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URBAIR

Urban Air Quality Management Strategy in Asia

KATHMANDU VALLEY
Specific Report

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Notice

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

Preface

In view of the potential environmental consequences of continuing growth of Asian metropolitan areas, the World Bank and UNDP launched the Metropolitan Environmental Improvement Program (MEIP) in five Asian metropolitan areas - Beijing, Bombay, Colombo, Jakarta, and Metro Manila. In 1993, Kathmandu joined the intercountry program as the sixth MEIP city. The mission of MEIP is to assist Asian urban areas 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, and comparison of costs of damage and costs of control options (cost-benefit or cost-effectiveness analysis). From this, an action plan can be set up containing the selected abatement measures, for implementation in the short/medium/long term.

The preparation of this city-specific report for Kathmandu 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 December 1993, June 1994 and March 1995. First drafts of the reports were prepared by Norwegian Institute for Air Research (NILU) and Instituut voor Milieuvraagstukken (IVM, Institute for Environmental Studies) before the first workshops, based upon general and city-specific information available from earlier studies. Second draft reports were prepared before the second workshops, 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 Kathmandu were as follows:

The report concludes 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.
- Air pollution impact (damage/assessment and its valuation (Ch. 3), describing and calculating the health damage from the air pollution.
- Description of institutional framework (Ch. 4).
- Abatement measures (Ch. 5), describing the effectiveness and costs of selected technical control measures.
- Draft action plan (Ch. 6), 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. 7).

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: Mr. Anil S. Giri, Royal Nepal Academy of Science and Technology (RONAST), Dr. Madan, L. Shrestha, Dpt. of Hydrology and Meteorology and Dr. Bimala Shrestha, Tribhuvan University. The city-level technical working groups provided operational support, while the steering committee members gave policy direction to the study team. The National Program Coordinator (NPC) of MEIP - Kathmandu, Mr. Guru Bar Singh Thapa, 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 Kathmandu URBAIR working groups were:

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Summary

Past and present development of Kathmandu Valley

Kathmandu Valley, like other larger cities in developing nations, is increasing rapidly in size and diversity. The concentration of population and industry in these cities is high and still getting higher. This situation creates urban air pollution problems in these cities caused by increasing emissions from vehicular traffic, industry and domestic heating, cooking and refuse burning. In the future, potential risk for air pollution exposures will deteriorate at an alarming rate, if the emissions are allowed to develop uncontrolled.

Kathmandu Valley has experienced strong growth over the past few decades. The population of the valley grew by 26% from 1970 to 1980, and further with 44% till 1990. The population was in 1992 about 1,060,000, of which 56% was considered urban.

The number of vehicles has increased rapidly, and has doubled over the past decade. In 1993 the number of vehicles was about 67,000, corresponding to about 15 inhabitants per vehicle. About 20,000 were cars/jeeps, and 36,000 were motorcycles. MC's and trucks/buses had the strongest increase.

The local brick industry, which, together with Himal Cement is the main air polluting industry, has expanded considerably over the later years, with the number of registered kilns tripled over the last decade. This has resulted in a large increase in coal consumption.

An increasing number of vehicles among other developments have caused a significant fuel consumption increase. Over the period 1980-93, the increase has been about 150%, 175%, 250% and 580% for gasoline, motor diesel, kerosene and fuel oil respectively. The per capita fuel consumption in 1993 was about 27 litres of gasoline, 150 litres of motor diesel, 125 litres of kerosene and 20 litres of fuel oil.

Data on air pollution concentrations, on which to base an evaluation of the results of this development on the air pollution of the valley, does not exist for earlier years. However, atmospheric visibility data from Kathmandu airport, analysed from 1970 and onwards, show that there has been a very substantial decrease in the visibility in the valley since about 1980. The visibility, outside of fog situations, is reduced when small particles, mainly from combustion processes, are present in the air. The number of days with good visibility (>8000 meters) around noon has decreased in the winter months, from close to every day in the 70's to about 5 days in 1992/93. In the summer (monsoon) season, the visibility has remained almost unaffected.

Present day air pollution measurements show that particles in the air in the valley represent the most serious air pollution problem with respect to health. WHO guidelines for TSP and PM_{10} are often substantially exceeded. There have been

measured 24-hour TSP concentrations above 800 μg/m^3, while the WHO air quality guideline is 150-230 μg/m^3.

The continued growth of population and GDP in Kathmandu Valley is expected to worsen air pollution, unless corrective measures are taken.

Air Quality Assessment

Kathmandu Valley's air quality has been assessed by reviewing available air quality measurements, constructing an emissions inventory, performing dispersion model calculations of long-term average concentrations, and, based on this, calculating the distribution of population exposure to air pollution.

Air pollution measurements show that TSP and PM_{10} represent Kathmandu Valley's major air pollution problem. This can be stated, although the measurement programs so far have not been extensive in time and spatial coverage. Concentrations of TSP and PM_{10} exceed WHO guidelines substantially and frequently. More than 50% of the days of measurements, which cover both the dry and the wet season, had TSP concentration above the WHO guideline. Maximum TSP concentrations measured in residential areas exceeded the guideline by more than a factor of 2, while hot spot concentrations in traffic and industrial exposed areas exceeded the guideline by up to a factor of 4. SO_2 and NO_2 pollution is not as serious as TSP and PM_{10} overall. CO and ozone have not been extensively measured.

The emission inventory was based upon available information, and many assumptions were made. **Main sources** of TSP and PM_{10} emissions were (relative contributions):

TSP		PM_{10}	
Himal Cement	36%	Brick industry	28%
Brick industry	31%	Domestic fuel	25%
Domestic fuel combustion	14%	Himal Cement	17%
Road resuspension[1]	9%	Vehicle exhaust	12%
Vehicle exhaust	3.5%	Road resuspension	9%

Population exposure distributions for TSP and PM_{10} were calculated based on:

- calculated long-term average concentrations in a km^2 grid net using a gaussian, multisource dispersion model;
- population distribution in the same km^2 grid net; and
- estimated additional exposure in hot-spot areas (main road network and industrial areas).

[1] The calculation of resuspension from roads may represent an overestimate, as it is based on an overall emission figure of 2 g/km.

It was calculated that about 50% of the population lives in areas where the WHO AQ Guideline for TSP, annual average (90 μg/m³), is exceeded.

Estimated exposure exceeding two times the AQG for TSP, annual average, is 3-4% of the population. These are drivers and roadside workers and residents, and residents in the brick kiln areas.

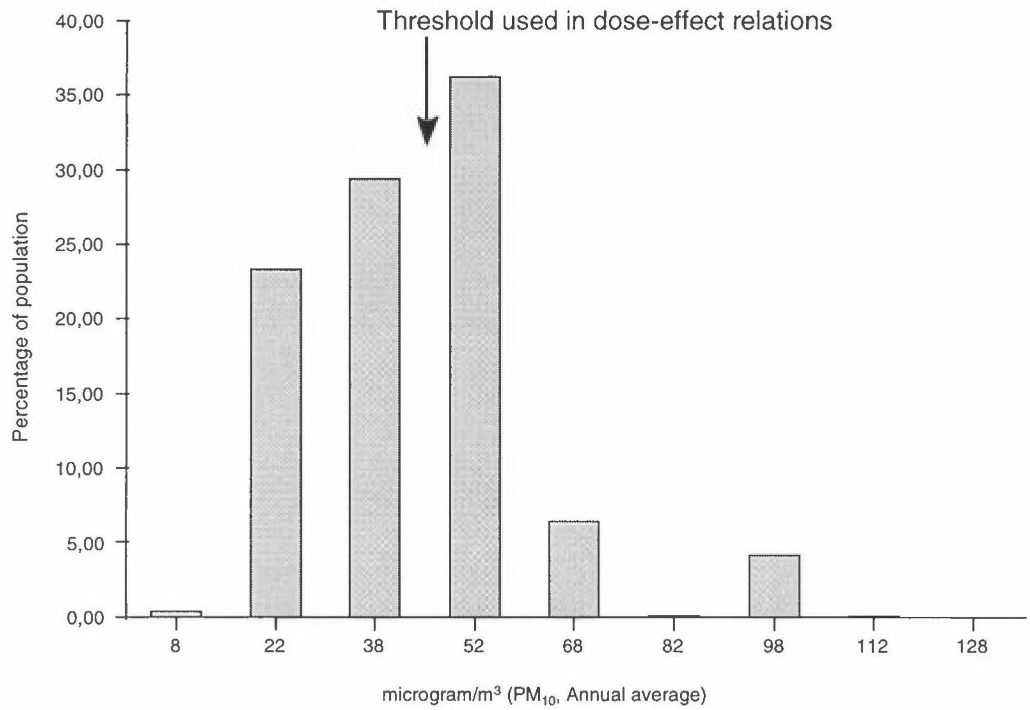
The exposure is due to the following main sources:

- For TSP: Resuspension from roads, Bull's trench kilns, domestic fuel com bustion, vehicle exhaust, domestic refuse burning and gasoline vehicles.
- For PM_{10}: Vehicle exhaust, domestic fuel combustion, Bull's trench kilns and resuspension.

Additional exposure in industrial areas is due to process emissions.

The highest exposure is due to roadside concentrations, which affect drivers, commuters, and roadside shops and residents.

The figure below shows the estimated population exposure distribution to PM_{10} (annual average) in Kathmandu Valley.



The concept of Air Quality Management Strategy (AQMS)

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

- Air Quality Assessment;
- Environmental Damage Assessment;

- Abatement Options Assessment;
- Cost Benefit Analysis or Cost Effectiveness Analysis;
- Abatement Measures Selection (Action plan); and
- Optimum Control Strategy.

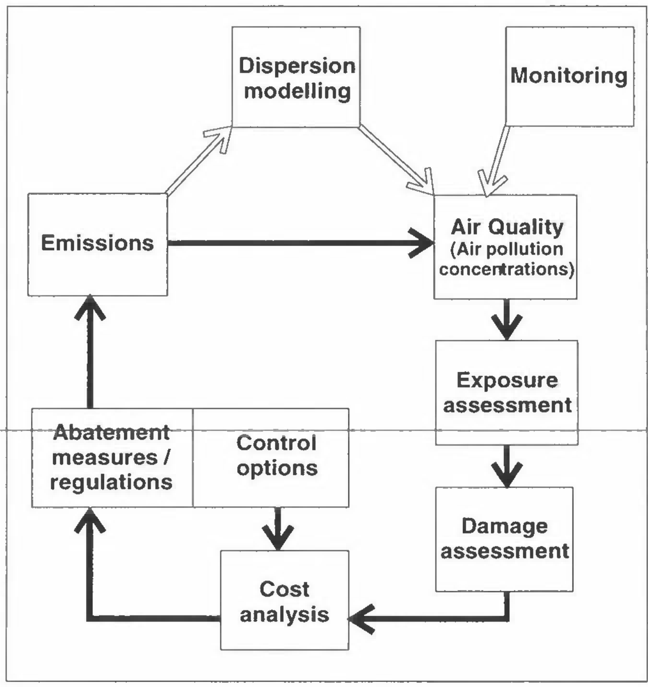
The Air Quality Assessment, Environmental Damage Assessment and Abatement Options Assessment provide input to the **Cost/Benefit Analysis, or a Cost Effectiveness Analysis**, which is also based on established Air Quality Objectives (i.e. guidelines, standards) and Economic Objectives (i.e. reduction of damage costs). The analysis leads to an **Action Plan** containing abatement/control measures, for implementation in the short/medium/long term. The final result of this analysis is the **Optimum Control Strategy**.

A successful AQMS requires the establishment/completion of an integrated system for continued air quality management. This system requires continuing activities on the urban scale in the following fields:

- inventory of air pollution activities and emissions;
- monitoring of air pollution and dispersion parameters;
- calculation of air pollution concentrations, by dispersion models;
- inventory of population, materials and urban development;
- calculation of the effect of abatement and control measures; and
- establishment and improvement of 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).

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



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 * quantifying sources — emission inventory	Assessment
* identifying sources * quantifying sources — emission inventory	
* monitoring air pollution	
* assessing the exposure (impact) situation	
* identifying source - exposure relations → modelling	
* 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 process of attaining acceptable urban air quality is dynamic and long term. As the urban areas develop, population, pollution sources and technology change. Throughout this process, it is very important to have an operating Air Quality Information System (AQIS), in order to:

- keep the authorities and the public well informed about the short-term and long-term AQ development
- assess the results of abatement measures, and thereby
- provide feed-back information to the abatement strategy process.

Needs for improvement of the Air Quality Assessment

At present there is no continuing air quality monitoring program, or stations, in operation in Kathmandu Valley. A comprehensive **monitoring program** for the valley is needed.

Such a program should include (using continuous monitors where possible:

- Compounds : TSP, PM_{10}, submicron particles, black smoke, CO (1. priority).
- Sites : Road side, city background, brick kiln area, rural, hilltop sites.
- Meteorology : Several (3-5) sites measuring wind, RH, stability, visibility.

The **emission inventory** should be improved, especially regarding

- fuel statistics
- emission factors for vehicles, domestic fuel combustion and resuspension from roads
- Bull's Trench Kiln emission measurements
- particle size distribution for the various emission sources.

The determination of **population exposure** in Kathmandu Valley is based upon a combination of dispersion modelling and pollution measurements.

A population exposure distribution of good quality is important since it is the basis for:

- estimating health damage
- assessing the effects on health of various measures to reduce the exposure, as part of a cost/benefit analysis.

To improve the population exposure calculations beyond what has been developed as part of the first phase of URBAIR for Kathmandu Valley, it is necessary to:

- establish dispersion models for the Valley capable of dealing with the complex topographical/temperature/dispersion conditions, and also for dispersion from roads.

- improve the input data base to such a model, regarding:

  - hourly air pollution concentration data
  - hourly dispersion data, spatial resolution
  - hourly emission data

Impacts of the air pollution and their valuation

The adverse air quality has several **impacts**: to human health, materials, vegetation and crops, buildings and monuments, ecosystems and tourism. For practical and methodological reasons only a partial assessment and valuation of the health impacts due to PM_{10} was possible. The table below presents the results. In monetary terms the total impact comes to about NRs 200,000 million. Impact of lead pollution due to the use of gasoline which contains lead is not included.

Impacts of air pollution (PM_{10}) on mortality and health and their valuation in Kathmandu Valley (1990).

Type of health impact	Number of cases	Value (NRs)	
		Specific	Total (1,000)
Excess mortality	84	340,000	28,644
Chronic bronchitis	506	83,000*	41,988
Restricted activity days	475,298	56	26,617
Emergency room visits	1,945	470-720 (600 in calculations)	1,167
Bronchitis in children	4,847	350	1,697
Asthma	18,863	45-4,170 (600 average in calculations)	11,318
Respiratory symptom days	1,512,689	50	75,634
Respiratory hospital admissions	99	4,160	415
Total			209,051

* Shrestha's estimate is about NRs 146,000, but based on a not discounted sum of amount over 27 years. Discounting with 5% leads to an estimate of NRs 83,000.

It is emphasised that health is not the only adverse impact of air pollution; however given the lack of appropriate data it was not possible to assess quantitatively different impacts such as reduction of the economic life of capital goods, tourism, crop growing and other intangible impacts. In particular, the **adverse impact on tourism**, Nepal's second industry, is a concern.

Legislation, policies and institutions regarding air pollution

The development of environmental and air pollution **legislation** in Nepal is in its first phase. Prior to 1994, there were no laws pertaining specifically to pollution. Now, an Environmental Preservation Council has been established, and also an Environmental Preservation Division within the National Planning Commission. The Government's environmental policies were set out in the Eighth Five Year Plan, in particular regarding the urban environment. Recently proposed environmental legislation, which also addresses air pollution, includes Environmental Impact Assessment (EIA) guidelines, and an Industrial Pollution Control Regulation (IPCR). Also, laws on vehicle pollution control have been proposed according to the recommendations from the Kathmandu Valley Vehicle Emission Control Project (KVVECP). Standards or guidelines for ambient air quality have not yet been passed. The basis for controlling air pollution in Kathmandu Valley needs to be further developed.

A number of **institutions** are involved in the air pollution sector in Kathmandu Valley. There are capable institutions involved in air quality monitoring and to some extent emission measurements. However, the monitoring actually taking place needs to be further advanced, both regarding availability of monitoring equipment, laboratories, training and increased man-power.

Abatement measures and costs

The share of traffic emissions (exhaust & resuspension) of the total PM_{10} emissions is about 20% (table 2.2). However, its impact is disproportionally larger; an increase of traffic PM_{10} emissions has about twice the impact of a corresponding increase in the emissions of domestic sources and brick kilns (NRs 570 per kg increased emission versus NRs 260 per kg increased emissions).

The model which was used to calculate the impacts, also allowed the estimation of the marginal benefits of emissions reduction by source category. The table below shows the results.

Marginal benefits from emissions reduction in different sources.

Source	Emissions (tonne)	Change in Emission (%)	Change in Mortality	Change in RSD (1000)	Change in health damage (NRs thousand)	Marginal benefits (NRs/kg)
Traffic (exhaust)	440	-10	-6	-108	-15,0374	341
Resuspension	400	-10	-2	- 35	- 4,903	122
Domestic emissions	1160	-10	-9	-155	- 21,360	185
Brick (Bull's trench kilns)	1250	-10	-3	- 57	- 7,832	62

The far right column of this table provides guidance in selecting measures for emissions reduction.

Several measures appropriate to addressing Kathmandu's air quality problem are listed below. Note that the figures are first estimates.

Vehicle emissions. Lack of maintenance has been shown to be a major cause of vehicle emissions. The scope for PM_{10} emissions reduction by introduction of a scheme for mandatory **Inspection & Maintenance** is estimated at 150 tonnes annually.

Estimated monetary health benefits: NRs 25 million
Estimated costs: Nil (compensated by fuel savings)

Introduction of **low-smoke lubricating oil** for two-stroke mixed lubrication engines in vehicles may decrease PM_{10} emissions with 50 tonnes.

Estimated monetary health benefits: NRs 15 million
Estimated costs: NRs 12,500

Addressing the **adulteration** of gasoline will decrease the PM_{10} emissions by an unknown extent.

Other measures include the introduction of **unleaded gasoline**, and improving the quality of **diesel fuel**. The benefit of the latter measure is estimated at NRs 7.5 million. Costs are unclear.

A final measure would be the introduction of clean vehicle standards, requiring the use of catalytic converters in the exhaust systems of gasoline driven vehicles. The magnitude of the annual costs per vehicle are NRs 5000.

Domestic emissions. From the perspective of energy consumption and air quality, an appropriate measure would be to promote the use of improved cook stoves (ICS). However, neither costs nor benefits could be assessed within the scope of this study

Bull's trench kilns. Cost figures for conceivable methods to reduce PM_{10} emissions from brick manufacturing were not found.

Action Plan

Through the work carried out by the local working groups, a number of proposed actions and measures have been listed and categorized within the following categories:

- Monitoring, inventory and dispersion modelling.
- Transport demand management and Infrastructure improvement.
- Land use planning and management.
- Fuel switch/Quality control.
- Awareness raising.
- Further studies.
- Institutional and regulatory framework.

A list of “obvious” technical measures for possible, proposed introduction in the short, medium and long term has been made, given in the table below. Very rough estimates of the costs and benefits of some of those measures were given above.

A list of technical pollution abatement measures, important for the reduction of the air pollution effects in Kathmandu Valley.

Abatement measure	Short term	Medium term	Long term
Technical measures, vehicles			
I/M scheme, comprehensive	xxx		
Improved motorcycle technology		xx	xx
Clean vehicle standards		xx	xx
Improved abatement/new propulsion techniques			xx
Fuel quality			
Control adulteration	xxx		
Low-lead gasoline	xx		
Unleaded gasoline		xx	
Improved diesel quality	xx	xx	
Low-smoke lub.oil, 2-stroke engines	xxx		
Road resuspension			
Road cleaning, garbage collection	xxx		
Domestic emission			
Improved cooking stoves	x	xx	
Switch to kerosene	x	xx	
Brick industry			
Improved technology	x	xx	

URBAIR

Urban Air Quality Management Strategy in Asia

KATHMANDU VALLEY
Specific Report

1. Background information

1.1 Scope of the study

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

The major objective of the URBAIR program is to develop a generalised Air Quality Management Strategy (AQMS) to be used for Asian cities, and to apply this strategy to develop Action Plans for improvement of 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 on 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 generalised 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 prioritised 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.

1.2 General description of Kathmandu Valley air pollution situation

Kathmandu is the administrative, trade and educational centre of Nepal, as well as the pivot point of communications. This densely populated area is made up of Kathmandu and Patan, the two areas being separated by the Bagmati River, which runs east-west between the two centres. This is a circular area roughly 7 km in diameter. The Tribhuwan international airport lies just east of this circle. Outside of this area are villages and scattered housing, and the city Bhaktapur is located about 10 km east of Kathmandu city.

Figure 1.1 shows the locations of the various cities and industrial zones of Kathmandu Valley. This area, which covers most of the valley, was used in the modelling of dispersion and population exposure in this study.

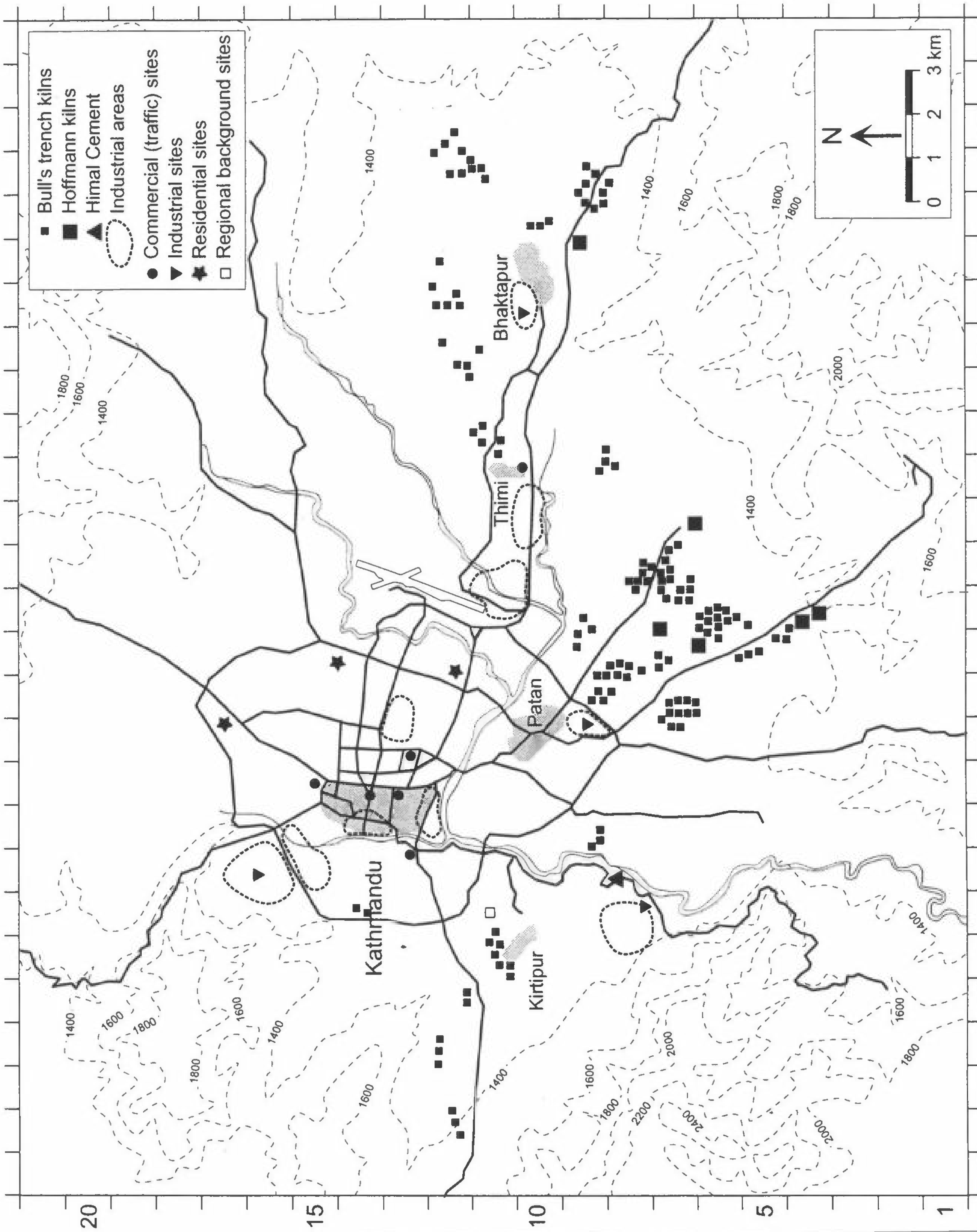


Figure 1.1: Air Quality Management area of Kathmandu Valley.

Apart from agricultural activities, substantial parts of the flat valley floor are used for brick production. There are more than a hundred brick production facilities in the valley, and many of them are situated in areas immediately south and east of Kathmandu City, within 5-10 km from the city centre. The coal and other energy sources used to fire bricks in these facilities creates air pollution emissions of significance to the air quality of the valley.

Road traffic is an important source of air pollution, both because of exhaust emissions and the resuspension of particles from dust and refuse on the roads. A substantial part of the vehicle fleet is in poor condition and the vehicles produce large amounts of visible emissions.

The road traffic is quite dense from the city centre to the ring road, about 3 km from the centre.

A cement plant is situated on the bank of the Bagmati river, about 6 km south of the city centre. The emissions from this plant dominate the air quality situation in its neighbourhood, and may contribute to air pollution in the city overall during southerly winds, which prevail in the monsoon season.

Domestic emissions include cooking, heating and refuse burning. In Kathmandu, primarily kerosene and wood are used for cooking.

Kathmandu Valley forms a basin of size approximately 30x30 km, surrounded by hills of height about 500-1,000 m above the valley floor (which is about 1300 m above sea level). The hills surround the valley completely, with only a narrow outlet where the Bagmati river runs out of the valley in the southwest corner. This bowl-like topography and generally low wind speeds during the dry (winter) season creates poor dispersion conditions for air pollution emissions, and predisposes the Kathmandu Valley to serious air pollution problems if emissions are not controlled and restricted. Increasing population along with polluting activities have resulted in a substantial increase in air pollution concentrations in the valley, particularly in the last decade.

1.3 Data sources

Previous studies

Some studies have been carried out on various subjects related to air pollution and its effects, such as air quality measurements, road traffic, brick industry, emissions, fuel and energy consumption and scenarios, which have provided much useful information used in this URBAIR analysis. However, there are no previous, comprehensive and complete studies of the air pollution situation of the Kathmandu Valley, describing air quality, sources, emissions and exposure.

The following are the most important studies providing background information, in chronological order:

- MS Degree Thesis of Surendra Raj Devkota: Energy Utilization and Air Pollution in Kathmandu Valley, Nepal (Devkota, 1992).
- Study of an Kathmandu Valley Urban Road Development by Japan International Cooperation Agency (JICA, 1992).
- Energy Use and Emission of Air Pollutants: Case of Kathmandu Valley, by Ram M. Shrestha and Sunil Malla of Asian Institute of Technology, Bangkok (Shrestha and Malla, 1993).
- Kathmandu Valley Vehicular Emission Control Project (KVVECP), a HMG/UNDP Joint Project (Mathur, 1993).
- Assessment of the Applicability of Indian Cleaner Technology for Small Scale Brick Kiln Industries of Kathmandu Valley, carried out by Nepal Environmental and Scientific Services (P) Ltd. (NESS, 1995).

Presentations at the first URBAIR workshop in Kathmandu also provided review data on the meteorological conditions (M.L. Shrestha), as well as the industrial and traffic (M.D. Bhattarai, S. Thapa et al.) pollution sources in the valley.

As part of an US AID funded study on vehicle emission measurements in Asia using a remote sensing (FEAT) technique, such measurements were made also in Kathmandu, providing useful data for their study (Steadman and Ellis, 1993). A joint UNDP/World Bank Energy Efficiency and Fuel Substitution Study (World Bank, 1993). Evaluated options for rationalizing the energy use in Nepal, having the objective to develop a coherent strategy for the National Industrial Energy Management Program (NIEMP).

URBAIR data collection

As part of the URBAIR project for Kathmandu, local consultants were contracted to collect available data on various items:

- RONAST collected data on population, pollution sources, fuel, vehicle and traffic statistics, and air quality measurements, air quality laws and regulations, and institutions dealing with the field of air pollution (project leader Anil S. Giri). As part of the task, they generated new traffic data by counting rush hour traffic at 33 locations.
- Dr. Madan L. Shrestha collected meteorological and visibility data and evaluated the dispersion and visibility conditions of the valley (M.L. Shrestha, 1995).

- Dr. Bimala Shrestha made an assessment of health effects and costs related to health damage (B. Shrestha, 1995).

1.4 Summary of past development in the Kathmandu Valley

Figure 1.2 gives a summary of the available data on growth trends in Kathmandu Valley (and Nepal) over the past 20 years, regarding population, fuel consumption, vehicles, brick kilns, and visibility.

The population in Kathmandu Valley increased by 81% from 1971 to 1991. The urban fraction was 56% in 1991. The number of registered road vehicles has increased by close to 100% over the last decade, while the number of registered brick kilns have increased by 200% over this period. Liquid fuel consumption for Nepal as a whole, has increased substantially since 1980, by more than 150% for gasoline and motor diesel (HSD) and much more for kerosene (SKO, +250%) and fuel oil (FO, +580%). The fuel wood consumption seems to be decreasing (by 20% from 1984 to 1987) (Devkota, 1992) having been replaced by SKO to a large extent.

In 1990, the GDP/capita for Nepal was 170 USD. Only four countries had a lower figure. There has been an average annual increase of 0.5% over the period 1965-90.

These growth trends have caused an increased air pollution problem in the valley, as exemplified in figure 1.2 by the observed degradation of visibility conditions. In the 4 month period November-February, the months with lowest visibility, the number of days with fairly good visibility (>8000 m at 1145 local time) has decreased from most of the days (some 115 days) in early 70's to only about 20 days in 1992/93.

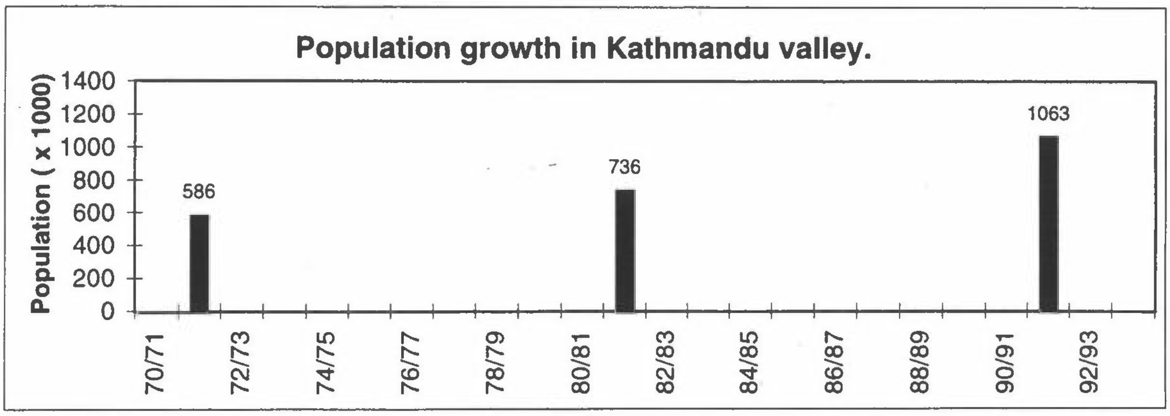
1.5 Population

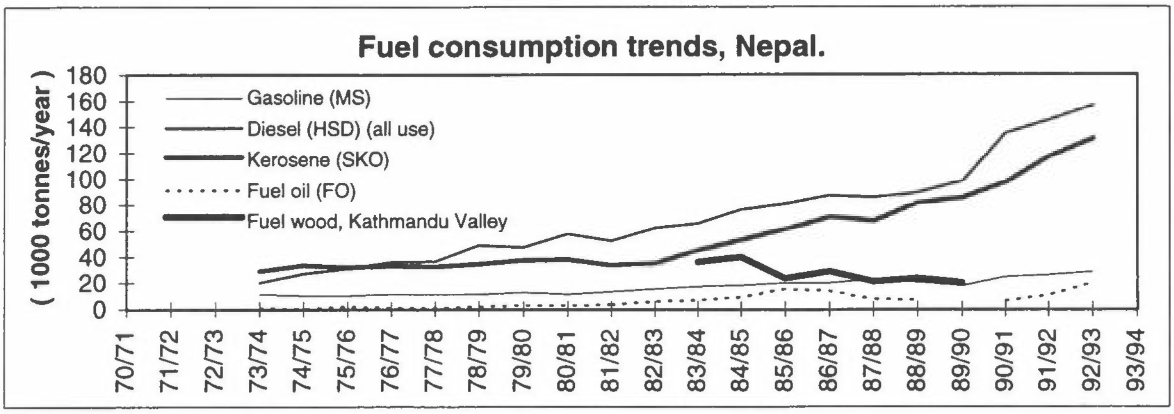
Available population data for 1971, 1981 and 1991 are shown in Table 1.1 (JICA, 1992).

Table 1.1: Population data ($x10^3$), Kathmandu Valley (Ref.: JICA, 1992).

	Kathmandu district		Lalitpur district		Bhaktapur district		Total	
	Pop.	% urban	Pop	% urban	Pop.	% urban	Pop.	% urban
1971	354		122		110		586	
1981	427		165		144		736	
1991	668	62	222	53	736	35	1063	56
Growth rate %								
71-81	1.9		3.1		2.7		2.3	
81-91	4.6		3.0		1.8		3.7	

In the valley as a whole, the growth rate has been 3.7% per annum.





Growth trends, Kathmandu valley.

- vehicles
- brich kilns (Bull's trench)

Bull's trench kilns:	+ 200%
Cars, jeeps:	+ 64%
Minibuses, buses, trucks:	+ 93%
MC, scooters:	+ 118%

1980......................................1990

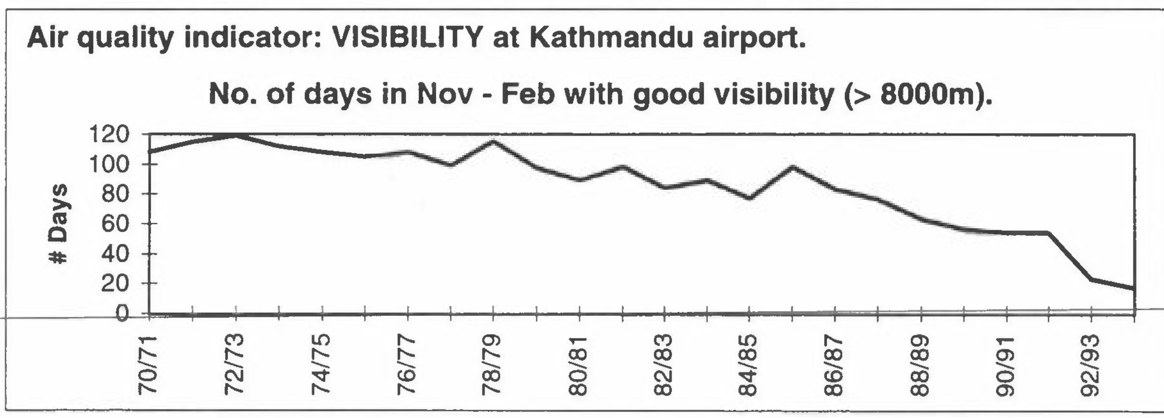


Figure 1.2: Development and growth trends over the last two decades, Kathmandu Valley.

1.6 Fuel consumption

The available data do not give a full picture of the trend in the total consumption of various fuels in Kathmandu Valley, but some data are available, for the valley, and for Nepal as a whole.

Motor diesel (HSD) and kerosene (SKO) are, by volume, the most used **liquid fuels** in Nepal, followed by gasoline (MS) and fuel oil (FO).

The quality of the liquid fuel is governed by required specifications. Maximum allowed sulphur contents are given in Table 2.3 (p. 28), ranging from 4% in fuel oil and 1% in motor diesel, to 0.2% in 93 octane gasoline. Maximum lead contents are 0.56 g/l in 83 octane gasoline and 0.80 g/l in 93 octane gasoline. The actual contents of sulphur and lead are not known, and may be considerably less than the maximum allowed.

As for **fuelwood**, Devkota (1992) gives the consumption data for the Kathmandu Valley (Table 1.3). Fuelwood consumption has declined by about a factor of 2 between 1983 and 1990, due to diminishing resources. For domestic use, fuelwood has been replaced by kerosene and may be by more use of agricultural residue.

Table 1.2: Liquid fuel consumption (10^3 kl/yr), Nepal (Ref.: Gautam, 1994).

	Gasoline MS	Motor diesel HSD	Kerosene SKO	Light diesel oil LDO	Aviation fuel	Fuel oil FO	LPG
75/76	10.5	30.8	32.2	9.4	11.2	1.8	0.6
80/81	11.5	57.3	37.8	10.3	16.8	3.0	0.7
85/86	20.4	80.4	62.2	8.3	23.2	15.8	2.6
90/91	24.6	135.6	97.7	3.0	19.0	6.3	7.4
92/93	28.3	156.9	131.1	0.3	28.1	20.3	?
Change 80-93%	+146	+174	+247	~-100	+67.3	+576	»

Table 1.3: Fuelwood consumption, Kathmandu Valley (Ref.: Devkota, 1992).

Year	10^3 t/a	Year	10^3 t/a
1983/1984	35.9	1987/1888	21.2
1984/1985	40.0	1988/1989	23.7
1985/1986	23.7	1989/1990	20.0
1986/1987	29.0		

In the brick industry, fuelwood has been replaced by coal. While in the early 80's fuel and coal were used in about the same amount in the local brick industry, today the ratio between coal and fuelwood consumption is about 7 to 1 (NESS, 1995).

Coal is used mainly in the brick and cement industry. Available data are shown in Table 1.4. In the Hoffman kilns coal consumption has been reduced somewhat since 1970. In the Himal Cement Factory, coal consumption was somewhat larger in 1990 than in 1980, while the 1992/93 data indicate substantial increased production and coal consumption in recent years.

Table 1.4: Coal consumption in the brick and cement industries, Kathmandu Valley (tons/a).

	Bull's trench[1] kilns	Chinese[2] (Hoffman) kilns	Himal Cement[2] factory	Total[3]
1970/71		3300		
1975/76		2950		
1980/81		1690	6400	
1985/86		2200	5860	
1990/91		2440	7980	
1992/93	21000	4100	17100	47000
1993	43800			
1994	54800			

References 1: NESS, 1995
2: Devkota, 1992
3: Shrestha and Malla, 1993

The dominant coal consumer in the valley is the Bull's trench kiln industry. Shrestha and Malla's estimate for 1992/93 appears to underestimate consumption, which has been estimated for 1993 and 1994 in a special NESS study. Data for earlier coal consumption in the Bull's trench kilns are not available. However, it has most probably increased substantially, since coal has, to a large extent, replaced firewood.

1.7 Industrial development

There has been a strong growth in the number of industries in Kathmandu Valley during the last decade particularly. In 1991/92 there were about 2200 industrial establishments in Kathmandu Valley with more than 10 employees, while the 1986/87 census showed 1504 industries in Kathmandu Valley.

The development of fuel consumption in the major air polluting industries, the brick and cement industries, has been briefly covered in Chapter 1.4. The Himal Cement Factory was established in 1974. The local brick industry has developed over a longer period, and the number of registered Bull's trench kilns has increased markedly in recent years, from 102 in 1984 to 305 in 1993. The number of operating kilns is much lower, about 130 presently, but it can be assumed that the number of operating kilns has increased relative to the total number.

The increase in the number of smaller industries represents an increase in the combustion of such fuels as fuel oil, HSD and agricultural refuse, as well as some process emissions. The exact amount of increase in such industrial combustion and process emissions is not known. It is believed to be of less significance to air pollution in general than the brick and cement industry, but indicates increased local air pollution exposure.

1.8 Road vehicle fleet

In 1993 the number of registered vehicles in Kathmandu Valley was about 67,000, distributed as follows (see Appendix 4):

- about 22,000 cars/jeeps; 21 per 1000 inhab.
- about 36,000 motorcycles; 34 per 1000 inhab.
- about 5,000 trucks/buses

No specific vehicle fleet data have been made available for previous years. The KVVECP study reported a 64% increase in registered car/jeeps from 1980 to 1990, 118% for MCs and 93% for buses and trucks.

2. Air quality assessment

The purpose of this chapter on Air Quality Assessment for Kathmandu Valley is to **provide an estimate of the population exposure** to air pollutants in the area, and to quantify the contributions to this exposure from the various pollution source categories.

This estimate was derived from an analysis of the following:

- Description of the 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 modelling.
- Calculation of the population exposure, by combining spatial distributions of population and concentrations, taking into account the exposure on and near roads as well as in industrial areas.

National Air Quality Standards or Guidelines have not been proposed yet for Nepal. In this study the Guidelines of the World Health Organization (WHO) are used to evaluate the air quality in Kathmandu.

2.1 Air pollution concentrations in Kathmandu Valley

Overview of air pollution measurements and observations

Subjective observations in the Kathmandu Valley, especially in the dry season, indicate the following significant air pollution problems:

- Very high roadside air pollution, dominated by particles and odour, due to a large extent of highly smoking vehicles of all types and resuspension of street dust and litter.
- Black smoke plumes from numerous brick kilns.
- Generally low visibility, especially before noon.

In addition one large point source, the cement factory, has highly visible particle emissions.

The air pollution concentrations in Kathmandu Valley have only recently been measured directly. In 1993 measurements were made in the ENPHA study (Karmacharya et al., 1993), within the KVVECP study (Devkota, 1993), by the Hydrological and Meteorological Services (HMS) (Shrestha, 1994) and by NESS (Pvt) Ltd (1994) to the following extent:

ENPHA study	:	Measurements of TSP, PM_{10}, SO_2, NO_x, CO and Pb in November 1992 and February 1993, at a total of 20 sites.
KVVECP study	:	Measurements of TSP, PM_{10}, SO_2, NO_2, September-December 1993. A total of 14 sites (traffic, industrial, residential, background), 4-22 days of measurements at each site. (Some CO measurements were also made.) The short measurement periods at each site limits the accuracy of the measurements. However, the study does provide a picture of the variation in space and time.
HMS measurements	:	TSP measurements at the HMS Building, Babar Mahal, January-August 1993. 10-31 days of measurement each month.
NESS (Pvt) Ltd measurements	:	PM_{10} and lead in air, and lead in road dust. Samples taken at a total of 19 sites during September-November, 1993.

Visibility observations have been made at the Kathmandu Airport since 1969, through hourly observations of meteorological visibility.

These observations and measurements indicate that air pollution by particles is the primary air pollution problem in the valley, leading both to potential health risks, and to visibility degradation. According to the measurements of SO_2 and NO_2, these compounds seem to represent little risk at present. The CO concentrations can be fairly high at rush hours along the roads with the heaviest traffic.

In Appendix 1, the analysis and evaluation of the results of these measurements and observations have been summarized. An extract of that summary follows.

Table 2.1: Ambient Air Quality Monitoring Stations in the KVVECP study.

S. No.	Category	Locations	Distance from main road (m)	Height of the station (m)
1	Commercial Areas:			
	i. Heavy traffic (30-40,000 ADT)	Singha Durbar, GPO	2 3	3 3
	ii. Medium traffic (20-30,000 ADT)	Ratnapark, Lainchaur, Kalimati	4 2 3	3 2.5 3
	iii. Low traffic (<7000ADT)	Thimi (NTC)	2	2.5
2	Residential Areas	Maharajgunj (TUTH), Naya Baneswor, Jaya Bageshwori	30 20 15	3 7 8
3	Industrial Areas	Balaju, Bhaktapur, Patan Industrialized districts, Himal Cement Factory surrounding	15 50 5 100	4 3 5 10
4	Regional background/ control site	Tribhuvan University Kirtipur	50	3

ADT: Average Daily Traffic

Air pollution concentrations

TSP concentrations

TSP concentrations measured by ENPHA, KVVECP and HMS show that the WHO guidelines for daily averages (120-230 μg/m^3) are substantially exceeded both in traffic and residential areas, and indicate that the guideline for the annual average (60-90 μg/m^3) is also exceeded.

Results of measurements are shown in Figures 2.1 and 2.2 (average and maximum concentrations).

The maximum 24 hour TSP measured at Babar Mahal was 467 μg/m^3 (HMS building, 15 m above ground), and ranged between the following values for the different sites of the KVVECP study (near ground level):

Traffic sites	:	319-876 μg/m^3
Residential sites	:	273-350 μg/m^3
Industrial sites	:	102-290 μg/m^3
Near Himal Cement	:	560 μg/m^3
Tribhuvan Univ. (reg. background)	:	155 μg/m^3

The KVVECP measurements were made in September-December 1993. Measurements through the winter would most probably give higher maximum concentrations.

The ENPHA measurements showed a maximum and average of 555 µg/m³ and 308 µg/m³ at 9 sites representing Central Kathmandu City air overall. For roadside sites, the measurements showed maximum and average TSP of 2258 µg/m³ and 1397 µg/m³ for the 11 sites measured. These values are based on a 9-hour average, and only one sample was taken at each site.

Regarding annual average concentration, the HMS measurements indicate a concentration around 180 µg/m³ at Babar Mahal, 15 m above ground level, which is more than twice the WHO standard. At more exposed sites, such as in traffic areas, and the Himal Cement area, the annual average would be much higher.

The WHO guideline values of 150-230 µg/m³ TSP were exceeded by 70% above the lower and 50% above the higher values at the KVVECP stations.

Also at Babar Mahal, the majority of the days had TSP above the guidelines.

The maximum TSP 24-hour concentrations measured, 467 µg/m³ at the Babar Mahal building, and 319-876 µg/m³ at traffic exposed sites in the KVVECP study, were more than twice the upper level of the 24 hour WHO standard.

The 2258 µg/m³ maximum in the ENPHA measurements represents a estimated 24 hour average value of about 1100 µg/m³.

These measurements point to a severe TSP pollution problem in the Kathmandu Valley, and in Kathmandu City in particular.

No measurements have been made in the brick kiln areas. However, the high concentrations at Thimi may be partly the result of contributions from the brick kiln emissions.

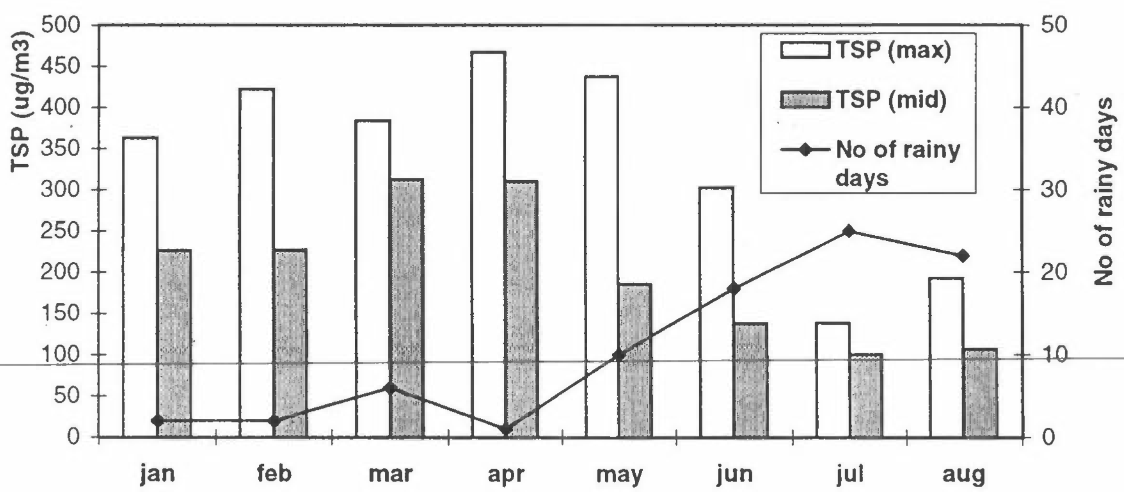


Figure 2.1: Summary of TSP measurements, Babar Mahal Building. (Ref.: Shrestha, 1995.)

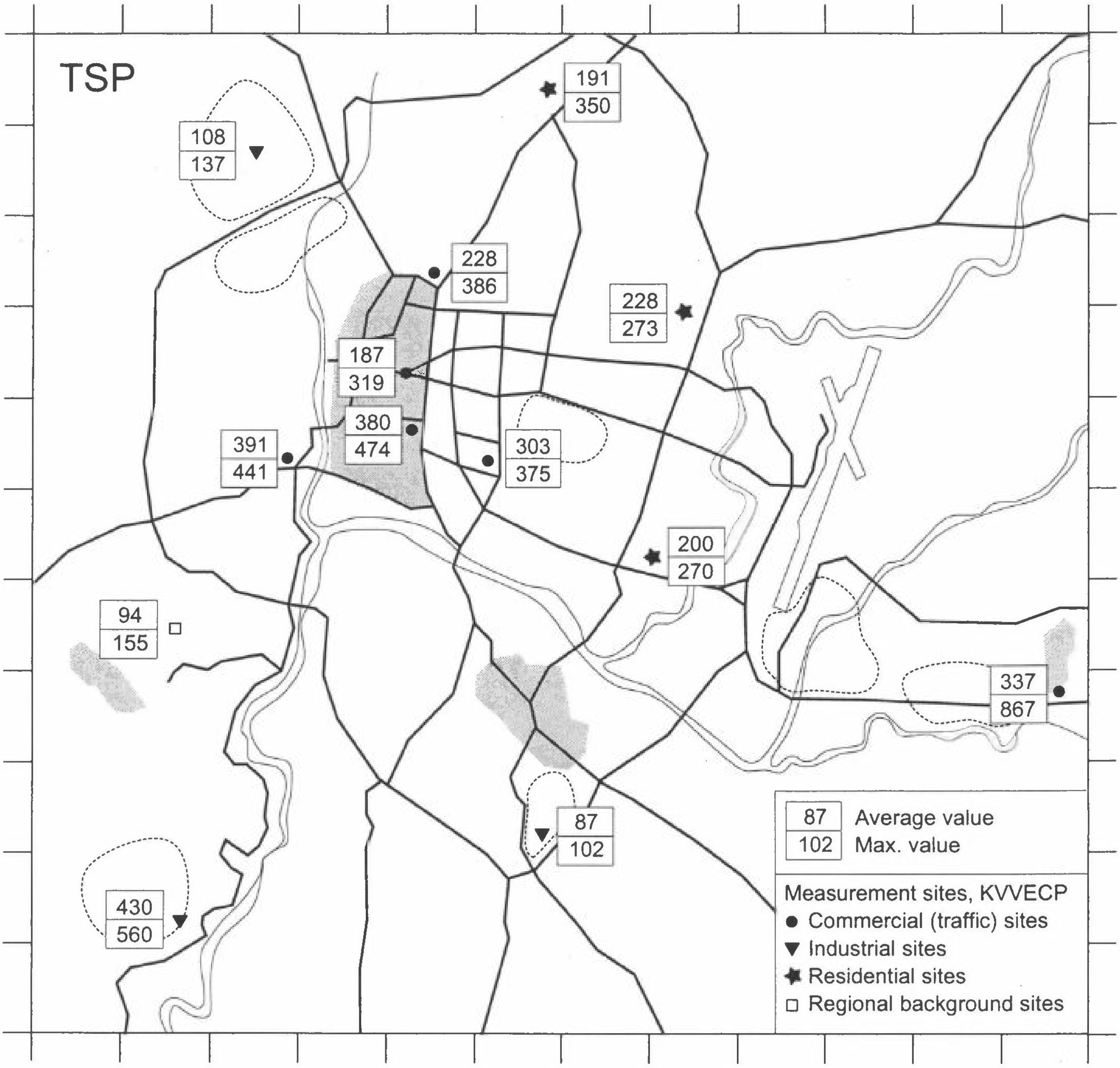


Figure 2.2: Results of TSP measurements, KVVECP study September-December, 1993. (Relatively short measurement periods at each site.) (Ref.: Devkota, 1993.)

PM_{10}-concentrations

PM_{10} has been measured by ENPHO, KVVECP, and by NESS. The results of the KVVECP measurements are shown in Figure 2.3. The PM_{10}-concentrations were above the WHO recommended guideline (70 µg/m³) on all of the days with measurements, except for the industrial sites Balaju and Patan (which had the lowest TSP and PM_{10} levels), the Ratnapark traffic site and at Trubhuwan University. At this last site, about 50% of the measured days had PM_{10} above the guideline. The low values at Balaju and Patan are not representative, since measurements were made only for a few days in September.

The highest PM_{10}-concentrations measured were 201 µg/m³ at GPO (heavy traffic) in November, and 194 µg/m³ at the Himal Cement site, in December, compared to the WHO recommended guideline, 70 µg/m³.

About 50% of all the measurements in the KVVECP study were above the recommended guideline.

The ENPHO PM_{10} measurements in Kathmandu City gave an average and maximum concentration of 89 µg/m³ and 127 µg/m³ respectively at the general air sites, and 296 µg/m³ and 498 µg/m³ at the 11 roadside sites (9 hour average values). The results support the results of the KVVECP study.

The NESS PM_{10} measurements, representing one 1 hour average samples during daytime, at each of 9 sites, gave much higher values, up to 2100 µg/m³, with an average of 800 µg/m³. Reasons for the apparent discrepancies between these results and those from the ENPHO and KVVECP studies may possibly be found when comparing the different samplers and laboratories used.

The ratios between measured PM_{10} and TSP are given in Table 2.1.

Table 2.2: Ratios between PM_{10} and TSP, from KVVECP and ENPHO measurements.

	Based on	
	Average concentration	Max. concentration
KVVECP		
Traffic sites	0.39	0.34
Residential sites	0.48	0.48
Industrial sites	0.47	0.51
Himal Cement site	0.39	0.35
Tribhuvan Univ.	0.70	0.52
(Background site)		
ENPHO		
Traffic sites	0.21	0.18-0.25
General sites	0.29	0.23

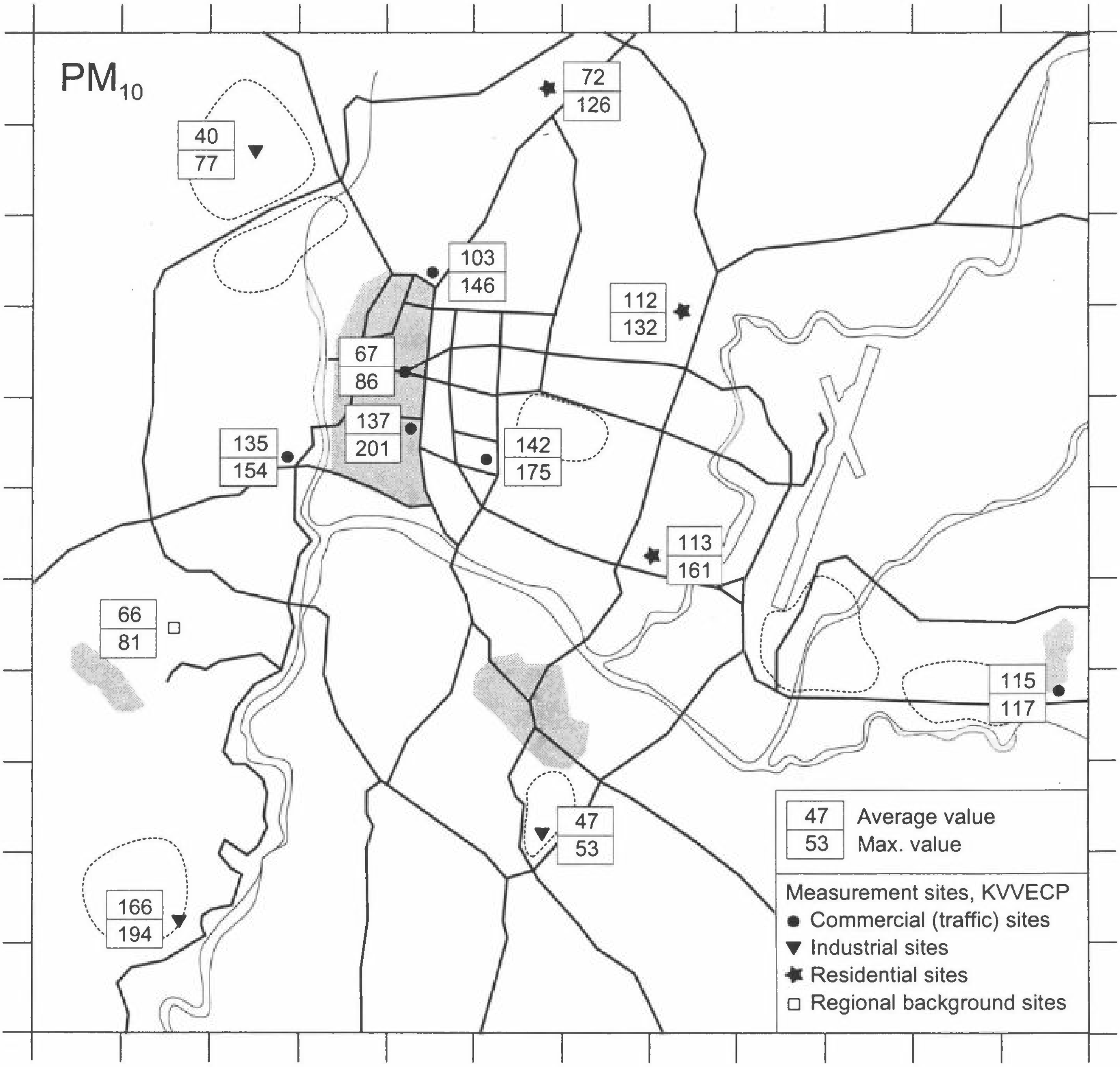


Figure 2.3: Results of PM_{10} measurements, KVVECP study September-December, 1993. (Relatively short measurement periods at each site.) (Ref.: Devkota, 1993.)

The ratios are generally in the range 0.4-0.5, except at the background site, where it was 0.70 on the average. This last ratio is in the range typically found at sites in other parts of the world not exposed to a high degree of resuspension. The low PM_{10} ratio for the other sites (0.4-0.5) indicate that the resuspension is rather strong. In the case of the Himal Cement site, the size distribution of cement factory emissions dominate the low ratio found there.

SO_2-concentrations

Results from the KVVECP measurements are shown in Figure 2.4. According to the measurements, the SO_2 concentrations in September-December 1993 were rather low, except at Kalimati (traffic site) and Jaya Bageshwori (residential), where several days showed SO_2 concentrations above the guideline (100-150 µg/m^3), with maximum 225 µg/m^3. These measurements indicate that although there is not a general SO_2 concentration problem in Kathmandu, local sources may create high local concentrations.

No measurements have been made in areas exposed to brick kiln emissions.

NO_2-concentrations

Figure 2.5 shows results from the KVVECP measurements.

The concentrations were generally low, and well below the 24-hour WHO guideline (150 µg/m^3).

The Jaya Bageshwori site had elevated NO_2 concentrations, as was also the case for SO_2, pointing to a local source.

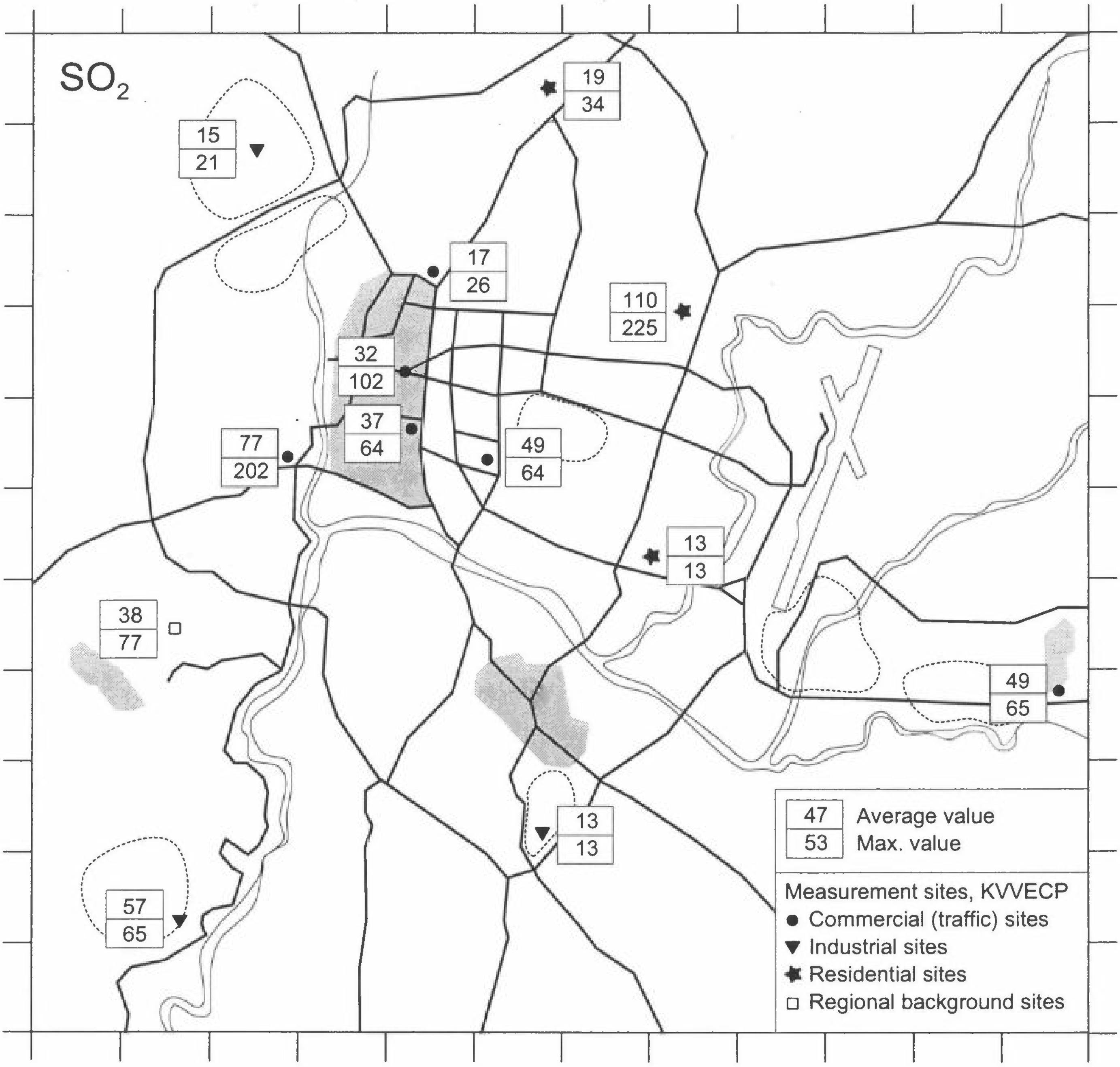


Figure 2.4: Results of SO_2 measurements, KVVECP study September-December, 1993. (Relatively short measurement periods at each site.) (Ref.: Devkota, 1993.)

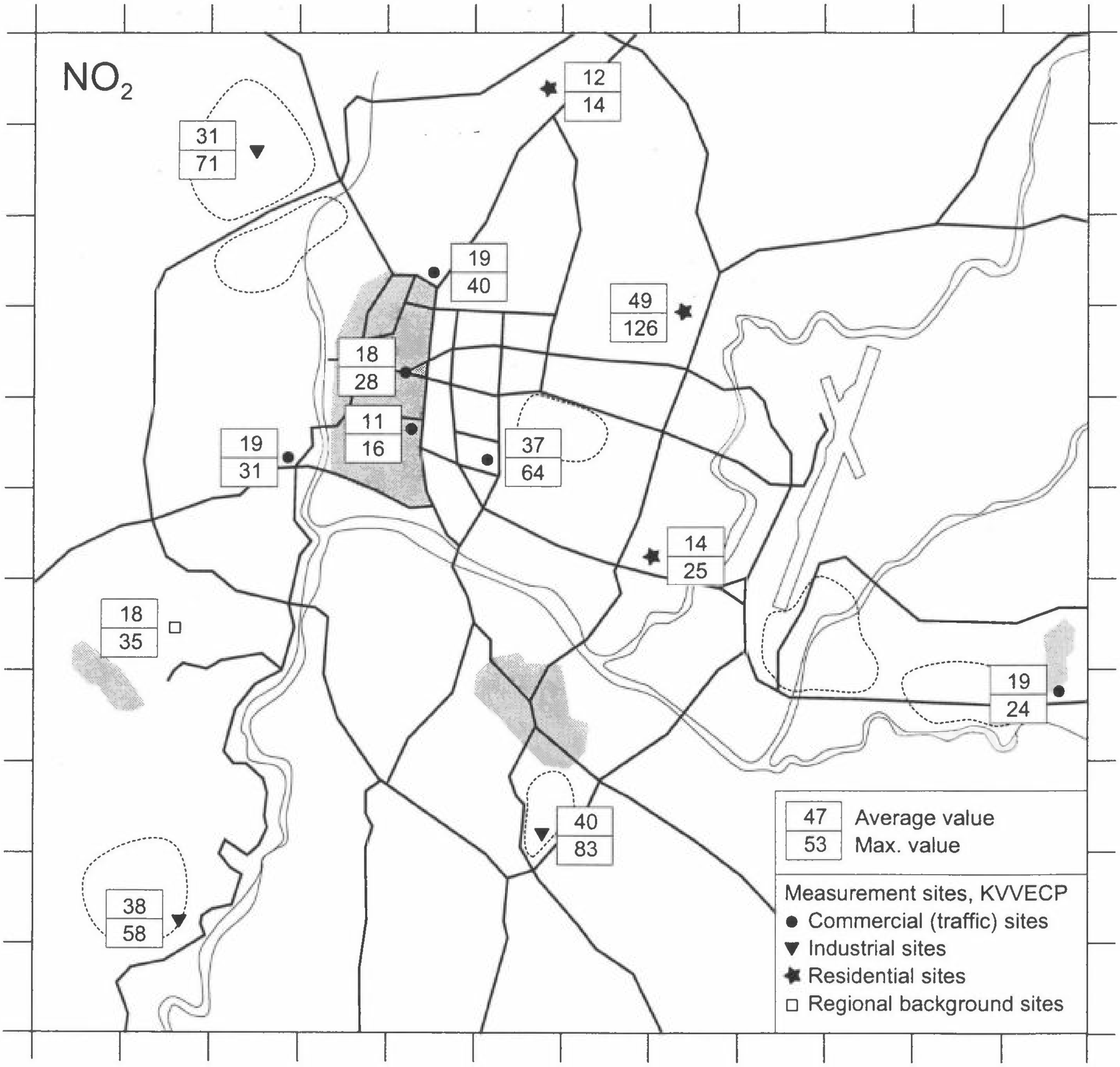


Figure 2.5: Results of NO_2 measurements, KVVECP study September-December, 1993. (Relatively short measurement periods at each site.) (Ref.: Devkota, 1993.)

Visibility

Madan L. Shrestha (1994) has made a thorough and valuable analysis of the visibility data from the Kathmandu Airport for 1963-1993. A summary of Dr. Shrestha's findings are described in Appendix 1.

It is clear from the observations that the visibility in Kathmandu Valley has generally deteriorated in the dry season (November-March), especially since around 1980. In the monsoon season, visibility seems unaffected.

This is demonstrated in Figure 2.6, which shows the number of days in the winter months with fair-to-good visibility (>8000 m) at noon local time. Before 1980, this was the case for most days, while at present, very few days have good visibility at noon.

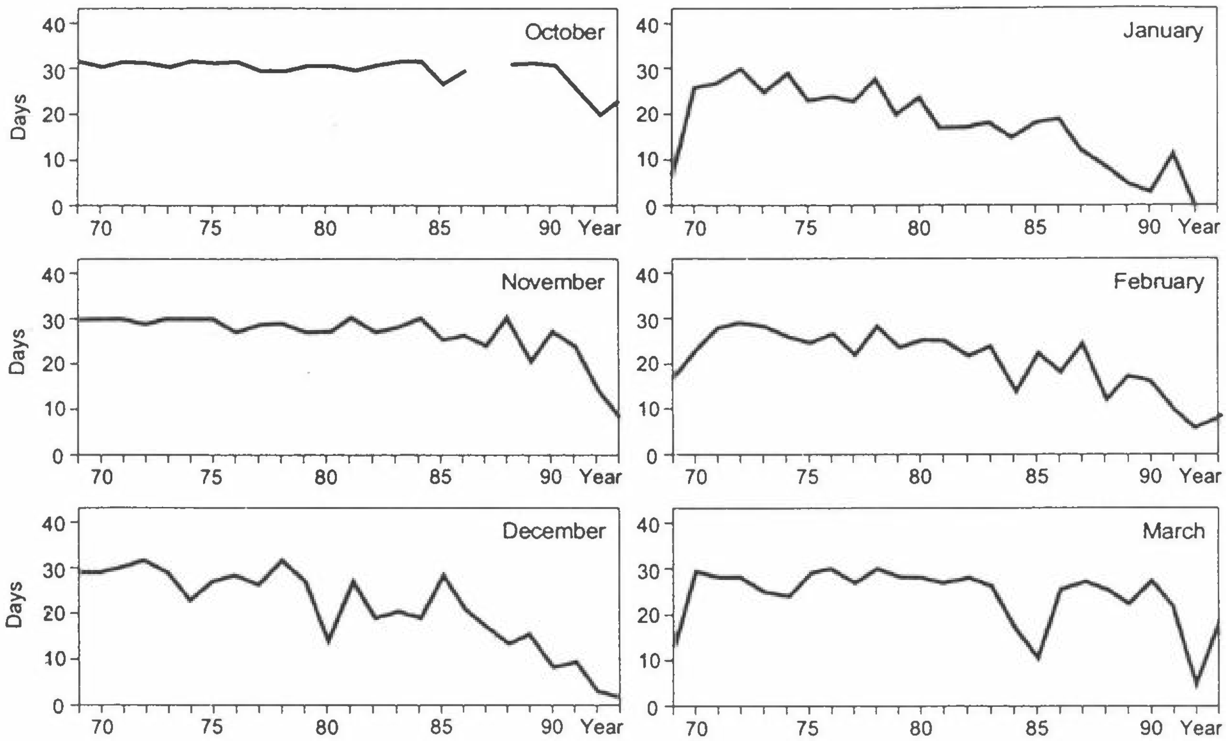


Figure 2.6: No. of days in Kathmandu Valley with fair-to-good visibility (>8000 m) in the winter months. (Ref. M.L. Shrestha, 1995).

This is further supported by Figure 2.7, which shows the number of foggy mornings (around 9 a.m.). This has, for the winter months, increased from 35-40 around 1970, to more than 60 at present.

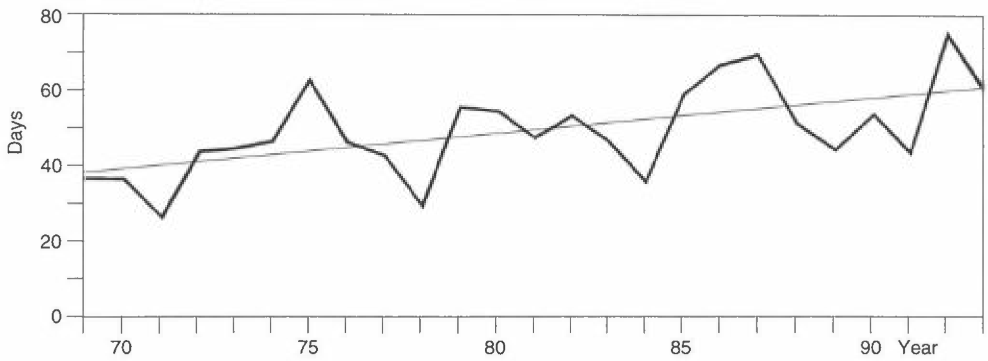


Figure 2.7: No. of foggy days at 9 a.m., Kathmandu Valley, 1969-93. (Ref.: M.L. Shrestha, 1995).

The nature of the "lifting" of the morning fog is visualized in Figure 2.8. In the relatively unpolluted atmosphere of the early 70's this normally took place before 10 a.m. At present time, fog dispersal is typically delayed for 3 hours, and on hazy days, good visibility is usually obtained only after 1p.m.-2p.m. For some days, the haze remains throughout the day.

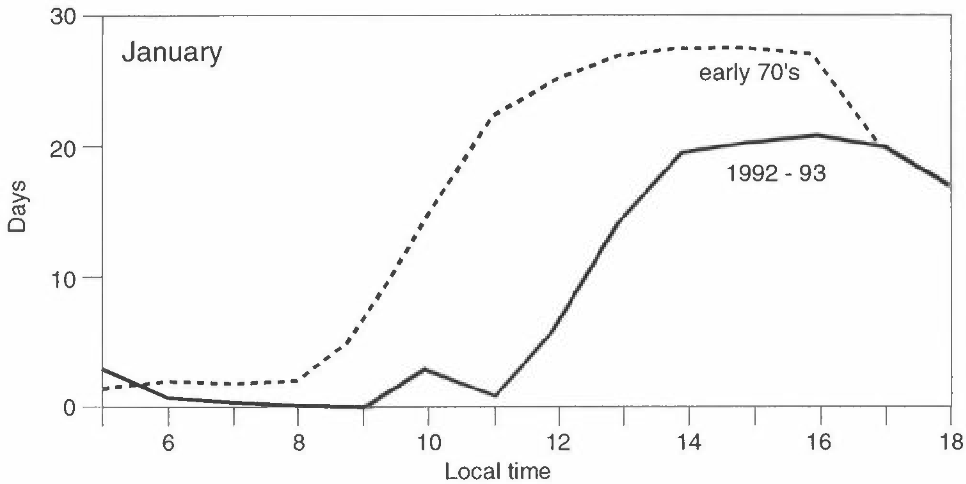


Figure 2.8: No. of days in January with good visibility (>8000 m) at given hours of the day. (Ref.: M.L. Shrestha, 1995).

Visibility reduction is caused mainly by particles (aerosol) of the size range comparable to the wavelength of light, e.g. 0.2-0.5 μm diameter. These are combustion aerosols from sources such as cars (diesel and gasoline), coal combustion, combustion of fuelwood, agricultural residue. This aerosol contains hygroscopic particles, such as particles containing sulphate (SO_4), condensed organic compounds, etc. Thus, the morning fog is caused by water vapour absorbed in the hygroscopic aerosol. As the temperature increases, the water vapour evaporates. In the afternoon, the still-reduced visibility is caused by the dry aerosol which is left.

The relative humidity (RH) in Kathmandu Valley is, on average, over 70% throughout the day in the monsoon period (June-September). Even so, the day-time visibility is not reduced in these months, indicating that the concentration of hygroscopic aerosol is rather low in the monsoon season.

In the winter months, the RH falls below 70% at 9-10 a.m. on the average. Still, there is visibility reduction throughout the morning, but it improves gradually until 12-1 p.m., at which time the RH in the winter is typically below 50%. This corresponds to the situation in which that a typical urban aerosol absorbs water vapour gradually already from an RH of 30-40% and upwards. Sulphate particles have a deliquescence point of 72%, which means that the RH must approach 72% before such particles grow substantially and cause visibility reduction. Thus, sulphate particles may be part of the visibility reducing aerosol, but other types of aerosol, e.g. organic aerosol, make important contributions.

2.2 Air pollutant emissions in Kathmandu Valley

Total emissions

An emissions inventory covering in principle all source categories, has been established for the Kathmandu Valley based on all data and information available. Emissions data are given for TSP, PM_{10} and SO_2. The details of the emissions inventory development are described in Appendix 4.

The calculated and estimated total emissions presented in Table 2.2, are based on the emissions factor data given in Table 2.3, and the fuel consumption and traffic activity data of Table 2.4

The inventory covers the main source categories. Shrestha and Malla (1993) is the main reference regarding fuel consumption. The emissions from road vehicles are relatively well determined, based on fuel consumption, traffic activity and emissions factors. Emissions from industrial/commercial activities other than brick combustion are based on Shrestha and Malla's figures, and their emissions factors. The emissions from Bull's trench brick kilns have been estimated by NESS (1995), while for Chinese kilns the emissions are based on coal consumption and on estimated emissions factors. The Himal Cement factory emissions used are as provided by the company (Bhattarai, 1993).

For resuspension from roads, the same TSP emissions factor is used as for Manila and Bombay: 2 g/km. This emissions factor is uncertain, but has been based upon factors given by US EPA in AP42.

There are uncertainties in the data used, both concerning fuel consumption and emissions factors, which cannot be determined at this time. The emissions inventory is comprehensive in that it covers all sources, and it is believed to be useful to give an estimate of the importance of the various air pollution problems of the valley. Viewed together with the air pollution measurements, and calculated concentrations from dispersion modelling based on the emissions inventory, the quality of the emissions inventory can be further evaluated.

The amount of open refuse burning, not for cooking purposes, is unknown. As a first estimate, the same estimate as used for Bombay, is used: 1 kg of refuse burnt per week per household (some 200,000 households in KV), with an emissions factor of 37 g/kg (Economopoulos, 1993; Semb, 1985).

The estimated emissions in Table 2.3 give the following relative source contributions to the total emissions:

Source category	Contribution %		
	TSP	PM_{10}	SO_2
Road vehicles			
gasoline	1.3	4.5	
diesel	2.2	7.6	
Resuspension from roads	9.3	8.5	
Domestic fuel combustion	14.1	24.7	
Brick industry	31.3	27.5	
Himal Cement	36.2	17.0	
Other industry/commercial	3.5	6.2	
Refuse burning	3.2	4.0	

The contributions to the concentrations in the air in populated areas, and thus the contribution to population exposure, may differ substantially from these contributions to total emissions. This difference depends on the height of the emissions (ground level or high stack), the distance from the source to populated areas, and the dominating wind directions.

TSP

Total emissions of some 16,500 tonnes/a has been estimated. No estimate has been worked out for the construction source.

The Brick industry, domestic fuel combustion and resuspension from roads are estimated to be the dominant sources, for the valley as a whole.

PM_{10}

Total estimated emissions are some 4,700 tonnes/a. For PM_{10}, the main sources are estimated to be the brick industry and domestic fuel combustion. Then comes road vehicles, and resuspension, Himal Cement and other industrial/commercial activities as fairly equal contributors.

Table 2.3: Total annual emissions in Kathmandu Valley, 1993 (tons/a).

		TSP	PM_{10}	SO_2
Transport sector				
Vehicles exhaust				
Gasoline	Cars/taxis	38.4	-	
	TC	67.5	-	4.2-105[1]
	MC	107.5	-	
Diesel	Jeeps	68.4	-	
	Minibuses	22.5	-	
	Buses	45.0	-	78-390[1]
	Trucks	114	-	
	Tractors	21.6	-	
	TC	85.8	-	
Sum vehicle exhaust		570	570	82-495[1]
Resuspension from roads		1530	~400	0
Energy/industry sector				
Fuel combustion				
Industrial/commercial				
(excl. brick/cement)	Fuelwood	61.9	31	
	Coal	48	24	172
	Charcoal	20	10	
	HSD	1.8	2	
	LDO/FO?			
	Kerosene/LPG	0.1		
	Agri.residue	450	225	
Sum industrial/commercial		582	292	
Domestic	Fuelwood	1832	916	
	Agri.residue	454	227	
	Anim.waste	30	15	
	Kerosene/LPG	2.3	2.3	
	Charcoal	10	5	
Sum domestic		2328	1165	
Industrial processes				
Brick industry				
Bull's Trench		5000	1250	4.8-4465[2]
Chinese		180	45	
Sum brick		5180	1295	
Himal Cement	Stack	~2000	~400	615
	Diffuse dust	~4000	~400	
Other				
Refuse burning		385	190	
Construction		?		
Sum		16565	4712	

[1] High value: Based on max. allowable S content
Low value: Based on actual S content, according to IOC Ltd. certificate
[2] NESS (1995): Estimates based on different methodologies.

	TSP		$\frac{PM_{10}}{TSP}$	SO_2	NO_x	%S max.
Fuel combustion (kg/t)						
Residual oil (FO) ind./comm.	1.25S+0.38		0.85	20S	7	4
Distillate oil ind./comm.	0.28		0.5	20S	2.84	HSD: 1[4]
(HSD, LDO) residential	0.36 → 1.6[2)]		0.5	20S	2.6	LDO: 1.8[5]
LPG ind./dom.	0.06		1.0	0.007	2.9	0.02
Kerosene dom.	0.06		1.0	17S	2.5	0.25
Natural gas utility	0.061		1.0	20S	11.3 · f	
ind./dom.	0.061			20S	2.5	
Wood dom.	15		0.5	0.2	1.4	
Fuelwood ind.	3.6		0.5			
Coal dom./comm.	10		0.5			
Charcoal dom./comm.	20		0.5			
Agri.residue	10		0.5			
Anim. waste	10		0.5			
Refuse burning, open	37		0.1	0.5	3	
Road vehicles (g/km)	A	B				
Gasoline Cars	0.2		1		2.7	83 Octane (RON) 0.25[3]
MC/TC	0.5		1		0.07	93 Octane (RON) 0.20
Diesel Cars, jeeps, tractors	0.6	0.9	1		1.4	1[4]
Minibuses, tempos	0.9	1.5	1		13	
Buses, trucks	2.0	3.0			13	

1) A: Ash content, in %; S: sulphur content, in %
2) Well → poorly maintained furnaces
3) Actual S content in 87 RON gasoline, according to IOC Ltd quality certificate: 0.009%
4) Actual S content, according to IOC Ltd quality certificate: 0.20%
5) Actual S content, according to IOC Ltd quality certificate: <1%
A Used for Manila, Jakarta, Bombay
B Proposed and used for Kathmandu Valley.

Table 2.5: Fuel consumption and traffic activity data for Kathmandu Valley.

Emission source/ fuel type	Category	Fuel consumption	Traffic activity 10^6 veh. km/a	
Vehicles		**kl/a**		
Cars	Gasoline	28.015	192	
Tempos (TC)	"		135	
Motorcycles (MC)	"		215	542
Jeeps	Diesel	22.955	76	
Minibuses/buses	"		30	
Trucks	"		15	
Tractors	"		38	
Tempos	"		24	225
Industry		**10^3 tonnes/a**		
Himal Cement				
Bull's trench kilns	Coal/fuelwood/rice husk	42/5.7/15.8		
Chinese kilns	Coal	20		
Other industry/ commercial	HSD/LDO	?/?		
	Coal/charcoal	4.8/1.0		
	Wood/agricultural residue	17.2/45		
	SKO/LPG	1.0/?		
Domestic	Wood/charcoal	122/0.5		
	Agric.res./anim.waste	45.4/3.0		
	SKO/LPG	35/4		
Refuse burning	Refuse	10		

Spatial distribution of emissions

The total emissions have been distributed within the grid system based on the actual location of point sources, industrial areas, and road links, and based upon the population distribution (as described in Appendix 4).

The resulting distribution of the emissions, summed for all source categories, is shown in Figure 2.9, in the form of isolines. This emissions distribution forms the input of the dispersion calculations.

The figure shows high emissions densities particularly in Kathmandu itself, due to a combination of vehicle exhaust, road resuspension and domestic fuel combustion, as well as in the areas with concentration of brick kilns, west of Kathmandu and SE of Patan. Also, the Himal Cement factory shows the maximum level in the distribution.

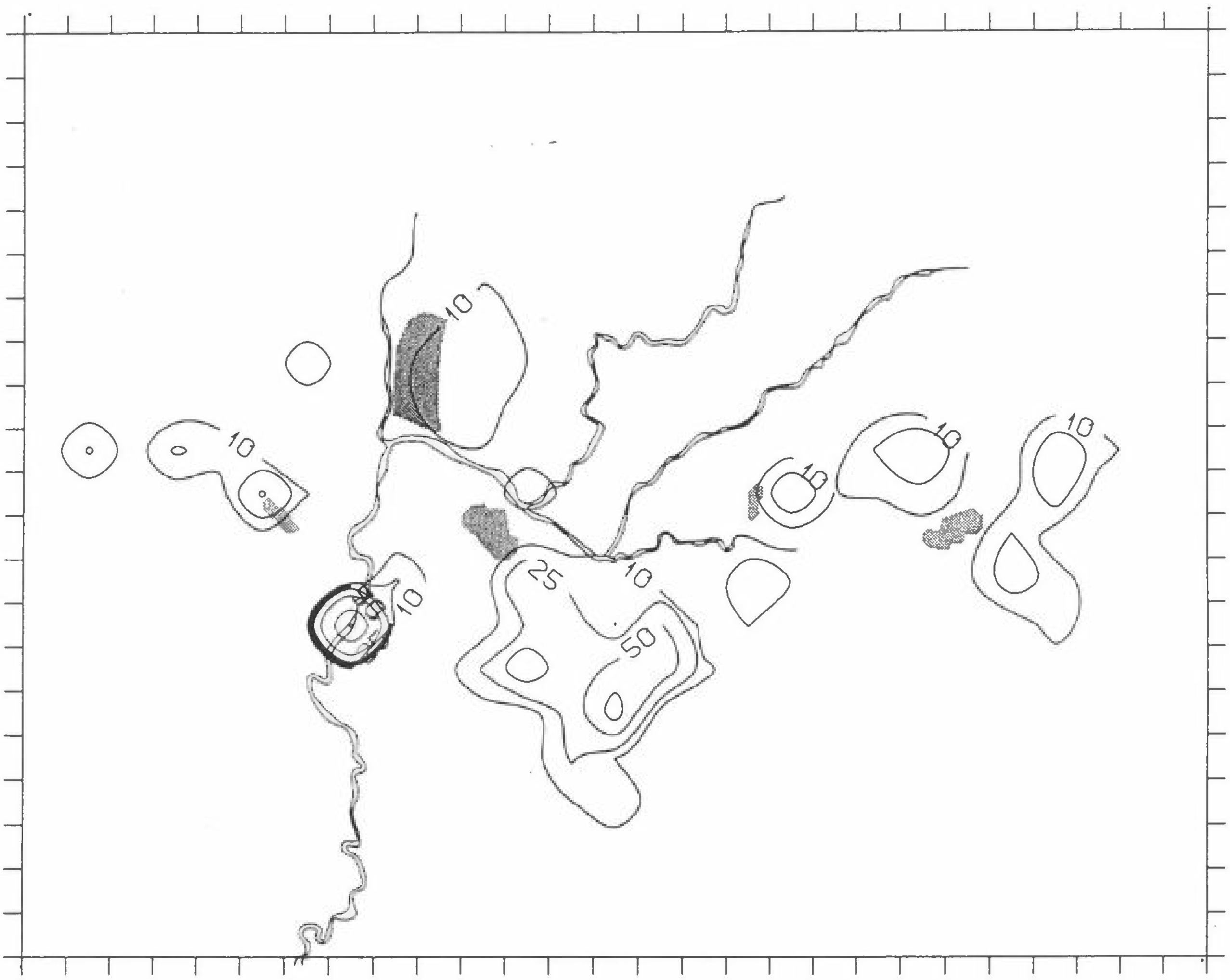


Figure 2.9: Spatial emissions distribution in Kathmandu Valley, 1993. Total emissions (kg/h, averaged over the winter 6 months) per sq.km, represented as isolines.

2.3 Dispersion model calculations, Kathmandu Valley

2.3.1 Dispersion conditions

General description of topography/climate/dispersion

The Katmandu valley is located between the Himalaya in the north and the Mahabharat mountains in the south. The city is located on a plain at about 1 325 m a.s.l. and is surrounded by hills and mountains.

The Siwalik mountains make the border between Terai and Nepal's core region, and the east-western valleys of which the Katmandu valley is the most important. The Bagmati river runs through the valley, and the river plain is covered with fertile river deposition. The Himalayan range rises north of the central valleys, with Mount Everest (8 848 m a.s.) and several other mountain tops above 8 000 m.

The large height differences and the monsoon circulation govern the climate. In the lowest parts of the country the climate is subtropical, at higher elevations one finds a cooler temperate climate, and in the high mountain ranges there are tundra and glacial climates.

During the winter there is a build-up of a strong high pressure centre over central Asia, the northern hemisphere's cold pole. In the northern parts towards the Himalaya the prevailing winds come from northwest. In the spring the Asian high pressure weakens and the northwest monsoon disappears. The summer monsoon is a continuation of the southeast monsoon from the southern hemisphere. After crossing the equator, the airmass is bent towards the east, which causes the southwest summer monsoon. The southwest monsoon is driven by a low-pressure area located over central Asia. This flow when reaching Nepal becomes southeast due to physical and dynamical reasons.

Local wind conditions in the Kathmandu Valley have been measured at the Tribhuwan Air Port for many years. Figure 2.10 shows selected monthly wind roses for the period 1971-75 and for 1993 (Shrestha, 1994).

In the summer and early autumn the prevailing wind regime in Kathmandu valley is the southwest monsoon. In the winter the prevailing winds are more westerly. The high mountains in the north prevents the outbreak of cold Siberian winds from the northeast. The pattern is dominated by weak winds. The measurements give a very high frequency of calm, typically 60-70% of the time in all months. Because of the high occurrence of calm and low wind speeds, the dispersion conditions in Kathmandu are poor.

The mean annual air temperature in Kathmandu is 18° C. The coldest month is January, with a mean temperature of 10° C. The warmest month is July/august with 24° C.

The annual rainfall in Katmandu is 1400 mm. The wettest month is July with an average rainfall of about 370 mm and the driest months are November/December when the average rainfall is less than 6 mm.

High altitude combined with extreme diurnal radiation variations lead to a potentially strong cooling during the night and warming during the day. In the dry season, the cooling in the night may cause the formation of deep inversion layers, where the air temperature increases with height. When the inversion layer is deep enough, it takes time for the insulation to break up the inversion. The atmosphere then acts as a lid over the city and the concentrations of pollutants can build up considerably.

Dispersion conditions

The dispersion of air pollution emissions is dominated by wind conditions and the vertical stability of the atmosphere.

Wind statistics from the meteorological station at Tribhuvan airport have been obtained from the Hydrological and Meteorological Service.

Figure 2.10 shows wind roses from Tribhuvan Airport for selected months (Shrestha, 1995) for the period 1971-75, and for 1993.

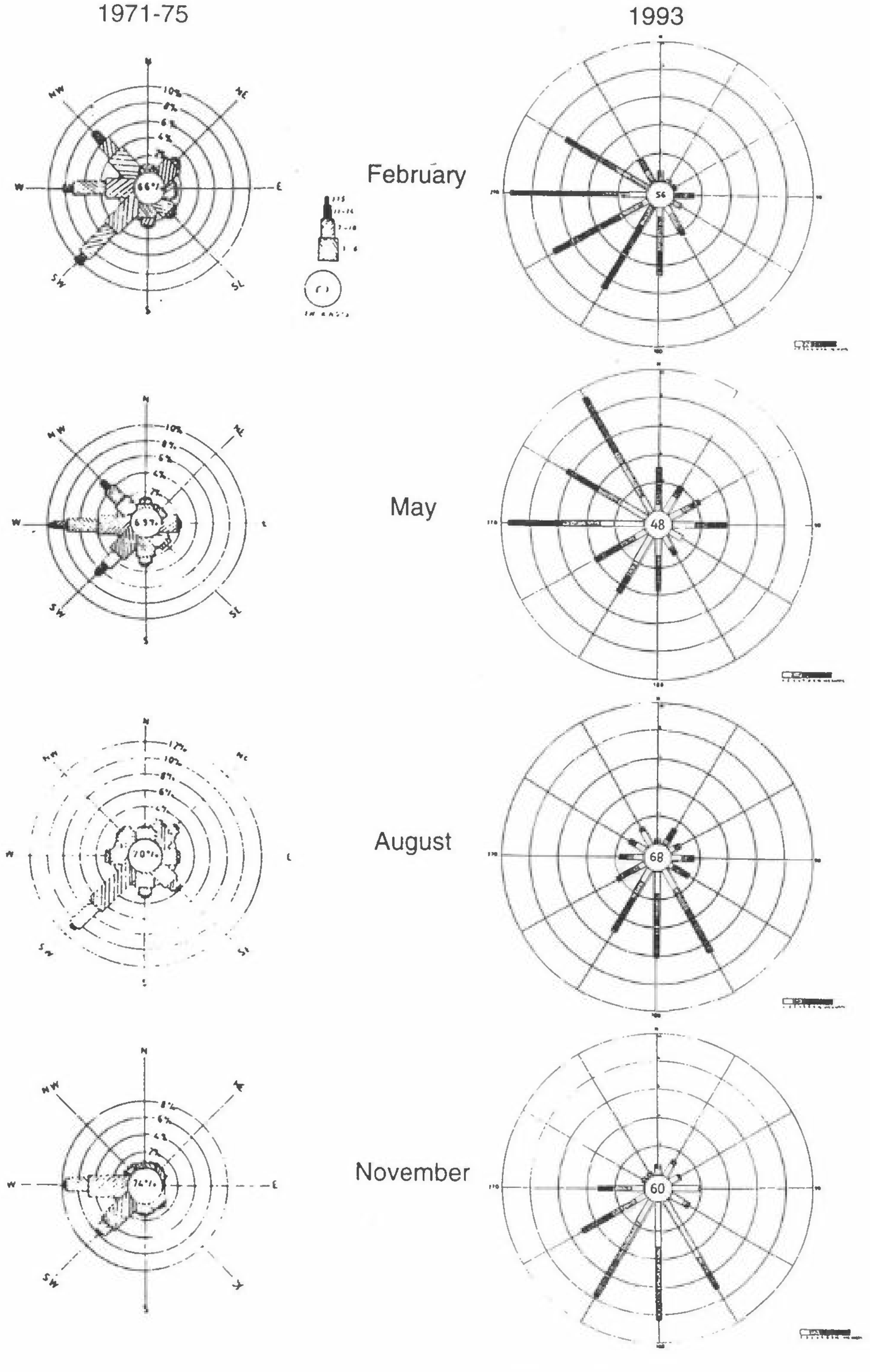
From these data, observations of the distribution of stability classes, as well as observations of and the diurnal wind pattern, a combined wind/stability matrix has been constructed. Such a matrix representing the statistics of dispersion climatology can be used as input to dispersion models for calculation of long-term average concentrations of pollutants, based also on emissions data. The combined matrix is given in Table 2.5.

Table 2.6: Wind/stability frequency matrix for the winter months (Jan-March, Oct-Dec) 1993, Tribhuvan Airport.

	.8 m/s				1.8 m/s				3.3 m/s				6.3 m/s	
	1	2	3	4	1	2	3	4	1	2	3	4	1	2
30	.6	.1	1.0	.6	.1	.0	.1	.1	.0	.0	.0	.0	.0	.0
60	.5	.1	1.0	.5	.1	.0	.2	.1	.0	.1	.0	.0	.0	.0
90	1.6	.3	2.8	1.6	.1	.0	.2	.1	.0	.1	.1	.0	.0	.1
120	.8	.3	2.6	1.6	.0	.0	.3	.2	.0	.0	.0	.0	.0	.0
150	1.9	.6	6.3	3.8	.2	.1	.6	.4	.0	.2	.1	.0	.0	.0
180	1.6	.5	5.4	3.2	.3	.1	1.0	.6	.1	.8	.3	.1	.0	.3
210	4.7	1.0	3.1	1.6	.9	.2	.6	.3	.4	1.4	.2	.2	.0	.6
240	3.5	.8	2.3	1.1	.9	.2	.6	.3	.5	1.6	.3	.3	.0	.3
270	1.8	.4	3.2	1.8	.5	.1	.8	.5	.4	1.4	.6	.4	.0	.8
300	.7	.1	1.3	.7	.3	.1	.5	.3	.2	.6	.2	.2	.0	.5
330	.8	.2	1.5	.8	.2	.0	.3	.2	.1	.2	.1	.1	.0	.1
360	.7	.1	1.1	.5	.1	.0	.1	.1	.0	.0	.0	.0	.0	.1
Stability					1	2	3	4						
Windprof. exponent					.20	.28	.36	.42						
Mixing height					1200.	1000.	400.	200.						

Stability classes	Velocity classes (m/s)
I : Unstable	0.3-1.5 (0,8 m/s average)
N : Neutral	1.5-2.0 (1.8 m/s average)
SS :Weakly stable	2.5-4 (3.3 m/s average)
S : Stable	>4 (6.3 m/s average)

The frequencies of calm are distributed in the direction sectors within each of the stability classes of the 0.3-1.5 m/s velocity class, proportional to the joint occurrence of wind and stability.



% calm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1971/75	71	66	69	68	69	63	70	70	77	74	74	79
1993	62	56	47	41	48	62	67	68	65	62	60	65

Figure 2.10: Wind roses for 1971-75 and 1993, Tribhuvan Airport (Shrestha, 1995).

2.3.2 Dispersion model calculations, city background

Model description

Dispersion modelling in this first phase of URBAIR concentrates mainly on the calculation of long-term (winter) average concentrations representing the average within 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.

It is clear that for the completely enclosed Kathmandu Valley, a dispersion model should be used which accounts for topographical and temporal effects (due to insulation) on the wind field, turbulence and dispersion conditions of the valley. Within the resources and time available for the URBAIR project, such a model could not be established and tested for Kathmandu Valley. Suitable dispersion models are available, but a proper description of the time-varying wind field which is the necessary input to such models, requires data from several wind monitoring sites within the valley, as well as vertical profiles of wind and temperature.

The dispersion model used for URBAIR in Kathmandu Valley 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 winter half-year. The dispersion conditions are considered as spatially uniform over the model area.

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 total emissions in a km^2 grid is simulated by 100 ground level point sources equi-spaced over the km^2, 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, 1992).

Total suspended particles (TSP)

Calculated winter average TSP concentration distributions are shown in Figure 2.11, for the following source categories, as well as the total distribution:

- Road vehicle exhaust (gasoline + diesel)
- Resuspension from roads
- Domestic fuel combustion (incl. estimated emissions from cottage-scale pottery)
- Bull's trench brick kilns

- Chinese (Hoffmann-Bhatta) brick kilns
- Himal Cement Factory

A regional background value of 10 µg/m3 has been added.

The added contributions from refuse burning and other commercial/industrial fuel combustion can be estimated.

TSP, total distribution

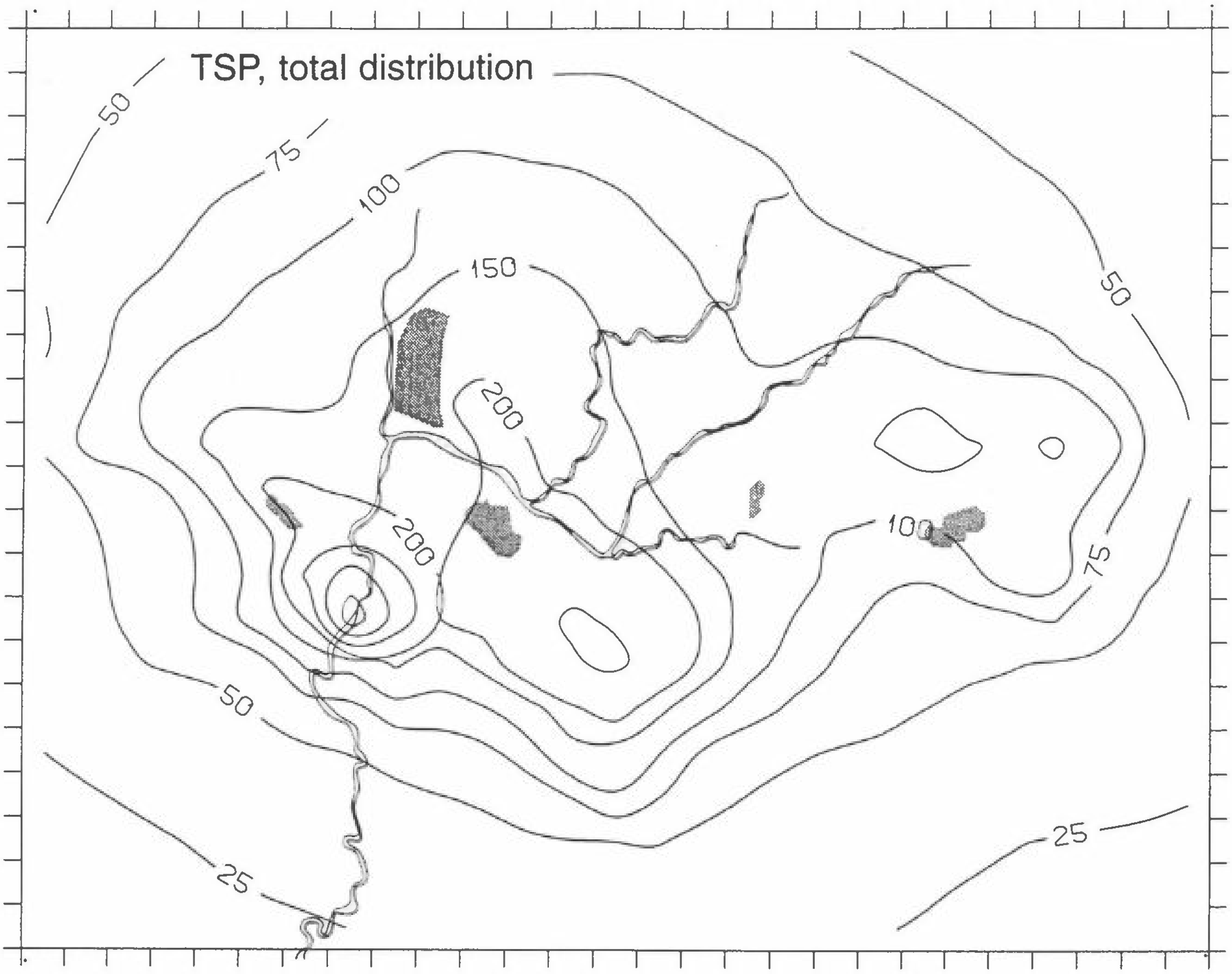


Figure 2.11: TSP concentrations in Kathmandu Valley.
Calculated winter average concentrations (km2 averages), 1993.
Total distribution and contributions from various source categories.

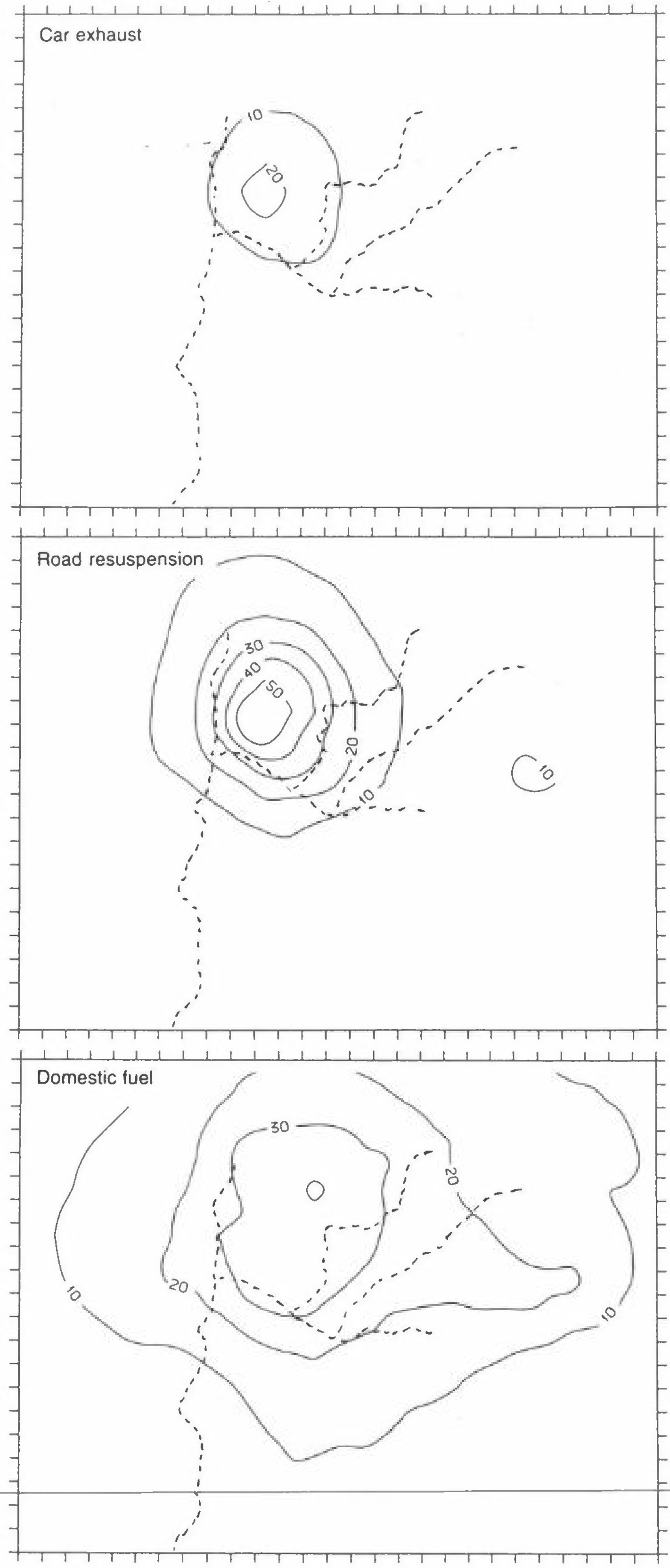


Figure 2.11 (continued).

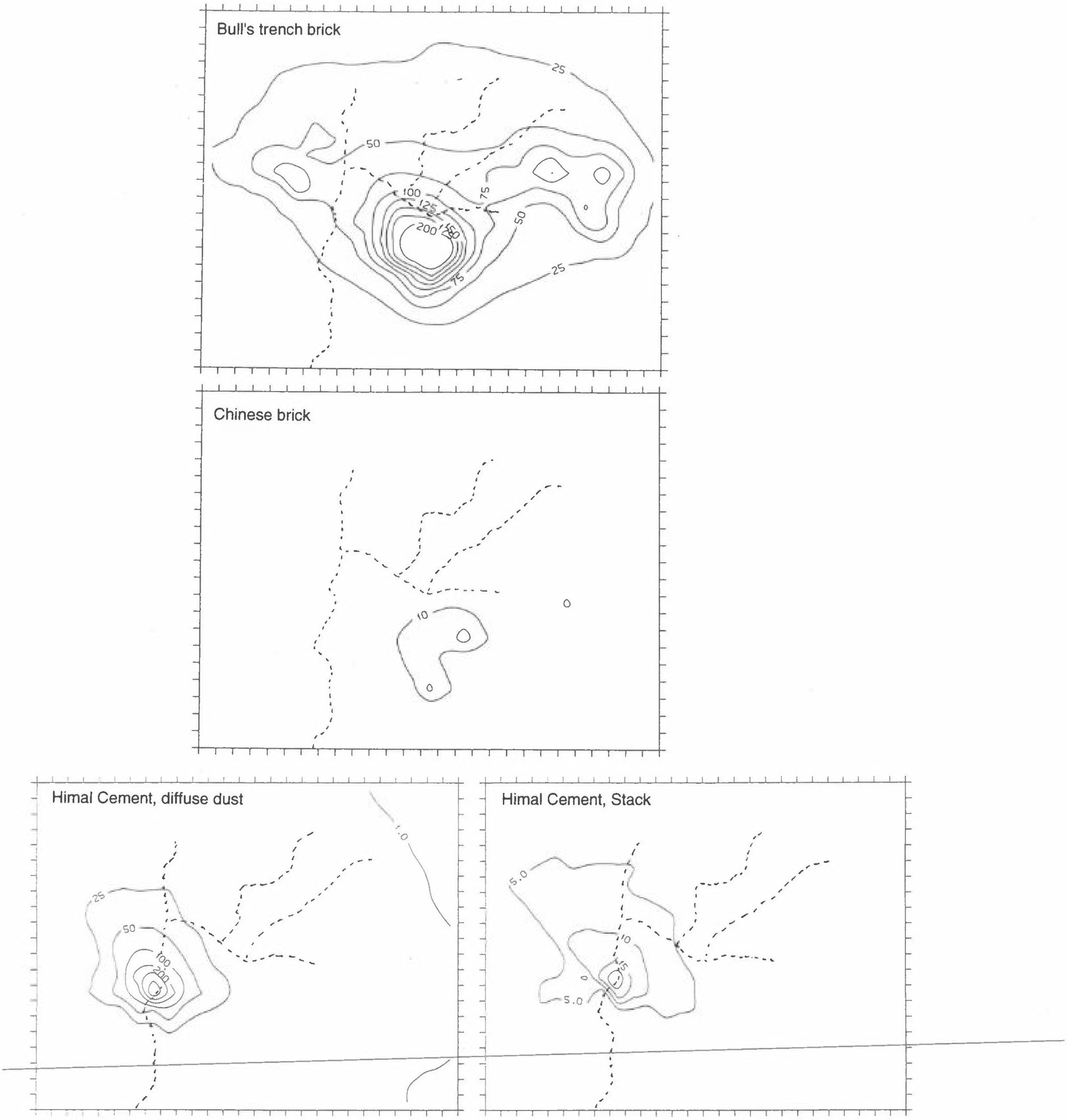


Figure 2.11 (continued).

There are distinct maxima in the distributions from the various sources:

- in Kathmandu City, due to road traffic (vehicle exhaust and resuspension) and domestic fuel combustion
- in the brick kiln areas, especially SE of Patan
- near Himal Cement factory.

In Kathmandu City and the brick kiln area, the calculated contributions from the various sources are as given in Table 2.6. The small contribution from Himal Cement, in spite of its large emission, is due to the tall stack, and sparse population close to the factory.

Table 2.7: TSP contributions (µg/m³, winter average), calculated for certain grids, and maximum grid contribution.

Source	Kathmandu City maxima (grid 11,14)	Brick area maxima (grid 14,7)	Maximum	
			From each source	in grid no.
Vehicle exhaust	22	2.5	22	(11,14)
Resuspension from roads	57	5	57	(11,14)
Domestic fuel combustion	35	17	41	(13,16)
Bull's trench kilns	47	238	238	(14,7)
Chinese kilns	2	19	24	(16,7)
Himal Cement	1	0,5	23	(9,9)
Regional background	10	10		
SUM	174	292		

Estimated additional contributions from refuse burning is some 5 µg/m³ at the Kathmandu City maximum with a spatial distribution similar to domestic fuel combustion (comments on source contributions). The contribution from commercial/industrial fuel combustion (in addition to brick kilns) is about the same.

These calculated concentrations can be compared with Shrestha's measurements at Babar Mahal Building (grid 11-12, 12):

Calculated winter average : 160-170 µg/m³ (in grids 11,12 and 12,12)
Measured average, Jan-March, 1993 : 255 µg/m³

The calculated value is lower than that measured. The calculated value represents the km^2 grid average, while the Babar Mahal Building is situated some 100 m downwind from the Arniko Rajmarg Road, with about 31,000 vehicles/day. The measurement site thus gets a contribution from the emissions from that road which is larger than accounted for in the calculations.

Nevertheless, the dispersion calculations seems to underestimate the actual TSP concentration in Kathmandu City to a certain degree.

Comparison with KVVECP measurements can only be indicative, since the measurements show only short autumn periods. It is clear, however, that the measurements close to roads (2-30 m from roads), expectedly give much higher concentrations than those calculated as grid square averages.

PM_{10}

Similarly, calculated PM_{10} distribution, and the source contributions, are shown in Figures 2.12. The PM_{10} calculations are based upon the TSP calculations, using the PM_{10}/TSP ratios of Table 8 in Appendix 3.

The calculated PM_{10} contributions in selected grids are given in Table 2.7.

Table 2.8: PM_{10} contributions (μ/m^3, winter average), calculated for certain grids, and maximum grid contribution.

	Kathmandu City (grid 11,14)	Brick area maxima (grid 14,7)	From each source	In grid no.
Vehicle exhaust	22	2,5	22	(11,14)
Resuspension from roads	15	1	15	(11,14)
Domestic fuel combustion	18	8	21	(13,16)
Bull's trench kilns	12	60	60	(14,7)
Chinese kilns	0,5	5	6	(16,7)
Himal Cement	~0	~0	10	(9,9)
Reg. background	10	10		
SUM	78	87		

As was the case for TSP, the PM_{10} measurements from the KVVECP study, close to roads, show considerably higher concentrations than those calculated, due to the local, street contribution.

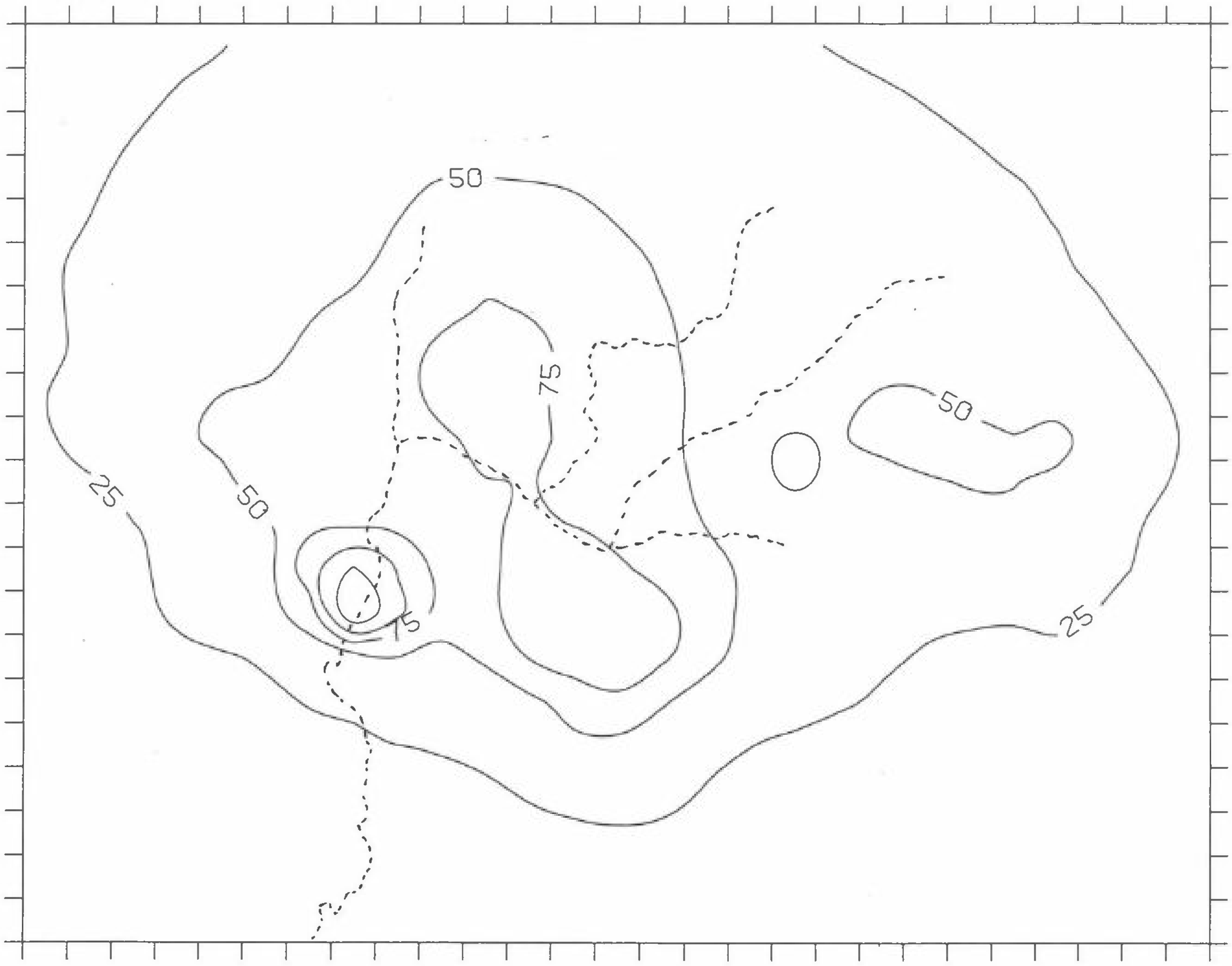


Figure 2.12: PM_{10} concentrations in Kathmandu Valley.
Calculated winter average concentrations (km^2 averages), 1993.
Total distribution, and contributions from various source categories.

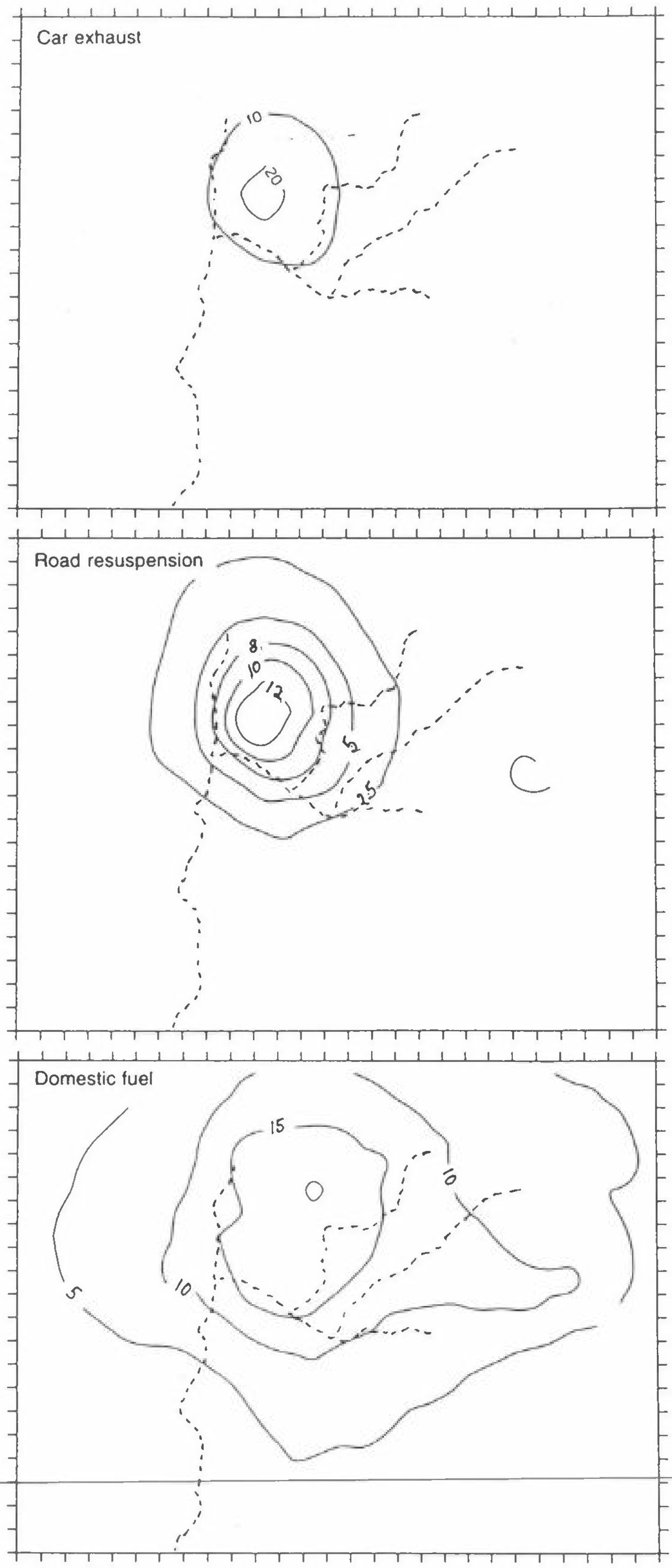


Figure 2.12 (continued).

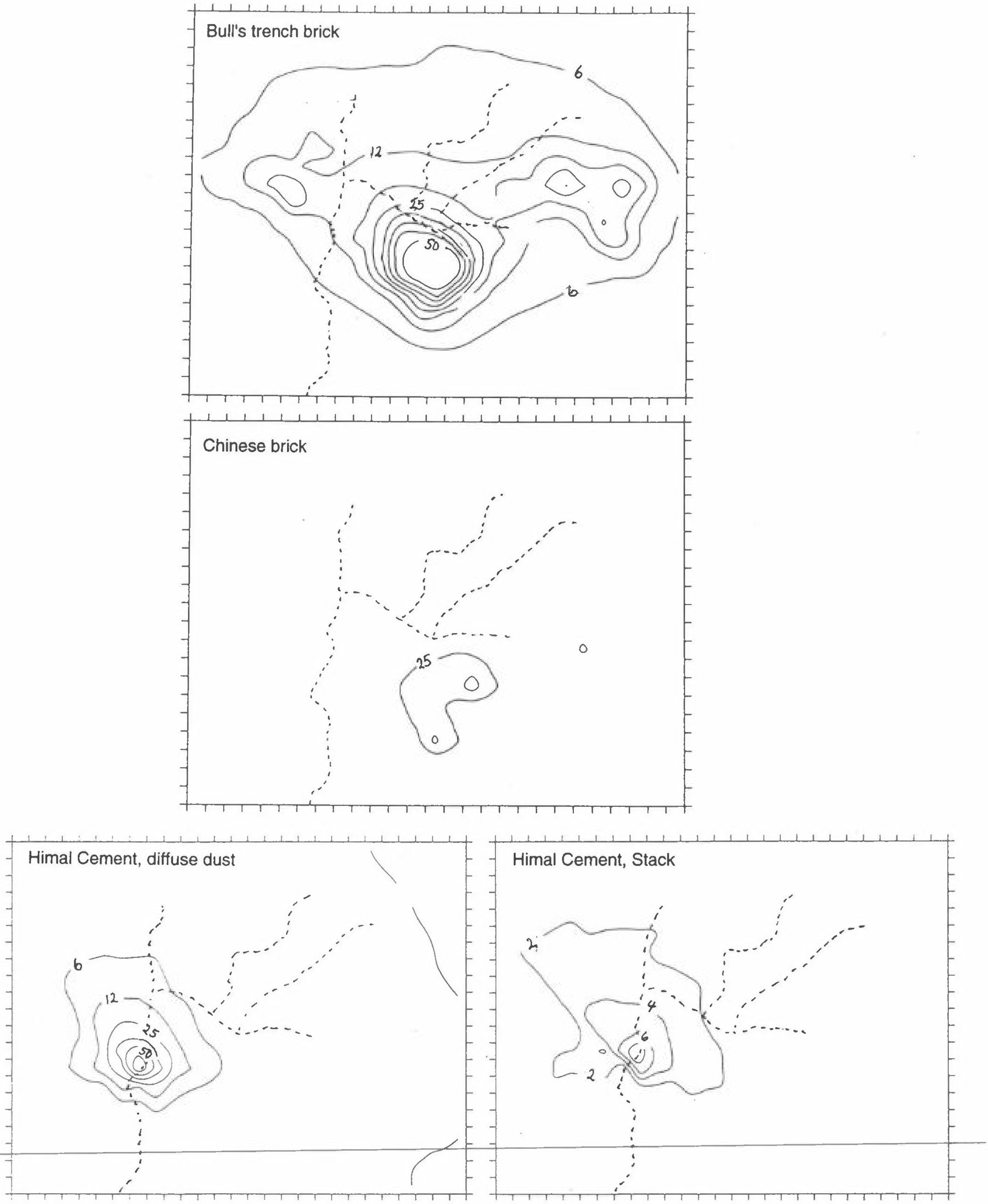


Figure 2.12 (continued).

SO_2 and NO_2

Dispersion calculations have not been carried out for SO_2 and NO_x (or NO_2). The measurements indicate fairly low values in general.

For SO_2, the emissions inventory indicates that the ratio between SO_2 and PM_{10} for road traffic (vehicle exhaust + resuspension) is within the range 0.1-0.6 (depending upon whether the maximal S content in fuel, or IOC certificate value is used). For the total emissions, the corresponding range is 0.2-1.4. The measurements give an SO_2/PM_{10} ratio of 0.3-0.6 for near-road sites, indicating that the actual S content in HSD is close to the max. value of 1% S.

2.3.3 Pollution hot spots

Significant pollution sources give large concentration contributions in their neighbourhoods, adding to the general city background.

Such pollution hot spots are:

- along the main road system
- near industrial areas with significant emissions through low stacks.

Industrial pollution hot spots in Kathmandu Valley include the areas near Himal Cement Factory exposed to the diffuse dust source associated with quarrying, transport and other handling of the materials. The brick kiln areas are also pollution hot spot areas. Emissions from each chimney, which is situated rather low, (10 metres), expose nearby areas with very high short-term concentrations, depending upon the wind and dispersion conditions. In the dispersion calculations of long-term averages, however (in Ch. 2.3.2), the kilns are represented as area sources, and the calculated concentrations represent the average of each km^2.

The KVVECP measurements of SO_2 and NO_2, such as at the Jaya Bageswori site, indicate that other sources in the valley may also create pollution hot spots.

Undoubtedly, the entire main road system with daily traffic above some 15-20 000 vehicles per day represents pollution hot spots, as also shown by the KVVECP measurements.

Such hot spot areas may contribute significantly to the health costs of air pollution.

2.4 Population exposure to air pollution, Kathmandu Valley

The term "population exposure" is defined as follows:

- the number of inhabitants experiencing concentrations of pollution compounds within given concentration ranges.

The cumulative population exposure distribution gives the percentage of the total population exposed to concentrations above given values.

People are exposed to air pollutants at home, while commuting, at work and other places. The correct mapping of pollution exposure requires data on:

- Concentration distributions, and its variation with time
  - at people's residences (general city air pollution termed "city background")
  - along main road network
  - near other hot spots, such as near industrial areas.

- Population distribution (residences and workplace), the number of commuters, and time-dependent travel habits.

The data necessary for population exposure calculations are most often not complete. A methodology has to be developed for each city, based on the actual data base.

TSP and PM_{10}

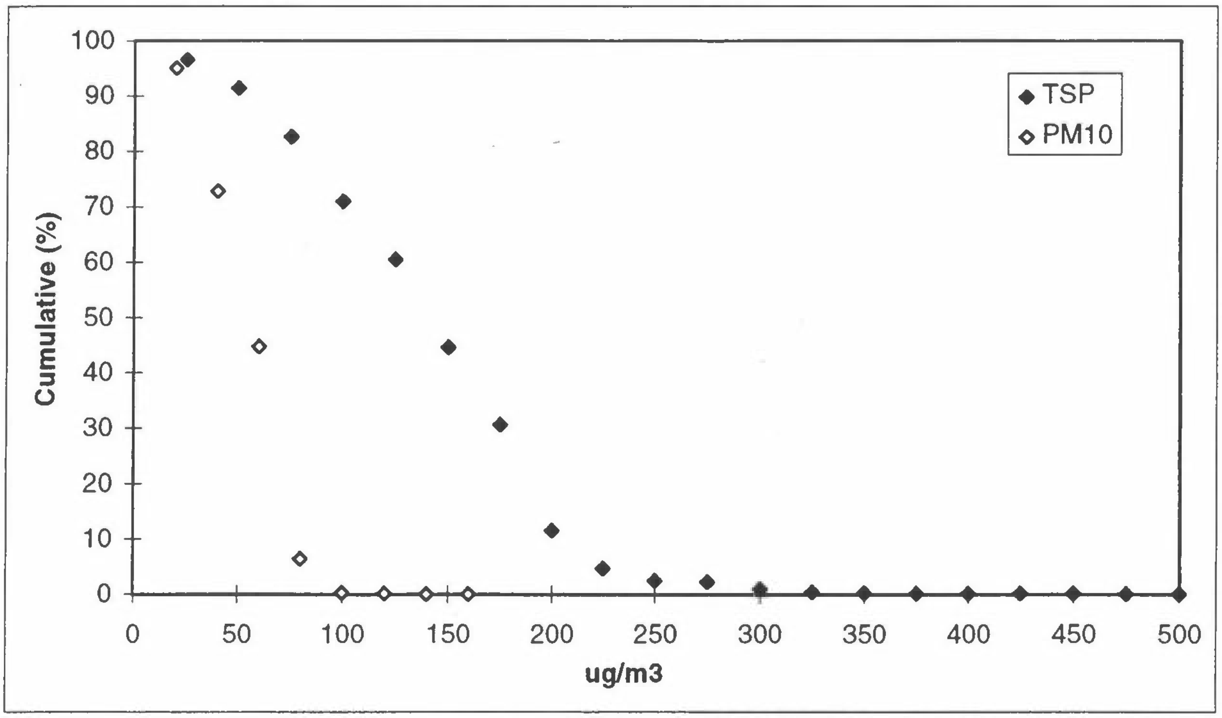
The population exposure has been calculated for **TSP** and **PM_{10}**, which is the major air pollution problem in Kathmandu Valley. The calculation has been done for the **winter average** concentration, to serve as input to health damage analysis.

This is not to diminish the importance of exposure to high short term concentrations of suspended particles, and other pollution compounds in hot spots such as on/near main roads, and near polluting industries. The calculation of such exposure requires, however, a more extensive database than has been available for Kathmandu Valley under URBAIR. Also, comprehensive dose-effect relationships regarding health have not yet been developed for short term exposures, although air quality guidelines have been set for short term exposures.

The results of the population exposure calculations for winter average TSP and PM_{10} in Kathmandu Valley, present conditions (1993), are shown in Figure 2.13.

This calculated population exposure is based solely on the calculated km^2 average concentrations, (i.e. the whole population within a grid square is given the same concentration, whether they live close to a hot spot, e.g. road, or near a park, for instance). Also, the high exposure of drivers and commutes while on the road is not taken into consideration.

Thus, the calculation represents a certain underestimate of the actual exposure. Calculations made for Manila and Bombay shows that some 5% of the population, who reside near roads, or are taxi/bus/tempo drivers, have a total exposure some 25-50 μg TSP/m^3 higher than that given by the km^2 average exposure.



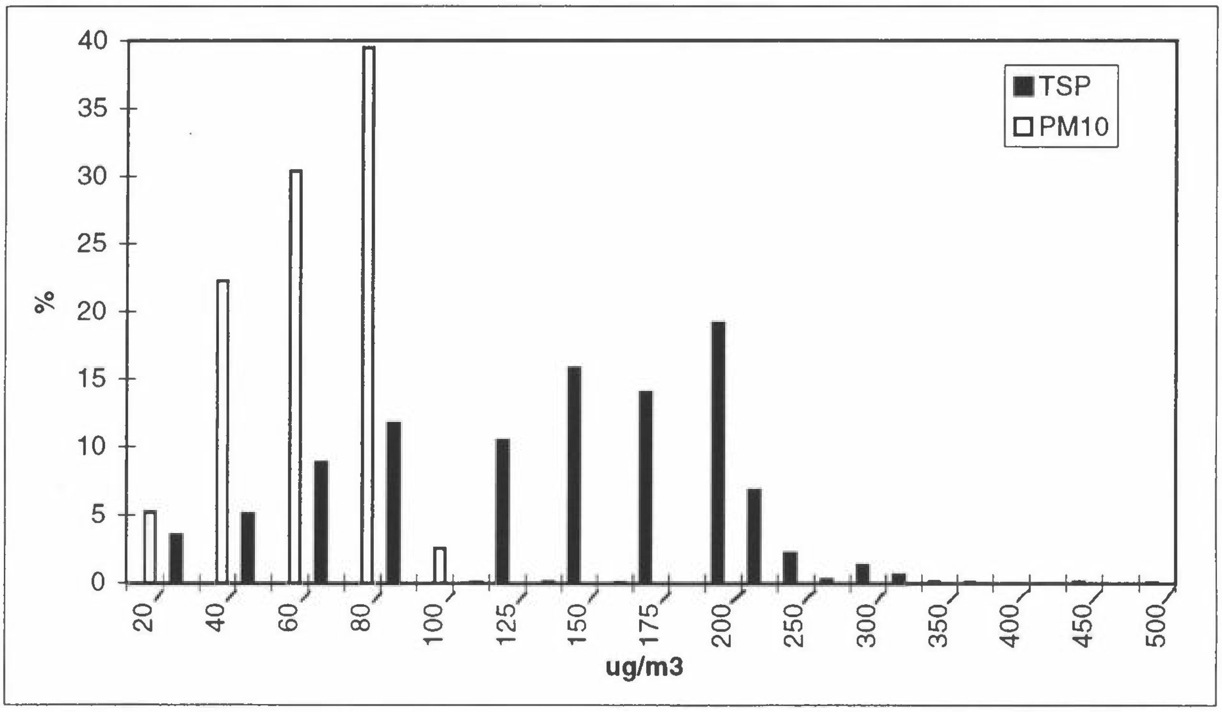


Figure 2.13: Population exposure distributions for TSP and PM_{10} (winter average concentrations, µg/m³), Kathmandu Valley, 1993, based on calculated average km² concentrations.

Figure 2.13 gives winter average exposure. An annual average exposure is then estimated, based on the ratio between annual average and winter average TSP, 0.75, measured at the Babar Mahal Building (Figure 2.1). The same ratio is used for PM_{10}.

The present exposure situation in Kathmandu Valley can be summarized as follows:

- About 50% of the population is exposed to a TSP concentration above the WHO Air Quality guideline (AQG), (90 $\mu g/m^3$, annual average).

- Some 3-4% of the population is exposed to TSP greater than two times the WHO Air Quality guideline AQG (180 $\mu g/m^3$). These are residents in the brick kiln areas, as well as drivers and roadside residents of the roads with the most heavy traffic.

Indoor air pollution exposure is not taken into account in these calculations, which only concern the outdoor pollution situation. No doubt, during cooking, the indoor exposure may be much higher than the outdoor concentrations, increasing the total exposure considerably, especially for housewives and small children.

The general exposure at residences is mainly caused by the following factors (in approximate order of importance):

For TSP : Resuspension from roads, brick kilns, domestic fuel combustion, diesel vehicles, gasoline vehicles (See Table 2.8.)

For PM_{10} : Diesel vehicles, gasoline vehicles, resuspension, domestic fuel, brick kilns. (See Table 2.9.)

Additional exposure in proximity to roads is significant for a part of the population.

In the subsequent health damage assessment (Chapter 3), this additional roadside exposure is taken account of in the following manner:

1. Considering the high TSP and PM_{10} measurements at roadside sites (KVVECP study and others) an average roadside TSP exposure concentration is estimated to some 500 $\mu g/m^3$ (winter average).

2. Additional roadside exposure is here given to 50% of the population living in the most highly exposed area in Kathmandu city, which are the about 200,000 people living within the 75 $\mu g/m^3$ PM_{10} isoline of Figure 2.12.

3. These 50% (100,000 people) are considered spending 50% of their time roadside, and 50% of the time at home. They are thus given a winter average TSP exposure value of 350 μg TSP/m^3, corresponding to about 130 μg PM_{10}/m^3 in Kathmandu.

4. Thus about 100,000 people is moved from the 60-80 $\mu g/m^3$ exposure level (see Figure 2.13, PM_{10}) to 130 $\mu g/m^3$.

The effect of increased and reduced emissions from each source category on the population exposure has been calculated. The results are shown in Figures 2.14 and 2.15 for TSP and PM_{10} respectively.

Calculations were made of the effect of ± 25% change in emissions from each source, on the number of people experiencing exceedance of the following pollution levels:

TSP :
- Exceedance of 100 $\mu g/m^3$ as winter average, corresponding to approx. 75 $\mu g/m^3$ as annual average in Kathmandu Valley (which is within the WHO AQG range 60-90 $\mu g/m^3$).
- Exceedance of 175 $\mu g/m^3$ as winter average, corresponding to an annual average of 130 $\mu g/m^3$.

PM_{10} :
- Exceedance of 60 $\mu g/m^3$ as winter average, corresponding to about 45 $\mu g/m^3$ as annual average in Kathmandu Valley.
- Exceedance of 100 $\mu g/m^3$ as winter average, corresponding to about 75 $\mu g/m^3$, as annual average.

These calculations show that in order to reduce the high TSP and PM_{10} exposures, reductions in the brick kiln emissions are crucial, followed by domestic fuel combustion, road resuspension and vehicle exhaust.

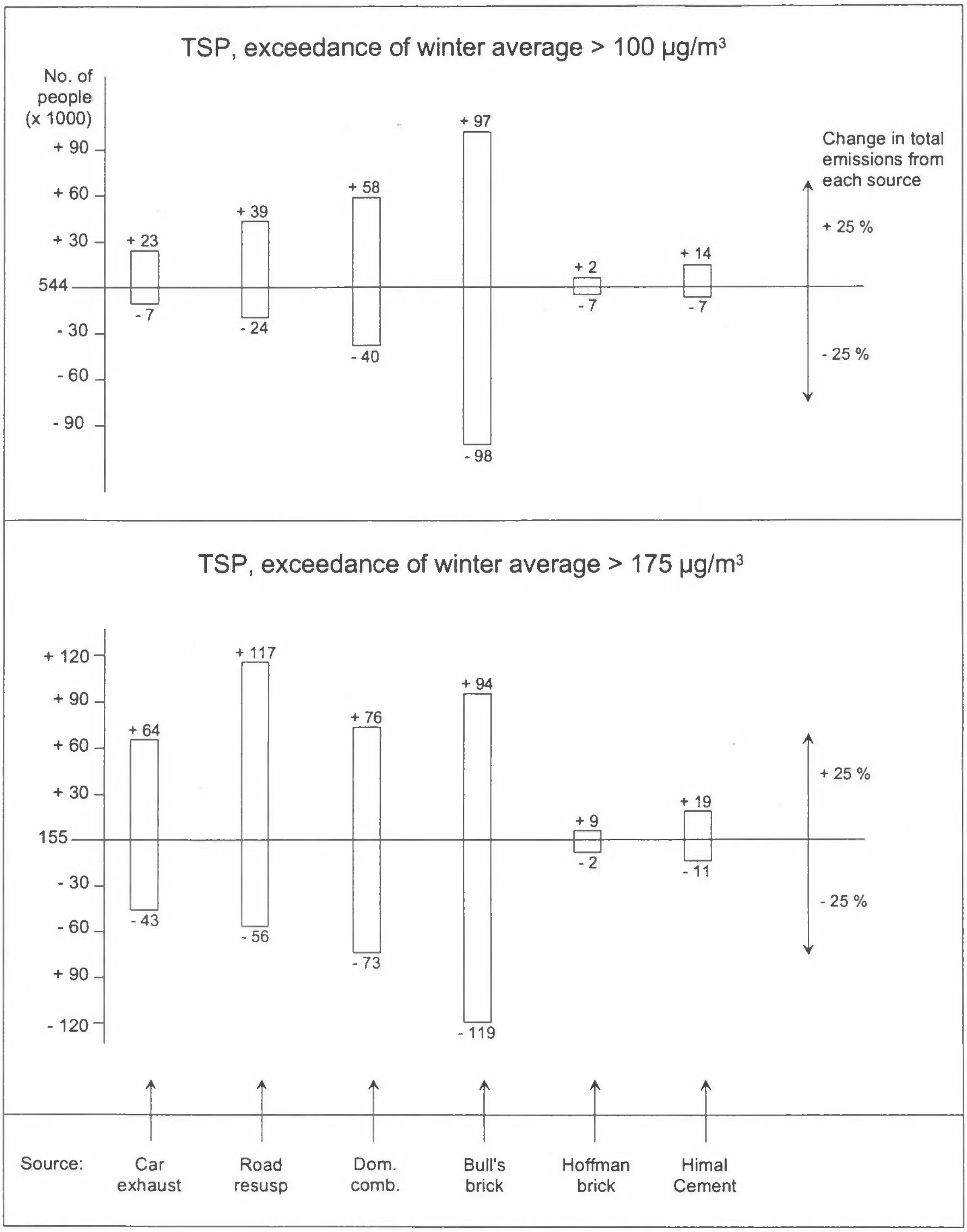


Figure 2.14: Change in population exposure to TSP (number of people exceeding the given concentrations) as a result of ±25% change in the total emissions from each source category.

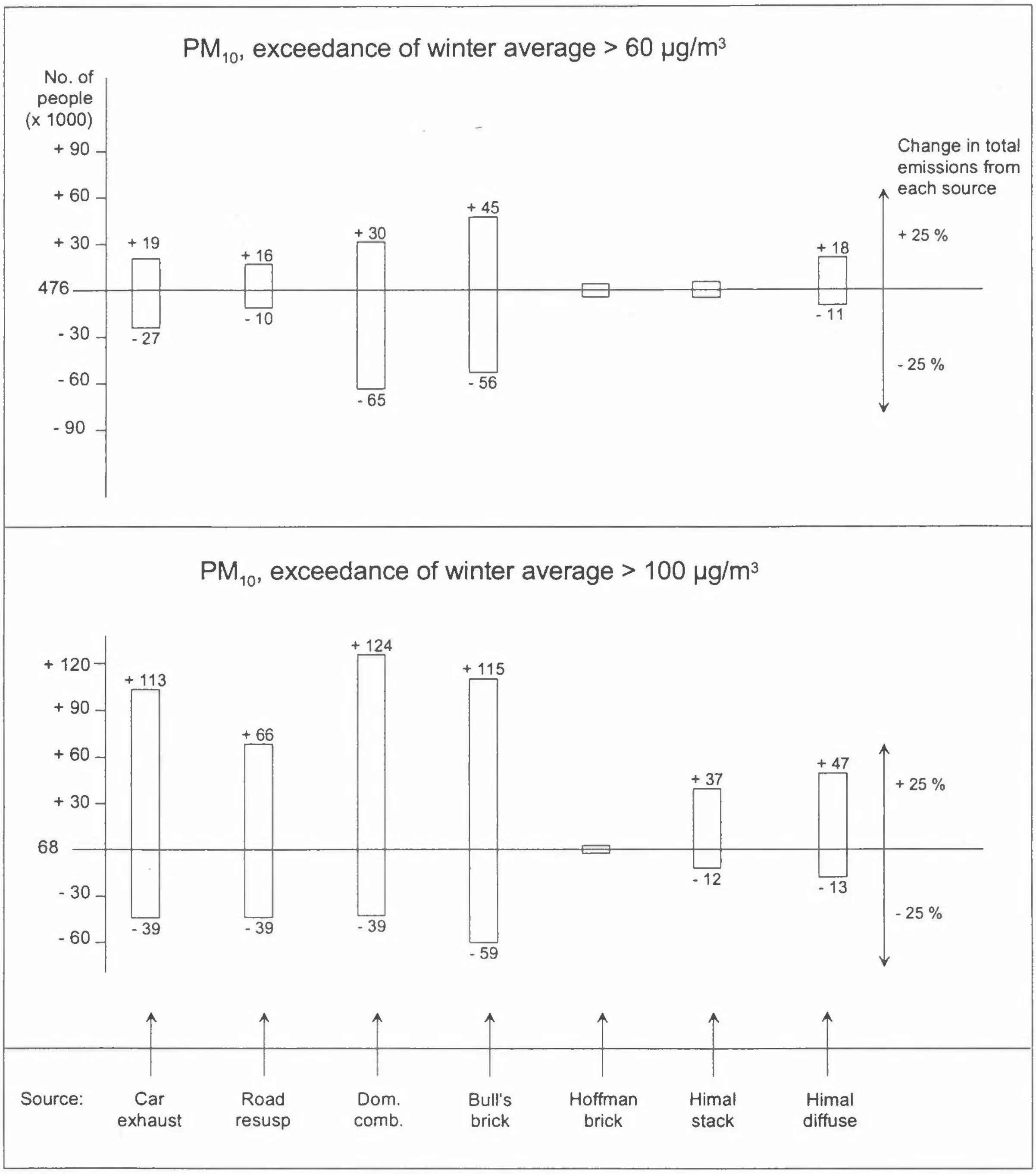


Figure 2.15: Change in population exposure to PM_{10} (number of people exceeding the given concentrations) as a result of ±25% change in the total emissions from each source category.

2.5 Summary of air quality assessment, Kathmandu Valley

Air pollution concentrations

- Air pollution concentrations have not been fully measured.

  - In the KVVECP, measurements of TSP, PM_{10}, SO_2 and NO_2 have been made at 14 sites, 5-30 days at each site during the autumn 1993.

  - One fairly long series of TSP measurements exist, from Babar Mahal Building, January-August 1994.

- These measurements, as well as subjective observations, show that the main air pollution problem in the valley is associated with **suspended particles**, such as TSP, PM_{10} and combustion particles.

- More than 50% of the days of measurement, which covered both the dry and wet season, had concentrations exceeding the WHO air quality guidelines.

  The highest 24-hour concentrations in comparison to the WHO guidelines, are as follows:

	Max. concentration	WHO Guidelines
TSP, KVVECP (traffic exposed)	867 µg/m^3	150-230 µg/m^3
TSP, Babar Mahal (residential)	467 "	150-230 "
PM_{10}, KVVECP (traffic exposed)	201 "	70 "

  The 8-month average TSP at Babar Mahal was 201 µg/m^3, compared to the WHO guideline of 60-90 µg/m^3 .

- The highest concentrations occurred in the most heavily trafficked sites and at the site near the Himal Cement factory.

- No measurements were made in the areas most exposed to brick industry emissions. High levels measured at the Thimi site may partly be due to such emissions.

Air pollutant emissions inventory

- Observations point to some of the main particle emission sources: smoking vehicles (diesel, and gasoline), brick kilns, Himal Cement.

- Based on available emissions data and estimates, a first approximation of an emission inventory for suspended particles has been worked out.

  In terms of total emissions, the main sources were (1993):

TSP		PM_{10}	
Himal Cement	36%	Brick industry	28%
Brick industry	31%	Domestic fuel	25%
Domestic fuel combustion	14%	Himal Cement	17%
Road resuspension	9%	Vehicle exhaust	12%
Vehicle exhaust	3.5%	Road resuspension	9%

Of the vehicle exhaust particles, diesel vehicles give out about 60% and gasoline vehicles about 40%.

- The actual impact of these emissions on one of the main effects of pollution, namely health risk from exposure, depends on the emission conditions (i.e. height of emissions) and their position relative to population centres (see below).

- There are major uncertainties in the emission figures for the sources. This may be especially important for road resuspension and Bull's trench kilns (which have the all-dominating emissions from the brick industry). Also, the PM_{10}/TSP ratios used for the various source categories are uncertain.

Overall, an improved emission inventory is needed.

Population exposure to air pollutants

- A first approximation of the population exposure has been worked out, based upon the emissions inventory, a multisource Gaussian dispersion model for long-term averages, and meteorological statistics from the Tribhuvan Airport.

- The calculated contributions to the winter average concentrations in Kathmandu City were as follows:

	TSP	PM_{10}
Vehicle exhaust	22 $\mu g/m^3$	22 $\mu g/m^3$
Road resuspension	57 "	15 "
Domestic fuel combustion	35 "	18 "
Bull's trench kilns	47 "	12 "

These four sources all contribute heavily to population exposure.

The other sources are much less important in Kathmandu City.

- The calculated winter average TSP concentrations seems to underestimate the actual concentrations in Kathmandu City (Babar Mahal Building) somewhat.

- In the brick kiln areas, the Bull's trench kiln emissions dominate completely.

- The present population TSP exposure situation in Kathmandu Valley is as follows:

  - About 50% of the population is exposed above the upper limit of the WHO air quality guideline (90 μg/m^3)

  - Some 3-4% of the population is exposed above twice this level (180 μg/m^3). These are residents in the brick kiln areas, and drivers and roadside residents.

- The indoor air pollution, which is rather large particularly in the rural areas, has not been taken into account in these calculations.

Visibility reduction

- The visibility of the valley has been reduced very significantly in the dry season since early 80's.

- At the same time, the population, the fuel consumption, the road traffic and industry has increased also significantly.

- The visibility is affected mainly by sub-micrometer particles, mainly from fuel combustion. Hygroscopic particles, like sulphate, nitrate and organic aerosols, cause strong visibility reduction at relative humidities above 70%. However, combustion aerosols absorb water, which causes reduced visibility, already at relative humidities from 30-40%.

- For the visibility reduction, the location and height of the emission sources is of little importance.

- The main sources of combustion particles in Kathmandu Valley are (in arbitrary order):

  - Domestic fuel combustion
  - Road vehicles
  - Brick industry
  - Himal Cement

  Given the present accuracy of the emission estimates, a ranking of the relative importance of these source categories cannot be given.

2.6 Needs for improvement of the Air Quality assessment for Kathmandu Valley

2.6.1 Main shortcomings and data gaps

Air pollution concentrations

A comprehensive air pollution monitoring program for the valley is needed. At present, no such program exists.

Such a program should encompass the following items:

Compounds	:	*1st priority*: TSP, PM_{10}, submicron particles, black smoke, chemical composition, CO. *2nd priority:* SO_2, NO_2, PAH, benzene, lead.
Air quality sites	:	Road side, city background, sites in brick kiln area, rural sites, valley outskirts (hilltop)
Meteorological data	:	Several sites (3-5), wind, relative humidity, stability, visibility.
Measurement methods	:	Continuous monitors for PM_{10} , combustion aerosol, CO, meteorological data, visibility.

Emissions

It is important to improve the emissions inventory, especially the following:

- improved, comprehensive fuel statistics
- improved emission factors for vehicles
- accurate measurement of emissions from Bull's trench kilns
- study of emission factors for domestic fuel combustion
- determination of resuspension emission factors
- study the particle size distribution for the various source emissions.

Population exposure

The determination of population exposure in Kathmandu Valley is based upon a combination of dispersion modelling and pollution measurements.

A population cxposurc distribution of good quality is important since it is the basis for:

- estimating health damage
- assessing the effects on health of various measures to reduce the exposure, as part of a cost/benefit analysis.

To improve the population exposure calculations beyond what has been developed as part of the first phase of URBAIR for Kathmandu Valley, it is necessary to:

- establish dispersion models for the Valley capable of dealing with the complex topographical/temperature/dispersion conditions, and also for dispersion from roads.

- improve the input data base to such a model, regarding:

  - hourly air pollution concentration data
  - hourly dispersion data, spatial resolution
  - hourly emission data

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 and meteorological/dispersion monitoring system - evaluate sites; number (at least 10) and locations; - select parameters (CO, NO_x, O_3, HC, TSP and PM_{10} recommended)/methods/monitors/operation schedule; and - upgrade laboratory facilities, and manpower capacities.	This activity should start immediately, and a proposed schedule is as follows: • By 31 June 1996: Finalize plan for an upgraded air quality monitoring system, including plans for laboratory upgrading. • During 1996: - Establish of 1-2 new modern monitoring stations; and - Carry out first phase of laboratory upgrading.
• Design and establish a Quality Control/Quality Assurance System	This activity should also start immediately, phased in with the improved monitoring system, and the laboratory upgrading.
• Design and establish an Air Quality Information System, including - database; and - information to . control agencies; . lawmakers; and . public.	

Emissions • Improve emission inventory for Kathmandu Valley a) Improve industrial emissions inventory(location, process, emissions, stack data) b) Improve road and traffic data inventory c) Improve domestic emissions inventory d) Study resuspension - from roads - from other surfaces e) Estimate contribution from construction and refuse burning. f) Establish emission factors for indian conditions. • Develop an integrated and comprehensive emission inventory procedure, include emission factor review, update and quality assessment procedures. • Improve methods and capacity for emission measurements.	• 1. priority: - industrial emissions inventory - study of resuspension from roads - start developing an emission inventory procedure.
Population exposure Assess current modeling tools/methods, and establish appropriate models for control strategy in Kathmandu Valley.	This activity should be started without delay.

3. Health impacts of air pollution

3.1 Introduction

Chapter 2 concludes that the analysis of the health impact of air quality in Kathmandu Valley should concentrate on suspended particles, in particular PM_{10}. Figure 3.1 summarizes the information presented in chapter 2 in a frequency distribution of population exposure to PM_{10}. The WHO guideline for PM_{10} (41 $\mu g/m^3$) is derived by multiplying the WHO guideline for TSP (70 $\mu g/m^3$) with a factor .55 which expresses the typical fraction of PM_{10} in TSP. In this chapter the impacts from air pollution and its associated damage costs are evaluated for the present situation. In addition, the results of calculations are presented with the aim of assessing changes in air quality and associated impacts which result from increased or decreased emissions from specific sources. This information can guide the development of strategies to address the air quality problem.

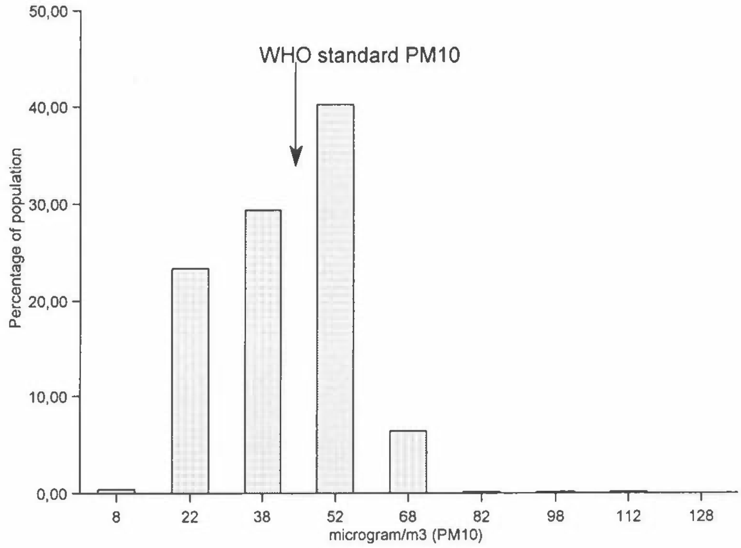


Figure 3.1: Frequency distribution of PM_{10} exposure (annual average). Kathmandu Valley, situation 1992/1993.

Section 3.2 deals with the calculation of the impacts of the present air pollution situation, while section 3.3 describes the attempts to valuate these impacts in terms of an estimate of the economic damage. Section 3.4 presents calculations of the marginal costs to health and benefits if emissions of specific source categories (e.g. traffic and brick manufacturing) change.

3.2 The impacts of Kathmandu Valley air pollution

The damaging effects of air pollution consists of various components: damage to human health, materials, vegetation and crops, buildings and monuments, ecosystems and tourism. In theory, damage can be assessed. In practice this is difficult because of a lack of appropriate empirical dose-effect relations.

Nevertheless, with respect to health impacts some information on dose-effect relations is available, although it is derived from epidemiological studies done in the US. The estimate of the impacts on health is primary based on B. Ostro's work, described in the general URBAIR report, which was recently updated (Ostro, 1994). In fact the present report (this chapter) may be seen as an extension of Ostro's work as published in Calkins et al. (1994) the difference being the "detailed" exposure data used here. Guidelines for acceptable air concentration - the "no-damage" benchmark - come from the World Health Organization (WHO).

Ostro’s work relates to TSP concentrations. In this URBAIR work it has been decided to work with PM_{10} instead, when evaluating health effects, and the relationships between measures to reduce exposure and their costs, and the resulting changes in health effects and their costs.

This was done since PM_{10} particles are considered more detrimental to health than the larger particles often dominating TSP. Working with TSP in a situation, as in Asian megacities where contributions from resuspension of road dust, construction activities and other coarse particle sources dominates the TSP concentrations, would overemphasize the health benefits of measures which would reduce the coarse particles.

The conversion from TSP to PM_{10} is in this analysis done as follows:

- The PM_{10} **concentrations** are calculated from dispersion models using actual PM_{10} emissions, and measurements of PM_{10} as control.

- The TSP **dose-response relationship** is converted to PM_{10}, using a ratio of 0.55 between PM_{10} and TSP concentrations.

- The WHO **Air Quality Guideline**, which is used as a no damage benchmark, is converted from TSP to PM_{10}, using the same ratio as above.

It is emphasized that health is not the only adverse impact of air pollution; because of a lack of appropriate data it was not possible to quantitatively assess impacts such as on monuments and temples, reduction of the economic life of capital goods, tourism, crop growing and other intangible impacts. In particular the **adverse impact on tourism**, being Nepal's second industry, is a concern. Moreover, congestion, which is a related adverse effect, leads to loss of valuable time.

In October 1993, “Newsweek” published an article which contained a pessimistic - but not incorrect - image of the air pollution situation in Kathmandu Valley. Such negative information could certainly have an adverse effect on tourism. In the early ‘90’s, foreign currency revenues amounted to ca. US$ 60 million/year. No “dose-effect” relationships of air pollution and tourism are available but suppose there is a ca. 10% decrease, the foregone foreign revenues amount to ca. US$ 6 million; an important amount for a country with a negative balance of trade. Moreover, indirect effects may have the same order of magnitude. This leads us to a tentative estimation of the amount of damage to tourism due to air pollution of some US$ 10 million, or NRs 0.5 billion per year.

The following sections 3.2.1 and 3.2.2. deal with the physical impacts on death rates and on illness in Kathmandu Valley respectively, while section 3.3 deals with the economic valuation.

3.2.1 Death

The impacts on health are divided into mortality (excess death rates) and morbidity (excess cases of illness). Mortality and morbidity rates are derived from air quality data using dose-effect relationships. In principle such relationships are found using 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 US and US cities and it is somewhat speculative to use them for the situation in Kathmandu. But until specific dose-effect relations are derived for other conditions, Ostro's dose-effect relations remain the best available.

Although it is clear that indoor pollution, e.g. caused by cooking, can also damage health, we have restricted 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
c: Crude rate mortality = 0.0091 in Kathmandu (Shrestha, 1995)
PM_{10}: Annual average concentration ($\mu g/m^3$) of PM10 (particles with a size smaller than 10 μm).

41 is the PM_{10} benchmark (corresponding to the WHO standard of 75 $\mu g/m^3$ TSP on a yearly basis) above which mortality will increase.

From this relation, the data presented in chapter 2 - as summarized in figure 3.1 - it can be concluded that excess mortality due to PM_{10} was about **85**[2] cases, in a population of about 1 million.

[2] Results of calculations are detailed for reasons of consistency, not to pretend a level of certainty.

3.2.2 Illness (morbidity)

Particles

The following effects can be attributed to particles: 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:

ChBr: The change in yearly cases of chronic bronchitis per 100,000 persons is estimated at 6.12 per µg/m^3 PM_{10}. The total number of yearly cases of chronic bronchitis per 100,000 persons is than 6.12 x ([PM_{10}] - 41).

RAD: The change in restricted activity days per person per year per µg/m^3 PM_{10} is estimated at 0.0575. If we use again the WHO standard, 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 µg/m^3 PM_{10}.
Using the WHO standards, the respiratory diseases requiring hospital treatment 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 µg/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 46% of the total population. (estimate based on communication with Prof. Bimala Shrestha).

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 20% of the population (estimate based on communication with Prof. Bimala Shrestha).

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

The result of combining the data of figure 3.1 and the above mentioned dose-effect relations are presented in table 3.1, in which the health impacts are presented together with valuations.

3.3 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, omitting the cost of 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 that gives the difference in purchasing power capacity between Nepal and USA. This factor is 930/21,900 = 0.0425 (Dichanov, 1994), leading to an estimate of US$ .1275 million or NRs 6.4 million per statistical life.

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 23 years, and the life expectancy at birth is 60 years, the value is:

$$V = \sum_{t=0}^{36} w \,/\, (1+d)^t$$

with w = average annual income (Shin et al., 1992) and d is the discount rate.

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. With a yearly wage of NRs 20,000 and a discount rate of 5%, the value of a statistical life is NRs 340,000. Considering both approaches to the valuation of premature death the cost figure associated with the increased mortality due to PM_{10} air pollution in 1990 (84 cases) ranges from NRs 28,3 million to NRs 540 million.

Morbidity

For the URBAIR project a city-specific study was performed by Shrestha (1995) on the valuation of illness. The valuation is based on the following:

- work loss days and wages;
- costs of medical care and medication;
- hospital visits;
- the valuation results of the Bombay URBAIR study;
- the study by Ostro (1992).

The study was complemented with personal communication with the URBAIR consultants, leading to the valuation as given in Table 3.1.

The valuation of illnesses should be interpreted with care as it is still based on a number of relations derived from other parts of the world. More research is needed to derive better valuations specific for Kathmandu Valley.

Table 3.1: Impact on mortality and health and their valuation (NRs) of health impact in Kathmandu Valley.

Type of health impact	Number of cases	Value (NRs)	
		Specific	Total (10^3)
Excess mortality	84	340,000	28,644
Chronic bronchitis	506	83,000*	41,988
Restricted activity days	475,298	56	26,617
Emergency room visits	1,945	470-720 (600 in calculations)	1,167
Bronchitis in children	4,847	350	1,697
Asthma	18,863	450-4,170 (600 average in calculations)	11,318
Respiratory symptom days	1,512,689	50	75,634
Respiratory hospital admissions	99	4,160	415
Total			209,051

* Shrestha's estimate is about NRs 146,000, but based on a not discounted sum of the amount over 27 years. Discounting with 5% leads to an estimate of NRs 83,000.

3.4 Health impact and economic damage by source category

In targeting and prioritizing actions it is useful to have insight into the source categories which are the most important in terms of impacts and damage inflicted. It is impossible to separate the contributions to the present damage of the different source categories. However, some insight is obtained by estimating marginal contributions of each source. Table 3.2 presents the results of these calculations. The first and second columns summarize emissions data as presented in Table 11 of the emissions inventory (see appendix). The third column, titled "change in emission", indicates the assumed changes in emissions which were evaluated in the air quality model (see chapter 2). The fourth, fifth and sixth columns summarize the changes in selected damage categories and the estimated costs associated with it. The last column shows the estimated marginal "damage costs" and "benefits" of changes in emissions (change in health damage costs divided by the change in emissions).

Table 3.2: Marginal impacts from different sources.

Source	Emission (tonne)	Change in Emission (%)	Change in Mortality	Change in RSD (1000)	Change in health damage (NRs thousand)	Marginal costs/benefits (NRs/kg)
Traffic (exhaust)	440	25	20	354	48,952	
		10	10	180	25,351	576
		-10	-6	-108	-15,037	341
		-25	-9	-160	-22,118	
Resuspension	400	25	12	219	30,273	
		10	9	165	22,842	571
		-10	-2	-35	-4,903	122
		-25	-7	-125	-17,382	
Domestic	1160	25	23	407	56,238	
		10	13	227	31,367	270
		-10	-9	-155	-21,360	185
		-25	-13	-239	-33,056	
Brick (Bull's	1250	25	25	443	61,199	
trench kilns)		10	13	229	31,688	253
		-10	-3	-57	-7,832	62
		-25	-15	-274	-37,921	
Hoffman brick kilns	45	25	0	-3	446	
		-25	0	-6	-765	

* These calculations are based on earlier version of the air quality damage model in which roadside air exposure is nor accounted for. Therefore, this model tends to under estimate the impacts or the air pollution, e.g. mortality is estimated at 65 instead of 84 as mentioned in the section above. However, for the purpose of giving a first estimate results presented in Table 3.2 are sufficient.

The data in the last column illustrate that the air quality is the most sensitive to changes in traffic (exhaust emissions and resuspension): an increase in emission of 1 kg increases health damage by NRs 570. In second place are domestic sources and the Bull's trench brick kilns (NRs 270 and NRs 250 respectively).

These results are more or less reflected in the ranking of marginal benefits of emissions reduction. Reduction of vehicle exhaust emissions is the most effective in terms of reduced health damage (NRs 341 per kg emission reduction). Next in order of importance is "reduction of domestic emissions" (NRs 185 per reduced kg of PM_{10} emission). In this case, it should be noted that, in absolute terms, reduction of these emissions yields the largest benefits.

Preliminary calculations (not shown here) indicate that a reduction of the diffuse (non-stack) emissions of the Himal cement plant will have benefits of similar magnitude.

Emissions forecasts

Recently, Malla and Shresta (1993) described scenarios predicting the development of emissions in Kathmandu valley. They conclude that in a business-as-usual scenario the TSP emissions of "transport", "households", and "industrial" are likely to increase by about 120%, 13% and 12,5% over a period of eleven years. Recent growth rates of fuel consumption (Gautam, 1994), of population (JICA, 1992) and of the brick industry (NESS, 1995) confirm the expected high growth rates. In particular the expected growth of the transport sector reinforces the conclusion that, from the health impact point of view, the transport sector is the highest priority.

3.5 Conclusions

Overall the damage caused by air pollution consists of various components: damage to human health, materials, vegetation and crops, buildings and monuments ecosystems and tourism. In theory, damage can be assessed. In practice actual assessment is difficult because of lack of appropriate empirical dose-effect relations.

Nevertheless, with respect to health impacts some information on dose-effect relations is available, although they are derived from epidemiological studies performed in the US. Using these relations and the air-quality model developed for Kathmandu Valley (see chapter 2) impacts can be calculated. Table 3.1 presents the results; key data are excess mortality - **85 cases -** and the number of respiratory symptom days (RSD): about 1.5 million.

A second difficult task is to value action of the damage done. It is not possible to value all different types of damage: no estimate was possible of the damage to Kathmandu's cultural assets (e.g. temples and monuments). A rough estimate of the amount of economic damage due to air pollution is NRs 0.5 billion.

However, damage to human health can be valued to some extent. Health damage consists of mortality and morbidity. The valuation of loss of life is difficult and can be given no more than an estimate. If estimated with the human capital approach (i.e. lost earnings due to premature death), the value of a statistical life amounts to ca. RNs 340,000. The valued excess mortality is then 28.3 million NRs. Using a value derived from the so-called Willingness-to-Pay (WTP) in the US result in a "damage value" of NRs 540 million.

Costs of morbidity (illness) are more relatively reliable. They consist of foregone wages and costs of medical treatment. Estimates were made specifically for Kathmandu Valley of costs of morbidity due to concentrations of PM_{10}. The valued morbidity costs amount to about NRs 180 million, and **total health damage at NRs 210 million** (with lost salary as the value of statistical life). This valuation of damage approach to human health tends to underestimate, as suffering due to illness or premature death is not included.

An analysis of the marginal impacts of emissions increase and reduction by source categories showed that the health impacts are most affected by developments in the transport sector, while domestic sources and brick manufacturing rank second in this respect.

4. Existing laws and institutions

4.1 Laws and regulations on Air Pollution

The development of environmental and air pollution legislation in Nepal is in its first phase. Prior to 1994, there were no laws or regulations pertaining specifically to air pollution. However, the rising environmental problems caused by the economic development of Nepal had long been recognized, and statements regarding the need to protect the environment had been included in Five Year Plans. An Environment Preservation Council had been established under the Chairmanship of the Prime Minister, and also an Environmental Preservation Division within the National Planning Commission (NPC).

The government's policies and intended actions regarding the environment were set out in the planning document for the Eighth Five Year Plan:

(a) adopt an integrated approach to environmental policy, with sustainability as the overall goal,

(b) develop strategies for sustainability and provide for their implementation directly through regional and local planning,

(c) require proposed development projects, program and policies to include environmental impact assessment and extended economic appraisal,

(d) establish a comprehensive system of environmental law and provide for its implementation and enforcement,

(e) recognize the legitimacy of local controls, implementation and enforcement mechanisms in local environmental planning and management,

(f) ensure that all national policies, development plans, budgets and decisions on investments take full account of their effects on environment,

(g) provide economic incentives for conservation and sustainable use,

(h) strengthen the knowledge base, and make information on environmental matters more accessible,

(i) ensure that strategies for sustainability include actions to motivate, educate and create conditions for individuals to lead their lives in a sustainable environment.

HMG in its "Approach to the Eighth Five-Year Plan" has specified policies and actions to ensure that all national policies, development plans, budgets and decisions on investments take full account of their effects on the environment. In particular, the Eighth Plan specifies that the urban environment will be improved through the control of wastes and through the establishment of water, air and noise standards.

According to His Majesty's Government, Ministry of Industry, Nepal, two basic activities for the formulation of legislation on air pollution have been recently completed and forwarded for approval by the cabinet:

a) Environmental Impact Assessment (EIA) guidelines for the industry sector have been forwarded for approval by the cabinet. The guidelines basically includes measures for the mitigation of the potential increase in on air pollution by new industrial establishments in Nepal;

b) Industrial Pollution Control Regulation (IPCR) for air and water discharges was drafted as an outcome of a workshop conducted by HMG/Ministry of Industry in June 1994 where concerned sectorial departments and agencies and NGOs, were involved. According to the Ministry, the draft was expected to become a regulation, by November 1994.

Laws on Vehicle Pollution Control have been proposed according to recommendations from the KVVECP study. They include, so far, limits on diesel smoke from diesel vehicles (65 Hartridge Smoke Units, HSU, free acceleration test) and CO emissions from gasoline vehicles (3%, at idle).

To our knowledge, standards or guidelines for air pollution concentrations have not yet been passed.

4.2 Institutions Involved

Description of existing institutions working in, and with responsibilities to, the air pollution sector regarding:

Coordination

- HMG/National Planning Commission (NPC/Environment Protection Council (EPC);
- Metropolitan Environment Improvement Program (MEIP)/World Bank.

Monitoring

- Department of Hydrology and Meteorology, Babarmahal, Kathmandu;
- Royal Nepal Academy of Science & Technology (RONAST), Naya Baneshwor, Kathmandu;
- HMG / Bureau of Standards.

Emission Inventories

- Department of Hydrology and Meteorology, Babarmahal, Kathmandu;
- Kathmandu valley vehicle Emission Control Project (the 1st phase), funded by UNDP, under Department of Transport Management, Naya Baneshwor, Kathmandu;
- Royal Nepal Academy of Science & Technology (RONAST), Naya Baneshwor, Kathmandu.

Legislation

- HMG / Ministry of Law, Babarmahal, Kathmandu.

Enforcement

- Department of Traffic Management, Naya Baneshwor, Kathmandu;
- Kathmandu Valley Traffic Police, Singhadurbar, Kathmandu.

The above mentioned departments are basically funded by the HMG / Nepal except for the 'Kathmandu Valley Vehicle Emission Control Project (1st phase)' where the financial support was provided by UNDP and MEIP.

Manpower, expertise and equipment data for the organizations are as follows:

Name of Dept.	Manpower	Expertise	Equipment
1. Dept. of Tran sport Manage-ment	255	26	10 smoke meters, analyzers and 4 High Volume Samplers of Enviro-tech Co., India, and 2 CO/HC analyzers of Horiba Co., Japan
2. KTM Valley Traffic Police	455	44	Shares the equipment from the Dept. of Management
3. Thapathali Campus	90	42	Being Technical vocational school, owns most of the equipment for repair and maintenance of machi-neries and also shares equipment for vehicle emission check from the Dept. of Transport Management
4. Dept. of H. & Meteorology	300	50	Meteorological station at Babarmahal
5. Vehicle Emission Control Project, 2nd phase			(under formulation)
6. Dept. of Civil Aviation			N.A. Fully equipped meteoro-logical station for aviation purposes at the airport, Kathmandu
7. RONAST	180	108	High Volume and Handy Samplers one each, and a fully equipped meteorological station at Sundari Ghat, Kirtipur, Kathmandu
8. HMG/Bureau of Standard	80	68	Laboratory for quality control of all kinds of products

Note: The equipment owned by the HMG/Department of Transport Management is rotated among the enforcing organizations in the valley.

5. Abatement measures: effectiveness and costs

5.1 Introduction

This chapter presents information about appropriate measures for the reduction of air pollution in Kathmandu Valley. This information relates primarily to effectiveness, in forms of abated or avoided emissions and associated impacts, and to the associated costs. This data can be used in prioritizing actions when drafting an action plan.

The chapter is organized by the source categories: traffic; fuel combustion in either industries or domestic and construction and refuse burning. For these source categories it is intended to present brief characteristics of appropriate measures - measure in a technical sense - and information about:

- their **effectiveness** in terms of both emission reduction and reduced impacts in the year 1992/1993 (according to the methodology used in constructing table 4.5). The reference data are: mortality 85 (due to PM_{10}), and number of respiratory symptom days 1.5 million in 1990 (see table 3.1, all figures rounded off);

- their **costs**;

- their **benefits** (in assessing the monetary benefits the conservative approach (see chapter 3) is used;

- the **policy instruments** which might be used in order to get the measures implemented, and institutions which might be involved in implementation of the measure;

- the **time schedule** in which a particular measure can result in emission reduction (short term 2 year, mid-term 2 - 5 year, long term > 5 year).

In the following text, all figures of emissions, costs and benefits represent **annual** figures for 1992/1993, unless otherwise stated.

The list of measures is derived from the information presented by local consultants, from the general URBAIR guidebook and from earlier plans (see chapters four/five) addressing (parts of) the problems in Kathmandu Valley. In the 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 Kathmandu-specific situation.

5.2 Traffic

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

- implementation of a scheme for inspection & maintenance and addressing excessively polluting vehicles;

- improving fuel quality
  - adulteration of fuel
  - improvement of diesel fuel quality;
  - introduction of unleaded gasoline;
  - improvement of quality of lubricating oil in two-stroke engines;

- adoption of clean vehicle emission standards;

- other measures.

Much of the information presented is also available in KVVECP study (Mathur, 1993).

5.2.1 Implementation of a scheme for inspection & maintenance (I&M)

Effectiveness. Next to reduced traffic safety and unnecessary costs of increased fuel consumption, a major problem is the large emissions associated with maladjustment of fuel injection or carburettors and worn-out motor parts. Introduction of a scheme, e.g. requiring annual I&M, will result in a reduction of emissions of PM10, VOC[3] (unburned hydrocarbons/HC), and CO. An accurate assessment of the emissions reduction associated with the implementation of an I&M scheme requires statistical data about emissions characteristics of the Kathmandu Valley vehicle fleet in relation to its state-of-maintenance. In 1993 a study was carried out entitled "Pollution control of motor vehicles by introducing effective maintenance/repair works" (Thapathali Campus, Institute of Engineering, 1993) in the framework of the Kathmandu Valley Vehicular Emission Control Project (KVVECP). The study evaluated the effects of maintenance and repair on smoke levels in exhaust gases of a sample of diesel vehicles by measuring Hartridge Smoke. The results strongly suggest that levels can be brought down substantially (25%-50%) in a very cost efficient manner, as simple maintenance improves the fuel efficiency drastically. The results of this research are in line with a similar estimate (Mehta, 1993) for the Manila case, its vehicle fleet being renowned for the bad state of maintenance, and also with an estimate of the Indian Automobile Manufacturers (AIAM, 1994) with respect to the situation in India. The study also addressed gasoline vehicles, measuring the amounts of CO and HC (VOC) in exhaust gases. The results also indicate possibilities for reducing emissions at negative costs.

[3] Volatile Organic Compounds

Thus local measurements support the assumption that through the proposed comprehensive I&M scheme, emissions of **PM10, VOC and CO** decrease by a third (35% reduction of tail-pipe emissions). From table 3.2 it can be inferred that the benefits exceed NRs 25 million.

Costs of an inspection & maintenance scheme

Presently, the capacity for vehicle-emission testing is insufficient. In order to circumvent problems due a lack of capacity of government agencies, testing can be performed by private firms[4]. The cost of a single test is estimated at NRs 100 (as an order of magnitude). This estimate is based on proposals (tests including roadworthiness) which have been made for Indonesia (Budirahardjo, 1994) and for Manila (Baker et al, 1992). Based on the experiences of the KVVECP- study, it is assumed that cost of enforcing the maintenance will be off-set by reduced fuel costs associated with improvements in engine performance.

Table 5.1, quoted from Tuladhar (1993), shows the check points of an I&M scheme.

Table 5.1: Recommended remedial steps in an Inspection & Maintenance scheme (Tuladhar, 1993).

Diesel engine	Gasoline engine
Air filter	Air filter
Fuel filter, tappet settings	Fuel filter, tappet settings
Injector Nozzle pressure	Ignition system (Spark plugs, Contact points, distributor etc.)
Injector pump calibration	Carburettor
Engine compression check up	Engine compression check up
Engine overhaul	Engine overhaul

Policy instruments and target groups.

A study of Thapathali Campus (1993) notes a low awareness of both the adverse environmental and economic effects of poor maintenance (breakdown maintenance). This is observed in the case of both private owners, as well as fleet owners (government). This observation suggests that an awareness program should be developed which conveys the message that good maintenance pays. Eventually inspection and maintenance could be made mandatory, through a legislation which sets emission standards (and road safety standards as well). The key issue in such legislation is how to enforce emissions standards. Spot-checks by the police might be the most practical approach (Mathur, 1993, Garrat, 1993).

[4] 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 shown a test report at request.
- vehicles are spot-checked also.

Term. An awareness programme could be designed and developed within one year. A mandatory I&M scheme might be implemented within five years.

5.2.2 Improving fuel quality

Improving fuel quality consults of four categories of measure: addressing fuel adulteration (of gasoline), introduction of low-lead gasoline and unleaded gasoline, "clean" diesel, and the improvement of the quality of lubricating oil in two-stroke engines.

5.2.2.1 Addressing adulteration of fuel

It is said that adulteration of gasoline by adding diesel is a common practice in Nepal. The incentive is the large price gap between diesel fuel and gasoline, which is the result of government pricing policy. The use of adulterated fuel in motorcycles and other gasoline vehicles results in increased emissions as well as increased wear and tear of the engines. Quantitative information about the extent of this practice and its adverse environmental effects has not been found.

5.2.2.2 Introduction of unleaded gasoline

The introduction of unleaded gasoline addresses the lead problem. It is also 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 - in the case of simultaneous introduction of vehicles equipped with catalysts - the use of a separate fuel distribution system so as to avoid the mixing of leaded with unleaded fuel. Retailers usually sell both leaded and unleaded fuel.

Engines - older vintages - 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 emission is proportional to the eventual market shares of unleaded/low-lead gasoline and, in the case of low-lead gasoline, the content of lead.

Costs of the measure. Gasoline, diesel oil and fuel oils are not produced in Nepal. The Nepal Oil Corporation imports all fuel from India (Indian Oil Corporation): therefore, Nepal has little or no possibility to import clean fuels until clean fuels are marketed in India.

The reduction of the amount of lead compounds in gasoline requires a reformulation of the composition of 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 with oxygenated compounds; MTBE (Methyl tertiary butyl ether) is a preferred substitute. These changes lead to an increase in production costs typically in the range of NRs 0.5-1 per liter gasoline, depending on the local market for refinery products, the required gasoline specifications and the costs of MTBE (Turner et al, 1993). It is expected that similar costs would evolve if the Indian petroleum industry were producing unleaded gasoline.

Policy instruments and target groups.

Considering the supply situation, the appropriate measure would be to support actions in India for the introduction of unleaded gasoline.

Term. Widespread availability of unleaded fuel could be implemented within five years, provided it becomes available in India.

5.2.2.3 Improving diesel quality

The ignition and combustion properties of diesel are integral to an explanation of the emissions of PM10 by diesel engines (Hutcheson and van Paassen, 1990, Tharby et al, 1992). The volatility (boiling range) and the viscosity, (including its cetane number, an indicator of the ignition properties), are major fuel characteristics which determine these properties, and, consequently, the emissions of PM10. The specification for the cetane number of Diesel fuel for automotive purposes is a minimum 42. In the US, Western Europe and Japan the corresponding quality requirement varies from 48 to 50.

Another effect on quality is the presence of detergents and dispersants in diesel fuels. These additives keep injection systems clean and have discernible effects upon efficiency (Parkes, 1988).

Effectiveness. It is assumed that an improvement of the properties, as expressed in an increase of the cetane number[5] and a quality improvement from detergent additives, results in a decrease of 10% - as an order of magnitude (AIAM, 1994, Mehta et al, 1993) - of PM10 emissions: about 25 tonnes. A reduction of the **sulphur** content leads effectively to a proportional decrease in emissions of sulphur dioxide. In addition, PM_{10} emissions decrease since a part of the particles emitted consist 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, Government interference in the national market. The latter eventually determines the price-at-the-pump for fuels.

The cost of reduction of the sulphur content of diesel fuel is caused by 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 0.5 NRs per litre.

[5] 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 parameters which complicates the picture.

Sulphur in diesel fuel leads to formation of corrosive sulphuric acid at combustion. Therefore, reduction of the sulphur content has a financial benefit due to a reduction of costs of vehicle maintenance and repair.
The **benefit** of improving diesel quality is about NRs 7.5 million.

Policy instruments and target groups.

The introduction of clean diesel faces the same problem as introduction of low-lead gasoline: improvement of the quality of diesel fuel depends on energy policy in India. The India Oil Corporation must take the physical steps to expand capacity for producing improved quality diesel fuel.

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

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

A characteristic of Kathmandu Valley traffic is the large number of motorcycles and tricycles, both equipped with two-stroke mixed lubrication engines. These vehicles cause about 100 tonnes of the PM10 emissions (in exhaust gases) of all road traffic. The particles emitted by these vehicles are in fact small droplets of unburned lubrication oil. According to Shell (private communication, 1993) the lubricating oil used in most South East Asian countries is cheap, but of poor quality with respect to combustion properties.

Effectiveness. It is assumed that with a better quality lubrication oil emissions could be halved (50 tonnes reduction). A 50 tonne emissions reduction corresponds to NRs 15 million (order of magnitude, calculated with data from Table 3.2).

Costs. Introduction of these oils will, in the first estimation, double the costs of lubricating oil. We estimate the annual consumption of these oils at 250 kg[6]. A first guess of the total cost of low-smoke oil is then NRs 12,500. Its benefit (see table 3.2) would be US$ 50,000.

Policy instruments and target groups.

The importers of lubrication oil are the main target groups.

[6] Gasoline consumption is estimated at 28.3 kl (Table 1.2). Assuming that about half of this is used in two-stroke engines and assuming an average content of 2 to 5% of lubricating oil in gasoline, brings an estimate of a few hundreds of kg of lubricating oil: say 250 kg.

5.2.3 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 which are equipped 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 emissions of motorcycles, requiring two-stroke engine powered vehicles to be equipped with open-loop catalysts. The latter devices control emissions of VOCs (PM_{10}) and CO, not NO_x. Weaver and Lit-Mian Chan (1993) recently wrote a reference report on how to introduce standards for these types of vehicles.

A prerequisite for successfully adopting clean vehicle standards is a certain standard for regular inspection and maintenance of the vehicles and, in the case of gasoline vehicles, the availability of unleaded gasoline and the condition that clean vehicle owners will use unleaded gasoline exclusively. The catalyst technology prohibits the use of leaded gasoline, and also the sulphur content should be at a low level (<500 ppm). Therefore, the introduction of such standards involves the build-up of a structure for production and distribution of unleaded gasoline[7].

Diesel engine powered vehicles should also be regulated. Those emission requirements are met by adjusting the motor management plan, as well as the design of motors.

Tail-pipe emission treatment is also envisaged, as well as retrofits (installation of abatement equipment in existing buses). In that case the requirements for the diesel fuel quality are made more stringent (such as sulphur content below 0.02%, which is a severe restriction). This type of standard is now being introduced in some parts of the world (1994).

Effectiveness

Closed-loop catalytic treatment of exhaust gases (three-way catalysts) of gasoline-engine equipped vehicles reduces all exhaust emissions, e.g. NO_x, CO and VOC, typically by 85%. In addition, lead emissions are reduced by 100% given that the availability and use of unleaded fuel is a prerequisite for the implementation of these types 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 catalysts also requires the use of unleaded gasoline. An alternative would be to use well-

[7] 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.

designed and maintained four-stroke engines. We estimate that a similar emission reduction could be obtained.

If currently all gasoline vehicles (including motorcycles) had been equipped with catalytic converters (emission reduction 150 tonnes), the mortality figure would be reduced by about 10, while the number of RSD would be reduced by 200,000 and the health costs avoided would be US$ 75,000 less (estimated from table 3.2). The use of catalytic devices for treatment of exhaust gases requires the use of unleaded gasoline (see section 5.2.1). Thus, improved health because of reduced lead pollution should be added to these benefits.

Costs

Due to methodological difficulties (definition of the reference situation, costs to whom) it is not possible to calculate costs of a possible introduction of standards in Kathmandu Valley. 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 300 to 500 US$, on the average about US$400 in the USA (Wang et al, 1993). The use of these devices does have an minor adverse effect on the fuel economy. However, associated costs are offset by decreased costs of maintenance, due to increased lifetimes of replacement parts, such as the exhaust system. The total annual costs per automobile are estimated at NRs 5,000 (NRs 2,500 depreciation per car and NRs 2,500 extra fuel costs).

- The costs of **open-loop catalytic treatment of exhaust gases** of two-stroke motor cycles are related to increased purchasing costs of the equipment and to decreased fuel costs due to improved operation of the engine. Taiwan adopted standards which require the use of (open loop) catalytic devices which result in US$ 60-80 costs increase, which are offset by fuel savings (Binnie & Partners, 1992). The total annual costs are estimated at NRs 3,500 per vehicle (depreciation + increased fuel costs). Provisionally it is assumed that the cost of motorcycles is similar to the cost of four-stroke engines.

Other costs are related to higher costs of unleaded gasoline due to increased costs of production and the adjustment of the logistic system (modification of pump nozzles). A very rough estimate of the costs, only for the purpose to obtain a perspective, is US$ 100 annually per vehicle (NRs 2,500 depreciation of control system + increased fuel costs NRs 2,500, depending on the possible subsidies/levies on gasoline). An obvious question 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:

- petroleum industry and gasoline retailers (introduction of clean cars requires the availability of unleaded gasoline)
- the Indian car and motorcycle industry
- workshops (have to acquire the skill for maintenance of clean vehicles)

- vehicle owners (have to pay the price)

Term. In practice, standards are set only for new model 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 now designed to be equipped with catalytic control systems.

The effect of these standards take place gradually, reflecting the rate of replacement for existing vehicles.

5.2.4 Improved abatement/other propulsion techniques

In the USA and Europe (European Union) the tightening of standards is being discussed. Possibilities are:

- improving current techniques for abatement;

- improving inspection and maintenance, as it now appears that only small numbers of maladjusted/worn-out cars cause unproportionally large emissions

- enforcement of the use of "zero-pollution" vehicles, i.e. electric vehicles in down-town areas.

A bottleneck in decreasing automotive air pollution are diesel engines given that exhaust gas treatment similar to that in gasoline cars is not possible. However, with respect to CO_2-emissions diesel engines perform better.

5.2.5 Addressing resuspension

Resuspension is clearly an issue of high priority. Unfortunately, quantitative information about measures appropriate for Kathmandu has not been found. However, in general, possible measures include improved pavement of roads, and periodical cleaning of roads. Resuspension is still a highly important matter for further analysis in order to propose viable measures.

5.2.6 Improvement of traffic management

Traffic management includes a variety of measures, ranging from traffic control by police 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 i.e. solving congestion problems. On the curb-side level traffic management may improve air quality[8]; however, on the city level it may increase air pollution (emissions) as traffic management usually results in increased performance of the transport system. In terms of exposure, traffic management can be beneficiary as the air quality in down-town areas improves and "road-exposure" declines; but, in the narrow sense 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 improvement of road safety and reduction of congestion.

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

In the action plan - see chapter 6 - several measures for improving traffic management are indicated. It was not possible to indicate costs and exposure benefits.

5.2.7 Construction and improvement of mass-transit systems

A methodology to assess costs and effectiveness of a measure "improvement of the Kathmandu Valley public transport system" involves elaborating on issues such as:

- description of a future system appropriate for Kathmandu Valley;
- assessment of the performance of such a system - (passenger x km)
- assessment of the costs of construction;
- a description of the baseline (future situation without such a system)
- avoided emissions;
- assessment of non-environmental benefits;
- design of a scheme to identify those costs and benefits to impute to the environmental aspects.

The cost of construction of mass-transit systems are high and projects cannot be justified from only an air pollution point of view. However, mass-transit systems have a wide variety of other benefits and any effort from the non-environmental point of view to initiate improved public transport should be supported in environmental policy.

In Kathmandu trolleybuses are operated. These are electrically powered vehicles which do not emit exhaust pollutants. Expansion of this system might be considered to provide for public transport services.

5.3 Industrial combustion (excluding brick manufacturing)

Major industries within this category include the carpet industry the food industry as well as industry of metal products. These industries operate boilers which are fired with fuel oil, HSD, and agricultural wastes (e.g. rice husks).

Unfortunately, only scanty information about these emissions was obtained. Therefore it was impossible to evaluate possible measures (e.g. good housekeeping practices, fuel substitution, encouraging energy efficiency) to a great extent.

5.4 Brick manufacturing

Brick manufacturing is a major source of pollutants in Kathmandu Valley (see table 11 of the emission inventory in the appendix). Currently two technologies are used, the most important being the Bull's trench kiln technology (Chimney Bhatta) accounting for about 80% of the brick production and for over 95% of the emissions by the brick industry of PM_{10}. The second technology is the Hoffmann (Chinese) kiln type. A third type of brick manufacturing technology (Vertical Shaft Brick Kiln) is currently being tested (NESS, 1995). This type of brick manufacturing is relatively clean in respect to air pollution. However, its disadvantage, among others, is the high rate of bricks breakage (NESS. 1995). Therefore, there is not much outlook that this technology will be adopted.

The NESS study proposes simple techniques to scrub the flue gasses in the chimneys of the Bull's trench kilns. These proposals are not fully elaborated with respect to the expected effectiveness of the device, its power consumption, the availability of scrubbing water and its effect on the draft of the chimney.
De Lange (1989) suggested a number of simple technological improvements (e.g. improved thermal insulation, mechanical draft), aimed at improving the energy efficiency of the kilns. It is expected that a decrease in fuel consumption will reduce emissions as well.

NESS made an extensive study of the economic situation of the brick industry and made a survey the problems which the brick factory-owners experience. The brick-factory owners face several difficulties: availability of land and fuel seems to be their primary problems. As fuel costs constitute a significant portion of the cost vector of the bricks produced, an approach to improve the energy efficiency of the kilns will be beneficial to both the environment and the economy of brick manufacturing.

5.5 Domestic emissions and refuse burning

Domestic emissions are mainly caused by cooking activities using local type stoves (chullas). It is a major source of emissions, ranking second to (to equal with) brick manufacturing (see emission inventory). Traditional cooking with chullas is less desirable from several perspectives. First, it constitutes public health threat (indoor pollution), in particular for women. Secondly, it is a waste of energy and threatens the natural forest resources. And thirdly, it has adverse effects on outdoor air quality.

Traditional cooking with fuel wood and agricultural waste is extremely inefficient, from an energy point of view. Improved cooking stoves (ICS), having an energy-efficiency of 20% - in the case of traditional stoves the corresponding figure is 12%- (Malla and Shrestha, 1993) constitute part of a solution. The introduction of improved cooking stoves is, from an environmental point of view, a highly effective approach to improve air quality. However, information about the ICS's attractiveness to traditional households - usually low-income households - was not found. Therefore, no estimate of its cost-effectiveness can be presented.

An alternative approach to reduction of the emissions from cooking is to foster the use of kerosene as a cooking fuel. Fuelwood is the preferred fuel in low-income households, for economic reasons. A scheme for subsidizing the use of kerosene, if feasible, might be an appropriate instrument to reduce the use of fuelwood.

Refuse burning can be avoided by extension of the public refuse collection system.

5.6 Conclusions

This chapter describes a number of measures which are appropriate to the air quality in Kathmandu Valley. It deals with several aspects of the measures; their effectiveness, costs, benefits, implementation and the institutions/authorities involved. An important issue was to indicate the benefits of reduced health impacts and reduced damage costs. Together with the costs of the measures, this information gives clues for the ranking of measures. It should be noted that the quantitative information presented often has to be characterized in order 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. The measure which stands out from a cost-benefit point of view is addressing the situation with respect to maintenance of vehicles. The costs to vehicle owners are offset by benefits in terms of reduced fuel costs. The benefits from reduced health damage costs should be added.

Due to lack of quantitative data no cost information is presented about measures other than that directed at the transport sector. This is an unfortunate circumstance as, presently, these other sources - in particular Bull's Trench Kilns brick industries and domestic use of fuelwood and agricultural waste - appear (see table 3.2) to be nearly equally important to the PM_{10} exposure of the Kathmandu Valley population as the traffic sources.

6. Draft Action Plan

The assessment given here of air pollution and exposure in Kathmandu Valley, 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, are based on the present state of knowledge and quantification. Shortcomings in the data base have been pointed out throughout the text. This 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.

For Kathmandu, the analysis for costs associated with abatement, as well as the benefits, has not been carried out for most of the possible abatement measures, because of lack of data on which to base such cost estimates. However, a number of effective abatement measures were evaluated in Ch. 5.

The "actions" consists 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 Kathmandu Valley.

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

6.1 Actions to improve Kathmandu Valley air quality and its management

6.1.1 Actions to improve air quality

Actions and measures have been proposed by the local Kathmandu Valley URBAIR working groups. The list of measures proposed by the URBAIR working group is presented in Table 6.3.

The proposed actions/measures have been put in the following categories:

Category 1: Air Quality Monitoring
Category 2: Inventory/dispersion modelling
Category 3: Institutional and regulatory framework
Category 4: Traffic management
Category 5: Transport Demand Management
Category 6: Land use planning
Category 7: Fuel switch
Category 8: Improved fuel quality
Category 9: Technology improvement
Category 10: Awareness raising
Category 11: Further studies
Category 12: Water Supply and Sanitary Management
Category 13: Solid Waste Management and Recycling

Each action/measure can be briefly described, 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.
- EffectsReduced emission/exposure/damage costs.
- Cost Cost of measure.
- Feasibility
- Remarks

Various technical abatement measures were evaluated in Chapter 5 for costs and benefits. For lack of cost data, a proper cost/benefit analysis/estimation has not yet been performed.

The previous analysis has shown that the following sources are of approximately equal importance both to the effects on health and the reduction in visibility:

- Vehicle exhaust (diesel and gasoline)
- Domestic fuel combustion
- Resuspension from roads
- Bull's Trench brick kilns.

Vehicle exhaust is somewhat more important that the others to reduce the health damage. For the visibility problem, Himal Cement emissions are also of importance, when uncontrolled.

Table 6.1 presents a list of technical measures, with an indication of the importance of the measure to reduce pollution (xxx more important than x). Introduction in the short/medium/long term is indicated with a view to the feasibility of introducing of the measure. It is considered that the proposed measures are economically feasible in the indicated time frame.

The measures are not described very specifically, only the needed abatement action is indicated. Also the list does not represent a ranking based on cost/benefit.

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

Table 6.1: A list of technical pollution abatement measures, important for the reduction of the air pollution effects in Kathmandu Valley.

Abatement measure	Short term	Medium term	Long term
Technical measures, vehicles			
I/M scheme, comprehensive	xxx		
Improved motorcycle technology		xx	xx
Clean vehicle standards		xx	xx
Improved abatement/new propulsion techniques			xx
Fuel quality			
Control adulteration	xxx		
Low-lead gasoline	xx		
Unleaded gasoline		xx	
Improved diesel quality	xx	xx	
Low-smoke lub.oil, 2-stroke engines	xxx		
Road resuspension			
Road cleaning, garbage collection	xxx		
Domestic emission			
Improved cooking stoves	x	xx	
Switch to kerosene	x	xx	
Brick industry			
Improved technology	x	xx	

Additional measures can be listen under the categories.

- traffic management
- transport demand management, incl. land use planning.

as listed in the action list of Table 6.3. Especially, expansion of the trolley bus system of Kathmandu can be supported from a local environmental point of view.

6.1.2 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 the inventory of abatement measures
- the improvement of institutional and regulatory framework
- building of awareness among the public and policy makers.

Chapter 2.7.2 (page 64) presents necessary actions to improve the Air Quality Assessment. They are summarized in Table 6.2, together with other necessary improvements.

Table 6.2: Actions to improve the Air Quality Management System of Kathmandu Valley.

Air pollution monitoring
• Establish a monitoring system, covering: - compounds such as TSP, PM_{10}, combustion particles, black smoke, CO, visibility, etc. - sites, such as traffic exposed, city background, brick kiln area, rural, hilltop, etc. - long term operation - continuous monitors, where available • Indoor air pollution study. • Up-grade laboratory, establish quality control system.
Emissions
• Improved, comprehensive fuel statistics. • Establish/improve emission factors for vehicles, brick kilns, domestic fuel combustion, resuspension. • Study particle size distribution of emissions from various sources, as well as for the ambient pollution.
Population exposure
• Establish appropriate dispersion model for Kathmandu Valley.
Assessment of damage and cost
• Epidemiological research, assessment of specific health costs (now US derived figures were used). • Empirical study of tourism and environment (tourists attitudes). • Identification of interest of other parties in a cleaner environment.
Inventory of abatement measures
• Effectively (abated/avoided emissions). • Costs. • Benefits other than strictly environmental.
Institutional and regulatory framework
• Involvement of the Nepal Oil Corporation. • Tax differentiation between clean and dirty diesel?, if there are practical possibilities for clean and diesel import. • Is the brick industry able to develop clean technologies?, via a sort of taxing system to raise the funds? (Is there an association of brick manufactures to discuss with?)
Awareness building
• Publicity campaigns on billboards and in the media (e.g. smoke belching campaigns; information campaigns on health damage; information campaigns on the expected developments if no actions are taken). • Environmental education in schools. • Organization of environmental courses. • Setting up an environmental information centre. • Support of environmental NGO's.

Table 6.3: List of proposed actions and measures to improve the air quality of Kathmandu Valley.

Category: 1. Ambient Air Quality Monitoring, Inventory and Dispersion Modeling

I. Air quality monitoring

What	How	When	Who	Remarks
1. A.Design national air quality monitoring programme.	- Review national air pollution status and assessment cabalities. - Establish field stations and base laboratory.	ASAP 1995	NPC/EPC DOHM, DOTM MOI, NGOS	Monitoring ambient air quiality will be trusted to DOHM with close cooperation with MOI and MOWT and NGOS
B. Design and establish quality assurance system. * Evaluation of sites, number and location.	- Tap funding agency support - Identify needs and gaps in the existing facilities. - Determine air pollution impact on health.	1995 ASAP 1995	NPC/EPC/DOTM DOHM Donors community, NGO, DOHM consultants academic MOH, consultants	

II. Inventory and dispersion modelling

What	How	When	Who	Remarks
1. Design / Develop a comprehensive emission inventory procedure including emission factor review and update. (all sources) and cost.	- Co-ordination with academic, policy making body, implementing agencies such as MOWT, MOI, DOHM, DOTM - Funding support such as MEIP	ASAP 1995 on-going	DOHM MOI Academic consultants NPC/EPC DOHM, NPC consultants	
2. Improve emission inventory of both mobile and stationary sources.	- mass balance approach	1995, on-going	Consultants, DOHM, MOI, DOTM	
3. Conduct inventory of domestic emission	- Co-ordinate with indoor-air pollution programme	S/S	academic consultants	Co-ordinating with donors

Table 6.3: Cont.

Category: 2. Traffic Demand Management and Infrastucture Imprevement

What	How	When	Who	Remarks
1. Improve traffic flow a. Improve existing road network b. Introduce traffic management concept.	- Remove obstructions viz. i. unloaded building materilas, ii. road side vendors, iii. alternate parking facilities, iv. repair and service shops etc	1995/onwards	DOR, DOTM municipalities, Traffic police	MOWT/MLD/MHPP will develop a comprehensive plan and traffic police as well as municipalities will serve as enforcing agencies.
	- Synchronize and optimize repair roads	1995/onwards	DOR, DOTM municipalities	
	- Ensure proper coordination among different units of government for digging.	1995/onwards	DOR, DOTM, NEA, NTC, NWSC, municipalities NEA, NTC, NWSC	
	- Radial roads and public transportation facilities.	1995/onwards	DOR, UCC	
b. Extend/develop road network	- Implement the recommendations of Urban Road Development Master Plan (JICA study report)	1993/onwards	DOR, MOWT, DOTM MHPP, municipalities	
c. Improve facilities for non-motorized traffic	- Construct pedestrian overpasses and side walks	1994/onwards	DOR, municipalities DOTM	

Table 6.3: Cont.

d. Implement Transport Service Rationalization Programme	- Study the implementation of a private car utilization restraint policy which could include: - Limit entry within certain areas - Define and mark the lanes and enforce the rules. - Encourage carpooling through demand management measures like parking regultions by charging a higher parking fee. - Designate where public utility vehicles (buses, taxis etc.) can stop.	 1994 1995 onwards 1994	DOTM, Traffic Police DOR,	
e. Immediate Improvement of Enforcement / Traffic Laws	- Rationalize / standardize traffic laws, rules and regulations by enacting traffic code and use standard form. - Provide proper training to enforcers drivers and require them to pass exams. - Set up monitoring and evaluation system for enforcers and for violators. - Effect traffic safety seminars and traffic rules and regulations re-education. - Use mass media for information dissemination.	1994 1994 onwards 1995 onwards 1994 1995 onwards	MOWT, DOR, DOTM, Traffic Police DOTM, Traffic Police DOTM, Traffic Police DOTM, Traffic Police, DOTM, Traffic Police, TV, Radio Print Media	
2. Introduce and expand computerized information system at Traffic Police	- Create technical group to evaluate existing information system and prepare plans.	Action Result 1994	Traffic Police MOH	

Table 6.3: Cont.

3. Strengthen Traffic Safety Programme	- Establishment of wide walk net work. - Organize traffic safety seminars/weeks and also re-education of traffic rules and regulation. - Immediately strengthen traffic police/traffic lights/zebra crossing for traffic improvement.	1995 1994 onward	DOR, DOTM DOTM, MOWT, DOR, Traffic Police DOTM, DOR, Traffic Police	
4. Expansion of public transport/system	- Advocate and support	1995	MOWT, DOTM	
5. Provide environment friendly transportation	- Extend trolley bus network	1994 onwards	MOWT, NTC,	
6. Survey present mass transit situation and improve: * time schedules * junctions and stations	- Implement survey results	1994 onwards	DOTM	

Category: 3 Land Use Planning and Management

What	How	When	Who	Remarks
1. Land use planning to reduce transport demand.	- Work-out strategy for dispersing facilities (shopping etc.) so that these are closer to users and generate less traffic.	S/S	MHPP, DOB DHUD, DOTM	MHPP/MLP are the key actors.

Table 6.3: Cont.

2. Update land use plan/GLDP? for Kathmandu Valley and revise zoning ordinates.	- Update land use plan and pass new zoning ordinances - Raise awareness through training and education campaigns to make people realise the benefits of planning. - Extend GLDP to areas where environmental standard is low	S/S S/S	MHPP, DHUD MHPP, DHUD NGOs municipalities	
3. Conservation of open spaces	- Ensure buffer zones, parks and other public amenities by strict enforcement of land use policy	ASAP	MHPP, MLD, DHUD municipalities, NGOs	
. Land Use policy for Industrial establishments	-Develop and enforce inter and intra industrial land use zoning.	ASAP	MHPP, MOI	

Table 6.3: Cont.

Category: 4. Fuel Switch/Quality Control

What	How	When	Who	Remarks
1. Switch on to less polluting utility vehicles in various organizations.	- Tax or subsidy modification. - Study restructuring of taxes on diesel vis-a-vis petrol with a view to encourage the use of petrol over diesel. - Study market implications of such modifications.	ASAP	MOS, MOF	Leading role should be played by MOS and NOC.
2. Address the problems of dilution and adulteration of fuel.	- Strict enforcement of laws relating to quality control of petroleum products: * Frequent inspection of petrol pumps or dealers and tanker lories. * Stiffer penalties for violations. * Start mobile laboratory van or testing fuels.	on-going	NOC, DAO	
	- Inform public about ways to detect adulterated and diluted fuel and its effect. Use filter paper or thermometer for testing fuels. NOC has introduced a system of thermometer but it needs to be made accesible and its existence known to the consumer.	ASAP	NOC	
	- Use NOGs and consumer protection councils for educating the public.	S/S	NOC, NGOs	
3 Phasing out of lead in pterol.	- Study its feasibility, possibility of revision of supply to some extent, the additional cost to the consumers.	ASAP	MOS, NOC	

Table 6.3: Cont.

4	Review energy pricing policy. Consider impacts to environment (petroleum products and electricity or other fuels).	- Study the issue and feasibility of removing all price distortions. Consider environmental costs. -- Study impacts of removal of subsidies on diesel. - Study the possibility of introducing pollution tax.	ASAP	MOS, MOF NOC,NPC/EPC, DOTM	

Table 6.3: Cont.

Category: 5 General Awareness Raising

(Please indicate whether this category should be intregated with other category or should be in separate).

What	How	When	Who	Remarks
1. Awareness / information on air pollution	- Use tri-media. - Start pollution information forum. - Publish bulletion/newspaper	ASAP, 1995	MECSW, NPC/EPC MHPP, MCI, MOH, NGOs EPC	Target groups: Public thourgh CBO / NGOs /Government units.
- Improve indoor/outdoor air quality	- Launch antismoke campaign and - Arrange talk programmes in public places (Haat/Bazar, school, restaurants etc.) - Indoor ventilation/improved cooking stoves - Designate smoke-free zones		MECSW, MHPP, MOH, NGOs MCI, MOH	
- Promote correct value system.	- Include in school curriculum		MECSW	
- Care for the environment/ fellowmen	- Media campaign to create awareness - Amend/Revise rules to ensure effectiveness. - Follow up KVVECP campaign		MCI, NGOs MOWT	
2. Traffic Management	- Train enforcers and drivers. - Proper tuning of vehicles. - Organize traffic week regularly. - Use mass media for public awareness.	ASAP S/S S/S	Traffic Police (TP), DOTM MECSW, TP, DOTM MCI, DOTM	
3. Supply quality fuel	- Information to detect diluted fuel and its effect. - Introduce an appropriate system of fuel testing at petrol pumps.	S/S S/S	NOC NOC	

Table 6.3: Cont.

Category: 6 Further Studies

What	How	When	Who	Remarks
1. Air Quality Monitoring	- Conduct appropriate studies which will relate to more rational emission standards.	ASAP	NPC/EPC	NPC/EPC will handle every items for further study in detail in consultation with line agencies and NGOS.
2. Inventory Dispersion Modelling	- Study re-suspension from roads and other sources.	1995		
3. Institutional and Regulatory Framework	- Study ways to strengthen legal mechanism for introducing "polluters Pay" principle. - Study possible incentives for enforce and other staffs involved in environmental management. - Study the possibility of accrediting private entities for vehicle inspection and emission inspection system. - Study the feasibility of phasing out importation of second hand and reconditioned vehicles.	1995 1995 1995 1995		
4. Traffic Demand/Management	- Study the implementation of a private car utilization restraint policy. - Study stagerring of work and study hours/days and day offs. - Study and update feasibility of extending trolley bus network.	1995 1995 1995		

Table 6.3: Cont.

5. Land Use Planning	- Study and update land use plans to facilitate transport demand.	1995		
6. Fuel Switch/Quality Control	- Study the feasibility of using LPG in public transport. - Study market implication of taxes on diesel vis-à-vis petrol with a view to encourage the use of petrol. - Study the feasibility of marketing unleaded petrol and identify/evaluate other additives. - Study impacts of removal or phasing out of existing subsidy for diesel. - Study the possibility of introducing pollution tax.	1995 1995 1995 1995 1995		
7. Research on Air Pollution Effects on Health	- Effects of Decrease in Lead/Lead free Petrol and other concomitant Pollutant. - Study on Air Pollution Effects on Cardio-Vascular and Respiratory Diseases.	1996 1996		
8. Study the possibility of alternative fuel such as LPG, CNG, electricitric vehicles etc	- Strat R & D	1995		

Table 6.3: Cont.

9. Review the policies of vehicle import to the Kathmandu valley/Nepal.	- Analyze present policies in comprehensive ways and correlate with the realities.	1995		
10. Study the economic aspect of the effects of air pollution in the valley.	- Explore the economic loss due to air pollution.	1995		

Table 6.3: Cont.

Category: 9 Institutional and Regulatory Framework

What	How	When	Who	Remarks
1. Introduce "Polluters pay" principle through appropriate regulatory measures and serve penalties against violators.	- Plug and amend existing environmental legislation. - Impose penalties to violators - Ensure regulation from the practical point of view. - Amend & pass bill. - Introduce mandatory third party insurance. - Incorporate users charge. - Formulate pollution standard. - Give pressure for the localization of industries. - Introduce quality drainage management.	S/S/ S/S/ ASAP ASAP 1995 ASAP ASAP ASAP	MLD, MHPP, MOWT BSM, MOI, EPC, Traffic Police, DOTM NPC/EPC, DOTM SWMRMC/MLD Municipality, NPC/EPC/DOTM MOI DWSS	A high level Coordinating and monitoring unit at NPC/EPC will be constituted with representation from government and private sector to supervise the overall managerial activities.
2. Strengthen technical capabilities relevant govt. agencies industry, municipality, SWMRMC and NGOs for environmental management.	- Est. and promote training institutions. - Promote technical and economic capabilities. - Encourage community/people participation. - Increase economic benefit of the staffs. - Encourage Pvt. sector involvement. - Promote Pvt. lab for testing.	S/S/ S/S/ ASAP 1995 ASAP ASAP	MLD EPC MLD, TDC Relevant Govt. Agencies NGOs	
3. Coordinate efforts among different Govt. and non Govt. agencies involved in air pollution control.	- Strengthen existing traffic management. - Execute common monitoring guidelines. - Creation of one environmental body.	S/S ASAP 1995	MLD, Traffic Police DOTM DWSS, RONAST DOTM EPC/NPC	

Table 6.3: Cont.

4. Analysis of regulation by all concerned agencies.	- Pass odometer law - Require total disclosure and technigraph for all vehicles - Encourage to import standard spare parts. - Fixing parameters on air, water, noise and land pollution control.	ASAP ASAP S/S S/S	MLD, EPC, DWSS SWMRMC NGOs EPC	
5.- Study possible incentive and funding for enforcer and other staffs involved in environmental monitoring management.	- Analyse existing salary scales for merit - Create a fund to procide and support economic benefit. - Allocate more budget. - Launch antismoke belching campaign. - Create environmental fees/fines and setup a trust fund.	ASAP ASAP	EPC, MLD, DWSS, MOF, SWMRMC Municipalities, NGOs	
6. Remove jurisdictional boundaries between different institutions.	- Duplication of jurisdictional boundaries and responsibilities be avoided. - Play vital role with O & M activities. - Provide detailed guide line and strengthen SWMRC and Municipalities.	S/S S/S S/S	MLD, MHPP, EPC	
7. Strengthen enforcement capabilities of Concerned authorities	- Train people or staffs and maintain coordination. - Tap NGO to assist, Use media pressure, Setup hot line to report violators.	ASAP S/S	MLD, MHPP EPC	

Table 6.3: Cont.

8. Strictly and uniformly implement antismoke belching campaign.	- Prepare a manual, strengthen implementation capability of traffic police, among others. - Encourage NGOs relevant government agencies to launch awareness campaigns. - Encourage garage testing. - Encourage school, office to start this campaign.	1995 ASAP ASAP ASAP	EPC, MOWT, MHPP, MLD, Traffic Police DOTM EPC, MHPP, MLD, MOE DOTM, MOE	
9. Strict emission control for cars, motorcycles, heavy duty vehicle, tempos.	- Policy, translation into implementation procedure, set time schedule.	on-going 1995	NPC/EPC Traffic Police MOWT, DOTM	
10. Address highly polluting: * vehicles * industries * road maintenance * construction on laws * use of emission control equipment/improvement	- Enforce existing laws/legislations. - Replacement of engines. - Follow-up of industrial EIA procedure.	ASAP on-going	NPC, MOI, Traffic Police, DOTM, DOR citizen group, NGO consulting firms	

ABBREVIATIONS

ASAP	As Soon as Possible
BSM	Bureau of Standards and Meterology
CNG	Compressed Natural Gas
DAO	District Administrative Officer
DHUD	Department of Housing and Urban Development
DOB	Department of Buildings
DOHM	Department of Hydrology and Meterology
DOR	Department of Roads
DOTM	Department of Transport Management
DWSS	Department of Water Supply and Sanitation
EPC	Environment Protection Council
LPG	Liquidated Petroleum Gas
MCI	Ministry of Communication and Information
MESCW	Ministry of Education Culture and Social Welfare
MHPP	Ministry of Housing Physical Planning
MLD	Ministry of Local Development
MDF	Ministry of Finance
MOH	Ministry of Health
MOHA	Ministry of Home Affairs
MOI	Ministry of Industry
MOS	Ministry of Supplies
MOLJ	Ministry of Law and Justice and Parliamentary Affairs
MOWT	Ministry of Works and Transport
NEA	Nepal Electricity Authority
NGO	Non-Governmental Organization
NOC	Nepal Oil Corporation
NPC	National Planning Commission
NTC	Nepal Telecommunication Corporation
NWSC	Nepal Water Supply Corporation
RONAST	Royal Nepal Academy of Science and ddTechnology
SWMRMC	Solid Waste Management and Resource Mobilization Centre
S/S	Start Soon
TDC	Town Development Committee
TP	Traffic Police
UCC	Utilities Coordination Committee
O&M	

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(1.000 kroner)	1995 Tildelt	1996 Tildelt	1997 Søknad	Endring i forhold til 1996
Basisbevilgning:				
Grunnbevilgning:	*6.800*	*7.720*	*9.000*	*16,58 %*
SIP:				
Avsluttes 1996				
Klororg.stoffer i artiske miljø	900	800		
Nitrogen fra fjell til fjord	400	300		
Fortsetter 1996				
Ozonforskning	1.400	1.200	1.200	0,00 %
Tettstedsproblemer	860	760	900	18,42 %
Jordobservasjoner		400	600	50,00 %
Nye 1997				
Organiske miljøgifter, Arktis			800	
SUM SIP:	3.560	3.460	3.500	1,16 %
Sum basisbevilgning:	**10.360**	**11.180**	**12.500**	**11,81 %**
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ABSTRACT
The report describes the development of an action plan for air quality improvement in Kathmandu Valley, based upon the assessment of emissions and air quality in the metropolitan area, population exposure and health effects (damage), the assessment of costs related to the damage and to a number of proposed abatement measures, and a cost-benefit analysis.

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