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URBAIR
Urban Air Quality Management Strategy in Asia

DKI JAKARTA
City Specific Report

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Notice

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Preface

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

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

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 in April and July 1993 and May 1994. A first draft of the reports was prepared by Norwegian Institute for Air Research (NILU) and Instituut voor Milieuvraagstukken (IVM, Institute for Environmental Studies, Amsterdam, the Netherlands) before the first workshop, based upon general and city-specific information available from earlier studies. A second draft report was prepared before the second workshop, with substantial inputs from the local consultants, and assessment of air quality, damage and control options, and cost analysis carried out by NILU and IVM.

The participating institutions and agencies from Jakarta were as follows:

The reports conclude with an action plan for air pollution abatement produced by the local working groups as a result of the deliberations and discussions during the second workshop. NILU/IVM carried out cost/benefit analysis of some selected abatement measures, showing the economic viability of many of the technical control options.

It is expected that the local institutions, based upon the results from the analysis, as presented in this report, formulate a prioritized plan of action. Here, prioritized measures to reduce the urban air pollution should be listed and given a term for start and completion. This prioritized action plan is expected to be the basis for the air quality work of the municipal authorities, in developing a control strategy, and an investment plan.

The report is organized as follows:

- An extensive Summary.
- Background information (Ch. 1), summarizing the development in the city over the last decade regarding population, pollution sources such as industry and road traffic, and fuel consumption.
- Air quality assessment (Ch. 2), containing summary of the present air pollution situations, emissions, inventory, dispersion and population exposure calculations, and suggestions for improving the data base for the assessment.
- Projections of air pollution emissions (Ch. 3).
- Air pollution impact (damage/assessment and its valuation (Ch. 4), describing and calculating the health damage from the air pollution.
- Description of institutional framework (Ch. 5).
- Abatement measures (Ch. 6), describing the effectiveness and costs of selected technical control measures.
- Draft action plan (Ch. 7), containing the full Action Plan as developed by the local working groups, and a summary of the cot-benefit analysis of the selected technical control options.
- References (Ch. 8).

An Appendix report contains more detailed descriptions of the air quality data, the emissions inventory and emission factors, population exposure calculations, and laws and regulations.

Acknowledgements

Many contributed to the URBAIR process. URBAIR core funds were provided by UNDP, the Royal Norwegian Ministry of Foreign Affairs, the Norwegian Consultant Trust Funds, and the Netherlands Consultant Trust Funds. Substantial inputs were provided by host governments and city administrations.

City studies were conducted by the Norwegian Institute for Air Research (NILU) and the Institute of Environmental Studies (IVM) at the Free University in Amsterdam, with assistance from the selected local consultants, Dr. Moestikahadi Soedomo, Dpt. of Environment Engineering, Inst. of Technology Bandung and Dr. Umar F. Achmadi, Faculty of Public Health, Univ. of Indonesia. The city-level technical working group provided operational support, while the steering committee members gave policy direction to the study team. The National Program Coordinator (NPC) of MEIP - Jakarta, Mr. Suhadi Hadiwinoto, provided substantial contribution to the successful outcomes.

At the World Bank, the URBAIR was managed by Jitendra Shah and Katsunori Suzuki, and under the advice and guidance of Maritta Koch-Weser and David Williams. Colleagues from Country Departments commented on the numerous drafts. Management support was provided by Sonia Kapoor and Ronald Waas.

Many international institutions (WHO, US Environmental Protection Agency, US Asia Environment Partnership) provided valuable contribution through their participation at the workshops. Their contribution made at the workshop discussions and follow-up correspondence and discussions has been very valuable for the result of the project.

The individuals participating in the Jakarta URBAIR working groups were:

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Summary

Air pollution in urban areas is a major public concern in most countries. Air pollution has hit large cities in the industrialized countries in Europe and North America first as the level of air pollution is highly related to energy use and to economic development. The major reason for concern is the effect of air pollution on public health. SO_2, suspended particles, heavy metals such as lead, persistant organic micro pollutants such as polycyclic hydrocarbons are among the most notorious pollutants threatening public health and economic assets.

With the economic development and growth of large cities in Asia, air pollution problems have visually become endemic to them also.

Considering the clearly deteriorating air quality and suspecting severe impacts, the question arises how to design, develop and implement policies wich address the problem efficiently, in other words how to develop an **Air Quality Management Strategy**.

The Concept of Air Quality Management Strategy (AQMS)

The basic concept for an Air Quality Management Strategy contains the following main components:

- Air Quality Assessment
- Environmental Damage Assessment
- Abatement Options Assessment
- Cost Benefit Analysis or Cost Effectiveness Analysis
- Abatement Measures
- Optimum Control Strategy

The Air Quality Assessment, Environmental Damage Assessment and Abatement Options Assessment provide input to the **Cost/Benefit Analysis, or a Cost Effectiveness Analysis**, which is also based on established Air Quality Objectives (i.e. guidelines, standards) and Economic Objectives (i.e. reduction of damage costs). The final result of this analysis is **Optimum Control Strategy**.

The establishment and follow-up of the AQMS require that an integrated system for continued air quality management is established/completed. A system for air quality management requires continuing activities on the urban scale in the following fields:

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

These activities, and the institutions necessary to carry them out, constitute the System for Air Quality Management that is a prerequisite for establishing the Strategy for Air Quality Management (AQMS).

Figure 1 below represents a simple visualisation of the elements of the System for Air Quality Management, and the flow of information between them.

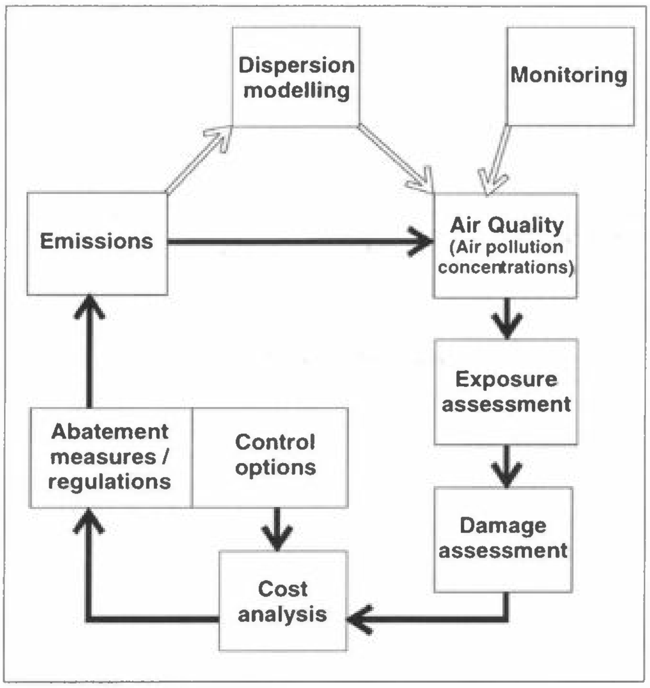


Figure 1: Elements of the System for Air Quality Management.

The process of developing an Air Quality Management Strategy (AQMS), for an urban area includes many steps. The most important of these are:

* identifying sources	emission inventory	Assessment
* quantifying sources		
* monitoring air pollution		
* assessing the exposure (impact) situation		
* identifying source - exposure relations	→ modeling	
* estimating the relative importance of various air pollution sources		
* assessing environmental damage		
* investigating short and long term control (abatement) options including urban planning needs		Control
* performing cost-benefit or cost-effectiveness analysis		
* developing a control strategy and an investment plan		
* developing institutions/regulations/enforcement		
* awareness raising		
* establishing an Air Quality Information System (AQIS)		Surveillance

As shown above, the AQMS consists of two main components, which are **assessment and control**. In parallel with the AQMS development, and to facilitate checking the effectiveness of the air pollution control actions, a third component is necessary, which is **surveillance** (monitoring).

The **air quality assessment**. Air quality in Jakarta is measured at several sites. The pollutants measured are TSP (Total Suspended Particles) and PM_{10} (particles with a size smaller than 10 µm), SO_2, NO_x, CO, O_3 and lead. It can be concluded that in particular TSP and lead pose problems. WHO-guidelines with respect to allowable concentrations are frequently exceeded (section 2.1). Unfortunately, only data of NO_x and particles (TSP) allowed to estimate the spatial distribution and the contribution from different groups of sources in Jakarta to the air quality.

Figure 2 presents the results. The figure shows how many persons are exposed to different levels of annually averaged concentrations of PM_{10}. Increasing concentration levels are associated with increasing effects according to experience from other cities.

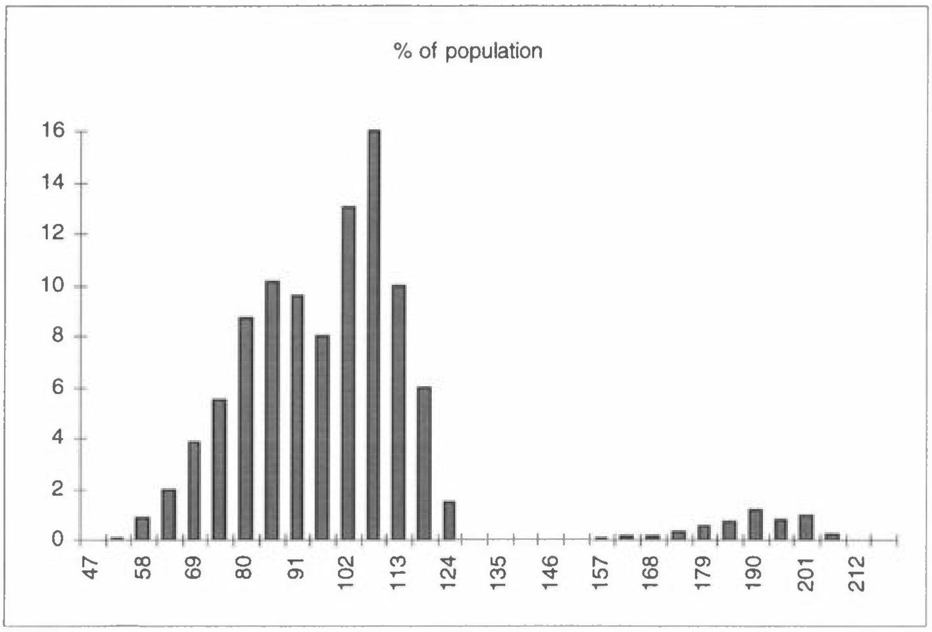


Figure 2: Population exposure to annual average PM_{10}-concentration in Jakarta. The concentrations at the living quarters for the different groups of the population are used as an estimate for exposure.

Norwegian Institute for Air Research has estimated emissions from car traffic, fuel combustion, industrial processes, airports, construction and harbour activities based on existing information. The total emissions have been spatially distributed in the Jakarta area using data on traffic intensities along main roads, local industries and population. Using data on frequencies of observed wind directions and dispersion conditions, concentration distributions for NO_x and PM_{10} have been calculated.

The contribution of each group of sources to the spatial concentration distribution have been quantified considering concentration values and spatial extent of pollution concentrations. The following calculations have been carried out:

- Typical concentrations in each element of 1.5x1.5 km a grid system (Soedomo system) covering Jakarta city. Local maximum and minimum concentrations occur within the grid area as a result of point and line source emissions.
- Maximum concentrations as a result of increased concentrations along roads with high traffic intencities.
- Considering data on population distribution and the concentration distribution including subgrid concentration variations, the number of residents that are exposed to different levels of pollution-concentration outside their home are presented.

The sensitivity of the population exposure on reduction in each source group indicates:

Car traffic is the most important source for NO_x and TSP pollution in the center of the city.

In the industrial area east and north of the city center industries may be the most important sources for local air pollution.

Reasons for differences between observed and calculated concentrations in the northern part of the city should be clarified before source apportionments are concluded.

The **current health impacts and health damages** were calculated based on dose-effect relations derived from studies in cities in the USA, lacking more appropriate data. A methodological issue relates to how to value mortality and morbidity. Different approaches give widely varying results as is shown in table 1. From US-data, converted into Rupiahs according to comparing the purchasing power of the US dollar and the Rupiah, the total health costs related to PM_{10} pollution are about Rp 3600 billion while using Jakarta estimates of values leads to a toal cost of Rp 725 billion. In the cost-benefit analysis the Jakarta specific data are used.

A necessity for designing strategies - sets of measures - to control air pollution is insight in the influence of sources on population exposure. Table 2 presents the contributions of different source categories to the emission of PM_{10}. The table does not show how these sources are spatially distributed over the Jakarta area. Spatial distribution is accounted for by dispersion calculations.

Table 1: 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 Indonesion 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 (PM10)			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

Table 2: PM_{10} emissions (tonnes) in Jakarta (1990).

Gasoline fueled vehicles	4115
Diesel fueled vehicles	2363
Resuspension traffic particles	14445
Process emission	13599 (industry)
Fuel combustion (except open burning)	2600 (diffuse)
Open burning	7027 (diffuse)
Other (airport/harbour/construction)	1128 (mainly diffuse)
Total	45277

The reduction of adverse effects as a result of reduced emissions are shown in table 3. The results of the preliminary calculations indicate that measures should firstly aim at reduction of emissions from both traffic and industry, as opposed to domestic emissions (open burning and fuel combustion), that is if not taking into account the costs of the measures.

Table 3: An assessment of the benefits of emission reduction.

Source category	Emission reduction (%)	Emission reduction (tonnes)	Avoided mortality	Avoided RSD (million)	Avoided health costs (Rp billion)	"Marginal" benefits (Rp million per tonne reduced)
Traffic	25	5230	854	20	124	24
Industry (process emissions)	25	3600	600	14	87	24
Diffuse/ domestic	25	3500	26	0.6	3.8	1

RSD = Respiratory Symptoms Days.

The design of **emission control strategies** based on a cost-benefit analysis requires a database of measures containing information about their costs, their effectiveness (avoided emissions) and, preferably also about their benefits in terms of avoided pollution impacts and damages. This information is presented in chapter 6. Unfortunately, the information is confined to measures appropriate for the transport sector. Lack of appropriate information did not allow identifying and evaluating measures to address domestic emissions and emssions from refuse burning.

Measures which stand out from a cost-benefit point of view are:

- introduction of low-lead gasoline;
- introduction of low-smoke lubricating oil;

Other measures, of which the cost-benefit ratios are less clear - due to a lack of data or to methodological problems - are:

- improving the quality of automotive diesel fuel;
- inspection and maintenance schemes;
- clean car standards (requiring the introduction of unleaded gasoline);
- (further) development of the use of natural gas both for automotive and stationary use;
- improvement of the public transport system.

Table 4 summarizes the data.

Table 4: A summary of technical meausures, their effectiveness, annual costs, selected health benefits and total valued benefits.

	Avoided emissions (PM10) (tonnes)	Costs (Annual) (billion Rupiahs)	Mortality benefit (number of cases)	Avoided number of RSD (million)	Avoided health damage (billion Rp) Lower estimate.
Low lead and unleaded fuel		50	310		300
Addressing excessively polluting vehicles	1000		163	3.8	23.7
Implementation of inspection & maintenance scheme	1300	67 (max)	212	5	31
Low-smoke lubricating oil in two-stroke engines	1350	2-10	220	5	32
Clean vehicle standards - cars with four-stroke gasoline engines	900	18	147	3.4	21.3
Adoption clean vehicle standards for vehicles now equipped with two-stroke engines	2000	67	325	7.6	47
Improving diesel quality	230		41	1	5.9
LNG to replace gasoline (50%) of gasoline consumption	650		98	2	14.2

These technical measures provide only a part of a solution. Other policies, e.g. relating to public transport, land use and industrial development, have also impact on the emissions. Further it should be noted that measures addressing industrial emissions were not listed and evaluated.

A scenario analysis indicates that if no additional pollution measures are taken, emissions will grow to almost double the current emissions by the year 2010.

Table 5: Preliminary scenario for developments of PM_{10} emissions (tonnes) in Jakarta.

	1990	2000	2010
Gasoline fueled vehicles	3,916	5,923	9,134
Diesel fueled vehicles	2,457	3,966	6,901
Resuspension traffic particles	6,958	9,932	16,426
Process emissions	13,586	13,599	13,599
Fuel combustion (except open burning)	2,350	3,430	5,145
Open burning	7,027	9,913	13,983
Other (airport/harbour/construction)	5,076	6,540	8,673
Total	41,370	53,303	73,861

This reference scenario is constructed by a simple extrapolation of trends in the number of vehicles and the Jakarta population, assuming other factors not changing. Industrial and domestic sources (wood burning and refuse burning) currently constitute an important source. However this position will eventually be overtaken by transport related emissions. Under the various assumptions it appears that emissions related with traffic will grow fastest. Important subsectors are passenger cars (gasoline) and motorcycles.

Clearly, environmental risks in Jakarta are on the rise. If one takes into account that the Jakarta population tends to grow with a rate of about 3% annually in the future more people will be exposed to higher concentrations and impacts may well double over the coming ten years.

Uncertainties

Many figures above are detailed. This is not to suggest a reliability, but only for reasons of consistency in calculation; in fact many figures are ball park estimates.

The following sources of errors have to be considered:

- Errors in emission estimates and dispersion calculations underestimate the number of people exposed to the high concentrations. In particularly in the northern part of the city a systematic difference between observed and calculated concentrations are observed.

- Errors in source apportionment and in quantifications of effects may influence the priority of abatement strategies.

- Lack of information about specific sources, in particular for emissions from industrial plants may reduce the effects of some source reduction actions. Control of individual sources may be more cost/effective than enforcing general rules for emission reduction.

- The integration of effects over the whole population of Jakarta may reduce the error as a result of local emission errors. The statements about groups of sources are influenced by smaller errors than individual sources in the groups i.e. abatement actions should also be based on individual source considerations using emission standards based on best practical technology.

URBAIR

Urban Air Quality Management Strategy in Asia

JAKARTA
City Specific Report

1. Background information

1.1 Scope of the study

The present city specific report on Air Quality Management for the DKI Jakarta region has been produced as part of the URBAIR program.

The major objective of the URBAIR program is to develop a generalized Air Quality Management Strategy (AQMS) to be used for Asian cities, and to apply strategy to develop Action Plans for improve the air quality in the following cities: DKI Jakarta, Greater Bombay, Kathmandu Valley and Metro Manila.

The developed AQMS is based on the costs and benefits analysis of proposed actions and measures for air pollution abatement. Benefits include the reduced costs of health and other damage due to air pollution, which results from implementation of the abatement measures. In this study, emphasis is put on health damage, which is estimated based upon the calculation of the distribution of population exposed to air pollutants, based again on measured and calculated concentrations of air pollution, through emission inventories and dispersion modelling.

The generalized strategy is described in a separate URBAIR Guidebook on Air Quality Management Strategy. City specific reports are produced for each of the four cities, based on city-specific analysis. The city specific reports conclude with prioritized Action Plans for air quality improvement, including costs and benefits figures. The action Plans are based on a comprehensive list of proposed measures and actions developed by local working groups in each of the four cities, and evaluated by the URBAIR consultants.

1.2 General description of DKI Jakarta

DKI Jakarta is situated at the northern coast of Java Island, around the mouth of the Ciliwung river, at about 106° East and 6° South. The DKI Jakarta covers an area of approximately 665 km². The area is very flat, with an mean elevation of 7 meter above sea level along the coast, while the southern area of DKI Jakarta is slightly undulated, with ground elevation of approximately 50 meter above sea level. Further south, outside the DKI Jakarta area in the area of Bogor the mountains raises up to 3000 meter. There are no natural topographical barriers near DKI Jakarta.

DKI Jakarta is still predominately a city of one or two storey buildings with high-rise buildings concentrated in corridors along the main roads. However, being a city of dynamic development the situation of Jakarta may easily change. Air pollution from traffic during rush-hours is already an issue and is likely to be more serious in the future. Further high-rise building activities may change the micro-climate at street level considerably.

DKI Jakarta is part of the greater JABOTABEK (Jakarta, Bogor, Tangerang and Bekasi) area. As air pollution moves across all boundaries, an emission survey has to also take into account activities in the surroundings of Jakarta, but the most dominant work has to be made for Jakarta.

At present there are five mayoralities in the DKI Jakarta which are subdivided into together 74 subdistricts (kelurahan). Figure 1.1 shows a map of DKI Jakarta with the regions.

North Jakarta covers the areas along the coast. There is a high tendency of developing this area as residential areas, despite the risks of flood and poor sanitation. At the areas of the old international airport at Kemayoran a new town is developped. The areas around Tanjung Priok Harbor has a population density of about 162 inhabitants per hectare, but a rapid development of residential area is anticipated in the area, particularly those in the middle and lower income groups. The eastern part is slow growing and is dominated by marsh lands and paddy fields, with a population density of about 24 inhabitants per hectare.

The **Central Jakarta** is mainly characterized with governmental offices and other related service's sectors. The area continues to develop rapidly, but in spite of the rapid economic development, the area it is characterized with low income population. Commercial and trading areas are located south of Central Jakarta, along the main roads that serve as the main transportation axes of Jakarta. The southern part of Central Jakarta has been growing and developing very rapidly during the last 20 years, especially as residential area for medium and high income groups. Today the area seems saturated in terms of population as well as economic activities. The northern part of Central Jakarta has a very dense population, up to 500 inhabitants per hectare, and most of the population with low income per capita dwells in the kampongs.

East Jakarta has a lower population density, but new industrial zones in the Bekasi region may encourage the development of other urban growth areas. It has a soil appropriate for city planning.

West Jakarta represents the most strategical areas in the city for medium and long term. It has a soil, ground water availability and structural conditions appropriate for residental area development.

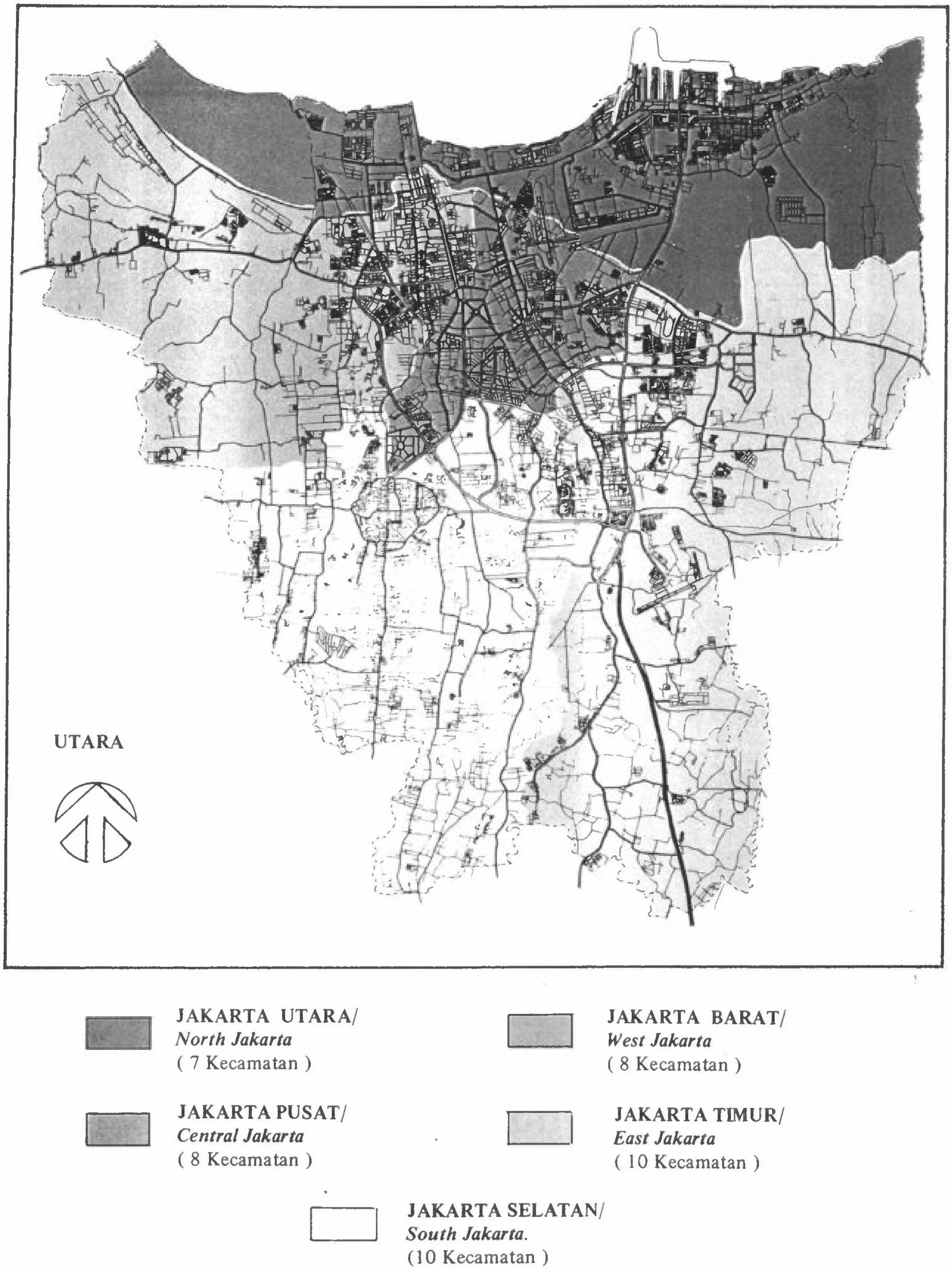


Figure 1.1: DKI Jakarta with 5 mayoralities.

South Jakarta has a lower population density. The area has been designated as ground water percolation area for recharging Jakartas ground water reserve. Controlling and managing the green belt areas competes with the increasing public needs in developing the areas.

1.3 Data sources

Previous studies

The air pollution situation in Jakarta has been studied and reported by several groups and institutions. The most important studies, which have formed part of the background for the URBAIR work on Air Quality Management Strategy for Jakarta, 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 consult/World Bank, 1992);
- LLAJR Air Pollution monitoring and control project (Bachrun et al., 1991);
- 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);
- Jakarta in figures (JSO, 1991).

URBAIR data collection

Further data on various aspects of population, pollution sources, dispersion, air quality, health aspects, etc., has been collected during the URBAIR process, starting for Jakarta in March 1992. The following local consultants have provided additional useful data according to the project description given in Appendix 9 in the Appendix Report:

- Dr. Moestikahadi Soedomo and his colleagues at the Inst. of Technology in Bandung collected existing data on air pollution concentrations, fuel and traffic data, emission data and meteorological conditions etc., which were valuable for the air quality assessment procedure.

- Dr. Umar F. Achmadi at the Univ. of Indonesia in Jakarta (Faculty of Public Health) collected, evaluated, and summarized data on health statistics and cost data related to disease and treatment. This information was valuable in the health damage and cost assessment.

1.4 Summary of development in the DKI Jakarta, 1981-1992

Figure 1.2 gives a summary of some available data regarding population, vehicles, fuel consumption and air quality, and development over the last decade. As can be seen, data are not available on all these items for the whole decade. The data shown and summarized here are described in greater detail in the subsequent chapters.

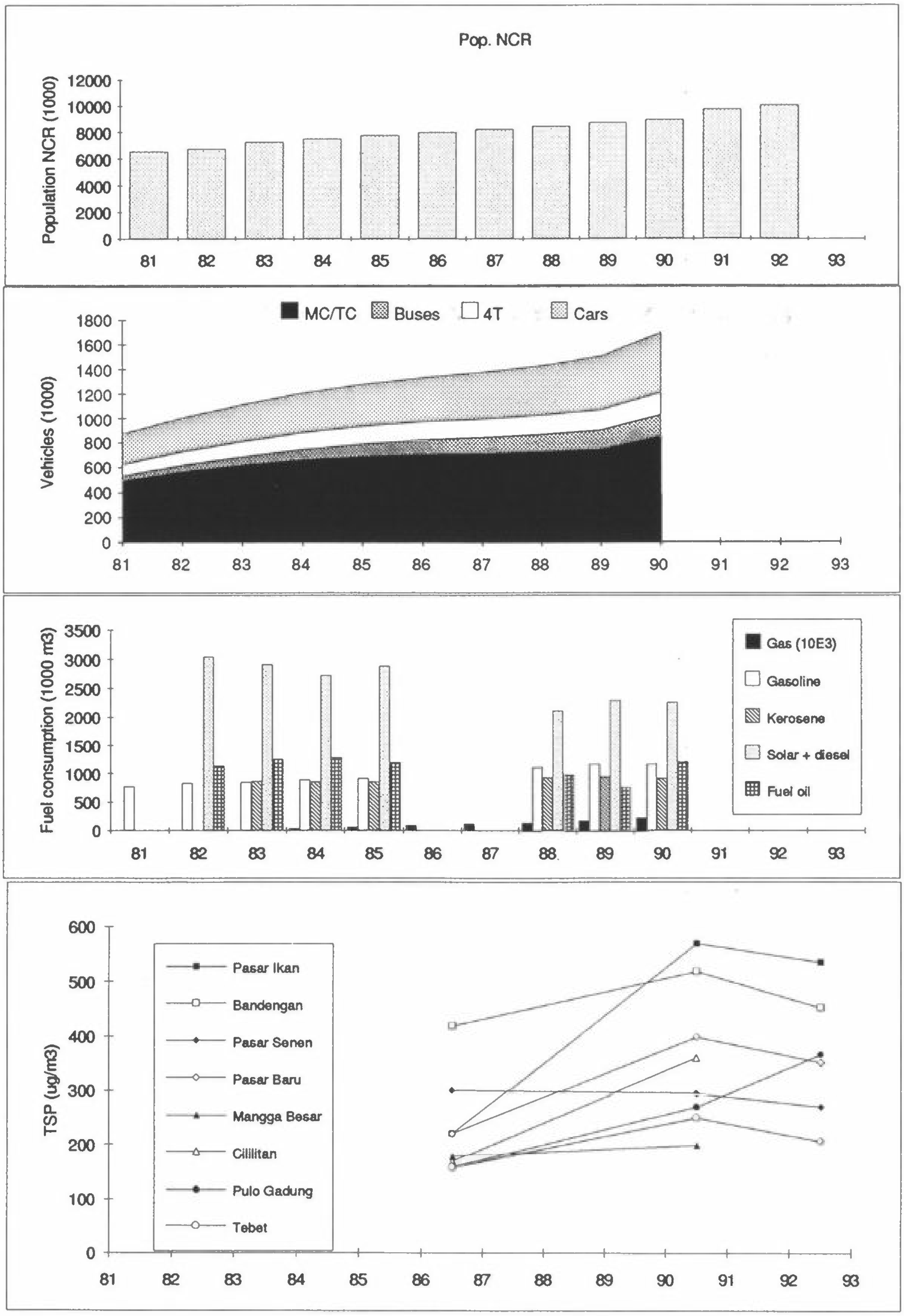


Figure 1.2: Development in the DKI Jakarta, 1981-93: Population, vehicle fleet, fuel consumption and air quality.

]

The population has increased by a factor of two in about 20 years, and the potential for further increase in population is large. The number of cars has increased by a factor of two during the last 10 years. The consumption of gasoline has increased according to the increased car traffic. The consumption of other fuel types do not show a well specified trend. In 1990 the GNP/capita figure for Indonesia was US$ 570. During 1965-1990 the growth rate in GNP/capita was +4.5%, among the highest in the developing countries.

Also in the surrounding areas in the Jabotabek region the population and other activities are increasing. Along the main roads towards Bogor, Bekasi and Tangerang there are industrial areas in Pulo Gadung, Cipinang and Mookevart, respectively (DHV, 1993a, b). Some of the industries are located outside DKI Jakarta, and it is important that the same regulations applies for the whole Jabotabek area.

Three agencies has been operating different monitoring networks in Jakarta with 24 hours samples with different intervals, measuring TSP, SO_2, NO_x, CO and O_3 (not all). The SO_2-values are generally low, and decreasing. TSP remain the most important pollution component in the area, and the concentrations were increasing until 1990. Afterwards the pollution trend is more variable. Very high TSP values of 5-6 times the Air Quality Guidelines are measured at all stations.

The quality of the NO_x measurements seems to vary much and differences in NO_x-levels from year to year seems difficult to explain. Recent results from the new monitoring station at Jl. M.H. Thamrin indicates that the 24-hour NO_x data from the other stations may be too low, especially at the more central located stations.

1.5 Population

Figure 1.2 shows that the population in the Jakarta region has increased about 50% from 1981 to 1991 and a further increase in population and economic development in the years to come are expected.

Immigrants mainly settle down in the southern and eastern parts of Jakarta. The main part of the population increase is due to the birth rate within Jakarta. Table 1.1 shows the age distribution in Jakarta in 1990 indicating a considerable growth in population in the years to come.

Table 1.1: The age distribution of Jakarta population in 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

1.6 Vehicle fleet

The vehicle fleet in Jakarta is separated into these categories:

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

In 1981 56.6% of the vehicles were motorcycles and tricycles, in 1990 50.5%. On the other hand the buses had increased from 4.3% to 9.9% of the vehicle fleet. 28% were passenger cars and 11% cargo cars.

Table 1.2 shows thc estimated yearly traffic work for each of these categories using gasoline or diesel.

Table 1.2: Estimated traffic work in Jakarta for each of the vehicle categories. Unit: 10^6 carkm/year.

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

1.7 Industrial sources

Jakarta has a large and diversified industrial structure. Various estimates for industrial emissions have been developed. These are not specified in sufficient detail, and further work needs to be carried out to evaluate the impact on air quality.

Table 1.3 shows the number of establishments and the number of employees working with production in eight groups of industries.

Table 1.3: Number of establishments and persons engaged in production in large and medium factories 1989 (Jakarta in figures 1991).

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

1.8 Fuel consumption

Data on sales of oil and gas by type of fuel are published in "Jakarta in figures 1991" as shown in Table 1.4.

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

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

In Jakarta three electric power stations use gas and marine fuel oil for production of electric power, with a yearly production of 9 10^9 KWh in 1990.

2. Air quality assessment

The purpose of this chapter on Air Quality Assessment is to **estimate population exposure** to area air pollutants, and to quantify the contributions to this exposure from the various pollution sources.

This estimate is arrived at through the following analysis:

- Description of existing air pollution concentration measurements and their variation in time and space;
- Inventory of air pollution sources and their relative contributions:
- Description of the concentration distributions in the area, by means of dispersion modeling; and
- Calculating of the population exposure, by combining spatial distributions of population and concentrations, also incorporating exposure on roads and in industrial areas.

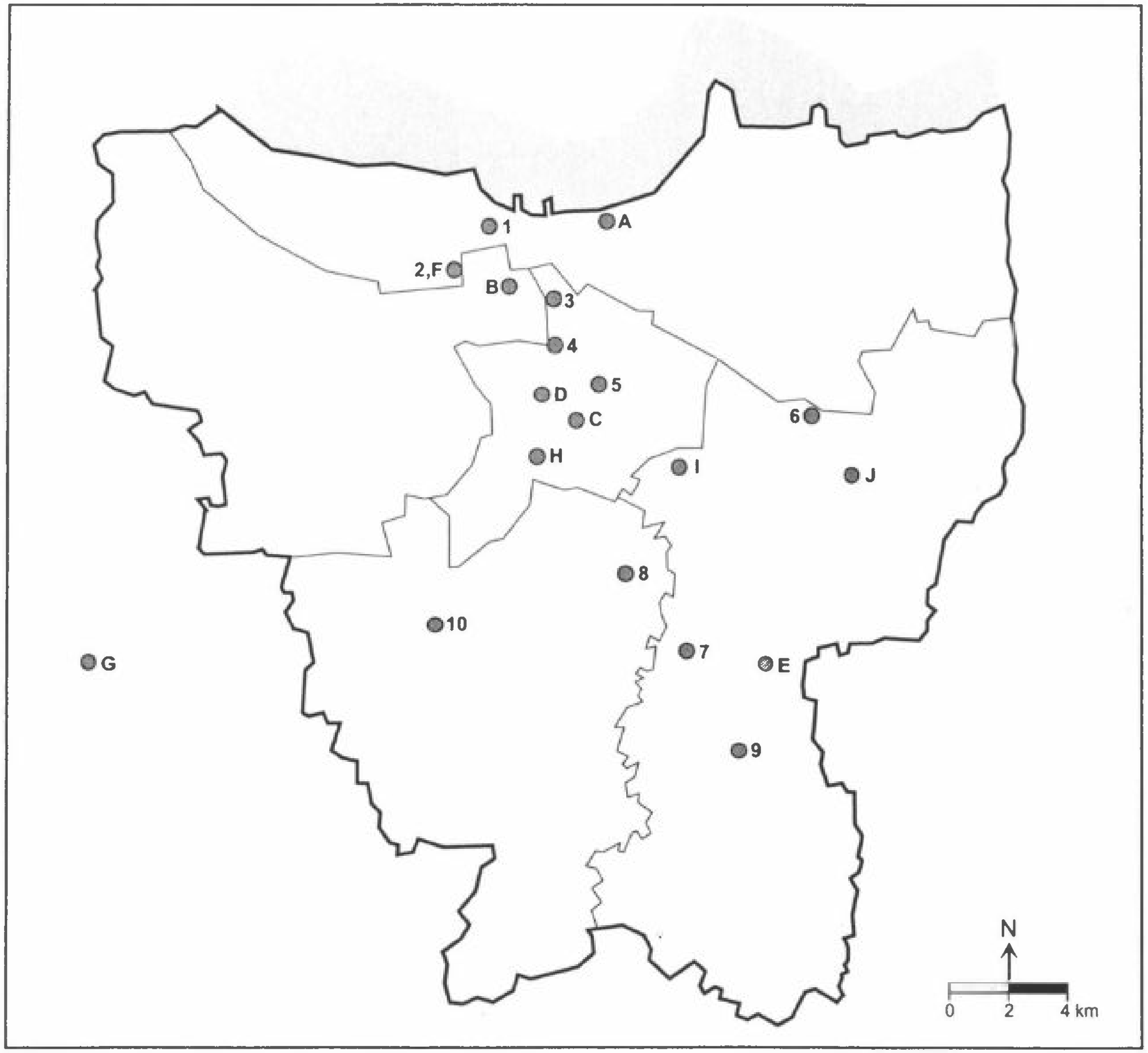
2.1 Air pollution concentrations

Overview of data base

The measurement programmes of air pollution in Jakarta reveal that Jakarta has a substantial particle pollution problem, with frequent and spatially extended exceedances of air quality guidelines for TSP. According to the SO_2 measurements, SO_2 pollution problem seems to be less pronounced.

In Appendix 1, the monitoring networks and results of measurements are described in more detail. The monitoring networks which have provided data in recent years on which our assessment are based, are the following as shown in Figure 2.1:

- Seven permanent stations run by BMG (Meteorological and Geophysical Agency). The first BMG station has been operated 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 is measured at the other six BMG stations. At the BMG stations there is one 24 hour measurement every 6th day.
- Two permanent stations run by the Jakarta Municipal Government (JMG) (before 1980 by the Ministry of Health). These are part of the United Nations Global Environment Monitoring System (GEMS) since 1979. At the GEMS sites TSP, NO_x and SO_2 is monitored every 6th day.



Stations operated by BMG
A Ancol
B Glodok
C BMG Head Quarter
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

Figure 2.1: Air Quality Monitoring Networks in Jakarta.
The positions of Ciledug and Bandengan Utara are uncertain.

- Eight rotational stations 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 DKI-KPPL was formerly called DKI-P4L. The air monitoring stations are operated 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 month each year. TSP and CO (and oxidants on occasions) are measured at all sites.

- Since April 1992 continuous 1-hour average measurements have been made of SO_2, NO, NO_2, CO and PM_{10} at Jl M.H. Thamrin in Central Jakarta. No detailed analysis of these data has been made in this report, but some preliminary results are referred.

TSP

In Indonesia the upper limit of WHO Guidelines has been proposed as their National AQG (see Appendix 2). The WHO guidelines are as follows:

Long-term (annual) average : 60- 90 μg/m^3
Short-term (24 hour) average : 150-230 μg/m^3

These values are clearly exceeded at the measurement stations in Jakarta, as shown in Figure 2.2 and in Appendix 1. The figure shows averages for the period 1986-92. The highest values are measured in the northern part of Jakarta, but there are many stations that seems to be influenced by local sources. The bus terminals in Pulo Gadung and Cililitan have both average values above 300 μg/m^3.

The TSP concentration is reduced towards 100-150 μg/m^3 as an average in the outskirts. The annual TSP averages in the most polluted areas are 5-6 times the AQG value.

Very high 24 hour average values are recorded at all stations. Except for two extreme values, one at 864 μg/m^3 at Bandengan (possibly due to some extreme local sources influence), the maximum values are about 300-450 μg/m^3, i.e. up to 2 times the AQG value on several stations.

The day to day variations show important fluctuations indicating variations with meteorological conditions. These data have not been available for further studies. However, it is expected that the TSP concentrations are reduced during rainy periods and when the dispersion conditions remain good (high windspeed and good vertical mixing). This reflects one or more of the following effects:

- 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.

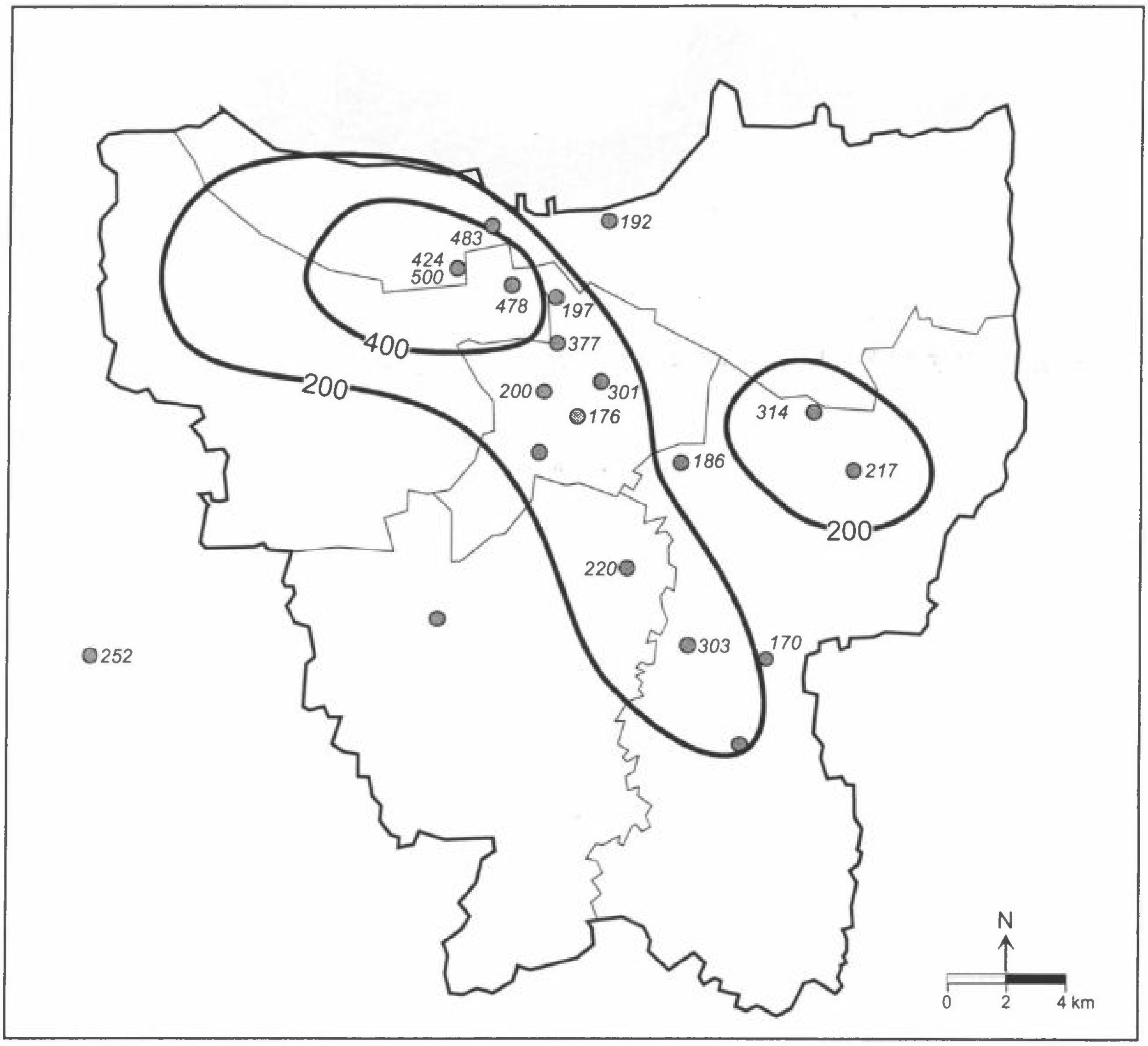


Figure 2.2: *Annual TSP-concentrations in Jakarta 1986-92.*
Unit: µg/m³.

Nitrogen oxides (NO_x)

NO_x data for KPPL and BMG/health stations are presented in Table 2.1. NO_x is reported, but the main component would probably be NO (Kozak and Sudarmo, 1992).

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.

Table 2.1: Comparison of annual NO_x averages for 1986-1991 at BMG and Health Air Monitoring Stations in Jakarta.

YEAR	NO_x (ppb)		
	BMG.HQ	HEALTH	
		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

During 1989 and 1990 the average concentration at the Bandengan station in the city centre was as low as 28 µg NO_x/m^3.

DKI-KPPL stations show a remarkable fall i NO_x concentrations from 113 µg/m^3 in 1983 to 9.4 µg/m^3 in 1986, and similarly, maximum 24-hour values fell from 395 µg/m^3 to 15 µg/m^3. 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 2.1 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/m^3). 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 shows mean values of 64 ppb NO_2 (about 120 µg/m^3) and 169 ppb NO_x (about 320 µg/m^3). NO_2 daily values ranged from 46 ppb (about 85 µg/m^3) to 93 ppb (about 175 µg/m^3). The highest values are above the proposed Indonesian ambient air quality standard of 150 µg/m^3.

Hourly NO_2 values on 25 June 1992 ranged from 22 ppb (about 40 µg/m^3) to 178 ppb (about 340 µg/m^3). The highest values are not far below the 1-hour proposed national ambient air quality standard of 400 µg/m^3.

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

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

Measurements of nitrogen oxides have given varying results, probably due to changes in methods. 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 ranges from about 20 to 160 μg/m³. Figure 2.3 shows average values from some KPPL sites 1988/89.

At the new, continuous station at Jl M.H. Thamrin the daily averages are in the range 200-500 μg/m³ with an hourly maximum exceeding 650 μg/m³. The values are much closer to those which would be expected at a site with a high traffic density than those recorded at the network sites, however, these results are from a very limited data set, and longer time series are needed.

Ozone (O_3)

O_3 has been 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 urban Jakarta seem to be well below the proposed national ambient air quality standards.

These measurements indicate that the O_3 levels inside the city 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.

A different picture is given by the high O_3 concentrations (above 200 μg/m³) which have recently been measured at the Environment Management Centre outside the city (to the southwest) (EMC, 1994). Such high concentrations of oxidants may cause eye irritation or sometimes acute health effects. In Indonesia, ultraviolet radiation intensity which contributes to photochemical reactions, is high in 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.

These measurements show that an ozone monitoring program with good quality measurements in and around Jakarta is urgently needed.

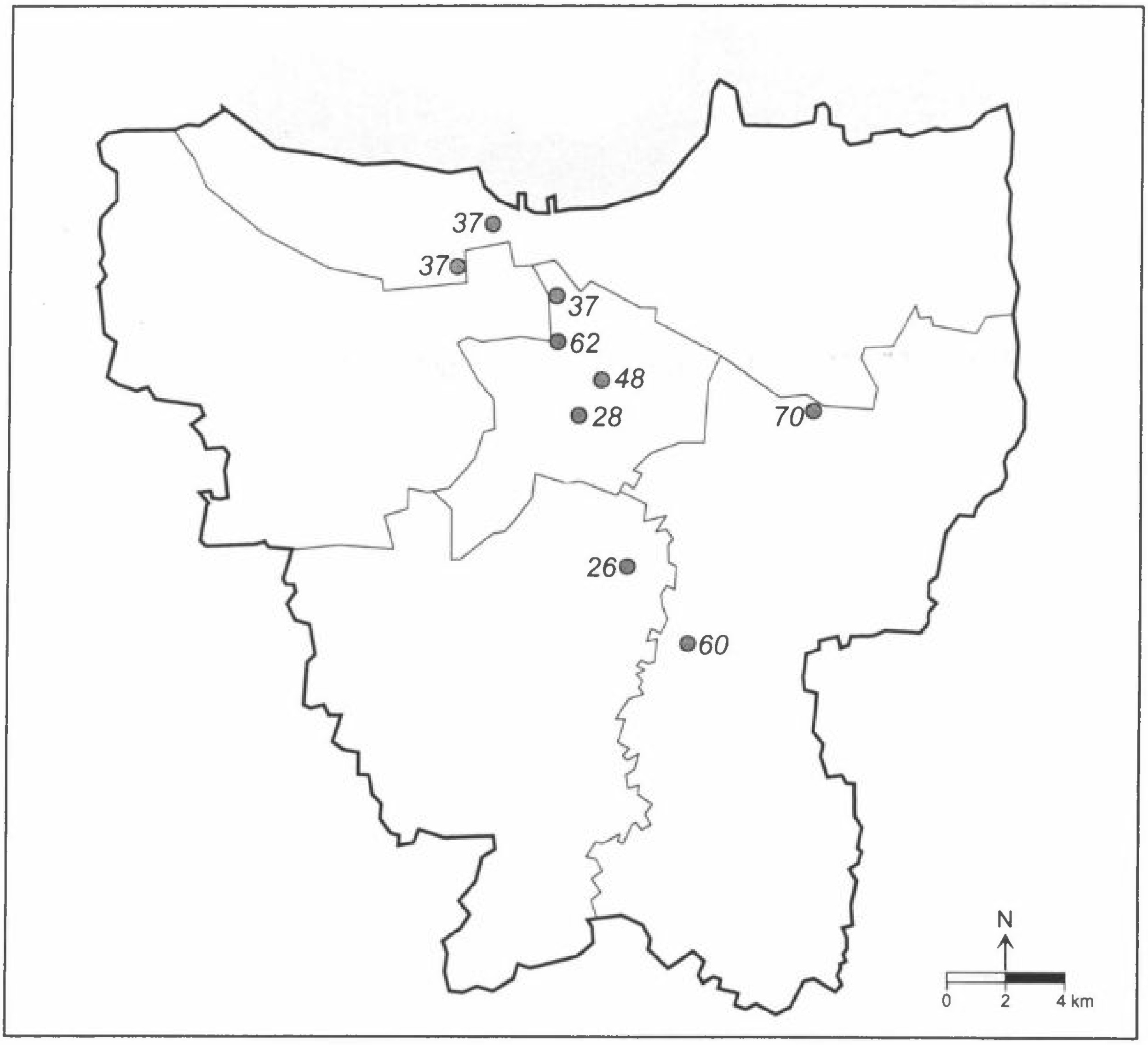


Figure 2.3: *Annual NO_x-concentrations at some KPPL stations in Jakarta 1988/89.*
Unit: $\mu g\ NO_2/m^3$.

Carbon monoxide (CO)

CO is measured at the DKI-KPPL network. 8-hours 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 values 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 intencity 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 (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 analysed 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 trafficated areas in Jakarta.

The lead content in gasoline in Indonesia is reported to be 0.44 g/l for 88 octane premium and 94 octane premix gasoline.

AQ standards for lead is expected to be exceeded along the main roads, but not over the urban area in general as a result of emission from car traffic.

Lead in the atmosphere arises predominantly from vehicle exhausts. Lead is added to the gasoline to improve performance. In Jakarta the lead content has been in the range of 0.4-0.75 g/litre. Lead free gasoline has been introduced in 1995, so far in other small amounts, at a higher price that leaded gasoline. This is considered being the start of a development towards full availability of lead-free gasoline in Jakarta.

The WHO guideline for lead is an annual average of 0.5-1.0 µg/m^3. Figure 2.4 shows results of the measurements of lead in particulate samples from 8 KPPL sites in 1991/92. The measurements were made for ten months starting in June 1991 and ending in March 1992, 24 hours every 8th day.

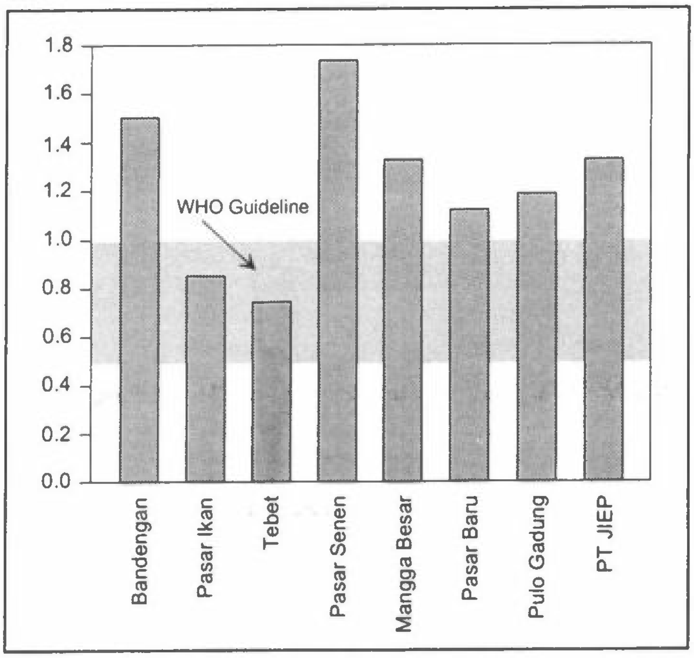


Figure 2.4: Particulate lead. Annual average - Jakarta 1991/92.

2.2 Air pollutant emissions in Jakarta

Total emissions

The data which were available for Jakarta on fuel consumption and traffic and industrial activities were utilized to produce an emission inventory for DKI Jakarta, as given in Table 2.2. Emissions of TSP, PM_{10} (particles less than 10 µm diameter) and NO_x have been calculated/estimated. There were significant shortcomings in the data base for constructing emission inventories. In particular, data on industrial activity and emissions were very scarce, and so were traffic data. Data on power plant emissions were not available. The data base and procedures are described in Appendix 4.

Some of the estimates are very rough, and based upon incomplete background information. It is not attempted at this stage to estimate the accuracy of the figures. Nevertheless, the presented inventory is considered adequate for a first estimate of source contributions, and a suitable background for a first stage cost-benefit analysis. The emission estimates gives information of the magnitude of the emissions, and the modelling work shows how to proceed in such a study. It is really necessary to improve the emission inventory for Jakarta, by improving and making available the necessary base data.

Due to the limited data available the emissions from traffic from traffic were calculated by a special procedure: A main road network for DKI Jakarta was defined from different maps, as shown in Figure 2.5. From a limited set of traffic counts Average Annual Daily Traffic (AADT) for some road classes was defined, and data fields with daily traffic work was calculated. Based upon traffic counts from 22 different roads (Soedomo, 1993) a "normalized" traffic composition was defined as shown in Table 2.3. Table 2.4 shows the emission factors used for car traffic.

Table 2.2: Estimate of total annual TSP, PM_{10} and NO_x emissions in Jakarta, 1990, according to existing data for source groups
Unit: 10^3 kg/year.

Emission sources		TSP	PM_{10}		NO_x
Transport sector			Note		
Vehicle exhaust					
Gasoline	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	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	2,457		2,457	13,158
Resuspension from roads		27,832	4	6,958	
Sum vehicles		34,205		13,331	31,543
Energy/industry sector					
Fuel combustion					
Industrial/com.	Destillate fuel	185.4	2	92.7	1,483
	Coal	0.4	2	0.3	1
	Coke	12.5	2	6.2	26
	Gas	3.0		3.0	141
Domestic/small ind.	Fuel oil	1,682.8	1	1,430.4	2,404
	Destillate fuel	1,617.0	2	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
Ind. processes	Food and textile	9,390	4	2,348	
	Wood and w. products	2,036	3	1,153	
	Paper and p. products	5,211	3	2,606	
	Chemicals	3,800	3	1,900	
	Non met. min. prod.	1,710	3	855	
	Iron and steel	9,450	3	4,725	
Sum ind. sources		31,867		13,586	
Other	Airports	26		26	661
	Construction	20,000	4	5,000	
	Harbour	100	2	50	1,000
Sum other		20,126		5,076	1,661
Sum total		96,733		41,369	43,031

1 $PM_{10} = 0.85 \cdot TSP$ (ref. EPA AP42)
2 $PM_{10} = 0.5 \cdot TSP$ (ref. EPA AP42)
3 $PM_{10} = 0.5 \cdot TSP$ (rough estimate)
4 $PM_{10} = 0.25 \cdot TSP$ (rough estimate)

PM_{10} is a notation for the smaller particles (<10 μm) in TSP. As PM_{10} is the main harmful component, the exposure calculations are based upon PM_{10}-values.

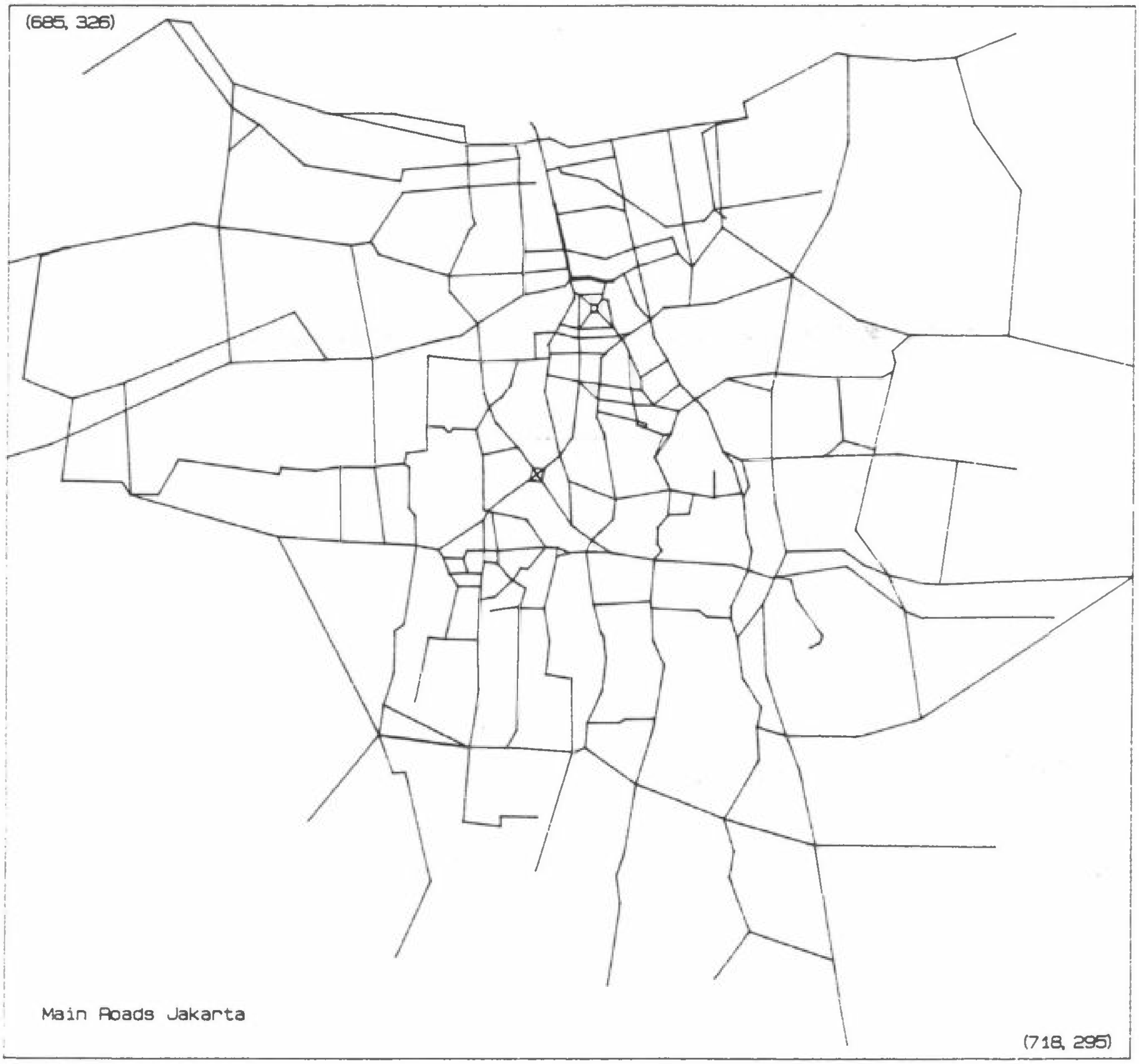


Figure 2.5: Main road network in DKI Jakarta.

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: Emission factors for traffic in 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
Bus, Coplet etc.	0.9	13

The counts were also used together with data for the yearly gasoline consumption given in Table 2.5 to estimate Annual Average Daily Traffic (AADT) to the roads, giving a total traffic each of $17.2*10^9$ car-km/y. From this average emission factors of 0.35 og TSP/km and 2.267 g NO_x/km were used to calculate area emission fields, as shown in Appendix 4.

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

Emission source		$10^3 m^3/a$	10^6 vehicle km/a
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	

In addition to the primary emissions from the vehicles is an emission from resuspended road dust. For road dust resuspension, a rough estimate is given here. Based upon the following emission factors proposed by US EPA(EPA, AP 42):

- local streets (AADT < 500): 15 g/km
- collector streets (AADT 500-10 000): 10 g/km
- Major streets (AADT 10 000-50 000): 4.4 g/km
- Freeways/expressways (AADT >50 000): 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 >50 000. Assuming the traffic activity share of these road classes are 5%, 25%, 30%, 40% respectively, and that the roads are wet 50% of the time, EPA emission factors suggest an average factor of somewhat more than 2 g/km. This may be felt as an overestimate. However, 2 g/km was selected as an average resuspension emission factor for DKI Jakarta. A recent evaluation of emission rates from roads, based on measurements, supports in general the EPA emission factors for paved roads, although the study concludes that more investigation is needed (Claiborn et al., 1995).

TSP-emissions:

The total annual emissions of TSP in Jakarta shown in Table 2.2 and Figure 2.6 indicate the following four dominant groups of emission:

- resuspension from road traffic;
- industrial processes;
- open refuse burning;
- construction (misc.).

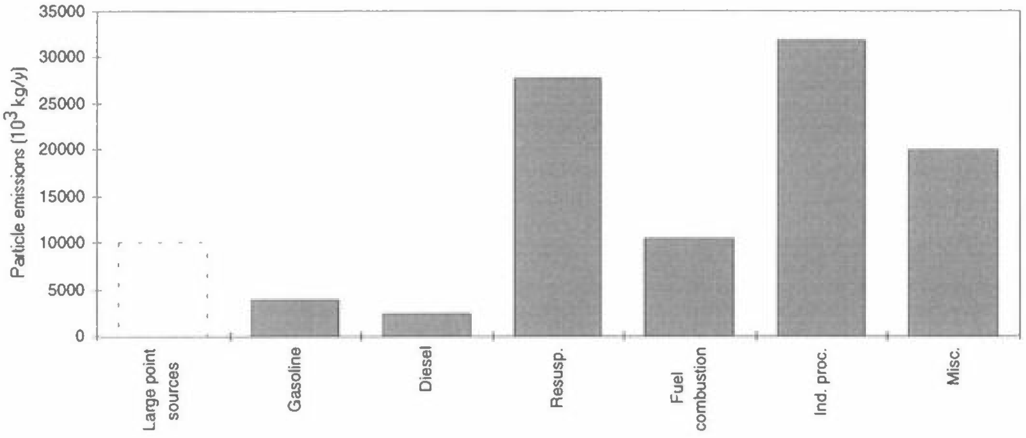


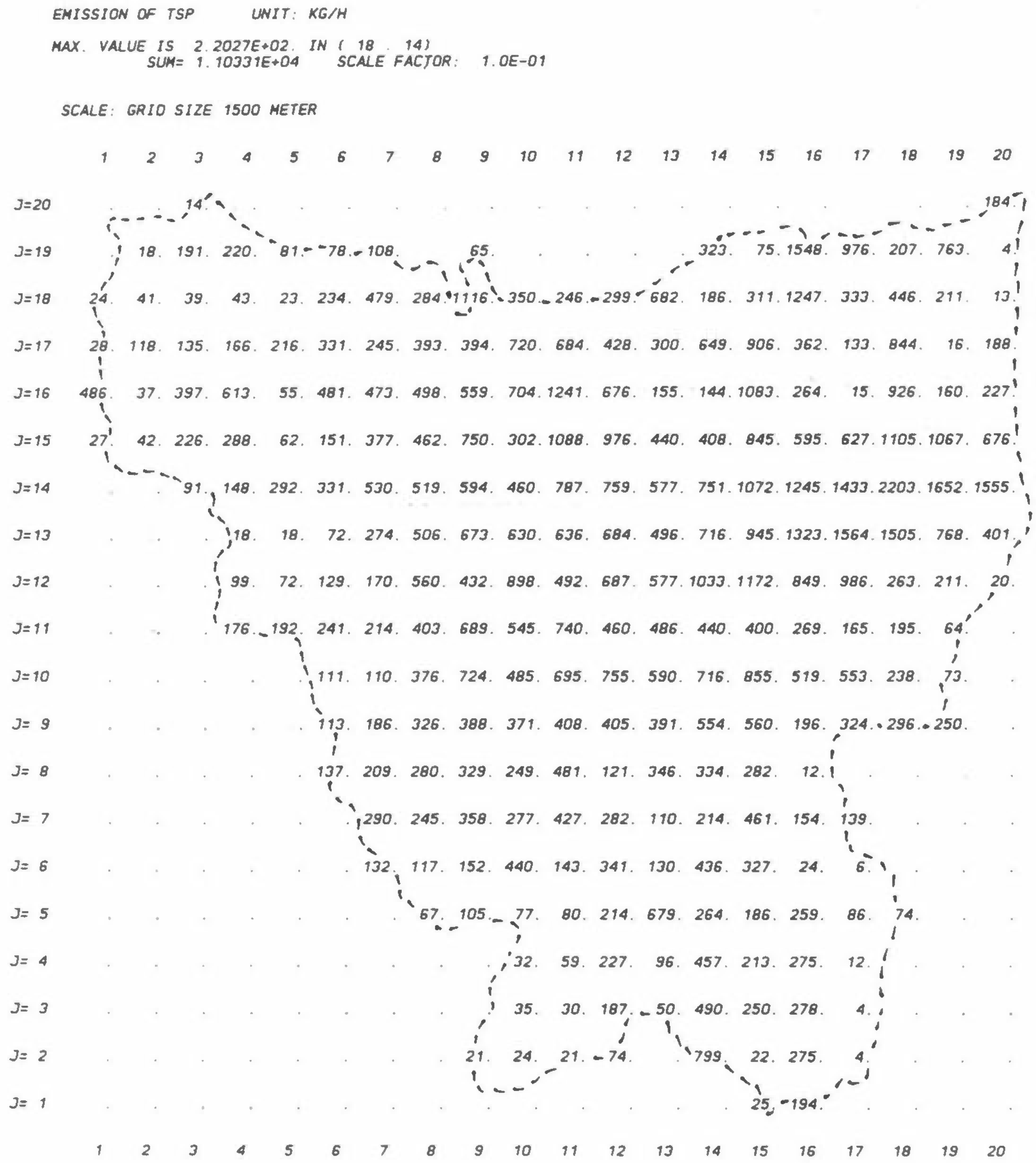
*Figure 2.6: Total annual emission of TSP from different groups of sources in 1990.
Unit:* 10^3 *kg/y.*

The source groups resuspension, open refuse burning and construction are sources that often are omitted in emission estimates. Resuspension occurs from unpaved roads in the dry season, but also along main roads there will be a dust deposit which is raised as the traffic passes.

For the URBAIR study in Metro Manila the TSP-emissions for refuse burning the estimate was based on 1 million households in Metro Manila each burning 0.5 kg of refuse per day. This is probably an overestimate and will vary with different values for the various regions of the city.

In Jakarta there is a lot of activity in construction of buildings and roads, from observations considerably higher than in Metro Manila. We have, in lack of actual data, used a total emission figure of 20,000 tons/y, the double of the figure which has previously been estimated for Metro Manila. These emissions were distributed spatially according to the traffic distribution.

Figure 2.7 shows the spatial distribution of TSP emissions in Jakarta.



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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
```

Figure 2.9: *Spatial distribution of TSP emissions in Jakarta. Unit: 0.1 kg TSP/h.*

NO$_x$-emissions:

Data on combustion in mobile and stationary sources have been used to estimate the amount of emission given in Table 2.2 and shown in Figure 2.6. Mobile sources burning gasoline and diesel fuel are the main source group for NO$_x$. Emissions of NO$_x$ from industrial processes in Jakarta are not known, but are assumed to be small.

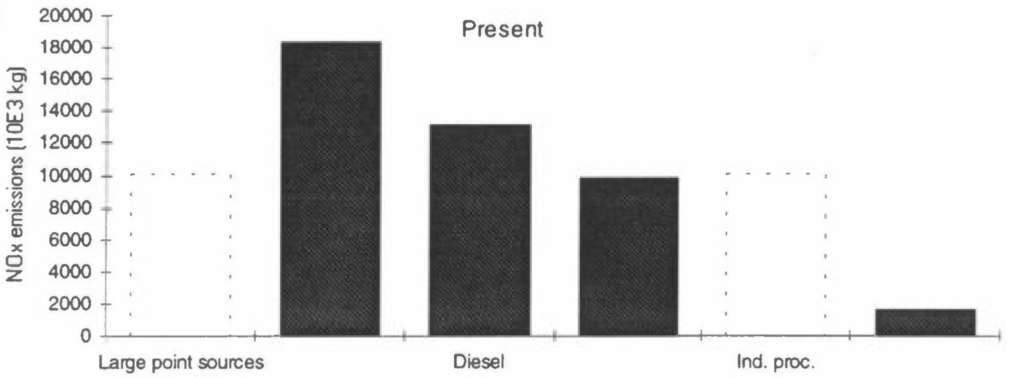
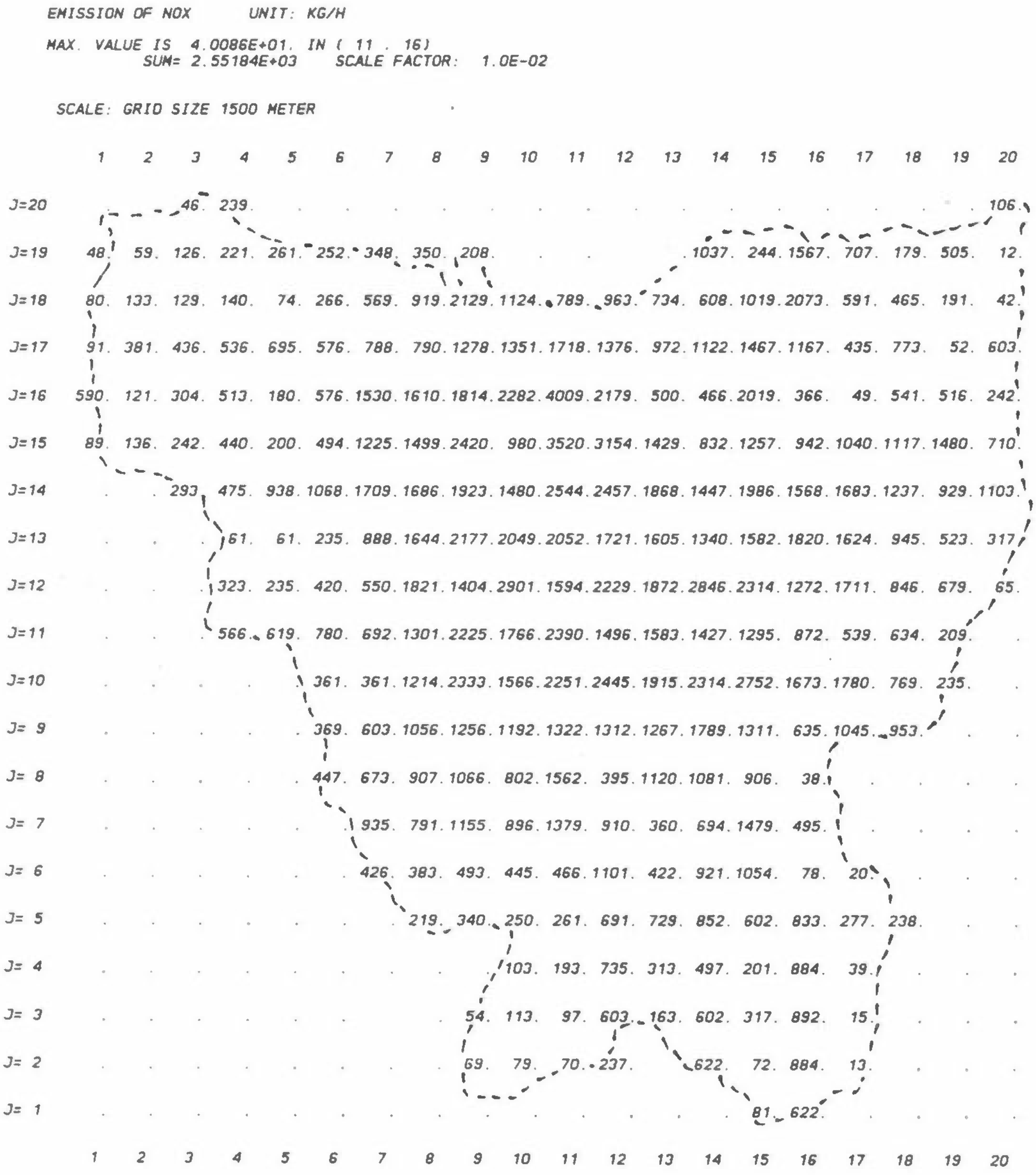


Figure 2.8: Total annual emission of NO_x from different groups of sources in 1990.
Unit: 10^3 kg/y.

Car traffic is the main source for NO_x-emissions in Jakarta and the spatial distribution within the area is fairly well known. Considering process emissions from industry NO_x is not considered to be an important component. Figure 2.9 shows the spatial distribution of NO_x emissions in Jakarta.



```
EMISSION OF NOX       UNIT: KG/H

MAX. VALUE IS  4.0086E+01. IN ( 11 . 16)
           SUM= 2.55184E+03    SCALE FACTOR:  1.0E-02

 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                  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
```

Figure 2.9: Spatial distribution of NO_x emissions in Jakarta.
Unit: 0. 01 kg NO_2/h.

Topography, climate and dispersion conditions in Jakarta

The area around Jakarta is very smooth with no local topography that can affect the dispersion conditions. The climate is very hot and humid. The solar heating during the day and the earth cooling during night may produce local land-sea breeze.

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

- 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 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 >6 knots).

The description of the dispersion conditions in Jakarta is given in Appendix 8. Yearly data from the BMG-weather station have been applied for calculation of annual average concentration values of NO_x and TSP in the Jakarta region. Figure 2.10 shows the occurrence of wind for BMG Jakarta. For Jakarta were stability data not available, so the calculations were performed with neutral conditions. The models are using 30°-sector averages, and the frequency distribution with 8 wind sectors is transferred to 30°-sectors.

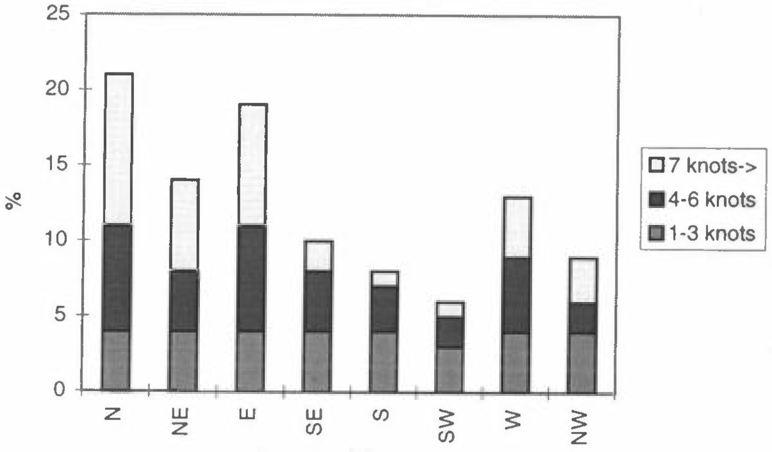


Figure 2.10: Annual wind frequency, BMG, Jakarta.

Lead (Pb)

The total content of lead in gasoline consumed in Jakarta in 1990 is calculated below.

Super 98	$105 \cdot 10^3\ m^3 \cdot 0.4\ kg\ Pb/m^3$	$= 42.0 \cdot 10^3\ kg$
Premium	$1\ 070 \cdot 10^3\ m^3 \cdot 0.4\ kg\ Pb/m^3$	$= 428.0 \cdot 10^3\ kg$
		$470.0 \cdot 10^3\ kg$

A part of the lead is deposited in the exhaust system. Measurements have shown that during urban driving, about 35% of the gasoline lead is exhausted immediately as particles in the PM_{10} fraction (Haugsbakk and Larssen, 1985). The exhaust system functions partly as a permanent, partly as a temporary deposit. During accelerations parts of the deposited lead is exhausted as larger particles. It is generally assumed that about 25% of the gasoline lead is permanently deposited in the exhaust system. Thus, the emission of lead to air in Jakarta:

In the TSP fraction	$353 \cdot 10^3$ kg Pb/year
In the PM_{10}-fraction	$164 \cdot 10^3$ kg Pb/year

In addition emission from industry using lead in their activity has to be considered.

2.3 Dispersion model calculations, DKI Jakarta

2.3.1 Dispersion conditions

General description of topography and, climate in Indonesia

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 moist air from the sea influence Jakarta (December-February). When the sun moves to the northern hemisphere Jakarta is influenced by dry air to a larger extent (June-August). Normally, Indonesia experience 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 run 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.

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

As pointed out in Appendix 8 the meteorological data tells that the dispersion conditions in Jakarta is complex and sharp gradients are found in wind between the center of the city and the coastline. These observations indicate that it is important to account for vertical exchange of pollution in a realistic way. Few high stacks occur in Jakarta, and the main contribution of pollution is caused by low level emissions. In these situations the spatial distribution of source intensity is nearly proportional to the distribution of concentration values. As a estimate of vertical exchange neutral stability conditions is used in the mixing layer.

In this way the influence of low level sources is probably overestimated in periods with strong sun radiation and underestimated during nighttime. For the annual average concentration a minor overestimation of the concentrations is expected. More accurate dispersion calculations may be carried out using numerical models describing actual dispersion conditions. It is important to apply actual measurements for input data and to control numerical errors.

In this study we have only had 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 wind roses for the measurements stations are so different that it is necessary to study the representativity of the stations.

Adverse meteorological situations in Jakarta

Studies in the Jakarta area indicate weak and short-lived inversions. During the night the cooling may produce ground-level inversions that may trap the emissions and give high concentrations, but as soon as the sun vises the inversions will break up.

One meteorological situation that can lead to high ground level concentrations will be when the local land-sea breeze is directed opposite of the large scale wind system. 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.

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.

2.3.2 Dispersion model calculations

Model description

The dispersion modelling in this first phase of URBAIR concentrates mainly on the calculation of long-term annaul average concentrations representing the average within 1.5x1.5 km^2 grids (“city background” concentrations). Contributions from nearby local sources in specific receptor points (e.g. street side, industrial hot spots) is evaluated additionally.

The dispersion model used for URBAIR in Jakarta is a multisource Gaussian model which treats area, point, and volume sources separately. Such a model is sufficient 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 as spatially uniform over the model area. The wind distribution shown in Figure 2.10 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 as well as 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 m emission height is used).

The Brookhaven dispersion parameter classification was 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, are not taken into account by this modelling exercise, which treats only dispersion of primary emission compounds. Further modelling and particle analysis should be done to estimate the extent of secondary particle formation.

TSP

Figure 2.11 shows calculated and observed TSP concentrations in Jakarta.

The contribution to annual average TSP-concentrations from three groups of sources are

- traffic;
- industry;
- domestic burning;

and an extra-urban background concentration (70 μg/m^3) has been added.

It is seen that the contributions have different spatial distributions.

Traffic is the most important source to TSP concentrations, and the contribution has a maximum of 120 μg/m^3 over the center of the city. Of this, resuspension contributes 100-110 μg/m^3 . The concentration distribution as a result of industrial emissions shows a maximum of 70 μg/m^3 over the industrial areas in the eastern part of the city. The emissions from domestic burning shows a smaller maximum (10-15 μg/m^3) in the suburbs as a result of the population distribution and dispersion conditions.

The observed concentrations are inserted on the figure showing the total concentrations.

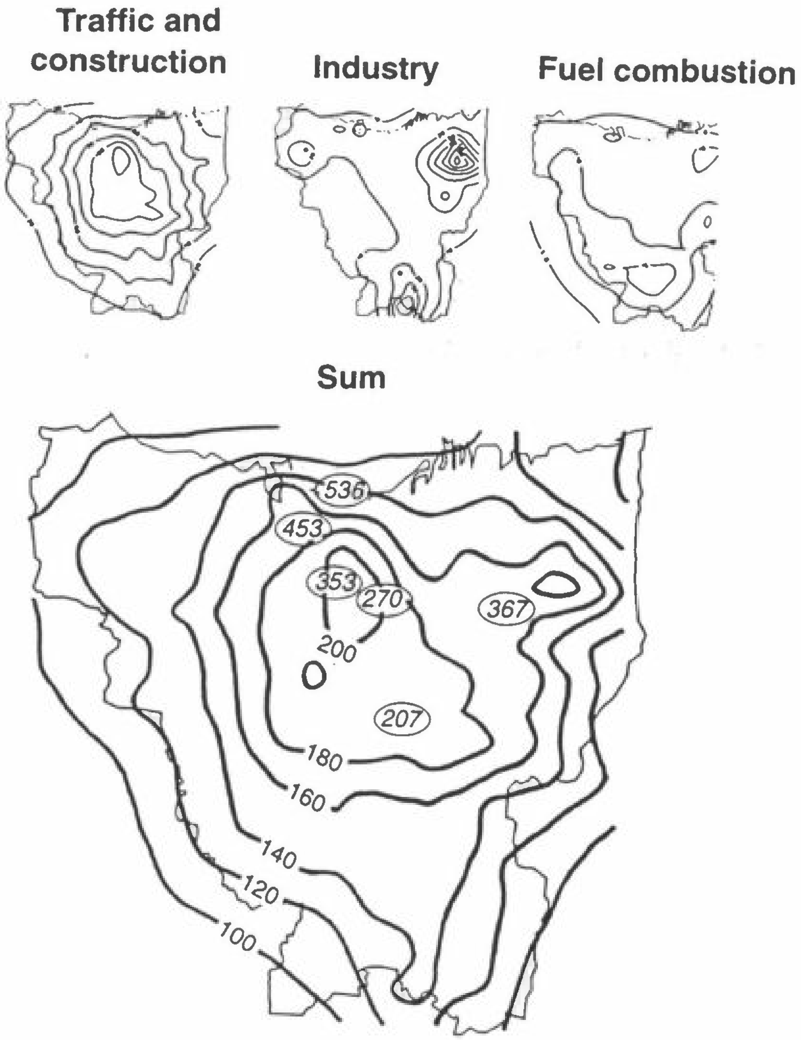


Figure 2.11: Observed (encircled values) and calculated TSP concentrations in Jakarta.
Unit: µg/m³.

Generally, the calculated values are lower than the observed TSP-values, in particular close to the harbour in the northern part of the city. Some of the measuring stations are located close to streets with high traffic intensity. This may explain some of the discrepancy. However, in the northern part it is not possible to explain the observed concentrations by the estimated emissions.

In order to improve air quality effectively in this 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 underestimated as well.

NO_x

The concentration contribution from each of the source groups to the total concentration distribution is shown in Figure 2.12 comparing observed and calculated concentrations.

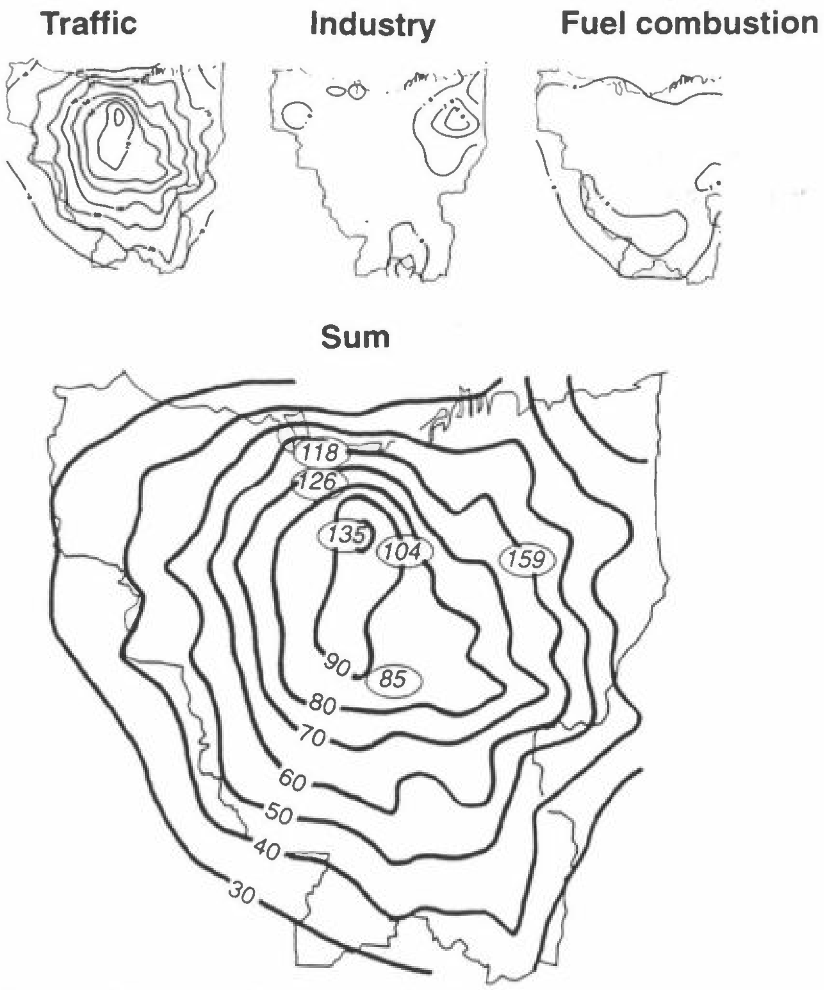


Figure 2.12: Observed (encircled values) and calculated NO_x concentrations in Jakarta.
Unit: $\mu g\ NO_2/m^3$

A reasonable correspondance between observed and calculated concentrations is found in the central and southern part of the area. In the northern part (close to the harbour) and in the eastern part (close to the industrial area) the calculated emissions remain an underestimate of observed concentrations.

The calculated concentrations are separated in the following three parts as shown in the figure:

- car traffic;
- industry;
- domestic burning;

and an extra-urban background concentration; 15 $\mu g/m^3$ has been added.

Some of the observations may be influenced by local pollution concentrations as a result of emission from a main street located in the neighbourhood of the measuring station.

It is seen that mobile sources are the most important source for NO_x pollution.

Measurements from the area indicate that NO_2-concentrations are 30-50% 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 emissions.

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

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

2.3.3 Pollution hot spots

At pollution hot spots, significant pollution sources give large concentration contributions in their neighborhoods, adding to the general city background.

Pollution hot spots are:

- along the main road system;
- near industrial areas with significant emissions 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. Lines of additional pollution along the main roads occur as a result of local traffic emisisons.

2.4 Population exposure to air pollution in Jakarta

Because of the lack of data for the emissions of NO_x from industry, we could not calculate a total NO_x-field, thus the exposure calculations are restricted to TSP exposure.

The population exposure was estimated on the assumption that the number of inhabitants in each grid square is exposed to annual average TSP-concentrations as shown in Figure 2.11.

In order to account for increased concentrations along roads with high traffic intensity, concentration calculations were made for typical emission and dispersion conditions. Based on a such calculated decrease in TSP-concentration with increasing distance from the road as shown in Figure 2.13, an increment in pollution concentration is given additional to the grid value for the zone which is

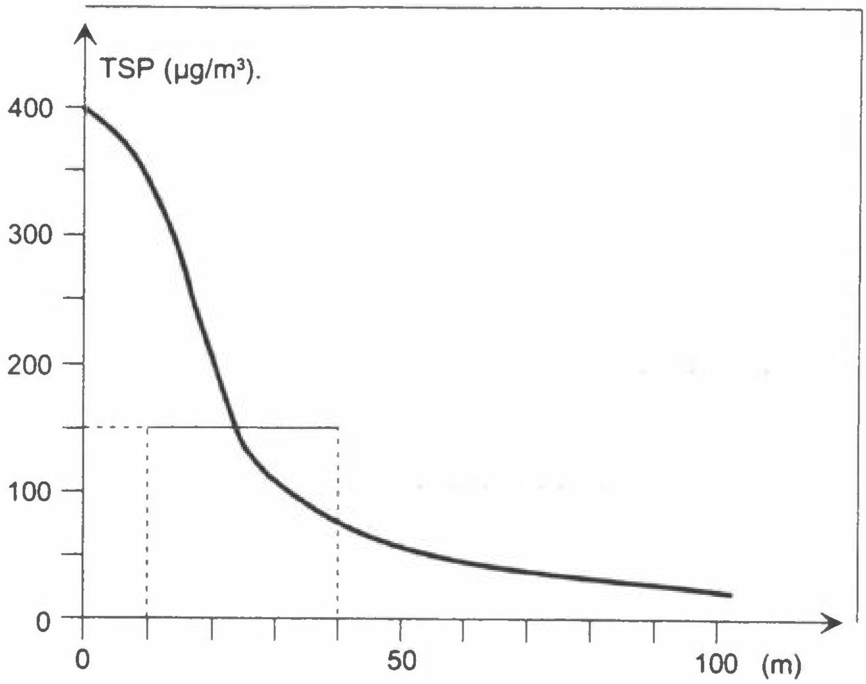


Figure 2.13: Long term average TSP-concentration close to road with high traffic intensity (1 car/s = 3 600 cars/hour) as an annual average.

The results of the TSP exposure calculations are shown in Figure 2.14 presenting the percentage of the Jakarta population that is, according to this procedure, exposed to annual TSP concentration values given above. 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 the total exposure and for the effect of source reduction on exposure is given in Table 2.6.

Table 2.6 also shows the effect on the pollution distribution accounting for commuting exposure. It is assumed that 30% of the population in each grid square is exposed to concentration at the roads 2 hours during the day during commuting. With reference to Figure 2.13 a typical road concentration of 400 µg/m^3 is used for calculating the influence on annual average concentration.

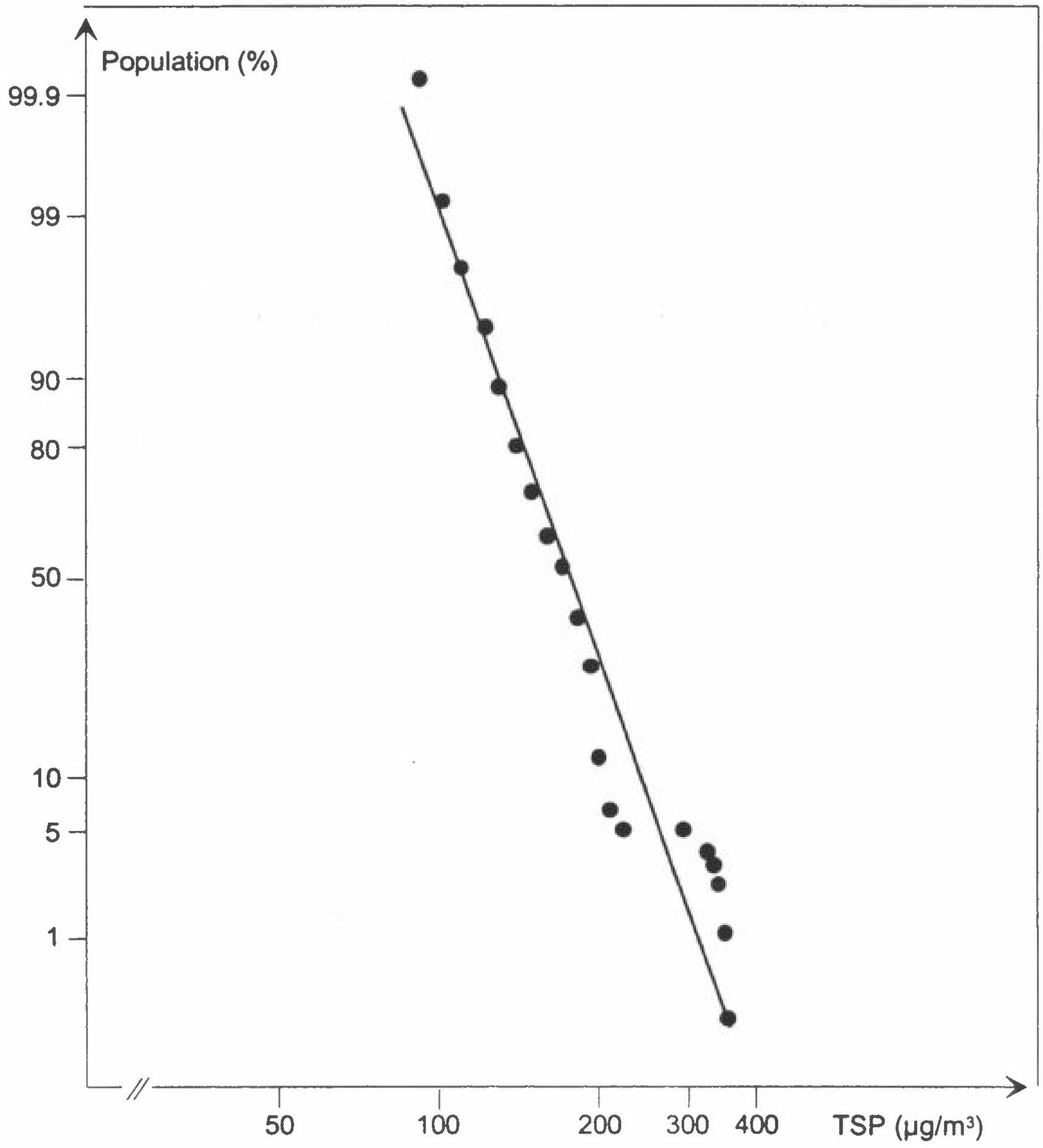


Figure 2.14: Percentage of Jakartas population that are exposed to annual average TSP-concentrations above different values as given along the x-axis.

Table 2.6: *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	329 558	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

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

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.

2.5 Summary of the Air Quality Assessment

DKI Jakarta Air Quality

- Concentrations of TSP have for many years been measured regularly at 17 fixed locations, a few days per month. The locations are partly street-side, partly area-representative stations, some in industrial areas.

- This data base, which has its limitations, show the following:

    - Relative to Air Quality Guidelines, TSP is the most important pollution parameters in Jakarta.

    - Observed TSP-concentrations frequently exceed Air Quality Guidelines (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 km outside Jakarta area indicate that secondary pollutants are developed as a result of NO_x and VOC emission in Jakarta. Further investigations are urgently needed to clarify the extent of this pollution problems.

Emission sources

Rough estimates of emission of TSP in Jakarta region indicate that a considerable part of total emissions comes from car traffic, industrial processes and open burning. The estimates are based on statistical data on activities producing pollution and on emission factors for the Jakarta region. Further investigations are of vital importance to control and improve the rough estimates.

Road traffic is the main source of NO_x emissions. In this study, no data to estimate NO_x-emissions from industry was available. Industrial process emissions of NO_x should be estimated to get a total picture, but these emissions are expected to be of less importance.

Population exposure

The numbers of residents exposed to different levels of TSP- (or PM_{10}-) concentrations (Table 2.6) remain the basis for estimation of adverse health effects.

The WHO Air Quality Standard of 60-90 µg/m^3 TSP as annual average is exceeded for all residents in DKI Jakarta. For each grid the mean concentration is compared with different concentration levels, and if the concentration is above the value, the good population is counted. In addition to this, several people are exposed to sub-grid exposure from main roads, as shown in the lower part of Table 2.6 and the right part of Figure 2. These will be drivers (8 hr/day), commuters (½-2 hr/day) and roadside residents (24 hrs).

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

To evaluate the concequenses of different development strategies to exposure calculations it is important also to have data for the future population distribution.

Due to the lack of industrial NO_x emission data, annual exposure to NO_x is not calculated. High road-side exposure from NO_x is expected. The observed NO_x-values from the measurements indicates either that NO_x is not an area problem, or that the measurements or stations are not representative for the region.

Background for calculating effects of abatement measures

A simplified procedure for calculating emissions and the effects of different control measures to 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 new calculated concentration distribution new exposure calculations should be performed, and from these new effect calculations. This may also be programmed into spreadsheets.

2.6 Needs for improvement of the air quality assessment

2.6.1 Main shortcomings and data gaps

Monitoring

The results of concentration measurements indicate that high TSP concentrations, in particular in the northern and central part of the city are the main pollution problem in Jakarta. Measurements should be carried out to specify the typical chemical composition of the particles on the different stations, in particular in air pollution episodes. The effects of high TSP concentrations depend 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.

The present measurements in Jakarta can be briefly characterized as follows:

- 24 hour samples of TSP, NO_x and SO_2;
- Monitoring network run by different agencies, with different routines for sampling, analysis calibration and reporting;
- Detailed station descriptions is needed, for control of local influence;
- Few measurements in the other parts of Jakarta;
- Hourly meteorological data (wind, stability etc.) from several places are needed.

It is clear that the agencies are operating under considerable financial constraints, affecting methodological and manpower capacities. It is nevertheless important to improve the air quality monitoring in the whole Jabotabek area (DKI Jakarta and the surroundings), as the air entering DKI Jakarta comes from the environs.

It is anticipated that 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 area 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 direct to a lab database, via telephone or modem.

by a continuous control of on-line data the quality of the data will be improved, and it should be **one** agency that is responsible for the monitor network control.

In particular, O_3 measurements should be carried out soon in Jabotabek to determine whether the area has a photochemical air pollution problem. Such measurements should be carried out continuously over a one-year period at sites inside and outside DKI Jakarta.

Emission

Spatial investigation should be planned to specify:

- Industrial emissions (questionnaires and measurements);
- Open burning;
- Resuspension;
- Traffic countings;
- Traffic composition.

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

Quantification of effects

In Chapter 4 the impact of PM_{10}-concentrations and lead on health in Jakarta is discussed. The measured values of SO_2, NO_x and O_3 (photochemical air pollution) are so low that they seems today not to represent any problem to health.

Ostro (1994) has made studies of dose-effect relations in the US and his findings should not be used directly in Jakarta or other tropical places. The temperature and humidity is higher in South-Asia than in the US or Europe where most of the dose-effect studies has been made. Studies of adverse effects should be further developed to identify the urban cost function for Jakarta. It will also be necessary to study dose-effect relations to building materials.

2.6.2 Proposed Actions to improve the Air Quality Assessment

"Actions"	**Time schedule**
Air Quality Monitoring • Design and establish a modified/improved/extended ambient air monitoring system - evaluation of sites; number and locations - selection of parameters/ methods/monitors/operation schedule. - necessary upgrading of laboratory facilities, and man power capacities.	This activity is started as a part of the JICA study in Jarta, started in 1995.
• Design and establish a Quality Control/Quality Assurance System	This activity should also start immediately, phased in with the establishment of the improved monitoring system, and the upgrading of the laboratory.
• Design and establish an Air Quality Information System, including - database - information to . control agencies . law makers . general public.	This activity should be started as soon as modern, on-line monitoring stations have been established.

Emissions • Improve emission inventory a) Produce inventory of industrial emissions (location, process, emissions, stack data) b) Improve inventory of road and traffic data c) Improve inventory of domestic emissions d) Study resuspension - from roads - from other surfaces • Develop an integrated and comprehensive emission inventory procedure, incl. emission factor review, update and QA procedures. Must cover the whole Jabotabek area. • Improve methods and capacity for emission measurements.	This is a part of the JICA study in Jakarta, which is started i 1995. 1. priority: • industrial emission inventory • study of resuspension from roads • start the developement of an emission inventory procedure • collecting traffic data • classifying the road network.
Population exposure Assess current modeling tools/methods, and establish appropriate models for control strategy in DKI Jakarta..	This activity should be started without delay by establishing a group which will have a long-term responsibility for performing such modelling in DKI Jakarta.

3. Developments of emissions in Jakarta

3.1 Introduction

In this chapter, an effort is made to indicate developments of the emissions and air quality in Jakarta when no measures are taken in addition to those already decided upon. Basically such a forecast is derived from:

- emissions by the various source categories in 1990 (see Chapter 2);
- forecasts of those variables[1] influencing emissions, such as fuel consumption, vehicle mileages or production figures;
- technological developments relevant to emissions but independent of environmental policies;
- environmental measures already taken (see Chapter 5);
- the number of people exposed to air pollutants.

The time horizon is the year 2010. This choice is based on the assumptions that it will take at least fifteen years to deploy an environmental policy; note, for instance, that typical lifetimes of vehicles are 15-20 years, which implies that renewal of the vehicle fleet (clean vehicles) is only completed after 15 to 20 years (unless chosen for a forced development).

The lack of reliability of the emission inventory, in particular with respect to industrial emission constitutes a serious shortcoming in the information required for making forecasts; this fact should be acknowledged when drawing conclusions from the presented results (Section 3.8).

3.2 Traffic

The evolution over time of emissions due to road traffic is the result of various developments:

- the size of the vehicle fleet;
- the vehicle technology (gasoline - four-stroke, two stroke/mixed lubrication -, diesel);
- the use of emission control techniques required by legislation;
- the pattern of use (annual mileage, driving pattern).

The number of vehicles and use patterns are in turn dependent on socio-economic developments such as income, demographic situation, availability of alternative modes of transport (mass transit systems) and the like. A study taking into account these type of factors has been carried out for Surabaya (PT. Mojopahit Konsultana, 1991). A similar study for Jakarta was not found.

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[1] Emission = emission factor (Ef) * emission explanatory variable (eev).

A key factor is the development of the vehicle fleet. Table 3.1 presents our projection of its development, only for demonstration purposes. The chosen growth rates are in fact the experienced rates in the period 1980-1990 as derived from the statistical data in Table 3.1 (see also Chapter 1 and Appendix 4). The numbers refer to 5 statistical categories of vehicles. In order to account for differences in the emission characteristics of vehicles a further division is made, as indicated. On top of this division, the vehicles are grouped by engine type (gasoline engines, either four stroke or two stroke (mixed lubrication), and diesel engines). These growth rates are used for making forecasts. A more elaborate projection, taking into account developments in income, income elasticity of vehicle ownership and other factors was outside the scope of this study.

Table 3.1: The Jakarta vehicle fleet and assumed growth rates (%).

Vehicle category	1980	1990	Growth rate historical	Growth rates 1990-2010
Passenger cars	222,345	441,843	4.4	4.4
Trucks	77,781	174,944	4	
Pick-up trucks				4
Medium trucks				4
Heavy trucks				4
Buses	29,350	152,444	11.5	
Buses (large)				2
Minibuses				11
Motorcycles	428,144	762,874	4	4
Bajaj	10,000	14,000		2

The growth of large buses is assumed to be low. Due to organizational and financial constraints, it appears less likely that a public transportation system with buses can grow very fast

It is assumed that the annual mileages associated with each vehicle category increases with the same growth rate. In fact, the calculation of future emission is based on a projection of future mileage of the Jakarta vehicle fleet (mileages to be multiplied with appropriate emission factors).

3.3 Power production

Production of electricity in large power plants hardly contributes to ambient concentrations in Jakarta due to high stacks, resulting in an effective dispersion of the emitted pollutants. Therefore, power production is presently of less significance in comparison with other activities. Its contribution is not accounted for.

3.4 Fuel combustion (other than in power production)

Industrial

The preferred fuel is distillate fuel. Coal, coke, and gas are only used in small quantities according to the available data and contributes only little to emissions of PM_{10}. It is assumed that fuel consumption increases with a rate of 10% over the period 1990-2010, in line with the estimate for the growth rate of the output of the Indonesian manufacturing sector found in a recent World Bank report (Calkins et al., 1994).

Domestic/small industry

The major source in this category is "open burning" (see Chapter 2). It is assumed that this emission develops along with the population growth (Section 3.7).

3.5 Industrial processes (non-combustion sources)

The inventory distinguishes six types of industrial process emissions. This category constitutes one of the weakest spots in the inventory. Unfortunately, it appears to be a major source. Regarding the uncertainties involved, an extrapolation of the emissions into the future makes little sense.

3.6 Construction, airport and harbour operations

This category, a miscellaneous group, contributes to some extent to the emissions. It is assumed to develop along with the industrial combustion (section 3.4).

3.7 Population at risk

The Jakarta population was in 1980 6.5 million. Since then the population has grown to 7.9 million in 1985 and 9.4 million in 1990. It is assumed that this trend continues: a growth rate of 3.5% (1990-2010).

3.8 Conclusions

The results of the calculations are presented in table 3.2.

Table 3.2: Preliminary scenario for developments of PM_{10} emissions (tonnes) in Jakarta.

	1990	2000	2010
Gasoline fueled vehicles	3,916	5,923	9,134
Diesel fueled vehicles	2,457	3,966	6,901
Resuspension traffic particles	6,958	9,932	16,426
Process emissions	13,586	13,599	13,599
Fuel combustion (except open burning)	2,350	3,430	5,145
Open burning	7,027	9,913	13,983
Other (airport/harbour/construction)	5,076	6,540	8,673
Total	41,370	53,303	73,861

It appears from these results that over the coming year emissions will strongly increase, given the development trends assumed. Drawing more conclusions than this fairly obvious one, requires a further analysis, especially with regard to resuspension emissions and the emissions from industrial non-combustion sources (process emissions).

4. The health impacts of air pollution and their valuation

4.1 Introduction

Air pollution in urban areas is a major public concern in most countries. As the level of air pollution is highly related to energy use, and energy use is highly related to economic development, air pollution has hit large cities in the industrialized countries in Europe and North America first. The major reason for concern is the effect of air pollution on public health. Exemplary of this are the "killer fogs", which hit London in 1952 and 1956, causing 4,000 and 1,000 deaths, respectively (Lave and Seskin, 1977).

With the economic development and growth of large cities in Asia, air pollution problems have become endemic to them also. This chapter presents an overview of major impacts of the air pollution in Jakarta including an estimation of the monetary value on these damages.

In Chapter 2 it is concluded that the concern about air pollution is mainly due to high concentrations of suspended particles (TSP and PM_{10}) and lead, both exceeding health guidelines. The latter appears not to be the case for for air pollution due to SO_2, NO_x and ozone (photochemical air pollution). Therefore, this chapter concentrates on PM_{10} and on lead. Figure 4.1 present the frequency distribution of the exposure to PM_{10}.

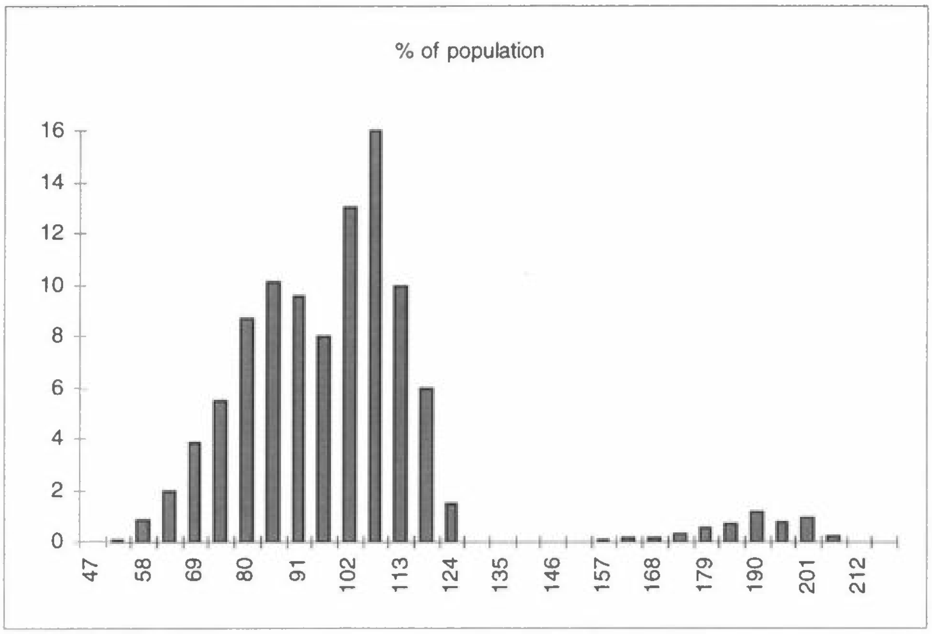

Figure 4.1: Distribution of exposure of population to PM_{10}.

PM_{10} is a notation for the smaller particles (<10 µm diameter) in TSP. As PM_{10} is the main harmful component in TSP, we concentrate on PM_{10}, instead of TSP.

The estimate of the impacts on health is mainly based on Ostro's work described in the general URBAIR report, which was updated recently (Ostro, 1994). In fact the present report (this chapter) may be seen as an extension of his Ostro's work as published by Calkins et al. (1994), the difference being the "detailed" exposure data used here. Guidelines for acceptable air concentration - "no-damage" benchmark - are proposed by the World Health Organization (WHO). For an overview of health impacts, particularly of lead, in Jakarta we refer to the URBAIR report of Achmadi (1994).

It is emphasized that health is not the only adverse impact of air pollution, only beacuse of lack of appropriate data it was not possible to assess quantitatively different impacts such as reduction of economic life of capital goods, tourism, crop growing and other intangible impacts.

Not an air pollution problem by itself, but a related problem is traffic congestion which is severe in Jakarta. Just to give an indication of the possible damage of congestion, let us suppose that 1/3 of the population (ca. 9.4 million in 1990) loses on average two hours per day during 250 days per year. With an hourly wage rate of Rp 840, this results in a damage of ca. Rp 1316 billion.

Sections 4.2 and 4.3 deal with the impacts on death rates and on health in Jakarta. Section 4.4 presents a calculation of the costs wich can be attributed to these impacts.

4.2 Death (mortality)

The impacts on health are divided in mortality (excess death) and morbidity (excess cases of illness). Mortality and morbidity are derived from air quality data using dose-effect relationships. In principle such relations are found by statistical comparison of death rates and morbidity in urban areas with different air quality. Appropriate dose-effect relations have been estimated by Ostro (1994). Admittedly, these dose-effect relations are derived from studies of the situation in the US and it is somewhat speculative to use them for the situation in Jakarta. But until specific dose-effect relations are derived for tropical conditions, Ostro's relations are the best available. The dose-effect relations of Ostro are described in more detail in the general URBAIR report.

Although it is clear that indoor pollution, e.g. caused by cooking, can also damage health, we restrict the analysis to outdoor concentrations.

Mortality due to PM_{10}.

The relation between air quality and mortality used is:

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

where

P: number of people exposed to a specific concentration (from Figure 4.1)
c: crude rate mortality = 0.007 in Jakarta (Calkins et al., 1994)
PM_{10}: Annual average concentration (μg/m³) of PM_{10} (particles with a size smaller than 10 μm)

The number 41 in the equation is the WHO-guideline for long term annual average TSP concentrations (75 μg/m³), taking into acount that PM_{10} concentrations typically are ca. 55% of the TSP concentrations.

From this relation, the data presented in Chapter 2 - as summarized in Figure 4.1 - it can be concluded that the excess mortality due to PM_{10} was about **4500** cases, at a population of 9.4 million. Note that the mortality is proportional to the population. If the air quality would not detoriate the mortality will still increase along with the population growth.

Mortality due to lead

In the dose-effect function of mortality caused by lead, the diastolic blood pressure (DBP) plays a role. The relation between lead concentration and change in DBP is estimated as:

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

where [Pb in blood] indicates the concentration of lead in blood (μg/dl).

The relation between lead in blood and lead in air is complex, but a good approximation is proportionality. In that case:

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

where [PbA] indicates the concentration of lead in the air (μg/m³).

Evidence of a threshold level of [PbA] is scant, and the threshold might well be zero. However, WHO guidelines, a benchmark for $[\text{PbA}]_{\text{old}}$, of 0.5 μg/m³ can be used. If we fill in the existing lead concentration for $[\text{PbA}]_{\text{new}}$ we derive the change in DBP. The change in the 12 year probability of death related to the change in blood pressure due to lead is estimated as:

$$\Pr(M) = (1+\exp\text{-}(-5.315 + 0.03516\,\text{DBP}_{\text{old}}))^{-1} - (1+\exp\text{-}(-5.315 + 0.03516\,\text{DBP}_{\text{new}}))^{-1}$$

As the reference value DBP_{old} can be chosen 76, the average value in the US.

The average 24-hours concentrations measured in Jakarta vary between 0.5 and 2.0 μg/m³, but no exact exposure figures could be derived. Therefore, use was made of the study by Calkins et al. (1994), who estimated on the basis of the same dose-effect relations 340 cases of mortality per year due to lead.

4.3 Illness (morbidity)

Particulates. The following effects can be attributed to particulates: chronic bronchitis (CrBr), restricted activity days (RAD), respiratory hospital diseases (RHD), emergency room visits (ERV), bronchitis (B), asthma attacks (A) and respiratory symptoms days (RSD).

We use the following dose-effect relationships, which are described in more detail in the general URBAIR report:

RAD : the change in restricted activity days per person per year per $\mu g/m^3$ PM_{10} is estimated at 0.0575. If we use again the WHO guideline, the change is 0.0575 x ($[PM_{10}]$ - 41).

RHD : the change in respiratory hospital diseases per 100,000 persons is estimated at 1.2 per $\mu g/m^3$ PM_{10}. Using the WHO guideline, the respiratory hospital diseases per 100,000 persons are estimated at 1.2 x {$[PM_{10}]$ - 41).

ERV : the number of emergency room visits per 100,000 persons is estimated at 23.54 per $\mu g/m^3$ PM_{10}, and the total number per 100,000 persons at 23.54 x ($[PM_{10}]$ - 41).

B : the change in the annual risk of bronchitis in children below 18 years is estimated as 0.00169 x ($[PM_{10}]$ - 41). The number of children below the age of 18 is estimated at 35% of the total polulation. (Achmadi, 1994).

A : Likewise, the change in daily asthma attacks per asthmatic person is estimated at 0.0326 x ($[PM_{10}]$ - 41). The number of asthmatic persons is estimated at 7% of the population (Achmadi, 1994).

RSD : the number of respiratory symptoms days per person per year is estimated at 0.183 x ($[PM_{10}]$ - 41).

The impact of PM_{10} air pollution on health in Jakarta are summarized in Table 4.1.

Table 4.1: Impact of PM_{10} air pollution on health in Jakarta, 1990.

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

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

Lead

Like in the case of mortality evidence on a threshold level is scant and the threshold level might well be zero. But for practical purposes the WHO guideline could be used. The main effects of lead are hypertension, coronary heart disease and decrement of intelligence in children. The relation between the change of the probability of hypertension and a change in air quality is estimated as

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

in which

$[PbA]_2$ is the ambient lead concentration in the air. As $[PbA]_1$, the WHO guideline of 0.5 µg/m³ can be used.

The dose-effect relationship of coronary heart disease (CHD, the increase in the 10 years probability of a case) is:

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

in which DBP can be treated as in Section 3.2.1.

For the decrement of IQ points of children is:

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

in which for $[PbA]_1$ the WHO standard can be used.

For the benchmark concentration we use the WHO guideline of 0.5 µg/m³. It can be argued that a no-effect level is lower, possibly zero, also because the lead intake from air adds to other intakes.

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 relations. These results are given in table 4.2.

Table 4.2: Health impact of lead air pollution (1992).

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

4.4 Valuation of health impacts

Mortality

Admittedly, a monetary value for mortality is a debatable figure. Many argue that, on ethical grounds, such valuation cannot be made. However, deleting mortality damage would lead to a serious underestimation of total damage.

For the value of a case of mortality, two different approaches can be used; one is based on willingness to pay (WTP), the other on salaries. The WTP approach is described in the general part of the URBAIR report. In the US a value of ca US $ 3 million per statistical life is often used. Although such a valuation is not readily transferable from one country to the other, an approximation can be derived by correcting the US figure by a factor of the purchasing power parity in Indonesia divided by the purchasing power parity in the USA. This factor is 2,120/21,900 = 0.096 (Dikhanov, 1994). At an exchange rate of 1 US$ = Rp 2233, this results in a value of Rp 650 million per statistical life in Indonesia.

The other approach is based on lost income due to mortality. The value of a statistical life is then 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:

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

with w = average annual income (Shin et al., 1992). In this method, the value of those persons without a salary (e.g. housewives) is taken to be the same as the value of those with a salary. If we estimate the daily wage in Jakarta Rp 6,700 (US$ 3.00) and taking 200 working days in a year, w = Rp 1,340,000. With a discount rate d = 5%, V = Rp 23.45 million per statistical life.

Considering both approaches to the valuation of premature death the cost figure to associate with the increased mortality due to PM_{10} air pollution in 1990 ranges from 2,836 billion Rupiahs to 102 billion Rupiahs.

Morbidity

The general URBAIR report presents an estimation of morbidity (medical treatment, lost earnings), based on values from the US for the various categories of morbidity. These figures are here corrected for differences between US and Indonesia in purchasing power with a factor of 0.096.

Prof. Achmadi (1994) made for this URBAIR project estimation of morbidity valuation in Jakarta. Both estimates are given in Table 4.3, together with the total costs.

Table 4.3: 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 Indonesion 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 (PM10)			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

4.5 Conclusions

The damage of air pollution consists of various components: damage to human health, materials, vegetation and crops, buildings and monuments ecosystems and tourism. It is not possible to value all of them. But damage to human health is estimated, by using US dose-effect relationships. Damage to health consists of mortality and morbidity. The valuation of loss of life is difficult and no more can be given than an estimate of the order of magnitude. If estimated with the human capital approach (i.e. lost earnings due to premature death), the value of a statistical life amounts to ca. Rp 23.5 million.

Costs of morbidity (illness) are more reliable, relatively. They consist of foregone wages and costs of medical treatment. Estimates were made specifically for Jakarta, of costs of morbidity due to concentrations of PM_{10}. This valuation of damage to human health contains a tendency to underestimation as the suffering due to illness or premature death is not included.

Table 4.4 presents the result of a calculation aimed at attributing air-pollution (PM_{10}) impacts to source categories. These figures, calculated via an approximation procedure from the results of the Jakarta air quality modelling (see Figure 4), are basically the reduced impacts resulting from leaving the indicated sources from the calculations. The health costs are based on Achmadi's (1994) information.

The damage due to lead is estimated at Rp 291 billion (see Table 4.3). Other health damage (e.g. due to ozone, NO_x, SO_2) could not be estimated for lack of exposure figures.

Table 4.4: Air pollution (PM_{10}) impacts attributed to source categories 1990.

Source category	Emission (tonnes)	Mortality (cases)	Respiratory symptom days (millions)	Health costs Rp (billion)
All sources	42417	4364	100	725
Gasoline cars (four stroke)	1284	730	17	28
Motorcycles/Bajaj	2700	1460	34	54
Diesel fueled vehicles	2363	1158	27	44
Combustion of heavy fuel oil (domestic sources)	1430	13	0.3	2
Half of process emissions*	7000	336	8	41

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

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

Table 4.5: An assessment of the benefits of emission reduction.

Source category	Emission reduction (%)	Emission reduction (tonnes)	Avoided mortality	Avoided RSD (million)	Avoided health costs (Rp billion)	"Marginal" benefits (Rp million per tonne reduced)
Traffic	25	5230	854	20	124	24
Industry (process emissions)	25	3600	600	14	87	24
Diffuse/ domestic	25	3500	26	0.6	3.8	1

Based on Table 2.2 calculations could be made of which the results are shown in Table 4.5. These results indicate that measures should firstly aim at reduction of emissions from both traffic and industry, as opposed to domestic emissions (open burning and fuel combustion), that is if not taking into account the costs of the measures.

It should be considered that health impacts and associated costs tend to increase along with a detoriating air quality, which can be expected from increasing emissions (see table 3.2) and an increase of the population at risk, along with the increase of the population of Jakarta.

5. Existing institutions, functions, and policy plans

5.1 Institutions

Recent publications available to describe the institutional hierarchy of environmental/air pollution management and control in Indonesia and Jakarta are:

- LLAJR Air Pollution Monitoring and Control, Draft report, March 1991 (K. Bachrun, Institut Teknologi Bandung, ITB).
- An overview of air pollution in Indonesia, July 1992, (J.H. Kozak and Drs R.P. Sudarmo, Environmental Management Development, Indonesia).
- Analysis of key institutions affecting urban environmental quality in Jakarta Region, August 1992, (F. Bulkin, Institute of Research and Development of Social Sciences of the University of Indonesia in cooperation with MEIP-World Bank).
- Regulations and Institutions in Air Pollution (1994). An URBAIR report by Dr Budirahardjo.

In these reports, the institutions and the problems regarding their efficiency and performance is discussed in some detail. The following is a summary of this discussion.

KLH

The State Ministry of Population and Environment, (KLH), is the main institution regulating environmental management and control on the central governmental level. The environmental control legislation started with Decree 02/MENKLH/I/1988 issuing pollution standards for air and water. Regarding air pollution, the 2nd Assistant-Minister coordinates mobile source air pollution management together with the Ministries of Industry and Health. The 3rd Assistant-Minister coordinates industrial air pollution control together with the Ministries of Industry and the Interior.

BAPEDAL

The BAPEDAL (the Environmental Impact Control Board) was established in 1990 as a central control agency for environmental control in Indonesia. This should work in addition to the state Ministries. The BAPEDAL organizational structure from 1990 is shown in Figure 5.1. In this chart, the office of Air Pollution Control lies under the Directorate for Marine and Air Pollution control, again under the Deputy for Environmental Pollution Control. The organizational structure has later been revised.

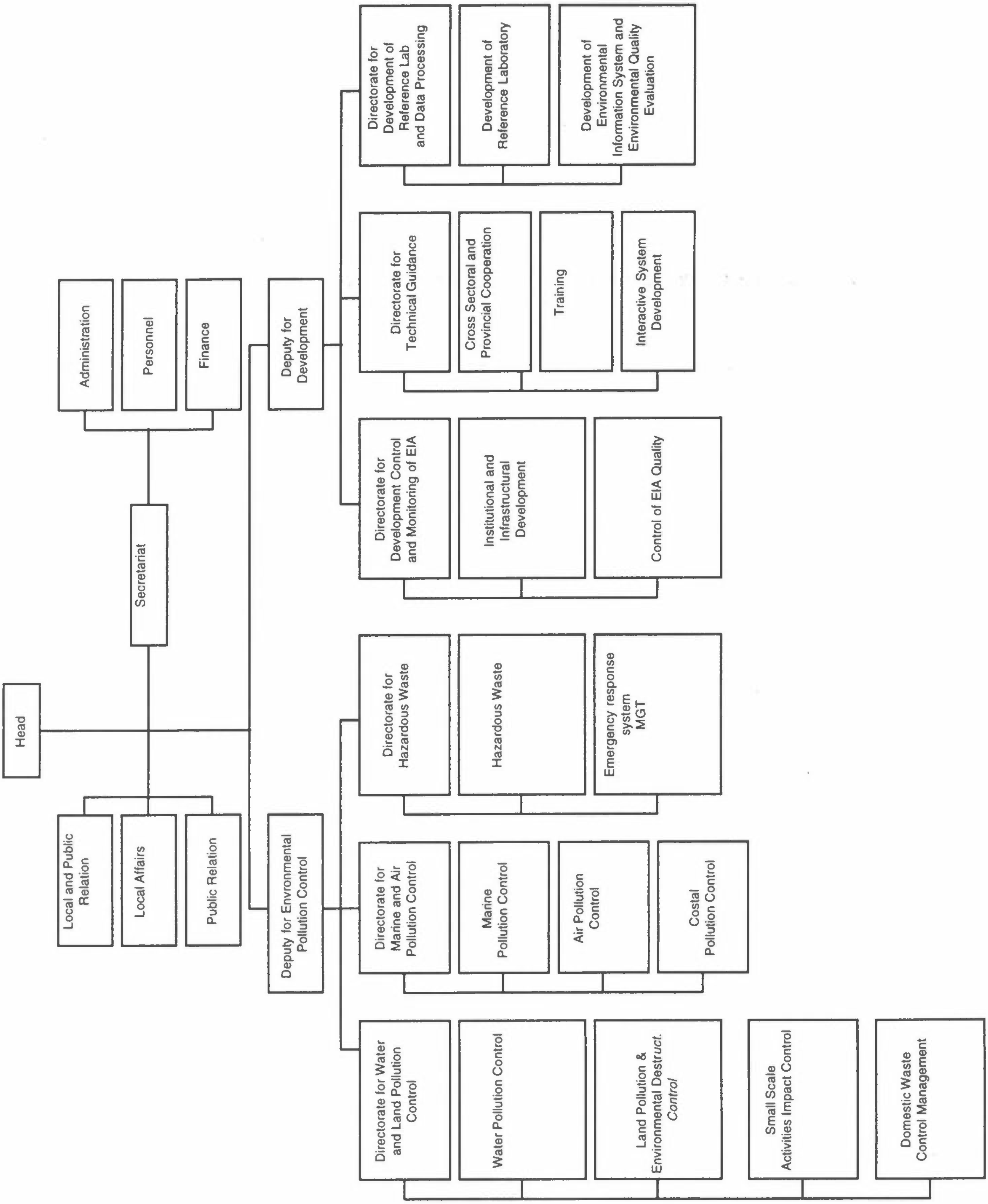

Figure 5.1: Organization structure of central BAPEDAL, 1990.

The World Bank and several other consultants are involved in the BAPEDAL Development Plan, to be implemented over 5 years. Under the Bank's BAPEDAL Development Technical Assistance Projects, TORs have been developed for the following programs:

- BAPEPAL Regulatory, Enforcement and Complience Program;
- Regional Laboratory Development Planning, Certification and Training Program;
- Regional BAPEDALDA Institutional Development;
- Development of an Operational Pollution Control Permit System.

Other organizations are proposing programs regarding an Environmental Management Centre (for research and training) and a Reference Laboratory, as part of BAPEDAL.

Redecon Consultants has drafted a program for development of the Air Pollution Control activities of BAPEDAL (Mitchell, 1991). This draft describes activities in the development of the following sectors:

- Air quality (ambient) monitoring, including:
  - standards, monitoring stations, data and information procedures;

- Mobile sources, including:
  - monitoring data, emission inventories, control options, cost/benefit analysis, control program;

- Stationary sources, including:
  - control, permits, inventories.

- Organization, including:
  - staff, training.
  - Action plan.

This broad development plan should, when implemented, provide a good basis for an efficient environmental control board.

Biro BLH

The Bureau of Environment (BLH) is under the coordination of the Assistant of the Secretary for Social Welfare at the Secretariate of the Province. Its mandate includes the following:

- Developing implementation and technical guidelines for industrial emission;

- coordinateing formulation of implementation guidelines of motor vehicle emission standards;

- Air cleaning program through campaigning and persuating, especially to car owners not to use their cars on holidays, to give the time for the city to clean the air;

- Co-ordinating implementation study for staggering working hours and work-days.
- Co-ordinating assessment and program formulation on the age limit for motor vehicle;
- Air quality monitoring program and utilization plan for mobile monitoring equipment.

The structure of BLH is rather confusing and needs some adjustment.

DLLAJR

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

- Implementation program of common periodic operations between the local government and the traffic police to check and enforce the inspection requirements on motor vehicles;
- Integration of computer system on car registration and car inspection;
- Assignment of special workshops to participate in car exhaust inspection, and to issue pollution free certificate;
- Information campaign on catalytic converter and its utilization.

KPPL

Organization structure:

Regional implementation unit of urban and environmental research and development, directly responsible to the Governor of DKI Jakarta. The administrative co-ordination structure of KPPL DKI Jakarta consist of:

a) The Head of KPPL DKI Jakarta.

b) Administrative Division, consist of:
  - Sub Division of Correspondence and Personal
  - Sub Division of Finance
  - Sub Division of Equipment and Household.

c) Programming and Evaluation Division, consist of:
  - Data and Information Section
  - Programme formulation Section
  - Programme evaluation Secetion

d) Functional staffs, are divided into:
  - Research group of Urban Ecology
  - Research group of Environmental Management
  - Research group of Socio economic and Socio-culture of Urban and Environment
  - Research group of Urban and Environment legislation
  - Research group in Laboratory Analysis
  - Librarian
  - Computer group.

Task and Functions:

KPPL perform part of control and guidance in the implementation of governing and developing the territory, especially on urban and environmental aspect. The functions such as:

- Collecting data and information, to formulate program and evaluate its implementation;
- assesing urban ecology, environmental management, Socio economic and Socio-culture and Legal aspect of Urban and Environment;
- Carrying out laboratory analysis on environmental problems;
- Carrying out documentation and information collection in the field of Urban and Environment;
- Co-ordinating technically the region government institutions which are involved in the integrated assessment on urban and environment;
- Carry out the administration of KPPL DKI Jakarta.

Supporting Personnel:

The total number of personnels working for KPPL DKI Jakarta up to November 1993 were 58 comprised of:

- 1 staff of Master, majoring in Environemental Science
- 17 staffs of university graduates (S1) from several disciplines among others Technical Chemistry, Physics, Biology, Statistics, Law, Economics, Sanitation Engineering, Chemistry, Public Health
- 4 staffs are Bachelor degree in Chemistry, Public Administration and Library
- 8 staffs of Chemistry Analyzer
- 19 staffs of Senior High School
- 4 staffs of Junior High School
- 5 staffs of Primary School

Facilities in KPPL DKI Jakarta:

Facilities owned by KPPL DKI Jakarta are among others:

a) Land:
The entire land owned is 4,118 m^2.

b) Buildings:
The building owned consists of 2 blocks of 2 storey and 4 storey building with a total floor space of 2,649 m^2

The building are used for:

- Office buildings	800 m^2
- Chemical/Physical Laboratory	550 m^2
- Microbiology Laboratory	330 m^2
- Air & Noise Laboratory	126 m^2
- Toxicology Laboratory	96 m^2
- Library	120 m^2
- Other ancillary spaces (warehouses, toilets, etc.)	627 m^2

KPPL DKI Jakarta has 4 (four) Laboratories, these are:

1. Physical & Chemical Laboratory:

The activities in this laboratory consist of activities in the analysis of physical and chemical parameters from the water samples, ground water samples, land and slugde samples, sea water samples, plant, vegetables, and fish samples.

Water analysis includes parameters such as:

- Conductivity
- Turbidity
- Colour
- Temperature
- Acidity/alkalinity
- Chloride
- Ammonia, Nitrate, Nitrit and Total Nitrogen
- Sulfate, Sulfide, Hydrogen Sulfide
- Fluoride
- Hardness
- Suspended Solid, Total Disssolved Solid
- Chemical Oxygen Demand (COD)
- Biochemical Oxygen Demand (BOD)
- Detergent
- Cyanide
- Iron, Copper, Lead, Chromium, Nickel, Mangan, Mercury, Cadmium, Calcium, Magnesium, Sodium, Potassium
- Caloric value.

2. Microbiology Laboratory:

   In the Microbiology Laboratory is performed activities in the analysis of microbiological parameters including analysis of plankton, benthos, Coli form, Fecal Coli, and tests by using bioassy.

3. Air and Sound Laboratory:

   The air and sound laboratory is engaged in activities of analysis of the quality of the air consisting of ambient air quality, emissions and sound/noise including NO_x, NO, SO_2, Dust, Ozone, H_2S, Ammonia, Hydrocarbon, CO, CO_2, Climate (wheather, wind speed and direction), heavy metals in the dust, and rainfall.

4. Toxicology Laboratory:

   The toxicology laboratory performs analysis of organic chemicals, and pesticides including the hazardous materials.

Legislation Products Related to KPPL DKI Jakarta

According to its function, the KPPL DKI Jakarta has performed research, both in the field of environment as well as in the social, economical, cultural aspect of the city. Physical surveys of the environment are among others the regular monitoring of river water and ambient air quality in the DKI Jakarta Territory, performed as from 1978 through 1988 up to date, apart from other surveys like the monitoring of industrial waste including Clean River Programme (Prokasih) DKI Jakarta.

The results of surveys mentioned has been widely used by the regional Administration of the DKI Jakarta to establish policies in the framework of environmental monitoring in the territory of the DKI Jakarta, among others with the issue of several Decisions of the Government.

Environmental Support Network

KLH took the initiative to develop university-based Environmental Studies Centres (PSLs), with the primary objective to enhance the availability of environmental expertise to 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.

5.2 Functions

The MEIP analysis of key institutions (Bulkin, 1992) provides the overview of institutional functions and linkages in air management shown in Figure 5.2.

The 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.

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

	Provincial government									
Management function	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					*			*	*	

Figure 5.2: Institutional linkages in Managing Air Pollution according to management function (Bulkin, 1992).

Based on the matrices in Figure 5.3 the following overview of institutions with functions in central fields of air pollution management can be given:

Monitoring

Central government

The Ministries of Health, Public Works, and Transportation are listed as having functions on the central level regarding monitoring of air pollution. Their actual functions are not described in the reports.

Provincial government

Ten agencies are listed as having functions regarding to air pollution monitoring. In addition, BMG should be on the list.

The actual monitoring in Jakarta is done by the agencies JMB (GOV), BMG, and KPPL. The other agencies listed have functions regarding the issuing of information from the monitoring to the public and to other agencies presumably using the information, for enforcement, and in planning processes.

Permitting

Central government

The Ministries of Population and Environment, Public Works and Transportation are listed as having functions on the central level regarding permitting and licensing of air polluting activities.

Provincial government

The KPPL, and the Ministries of Public Works and Industry, the Provincial Investment Board, and the Agency of Traffic and Highway Transportation are listed with permitting and licensing functions.

AMDAL Environmental Impact Assessment

The Environmental Impact Assessment process for new and extending pollution activities involves, according to Figure 5.2, the Ministries of Population and Environment, Health, Public Works and Transportation on the central level and the Ministry of Industry, and the Bureau for Population and Environment, Office of Urban and Environment Studies, the Traffic and Highway Agency and the Investment Coordinating Board on the provincial level.

Law Enforcement

According to Figure 5.3, the Ministries of Population and Environment, Health, Public Works and Transportation has functions regarding law enforcement on the central level, while on the provincial level, the Municipal Government, the Ministry of Industry, and the Investment Control Board are listed.

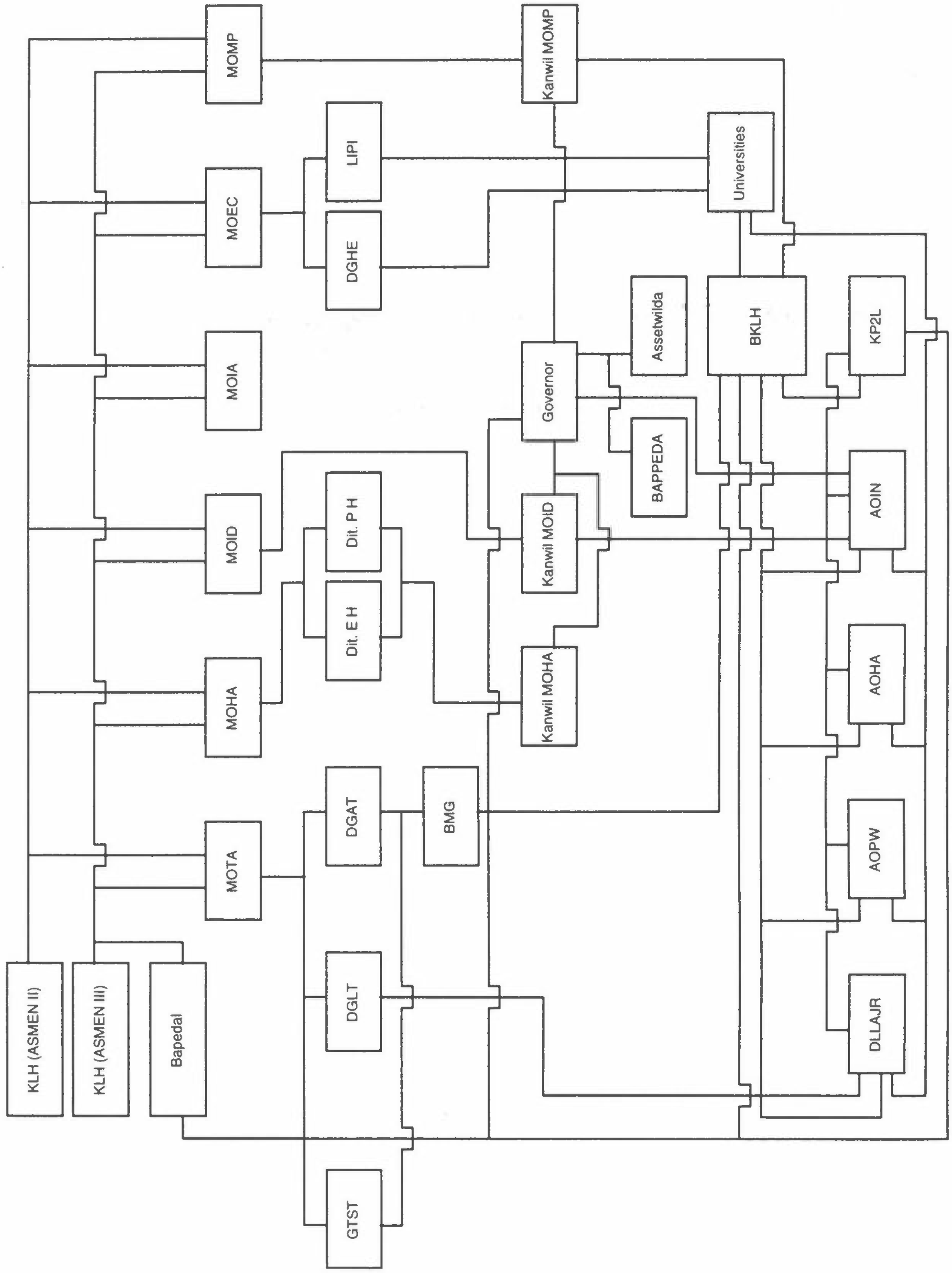

Figure 5.3: Diagram of interagency linkages in Air Quality Management.

Emission Standards

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

- Provincial Planning Board of Jakarta (Bappedal)
- 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)

Supervision of the emission parameters evaluation is coordinated by the Urban Research and Environment Office.

Supervision of implementation evaluation is coordinated by the Bureau of Environment.

Supervision of the evaluation of regulation affairs is coordinated by the Bureau of Law.

5.3 Existing Laws and Regulations on Air Pollution

The air pollution legislation in the Republic of Indonesia and in Jakarta has been described in a report from the LLAJR Air Pollution Monitoring and Control Project performed by Institut Teknologi Bandung (Bachrun et al., 1991), by Kozak and Sudarmo (1992), and by the URBAIR report of Dr. 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 Living Environment"*. This is the umbrella provision for all environmental regulations in Indonesia. Under this law, the KLH (The State Ministry for Population and Environment) issued the Ministerial Decree KEP-35/MENKLH/10/1993, which established national ambient air quality standards, and emission 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 emission standards in the context of road worthiness. This decree limites CO and HC at idling of gasoline powered vehicles. The paragraph concerning smoke emission has been taken out, now it refers to the standard of KLH.
- *Draft Regulation of KLH* now has been promulgated as the Decision of the State Minister of Environment no. KEP-35/MENLH/10/1993 on Emission 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 emission inventories, and specifies the BAPEDAL as responsible agency 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 US Gallon in the mid 1980s to presently 1.5 ml per US 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 the testing is with the Provincial Government and the tests are to be carried out by the Traffic and Transportation Service in the province or can be 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 let investigate their wastes to the PPMPL (Pollution Laboratory or a Laboratory appointed).
- *Governor's Decree No. 220 Year 1979,* on grant authority to enter industrial companies and entities within the territory the Capital City of Jakarta for the purpose of inspection and investigation of the industrial waste of the industrial companies/entities.

- *Governor's Decree No. 587/1988*, issuing ambient air quality standards. these are equivalent to the national standards.

- *The Decision of the Governor of the DKI Jakarta No. 709 Year 1990*, on the establishment of the co-ordination team for the law enforcement of life environment within the territory of DKI Jakarta.

- *The Decision of the Governor of the 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 violence of laws on the regulation on life environment in the territory of the DKI Jakarta.

- *Governor's Decree No. 1222/1990*, issuing vehicle emission standards, also equivalent to the national standards. In Chapter 4 it is mentioned that DLLAJR is responsible for vehicle emission testing in Jakarta.

- *Governor's Decree No. 1236/1990* is on the implementation of the control of vehicle emissions. More than 10 institutions are involved.

Blue Sky Program

The Ministry of Environment launched “Program Langit Biru” (blue sky program) in 1991 which was designed to address air pollution. For stationary sources the program at present time will give priority to powerplants, cement, paper & pulp, and steel industries. To control air pollution from mobile sources Bapedal plans to control black smoke, and to switch to unleaded gasoline. DKI Jakarta announced in November 1991 its Clean Air Program (Prodasih) as an effort to increase public awareness of air pollution and to emphasize the enforcement of Decrees.

- *Provincial Act No. 5/1984* on a Master Plan Jakarta up to the year 2005 mentions zoning. Two experiments have so far been carried out. "Three in One" is the requirement in a restricted number of main roads that cars have to transport at least three passengers. And in a number of places a Special Bus Lane was introduced. The results of the experiments seem to be positive.

5.4 Shortcomings

A large number of institutions is involved in air pollution management. Efficient management would require clear lines of authority and responsibilities.

Institutional shortcomings are lack of control and law enforcement and lack of well-trained personnel and qualified consultants.

Especially the MEIP report has analysed the factors leading to inefficient control and management. Some of those main factors are:

- Functional relations between agencies may be developed to improve;
- communication and co-operation between agencies;

- enforcement agencies often do not refer to reports on pollution problems, to take legal action;
- the orientation 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;
- obstacles in Government-Private Sector co-operation.

6. Abatement measures: Effectiveness and costs

6.1 Introduction

This chapter presents information about measures which are appropriate for reducing air pollution in Jakarta. This reducing information can be used to draft an action plan. The chapter is organized according to source categories: traffic; power plants; fuel combustion other than in power plants; non-combustion sources; construction; and refuse burning.

For the main sources, brief characteristics of appropriate measures are presented, including information about:

- their effectiveness in terms of both emission reduction and reduced exposure impacts in the year 1995 (according to the methodology used in constructing table 4.5). The reference data are: mortality 4500 (due to PM_{10}), and number of respiratory symptom days 100 million in 1995 (all figures rounded off);

- their costs;

- their benefits (in assessing the monetary benefits the conservative approach (see Chapter 4) is used;

- the policy instruments which might be used to implement the measures, and the institutions which might be involved in the implementation of the measure;

- the term in which the measure can result in emission reduction (short term 2 year, mid-term 2-5 years, long term > 5 years).

In the following text, all figures of emissions, costs and benefits represent **annual** figures for 1990, unless otherwise stated.

The list of measures is derived from the information presented by the local consultants, from the URBAIR guidebook and from earlier plans (see Chapters four/five) addressing parts of the problems in Jakarta. In case of source categories such as process emissions, construction and open burning it was not possible to present measures due to lack of information about the Jakarta specific situation.

6.2 Traffic

Chapter 3 shows what is to be expected of future traffic emissions if no environmental measures are taken. This section describes the effectiveness (abated emissions) and, to the extent possible, the benefits of various 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 (diesel/ gasoline→LPG/CNG) in the transportation sector;
- adoption of clean vehicle emission standards;
- other measures.

6.2.1 Introduction of low lead or unleaded gasoline

Introduction of unleaded gasoline addresses the lead problem and it also is a prerequisite for the introduction of strict emission standards, such as currently common in many countries in the world. An "intermediate" approach is to limit the lead content of gasoline to lower levels.

Introduction of unleaded gasoline requires assuming simultaneous introduction of vehicles with catalytic convertors separate fuel distribution system that does not mix leaded with unleaded fuel. Retailers usually sell both leaded and unleaded fuel. Oder types engines may require the use of leaded fuel because of the material used for valve seats and/or the high RON-number gasoline required.

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

Costs of the measure. Reducing lead in gasoline requires reformulating the gasoline in order to retain the required properties (*inter alia* RON number). In order to obtain gasolines with sufficiently high RON numbers the lead compound is substituted by oxygenated compounds; MTBE (Methyl tertiary butyl ether) is a preferred substitute. These changes lead to a increase of production costs typically in the range of Rp 40-60 per litre gasoline, depending on the local market for refinery products, the required gasoline specifications and the costs of MTBE (Turner et al., 1993).

Table 1.5 infers that about 1 billion litres of gasoline was consumed, leading to an estimate of a total cost of a 100% shift to the use of unleaded gasoline in the order of magnitude of Rp 50 billion.

Policy instruments and target groups. Lowering the lead content of gasoline sold is usually effected by lowering the maximal allowed lead content. In countries where gasoline is taxed, unleaded gasoline is taxed less and for leaded fuel taxed more so that the net yield for the fiscal authority does not change.

The petroleum industry and the gasoline distribution firms will have to produce and distribute the gasoline.

Term. A large scale availibility of unleaded fuel can be implemented within 5 years. Low-lead gasoline may be produced at short notice, technically.

Summary. Introduction of low-lead and unleaded fuel	
Effectiveness:	*Depending on the rate of introduction*
Costs:	*Costs at refinery Rp 40-60 (per litre unleaded fuel)*
Benefits:	*Order of magnitude Rp 300 billion (see Table 4.3)* *Mortality : 340 cases, loss of IQ points (children) (section 4.3), if in 1990 only unleaded gasoline would have been used. Unleaded fuel is required when catalytic-exhaust gas control is introduced*
Instruments/institutions	
Term	*Two - five years*
Target groups	*Petroleum industry, firms which sell gasoline*

6.2.2 Implementation of a scheme for inspection and maintenance

Effectiveness. Next to a threat of traffic safety and unnecessary costs of increased fuel consumption a major problem are the large emissions associated with mal-adjustmed fuel injection system or carburettor and worn-out motor parts. Introducing a scheme requiring semi-annual inspection and maintenance, will result in a substantial reduction of **PM_{10}**, **VOC,** and **CO** emissions. An accurate assessment of emission reduction associated with an inspection and maintenance scheme requires statistical data about emission characteristics of the Jakarta vehicle fleet relative to its state of maintenance. Such information is not available.

It is assumed that through the proposed inspection and maintenance scheme emissions of **PM_{10}**, **VOC,** and **CO** decrease with a third (35% reduction of tail-pipe emissions) in line with a Worldbank estimate for Manila (Mehta, 1993).

Costs of an inspection and maintenance scheme. Presently, capacity for vehicle-emission testing is insufficient. It was estimated that about 650 test units are neccesarry to carry out 33 million tests (twice-a-year a 20 minute procedure). It was suggested that private firms[2] could be involved (Budirahardjo, 1994) (a similar idea is developed in Manila, (Baker et al., 1992)). Roughly estimating, such scheme might involve a total costs of about Rp 67 billion for vehicle owners (Rp 2200 per test). Note that this scheme involves all vehicles.

It is assumed that the maintenance costs will be offset by reduced fuel costs associated with better engine performance.

Policy instruments and target groups. According to the Governor Decree 122 and 1236 (1990) vehicles have to comply with standards and an inspection scheme is designed. Emissions are measured at roadworthiness 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.

Summary. Implementation of an inspection and maintenance scheme	
Effectiveness:	*35% reduction, 1300 tonnes* PM_{10}
Costs	*Rp 67 billion. Maintenance costs are expected to be off setted by improved fuel efficiency*
Benefits	*Mortality : 212, RSD : 5 million, avoided health costs Rp 30.8 billion* *Reduction of CO, VOC emissions, improvement of road safety (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	*The scheme could be carried out by the private sector.*

---

[2] A set-up of such scheme might be:
- firms are licensed to carry out inspection.
- authorities spot-check the firms whether inspections are made properly
- vehicles which pass the test get a sticker valid for a specific period, drivers have to show a test report at request.
- vehicles are spot-checked also.

6.2.3 *Address excessively polluting vehicles*

About 25% of the various vehicles are estimated to emit excessively (say more than twice the average). These vehicles are badly maintained, use worn-out engines, ore those engine controls are maladjusted.

The order of magnitude of emission reduction which might be obtained at a strict enforcement of the regulation is about 1000 tonnes (15% reduction of traffic-exhaust emissions).

Summary. Excessively polluting vehicles	
Effectiveness:	*1000 tonnes PM_{10}*
Costs	
Benefits	*Mortality 163, RSD 4 million, Rp 23.7 billion*
Instrument/institution	
Term	
Target groups	*Traffic authorities/Vehicle owners/*

6.2.4 *Improving diesel quality*

Diesel's ignition and combustion properties are important parameters in explaining PM_{10} emissions from diesel engines (Hutcheson and van Paassen, 1990, Tharby et al., 1992). The volatility (boiling range) and viscosity (and its cetane number[3], an indicator of the ignition properties) are major fuel characteristics which determine these properties, and, consequently, PM_{10} emissions. The specification for cetane number for diesel fuel automotive purposes is at minimum 45. In the US, Western Europe, and Japan the corresponding quality varies from 48 to 50.

Another factor is the presence of detergents and dispersants in diesel fuels: these additives keep injection systems clean and have discernable effects upon efficiency (Parkes, 1988).

Effectiveness. It is assumed that an improvement of the properties, as expressed in an increase of the cetane number and a quality improvement by detergent additives, results in a decrease of 10% - as an order of magnitude - of PM_{10} emissions: about 230 tonnes (situation 1990).

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[3] The physico-chemical properties - as expressed in the **cetane number** - of diesel fuel influence the magnitude of the emissions of **TSP** of diesel powered vehicles. The relation 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.

A reduction of the **sulphur** content leads to a proportional decrease of emissions of sulphur dioxide. In addition, PM_{10} emissions decrease as a part of the particulates emitted consists of sulphates originated from the sulphur in the fuel.

Costs. The costs of improvement of diesel fuel, in particular increasing the cetane number, is determined by the oil-product market, the refinery structure (capacity for producing light fuels/visbreaking/hydrotreating and the like), and, the Government involvement in the national market. The latter eventually determines the price-at-the-pump for fuels.

The costs of reduction of the sulphur content of diesel fuel are due to more extensive desulphurization activity at the refinery. The costs per litre for a reduction from 0.7% to 0.2% are in the order of magnitude of Rp 20 per litre. Sulphur in diesel fuel leads at combustion to formation of corrosive sulphuric acid. Therefore, reduction of the sulphur content has a financial benefit due to a reduction of costs of vehicle maintenance and repair.

Policy instruments and target groups. Improvement of the quality of diesel fuel affects the energy policy of Indonesia.

Term. The typical period for a required adjustment of refineries (such as extension of visbreaking capacity) is about 3-5 year.

Summary. Improving diesel fuel quality	
Effectiveness:	*230 tonnes PM_{10} (1990)*
Costs	*Low*
Benefits	*Mortality: 41, RSD : 1 million, Rp 5.9 billion* *Reduction of SO_2 emissions*
Instruments/institution	*Energy authorities*
Term	*Three-five years*
Target groups	*Petroleum industry*

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

A characteristic of the Jakarta traffic is the large share of motorcycles and bajajs, both equipped with two-stroke mixed lubrication engines. These vehicles cause about a third (2700 tonnes) of the PM_{10} emissions (from exhaust traffic). A substantial fraction of the particles emitted by these vehicles are in fact little droplets of unburned lubrication oil used. According to Shell (private communication, 1993) the lubricating oil used in most South-Asian countries is cheap, and of poor quality with respect to combustion properties.

Effectiveness. It is assumed that by a better quality lubrication oil will be halve the emissions (1350 tonnes reduction).

Costs. Introducing these oils is estimated to double the costs of lubricating oil. The annual consumption of these oils is estimated at 2000-5000 tonnes[4]. A first guess of the total costs of using low-smoke oil is then Rp 2-10 billion.

Policy instruments and target groups. An economic instrument might be preferred.

Summary. Introduction of low-smoke lubricating oil	
Effectiveness:	*1350 ton PM_{10} (1990)*
Costs	*Rp 2-10 billion*
Benefits	*Mortality : 220, RSD : 5 million, Rp 32 billion*
Instruments/institution	
Term	*Two years*
Target groups	*Petroleum industry*

6.2.6 Fuel switching in the transportation sector

A major option for addressing air pollution due to PM_{10} emissions from vehicles is using gaseous fuels, such as LPG and CNG. LPG is widely used in areas where supply is abundant and fuel taxes favors the use of LPG. The use of LPG and CNG requires adaptating the engine and its controls, which will only pay off when LPG or CNG price is lower than gasoline or diesel.

LPG (Liquid Petroleum Gas) is a fuel which can be used as a clean alternative to both gasoline and diesel. PM_{10} emissions are very low. The use of LPG for automotive purposes is not allowed in Indonesia (P.T. Mojopahit, 1991, pp.5-9). This prohibition might be reconsidered.

CNG (Condensed Natural Gas). In contrast CNG is promoted for use in vehicles (it is not an option for motorcycles or bajajs). In few reports the use of CNG as a fuel is mentioned (P.T. Mojopahit, 1991, Bachrun et al., 1991). It has been introduced for use in taxis (Blue Bird taxis), however it is mentioned ((P.T. Mojopahit, 1991, p.5-11) that the acceptation was low in spite of the economic viability. It was stated that the investments paid off in 1-1.5 year. A practical problem of CNG use is the loss of luggage space (fuel tank) and a reduction of motor power.

We are not aware of the present situation with respect to the use of CNG.

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[4] Mileage of motorcycles and bajajs is estimated at 5.3 billion km. At an average fuel efficiency of 0.02 liter/km and an average content of 2 to 5%, lubrication oil total annual consumption is about 2000 - 5000 tonnes.

Effectiveness. CNG is used as substitute for four-stroke gasoline cars. It is very effective in reducing PM_{10} emissions (90%). If all gasoline cars had been modified for the use of CNG, emissions would have been 1300 tonnes less in 1990 (about 3% of the total emission). Table 4.5 gives an indication of the associated hypothetical benefits.

Costs. In 1991 investments for a taxi, a CNG tank and the modification of fuel-system was estimated at Rp 1.5 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).

Summary. Introduction of CNG to replace 50% of gasoline consumption (1990 situation), passenger cars	
Effectiveness:	*650 tonnes*
Costs	*Costs for vehicle owner depends on the price differential between gasoline and CNG (Natural gas is cheaper)*
Benefits	*Mortality : 98, RSD 2 million, Rp 14,2 billion*
Trade-off	*Increase of emissions of methane (greenhouse gas), the main constituent of natural gas.*
Instruments/institution	
Term	*Two-five years*
Target groups	*Energy authorities*

6.2.7 Adoption of clean vehicle emission standards

Many countries with severe air pollution problems due to vehicles have adopted standards for allowable emissions from vehicles. Current modern 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, among them Austria and Taiwan, have also set standards for the motorcycles emissions, requiring two-stroke engine powered vehicles to be equipped with open-loop catalysts. The latter devices control VOCs, PM_{10}, and CO emissions, but not NO_x. Weaver and Lit-Mian Chan (1993) recently made a reference report on how to introduce standards for these types of vehicles.

The catalyst technology prohibits the use of leaded gasoline while also the sulphur content should be at a low level (<500 ppm). Therefore, introduction of such standards involves the build-up of a structure for production and distribution of unleaded gasoline[5].

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[5] To maintain the operation of the catalyst it is absolutely necessary that the use of leaded fuel is avoided. A single gram of lead will contaminate the catalyst and render it useless. In addition, lead destroys the oxygen sensor of the fuel injection system.

Diesel powered vehicles are also subject to regulations. The emission requirements are met by adjusting the motor management plan, and the motors design.

Tailpipe emission treatment is also envisaged, as well as retrofiting abatement equipment in existing buses. In that case the requirements on the diesel fuel quality are made stronger (such as sulphur content below 0.02%, which is a severe condition). This type of standard is now being introduced in some parts of the world.

Effectiveness.

Closed-loop catalytic treatment of exhaust gases (three-way catalysts) of gasoline-engine equipped vehicles. All exhaust emissions, NO_x, CO, and VOC, are reduced with typically 85%. In addition lead emission is reduced with 100% as the availability and use of unleaded fuel is a prerequisite for these type of standards.

Open-loop catalytic treatment of exhaust gases of two-stroke motor cycles reduces CO, VOC and PM_{10} (in fact oil mist) emissions, two-stroke engines being a major source, typically with 90%. Successful use of these catalyst also requires the use of unleaded gasoline. An alternative is using well-designed and maintained four-stroke engines. We estimated that a similar emission reduction can be obtained.

The use of catalytic devices for treatment of exhaust gases requires the use of unleaded gasoline. Removal of the lead compound in gasoline leads to a reformulation of gasoline in order to maintain ignition properties (Octane number). This can be effected by increasing the content of aromatics in gasoline and/or by adding oxygenated compounds such as MTBE (methyl-tertiary-butyl-ether) to gasoline. Aromatics encompass benzene, a carcinogenic compound. This might result in an environmental concern, both from the expectation that benzene exposure due to evaporation of gasoline (at production, storage and handling) may be harmful and from the expectation that the benzene content in exhaust gases may increase (Tims et al., 1981, Tims, 1983). A limit for the benzene content of gasoline might be necessary. A decision on the height of the limit requires data of the current air quality with respect to benzene. This issue in technical and, as experience in other countries indicates, can be resolved. It should be noted that catalytic devices are effective in destroying benzene is exhaust gases, which leads to the expectation that the net result is small - decrease of benzene emissions from "clean" cars and an (possible) increase of the exhaust emissions of dirty cars using unleaded gasoline.

Unleaded gasoline with a high RON-number is usually produced through adding MTBE, the preferred substitute for lead. It has to be imported or plants may be built.

Costs. Due to methodological difficulties (definition of the reference situation, costs for whom) it is not possible to calculate costs for a possible introduction of standards in Jakarta. However, costs can be estimated on a vehicle-by-vehicle basis.

The costs of **closed-loop catalytic treatments of exhaust gases** is mainly related to the extra purchasing costs of vehicles: ranging from US$ 300 to 500, on average about US$ 400 (Wang et al., 1993) in the USA. These devices have a minor adverse effect on the fuel economy. However, associated costs are compensated by decreased costs of maintenance, due to increased life-times of replacement parts, such as the exhaust system.

The costs of **open-loop catalytic treatment of exhaust gases** of two-stroke motor cycles are related to increased equipment costs and decreased fuel costs due to improved engine operation. Taiwan adopted standards which require the use of open loop catalytic devices which result in an US$ 60-80 costs increase, which are offset by fuel savings (Binnie & Partners, 1992). Total annual costs are estimated at US$ 75 per vehicle (depreciation + increased fuel costs). It is assumed that the cost of four-stroke engines or motorcyles is similar to the cost of four-stroke engines.

Other costs are related to higher costs of unleaded gasoline due to increased production cost and adjusting the logistic system (modification of pump nozzles). A very rough estimate of the costs, only for the purpose to obtain a perspective, is Rp 200 thousand annualy per car (Rp 100 thousand depreciation of control system and Rp 100 thousand increased fuel costs, depending on the possible subsidies/levies on gasoline). An obvious issue is to what extent the costs of unleaded fuel should be attributed to the PM_{10} problem (and to the problem of lead pollution).

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

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

Term. In practice, standards can be set only for new cars and motorcycles; it is too expensive to equip existing vehicles with the necessary devices. Practically all vehicles currently sold at 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.

Summary. Adoption clean vehicle standards. Gasoline passenger cars and vans

Effectiveness:	*80% effectiveness per (gasoline) vehicle (for 1990 in total 900 tonnes)*
Costs	*Rp 200 thousand (including costs of unleaded fuel)- order of magnitude! In total Rp 18 billion.*
Benefits	*Mortality 147: , RSD : 3 million, Rp 21 billion (hypothetical situation in 1990)* *Reduction of emissions of CO, NO_x and VOC, in fact the main justification of introduction of these systems in other countries.*
Instruments/institution	
Term	*Two-five years. The result of such measures turns up with the renewal of the car fleet.*
Target groups	*Petroleum industry - the first move is to have unleaded fuel available, vehicle importers, vehicle manufacturers*

Summary. Adoption clean vehicle standards for motorcycles and Bajajs (Two-stroke engines) (either requiring catalytic converters or four-stroke engines).

Effectiveness:	*80% effectiveness per vehicle (for 1990 in total 2000 tonnes)*
Costs	*Rp 170 thousand (including costs of unleaded fuel)- order of magnitude! In total Rp 67 billion.*
Benefits	*Mortality > 325: , RSD : > 8 million, Rp 47 billion (hypothetical situation in 1990)* *Reduction of emissions of CO, NO_x and VOC, in fact the main justification of introduction of these systems in other countries.*
Instruments/institution	
Term	*Two-five years. The result of such measures turns up with the renewal of the fleet.*
Target groups	*Petroleum industry - the first move is to have unleaded fuel available, vehicle importers, vehicle manufacturers*

6.2.8 Improvement abatement or other propulsion techniques

In the USA and the European Union tightening these standards is being discussed. Possibilities are:

- improving current abatement techniques;
- improving inspection and maintenance, as it now appears that only small numbers of maladjusted/worn-out cars cause unproportionally large emissions;
- enforcing the use of "zero-pollution" vehicles, i.e. electric vehicles in down town areas.

A bottleneck in decreasing automotive air pollution are diesel engines as exhaust gas treatment similar to gasoline cars is not possible. However, diesel engines emit less CO_2.

6.2.9 *Addressing resuspension emission*

Resuspension is clearly an issue of highest importance. Unfortunately, quantitative information about measures appropriate for Jakarta has not been found. Resuspension is still an important matter for further analysis in order to propose viable measures.

6.2.10 *Improving traffic management*

For reasons of consistency some remarks are made with regard to traffic management measures. Traffic management includes a variety of measures, ranging from traffic control by policeman or traffic lights to one-way streets, construction of new roads, and road-pricing systems. Traffic management is usually carried out for a variety of reasons; solving congestion problems is a major one. Curb-side traffic management may improve air quality[6], but it may also increase air pollution - emissions - as traffic management usually results in an increased performance of the transport system. In terms of exposure traffic management can be beneficial as the air quality in downtown areas improves and road-exposure declines, but, in terms of total exposure, the net result may be small.

It is noted that improved traffic management may have other environmental benefits such as reduction of noise and congestion. More detailed analysis is needed, but traffic management seems to be a cost-effective policy.

6.2.11 *Construction and improvement of mass-transit systems*

Mass-transit systems, such as light-rail transport, may constitute a part of the solution of environmental problems due to traffic as well as a means to increase transport capacity. Building such a system is a long-term process and requires large investments, but can have large benefits in terms of reduction of pollution and congestion.

A methodology to assess costs and effectiveness of a measure "construction of mass-transit systems" involves elaborating issues such as:

- description of a future system appropriate for Jakarta;
- assessment of the performance of such system - (passenger*km);
- assessment of the costs of construction;
- a description of the baseline (future situation without such system);

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[6] Accelerating vehicles, a dominating feature of congested traffic, emit unproportionally large amounts of pollutants.

- avoided emissions;
- assessment of non-environmental benefits;
- design of a scheme to identify those costs and benefits to impute to the environmental aspects.

The costs of construction of mass-transit systems are high and projects may not be justified from only an air-pollution point of view. However, mass-transit systems have a wide variety of other benefits, among which reduction of congestion.

6.3 "Large point sources"

Cleaner fuels in existing plants

Power plants hardly contribute to the air quality problems in Jakarta. The use of cleaner fuel (low sulphur oil or coal) or natural gas might be contemplated but the benefits relate to emissions such as of SO_2 and CO_2, of which the associated problems are of extra-urban scale.

Fuel combustion other than in power production

The main source of PM_{10} emissions due to fuel combustion is the use of fuel oil by small industry (source category "domestic"). This emission is estimated at 1700 tonnes (+1620 tonnes from destillate fuel) (Chapter 2). The damage associatated with this emission is low (mortality 13 RSD below one million, health cost below Rp. 2 billion).

6.4 Industrial processes (non-combustion sources)

Unfortunately, the lack of data about process emissions, estimated at 14000 tons and a major source, in Jakarta does not allow for listing an appropriate set of measures.

First estimates based on data for large factories in Jakarta producing steel ingots and billets indicate that TSP-emissions may be reduced by 4000 tonnes/year at an investment cost of 10 million dollars (COWIconsult/World Bank, 1992).

6.5 Open burning and construction

Refuse burning results in a PM_{10} emission estimated at 7000 tonnes. A concrete proposal for measures to address these emission require more information about the characteristics of this source.

PM_{10} emission due to construction is estimated at 10,000 tonnes. A main source are demolition activities. Various means for controlling these emissions can be envisaged, such as screens alongside demolition works, the use of chutes to remove rubble and other.

However, details about these emissions are lacking; it is not possible to elaborate a proposal for measure to take.

6.6 Conclusions

This chapter describes a number of measures which are appropriate for improving the air quality in Jakarta. It was intended to deal with several aspects of measures, their effectiveness, costs, benefits, how to implement the measures and the institutions and authorities involved. An important issue was to indicate the benefits, the reduced health impacts and reduced damage costs. Together with the costs of the measures this information gives clues for prioritization of measures. It should be noted that the quantitative information presented often has to be characterized as orders of magnitude.

The identification of measures to address traffic emissions was rather straightforward as some of the major causes of the air pollution are obvious. Measures which stand out from a cost-benefit point of view are:

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

A similar listing of measures addressing other sources was not possible due to lack of information. This is an unfortunate circumstance as these other sources appear - in terms of emissions (see Table 3.2, and Table 4.5) - to be more important than the traffic sources. These groups are:

- Resuspension of particles, mainly from traffic and roads;
- Industrial process emissions;
- Open burning.

7. Draft Action Plan

The assessment given here of air pollution and exposure in DKI Jakarta, the health damage associated with it, and the analysis of the costs and benefits of various measures to reduce the exposure and damage, described in Chapters 2-6, is based on the present state of knowledge and quantification. Shortcomings in the data base have been pointed out throughout the text. Nevertheless, the analysis forms the basis for proposing a plan of actions to reduce the air pollution problems in a cost-effective manner. Improvement of the data base is necessary to extend the action plan to include additional measures.

The "actions" are of two categories:

1. Technical and other measures which will reduce the exposure and damage.

2. Improvement of the data base, and the regulatory and institutional basis for establishing an operative System for Air Quality Management in DKI Jakarta.

The time frame in which the actions/measures should be implemented, and will be effective, is indicated (short (<5 years), medium (5-10 years) or long-term (>10 years)).

7.1 Actions to improve DKI Jakarta air quality and its management

7.1.1 Actions to improve air quality

Actions and measures have been proposed by the local Jakarta URBAIR working groups, through other World Bank projects, and by the URBAIR consultants.

Proposed actions or measures to reduce air pollution impact can be put in the following categories:

1. Improved fuel quality;
2. Technology improvements;
3. Fuel switching;
4. Traffic management;
5. Transport demand management.

Each action/measure is described briefly, according to the following items:

• What	Description.
• How	Policy instrument to instigate and carry out the measure.
• When	When should actions be instigated. When can results be expected.
• Who	Institutions/organizations responsible or affected.
• Effects	Reduced emission/exposure/damage costs.
• Cost	Cost of measure.
• Feasibility	
• Remarks	

The list of proposed measured is presented in Section 7.3.

Various technical abatement measures were analyzed in Chapter 6, for costs and benefits.

A draft **Action Plan** of prioritized measures which can be introduced in the short term, is given in Table 7.1.

Table 7.1: Draft Action Plan of abatement measures, DKI Jakarta, based on cost/benefit analysis.

Priority	Abatement measure	Avoided emissions, tonnes PM_{10}/a	Benefits Avoided health damage	Costs of measure	Time frame	
					Introduction of measure	Effect of measure
	Vehicles					
	Low-lead and unleaded fuel		Rp 300 billion 340 deaths loss of IQ points in children	Rp 40-60/ liter total Rp 50 billion	Immediate	2-5 years
	Inspection/ maintenance	1,300	Rp 31 billion 212 deaths 5 mill RSD	Rp 67 billion	Immediate	2-5 years
	Address excessively polluting vehicles	1,000	Rp 24 billion 163 deaths 4 mill RSD	Low	Immediate	2 years
	Low-smoke lubricating oil, 2-stroke	1,350	Rp 32 billion 220 deaths 5 mill RSD	Rp 2-10 billion	Immediate	2 years
	Improving diesel quality	230	Rp 6 billion 41 deaths 1 mill RSD	Low	Immediate	2-5 years
	CNG to replace gasoline (50%)	650	Rp 14 billion 98 deaths 2 mill RSD	?	Short	~5 years
	Clean vehicle standards (Pass. cars and MC/bajaj)	2 900	Rp 68 billion 500 deaths 12 mill RSD	Rp 85 billion	Immediate	5-15 years

RSD: **R**espiratory **S**ymptom **D**ays

For many measures the calculated benefits are substantial, up to tens of billions Rupiahs annually. The benefits are for some of the measures, such as low-smoke lubricating oil and, expected improving diesel quality, higher than the estimated costs.

Regarding lowering of lead content in gasoline, we consider this important measure as already initiated through current legislation. Lead-free gasoline is a prerequisite for clean vehicle standards.

The success of the measures rests with the enforcement sector of the action. It is important to ensure that conditions are met for carrying out the technical improvements and adjustments which are necessary, e.g. workshop capacity or capability for efficient adjustment of engines, and availablility of spare parts at a reasonable prize.

To reiterate Chapter 6, the actions incorporate the following measures:

Adressing excessively polluting vehicles:

- Strict enforcement of smoke opacity regulation.

  Success is dependent upon that the maintenance/adjustment of engines actually takes place. Routines for ensuring that must be a part of the action.

Improving diesel quality:

- Import of quality low-sulphur diesel (0.2%),
- Modifications in Indonesian refineries; or
- Possibly taxes/subsidies to differentiate fuel price according to fuel quality.

Inspection/Maintenance

- Annual (or bi-annual) inspection
- Establishment of inspection and maintenance stations (government or private);
- Basic legislation is in place (Governor's Decree 122/1236).

  The potential for reduced emissions is the largest for diesel vehicles. The inspection and maintenance might, at the start, be concentrated on diesel vehicles.

Clean vehicle emission standard:

- Establish state-of-the-art vehicle emission standards for gasoline cars, diesel vehicles and motorcycles;
- Ensure the availability of lead-free gasoline, at a lower price than the leaded gasoline.

Table 7.2 lists other selected abatement measures, also of other categories, for which cost/benefit analysis has not been performed, which could be introduced in the short term, and have a beneficial effect on the air quality.

Table 7.2: Additional measures for short/medium-term introduction.

Abatement measure/action		Time frame	
		Introduction of measure	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	Short term	Short term
	- parking near mass transit terminals		Short term
	- car-pooling		Short term

7.1.2 *Actions to improve the Air Quality Management System*

Such actions concern:

- the improvement of the Air Quality Assessment;
- the improvement of the Assessment of Damage and its Costs;
- the improvement of institutional and regulatory framework;
- building of awareness among the public and policy-makers.

Necessary actions are summarized in Table 7.3.

Table 7.3: Actions to improve the Air Quality Assessment of DKI Jakarta.

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

7.2 A comprehensive list of proposed measures and actions

Table 7.4 presents the full list of proposed measures to improve the Jakarta DKI air quality, which was developed by the local working groups established for Jakarta as part of the URBAIR process.

Table 7.4: Categorized action list to improve the air quality in Jakarta.
S: <2 years, M: 2-5 years, L: 5-10 years, VL: >10 years

CATEGORY: Improved Fuel Quality								
	WHAT	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	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. Evaulate 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, sulphur)	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: Technology Improvement								
	WHAT Vehicles	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
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					

Table 7.4: Cont.

CATEGORY: Technology Improvement, cont.

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

CATEGORY: Fuel Switch

	WHAT	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
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 7.4: Cont.

CATEGORY: Traffic management								
	WHAT	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	Improve traffic flow		S/S					
	a. Improve exsisting road network	Place responsibility, enforce						
	b. Extend/develop road network	- Analysis of the situation (bottlenecks, etc.) - Support responsible agencies	S/M					
	c. Improve/co-ordinate traffic signal systems							
	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.							

Table 7.4: Cont.

CATEGORY: . Transport Demand Management

	WHAT Vehicles	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	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, co-ordination - 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.							
	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.							

Table 7.4: Cont.

CATEGORY: . Inventorying/Dispersion Modeling								
	WHAT Vehicles	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	Improve emission inventory for DKI Jakarta							
	a. Produce inventory of industrial emissions (location, 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 modelling tools/methods, and establish appropriate models for control strategy in DKI Jakarta.							

Table 7.4: Cont.

CATEGORY: . Air Quality Monitoring								
	WHAT Vehicles	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	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								
	WHAT	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
CATEGORY: Awareness raising								
	WHAT	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
CATEGORY: Further studies								
	WHAT Vehicles	HOW	WHEN Action/ Result	WHO	EFFECTS	COST	FEASIBILITY	REMARKS
	Study resuspension from roads							

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ABSTRACT

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

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