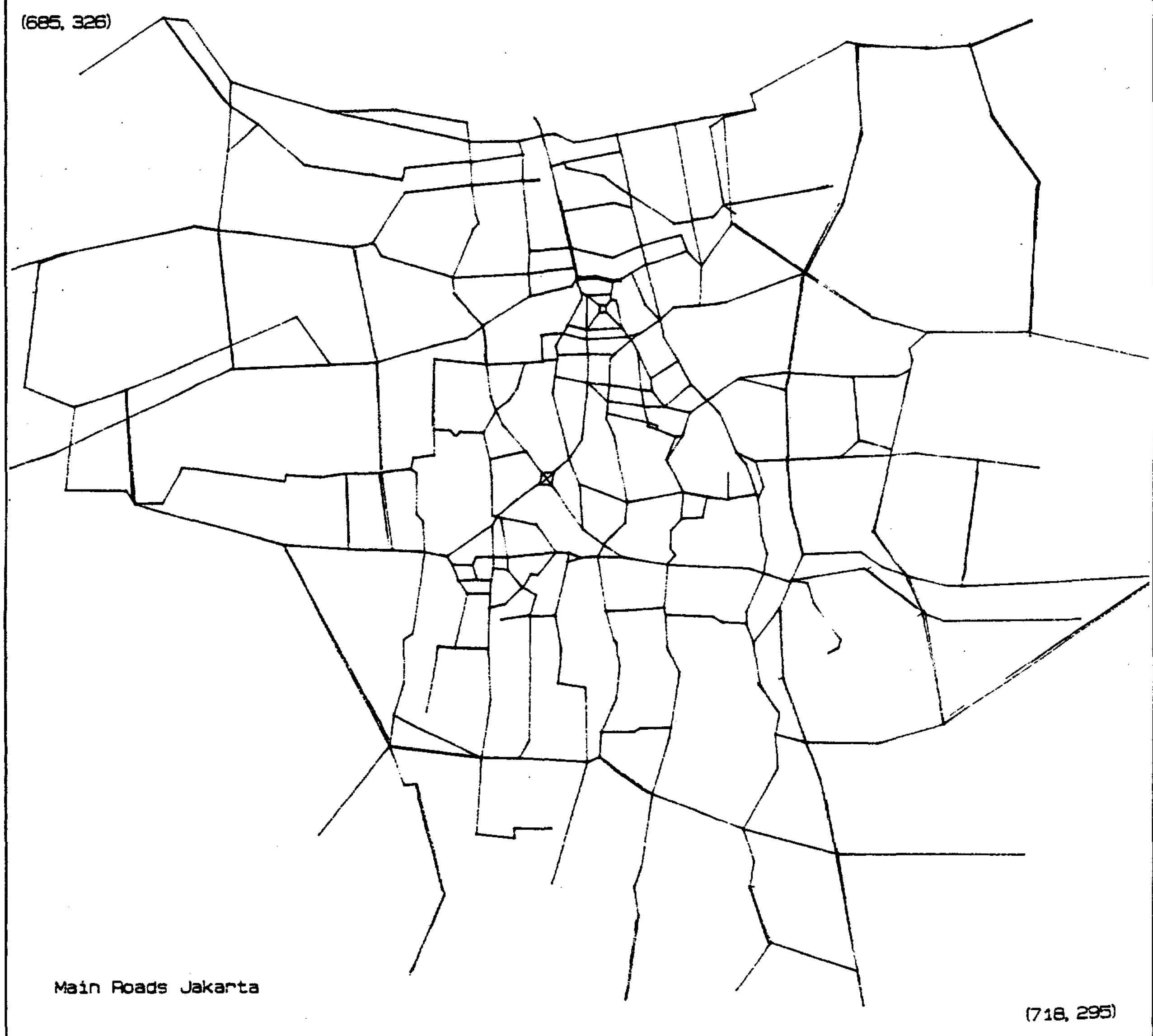
	TSP (g/km)	NO_x (g/km)
Gasoline		
Passenger cars	0.2	2.7
Pick-up etc.	0.33	2.7
Truck medium, bus	0.68	8.0
Bajaj, MC	0.50	0.07
Diesel		
Passenger cars	0.6	1.0
Pick-up etc.	0.9	1.0
Truck, bus	2.0	13.0
Bus, Coplet etc.	0.9	13.0

Table 6: Emissions of NO_x (as NO_2) and TSP in Jakarta from different vehicle groups

Gasoline	AADT 10^6 car-km/a	Emission factor g NO_x/km	Emission factor g TSP/km	Emission ton/year NO_x	Emission ton/year TSP
Sedan/Taxi	5,659	2.7	0.2	15,279	1132
Pickup	365	2.7	0.33	986	120
Truck, medium	38	8.0	0.68	304	26
Bus, Oplet/Sundaco	183	8.0	0.68	1,464	124
Bajaj	589	0.07	0.5	41	295
MC	4,438	0.07	0.5	311	2219
Sum gasoline	11,272	1.63	0.347	18,385	3916
Diesel	**AADT 10^6 car-km/a**	**Emission factor g NO_x/km**	**Emission factor g TSP/km**	**Emission ton/year NO_x**	**Emission ton/year TSP**
Sedan/Taxi	1,415	1.0	0.6	1,415	849
Pickup	365	1.4	0.9	511	329
Truck, medium	154	13.0	2.0	2,002	308
Truck, heavy	1	13.0	2.0	20	3
Bus, Oplet/Sundaco	408	13.0	0.9	5,304	367
Bus general	301	13.0	2.0	3,913	602
Sum diesel	2,644	4.98	0.93	13,165	2458
Total	13,916	2.267	0.35	31,550	4866

Main road network and local roads. From Jakarta maps a main road network was defined. At the beginning this was a coarse network, but as the work proceeded the network was gradually made finer. The coordinates for all crossings in this network were measured and transformed to the grid net. Figure 3 shows the main road network used in Jakarta. We had traffic data only for a few major roads, so we had to use the data very extensively. From other reports from Jakarta there seems to exist more data, but these have not been available in this work.

Figure 3: Main road network in Jakarta



From a road map for Jakarta (FALK-plan: Street atlas and index, 1992) the main roads were grouped into four classes, based upon the map's representation of the roads, and these were later subdivided according to other maps. Finally the groups were given values for AADT from 140,000 to about 20,000. From this road network the total road length and the traffic work were calculated within each grid. This gave a total of 569 km roads and 38.5 mill. car-km/day ($14x10^9$ car-km/yr). By this method we got an overestimate of the traffic work. The calculated traffic work on the main road network only gave about the same value as for the total traffic work (incl. local roads) which was calculated on the basis of the data for total and specific fuel consumption, and vehicle composition. The traffic data for the road network was therefore reduced, except for roads near places with counts, where the counts were still used. In this way the estimate of the traffic work on the main roads was reduced to about $10x10^9$ car-km/yr, some 70% of the total traffic activity. The rest of the traffic, traffic on local roads, estimated to about $4x10^9$ car-km/yr, was distributed according to the population distribution. This is probably not correct since much of the population in the densest populated areas does not own motor vehicles. When more accurate data for the traffic on the main road net is available, the spatial distribution of the traffic and the traffic emissions can be calculated more correctly.

Figure 4 shows a map of the total traffic work for Jakarta, and figures 5 and 6 show the emissions of NO_x and TSP from car traffic in Jakarta.

Figure 4: Traffic work in Jakarta

```
MAP OF   : TRAFFIC  UNIT : CAR-KM/Y  SOURCE    : POP
 PERIOD : 1990      PLACE: JAK       GRID SIZE: 1500 METER
 CREATED: 1995/07/28 17.41

MAXIMUM VALUE IS  2.9004E+08, IN (11,16)
SUM= 1.71176E+10    SCALE FACTOR:  1.0E+05
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	31.	112.	31.	165.	15.	0.	0.	0.	0.	0.	0.	0.	0.	0.	418.	808.	386.	127.	73.	6.
J=19	38.	47.	23.	85.	181.	174.	240.	241.	143.	130.	16.	396.	459.	725.	189.	615.	170.	64.	82.	9.
J=18	63.	105.	102.	101.	52.	120.	277.	667.	1298.	775.	544.	689.	321.	475.	809.	1245.	392.	214.	67.	30.
J=17	70.	272.	316.	387.	492.	332.	559.	550.	950.	866.	1168.	962.	722.	702.	908.	841.	345.	301.	41.	419.
J=16	281.	96.	86.	164.	143.	287.	1116.	1170.	1354.	1690.	2900.	1555.	364.	340.	1206.	202.	38.	38.	360.	102.
J=15	70.	108.	114.	248.	150.	386.	927.	1128.	1742.	727.	2584.	2286.	1068.	546.	680.	531.	590.	436.	755.	290.
J=14	93.	183.	212.	337.	662.	762.	1226.	1270.	1411.	1050.	1860.	1810.	1371.	908.	1192.	762.	766.	45.	35.	230.
J=13	119.	92.	51.	48.	48.	186.	660.	1235.	1596.	1556.	1479.	1182.	1172.	872.	939.	946.	677.	126.	103.	96.
J=12	100.	310.	123.	247.	176.	319.	409.	1382.	1067.	2099.	1175.	1660.	1403.	1987.	1460.	699.	996.	594.	478.	50.
J=11	0.	11.	366.	403.	442.	571.	511.	942.	1608.	1313.	1737.	1131.	1212.	1073.	942.	646.	416.	479.	166.	0.
J=10	0.	0.	0.	0.	151.	283.	287.	878.	1662.	1133.	1667.	1799.	1430.	1688.	1944.	1188.	1255.	557.	162.	81.
J= 9	0.	0.	0.	0.	77.	285.	455.	786.	919.	841.	984.	964.	943.	1301.	845.	460.	741.	671.	552.	636.
J= 8	0.	0.	0.	0.	28.	348.	485.	676.	786.	568.	1164.	314.	828.	794.	634.	30.	80.	317.	194.	97.
J= 7	0.	0.	0.	0.	46.	196.	661.	572.	831.	651.	991.	655.	278.	513.	1028.	348.	308.	248.	0.	0.
J= 6	0.	0.	0.	0.	0.	324.	310.	298.	368.	197.	350.	798.	325.	603.	750.	62.	16.	0.	0.	0.
J= 5	0.	0.	0.	0.	0.	127.	72.	164.	249.	191.	204.	503.	336.	611.	436.	584.	196.	164.	82.	0.
J= 4	0.	0.	0.	0.	0.	0.	0.	86.	25.	79.	152.	538.	248.	214.	81.	617.	32.	0.	0.	0.
J= 3	0.	0.	0.	0.	0.	0.	10.	55.	44.	89.	77.	434.	130.	292.	158.	619.	12.	0.	0.	0.
J= 2	0.	0.	0.	0.	0.	0.	0.	9.	54.	63.	56.	164.	86.	170.	58.	614.	11.	0.	0.	0.
J= 1	0.	0.	0.	0.	0.	0.	0.	6.	40.	25.	0.	0.	0.	30.	65.	431.	7.	0.	0.	0.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 5: Emission of NO_x from car traffic in Jakarta

```
MAP OF  : NOx traf  UNIT : kg/h  SOURCE    : Traffic
 PERIOD : 1990      PLACE: JAK   GRID SIZE: 1500 METER
 CREATED: 1995/07/28 17.41

MAXIMUM VALUE IS  7.5062E+01, IN (11,16)
SUM= 4.43003E+03    SCALE FACTOR:  1.0E-02
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	80.	290.	81.	427.	39.	.	.	.	.	.	.	.	.	.	1082.	2091.	999.	329.	190.	14.
J=19	100.	121.	59.	220.	468.	449.	621.	624.	370.	336.	41.	1025.	1188.	1877.	490.	1591.	440.	165.	213.	23.
J=18	163.	272.	264.	260.	134.	312.	718.	1725.	3358.	2006.	1408.	1784.	830.	1229.	2094.	3223.	1015.	553.	173.	78.
J=17	180.	705.	819.	1001.	1273.	860.	1447.	1423.	2459.	2241.	3022.	2490.	1867.	1817.	2350.	2178.	894.	780.	105.	1085.
J=16	727.	248.	222.	424.	371.	744.	2888.	3028.	3503.	4375.	7506.	4023.	942.	880.	3122.	522.	100.	100.	933.	265.
J=15	182.	281.	295.	641.	388.	1000.	2400.	2919.	4507.	1881.	6686.	5917.	2765.	1414.	1759.	1374.	1528.	1129.	1953.	750.
J=14	241.	475.	550.	873.	1713.	1971.	3174.	3286.	3652.	2718.	4815.	4684.	3549.	2351.	3085.	1971.	1981.	116.	90.	595.
J=13	308.	238.	131.	123.	123.	481.	1709.	3195.	4131.	4026.	3826.	3060.	3033.	2256.	2429.	2447.	1753.	325.	266.	248.
J=12	259.	802.	318.	640.	456.	826.	1058.	3578.	2762.	5433.	3041.	4297.	3632.	5142.	3778.	1809.	2579.	1538.	1238.	128.
J=11	.	28.	947.	1043.	1144.	1477.	1322.	2438.	4161.	3398.	4496.	2928.	3137.	2777.	2438.	1672.	1077.	1240.	431.	.
J=10	.	.	.	.	392.	733.	743.	2273.	4301.	2931.	4314.	4655.	3700.	4369.	5030.	3075.	3248.	1442.	419.	210.
J= 9	.	.	.	.	200.	739.	1177.	2034.	2378.	2176.	2547.	2495.	2439.	3366.	2186.	1190.	1917.	1737.	1429.	1646.
J= 8	.	.	.	.	73.	901.	1256.	1748.	2035.	1470.	3012.	812.	2142.	2055.	1640.	78.	207.	820.	502.	251.
J= 7	.	.	.	.	119.	507.	1712.	1481.	2149.	1684.	2565.	1695.	720.	1328.	2661.	901.	797.	642.	.	.
J= 6	.	.	.	.	.	838.	802.	771.	952.	511.	907.	2066.	840.	1560.	1940.	159.	41.	.	.	.
J= 5	.	.	.	.	.	329.	186.	425.	645.	494.	529.	1303.	870.	1582.	1129.	1512.	506.	424.	212.	.
J= 4	.	.	.	.	.	.	.	222.	64.	205.	395.	1393.	643.	553.	209.	1598.	82.	.	.	.
J= 3	.	.	.	.	.	.	26.	142.	113.	231.	199.	1123.	336.	755.	410.	1603.	31.	.	.	.
J= 2	.	.	.	.	.	.	.	24.	140.	163.	144.	424.	223.	439.	149.	1589.	28.	.	.	.
J= 1	.	.	.	.	.	.	.	14.	104.	64.	.	.	.	77.	168.	1117.	18.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 6: Emission of TSP from car traffic in Jakarta

MAP OF : TSP traf UNIT: kg/h SOURCE : Traffic
PERIOD : 1990 PLACE: JAK GRID SIZE: 1500 METER
CREATED: 1995/07/28 17.41

MAXIMUM VALUE IS 1.2835E+02, IN (11,16)
SUM= 7.57521E+03 SCALE FACTOR: 1.0E-01

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	14.	50.	14.	73.	7.	.	.	.	.	.	.	.	.	.	185.	358.	171.	56.	32.	2.
J=19	17.	21.	10.	38.	80.	77.	106.	107.	63.	58.	7.	175.	203.	321.	84.	272.	75.	28.	36.	4.
J=18	28.	47.	45.	44.	23.	53.	123.	295.	574.	343.	241.	305.	142.	210.	358.	551.	174.	95.	30.	13.
J=17	31.	121.	140.	171.	218.	147.	247.	243.	420.	383.	517.	426.	319.	311.	402.	372.	153.	133.	18.	185.
J=16	124.	42.	38.	72.	63.	127.	494.	518.	599.	748.	1284.	688.	161.	151.	534.	89.	17.	17.	160.	45.
J=15	31.	48.	50.	110.	66.	171.	410.	499.	771.	322.	1143.	1012.	473.	242.	301.	235.	261.	193.	334.	128.
J=14	41.	81.	94.	149.	293.	337.	543.	562.	624.	465.	823.	801.	607.	402.	528.	337.	339.	20.	15.	102.
J=13	53.	41.	22.	21.	21.	82.	292.	546.	706.	689.	654.	523.	519.	386.	415.	418.	300.	56.	46.	42.
J=12	44.	137.	54.	109.	78.	141.	181.	612.	472.	929.	520.	735.	621.	879.	646.	309.	441.	263.	212.	22.
J=11	.	5.	162.	178.	196.	253.	226.	417.	711.	581.	769.	501.	536.	475.	417.	286.	184.	212.	74.	.
J=10	.	.	.	.	67.	125.	127.	389.	735.	501.	738.	796.	633.	747.	860.	526.	555.	247.	72.	36.
J= 9	.	.	.	.	34.	126.	201.	348.	407.	372.	436.	427.	417.	576.	374.	204.	328.	297.	244.	281.
J= 8	.	.	.	.	13.	154.	215.	299.	348.	251.	515.	139.	366.	351.	281.	13.	35.	140.	86.	43.
J= 7	.	.	.	.	20.	87.	293.	253.	368.	288.	439.	290.	123.	227.	455.	154.	136.	110.	.	.
J= 6	.	.	.	.	.	143.	137.	132.	163.	87.	155.	353.	144.	267.	332.	27.	7.	.	.	.
J= 5	.	.	.	.	.	56.	32.	73.	110.	84.	90.	223.	149.	271.	193.	258.	87.	73.	36.	.
J= 4	.	.	.	.	.	.	.	38.	11.	35.	67.	238.	110.	95.	36.	273.	14.	.	.	.
J= 3	.	.	.	.	.	.	4.	24.	19.	40.	34.	192.	57.	129.	70.	274.	5.	.	.	.
J= 2	.	.	.	.	.	.	.	4.	24.	28.	25.	73.	38.	75.	25.	272.	5.	.	.	.
J= 1	.	.	.	.	.	.	.	2.	18.	11.	.	.	.	13.	29.	191.	3.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

In the calculations of the traffic work we had no specific information about the traffic composition on each road, or variations in the traffic composition in various parts of Jakarta. This means that for calculating the emission field for traffic we had to make use of the average, weighed emission factors from Table 5, 2.27 gNO_x/km and 0.45 gTSP/km. This gives traffic emission fields for NO_x and TSP shown in figures 5 and 6.

EMISSIONS FROM INDUSTRY

Industrial emissions will normally consist of process emissions and emissions from combustion of fossil fuels. To have a good emission survey it is necessary to collect data about consumption, production and emitting conditions. It is desirable to estimate the emissions from measurements, and this is done in many cases. The results of such measurements are used to develop emission factors, for example, from the combustion of one ton of coal or from production of one ton of steel. Emission factors will only give average estimates; individual analyses are required for accurate values.

In this study we have no information available about individual industrial activities in Jakarta. Bosch has estimated emissions of TSP for different industries in Medan at Sumatra, as shown in Table 7 for TSP.

The industrial emission of TSP for Jakarta are estimated by using statistical data for Jakarta combined with Bosch's data. Table 8 shows the number of medium and large establishments, the number of workers and estimated emission of TSP for 1989, separated into 9 classes of industry.

Table 7: Emission factors for industry

	Number of establishments	Employment	Mg TSP* per est.	kg TSP per employee
Food and tobacco	129	21,765	10	59
Textiles	32	2,866	25	279
Wood and furniture	50	4,972	25	251
Paper, Printing	40	2,849	25	351
Non-metallic minerals	100	12,556	25	199
Basic metals	23	1,424	50	808
Metal works	4	1,081	50	185
Chemicals, Oil Plastics	94	8,866	10	106

* Average estimates only; individual analyses are required for accurate values.
Source: Bosch (1991).

Table 8: Industrial emission of TSP

	Number of establishments	Workers	Factor kg/yr employee	Emissions tons/year
Food, beverage and tobacco	222	14,724	59	869
Textiles	717	87,620	279	24,446*
Wood and wood prod.	131	9,250	251	2,322
Paper and paper prod.	193	14,684	351	5,154
Industrial chemicals	380	36,022	106	3,818*
Non-metallic mineral products	38	8,884	199	1,768
Iron and steel basic industry	17	2,796	808	2,259**
Mineral products, machines and equipment	361	54,471	185	10,077
Other	41	3,745		
Total	2,100	232,196		50,713

* appears too high
** appears much too low, considering data from Cowiconsult.

According to Table 8, 2,100 medium and large enterprises employ more than 200,000 production workers. Each of these enterprises employing more than 100 production workers emits an average of 25 tons TSP/year.

Considering the two last groups in Table 8 (except "other"), 378 medium and large enterprises employing more than 57,000 production workers, it is assumed that each enterprise emits an average of 30 tons TSP/year. Based upon these assumptions Table 9 shows

Table 9: TSP emission from industrial processes in Jakarta (tons/year)

	Number of establishments	TSP emission tons/year
Food, beverage, tobacco and textiles	939	9,400
Wood and wood prod.	131	2,300
Paper and paper prod.	193	5,200
Industrial chemicals	380	3,800
Non-metallic mineral products	38	1,700
Iron, steel, mineral products etc.	378	9,500
Sum		31,900

average emissions from industrial processes in Jakarta.

Large differences are expected to be found between individual factories, and information about location and emissions from polluting factories is needed before air quality guidelines are enforced. Referring to the list of 100 industries which may qualify for assistance (World Bank, 1992) a number of industries in Jakarta emitting $(2\text{-}8)\times10^6$ kg TSP per year are identified and the cost of pollution abatement is estimated.

Spatial distribution of industrial emissions. As already mentioned we have had no information about the location of the industries in Jakarta, so we had to use an unorthodox method: From two different maps of Jakarta with symbols of industries we have counted the number of industrial symbols within each grid, with a total of 207 "industry" symbols, and the emissions are distributed according to this. Figure 7 shows the distribution of industry symbols.

The total emission of NO_x from industrial processes is estimated to 1,784 tons/year, and the "industry" file is multiplied by 0.9838 to give an average NO_x emission field as shown in Figure 8.

From Figure 1 in Appendix 7 the emission of TSP from industrial processes and fuel combustion are estimated to 32,068 tons/year. When the "industry" file is multiplied by 17.685 we get an average TSP emission field as shown in Figure 9.

EMISSIONS FROM FUEL COMBUSTION IN SMALL INDUSTRIES/DOMESTIC ACTIVITIES

From Figure 2 in Appendix 7 the NO_x emission from fuel combustion in homes/small industry are estimated to 8,176 tons NO_x per year. This is distributed according to the population distribution, and the population file is multiplied by 1.313E-4 to give an average NO_x emission field as shown in Figure 10. From Figure 1 in Appendix 7, the TSP emission is estimated to be 10,536 tons per year, and the population file is multiplied by 1.660E-4 to give an average TSP emission field as shown in Figure 11.

Figure 7: Industry symbols on Jakarta map

```
MAP FOR FACTORIES   UNIT: NUMBERS
    HIGHEST VALUE IS  12, IN ( 18 , 14)
                 SUM= 207
    GRID SIZE:   1500 METER
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.	.	.	3.	1.
J=19	.	.	1.	1.	.	.	.	.	.	.	.	.	.	.	.	7.	5.	1.	4.	.
J=18	.	.	.	.	.	1.	2.	.	3.	.	.	.	3.	.	.	4.	1.	2.	1.	.
J=17	.	.	.	.	.	1.	.	1.	.	2.	1.	.	.	2.	3.	.	.	4.	.	.
J=16	2.	.	2.	3.	.	2.	.	.	.	.	.	.	.	.	3.	1.	.	5.	.	1.
J=15	.	.	1.	1.	.	.	.	.	.	.	.	.	.	1.	3.	2.	2.	5.	4.	3.
J=14	.	.	.	.	.	.	.	.	.	.	.	.	.	2.	3.	5.	6.	12.	9.	8.
J=13	.	.	.	.	.	.	.	.	.	.	.	1.	.	2.	3.	5.	7.	8.	4.	2.
J=12	.	.	.	.	.	.	.	.	.	.	.	.	.	1.	3.	3.	3.	.	.	.
J=11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.	.	.	.	.	.
J= 8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 6	.	.	.	.	.	.	.	.	.	2.	.	.	.	1.	.	.	.	.	.	.
J= 5	.	.	.	.	.	.	.	.	.	.	.	.	3.	.	.	.	.	.	.	.
J= 4	.	.	.	.	.	.	.	.	.	.	.	.	.	2.	1.	.	.	.	.	.
J= 3	.	.	.	.	.	.	.	.	.	.	.	.	.	2.	1.	.	.	.	.	.
J= 2	.	.	.	.	.	.	.	.	.	.	.	.	3.	4.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	2.	2.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 8: Average industrial emission of NO_x in Jakarta (0.01 kg NO_x/h)

```
MAP OF : NOx IND            UNIT : KG/H            SOURCE    : Industry
 PERIOD : 1990              PLACE: Jakarta         GRID SIZE: 1500 METER
 CREATED: 1995/09/27 12.15

    MAXIMUM VALUE IS  1.1812E+01, IN (18,14)
               SUM= 2.03653E+02    SCALE FACTOR: 1.0E-02
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	98.	.	.	295.	98.
J=19	.	.	98.	98.	.	.	.	.	.	.	.	.	.	.	.	689.	492.	98.	394.	.
J=18	.	.	.	.	.	98.	197.	.	295.	.	.	.	295.	.	.	394.	98.	197.	98.	.
J=17	.	.	.	.	.	98.	.	98.	.	197.	98.	.	.	197.	295.	.	.	394.	.	.
J=16	197.	.	197.	295.	.	197.	.	.	.	.	.	.	.	.	295.	98.	.	492.	.	98.
J=15	.	.	98.	98.	.	.	.	.	.	.	.	.	.	98.	295.	197.	197.	492.	394.	295.
J=14	.	.	.	.	.	.	.	.	.	.	.	.	.	197.	295.	492.	590.	1181.	885.	787.
J=13	.	.	.	.	.	.	.	.	.	.	.	98.	.	197.	295.	492.	689.	787.	394.	197.
J=12	.	.	.	.	.	.	.	.	.	.	.	.	.	98.	295.	295.	295.	.	.	.
J=11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	98.	.	.	.	.	.
J= 8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 6	.	.	.	.	.	.	.	.	.	197.	.	.	.	98.	.	.	.	.	.	.
J= 5	.	.	.	.	.	.	.	.	.	.	.	.	295.	.	.	.	.	.	.	.
J= 4	.	.	.	.	.	.	.	.	.	.	.	.	.	197.	98.	.	.	.	.	.
J= 3	.	.	.	.	.	.	.	.	.	.	.	.	.	197.	98.	.	.	.	.	.
J= 2	.	.	.	.	.	.	.	.	.	.	.	.	295.	394.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	197.	197.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 9: Average industrial emission of TSP in Jakarta (0.1 kg TSP/h)

```
MAP OF : TSP IND            UNIT : KG/H          SOURCE    : Industry
 PERIOD : 1990              PLACE: Jakarta       GRID SIZE: 1500 METER
 CREATED: 1995/09/27 12.15

     MAXIMUM VALUE IS  2.1865E+02, IN (18,14)
                SUM= 3.77009E+03    SCALE FACTOR:  1.0E-01
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	182.	.	.	546.	182.
J=19	.	.	182.	182.	.	.	.	.	.	.	.	.	.	.	.	1275.	911.	182.	729.	.
J=18	.	.	.	.	.	182.	364.	.	546.	.	.	.	546.	.	.	729.	182.	364.	182.	.
J=17	.	.	.	.	.	182.	.	182.	.	364.	182.	.	.	364.	546.	.	.	729.	.	.
J=16	364.	.	364.	546.	.	364.	.	.	.	.	.	.	.	.	546.	182.	.	911.	.	182.
J=15	.	.	182.	182.	.	.	.	.	.	.	.	.	.	182.	546.	364.	364.	911.	729.	546.
J=14	.	.	.	.	.	.	.	.	.	.	.	.	.	364.	546.	911.	1093.	2186.	1639.	1457.
J=13	.	.	.	.	.	.	.	.	.	.	.	182.	.	364.	546.	911.	1275.	1457.	729.	364.
J=12	.	.	.	.	.	.	.	.	.	.	.	.	.	182.	546.	546.	546.	.	.	.
J=11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 9	.	.	.	.	.	.	.	.	.	.	.	.	.	.	182.	.	.	.	.	.
J= 8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 7	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 6	.	.	.	.	.	.	.	.	.	364.	.	.	.	182.	.	.	.	.	.	.
J= 5	.	.	.	.	.	.	.	.	.	.	.	.	546.	.	.	.	.	.	.	.
J= 4	.	.	.	.	.	.	.	.	.	.	.	.	.	364.	182.	.	.	.	.	.
J= 3	.	.	.	.	.	.	.	.	.	.	.	.	.	364.	182.	.	.	.	.	.
J= 2	.	.	.	.	.	.	.	.	.	.	.	.	546.	729.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	364.	364.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 10: No_x emission from domestic activities/small industry in Jakarta (0.01 kg TSP/h)

```
MAP OF : NOx DOM     UNIT : KG/H          SOURCE    : DOMESTIC
 PERIOD : 1990       PLACE: JAK           GRID SIZE: 1500 METER
 CREATED: 1995/07/28 17.41

      MAXIMUM VALUE IS  1.5807E+01, IN (11,15)
                  SUM= 9.33326E+02     SCALE FACTOR:  1.0E-02
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	0.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	8.
J=19	51.	62.	30.	7.	3.	5.	0.	0.	0.	0.	0.	0.	0.	100.	213.	83.	227.	83.	54.	12.
J=18	84.	140.	137.	42.	9.	51.	206.	335.	335.	0.	0.	256.	182.	559.	1079.	884.	523.	285.	37.	13.
J=17	67.	95.	154.	171.	123.	29.	161.	733.	693.	709.	512.	131.	515.	647.	1014.	365.	461.	402.	55.	32.
J=16	102.	127.	114.	139.	190.	265.	616.	603.	1037.	1179.	1372.	521.	193.	193.	172.	180.	51.	51.	51.	38.
J=15	95.	144.	152.	121.	121.	467.	834.	948.	742.	519.	1581.	1123.	834.	415.	160.	173.	85.	56.	49.	34.
J=14	56.	138.	110.	91.	146.	253.	486.	1087.	855.	299.	1067.	1175.	838.	467.	261.	198.	126.	59.	46.	118.
J=13	0.	0.	46.	64.	64.	248.	486.	1021.	958.	1442.	642.	638.	655.	835.	515.	303.	331.	167.	137.	127.
J=12	0.	0.	53.	249.	147.	295.	298.	1279.	995.	1002.	768.	1241.	1136.	930.	683.	255.	203.	106.	106.	49.
J=11	0.	0.	77.	127.	152.	328.	341.	457.	742.	957.	895.	1008.	1225.	895.	504.	448.	448.	427.	222.	0.
J=10	0.	0.	0.	0.	169.	345.	382.	411.	534.	524.	1166.	1133.	1103.	933.	469.	352.	277.	274.	0.	0.
J= 9	0.	0.	0.	0.	104.	315.	391.	584.	528.	182.	731.	593.	692.	674.	87.	230.	201.	147.	0.	0.
J= 8	0.	0.	0.	0.	38.	398.	209.	499.	520.	155.	882.	419.	558.	484.	87.	41.	0.	0.	0.	0.
J= 7	0.	0.	0.	0.	62.	261.	169.	268.	337.	332.	411.	273.	299.	352.	81.	68.	0.	0.	0.	0.
J= 6	0.	0.	0.	0.	0.	108.	161.	339.	280.	263.	299.	399.	335.	357.	232.	83.	21.	0.	0.	0.
J= 5	0.	0.	0.	0.	0.	0.	96.	138.	147.	189.	247.	272.	377.	238.	215.	100.	42.	0.	0.	0.
J= 4	0.	0.	0.	0.	0.	0.	0.	30.	33.	88.	203.	311.	331.	64.	108.	79.	42.	0.	0.	0.
J= 3	0.	0.	0.	0.	0.	0.	0.	0.	58.	119.	102.	180.	173.	123.	72.	42.	16.	0.	0.	0.
J= 2	0.	0.	0.	0.	0.	0.	0.	13.	72.	84.	74.	0.	116.	117.	76.	43.	14.	0.	0.	0.
J= 1	0.	0.	0.	0.	0.	0.	0.	8.	54.	33.	0.	0.	0.	39.	87.	26.	9.	0.	0.	0.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Figure 11: TSP emission from domestic activities/small industry in Jakarta (0.01 kg/TSP/h)

```
MAP OF : TSP DOM            UNIT : KG/H         SOURCE    : DOMESTIC
 PERIOD : 1990              PLACE: JAK          GRID SIZE: 1500 METER
 CREATED: 1995/07/28 17.41

    MAXIMUM VALUE IS  1.9985E+01, IN (11,15)
                SUM= 1.17999E+03    SCALE FACTOR:  1.0E-02
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
J=20	0.	0.	2.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	10.
J=19	65.	78.	38.	8.	3.	7.	0.	0.	0.	0.	0.	0.	0.	126.	269.	105.	287.	105.	68.	15.
J=18	106:	178.	173.	53.	12.	65.	261.	423.	423.	0.	0.	324.	231.	707.	1364.	1117.	661.	360.	46.	17.
J=17	85.	120.	194.	216.	156.	37.	204.	926.	876.	896.	647.	166.	651.	818.	1281.	461.	583.	508.	70.	40.
J=16	129.	161.	144.	176.	241.	335.	778.	762.	1311.	1491.	1735.	659.	244.	244.	217.	227.	65.	65.	65.	48.
J=15	120.	183.	193.	153.	153.	591.	1054.	1198.	938.	656.	1998.	1419.	1054.	525.	203.	219.	108.	71.	61.	43.
J=14	71.	174.	139.	115.	184.	320.	614.	1374.	1081.	378.	1349.	1486.	1059.	591.	330.	251.	159.	75.	58.	149.
J=13	0.	0.	58.	81.	81.	314.	614.	1291.	1212.	1823.	812.	807.	828.	1056.	651.	383.	418.	211.	173.	161.
J=12	0.	0.	66.	315.	186.	373.	377.	1617.	1258.	1266.	971.	1569.	1436.	1175.	863.	322.	257.	134.	134.	61.
J=11	0.	0.	98.	161.	193.	415.	432.	578.	938.	1210.	1132.	1275.	1549.	1132.	637.	566.	566.	539.	281.	0.
J=10	0.	0.	0.	0.	214.	437.	483.	520.	676.	662.	1474.	1432.	1394.	1180.	593.	445.	350.	347.	0.	0.
J= 9	0.	0.	0.	0.	131.	398.	495.	739.	667.	231.	925.	750.	875.	852.	110.	290.	254.	186.	0.	0.
J= 8	0.	0.	0.	0.	48.	503.	264.	631.	657.	196.	1115.	529.	705.	612.	110.	51.	0.	0.	0.	0.
J= 7	0.	0.	0.	0.	78.	330.	214.	339.	427.	420.	520.	345.	378.	445.	103.	86.	0.	0.	0.	0.
J= 6	0.	0.	0.	0.	0.	136.	204.	428.	354.	332.	378.	505.	423.	451.	294.	105.	27.	0.	0.	0.
J= 5	0.	0.	0.	0.	0.	0.	121.	174.	186.	239.	312.	344.	476.	300.	272.	126.	53.	0.	0.	0.
J= 4	0.	0.	0.	0.	0.	0.	0.	38.	41.	111.	257.	393.	418.	81.	136.	100.	53.	0.	0.	0.
J= 3	0.	0.	0.	0.	0.	0.	0.	0.	73.	151.	129.	227.	219.	156.	91.	53.	20.	0.	0.	0.
J= 2	0.	0.	0.	0.	0.	0.	0.	17.	91.	106.	93.	0.	146.	148.	96.	55.	18.	0.	0.	0.
J= 1	0.	0.	0.	0.	0.	0.	0.	10.	68.	41.	0.	0.	0.	50.	110.	33.	12.	0.	0.	0.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

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APPENDIX 5: EMISSION FACTORS, PARTICLES

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 emissions 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.

MOTOR VEHICLES

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

- WHO (1993),
- USEPA (EPA AP42 report series) (1985),
- Vehicles Emission Control Project (VECP), Manila (Baker, 1993),
- Indonesia (Bosch, 1991),
- Williams et al. (1989),
- Motorcycle emissions standard and emissions 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.

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 USEPA/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 have 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 database 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 USEPA, we also take into consideration the factor 2 g/km used in the VECP study in Manila, which indicates evidence for very large emissions from such vehicles.

Table 1: Emission factors (g/km) for particle emissions from motor vehicles

Fuel and Vehicle	Particlesg/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

Note: Relevant as a basis for selection of factors to be used in South-East Asian cities.

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

Vehicles class	Gasoline	Diesel
Passenger cars/taxies	0.20	0.6
Utility vehicles/light trucks	0.33	0.9
Motorcycles/tricycles	0.50	
Trucks/buses		2.0

- 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 the United States, 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 database 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.

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 (kg/m^3)

	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: Sulfur content in % by weight

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

Source: USEPA, AP 42.

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APPENDIX 6: POPULATION EXPOSURE CALCULATIONS

METHODOLOGY

Data for population exposure in Jakarta are estimated for annual average TSP-values. The measured values specify the pollution level at the measuring stations. Dispersion calculations are used to specify the spatial distribution of concentration values over the urban area. The dispersion calculations are based on data for wind, dispersion conditions and for emission distribution over the city. The input data for dispersion calculations should be improved in the future regarding the following points:

- Emission from industry including emissions from the power plant should be measured and emission conditions are important for the local air quality.
- Emissions due to resuspension and due to refuse burning (Bosch, 1991) should be controlled by measurements in Jakarta.
- The relationship between emission conditions and measured concentration values in the northern part of Jakarta should be clarified.
- The data on dispersion conditions should be improved and a wind model accounting for coastal effects may be important for discussing effects of emission reductions in air pollution episodes.

To give a first estimate for considering cost/effect relationships only annual average concentrations were considered. To specify the annual urban scale pollution level, average concentration in grid squares covering 1.5 x 1.5 km^2 was calculated.

The following groups of sources were considered:

- car traffic including resuspension,
- fuel combustion including refuse burning,
- industrial processes, and
- miscellaneous, including airports, harbor and construction.

The spatial population distribution is calculated by establishing the number of inhabitants in each subdistrict (Kelurahan). A distribution key was estimated to transform the data on population in "kelurahans" to data on population in the grid system. To develop the distribution key a detailed map of Jakarta was used (Peta Rupabumir Indonesia, 1990 1:25 000) to take into account the location of residential areas. To take account of polluted areas along roads with high traffic intensities the locations of the main roads were specified as shown in Figure 1.

Figure 1:The network of main roads

The length of main roads in each grid square is determined and an additional concentration is estimated for people living in 30 m zones on each side of the road starting from a distance of 10 m from the edge of the road. The population density in this zone is assumed to be equal to the average density in the grid square. We have not taken into account double exposure from crossing roads.

The distribution of population exposure is calculated by counting the number of people living in each grid square and the number of people living along roads in each grid square separately, considering the respective concentration levels.

The calculated concentration in each grid square consists of contributions from four source groups:

- car traffic,
- industry and commercial,
- domestic, and
- extra-urban background concentration.

Each of the contributions is calculated separately, and a source reduction influences the respective contribution proportionally to the amount of the source reduction in question. The effect on the exposure curve of the source reductions is calculated for a 25 and 50 percent source reduction for each group.

Calculation of exposure to air pollution in Jakarta. Table 1 shows the exposure distribution and the effect of source reduction in three main sources groups.

In each of the annual concentration classes a quantified damage by pollution may be determined. This may be below certain exposure levels and the total damage may be determined by integrating the damage function over the exposure distribution.

$$D_{T,O} = \sum_k \Delta N_k \cdot D_{k,O}$$

ΔN_k: the number of people in each concentration class k
D_k : the specific damage function for the annual average concentration class k.
The total damage function D_T may be determined for different source reduction schemes.

Additional exposure due to the activity pattern of the population. The exposure is first calculated for people staying at home. When people's activity pattern is better known additional exposure may be calculated accordingly. Commuters and drivers/policemen should be considered when the damage function is further developed.

It is estimated that approximately 30% of the population in Jakarta make regular trips along roads every day and spend 1–2 hours close to roads with high traffic intensity every day. This means an addition of 15–30 µg/m³ to their home exposure. Drivers and street workers spend approximately 8 hours in traffic environments every day, i.e. the additional exposure amounts to

$$(400\,\mu g\,TSP / m^3 - C_{HOME}) \cdot 6 = 25 - 75\,\mu g\,TSP / m^3$$

Approximately 300,000 "road workers" are exposed to this annual average additional pollution stress. The low end of the range applies for the people living in the center and the high end applies for the people living in the suburbs.

According to the statistical survey of Jakarta, 290,000 people work in industry and some of them are exposed to an additional pollution load in their occupational environment. In some industrial environments the air will be more polluted than air close to the main roads. The number of people exposed to this additional stress is probably quite small.

The exposure calculations are based upon annual average TSP-concentrations. To evaluate the PM_{10} exposure the fraction PM_{10}/TSP should be estimated for each source group, and the TSP-values transformed to PM_{10} values before the exposure calculations. This procedure was followed in the URBAIR Kathmandu study. In Jakarta, PM_{10} concentrations were assumed to be 55% of the TSP-concentrations.

Table 1: Number of residents in Jakarta exposed to different levels of TSP-concentrations outside their homes

$C\varepsilon[C_1$	$C_2]$	$N_c > C_2$	ΔN	P	ΔP	Traffic reduction		Industry reduction		Domestic reduction	
$\mu g/m^3$		$\mu g/m^3$	inh.	%	%	25%	50%	25%	50%	25%	50%
80.0	90.0	6,458,608	0	100.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
90.0	100.0	6,454,574	4,034	99.938	0.062	0.225	0.792	0.062	0.314	0.062	0.062
100.0	110.0	6,400,467	54,107	99.100	0.838	1.458	3.741	0.987	1.257	0.838	0.838
110.0	120.0	6,272,124	128,343	97.113	1.987	3.794	11.120	2.494	3.398	2.190	2.439
120.0	130.0	6,024,203	247,921	93.274	3.839	7.485	19.039	4.437	5.806	3.976	4.065
130.0	140.0	5,668,254	355,949	87.763	5.511	11.207	19.477	6.873	8.571	5.170	5.357
140.0	150.0	5,106,759	561,495	79.069	8.694	13.964	30.877	9.416	9.281	8.973	9.366
150.0	160.0	4,454,121	632,638	68.964	10.105	13.167	10.570	11.598	9.683	10.190	11.491
160.0	170.0	3,835,884	618,237	59.392	9.572	13.172	1.774	7.440	9.383	10.115	8.430
170.0	180.0	3,320,573	515,311	51.413	7.979	23.949	0.059	9.870	11.354	7.511	8.270
180.0	190.0	2,478,595	841,978	38.377	13.037	6.219	0.000	9.175	9.476	12.597	11.305
190.0	200.0	1,446,275	1,032,320	22.393	15.984	1.522	0.000	8.926	18.088	18.792	18.792
200.0	210.0	807,480	638,795	12.502	9.981	0.000	0.000	7.784	4.611	7.083	7.700
210.0	220.0	424,136	383,344	6.567	5.935	0.000	0.000	4.370	3.676	5.935	5.318
220.0	230.0	329,558	94,578	5.103	1.464	0.000	0.000	1.464	0.000	1.464	1.464
230.0	240.0	329,558	0	5.103	0.000	0.000	0.000	0.000	0.000	0.000	0.000
240.0	250.0	329558	0	5.103	0.000	0.000	0.000	0.000	0.000	0.000	0.000
250.0	260.0	329,557	1	5.103	0.000	0.000	0.009	0.000	0.000	0.000	0.000
260.0	270.0	329,276	281	5.098	0.004	0.015	0.049	0.006	0.012	0.004	0.008
270.0	280.0	328,246	1,030	5.082	0.016	0.055	0.226	0.019	0.039	0.016	0.012
280.0	290.0	325,169	3,077	5.035	0.048	0.130	0.473	0.075	0.069	0.048	0.059
290.0	300.0	317,409	7,760	4.915	0.120	0.296	1.034	0.132	0.169	0.132	0.136
300.0	310.0	304,915	12,494	4.721	0.193	0.482	0.640	0.292	0.337	0.194	0.236
310.0	320.0	283,503	21,412	4.390	0.332	0.620	0.119	0.356	0.523	0.358	0.348
320.0	330.0	249,940	33,563	3.870	0.520	1.378	0.001	0.611	0.629	0.509	0.539
330.0	340.0	203,937	46,003	3.158	0.712	0.679	0.000	0.516	0.609	0.684	0.606
340.0	350.0	125,549	78,388	1.944	1.214	0.172	0.000	1.496	1.510	1.425	1.425
350.0	360.0	73,132	52,417	1.132	0.812	0.000	0.000	0.664	0.573	0.600	0.670
360.0	370.0	14,852	58,280	0.230	0.902	0.000	0.000	0.707	0.633	0.902	0.832
370.0	380.0	0	14,852	0.000	0.230	0.000	0.000	0.230	0.000	0.230	0.230
380.0	390.0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
390.0	400.0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

$C\varepsilon\lfloor C_1, C_2 \rfloor$: concentration interval $N_C > C_2$: cumulative concentration dist. ΔN: number of people in each pollution

P: cumulative concentration distribution in percent of total population. ΔP: percentage of population in each concentration interval.

Emission reduction: Percentage of population in each concentration interval after emission reduction.

APPENDIX 7: SPREADSHEETS FOR CALCULATING EFFECTS OF CONTROL MEASURES ON EMISSIONS

EMISSIONS SPREADSHEET

The spreadsheet is shown in Figure 1 and Figure 2. (Examples: TSP and NO_x emissions, DKI Jakarta, Base Case Scenario, 1990.) Figure 3 shows TSP emission contributions 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, achieved by measures on existing technology, and reduced traffic activity/fuel consumption.

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;" - F (m^3 or ton) for fuel consumption in industrial production. - T (vehicle km) for traffic activity.
(c) qF,qT	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.
(e) qF fq fF f-:	Modified emissions, due to control measures.
(f) d(qF fq fF f-)	Relative emission contributions from each source category such as vehicles, fuel combustion, and industrial processes.
(g) d(qF fq fF f-)	Relative emissions contributions, sum of all categories.

Rows

(a)	Separate rows for each source type and category, "existing" and "new" technology.
(b)	"Background": Fictitious emissions, corresponding to extra-urban background concentration.
(c)	Modified emission(s): ratio between modified and base case emissions.

Figure 1: URBAIR spreadsheet for emissions calculations

TOTAL ANNUAL EMISSIONS, JAKARTA

Particles, scenario: 1990

	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 (10E6 kg)	fq	fF	f-	qF fq fF f- (10E6 kg)	d(qF fq fF f-) (percent)	d(qF fq fF f-)tot (percent)
Power plants			0,00	1,00	1,00	1,00	0,00		#DIV/0!
							0,00		#DIV/0!
							0,00		#DIV/0!
Sum large point sources			0,00				0,00		#DIV/0!
Modified emissions/emissions, point sourc.							#DIV/0!		
AREA SOURCES AND DISTRIBUTED POINT SOURCES									
Vehicles	q (g/km)	T (10E6 km/y)	qT (10E3 kg/y)	fq	fT	f-	qT fq fT f- (10E3 kg)	d(qT fq fT f-) (percent)	d(qT fq fT f-) (percent)
Gasoline									
Pass. cars	0,20	5659	1132	1	1	1	1132	3,3	1,2
Pick-up etc.	0,33	365	120	1	1	1	120	0,4	0,1
Truck medium	0,68	38	26	1	1	1	26	0,1	0,0
Bus	0,68	183	124	1	1	1	124	0,4	0,1
Bajaj	0,50	589	295	1	1	1	295	0,9	0,3
MC	0,50	4438	2219	1	1	1	2219	6,5	2,3
Sum gasoline		11272	3916				3916	11,4	4,0
Modified emissions/emissions, gasoline							1,00		
Diesel									
Pass. cars	0,6	1415	849	1	1	1	849	2,5	0,9
Pick up etc.	0,9	365	329	1	1	1	329	1,0	0,3
Truck medium	2	154	308	1	1	1	308	0,9	0,3
Truck heavy	2	1	2	1	1	1	2	0,0	0,0
Bus, Coplet etc.	0,9	408	367	1	1	1	367	1,1	0,4
Bus regular	2	301	602	1	1	1	602	1,8	0,6
Sum diesel		2644	2457				2457	7,2	2,5
Modified emissions/emissions, diesel							1		
Resuspension	2	13916	27832	1	1	1	27832	81,4	28,8
Modified emissions/emissions resuspension							1		
Sum total vehicles			34205				34205	100,0	35
Modified emissions/emissions, total vehicles							1,00		
Fuel combustion	q (kg/m3)	F (10E3m3)	qF (10E3 kg)	fq	fF	f-	qF fq fF f- (10E3 kg)	d(qF fq fF f-)fuel (percent)	d(qF fq fF f-)tot (percent)
Industrial/commercial									
Distillate fuel	0,3	618,0	185,4	1,00	1,00	1,00	185,4	1,8	0,2
Coal	7,50	0,1	0,4	1,00	1,00	1,00	0,4	0,0	0,0
Coke	5,00	2,5	12,5	1,00	1,00	1,00	12,5	0,1	0,0
Gas	0,048	63,0	3,0	1,00	1,00	1,00	3,0	0,0	0,0
Domestic/small industry									
Fuel oil	1,40	1202,0	1682,8	1,00	1,00	1,00	1682,8	16,0	1,7
Distillate fuel	1,40	1155,0	1617,0	1,00	1,00	1,00	1617,0	15,3	1,7
Gas	0,048	163,0	7,8	1,00	1,00	1,00	7,8	0,1	0,0
Open burning	8,00	878,4	7027,0	1,00	1,00	1,00	7027,0	66,7	7,3
Sum fuel combustion			10535,9				10535,9	100,0	10,9
Modified emissions/emissions, fuel							1,00		
Industrial processes	q (10E3 kg/y)	F (n. of est.)	qF	fq	fF	f-	qF fq fF f-	d(qF fq fF f-)ind. (percent)	d(qF fq fF f-)tot (percent)
Food and textile	10,0	939	9390	1	1	1	9390	29,5	9,7
Wood and prod.	17,6	131	2306	1	1	1	2306	7,2	2,4
Paper and pr.	27,0	193	5211	1	1	1	5211	16,4	5,4
Chemicals	10,0	380	3800	1	1	1	3800	11,9	3,9
Non met. mineral prod	45,0	38	1710	1	1	1	1710	5,4	1,8
Iron and steel	25,0	378	9450	1	1	1	9450	29,7	9,8
Sum industrial processes			31867				31867	100,0	32,9
Modified emissions/emissions, ind. proc.							1,00		
Miscellaneous	q (kg/LTD)	M (LTD)	qM	fq	fM	f-	qM fq fM f-	d(qM fq fM f-)misc (percent)	d(qM fq fM f-)tot (percent)
Airports	0,355	73411	26	1	1	1	26	0,1	0,0
Construction			20000	1	1	1	20000	99,4	20,7
Harbour			100	1	1	1	100	0,5	0,1
Sum miscellaneous			20126				20126	100,0	20,8
Modified emissions/emissions, misc.							1,00		
"Background"									
Unknown									
Sum total, excl. "Background"			96733				96733		100
Modified emissions/emissions, total							1,00		

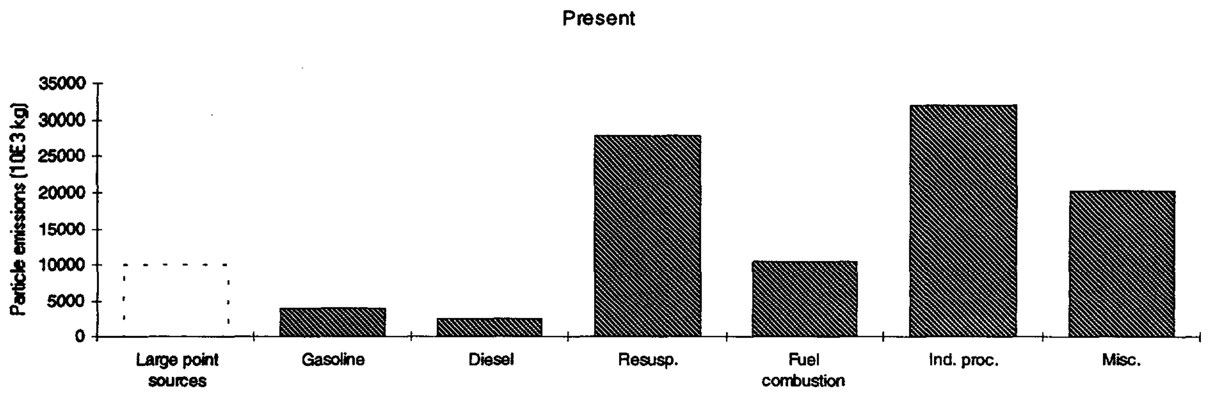
Figure 2: Total annual emissions, DKI Jakarta. NO_x. (1990)

TOTAL ANNUAL EMISSIONS, JAKARTA

NOx, scenario: 1990

	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 (10E6 kg)	fq	fF	f-	qF fq fF f- (10E6 kg)	d(qF fq fF f-) (percent)	d(qF fq fF f-)tot (percent)
Power plants			0,00	1,00	1,00	1,00	0,00		#DIV/0!
							0,00		#DIV/0!
							0,00		#DIV/0!
Sum large point sources			**0,00**				**0,00**		**#DIV/0!**
Modified emissions/emissions, point sourc.							#DIV/0!		
AREA SOURCES AND DISTRIBUTED POINT SOURCES									
Vehicles	q (g/km)	T (10E6 km/y)	qT (10E3 kg/year)	fq	fT	f-	qT fq fT f- (10E3 kg)	d(qT fq fT f-) (percent)	d(qT fq fT f-) (percent)
Gasoline									
Pass. cars	2,70	5659	15279	1	1	1	15279	48,4	35,5
Pick-up etc.	2,70	365	986	1	1	1	986	3,1	2,3
Truck medium	8,00	38	304	1	1	1	304	1,0	0,7
Bus, Coplet etc.	8,00	183	1464	1	1	1	1464	4,6	3,4
Bajaj	0,07	589	41	1	1	1	41	0,1	0,1
MC	0,07	4438	311	1	1	1	311	1,0	0,7
Sum gasoline		11272	18385				18385	58,3	42,7
Modified emissions/emissions, gasoline							1,00		
Diesel									
Pass. cars	1	1415	1415	1	1	1	1415	4,5	3,3
Pick up etc.	1,4	365	511	1	1	1	511	1,6	1,2
Truck medium	13	154	2002	1	1	1	2002	6,3	4,7
Truck heavy	13	1	13	1	1	1	13	0,0	0,0
Bus, Coplet etc.	13	408	5304	1	1	1	5304	16,8	12,3
Bus regular	13	301	3913	1	1	1	3913	12,4	9,1
Sum diesel		2644	13158				13158	41,7	30,6
Modified emissions/emissions, diesel							1		
Sum total vehicles			**31543**				**31543**	100,0	**73**
Modified emissions/emissions, total vehicles							1,00		
Fuel combustion	q (kg/m3)	F (10E3m3)	qF (10E3 kg/y)	fq	fF	f-	qF fq fF f- (10E3 kg)	d(qF fq fF f-)fuel (percent)	d(qF fq fF f-)tot (percent)
Industrial/commercial									
Distillate fuel	2	618	1483	1,00	1,00	1,00	1483	15,1	3,4
Coal	11	0	1	1,00	1,00	1,00	1	0,0	0,0
Coke	10	3	26	1,00	1,00	1,00	26	0,3	0,1
Gas	2,24	63	141	1,00	1.00	1,00	141	1,4	0,3
Domestic/small industry									
Fuel oil	2	1202	2404	1,00	1,00	1,00	2404	24,5	5,6
Distillate fuel	2	1155	2772	1,00	1,00	1,00	2772	28,2	6,4
Gas	2,24	163	365	1,00	1,00	1,00	365	3,7	0,8
Open burning	3	878	2635	1,00	1,00	1,00	2635	26,8	6,1
Sum fuel combustion			**9827**				**9827**	100,0	**22,8**
Modified emissions/emissions, fuel							1,00		
Industrial processes	q (10E3 kg/y)	F (n. of est.)	qF	fq	fF	f-	qF fq fF f-	d(qF fq fF f-)ind. (percent)	d(qF fq fF f-)tot (percent)
			0	1	1	1	0	#DIV/0!	0,0
			0	1	1	1	0	#DIV/0!	0,0
			0	1	1	1	0	#DIV/0!	0,0
			0	1	1	1	0	#DIV/0!	0,0
			0	1	1	1	0	#DIV/0!	0,0
			0	1	1	1	0	#DIV/0!	0,0
Sum industrial processes			*0*				**0**	#DIV/0!	**0,0**
Modified emissions/emissions, ind. proc.							#DIV/0!		
Miscellaneous	q (kg/LTD)	M (LTD)	qM	fq	fM	f-	qM fq fM f-	d(qM fq fM f-)misc (percent)	d(qM fq fM f-)tot (percent)
Airports	9	73411	661	1	1	1	661	39,8	1,5
Harbour			1000	1	1	1	1000	60,2	2,3
Sum miscellaneous			**1661**				**1661**	100,0	**3,9**
Modified emissions/emissions, misc.							1,00		
"Background"									
Unknown									
Sum total, excl. "Background"			**43030**				**43030**		**100**
Modified emissions/emissions, total							1,00		

Figure 3: Emissions contributions from various source categories



APPENDIX 8: METEOROLOGY AND DISPERSION CONDITIONS IN JAKARTA

GENERAL DESCRIPTION OF DISPERSION AND EFFECTS OF TOPOGRAPHY/CLIMATE IN THE JAKARTA REGION

In general, the atmospheric circulation over Indonesia is affected by the meridional circulation termed Hadley circulation or trade wind. When the sun moves toward the southern hemisphere, the north east trade wind is attracted to the south, crossing the equator and becomes west or northwest monsoon in the rainy season (January–June). On the contrary, when the sun moves toward the northern hemisphere the east or southeast monsoon is created (the dry season, July–December). Normally, Indonesia experiences relatively low wind speeds. In the coastal regions of Indonesia local land or sea breeze may cause stagnation in the air when it is directed against the monsoon. Seasonal variations may occur with stagnation in the mornings during the rainy season and in the evenings during the dry season. The dispersion of pollutants may therefore vary with season and time of day.

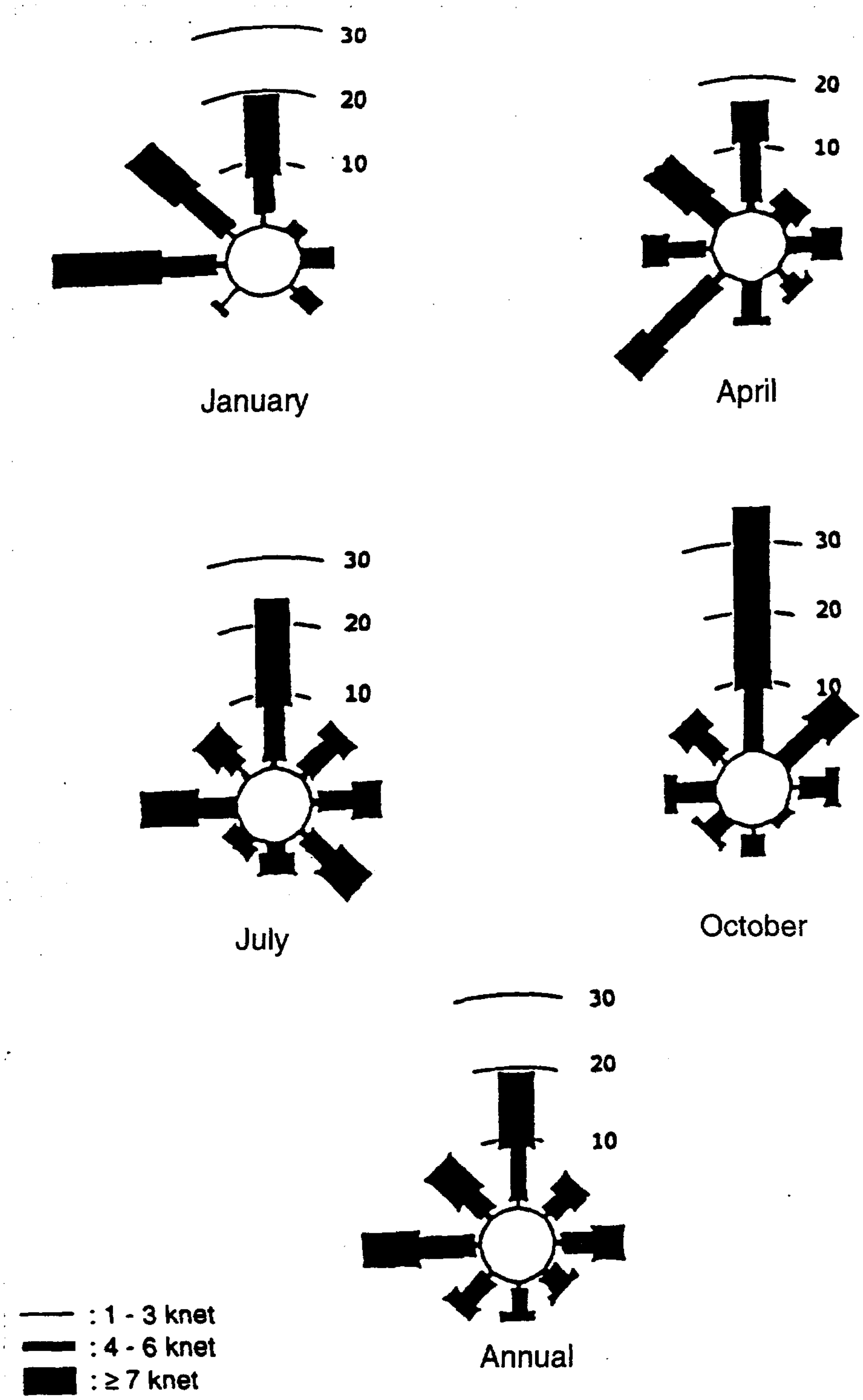
The topography of Indonesia is dominated by the volcanic belt which runs from the western tip of Sumatra to the eastern Irian Jaya and from the northern tip of Sulawesi to the southern part. In the western and central parts of Java the topography has an important effect on the dispersion conditions.

The climate of Indonesia belongs to the tropical maritime continent type and is described as one of the most humid regions of the world. The humidity varies between 70–90%.

GEOGRAPHY, TOPOGRAPHY AND CLIMATE IN JAKARTA

Jakarta is the biggest city in Indonesia, and is located on the mouth of the Ciliwung river. The city is located 6°12'S and 106°48'E. The area is very smooth with no local topography that can affect the dispersion conditions (average height 7 m a.s.l.). The climate is very hot and humid. Because Jakarta lies so close to the equator, the solar heating during the day and the earth cooling during the night may produce local land-sea breeze. When the land-sea breeze is working against the monsoon, it causes a stagnation of the airmasses, allowing pollutant concentrations to build up significantly.

Figure 1: Seasonal variation of the frequency of wind direction and wind speed for the BMG weather station in the DKI Jakarta area



The Agency of Meteorology and Geophysics (BMG) is running six weather stations spread in the DKI Jakarta and BOTABEK area. The measurements consist of:

- air temperature,
- air humidity,
- wind speed,
- wind direction,
- cloudiness,
- barometric pressure,
- rainfall,
- rainy days.

The mixing height is derived from upper air measurement by means of the rawindsonde. The upper air data are obtained from the Soekarno Hatta International Airport.

Two-way frequency distribution of wind speed and direction is derived for the six weather stations in the DKI Jakarta area. The wind is categorized into 8 directions and 4 classes of speed (0; 1–3 knots; 4–6 knots; and 7 knots and more.

Atmospheric stability is derived from upper air measurement by means of the tethered radiosonde. The atmospheric stability is classified according to Pasquill's classification. The applicability of different methods of classification in Jakarta should be investigated. Neutral conditions were used for the calculations of yearly average concentrations.

Wind speed and direction. The wind roses from the six stations in DKI Jakarta, Figure 2 and 3 show similar patterns. The distance between the adjacent existing weather stations is not significant. The weather station that is located at the BMG office is used as a representative station.

The DKI Jakarta area is situated in the coastal region, consequently it is affected by the local winds, especially sea and land breeze. Although the local winds often affect the wind pattern, the prevailing wind in the DKI Jakarta is still governed by the monsoon. These two winds reinforce each other when they blow in the same direction and weaken each other when they blow in the opposite direction.

The sea breeze occurs at the coastline on sunny days, due to the warming of the land and a temperature gradient from sea to land is developing. The sea breeze may penetrate several kilometres into the inland (more than 40 km) when the temperature difference between sea and land is sufficiently large. In general the sea breeze starts to blow around 10 o' clock in the morning and it reaches its maximum when the inland air temperature is at its maximum. The local sea breeze comes from the north east direction. In the rainy season the sea breeze is weaker than in the dry season due to the effect of clouds on the solar warming.

The annual isotachs (iso-curves for wind speed) of the region, shown in Figure 4, show that the wind speed is weakest at Ciledug. The weather station in Ciledug is affected by local forcing. This may be due to a channel effect through the street canyons.

The dominant wind direction in Jakarta during the southern summer is from west to north. When the prevailing winds come from the northwest, the dominant wind direction at Ciledug is from the north. In July during the southern winter, the prevailing winds in Jakarta come from northeast to east. The station in Ciledug is affected by local forcing with dominant wind direction east west. The location of the Ciledug weather station should be evaluated with respect to local effects.

Figure 2: Map over the DKI Jakarta area with windroses from the six weather stations in January (0600 GMT, 1300 local time)

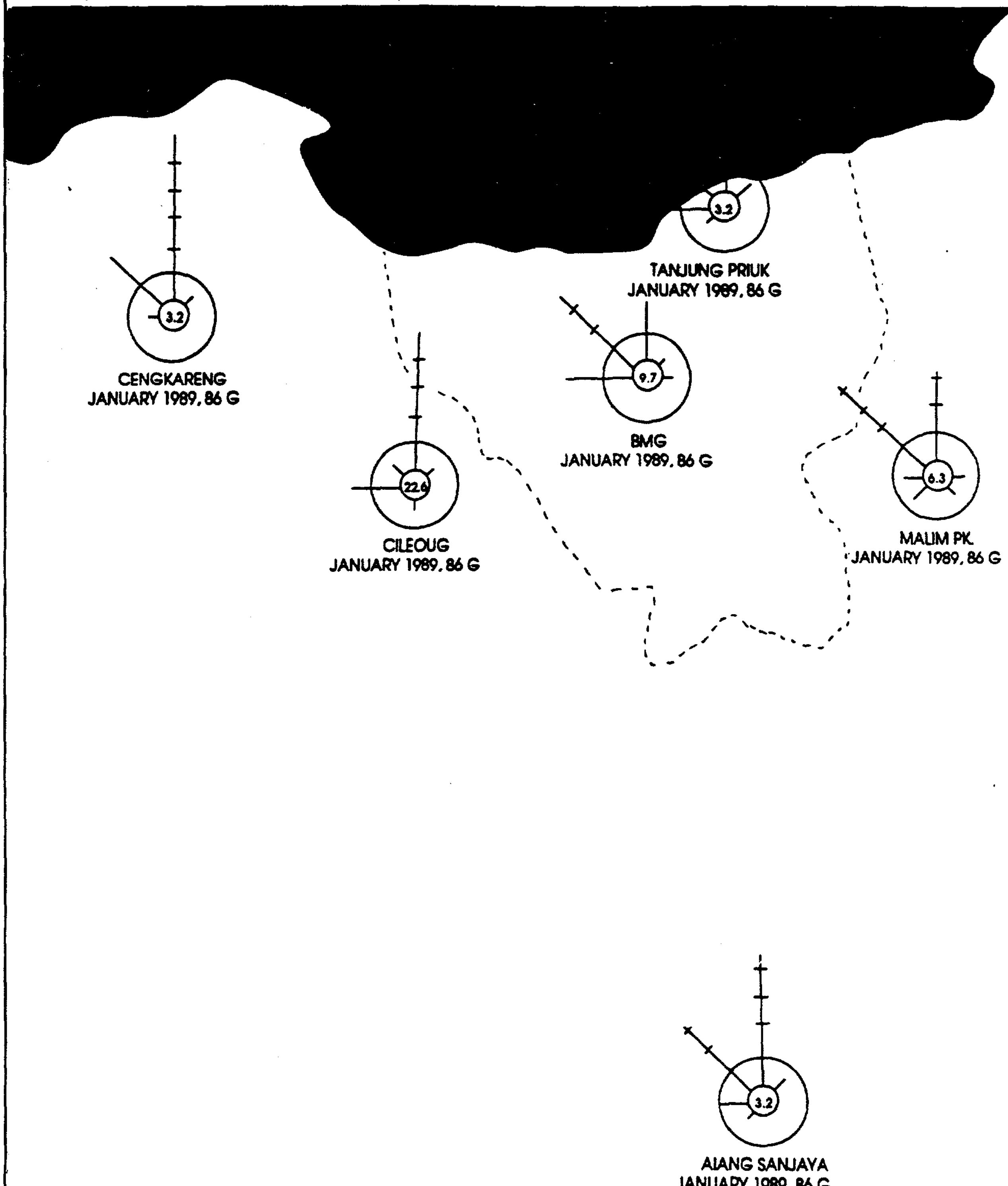
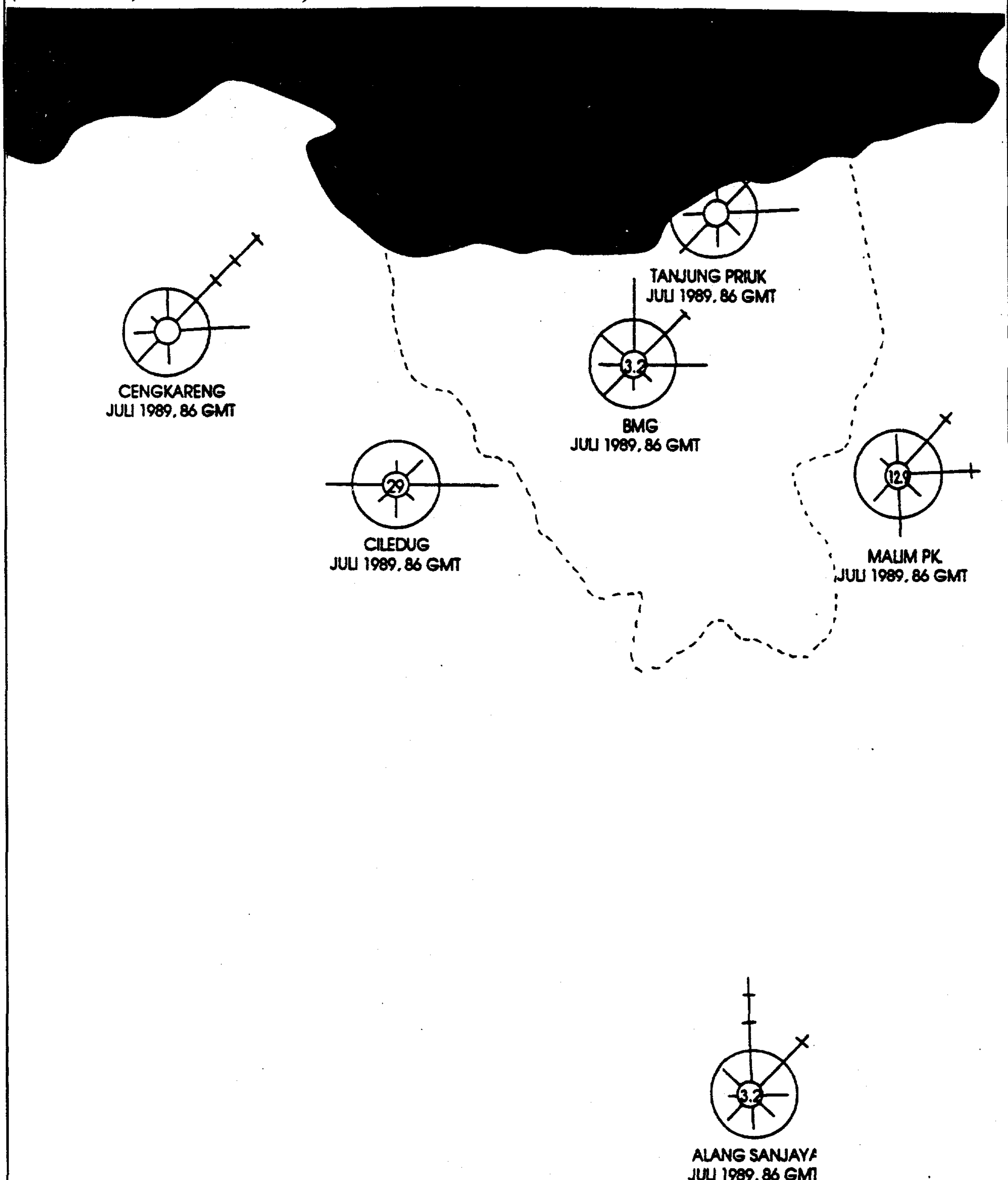


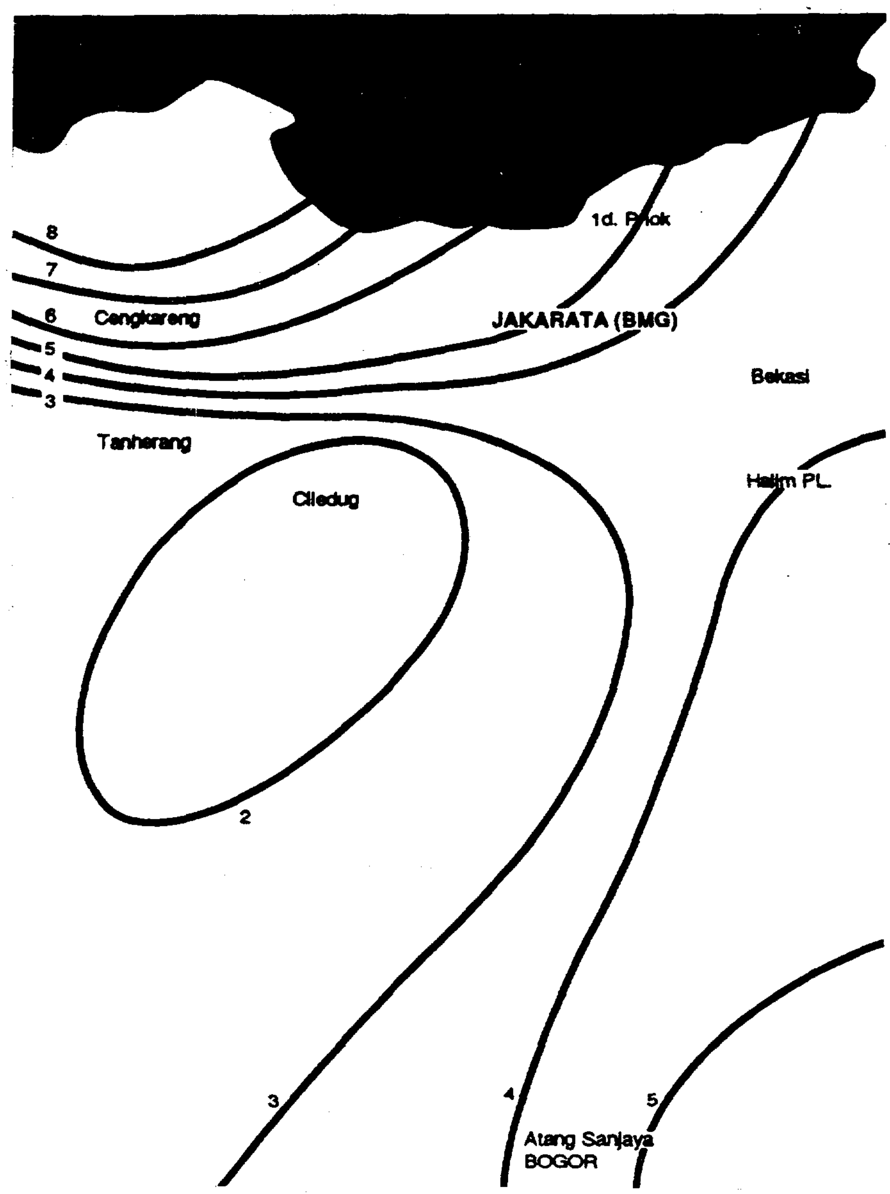
Figure 3: Map over the DKI Jakarta area with windroses from the six weather stations in July (0600 GMT, 1300 local time)



The winds are generally from calm to weak in the morning while in the afternoon the winds are from weak to strong. This is due to the land-sea breeze. The local winds modify the monsoon winds.

The wind speed pattern varies through Jakarta. To the northwest there are sharp gradients of the wind speed from Cengkareng to Ciledug that lies in an area with calm winds (annual average about 2 knots). The main station Jakarta BMG lies in the strong gradient field between the calm area in Ciledug and the harbor area that is strongly affected by the sea breeze during the day. The annual average wind speed for Jakarta BMG is about 4–5 knots. In the southern part of Jakarta, at Atang Sanjaya, the wind speed is about the same as at BMG, and stronger than at Ciledug.

Figure 4: Average annual isotachs in the DKI Jakarta area



The mixing height. The mixing height is a parameter that describes the level where an air parcel, after being heated, will continue to rise until its temperature equals the surrounding air temperature. The airmass under the mixing height is well mixed and therefore often referred to as the mixing layer. The mixing heights for the DKI Jakarta region are given in Table 1.

The mixing height depends on the maximum air temperature and the weather conditions. The monthly average mixing height in the DKI Jakarta varies from 469 m to 1,174 m and the annual average mixing height is 902 m.

Table 1: Mean mixing height (m) in the DKI Jakarta

Months	Area					Average mixing height in DKI Jakarta
	Jakarta Pusat	Jakarta Selatan	Jakarta Timur	Jakarta Utara	Jakarta Barat	
January	565	495	495	596	481	526.4
February	496	429	452	582	388	469.4
March	952	712	840	1,033	840	891.4
April	820	714	741	965	661	780.2
May	1,007	961	944	1,159	927	999.6
June	1,020	958	925	1,134	886	984.6
July	1,149	1,074	1,053	1,226	995	1,099.4
August	1,213	1,199	1,155	1,252	1,049	1,173.6
October	1,091	1,058	1,059	1,178	1,091	1,095.4
November	848	815	872	927	794	851.2
December	814	738	738	857	738	777.2

Source: BMG Jakarta (1989).

Atmospheric stability. The atmospheric stability plays an important role in the dispersion of pollutants. The atmospheric stability is determined by vertical temperature profiles. The vertical lapse rate is classified according to Pasquill as follows:
A: Extremely unstable conditions.
B: Moderately unstable conditions.
C: Slightly unstable conditions.
D: Neutral conditions.
E: Slightly stable conditions.
F: Moderately stable conditions.

In the east of Jakarta (Pulo Gadung and Halim Perdana Kusumah) the frequency distribution of the atmospheric stability was in May 1990 33% extremely unstable, 43% neutral and 14% slightly stable.

The daily variation of the atmospheric stability in East Jakarta is given in Table 2.

The table shows that the stable conditions occur during the morning and evening and the unstable conditions are at a maximum in the middle of the day. The frequency of neutral conditions varies only slightly as function of time of day.

Table 2: The diurnal variation of stability in the eastern part of the DKI Jakarta area

Time	Stability		
	Extremely unstable conditions	Neutral conditions	Slightly stable conditions
0700	9	38	28
1000	18	23	28
1300	45	16	-
1600	18	23	44

Source: BMG Jakarta (1990).

Temperature. The average annual temperature in Jakarta is about 27°C. The temperature in Jakarta has only got a slight annual variation, about 1–1.5°C variation. This is caused by the tropical monsoon near the equator.

Rainfall. The annual rainfall is approximately 2000 mm. The amount of rainfall varies significantly within the DKI Jakarta region. The annual range of rainfall variation in Central Jakarta is 362 mm, in South Jakarta 313 mm, in East Jakarta 336 mm, in North Jakarta 478 mm, and in West Jakarta 396 mm.

There are four seasons in Jakarta: the rainy season, the first transition season, the dry season and the second transition season. The rainy season is characterized by west or northwest monsoon and the dry season by east or southeast monsoon. For both west and east monsoons the amount of rainfall and number of rainy days increase toward the south region (Bogor). The orographic effect and the local sea and valley breeze contribute to the cloud and rain formation on the windward side. The rain in DKI Jakarta is dominated by the west monsoon. The amount of rainfall and the number of rainy days is much greater in December–February than in June–August.

Adverse Meteorological Situations in Jakarta

Studies in the Jakarta area indicate weak and short-lived inversions. The inversions break up as soon as the sun rises.

One meteorological situation that can lead to high ground level concentrations will be when the local land-sea breeze blows against the monsoon, and the local wind is faster than the monsoon. This could happen during the early mornings when the sky is clear, when the airmass in the inland is cooled from below by ground infrared radiation. The airmass will tend to follow the topography towards the coast. In the Jakarta area the wind will probably follow the river valleys from south to north. When the northwest monsoon is blowing, the local wind and the monsoon can lead to stagnation of the airmasses, leading to pollutant build-up.

The combination of the weak wind speed and unstable atmospheric conditions in the daytime can lead to high ground level concentrations near point sources (stack emissions) due to the vertical turbulent motions. The plume may not be much diluted before the downdrafts move the plume towards the ground.

APPENDIX 9: PROJECT DESCRIPTION, LOCAL CONSULTANTS

PROJECT DESCRIPTION REGARDING AIR QUALITY ASSESSMENT

Information should 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 System Development in DKI Jakarta:

- Meteorological measurements in and near the city.
- Activities/population data for DKI Jakarta:

  — Fuel Consumption data:

  Total fuel consumption (1) per type (high/low sulfur oil, coal, gas, firewood and other biomass fuels, other) and (2) per sector (industry, commercial, domestic)

  — Industrial plants:

  Location (on map), type/process, emissions, stack data (height, diameter, effluent velocity and temperature)

  — Vehicle statistics:

  1. number of vehicles in each class (passenger cars, small/medium/large trucks, buses, motorcycles (2- and 3-wheels, 2- and 4-stroke);
  2. Age distribution;
  3. Average annual driving distance per vehicle class.

  — Traffic data:

  Definition of the main road network marked on map.

  Traffic data for the main roads:

  1. annual average daily traffic (vehicles/day)
  2. traffic speed (average, and during rush hours)
  3. vehicle composition (passenger cars, motorcycles, trucks/buses).

  — Population data:

  Per city district (as small districts as possible)

  1. total population;
  2. age distribution.

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

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

- Dispersion modeling: 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:
  1. monitoring;
  2. emission inventories
  3. law making;
  4. enforcement.

  — The information shall include:
  1. responsibilities and tasks of the institution;
  2. authority;
  3. manpower;
  4. expertise;
  5. equipment (monitoring, analysis, data, hard/software)
  6. funds.

It is important that the gathering of information is as complete as possible 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 database is to form the basis for an action plan regarding Air Quality Management in DKI Jakarta. 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 complete.

PROJECT DESCRIPTION REGARDING DAMAGE ASSESSMENT AND ECONOMIC VALUATION

URBAIR: TOPICS FOR RESEARCH

Physical Impacts

1. Describe available studies on relations between air pollution and health.
2. Decide on the acceptability of dose-effect relationships from the United States.
   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/m^3 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 persons.
   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 ([Pb in blood]$_{old}$ -[Pb in blood]$_{new}$) 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:
   $$[1 + exp - \{-4.996 + 0.030365(DBP)\}]^{-1} - [1 + exp - \{-4.996 + 0.030365(DBP_2)\}]^{-1}$$
   i) Decrement IQ points: IQ decrement = 0.975 x change in air lead (μg/m^3)

Calculation example:

- Let population be 10 million people.
- Let threshold value of TSP be 75 μg/m^3 (the WHO guideline).
- Let the concentration TSP be 317 μg/m^3.
  ⇒ Concentration-threshold = 317 - 75 = 242 = 24.2 (10 μg/m^3).
  ⇒ Change in mortality = 24.2 x 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 dose-effect relationships that are acceptable, base value must be gathered, e.g.:
   a) crude mortality
   b) present work days lost
   c) etc.

Valuation

1. Mortality.

   a) *Willingness to Pay.* In the United States 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. US$1,000. If this figure is applicable to all persons of a large population (10 million), the whole population values 1 promille change in risk of mortality at US$1,000 x 10 x 10^6 = US$10 billion. An increase in risk of 1 promille will lead to ca. 10,000 death cases, so per death case the valuation is US$1 million. It should be decided if in other countries, c.q. cities, this valuation should be corrected for wage differences (e.g. if the average wage is 40 times lower than in the United States, the valuation of 1 death case is US$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 approach to pay to prevent a day of illness.
3. *Willingness to Pay to prevent a day of illness.* Valuation in the United States, based on surveys among respondents, indicate that the willingness to pay to prevent a day of illness is approximately US$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 U.S. estimate is approximately US$4,600 per child, per IQ point, summed over the child's lifetime. If this is acceptable, the figure could be corrected for wage differences between the United States and the city.

Other Impacts.

1. *Buildings.* An estimate by Jackson et al is that prevented cleaning costs per household per year are US$42 for a reduction in TSP concentration, from 235 μg/m3 to 115 μg/m3. This would imply a benefit of US$0.35 per household per μg/m3 reduction. This figure could be corrected for wage differences between the United States 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 valuation of future damage to monuments.

Remark

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

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-of procedures. Costs will often depend to a large extent on local conditions.
- 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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