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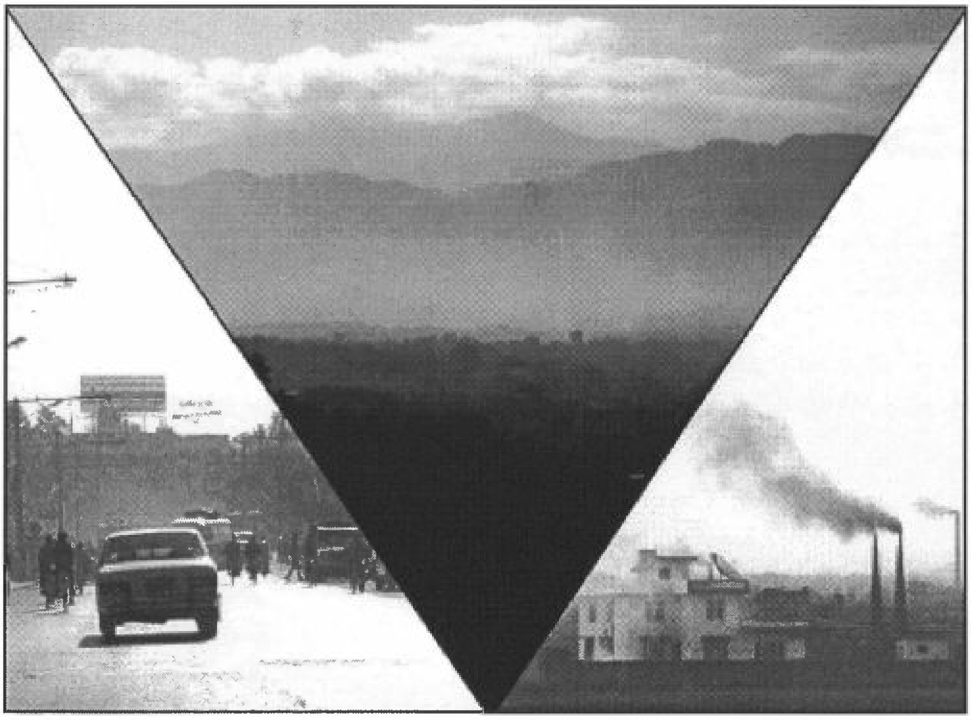
Air Quality
Emissions
Exposure
URBAIR
Abatement
Damage
Cost

Urban Air Quality Management Strategy in Asia



KATHMANDU VALLEY City Specific Report

APPENDICES

Prepared under contract from
The World Bank
Asia Technical Division

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URBAIR

Urban Air Quality Management Strategy in Asia

KATHMANDU VALLEY

Appendices

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Notice

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

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

Preface

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

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

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

This report contains the appendices to the main report.

Acknowledgements are presented in the main report.

Contents

Appendix 1

Air Quality Status, Kathmandu Valley

Contents

1. Outdoor (ambient) concentrations

1.1 Past measurements

Prior to 1993, only scattered measurements of air pollution concentrations have been performed. The KVVECP (Kathmandu Valley Vehicle Exhaust Control Program) (Mathur, 1993) study identified 7 previous studies, which included some measurements (Table 1). In these studies, measurements were confined to roadside sites. Thus, the results are not representing the status of general population exposure.

Mathema et al. (1992) describes some results from measurements done, in the following manner:

> "A 1980-study carried out by Bhattarai and Shrestha (1981) on dust pollution at Kathmandu concludes that at 18 spots where the data was collected, lead content was far in excess of the reasonably acceptable level of 0.6 parts per million. At busy street and cross-roads the lead content was found to be in the range of 544 ppm (Maitighar) to 153 ppm (Tripureswor). A 1987 study on pollution in the Kathmandu city carried out experiments to determine "particulate loading" (extent of dust present in the air) in the month of September when dust pollution is expected to be low. It was found that at the three locations where measurements were recorded (Jochhen Tole, Singha Durbar, and Lazimpat) the amounts of dust particles per cubic meter of air were between 6 and 11 times the relevant US standard (MHPP, 1991(b). Similar experiments carried out by CEDA (1990) in Pokhara, Kathmandu, and Biratnagar have led to similar conclusions, during the 1989/90 India-Nepal trade impasse when vehicular traffic volume was considerably lowered due to shortage of gasoline/petrol. Davidson and Pandey (1986/p 115-119) have shown that the concentration of SO_4, NO_3 and C (organic) and lead at the curb of a busy street of Kathmandu is comparable to those in urban areas in industrialized countries."

Measurements of particles and their content of mycoflora in Kathmandu city were performed in June, October and November, 1992 (U. Sharma et al., 1992). 16 samples were collected at 16 different locations near roads, using a Millipore pump and filters (6-8 hours of sampling). The sampling method indicates that the measurements are related to measurements of Total Suspended Particle (TSP), as measured with a high volume sampler.

The particle concentration was within the range 197-524 $\mu g/m^3$, averaging 304 $\mu g/m^3$. The corresponding Air Quality Guideline of WHO is 120 $\mu g/m^3$. Thus, the measured concentrations were all above this guideline. It can be expected that the TSP concentrations are considerably higher in the dry season, especially during the January-April period.

Various species of fungi were isolated from the particle samples described above. The fungi may be agents of different diseases, and some of them are allergens. The source of this mycoflora in the particles is resuspended dust on the roads.

This dust is composed of dust from dirt roads and construction sites, as well as scattered refuse from human activities.

Table 1: Air quality related studies in Kathmandu Valley prior to 1993 (Ref.: KVVECP study).

S.No.	Reference of study	Year	Conclusions
1.	Bhattarai and Shrestha	1980	Kathmandu: Pb Maitighar : 544 ppm Tripureshwor : 153 ppm
2.	MHPP Pollution study	1987	Kathmandu: Road side dust: 6 to 11 times of US Std.
3.	CEDA study	1989/90	Pokhara, Kathmandu Biratnagar, road side dust: (SPM) higher than WHO standards.
4.	Davidson and Pandey	1986	Kathmandu: SO_2, NO_x and Pb higher than WHO std.
5.	Sharma and Pradhanang	1992	Kathmandu: Milipore pump & micro flora SPM range: 197-524 $\mu g/m^3$.
6.	NILU Team observation	1993	Kathmandu: Low visibility and haze, road side SPM high
7.	RONAST	1993	Kathmandu: Road side SPM 197-775 $\mu g/m^3$ higher than international stds.

The latest study before the KVVECP measurements, the ENPHO (NGO) study, confirmed the very high TSP concentrations roadside in the valley, with daytime concentrations up to 2258 $\mu g/m^3$ (at Kuleswore). This study also included PM_{10} measurements giving concentrations within 50-130 $\mu g/m^3$. Measurements of CO, SO_2 and NO_2 gave rather low values, within WHO standards.

NILU observations, April 1993

During a field trip to Kathmandu 18-21 April, 1993, the CO concentrations were monitored along some road routes (Figure 1). Generally, the recorded CO concentrations in highly trafficked areas were in the range 15-20 ppm, with peaks up to 60 ppm.

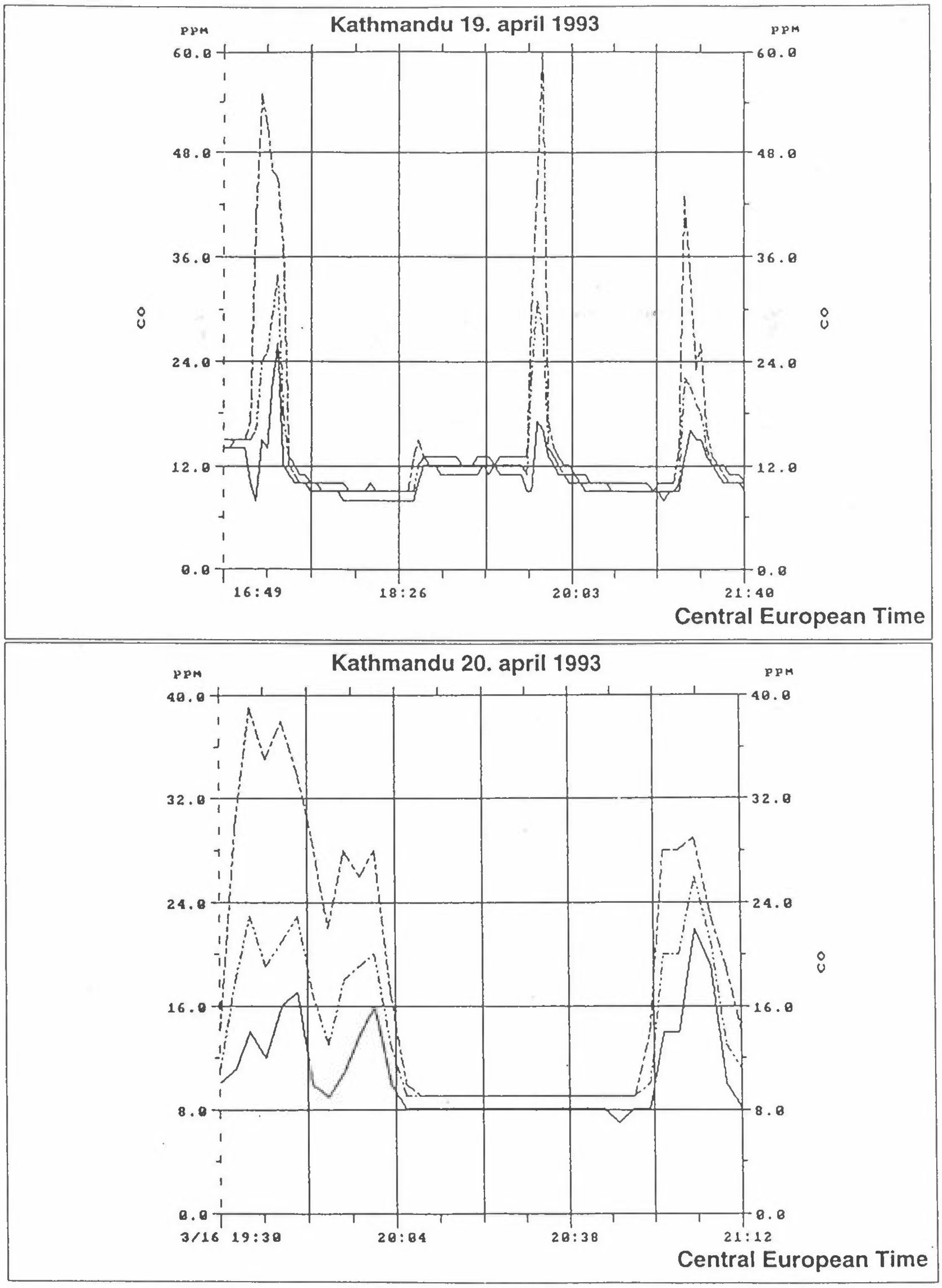

Figure 1: *CO measurements performed by NILU in Kathmandu, travelling on roads by taxi, April 1993.*

1.2 Results of measurements after 1992

The following measurement campaigns have been carried out after 1992 (in chronological order):

- Environment & Public Health Organization (ENPHO) carried out TSP, PM_{10}, NO_x, CO, SO_2 and lead measurements at a total of 20 sites in Kathmandu City, in November 1992 and February 1993 (Karmacharya and Shrestha, 1993).

- The Kathmandu Valley Vehicle Exhaust Control Program (KVVECP) carried out a measurement campaign of TSP, PM_{10}, NO_2, SO_2, CO and lead at 14 sites during September-December 1993 (Devkota, 1993).

- Measurements by NESS (Pvt) Ltd. of PM_{10} and lead at a number of sites in Kathmandu City during September-November, 1993 (Sharma et al., 1994).

- Measurements of TSP by the Hydrological and Meteorological Service at the HMS building at Babar Mahal, starting from January 1993.

In addition, visibility observations have been made at Tribhuvan International Airport since the early 1970's (see Chapter 3 of this Appendix).

Results from the ENPHO measurements

The measurements were carried out in two phases (Karmacharya et al., 1993):

- In November 1992, at 9 sites of various height and distance from roads, to get a general picture of the air quality of the area. 24-hour averages.

- In February, 1993, at 11 roadside sites, to get a picture of roadside exposure. 9-hour averages.

Monitoring sites are shown in Figure 2, and described in Table 2. The methods are given in Table 6. The description of the project indicates that only one sample was taken at each site. Results are given in Table 3 and 4 for phase 1 and 2 respectively.

The results indicate that TSP is the main problem compared to the WHO guideline. The measurements from phase 1 (24 hour averages) averaged 308 $\mu g/m^3$, with maximum concentration of 555 $\mu g/m^3$, at Chabahil. PM_{10} also exceeded the guideline at many of the sites, but to a lesser extent than TSP. Maximum PM_{10} concentration was 127 $\mu g/m^3$ (WHO guideline: 70 $\mu g/m^3$). The SO_2, NO_x and CO measurements indicated rather low concentrations.

The lead measurements also indicated fairly low concentrations, with a maximum 24-hour value of 0.53 $\mu g/m^3$, against a long-term WHO guideline of 0.5-1 $\mu g/m^3$.

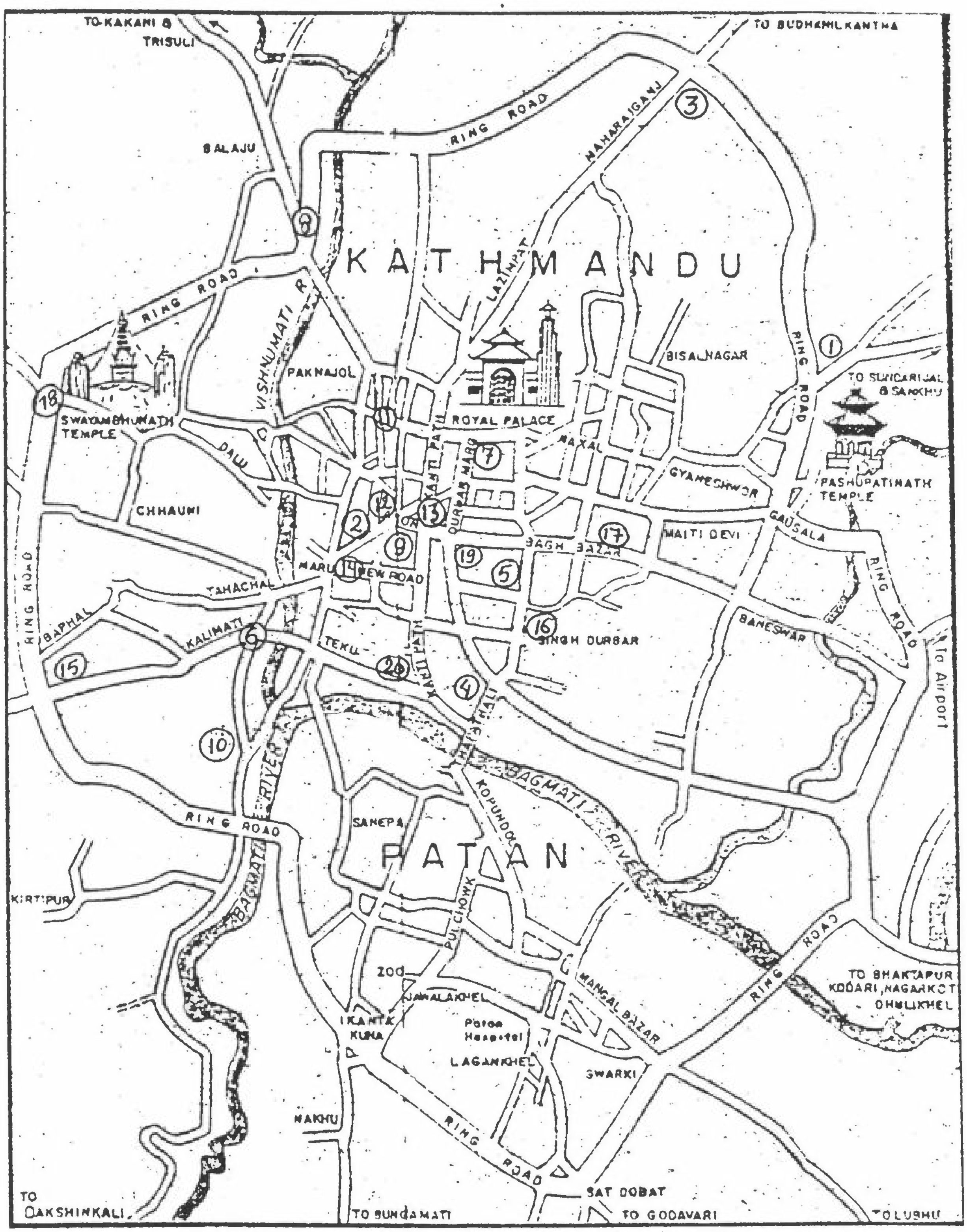

Figure 2: ENPHO campaign measurement sites (Karmacharya et al., 1993).

Table 2: Description of ENPHO campaign measurement sites (Karmacharya et al., 1993).

S.No.	Sampling station	Height (m)	Distance from closest road (m)	Distance from popular junction (m)	Direction from the popular junction (m)	Type of area	Traffic density
1	Chabahil	3	5	100	North-East	Residential/ Market	Busy
2	Indrachowk	12	5	50	North-West	Residential/ Market	Busy
3	Maharajgunj (Ring Road)	5	15	30	South-East	Residential	Moderate
4	Thapathali	3	5	75	North-West	Residential/ Market	Busy
5	Putalisadak	6	8	75	South	Residential/ Market	Busy
6	Kalimati	10	5	25	North	Residential/ Market	Busy
7	Royal Palace	5	8	30	South-West	Market	Busy
8	Balaju (Ring Road)	6	15	35	North-West	Residential/ Market	Busy
9	Bir Hospital	3	5	25	North-West	Residential/ Market	Busy
10	Kuleswor	0.75	2	Right at the junction	West	Residential/ Market	Busy
11	Thamel	0.75	0	Right at the junction	East	Residential/ Market	Busy
12	Ason	0.75	0	Right at the junction	South-West	Residential/ Market	Low
13	Nachghar (Jamal)	0.75	0	Right at the junction	North	Residential/ Market	Busy
14	Kasthamandap	0.75	2	Right at the junction	South-East	Residential/ Market	Moderate
15	Kalanki (Ring Road)	0.75	2	Right at the junction	North-West	Residential (outskirt)	Busy
16	Singha Durbar	0.75	2	Right at the junction	South-West	Office Complex	Busy
17	Dillibazar (Pipalbot)	0.75	2	Right at the junction	North	Residential/ Market	Moderate
18	Swayambhoo (Ring Road)	0.75	2	Right at the junction	South-West	Residential (outskirt)	Moderate
19	Ratna Park (Bus park)	0.75	2	Right at the junction	North-West	Residential	Busy
20	Tripureswor	0.75	2	50	South-East	Residential/ Market	Busy

Table 3: Concentration of the pollutants (first part - 24 hour averaging time), ENPHO study.

S. No.	Stations	TSP µg/m3	PM_{10} µg/m3	SO_2 µg/m3	NO_x µg/m3	CO mg/m3	Pb µg/m3
1	Chabahil	555	127	<13.0	28	<11	0.35
2	Indrachowk	194	59	<13.0	24	<11	0.21
3	Maharajgunj (Ring Road)	233	64	<13.0	17	<11	0.18
4	Thapathali	206	74	<13.0	12	<11	0.31
5	Putalisadak	267	92	<13.0	28	<11	0.37
6	Kalimati	232	76	<13.0	24	<11	0.30
7	Royal Palace	182	93	<13.0	25	<11	0.53
8	Balaju	465	102	<13.0	24	<11	0.23
9	Bir Hosptal	438	116	<13.0	36	<11	0.43
	Average	308	89	*6.5	24.2	<11	0.32
	WHO Standard	120	70	125	150		0.5-1.0

Table 4: Concentration of the pollutants (Second part - 9 hour averaging time), ENPHO study.

S. No.	Stations	TSP µg/m3	PM_{10} µg/m3	SO_2 µg/m3	NO_x µg/m3	CO mg/m3	Pb µg/m3
10	Kuleswor	2258	415	19	59	<11	0.7
11	Thamel	1978	498	<13	48	<11	1.2
12	Ason	1772	281	<13	28	<11	0.5
13	Nachghar (Jamal)	1283	257	<13	32	<11	0.9
14	Kasthamandap	1056	182	<13	17	<11	0.4
15	Kalanki (Ring Road)	1201	239	22	40	<11	0.2
16	Sinha Durbar	789	225	20	69	<11	0.2
17	Dillibazar	1077	240	18	30	<11	0.5
18	Swayambhu (Ring Road)	1161	258	<13	26	<11	0.3
19	Bus Park (Ratna Park)	1709	355	17	41	<11	0.6
20	Tripureswor	1090	313	<13	30	<11	0.4
	Average	1397	296	12.3	38	<11	0.54

* SO_2 - <13 has been arbitrarily considered half of 13, i.e. 6.5.

The phase 2 measurements at roadside sites gave much higher concentrations. Also here, TSP and PM_{10}, presented the largest problem compared to guidelines.

TSP-concentrations (9-hour day-time average) averaged almost 1400 µg/m3, with max. concentration 2258 µg/m3, at Kuleswor. PM_{10} averaged almost 300 µg/m3, with maximum 498 µg/m3 at Thamel.

Again SO_2, NO_x and CO concentrations were low, while the lead concentrations were up to 1.2 µg/m3, averaging 0.54 µg/m3. Still fairly low, but increased compared to the phase 1 sites.

These measurements, covering a number of sites in general Kathmandu City atmosphere and the roadside atmosphere, can be used to give a rough estimate of a long-term average TSP and PM_{10} concentration which might represent a typical exposure value for the population in central Kathmandu City, based on the following assumptions:

- Consider that the average 24 hour average roadside concentration is 50% of the 9 hour average, i.e. 700 $\mu g/m^3$ for TSP and 150 $\mu g/m^3$ for PM_{10}.
- Consider that the average person spends 25% of the time roadside.
- Consider that the summer (monsoon) season average is 50% of the winter season average.

This results in an annual average of 300 $\mu g/m^3$ for TSP and 75 $\mu g/m^3$ for PM_{10} for an average person living in central Kathmandu City spending 25% of his time roadside.

Results from the KVVECP study

As part of the Kathmandu Valley Vehicle Exhaust Control Program (KVVECP), measurements of TSP, PM_{10}, NO_2, SO_2, CO and Pb were made at a number of sites (roadside, residential, industrial). Results have been reported for the period September-December, 1993 (Devkota, 1993).

The measurement sites are shown in Figure 3 and described in Table 5. Individual results, as reported by Devkota, are annexed to this appendix. Methods are listed in Table 6.

Table 5: Ambient Air Quality Monitoring Stations, 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

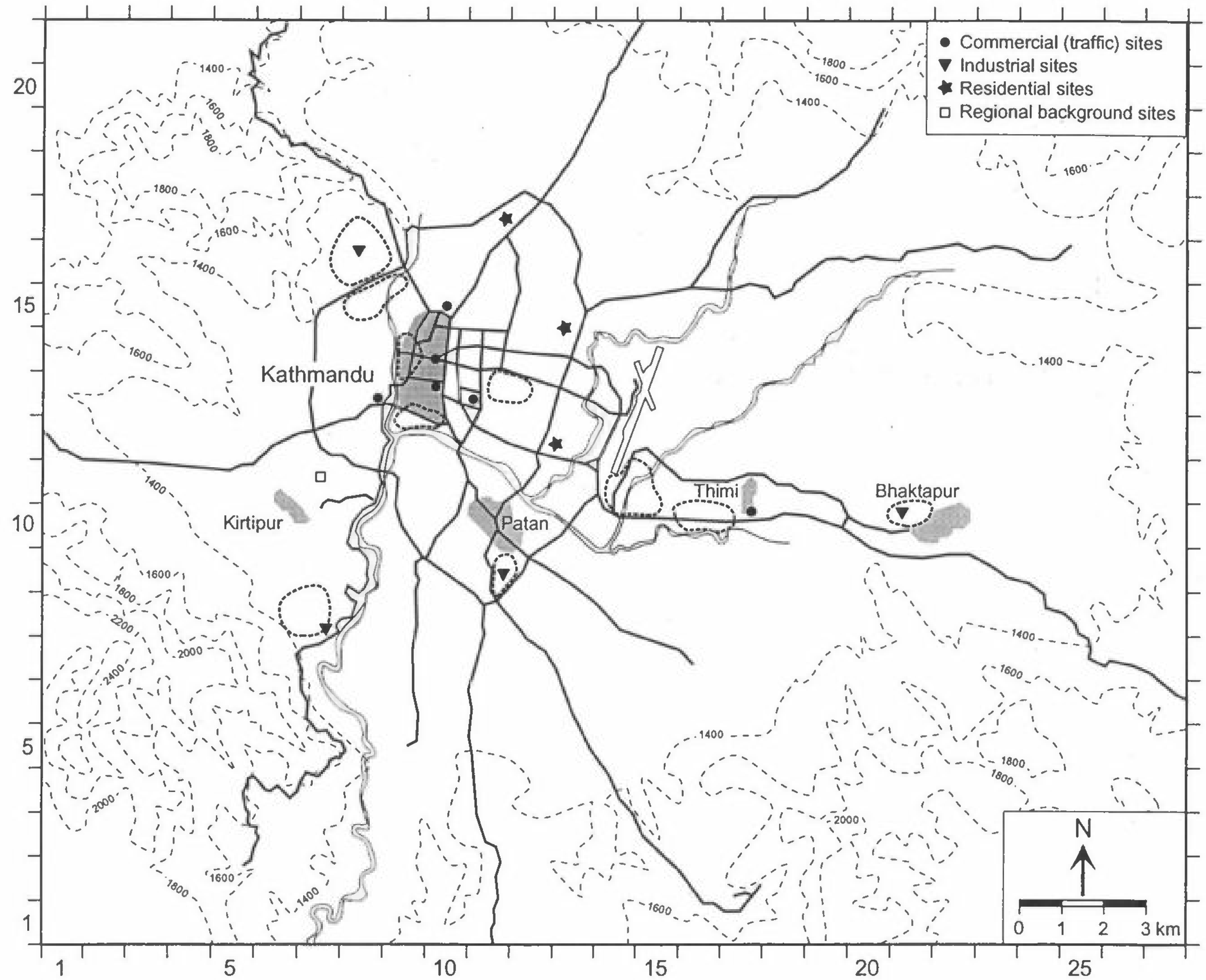

Figure 3: Measurement sites, KVVECP study.

The results of the 24-hour measurements are summarized in Table 7. Figures 4-7 show the average and maximum concentrations at the measurement sites for TSP, PM_{10}, SO_2 and NO_2 respectively.

Table 6: Monitoring methods, ENPHO and KVVECP study.

Sampling:

En Envirotech APM 451 Respirable Dust Sampler (Indian produce) was used as sampler for TSP, PM_{10}, SO_2 and NO_2. The flow rate for TSP/PM_{10} was 0.8-1.2 m^3/min, and for SO_2 and NO_x 1 l/min.

The samples were partly 24 hour samples (midnight-to-midnight), and partly 8 hour samples during peak daytime traffic (9-10 AM to 5-6 PM).

Analysis:

SO_2	:	Pararosaniline method
NO_2	:	Jacobs-Hochheiser Arsenite, Modified method
TSP	:	Gravimetric analysis, Whatman GF/A filter (PM_{10}) and ceramic thimble (non-respirable fractions).
CO	:	Roadside spot measurements with Kitegava Precision Gas Detector, Model APS. Gas Detector tubes, 5-50 ppm.
Heavy metals (Cr, Fe, Pb)	:	AAS analysis (Perkin Elmer - 2380) of the glass fibre filters.

Table 7: Summary of AQ measurements, KVVECP study.

	Average/max 24 h conc. (µg/m^3)				
	TSP	PM_{10}	SO_2	NO_2	No. of days
Commercial (traffic) sites					
Singha Durbar (heavy traffic)	303 / 375	142 / 175	49 / 64	37 / 64	22 (nov./dec.)
GPO (heavy)	380 / 474	137 / 201	37 / 64	11 / 16	16 (nov.)
Ratnapark (medium)	187 / 319	67 / 86	32 / 102	18 / 28	16 (sept.)
Lainchaur (medium)	228 / 386	103 / 146	17 / 26	19 / 40	13 (nov.)
Kalimati (medium)	391 / 441	135 / 154	77 / 202	19 / 31	12 (nov.)
Thimi (low)	337 / 867	115 / 117	49 / 65	19 / 24	20 (dec.)
Residential sites					
Maharajgunj	191 / 350	72 / 126	19 / 34	12 / 14	13 (nov.)
New Baneswor	200 / 270	113 / 161	13 / 13	14 / 25	5 (sept./nov.)
Jaya Bageshwori	228 / 273	112 / 132	110 / 225	49 / 126	10 (dec.)
Industrial areas					
Balaju	108 / 137	40 / 77	15 / 21	31 / 71	9 (sept.)
Patan	87 / 102	47 / 53	13 / 13	40 / 83	5 (sept.)
Bhaktapur	213 / 290	105 / 131	58 / 79	20 / 24	6 (dec.)
Himal Cement surrounding	430 / 560	166 / 194	57 / 65	38 / 58	5 (dec.)
Regional background site					
Tribhuvan Univ.	94 / 155	66 / 81	38 / 77	18 / 35	19 (nov./des.)

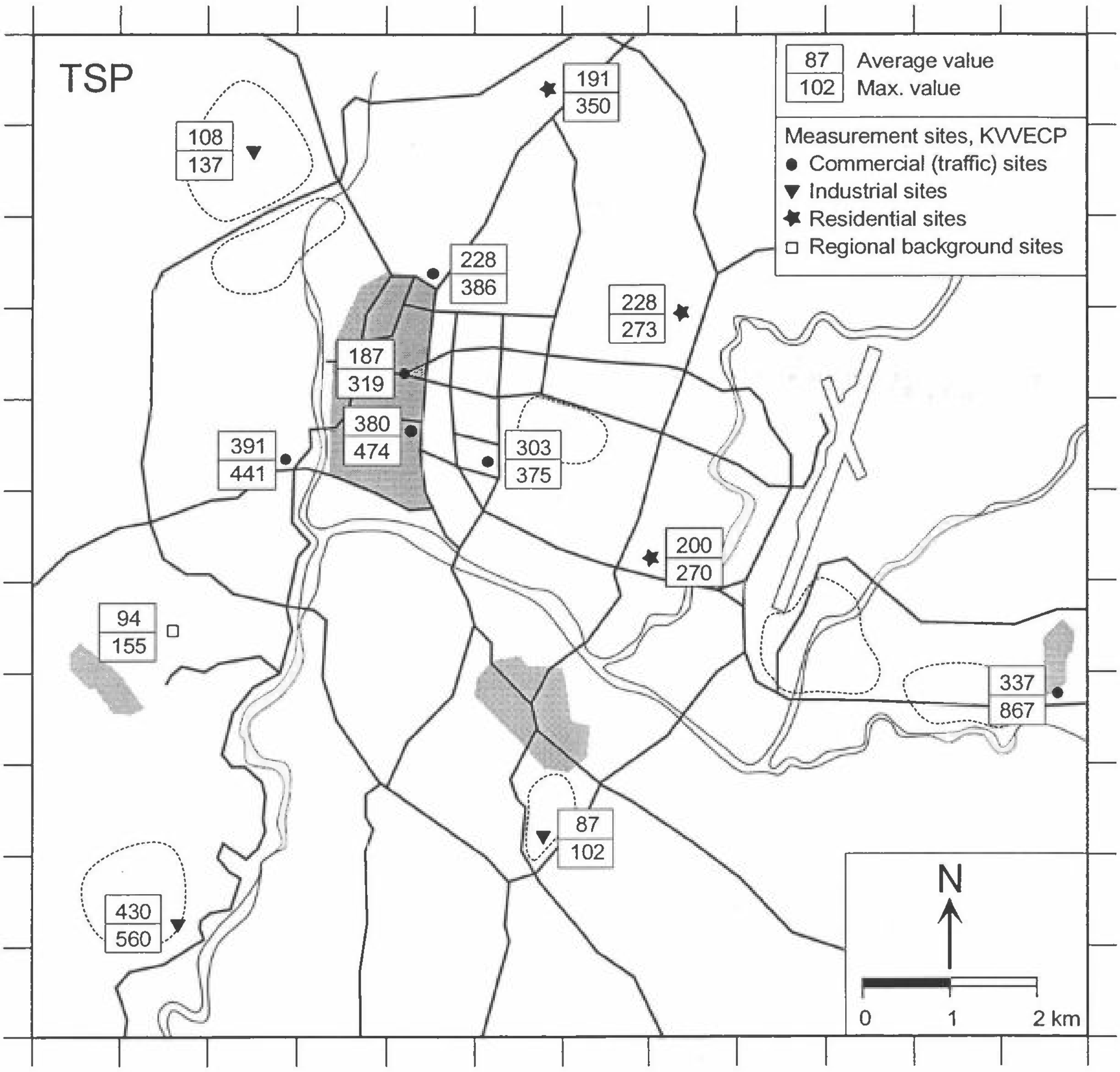

Figure 4: TSP measurements, KVVECP study.

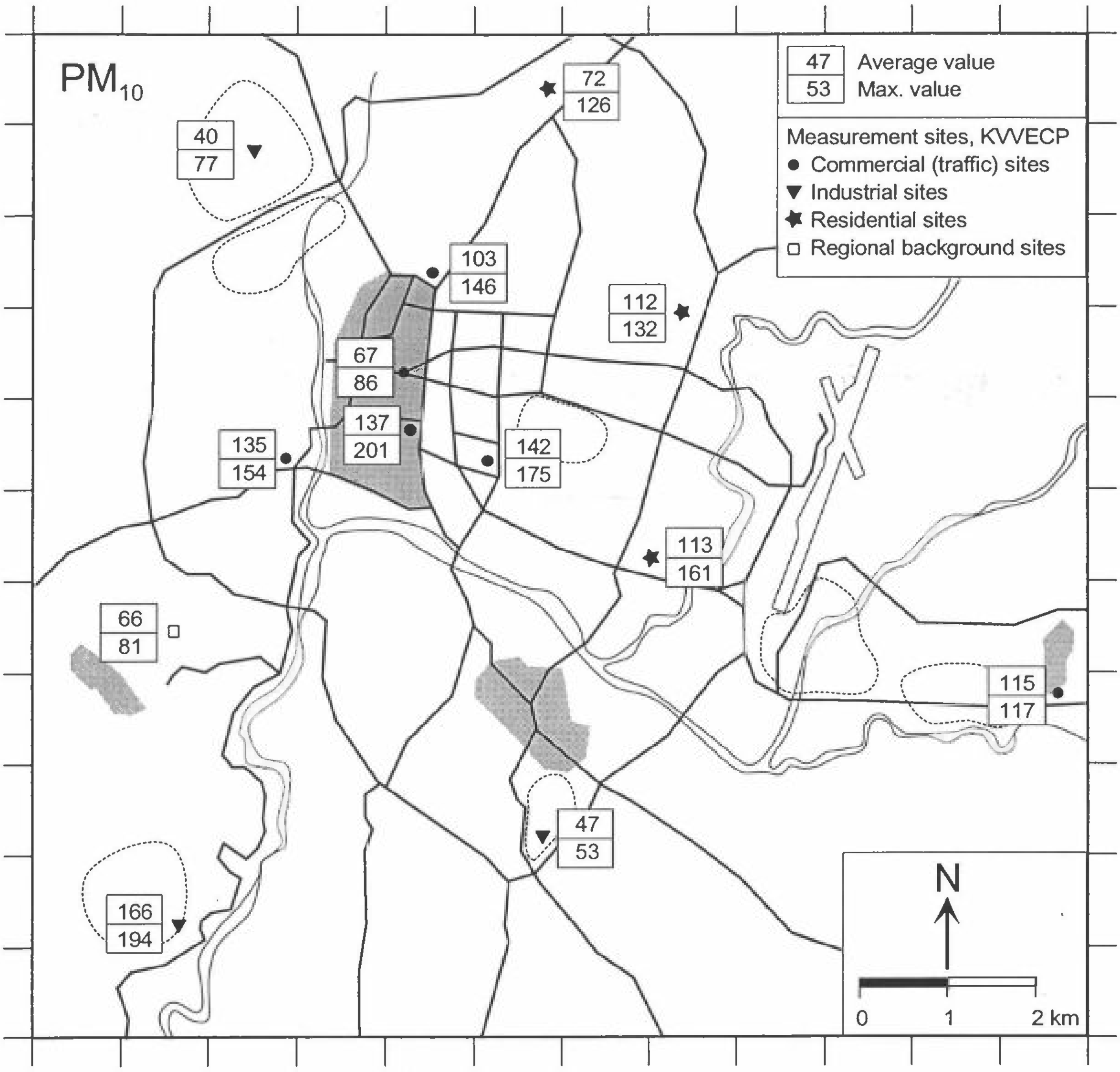

Figure 5: PM_{10} measurements, KVVECP study.

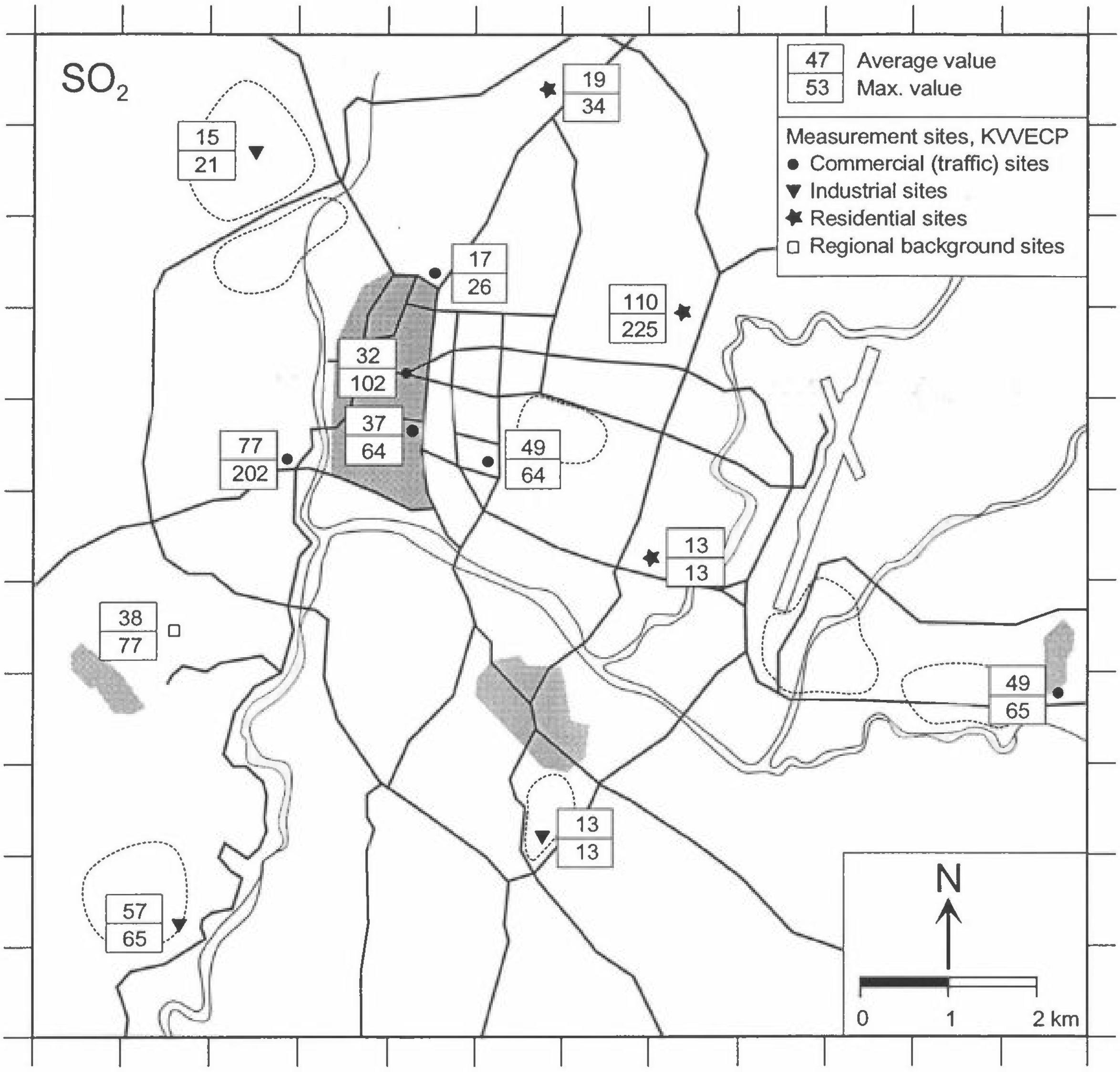

Figure 6: SO_2 measurements, KVVECP study.

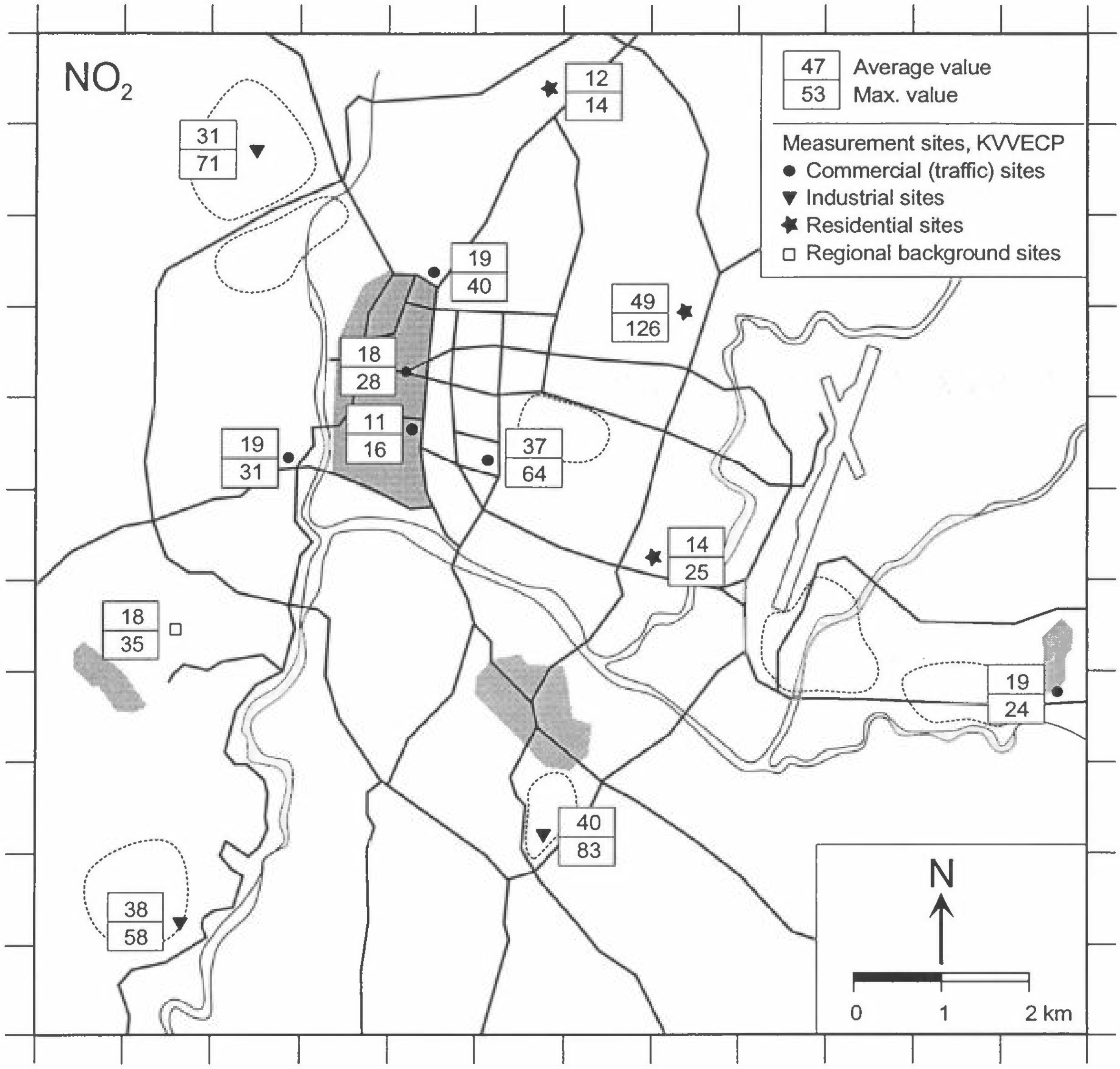

Figure 7: NO_2 measurements, KVVECP study.

For TSP, the concentration ranges for average and maximum values are 94 (background value)-430 μg/m³ and 102-867 μg/m³, respectively.

Granted that the measurement periods differ from site to site, the traffic sites have generally higher TSP concentrations than the other sites (except Himal Cement). However, differences between the traffic sites reflect also other parameters than just the amount of traffic. Thimi, with low traffic, has very high TSP concentrations. Local sources/conditions seem important.

For PM_{10}, the traffic and residential sites seem to have similar levels, higher than the industrial sites (again except Himal Cement). Actually, the Balaju and Patan sites have values similar to the regional background at Tribhuvan Univ., as was also the case for TSP.

SO_2 and NO_2 concentrations were generally low, according to the measurements, except at Kalimati (SO_2) and Jaya Bageshwori (SO_2 and NO_2).

The very short measurement periods at some sites reduce to some extent the general nature of these conclusions.

The measurements at the Tribhuvan Univ. indicate that the general background level of TSP was on the average some 90-100 μg/m³ in the autumn of 1993, with maximum concentrations up towards 150 μg/m³. The similar figure for PM_{10} was some 50 μg/m³ (average) and 80 μg/m³ (maximum).

On top of this, sources nearby the monitoring sites gave higher concentrations. The variation from site-to-site does not seem to be explained simply by amount of traffic, or being in an industrial area.

The Himal Cement site had the highest average concentrations of TSP and PM_{10}, being close to the cement factory.

Relative to WHO guidelines, the TSP and PM_{10} concentrations both rise to twice the guidelines. For TSP, about 70% of all the measurement days were above the lower guideline value (150 μg/m³), and about 50% of the days were above the higher guideline value (230 μg/m³). About 50% of the total days of measurement had PM_{10} above the guideline of 70 μg/m³.

The results of the KVVECP CO measurements gave typical values below 5 ppm, and the highest value measured was 7.5 ppm, using detector tubes with range 0-50 ppm. Morning wind speeds were reported generally below 0.5 m/s. These are very low CO values considering the heavy traffic at some of the roads, and they are considerably lower than the results from the NILU measurements.

Results from TSP measurements on the Hydrology and Meteorology Service Building

TSP measurements were performed on the roof of the building at Babar Mahal, some 15 m above ground, from January to August 1994 (Shrestha, 1994). Results are given in Table 8, and shown in Figure 8.

Table 8: TSP measurements at Babar Mahal, 1994 (Hydr. and Met. Service Building) (Shrestha, 1994).

	Jan.	Feb	Mar	April	May	June	July	Aug	Average Jan-April	Average May-Aug
Average	226	227	312	310	185	137	100	106	269	132
Max.	363	422	384	467	437	302	138	192		
No. of days above AQG:										
-150 µg/m3	21	14	10	18	15	9	0	2	63*	26*
-230 µg/m3	12	4	10	15	6	1	0	0	41*	7*
No. of rainy days	2	2	6	1	10	18	25	22	11*	75*
No. of samples	24	15	10	19	25	25	23	16	68*	89*

* Total no. of days.

The highest TSP concentrations occurred in February-April, the dry season, as expected. The TSP levels are substantially reduced on rainy days.

The results are at the same level as the KVVECP data for New Baneswar residential site from September and November 1993 (aver.: 200 µg/m3; max: 270 µg/m3; 5 sampling days).

The WHO guidelines were exceeded on the majority of the days. The highest concentration, 467 µg/m3, was more than twice the upper level of the 24-hour guideline range, 230 µg/m3.

The 8-month average concentration was 200 µg/m3, compared to the WHO guideline for annual average, 60-90 µg/m3.

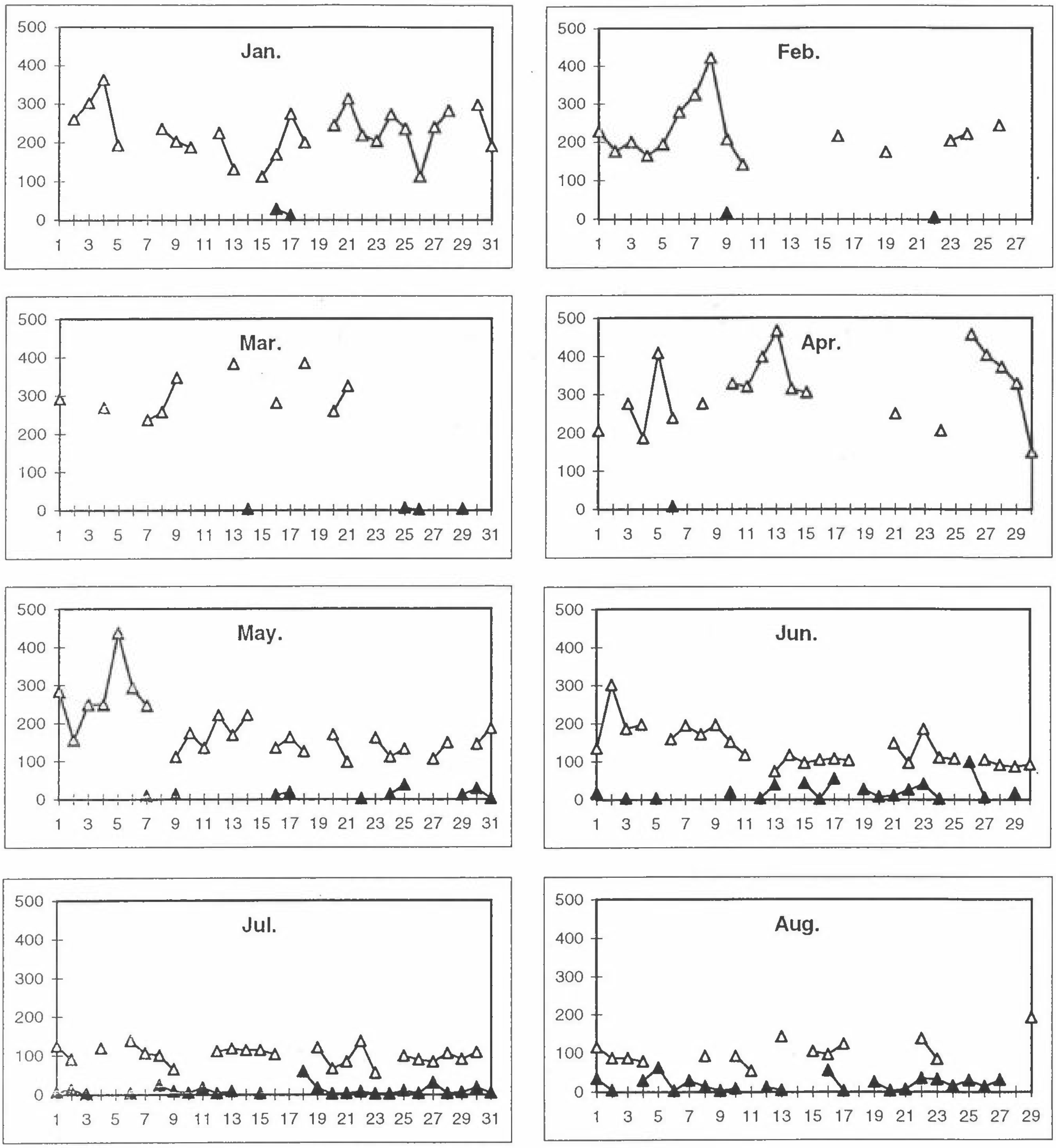

Figure 8: TSP measurements at Babar Mahal, 1994 (HMS building) (Shrestha, 1994).

Results from the NESS (Pvt) Ltd campaign

The following samples were taken in 1993:

- Dust samples from roads, for lead analysis, at 10 road sites on September 10, 22 and 23, and 21 road sites on October 27 and 28.

- PM_{10} samples from air at 4 sites on September 5-6, and at 9 sites on October 27 and November 1-2, using a Sibata high-volume air sampler HVS-500-5, with a 10 µm cut off slotted impactor in front.

- Monitoring of particle concentration by a Laser Dust Monitor (Japanese make) at 59 sites during November 3-19.

The measured road dust lead content is given in Table 9.

Table 9: Lead content in street dust of Kathmandu City, 1993 (NESS study, T. Sharma et al., undated).

Samples	No. of sites	ppm Pb in dust			
		Average	Range	Average	Range
September 10, 22, 23	10	275	50-1,187	140	81-344
October 27-28	21	160	1-965	-	-

Lead, assumingly mainly from lead in gasoline, is clearly present in roadside dust. The concentration of lead is typically 200-300 ppm in the >2 mm fraction, and somewhat less in the <0.2 mm fraction.

The measured PM_{10} and lead concentrations in air are presented in Table 10. The values represent typical one-hour averages during daytime hours.

Table 10: PM_{10} and lead in air analyzed from samples drawn with the Sibata high-volume sampler.

Period	No. of sites	PM_{10} (mg/m^3)		Lead (µg/m^3)	
		Average	Range	Average	Range
September 5-6	3			3.5	0.23-6.08
October 25 and November 1-2	9	0.80	0.23-2.11	1.1	0.65-2.60

The PM_{10} concentrations are very high (up to 2,100 µg/m^3), much higher than those from the ENPHA and KVVECP studies. The Sibata sampler has a slotted 10 µm impactor in front of the filter where particles are collected. The function of the impactor is to hold back particles of diameter above 10 µm from the filter. It is possible, as known from experience with similar impactors, that dry dust particles are not collected with full efficiency. However, it is still difficult to explain the high PM_{10} concentrations measured, when compared to those of the other studies.

The lead concentrations are also substantially higher than those measured in the ENPHA and KVVECP studies.

Based on these results, and the Laser dust monitor samples from 59 roadside sites, Otaki et al. (undated) has plotted PM_{10} and lead pollution indicator values for the road network of Kathmandu City, and also a dust deposit map.

2. Indoor air pollution exposure

High indoor air pollution exposure due to cooking practices is recognized as a potentially significant environmental health impact in Nepal (e.g. Pandey, 1984; Reid et.al., 1986; Pandey et al., 1989). The cooking practices undoubtedly also create localized outdoor air pollution problems in settlements in meteorologically shielded locations.

Extremely high TSP and CO concentrations have been measured in village houses, and a pronounced positive effect of improved cooking practices has been detected. Table 11 shows results obtained by Reid et al. (1986). Pandey et al. (1990) obtained similar results.

Table 11: Mean personal exposures to TSP and CO area concentrations by village and stove type (Reid et.al., 1986).

	Traditional		Improved		P
	n	x	n	x	(%)
TSP (mg/m^3)					
Gorkha	11	3.17 (2.2)	13	0.87 (0.71)	<5
Beni	11	3.11 (2.9)	14	1.37 (1.3)	<2.5
Mustang	2	1.75	2	0.92	>10
CO (ppm)					
Gorkha	13	280 (230)	14	70 (35)	<0.5
Beni	14	310 (220)	12	64 (39)	<0.1
Mustang	2	64	2	41	>20

Note that there is a statistically significant (<5%) difference between the levels for both pollutants, experienced by women cooking with improved stoves compared to traditional ones in both Middle Hill villages. There are too few samples in Mustang.

n= sample size
X= mean (geometric mean)
P= level of significance, i.e. probability that observed difference between the averages of improved and combined traditional stoves has occurred by chance based on a two-tailed t-test. All calculations are based on sample standard deviations (n-l).

This situation in Kathmandu is described by Mathema et.al. (1992) as follows:

> "About 82% of the urban households depend on fuel-wood for cooking purposes. If Kathmandu is a typical example then very few urban families have the provision of a smokeless chulo and chimney. They are increasingly becoming more dependent on kerosene. A recent study found that only 0.6% of families in the Kathmandu city have a smokeless chulo, 47% have no chimney, and 6.97% of those who have a chimney felt that their kitchen is still "full of smoke" (REGMI & JOSHI, 1988/p45-47). Furthermore, about 36.5% use a Kerosene stove for cooking. The smokeless chulo, chimney and use of kerosene when used in absence of good ventilation are potential sources of indoor pollution. The fact that almost one-third of the households have their kitchen on the ground floor, a preference which is becoming very common with the advent of modern one-storey house constructions, suggests that the problem of indoor smoke could spread over the rest of the house.
>
> The composition of major pollutant emissions from different types of traditional fuel sources, based on an Indian study, is shown in Table 48[x] . From the table it is seen that, measured in terms of pollutants emitted from firewood, the most common form of fuel source in urban areas, appears to be the worst among the three sources shown. Assuming a 6 hours cooking period per day, an average urban household is subjected to 16 mg/cu.m. of particulate per day - a figure which is extremely high when seen in terms of its impacts on health. Shrestha states that a traditional Nepali chulo emits a high dose of Carbon Monoxide and "working in such an environment for more than ten minutes is considered poisoning" (SHRESTHA, 1986/p42)."

3. Visibility

The meteorological visibility of the Kathmandu Valley has been recorded at the Kathmandu airport since 1969. Shrestha (1994) has made a thorough and valuable analysis of the visibility data for the period 1969-1993, based on hourly meteorological observations and 3-hourly synoptic reports at the airport. The following text is a brief summary of Dr. Shrestha's findings.

Diurnal and annual variation of visibility

The present visibility situations is such that during the period November-February the visibility is very poor before 9AM, with only 10% of the day with visibility >8000 m (Figure 9). The visibility improves generally during the day, with typically good visibility in the afternoon. During the monsoon season and early fall, the visibility is generally good.

[x] Not shown here.

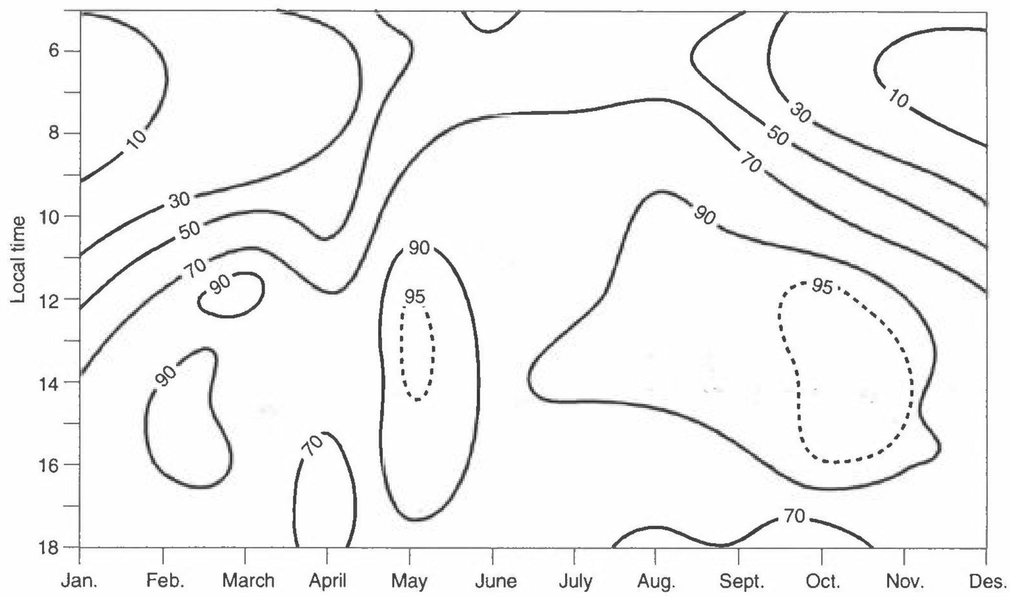

Figure 9: Fraction of days (percent) with fair-to-good visibility (>8000 m), Kathmandu Valley, November-February, 1993. (Ref.: Shrestha, 1994).

This annual variation, with improved visibility during the summer months, reflects several of the following conditions:

- generally better dispersion during summer,
- reduced resuspension during summer (wet surface),
- increased rain-out of particles,
- reduced fine particle emissions in summer (no brick industry).

Trend of reduced visibility

The trend towards reduced visibility in the valley is quite dramatic for the months November-March, and particularly for December-February (Figure 10). While in the early 70's, visibility >8000 m prevailed (at 1145AM) for 25-30 days per month, there has been a steep downwards trend since about 1980. Today, the number of days per month in December-February with good visibility at noon approaches zero!

The nature of the worsened visibility situation in the winter (dry season) is also shown by the example of Figure 11. For the month of January, this figure shows how the natural lifting of the fog and haze during the morning hours, which in the early 70's occurred around 9-10AM, is typically delayed until noon or early afternoon at present.

The relative humidity (RH) is an important parameter for visibility variation. Figure 13 shows the average RH as a function of time at Tribhuwan Airport in 1993.

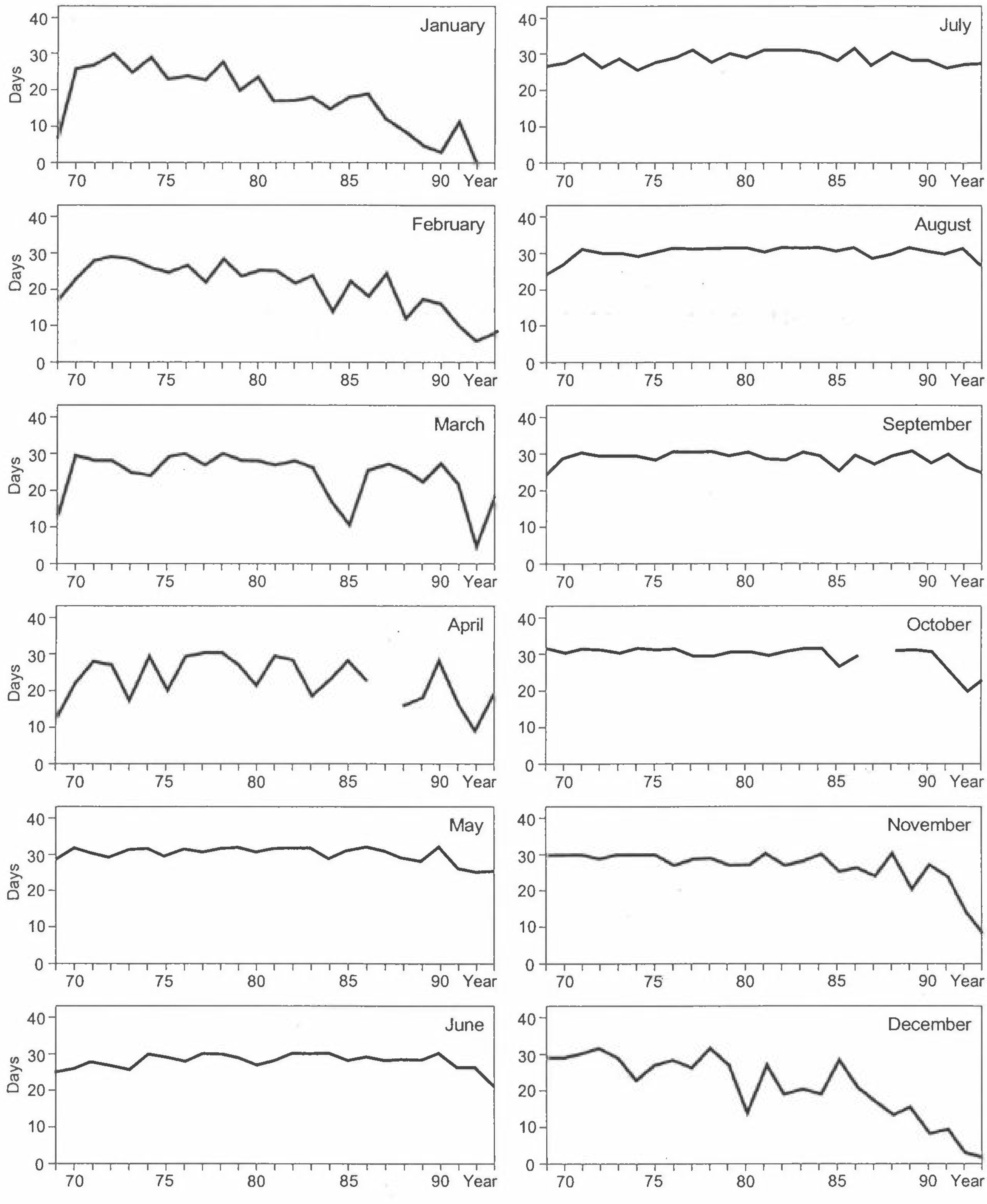

Figure 10: *No. of days per month with fair-to-good visibility (>8000 m), Kathmandu Valley, 1969-93.*
(Ref.: Shrestha, 1994).

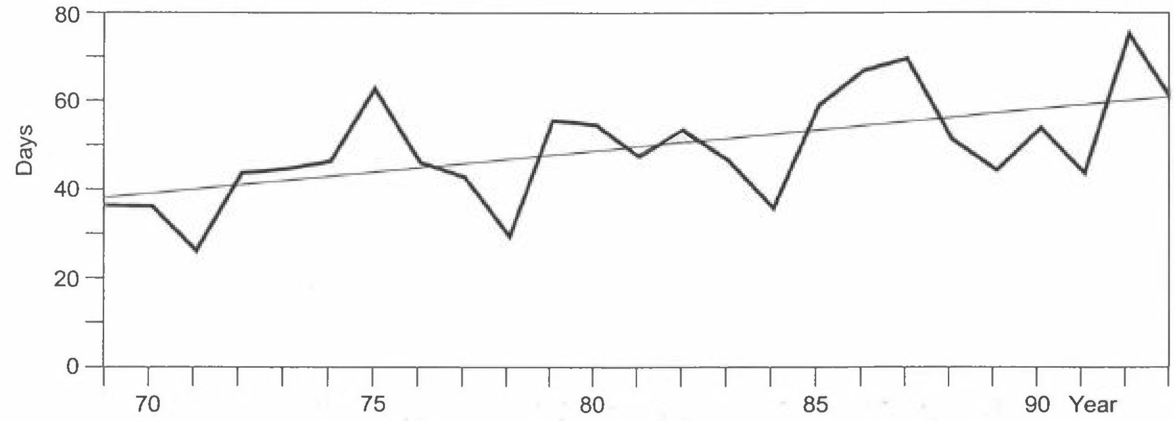

Figure 11: No. of foggy days at 9 a.m. for the period November-February, Kathmandu Valley, 1969-93. (Ref.: Shrestha, 1994).

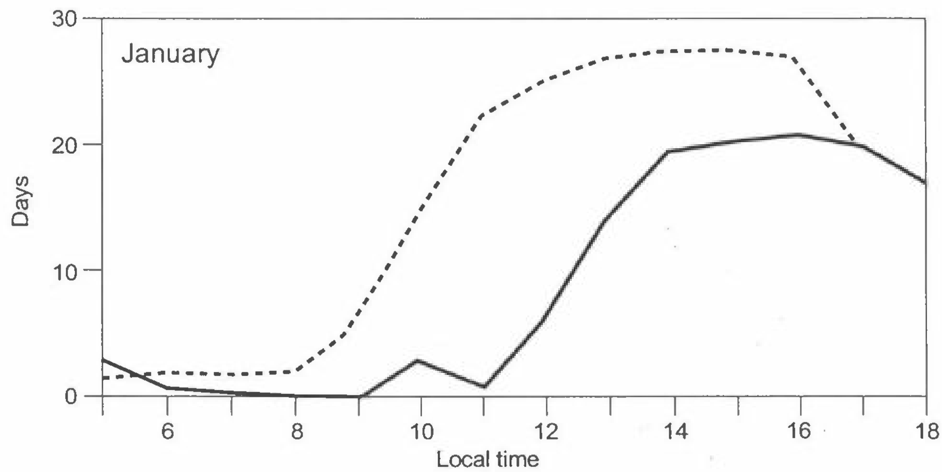

Figure 12: No. of days in January with visibility >8000 m, at given hours, 1970 (full line) and 1993 (dotted line) (Shrestha, 1994).

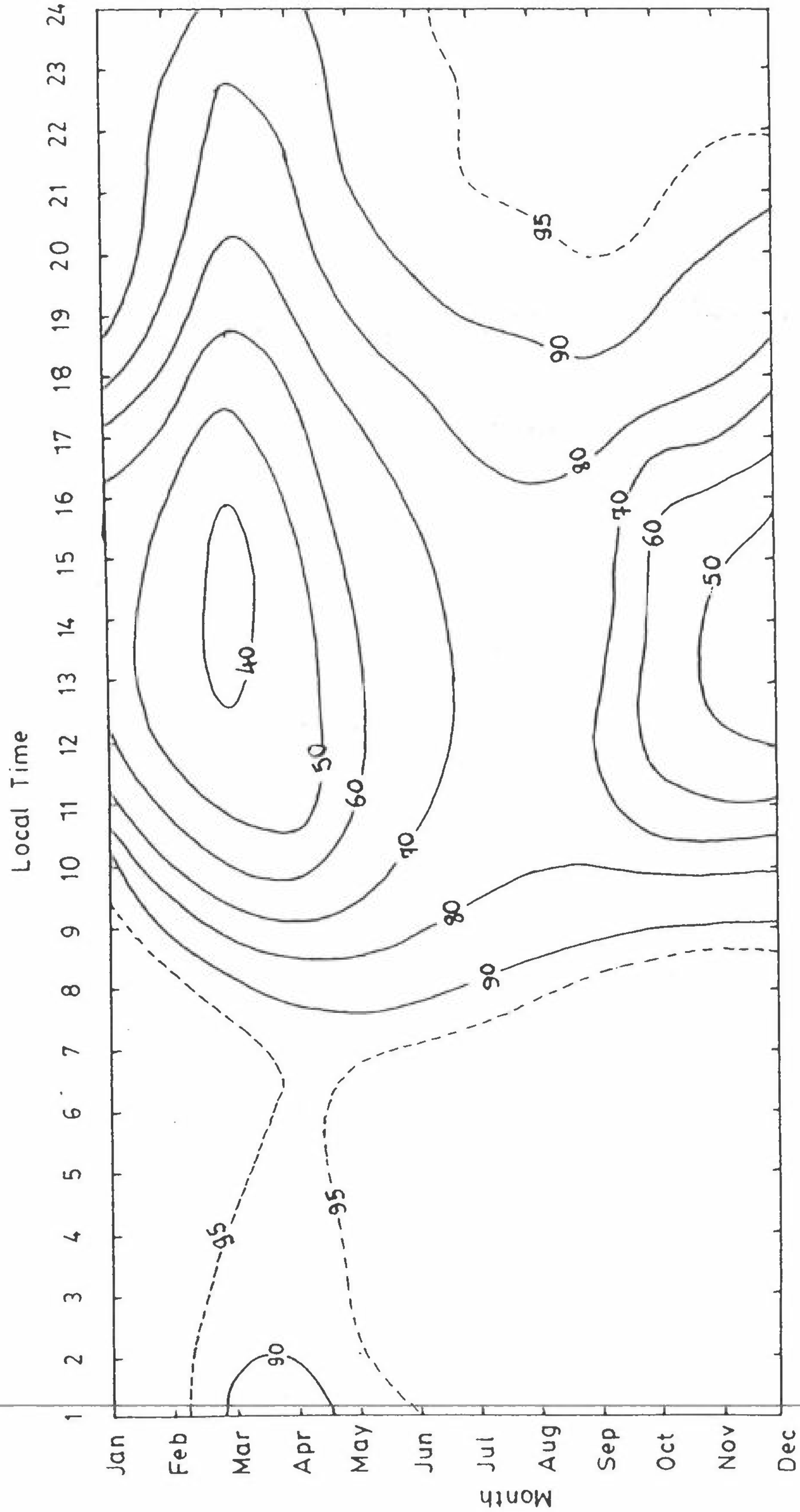

Figure 13: Temporal variation of Relative Humidity at Tribhuwan Airport, 1993 (per cent).

Trend of foggy days

Further description of the visibility situation is given in Figure 12 which shows that the number of foggy days, at 0845AM, during the four winter months November-February has increased from 35-40 around 1970 to more than 60 in 1992-93.

Dr. Shrestha's analysis clearly shows the dramatically worsened visibility situation in the Kathmandu Valley. It seems clear that the reason is the increased particle concentration in the atmosphere, particularly in the fine particle fraction (diameter <1 μm). It is probable that this increase has taken place in the regional atmosphere in general, as well as for sure in the local valley atmosphere, due to the increased industrial and commercial activities in the valley as well as increased population, resulting in increased fine particle emissions and concentrations.

4. References

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ANNEX

Copy of the KVVECP air quality measurements (Ref.: Devkota, 1993).

Table 2 : Ambient Air Quality Monitoring in Commercial Area - Heavy Traffic (GPO Complex)

Date	Pollutants ug/m³					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
3/11/93	201	273	474	16	29	24	
5/11/93	157	213	370	15	18	8	
6/11/93	152	590	742	29	13	8	Holiday
7/11/93	172	414	586	30	13	8	
8/11/93	200	527	727	22	46	8	Holiday
9/11/93	168	632	800	25	14	7	
10/11/93	99	267	366	10	46	22	
11/11/93	172	665	837	19	35	8	12- 8.30
12/11/93	121	79	200	17	13	8	8.30-4.30
12/11/93	173	1399	1572	17	13	8	5-12 pm
12/11/93	138	257	395	23	13	7	
13/11/93	106	527	633	12	13	8	Holiday
14/11/93	129	367	496	25	13	8	Hoilday
16/11/93	108	229	337	9	13	24	
17/11/93	152	431	583	41	13	7	
18/11/93	142	179	321	11	35	24	
19/11/93	179	409	588	22	81	8	
20/11/93	135	265	403	11	64	24	Holiday
21/11/93	179	697	876	35	162	8	

(I) Range :

SPM : 321 - 474 (24 h)
: 200 - 1572 (8 h)
PM_{10} : 99 - 201 (24 h)
: 106 - 200 (8 h)
NO_2 : 9 - 16 (24 h)
: 12 - 41 (8 h)
SO_2 : 13 - 64 (24 h)
: 13 - 162 (8 h)

(II) Average :

SPM : 380 (24 h), 682 (8 h)
PM_{10} : 137 (24 h), 157 (8 h)
NO_2 : 11 (24 h), 24 (8 h)
SO_2 : 37 (24 h), 33 (8 h)

Table 3 Ambient Air Quality Monitoring in Commcercial Area - Heavy Traffic, Singha Durbar

Date	Pollutants ug/m³					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
23/11/93	146	236	382	31	93	19	
24/11/93	180	419	599	52	99	8	
25/11/93	123	252	375	27	46	24	
26/11/93	152	713	865	45	51	8	
27/11/93	112	105	217	29	31	19	Holiday
28/11/93	113	161	274	49	13	8	5-12 pm
29/11/93	132	957	1089	39	67	8	
30/11/93	127	107	234	26	64	24	
01/12/93	102	201	303	75	188	20	
02/12/93	167	208	375	88	61	24	
03/12/93	112	219	331	52	69	10	
04/12/93	120	292	412	34	80	8	Holiday
05/12/93	134	216	350	41	95	8	
06/12/93	165	97	262	24	35	24	
07/12/93	170	341	511	45	93	8	
08/12/93	119	120	239	20	51	24	
09/12/93	143	332	475	40	85	8	
10/12/93	121	137	308	22	45	24	
11/12/93	128	241	369	33	74	8	Holiday
12/12/93	164	213	377	68	59	8	
13/12/93	175	256	331	55	41	24	
14/12/93	214	169	383	101	37	20	

I. Range:

TSP	:	234 - 375	(24 h)
	:	274 - 1089	(8 h)
PM_{10}	:	119 - 175	(24 h)
	:	113 - 180	(8 h)
NO_2	:	20 - 88	(24 h)
	:	33 - 686	(8 h)
SO_2	:	35 - 64	(24 h)
	:	13 - 99	(8 h)

II. Average:

TSP	:	303 (24 h), 532 (8 h)
PM_{10}	:	142 (24 h), 144 (8 h)
NO_2	:	37 (24 h), 45 (8 h)
SO_2	:	49 (24 h), 72 (8 h)

Table 4 Ambient Air Quality Monitoring in Commercial Area - Medium Traffic Kalimati

Date	Pollutants ug/m³					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
20/11/93	114	241	355	22	64	24	
21/11/93	110	492	602	40	57	8	Holiday
22/11/93	134	243	377	27	45	14	
23/11/93	164	533	697	48	103	8	
24/11/93	154	282	436	31	24	24	
25/11/93	179	861	1040	51	35	8	
26/11/93	137	194	331	12	202	24	
27/11/93	170	469	639	45	23	8	Holiday
28/11/93	122	450	572	28	131	8	
29/11/93	133	308	441	12	16	24	
30/11/93	168	534	702	26	100	8	
01/12/93	165	721	886	9	163	8	

I. Range:

TSP	:	331 - 441	(24 h)
	:	377 - 1040	(8 h)
PM_{10}	:	114 - 154	(24 h)
	:	110 - 179	(8 h)
NO_2	:	12 - 31	(24 h)
	:	10 - 51	(8 h)
SO_2	:	16 - 202	(24 h)
	:	13 - 163	(8 h)

II. Average:

TSP	:	391 (24 h),	734 (8 h)
PM_{10}	:	135 (24 h),	154 (8 h)
NO_2	:	19 (24 h),	35 (8 h)
SO_2	:	77 (24 h),	71 (8 h)

Table 5 Ambient Air Quality Monitored in Commercial Area- Medium Traffic (Ranipokhari Traffic Complex).

Date	Pollutants ug/m^3					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
10/9/93	67	252	319	17	13	24	
15/9/93	59	87	146	6	16	24	Rainfall
13/9/93	57	91	148	28	102	19	Rainfall
05/9/93	46	10	56	24	13	16	Rainfall
17/9/93	86	181	267	15	16	24	
18/9/93	76	307	383	30	20	10	Holiday
08/9/93	100	139	239	29	13	8	Rainfall
09/9/93	114	386	500	32	13	8	
11/9/93	56	156	212	35	13	8	Holiday
12/9/93	78	212	290	28	14	8	
06/9/93	n.a	n.a.	n.a.	29	13	7	Rainfall
14/9/93	67	115	182	33	21	7	
16/9/93	75	309	384	25	13	8	
19/9/93	78	242	320	21	13	8	Rainfall
20/9/93	100	211	321	20	17	8	Rainfall
21/9/93	109	59	168	11	22	10	NepalBanda

I. Range:

TSP	:	56 - 319	(24 h)
	:	182 - 500	(8 h)
PM_{10}	:	57 - 86	(24 h)
	:	67 - 114	(8 h)
SO_2	:	13 - 102	(24 h)
	:	13 - 22	(8 h)
NO_2	:	6 - 28	(24 h)
	:	11 - 35	(8 h)

II. Average :

SPM	:	187 (24 h),	300 (8 h)
PM_{10}	:	67 (24 h),	74 (8 h)
SO_2	:	32 (24 h),	27 (8 h)
NO_2	:	18 (24 h),	19 (8 h)

Table 6 Ambient Air Quality Monitoring in Commercial Area - Medium Traffic (Lainchaur DOMG)

Date	Pollutants (ug/m^3)					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
6/11/93	78	129	207	19	13	24	Holiday
7/11/93	82	201	283	18	13	8	
8/11/93	100	74	174	14	26	24	Holiday
9/11/93	82	261	343	18	13	7	
10/11/93	146	240	386	12	23	24	
11/11/93	115	242	357	36	13	8	
12/11/93	103	91	194	40	13	24	
13/11/93	116	221	337	12	13	8	Holiday
14/11/93	64	157	221	14	13	8	Holiday
16/11/93	67	96	163	10	13	24	
17/11/93	87	158	245	23	13	8	
18/11/93	121	125	246	19	13	24	
19/11/93	151	630	781	27	178	6	

(I) Range :

TSP	:	163 - 386 (24 h)
	:	221 - 781 (8 h)
PM_{10}	:	67 - 146 (24 h)
	:	64 - 151 (8 h)
NO_2	:	10 - 40 (24 h)
	:	12 - 36 (8 h)
SO_2	:	13 - 26 (24 h)
	:	13 - 178 (8 h)

(II) Average :

TSP	:	228 (24 h),	367 (8 h)
PM_{10}	:	103 (24 h),	100 (8 h)
NO_2	:	19 (24 h),	25 (8 h)
SO_2	:	17 (24 h),	38 (8 h)

Table 7 Ambient Air Quality Monitoring in Low Traffic - Thimi

Date	Pollutants ug/m³					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
20/11/93	114	241	355	n.a	n.a	24	Holiday
21/11/93	115	70	185	24	35	22	
22/11/93	138	273	411	32	87	8	
23/11/93	117	102	219	19	49	24	
24/11/93	136	233	369	43	23	8	
25/11/93	111	66	177	24	45	24	
26/11/93	141	192	333	48	15	8	
28/11/93	158	203	361	32	70	8	5-12 pm
29/11/93	104	381	485	13	118	8	
30/11/93	115	104	219	10	65	24	
01/12/93	124	327	451	36	132	8	
02/12/93	115	752	867	20	45	24	
04/12/93	81	94	175	30	57	18	
05/12/93	263	288	551	116	69	8	Holiday
06/12/93	243	274	517	77	184	8	
07/12/93	208	165	373	18	79	16	
08/12/93	214	669	883	58	73	8	
09/12/93	118	561	679	31	59	8	
10/12/93	132	351	483	32	72	8	
11/12/93	132	594	726	22	70	8	Holiday

I. Range:

TSP	:	185 - 867	(24 h)
	:	333 - 883	(8 h)
PM_{10}	:	111 - 117	(24 h)
	:	104 - 263	(8 h)
NO_2	:	10 - 24	(24 h)
	:	13 - 116	(8 h)
SO_2	:	35 - 65	(24 h)
	:	15 - 184	(8 h)

II. Average:

TSP	:	337 (24 h), 521 (8 h)
PM_{10}	:	115 (24 h), 159 (8 h)
NO_2	:	19 (24 h), 45 (8 h)
SO_2	:	49 (24 h), 81 (8 h)

Table 8 Ambient Air Quality Monitoring in Residential Area (TUTH, Maharajgunj)

Date	Pollutants					Sampling hour	Remark
	ug/m^3						
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
3/11/93	126	224	350	16	13	24	
4/11/93	36	50	86	n.a	n.a	8	
5/11/93	32	54	86	14	.	8	Saturday
6/11/93	51	84	135	14	13	24	
7/11/93	55	49	104	19	34	8	Holiday
8/11/93	68	52	120	20	13	16	
9/11/93	60	98	158	55	13	5	
10/11/93	56	106	162	9	13	24	
11/11/93	76	42	118	16	16	8	
12/11/93	56	59	115	10	13	24	Hoilday
13/11/93	67	35	102	16	13	6	Holiday
14/11/93	44	19	63	12	13	8	
16/11/93	39	19	58	11	13	16	

(I) Range :

TSP	:	115 - 350 (24 h)
	:	63 - 118 (8 h)
PM_{10}	:	51 - 126 (24 h)
	:	32 - 76 (8 h)
NO_2	:	9 - 14 (24 h)
	:	12 - 19 (8 h)
SO_2	:	13 - 34 (24 h)
	:	13 - 13 (8 h)

(II) Average :

SPM	:	191 (24 h), 93 (8 h)
PM_{10}	:	72 (24 h), 49 (8 h)
NO_2	:	12 (24 h), 15 (8 h)
SO_2	:	19 (24 h), 13 (8 h)

Table 9 Ambient air Quality Monitoring in Residential Area - Naya Baneshwor.

Date	Pollutants ug/m^3					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
01/9/93	27	48	75	25	13	24	Rainfall
02/9/93	19	16	35	57	14	8	Rainfall
03/9/93	43	21	64	66	13	8	Rainfall
11/11/93	150	120	270	9	13	24	
13/11/93	161	161	254	9	13	24	

I. Range:

TSP	:	75 - 270 (24 h)
	:	35 - 64 (8 h)
PM_{10}	:	27 - 161 (24 h)
	:	19 - 43 (8 h)
SO_2	:	0 - 13 (24 h)
	:	13 - 14 (8 h)
NO_2	:	0 - 25 (24 h)
	:	57 - 66 (8 h)

II. Average :

SPM	:	200 (24 h), 50 (8 h)
PM_{10}	:	113 (24 h), 31 (8 h)
SO_2	:	13 (24 h), 14 (8 h)
NO_2	:	25 (24 h), 62 (8 h)

Table 10 Ambient Air Quality Monitoring in Residential Area - Jaya Bageshwori (Chabahill)

Date	Pollutants ug/m^3					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
07/12/93	131	230	361	28	71	8	
08/12/93	108	125	233	20	23	24	
09/12/93	123	231	354	34	164	8	
10/12/93	95	76	171	17	23	8	
12/12/93	132	468	600	126	225	24	
13/12/93	132	141	273	11	41	5	
15/12/93	109	193	302	30	65	24	
17/12/93	93	142	235	23	49	20	
18/12/93	145	118	265	27	55	20	
19/12/93	115	292	307	53	121	20	
						8	

I. Range:

TSP	:	171 - 273	(24 h)
	:	307 - 361	(8 h)
PM_{10}	:	95 - 132	(24 h)
	:	123 - 131	(8 h)
NO_2	:	17 - 341	(24 h)
	:	28 - 53	(8 h)
SO_2	:	23 - 41	(24 h)
	:	71 - 164	(8 h)

II. Average:

TSP	:	228 (24 h), 341 (8 h), 267 (20 h)
PM_{10}	:	112 (24 h), 116 (8 h), 123 (20 h)
NO_2	:	49 (24 h), 38 (8 h), 37 (20 h)
SO_2	:	29 (24 h), 119 (8 h), 56 (20 h)

Table 11 Ambient Air Quality Monitoring in Industrial Area - Balaju (BID).

Date	Pollutants ug/m^3					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
01/9/93	21	50	71	71	13	24	Rainfall
10/9/93	77	60	137	11	13.4	24	
13/9/93	32	81	113	14	21	24	
16/9/93	30	79	109	28	13	22	
17/9/93	46	116	162	34	26	8	
18/9/93	35	75	110	21	21	8	
02/9/93	42	14	56	63	13	8	Rainfall
09/9/93	35	72	107	8	13	8	
05/9/93	n.a.	n.a.	n.a.	42	13	6	Rainfall

I. Range:

TSP	:	71 - 137 (24 h)
	:	56 - 162 (8 h)
PM_{10}	:	21 - 77 (24 h)
	:	35 - 46 (8 h)
SO_2	:	13 - 21 (24 h)
	:	13 - 26 (8 h)
NO_2	:	11 - 71 (24 h)
	:	8 - 63 (8 h)

II. Average :

TSP	:	108 (24 h),	109 (8 h)
PM_{10}	:	40 (24 h),	40 (8 h)
SO_2	:	15 (24 h),	17 (8 h)
NO_2	:	31 (24 h),	34 (8 h)

Table 12 Ambient Air Quality Monitoring in Industrial Area - Patan (PID)

Date	Pollutants ug/m^3					Sampling hour	Remark
	TSP			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
01/9/93	53	37	90	83	13	24	Rainfall
10/9/93	36	33	69	26	13	24	
13/9/93	53	49	102	12	13	21	Rainfall
02/9/93	64	61	125	69	13	8	Rainfall
05/9/93	n.a	n.a.	n.a.	80	13	8	Rainfall

I. Range:

TSP	:	69 - 102 (24 h)
	:	0 - 125 (8 h)
PM_{10}	:	36 - 53 (24 h)
	:	0 - 64 (8 h)
SO_2	:	13 - 13 (24 h)
	:	13 - 13 (8 h)
NO_2	:	12 - 83 (24 h)
	:	69 - 80 (8 h)

II. Average :

TSP	:	87 (24 h),	125 (8 h)
PM_{10}	:	47 (24 h),	64 (8 h)
SO_2	:	13 (24 h),	13 (8 h)
NO_2	:	40 (24 h),	75 (8 h)

Table 13 Ambient Air Quality Monitoring in Bhaktapur Industrial Areas

Date	Pollutants ug/m^3					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
12/12/93	104	186	290	19	79	20	
13/12/93	122	107	229	21	59	8	
14/12/93	95	64	159	19	38	20	
15/12/93	94	74	168	18	48	20	
18/12/93	131	104	235	24	67	20	
19/12/93	169	625	794	78	101	8	

I. Range:

TSP	:	159 - 290	(20 h)
	:	229 - 794	(8 h)
PM_{10}	:	94 - 131	(20 h)
	:	122 - 169	(8 h)
NO_2	:	18 - 24	(20 h)
	:	21 - 78	(8 h)
SO_2	:	38 - 79	(20 h)
	:	59 - 101	(8 h)

II. Average:

TSP	:	213 (20 h), 512 (8 h)
PM_{10}	:	137 (20 h), 146 (8 h)
NO_2	:	20 (20 h), 50 (8 h)
SO_2	:	58 (20 h), 80 (8 h)

Table 14 Ambient Air Quality Monitoring in Around Himal Cement Factory

Date	Pollutants ug/m^3					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
15/12/93	157	373	560	38	45	24	
16/12/93	147	158	305	17	61	24	
17/12/93	127	1093	1220	131	238	3	
18/12/93	215	329	544	54	120	8	
19/12/93	194	230	424	58	65	24	

I. Range:

TSP : 305 - 560 (24 h)

PM_{10} : 147 - 194 (24 h)

NO_2 : 17 - 58 (24 h)

SO_2 : 45 - 65 (24 h)

II. Average:

TSP : 430 (24 h)
PM_{10} : 166 (24 h)
NO_2 : 38 (24 h)
SO_2 : 57 (24 h)

Table 15 Ambient Air Quality Monitoring in Regional Background control site - Tribhuvan University, Kirtipur.

Date	Pollutants ug/m³					Sampling hour	Remark
	SPM			NO_2	SO_2		
	PM_{10}	Particle	TOTAL				
18/11/93	75	17	92	14	13	24	
21/11/93	39	38	77	23	21	8	
22/11/93	35	23	68	50	35	8	
23/11/93	41	39	80	26	35	8	
24/11/93	64	53	117	16	20	8	
25/11/93	19	55	74	17	26	8	
26/11/93	59	19	78	19	63	5	
27/11/93	83	18	103	9	13	8	Holiday
29/11/93	64	13	77	11	35	24	
01/12/93	29	16	45	10	77	24	
02/12/93	57	03	60	20	40	8	
06/12/93	75	22	97	20	32	24	
07/12/93	58	46	104	38	76	8	
08/12/93	69	12	81	82	70	8	
09/12/93	52	31	83	45	80	8	
12/12/93	73	24	97	35	39	24	
14/12/93	81	74	155	20	33	24	
16/12/93	113	169	282	90	260	3	
19/12/93	136	96	232	83	285	3	

I. Range:

TSP	:	45 - 155	(24 h)
	:	68 - 117	(8 h)
PM_{10}	:	64 - 81	(24 h)
	:	19 - 83	(8 h)
NO_2	:	10 - 35	(24 h)
	:	9 - 82	(8 h)
SO_2	:	13 - 77	(24 h)
	:	13 - 80	(8 h)

II. Average:

TSP	:	94 (24 h), 84 (8 h)
PM_{10}	:	66 (24 h), 52 (8 h)
NO_2	:	18 (24 h), 33 (8 h)
SO_2	:	38 (24 h), 42 (8 h)

Appendix 2

Air Quality Guidelines

Nepalese air quality guidelines/standards have not yet been established.

WHO Air Quality Guidelines and Standards

WHO air quality guidelines and standards are listed in Table 1.

Table 1: WHO Air Quality Guidelines/Standards (WHO, 1977a, 1977b, 1978, 1979, 1987)

Parameter		10 minutes	15 minutes	30 minutes	1 hour	8 hours	24 hours	1 year	Year of standard
SO_2	µg/m³	500			350		125[a]	50[a]	1987
SO_2	µg/m³						100-150	40-60	1979
BS[b]	µg/m³						125[a]	50[a]	1987
BS[b]	µg/m³						100-150	40-60	1979
TSP	µg/m³						120[a]		1987
TSP	µg/m³						150-230	60-90	1979
PM_{10}	µg/m³						70[a]		1987
Lead	µg/m³							0.5-1	1987, 1977b
CO	mg/m³		100	60	30	10			1987
NO_2	µg/m³				400		150		1987
NO_2	µg/m³				190-320[c]				1977[b]
O_3	µg/m³				150-200	100-120			1987
O_3	µg/m³				100-200				1978

Notes (WHO/UNEP 1992)

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

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

c Not to be exceeded more than once per month.

Suspended particulate matter measurement methods (WHO/UNEP 1992)

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

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

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

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

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

Appendix 3

Emission Inventory

Contents

1. Introduction

Two fairly comprehensive emission inventories have been previously worked out for Kathmandu Valley, namely by Devkota (1992) and by Shrestha and Malla (1993).

Both investigations covered emissions from most of the main air pollution sources in the valley: road vehicles, brick and cement industry, households, other industries (e.g. potters), aircraft. Shrestha only considered the emissions from "energy use", and not industrial process emissions. None of them considered resuspension from roads and other open surface construction, or refuse burning. Both treated the compounds TSP, CO, SO_2, NO_x, VOC and CO_2. Devkota attempted also to estimate emissions of benzene specifically, and of PAH from road traffic.

The following comprehensive emission survey is based on the works of Devkota (1992) and Shrestha and Malla (1993). The JICA Study on Kathmandu Valley Urban Road Development (JICA, 1992) gave valuable data on the distribution of traffic on the road network of the valley. RONAST, through the URBAIR contract on data collection, also provided data on traffic, fuels, production etc. used in the following.

In addition, the following investigations of the industry and its emissions have been used:

- Bhattarai (1993): Paper on Industrial Contribution to Air Quality, presented at the URBAIR Workshop in December, 1993.
- Thapa, Shrestha and Karki (1993): A Survey of Brick Industries in the Kathmandu Valley.
- NESS Ltd. (1995): Assessment of the Applicability of Indian Cleaner Process Technology for Small Scale Brick Kiln Industries of Kathmandu Valley.

Gridded emission fields (emissions distributed in a km^2 grid net) were produced using the supporting software programs for the KILDER dispersion modelling program system, developed by NILU (Gram and Bøhler, 1992).

The km^2 distribution of area source emissions was based on traffic distribution and population distribution data.

The area selected for air pollution modelling, and thus for emission inventorying, is shown in Figure 1. It consists of 27x21 km^2 grid squares, covering the full area of the valley.

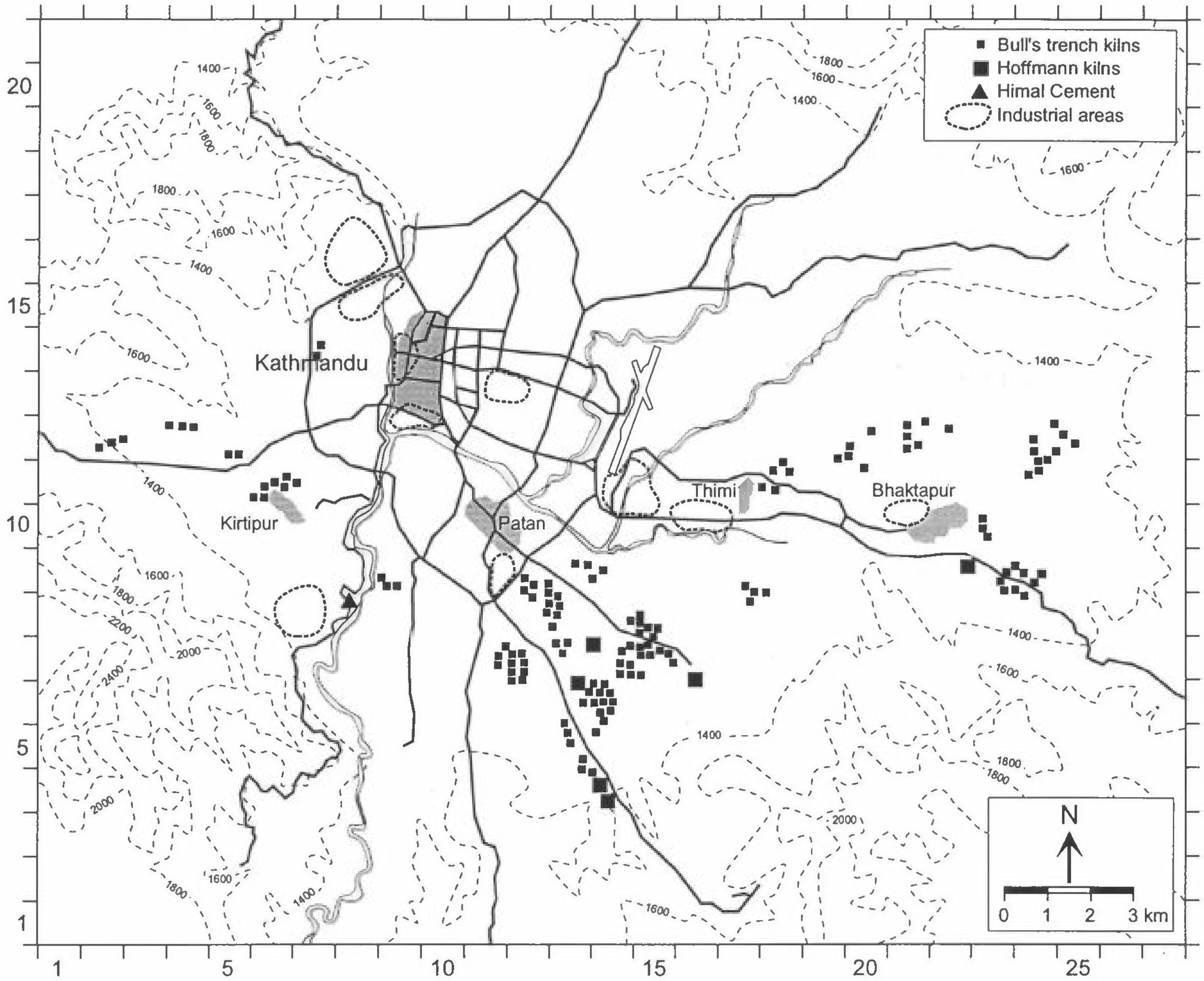

Figure 1: Kathmandu Valley air quality modelling area.

2. Population distribution

The spatial distribution of the population within the grid system is important information when the fuel consumption, especially domestic fuel consumption, is to be distributed within the grid system.

The total population of the URBAIR modelling area for Kathmandu Valley is 1.063.000 inhabitants for the year 1991.

This is the number used by JICA in the transportation study. The basis for distributing the population into km^2 grids is given by Table 1 and Figure 2, with reference to the JICA transportation study. The further distribution into km^2 grids was done subjectively, based on the distribution of villages within each km^2.

The resulting distribution of the total population is given in Figure 3.

The distribution between urban/rural populations is 62/38% for Kathmandu district, 53/47% for Lalitpur district, and 35/65% for Bakthapur.

Table 1: Population of "traffic zones", as given in Figure 2. (Ref.: JICA 1992).

Zone No.	1991	Zone No.	1991
101	6.691	301	16.099
102	8.288	302	9.794
103	29.749	303	18.752
104	8.592	304	16.477
105	37.380		
106	24.831	401	10.985
107	41.213	402	15.015
108	9.983	403	26.878
109	20.329	404	29.291
110	30.074	405	36.807
111	19.491	406	25.886
112	20.281	407	24.868
113	28.813	408	31.633
114	45.330	409	33.674
115	19.190	410	19.304
116	19.208		
117	12.753	501	21.273
118	32.068	502	32.270
		503	21.148
201	25.925	504	29.626
202	11.757		
203	15.300	601	31.919
204	28.019	602	29.991
205	15.856	603	24.282
206	20.346	604	25.783
		SUM	1.063.222

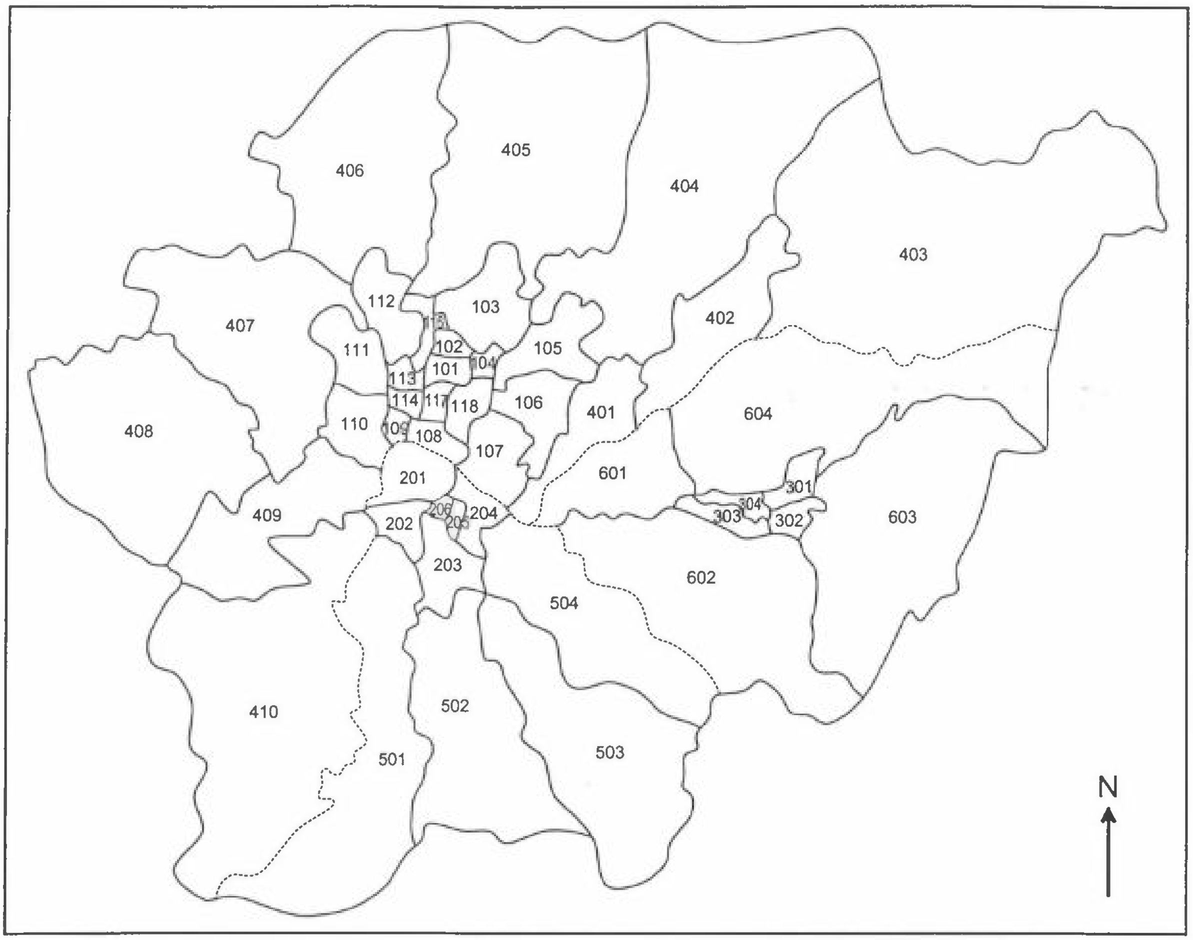

Figure 2: "Traffic zones" of Kathmandu Valley. (Ref.: JICA, 1992).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
J=21	.	.	.	.	.	.	68.	118.	186.	169.	169.	105.	105.	174.	140.	105.	70.	52.	106.	.	.	71.	71.	.	158.	.	.
J=20	.	18.	.	.	.	.	34.	85.	102.	135.	135.	174.	209.	209.	174.	174.	105.	35.	71.	106.	141.	79.	108.	79.	79.	79.	.
J=19	.	35.	18.	18.	18.	18.	35.	85.	51.	85.	220.	174.	105.	315.	157.	123.	141.	71.	106.	71.	156.	102.	88.	158.	79.	158.	.
J=18	.	35.	53.	35.	35.	35.	35.	35.	272.	406.	278.	271.	464.	446.	158.	814.	438.	177.	247.	114.	102.	117.	158.	158.	158.	237.	.
J=17	.	18.	88.	88.	71.	88.	88.	35.	433.	406.	779.	490.	446.	446.	220.	673.	332.	141.	106.	117.	117.	117.	97.	167.	158.	316.	79.
J=16	.	.	71.	71.	53.	71.	106.	71.	292.	893.	1049.	913.	769.	560.	561.	112.	141.	177.	129.	117.	138.	63.	54.	18.	18.	97.	97.
J=15	.	62.	124.	80.	66.	124.	141.	106.	98.	2716.	4546.	415.	1231.	585.	522.	298.	526.	156.	117.	120.	72.	72.	81.	63.	45.	63.	72.
J=14	.	155.	155.	124.	186.	133.	141.	371.	902.	3164.	2671.	1329.	1008.	710.	497.	369.	142.	154.	197.	236.	126.	81.	72.	72.	90.	89.	102.
J=13	.	124.	155.	155.	248.	239.	176.	276.	902.	1219.	559.	930.	989.	824.	785.	106.	146.	316.	373.	290.	144.	90.	90.	358.	134.	83.	125.
J=12	.	155.	186.	248.	248.	191.	456.	162.	162.	694.	519.	648.	758.	1385.	302.	110.	261.	448.	299.	251.	419.	319.	277.	693.	186.	78.	93.
J=11	.	62.	186.	193.	197.	216.	323.	216.	296.	732.	944.	2477.	1121.	256.	125.	144.	272.	267.	229.	479.	864.	1233.	976.	498.	55.	62.	109.
J=10	.	31.	112.	108.	216.	269.	132.	201.	148.	428.	506.	1004.	841.	228.	228.	182.	171.	171.	149.	256.	128.	273.	64.	86.	62.	93.	125.
J= 9	.	.	54.	54.	162.	81.	25.	98.	94.	219.	287.	383.	383.	171.	285.	228.	185.	214.	171.	171.	85.	53.	85.	43.	93.	125.	93.
J= 8	.	.	12.	39.	39.	52.	37.	49.	73.	67.	179.	27.	203.	155.	86.	157.	342.	86.	121.	64.	64.	43.	53.	32.	31.	31.	16.
J= 7	.	.	12.	12.	25.	49.	25.	37.	73.	90.	170.	161.	323.	434.	123.	189.	86.	114.	96.	21.	32.	32.	43.	21.	8.	23.	8.
J= 6	.	.	25.	25.	37.	31.	37.	49.	74.	22.	202.	188.	269.	135.	289.	101.	57.	57.	142.	53.	21.	21.	21.	21.	19.	16.	.
J= 5	.	.	.	12.	49.	25.	49.	49.	49.	.	121.	242.	161.	99.	230.	109.	54.	72.	61.	29.	.	.	11.	11.	11.	.	.
J= 4	.	.	.	25.	37.	37.	37.	25.	37.	.	69.	215.	94.	108.	63.	72.	72.	109.	54.	.	.	.	.	.	.	.	.
J= 3	.	.	.	6.	25.	12.	25.	31.	37.	.	67.	188.	161.	81.	54.	36.	36.	36.	.	.	.	.	.	.	.	.	.
J= 2	.	.	.	12.	18.	37.	12.	36.	17.	.	11.	161.	81.	54.	81.	18.	.	.	.	.	.	.	.	.	.	.	.
J= 1	.	.	.	6.	25.	25.	18.	18.	22.	.	.	.	13.	27.	27.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 3: Distribution of the Kathmandu Valley population within the km^2 grids of the modelling area, 1990/91. (In tens of inhabitants.)

3. Fuel consumption

The fuel sale and consumption data for Kathmandu Valley in the available references are given in Tables 2 and 3.

Table 2: Fuel sale and consumption data (Liquid fuels) , kl, for Kathmandu Valley.

	Gasoline (MS)	Sector	HSD	Sector	LDO	Sector	SKO	Sector
Shrestha and Malla (1993)	28.015	T	22.955	T	359	T	35.000	H
Estimated			564	I			315	I
Consumption, 1992/93							702	C
Total	28.015		23.519		359		36.045	
Devkota (1992)	20.093	T	70.317	?			60.826	?
"Consumption"			("Diesel")					
NOC, 1990/91								
Gautam et al. (1994)	11.098	T	21.825	T?	1.320		38.600	
NOC sales, 1992/93					("Fuel oil")			
KVVECP final report	14.250	T	27.000	T?				
1990			("Diesel")					

I Traffic H Household HSD High speed diesel SKO Kerosene
I Industrial C Commercial LDO Light diesel oil

There are wide discrepancies between the various reported numbers.

Gasoline (MS) is considered to be used almost exclusively for road traffic. The amount varies between about 11.000 and 28.000 kl/a. It appears that Shrestha arrived at his number by asking a number of vehicle operators about how much gasoline they use annually, and using the average number thus arrived at for the entire operating vehicle fleet (Table 6). He arrived at the operating vehicle fleet by assuming that a certain fraction of the registered vehicles in each category is actually in normal operation (see Table 6). On the basis of fuel efficiency figures, he also arrived at average vehicle km's travelled annually (and daily) per vehicle (see Table 7), which seems reasonable.

We decided to use Shrestha's gasoline consumption data in the following analysis.

Motor diesel (HSD) may be used for other purposes than for road vehicles. Three of the references give figures which agree fairly closely with HSD consumption for traffic.

Devkota's much higher total number may reflect, if correct, that HSD is used to a large extent also for other purposes, e.g. industrial/commercial. Shrestha does not report much use of HSD in industry.

As for HSD for road traffic, Shrestha's estimation is selected here for use in the emission survey of this study. We leave the question open that there also may be a substantial use of HSD for other purposes.

Diesel oil (LDO) is reported to be used only to a small extent, in industry. Only Shrestha is reporting this, based on CBS (1993). Cottage industries with less than 10 employees are, however, not included in that survey.

The consumption of kerosene seems to be around 37.000-39.000 kl annually, as reported by Shrestha and Gautam. Devkota's much larger SKO number is not taken into account in the following analysis.

Data reported on consumption of solid fuels is given in Table 3 (cement and brick industry excluded, which is shown in Table 5).

Table 3: Fuel consumption data (solid fuels), Kathmandu Valley (10^3 t/a). Commercial, industrial (excl. brick and cement) and household.

	Shrestha and Malla (1993) 1992/93	Devkota (1992) 1990/91
Fuel wood	122.0 H	
	17.2 I	
	0.5 C	
Coal	4.8 I	
Charcoal	0.5 H	
	0.6 C	
Agricultural residue	45.4 H	35-60 I
Animal waste	3.0 H	

Regarding fuel consumption in households, the estimate of per capita consumption for rural and urban populations as estimated by Shrestha and Malla (1993) is given in Table 4.

Table 4: Estimated Annual Per Capita Consumption of Fuels in Urban and Rural Areas of Kathmandu Valley in 1992/93. (Ref.: Shrestha and Malla, 1993).

Area	Fuelwood (kg)	Kerosene (l)	Agricultural Residues (kg)	Animal Waste (kg)	Charcoal (kg)	LPG (kg)
Urban[1]	93.5	34.5	7.5	0.0	0.8	6.3
Rural[2]	115.0	23.7	75.74	5.7	0.0	0.0

1 Source: Malla (1993)
2 Source: Shrestha (1993)

Devkota (1992) has given somewhat higher domestic fuel consumption data, based on investigation of the fuel use in 10 families living near Thankot: 175 kg of fuelwood per capita and 157 kg of agricultural residue per capita.

Table 5: Fuel consumption in the cement and brick industry (tons/year) Kathmandu Valley.

	Brick				Cement
	Bull's trench (NESS, 1995)			Chinese[2] (Shresta, 1993) 1992/93	Himal (Shrestha, 1993) 1992/93
	aver. per kiln 1994	no. of kilns	Total		
Coal	318.8	130	41.444	4.093[1]	17.096
Lignite	4.5		585		
Fuel wood	43.9		5.707		
Saw dust	20.5		2.665		
Rice husk	101.0		13.130		
Tire scrap	0.3		39		

1 Consumption in HHBF and BBF brick factories.
2 Devkota reports 1 ton of coal per 8000 bricks.

Shrestha (1993) is used in this study as the main source of information on solid fuel consumption. One figure from Devkota (1992) is added, which concerns the estimated amount of fuel used by local potters (12-15 tons per potter per year, 3 000-4 000 units).

For fuel consumption in the Bull's Trench brick kiln industry, NESS (1995) is used as the primary source, while for the Chinese kilns and Himal cement, Shrestha has reported consumption figures. For the Chinese kilns, the reported number from Shrestha concerns two of the 6 factories. Devkota reports the use of 1 ton of coal per production of 8 000 bricks, based on data from the Harisidhhi factory.

4. Traffic activity and its spatial distribution

The total traffic activity of Kathmandu Valley has been calculated here, based upon the data reported by Shrestha (1993) on average fuel consumption and average km's travelled annually per vehicle class, and the number of operating vehicles in the valley.

Traffic data reported by the JICA Urban Road Development Study (JICA, 1992) and by RONAST (1994) have been used here to distribute the traffic activity spatially, in the km^2 grid net.

The various data reported on the total number of registered vehicles in the valley are given in Table 6. Shrestha's estimate of the fraction of vehicles actually operating is also given.

Table 6: Registered vehicle population, Bagmati.

	Gasoline/ Diesel	Shrestha and Malla 92/93			RONAST	JICA	Devkota
		Reg. number	Operating fraction	Operating vehicles	Reg. april 93	Reg. 90/91	(year?) "No. of vehicles"
Car	G	16.522	0.61	10.105	20.273	18.000 +883(CD/UN)	19.535
Jeep	G	5.522	0.61	3.368			
Minibus	D	1.322	?	372	1.333		
Bus	D	715	?	110	773	7.069	7.397
Truck	D	3.114	0.44	693	3.231		
Tractor	D	1.917	0.50	959	1.587	1.729	1.864
3 wheeler	G	3.175	0.50	1.588	3.844	2.414	2.991
3 wheeler	D	669	0.50	335			
2 wheeler	G	35.002	0.80	28.000	36.129	24.211	26.121

Considering that the data represent different years, there is fair agreement between the sources. One notable discrepancy is that Shrestha and RONAST give a substantially lower number of registered buses and trucks than JICA and Devkota. The former are the most recent data.

Table 7 gives Shrestha's data on average fuel consumption, fuel efficiency and resulting average km's travelled per vehicle class.

Table 7: Estimated Annual Average Fuel Consumption and Average Number of Kilometres Travelled Per Vehicle in Transport Sector by Vehicle Types in 1992/93.
Ref.: Shrestha and Malla, 1993.

Vehicle Type	Fuel Type	Sample Size	Mean of Average Fuel Consumption	Fuel Efficiency		Average km travelled per vehicle	
			(l)	(km/l)	(l/10 km)	Annually	Daily
Truck	Diesel	15	8,704	4.5	2.2	39,168	107
Bus	Diesel	10	8,418	3.0	3.3	25,254	69
Minibus	Diesel	17	7,373	4.5	2.2	33,178	91
Jeep	Diesel	20	2,315	8.0	1.25	18,520	51
Tractor	Diesel	4	4,785	4.4	2.3	21,054	58
Car	Gasoline	61	1,595	10.6	0.94	16,907	46
3-Wheeler	Diesel	9	2,592	12.5	0.8	32,400	89
3-Wheeler	Gasoline	16	1,479	11.0	0.9	16,269	45
2-Wheeler	Gasoline	42	341	45.5	0.22	15,515	43

Shrestha's figures give the following traffic activity data for the year 1992/93:

Gasoline	**Mill. veh. km/a**	
Cars, taxis	170.8	
3-wheelers (TC)	25.8	
2-wheelers (MC)	434.4	631.0
Diesel		
Jeeps	62.4	
Minibuses	12.3	
Buses	2.8	
Trucks	27.1	
Tractors	20.2	
3-wheelers (TC)	10.9	135.7
Total		766.7

This total traffic activity corresponds to the total consumption of gasoline and motor diesel in traffic as given in Table 2, ref. Shrestha and Malla (1993).

The average vehicle composition of the traffic has also been reported by others (Table 8). There may be some discrepancy between the various authors regarding the classification of vehicles. The main discrepancy in the results of Table 7 is that Shrestha has a very high relative number for MC activity, at the expense of Tempo (3-wheelers) activity. His sum for Tempo and MC is, however, in fair agreement with other sources. The problem seems to be that Shrestha has based himself on a too low average driving distance for the Tempos and too long distance for the MC's.

The data give basis for the following estimate of average vehicle composition of Kathmandu Valley traffic:

Car/taxi	25%
Jeep/minibus/tractor	15%
Bus	2%
Truck	5%
Tempo (TC)	25%
Motorcycle (MC)	28%

The vehicle composition in the traffic varies substantially between roads. Streets in the centre have very high tempo/MC percentage, while the proportion of trucks is high on the Ring Road (10-15%).

In this study, account is not taken of this variation. The average composition is used as a basis for calculating composite vehicle emission factors for gasoline and diesel separately.

Table 8: Composition of vehicle categories in Kathmandu traffic.

		JICA (1992) Daily	Giri (1993) Rush-hour	Devkota (1992) Rush-hour	Shrestha (1993) Daily
PC/taxi	G	32.5 (20.0+12.5)	20.4	25	22.3
Jeep (Pickup)	D			7	8.1
Minibus/trolley	D	8.1	14.6	8	2.0
Trucks/tractors	D	4.9	2.3 (incl. bus)	4	6.2
Tempo	G/D	21.8	62.6	22	4.8
MC	G	30.0		22	56.6

JICA : Based upon 29 counting locations, 1992.
Giri : Based upon 33 counting locations, 1993.
Devkota : Based upon 22 counting locations, 1992.
Shrestha : Based upon an analysis of total traffic activity based on fuel consumption, annual average driving distance and number of operating vehicles.

The traffic data has been used to distribute the traffic on the main road system as shown in Figure 4, which gives the estimated annual average daily traffic (AADT) numbers on some of the main roads.

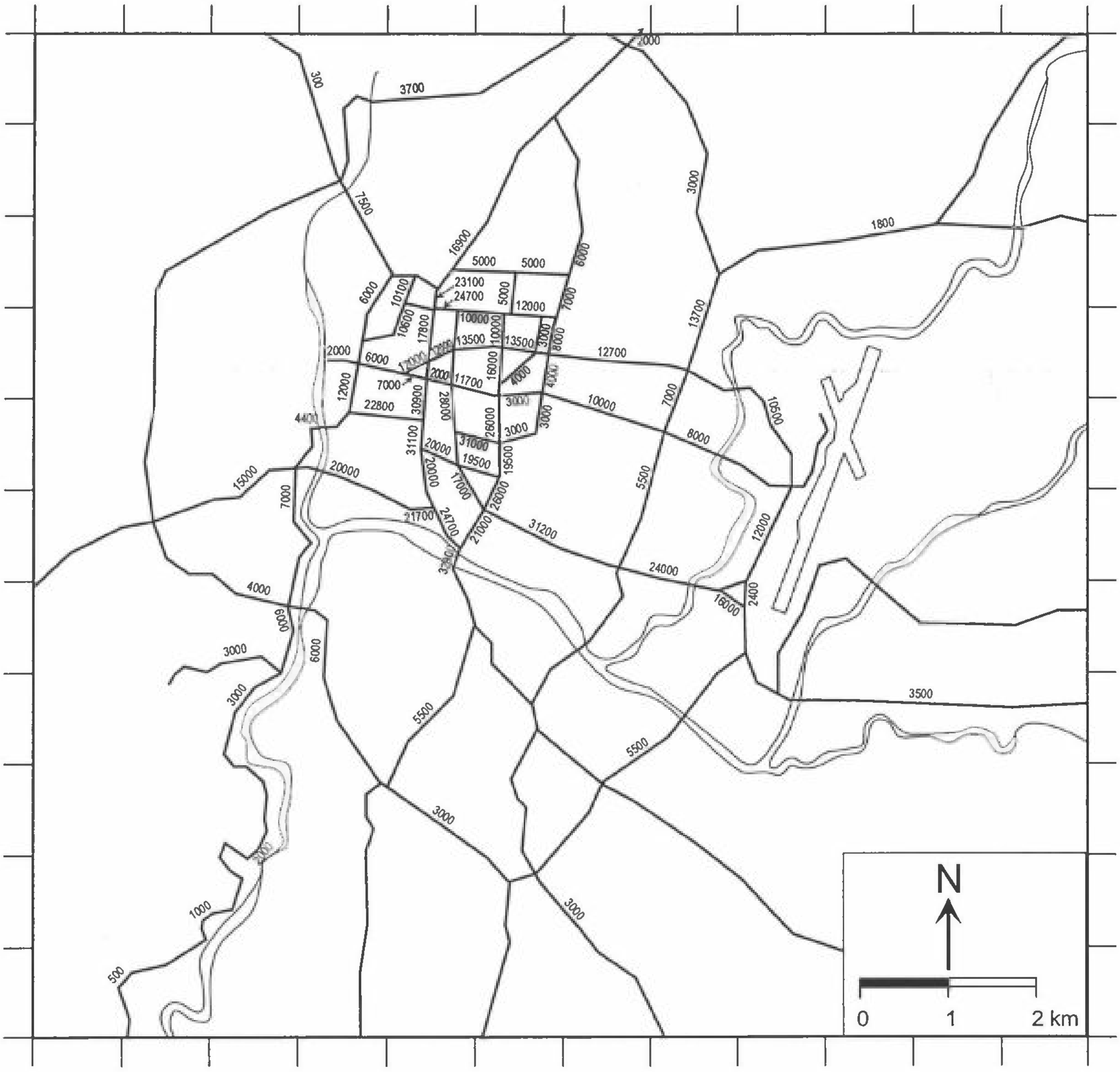

Figure 4: The main road system of Kathmandu Valley with some of the traffic data used in this study.

5. Emission factors

The selection of the emission factors used in this URBAIR calculation for fuel combustion and road vehicles in Kathmandu Valley was based on the following data sources:

- US EPA emission factors of AP42 publication.
- Emission factors of the WHO publication: "Assessment of Sources of Air, Water and Land Pollution", Part I: Rapid inventory techniques in Environmental Pollution (Geneva, 1993).
- Particle emission factors described in Appendix 5.
- Particle emission factors for road vehicles, as deduced from smoke meter measurements in the KVVECP study (see page 69).

The selected emission factors for fuel combustion, road vehicles and industry are shown in Tables 8 and 9.

Table 8: Emission factors used for URBAIR, Kathmandu Valley. Fuel combustion, refuse burning and road vehicles.

		TSP		PM_{10}/TSP	SO_2	NO_x	%S max.
Fuel combustion (kg/t)							
Residual oil (FO)	ind./comm.	1.25S+0.38[1]		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			1.8[6]
Charcoal	dom/comm.	20		0.5			
Agri.residue		10		0.5			
Anim. waste		10		0.5			
Refuse burning, open		37		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) 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%
6) NESS (1995)
A Used for Manila, Jakarta, Bombay
B Proposed and used for Kathmandu Valley.

Table 9: Emission factors (kg/ton) for brick and cement industries (US EPA AP42).

	TSP	$\frac{PM_{10}}{TSP}$	SO_2	NO_x	CO	%S	F	Pb
Brick industries								
Bull's trench								
per ton of bricks	9.42	0.25	6.06S	1.18	1.19		0.5	
per ton of fuel								
- coal (bituminous)								
- wood and bark								
- lignite								
Chinese (Hoffman Bhatta)								
Portland Cement								
Dry process, uncontrolled								
Dry process, kiln	128	0.42	5.4^1+$3.6S^2$	1.4				0.06
Clinker cooler	4.6	0.09						
Dryers, grinders, etc.	48							

1. From mineral source. 2. From coal.

The emission factors for Nepal/Kathmandu conditions may differ substantially from those given in the tables.

For road vehicles, observations of vehicle exhaust in the valley indicate that a substantial part of the fleet has very high emissions. There are indications that this is partly due to fuel adulteration. Steadman et al. (1993) have made exhaust measurements with a remote sampling technique on Kathmandu vehicles, also finding large emission factors. It should be mentioned that the measurement site was on a slightly uphill road. The fraction of "grass polluters" was 16% and 25% for HC and CO respectively. Also, their measurements showed high opacity readings, i.e. particle emissions. Very high opacity readings have also been measured for the Kathmandu vehicle fleet as part of the KVVECP study. These measurements cannot be used to calculate exhaust particle emission factors. They indicate, however, that the real particle emission factors for Kathmandu vehicles may be substantially higher than those given in Table 7.

Also, the particle emission factors for the various uses of solid fuels in Kathmandu, such as fuelwood, coal, charcoal, agricultural residue and animal refuse are not well determined.

Particle emissions from Kathmandu diesel vehicles

The particle emission factors for diesel vehicles used in the URBAIR study for Manila, Bombay and Jakarta, are, as described in Appendix 5, based upon available literature, especially the measurements made on diesel vehicles in Manila. The emission factor for trucks, 2 g/km, was based upon some 20% of the trucks being "smoke belchers", with an emission factor up to 8 g/km.

Observations in the Kathmandu traffic and the smoke testing results from the KVVECP study (Table 10) indicate that more than 75% of the vehicles in each class have smoke emissions of more than 75 HSU, and some 55% have emissions over 85 HSU. The test is done for free acceleration of the engine and does not represent the smoke emissions during driving. However, there is a correlation between smoke emissions during free acceleration and during normal driving.

Table 10: Summary of diesel vehicle smoke test results (Ref.: KVVECP study).

Vehicle type	Distribution (%) of tested vehicles in smoke (HSU) level ranges				
	<65	66-75	76-85	86-95	96-100
Tempo	2	14	16	55	13
Car	19	6	6	62	6
Jeeps/st.wgn.	2	7	25	59	6
Mini buses	4	5	28	56	7
Mini trucks	13	14	24	44	4
Buses	4	13	44	39	0
Trucks	4	8	40	44	4
Average	7	10	26	51	6

HSU: Hartridge Smoke Units.

In Table 11, emissions in g/km are estimated from HSU units, based on certain conditions. These g/km figures represent estimates of emissions during "smoking conditions".

Table 11: Particle emission factor (g/km) for diesel trucks, estimated from HSU data.

Hartridge Smoke Units	Particle emissions			
	g/m^3	g/km 1)	g/km 2)	
		40 l engine 2000 rpm 40 km/h	Light truck 0.2 l/km	Heavy truck 0.4 l/km
30	0.13	1.6	0.8	1.6
65	0.42	5.0	2.5	5.0
75	0.55	6.6	3.3	6.6
85	0.72	8.6	4.3	8.6
95	1.0	12	6	12

1) Based upon 12 m^3 air/km (4 l engine, 2000 rpm, 40 km/h).
2) Based upon 0.03 g fuel/g air.

For loaded buses and trucks in the Kathmandu topography, it may be a valid estimate that smoking conditions for the vehicle occur more than 50% of the time of operation.

Combining data from Tables 10 and 11, the average particle emission during "smoking conditions" for Kathmandu trucks is 4.3 g/km for light truck (0.2 l fuel/km) and 8.6 g/km for a heavy truck (0.4 l fuel/km).

Assuming that the average specific fuel consumption by trucks and buses in Kathmandu Valley is 0.3 l/km, that "smoking conditions" for the total traffic activity of the valley occur for 25-50% of the time, and that the emission factor for the rest of the time is 1 g/km, the average truck/bus emission factor for Kathmandu is calculated to 2.5-3.7 g/km.

This figure is supported by the emission factor presented by Dr. Mathur of IIT New Delhi in the KVVECP Summary Report, namely 11 kg particles/1000 litres of diesel, corresponding to 3.7 g/km for a fuel consumption of 0.22 l/km.

Table 10 shows that the HSU distribution is nearly the same for all diesel vehicle types, showing that all the vehicle types are dominated by smoking vehicles. The reason for this condition in the Kathmandu Valley is probably two-fold: i) old, poorly maintained vehicles, and ii) poor fuel quality.

The above considerations are a basis for increasing the emission factors for particles from diesel vehicles in Kathmandu Valley, relative to those used for Manila, Jakarta and Bombay. Both factors are shown in Table 8.

6. Emission from industry

The locations of the Bull's Trench kilns, the Chinese kilns and Himal Cement factory are shown in Figure 1.

6.1 The brick industry

The brick production data used in this study are as follows:

Area	No. of units	Total production mill. bricks		Stack height/ diam(m) typical
		1993	1994	
Bull's Trench (Thapa et al. 1993; NESS, 1995)				
Kathmandu	15	24.75		
Lalitpur	74	209.5		10/0.5
Bhaktapur	41	127.0		
Total	130	361.0	450	
Chinese (Thapa et al., 1993)				
Lahtpur	5	53		65/1.65
Bhaktapur	1	20		
Total	6	73		

Bull's Trench kilns

The emissions from these kilns have been estimated most recently by the NESS study (1995). The emissions originate mainly from the combustion of the fuel used, the most important of which are coal, fuelwood and rice husk. Handling of the bricks gives rise to particle emissions (resuspension). All fuels give substantial particle emissions, due to the inefficient combustion conditions in the kiln. The coal also gives rise to emissions of sulphur and other trace elements.

Coal analysis results from 1994 gave an average ash and sulphur content of 18% and 1.77% respectively (Table 12).

Table 12: Coal analysis results, 1994 (NESS, 1995).

	Moisture %	Volatile %	Ash %	Fixed carbon %	Sulphur %	Calorific value (kcal/kg)
Range (n=6)	0.3-6.2	7.3-37	1.9-73	20-60	0.3-4.4	5750-7460
Average	4.15	27.12	18.02	50.72	1.77	6708

The emissions were calculated by 3 methods:

- Based on brick production, using US EPA AP42 emission factors (the weight of a brick is approx. 2 kg).
- Based on fuel consumption, using US EPA AP42 emission factors.
- Based on emission measurements from Bull's Trench kilns in India.

The AP42 emission factors are given in Table 9.

The emission results (Table 13) show wide discrepancies between the methods:

Table 13: Total emissions from Bull's Trench kilns in Kathmandu Valley 1994 (tons/a) (NESS, 1995).

Method	Particles	SO_2	CO	VOC	NO_x	F
	(SP)					
A Based on brick production	15862	6435	1442	405	631	451
B Based on fuel combustion	5144	1536	2547	524	119	
C Based on emission measurements, India	4438	4.8	16384	2373	0.8	

Particles : Methods B and C agrees fairly well while method A gives very large emissions. Incidentally, using the AP42 factor for method A (9.42 kg/ton, 450 mill bricks and 2 kg/brick) gives 8,478 tons of particles, while 15,876 tons is reported by the NESS study.

SO_2 : The methods disagree basically. Method C results indicate that the sulphur released from the coal is absorbed on the brick surfaces.

NO_x : The methods disagree basically. Method C results (together with high CO emissions) indicate poor combustion conditions.

Based on this, we use an estimate of 5000 tons of particles emitted annually from Bull's trench kilns. The emissions of SO_2 cannot be estimated with confidence, due to the available data.

Chinese (Hoffmann Bhatta) kilns

No specific information is available on the emissions from these kilns in Kathmandu Valley. Also, total fuel and other input consumption data are not available. Shrestha (1993) has reported coal consumption for two of the factories, namely HHBF and BBF (4,093 tons in 1992/93).

Devkota (1992) reports that 1000 kg of coal is required to produce 8000 bricks (data from the HHBF factory). In addition, 15 tons of fuelwood is used annually for firing, which is negligible. Using the 1000 kg/8000 bricks figure, it is calculated that the Chinese kilns use a total of some 9100 tons of coal annually.

6.2 The Himal Cement Factory

The factory has a production capacity of 360 tons per day (Bhattarai, 1993), by 2 vertical shaft kilns.

Stack data are as follows (Bhattarai, 1993):

No. of stacks:	2
Height	33.5 m
Flue gas velocity	5.7 m/s
Flue gas temperature	120°C
Stack diameter	? m

The production has normally been some 45.000-50.000 tons annually in the period 1986-91 (Devkota, 1992), with a coal consumption of some 6.000-8.000 tons annually. In the most recent years, production has increased, and Shrestha (1993) reports a coal consumption of some 17.000 tons for 1992/93.

According to Bhattarai (1993) the Himal Cement Co estimated that prior to the planned installation of effective particle emission control equipment in 1994, there was an average particle emission of 2.85 tons daily from the stack, and around 10 tons from lime stone handling at the quarry. In addition, there were substantial dust emissions from material handling and transport within the factory area.

The pollution control equipment, which includes bag filters and wet scrubbers, was planned to be in operation as of December 1994.

6.3 Other industries

There is a total of 2174 industrial establishments in Kathmandu Valley, presumably with more than 10 employees.

Devkota (1992) has described the level of industrialization in the valley.

There are 3 designated "industrial districts" in the valley: Balaju (0.35 km^2) (the oldest one), Patan (0.14 km^2) and Bhaktapur (0.04 km^2). Besides these districts, the emergence of new industries along the "Ribbon zones", i.e. Kathmandu-Thankot and Kathmandu-Bhaktapur transportation corridors, and also in the southern part of Lalitpur district, is a matter of concern (see Figure 1 for location).

Devkota reports the following numbers of industrial establishments:

Industrial districts:	Balaju	:	71 units
	Patan	:	103 units
	Bhaktapur		27 units

"Cottage industries" (at mid-91)	Kathmandu	Lalitpur	Bhaktapur
Plastic and rubber	79	5	4
Metal crafting	409	97	7
Al, brass, Cu	32	9	-

Another major cottage industry in terms of number is backyard pottery, of which there may be several thousand in operation during the dry season.

Bhattarai (1993) describes briefly the dying industry (carpet and textile) in terms of air pollution emissions. They use boilers to generate steam. Previously, rice husk was mainly used as feed stock for the boilers, but now there is a transition towards the use of diesel oil (HSD). A recent survey of 19 industries gave that 12 of them used diesel.

Boilers are also used in other industries such as flour mills and leather mills. Presumably, there is a transition towards diesel also in such industries.

Devkota estimated the amount of rice husk used by potters in up-draft kilns. The annual demand per potter may be 12000-15000 kg of biomass.

These "other" industries definitely represent air pollution problems localized to the areas immediately adjacent. In addition, they represent a total emission from combustion of diesel and rice husk, and to some extent of process emission, which should be taken into account in the total emission survey for the valley. Their contribution to the background pollution of the valley, and thus their effect on visibility, should be considered.

RONAST (1994) reports a total diesel consumption of 7.83 mill litres by these smaller industries in the valley in 1992. Dairy products, textile processing and carpet/rugs were the largest industrial users.

With reference to the HMG/Ministry of Industry, RONAST (1994) reports the following TSP emissions from distributed industries:

Type of industry	No. of units	TSP in tons/a
Beverages/distilleries	3	5
Textile processing	85	8
Knitting mills	25	5
Carpet and rugs	1109	144
Paper and products	3	0.3
Animal feed	13	65
Plastic products	38	8
Soap and detergents	4	5
Marbles	1	67
Dry battery	1	880

7. Total emissions

Table 14 gives the estimated emissions of TSP, PM_{10}, SO_2 and NO_x associated with the various source categories, fuels, vehicle types and industries.

In the previous text, the quality of the data sources and the emission numbers have been briefly discussed. It is clear that the estimated emission figures given in Table 14 have a limited accuracy. For instance, brick industry emissions are not well determined. However, they are believed to be useful to give the first estimate of the importance of the various source categories, as contributors to the various air pollution problems of the Kathmandu Valley, such as:

- roadside pollution by suspended particles and PM_{10} (respirable particles),
- general air pollution exposure of the population,
- reduced visibility.

Dispersion modelling will clarify which sources contribute most to these problems. One important point in this respect is the fact that the brick industry is in operation only during the October to March period, i.e. half the year, while the other sources are in operation during the whole year. For the reduced visibility problem, this means that the brick industry is even more important, may be twice as important relatively, than indicated by the emission figures of Table 14.

Table 14: Estimated emissions from air pollution sources in Kathmandu Valley, 1992/93 (tons/a).

		TSP	PM_{10}	SO_2
Vehicles				
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
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	
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	
Miscellaneous				
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 methods.

The emission inventory of Table 14 itself, together with observations in the valley, indicate the following sources as being the most important:

	TSP	PM_{10}
Roadside pollution	Resuspension	Gasoline exhaust Diesel exhaust Resuspension
General population exposure	Domestic fuel combustion Brick industry (mainly Bull Trench) Resuspension	Domestic fuel combustion Brick industry (mainly Bull's trench) Vehicle exhaust Resuspension
Reduced visibility	Bull's trench brick kilns Domestic fuel combustion Vehicle exhaust	

8. Spatial emission distribution

The total emissions from each source category have been distributed within the km^2 grid net based on:

- the actual location of point sources (e.g. Himal Cement Factory, brick kilns and industrial areas; see Figure 1)
- the population distribution
- the cooking practices of the urban and rural population
- the traffic activity distribution.

The traffic activity was distributed as follows:

- The traffic activity (veh.km/a) on the roads with known traffic count was calculated (vehicles x road length), and distributed in the grid system according to the actual location of the road sections.

- This traffic activity accounted for about 50% of the total traffic activity, as calculated from the fuel consumption (Shrestha and Malla, 1993).

- The difference was distributed within the grid net, proportional to the population distribution, with an additional weight put on the highly populated city centre areas.

- The emissions from the total traffic activity in each grid square were calculated by first calculating composite emission factors for gasoline and diesel vehicles respectively, by combining the emission factors of Table 8 and the average vehicle composition as given on page 64.

Those composite emission factors were calculated to be:

* gasoline : 0,39 g/km
* diesel : 1,65 g/km

The emissions from the Bull's trench kilns were distributed in the grid net according to their actual location. An average emission figure for each kiln was calculated, and the emissions from each grid square calculated by multiplying this average emission figure by the number of kilns in the square.

Figures 5-9 give the resulting **TSP** emission distributions from each of the area-distributed source categories, as kg/h (averaged over the winter half-year, October-March, 1992/93.

The following ratios are used for PM_{10}/TSP:

Vehicle exhaust	:	1.0
Resuspension from roads	:	0.25
Fuel/refuse combustion	:	0.5
Brick industry	:	0.25
Himal Cement, stack	:	0.2
Himal Cement, diffuse	:	0.1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
J=21	.	.	.	.	.	12.	14.	17.	27.	24.	24.	15.	15.	28.	93.	15.	10.	7.	15.	.	.	10.	10.	.	23.	.	.
J=20	.	3.	.	.	.	10.	5.	12.	15.	19.	19.	25.	30.	104.	25.	25.	15.	5.	10.	15.	20.	11.	15.	11.	11.	11.	.
J=19	.	5.	3.	3.	3.	13.	14.	12.	7.	12.	32.	25.	40.	94.	23.	18.	20.	10.	15.	10.	22.	15.	13.	23.	11.	23.	.
J=18	.	5.	8.	5.	5.	5.	9.	19.	41.	58.	40.	123.	140.	64.	23.	116.	63.	25.	35.	16.	15.	17.	23.	23.	23.	34.	.
J=17	.	3.	13.	13.	10.	13.	13.	5.	122.	176.	252.	217.	253.	64.	31.	96.	48.	20.	15.	17.	17.	17.	14.	24.	23.	45.	11.
J=16	.	.	10.	10.	8.	10.	15.	10.	325.	135.	1344.	1013.	845.	80.	80.	16.	20.	25.	18.	17.	20.	9.	8.	3.	3.	14.	14.
J=15	.	9.	18.	11.	9.	18.	193.	187.	15.	1236.	4978.	641.	1401.	275.	166.	100.	110.	22.	17.	17.	10.	10.	12.	9.	6.	9.	10.
J=14	.	22.	22.	18.	27.	19.	164.	167.	220.	5381.	4385.	1956.	1827.	306.	71.	53.	20.	22.	28.	34.	18.	12.	10.	10.	13.	13.	15.
J=13	.	18.	22.	22.	36.	34.	169.	80.	1020.	3383.	2936.	1226.	651.	548.	352.	15.	21.	45.	53.	42.	21.	13.	13.	51.	42.	12.	18.
J=12	82.	125.	114.	36.	55.	111.	488.	525.	690.	1237.	2031.	1187.	564.	1072.	97.	16.	37.	64.	43.	36.	60.	46.	40.	122.	27.	11.	13.
J=11	.	9.	42.	130.	149.	118.	46.	196.	559.	399.	1107.	2363.	1490.	743.	68.	89.	103.	74.	66.	69.	124.	1176.	954.	71.	8.	9.	16.
J=10	.	4.	16.	15.	31.	39.	39.	138.	216.	340.	974.	195.	349.	283.	160.	153.	148.	137.	153.	179.	98.	146.	9.	12.	9.	13.	18.
J= 9	.	.	8.	8.	23.	12.	4.	128.	13.	306.	335.	360.	55.	24.	41.	33.	26.	31.	24.	52.	76.	58.	66.	33.	13.	18.	13.
J= 8	.	.	2.	6.	6.	7.	5.	79.	10.	10.	227.	215.	29.	22.	12.	22.	49.	12.	17.	9.	9.	6.	8.	39.	29.	4.	2.
J= 7	.	.	2.	2.	4.	7.	41.	7.	10.	13.	24.	92.	128.	62.	18.	27.	12.	16.	14.	3.	5.	5.	6.	3.	31.	37.	14.
J= 6	.	.	4.	4.	5.	4.	21.	7.	11.	3.	29.	27.	147.	19.	41.	14.	8.	8.	20.	8.	3.	3.	3.	3.	3.	2.	19.
J= 5	.	.	.	2.	7.	4.	19.	19.	7.	.	17.	35.	34.	112.	33.	16.	8.	10.	9.	4.	.	.	2.	2.	2.	.	.
J= 4	.	.	.	4.	5.	34.	29.	4.	5.	.	10.	31.	13.	117.	16.	10.	10.	16.	8.	.	.	.	.	.	.	.	.
J= 3	.	.	.	1.	4.	18.	4.	4.	5.	.	10.	27.	23.	12.	101.	5.	5.	5.	.	.	.	.	.	.	.	.	.
J= 2	.	.	.	2.	3.	12.	2.	5.	2.	.	2.	23.	12.	8.	35.	63.	12.	5.	.	.	.	.	.	.	.	.	.
J= 1	.	.	.	1.	4.	4.	3.	3.	3.	.	.	.	2.	4.	4.	18.	25.	.	.	.	.	.	.	.	.	.	.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27

Figure 5: Suspended particle ("TSP") emissions from ***road vehicle exhaust****, Kathmandu Valley.*
Winter half year emissions, 1992/93. Constant emissions, calculated as kg/hour.
Unit: 10^{-3} kg/hour per km^2 grid.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
J=21	.	.	.	.	.	3.	4.	4.	7.	6.	6.	4.	4.	7.	24.	4.	3.	2.	4.	.	.	3.	3.	.	6.	.	.
J=20	.	1.	.	.	.	3.	1.	3.	4.	5.	5.	7.	8.	27.	7.	7.	4.	1.	3.	4.	5.	3.	4.	3.	3.	3.	.
J=19	.	1.	1.	1.	1.	4.	4.	3.	2.	3.	8.	7.	10.	25.	6.	5.	5.	3.	4.	3.	6.	4.	3.	6.	3.	6.	.
J=18	.	1.	2.	1.	1.	1.	2.	5.	11.	15.	10.	32.	37.	17.	6.	31.	16.	7.	9.	4.	4.	4.	6.	6.	6.	9.	.
J=17	.	1.	3.	3.	3.	3.	3.	1.	32.	46.	66.	57.	66.	17.	8.	25.	12.	5.	4.	4.	4.	4.	4.	6.	6.	12.	3.
J=16	.	.	3.	3.	2.	3.	4.	3.	85.	35.	352.	265.	221.	21.	21.	4.	5.	7.	5.	4.	5.	2.	2.	1.	1.	4.	4.
J=15	.	2.	5.	3.	2.	5.	50.	49.	4.	324.	1304.	168.	367.	72.	44.	26.	29.	6.	4.	4.	3.	3.	3.	2.	2.	2.	3.
J=14	.	6.	6.	5.	7.	5.	43.	44.	58.	1410.	1149.	513.	479.	80.	19.	14.	5.	6.	7.	9.	5.	3.	3.	3.	3.	3.	4.
J=13	.	5.	6.	6.	9.	9.	44.	21.	267.	886.	769.	321.	171.	143.	92.	4.	5.	12.	14.	11.	5.	3.	3.	13.	11.	3.	5.
J=12	21.	33.	30.	9.	14.	29.	128.	138.	181.	324.	532.	311.	148.	281.	25.	4.	10.	17.	11.	9.	16.	12.	10.	32.	7.	3.	4.
J=11	.	2.	11.	34.	39.	31.	12.	51.	147.	105.	290.	619.	390.	195.	18.	23.	27.	19.	17.	18.	32.	308.	250.	19.	2.	2.	4.
J=10	.	1.	4.	4.	8.	10.	10.	36.	57.	89.	255.	51.	91.	74.	42.	40.	39.	36.	40.	47.	26.	38.	2.	3.	2.	4.	5.
J= 9	.	.	2.	2.	6.	3.	1.	33.	4.	80.	88.	94.	14.	6.	11.	9.	7.	8.	6.	14.	20.	15.	17.	9.	4.	5.	4.
J= 8	.	.	.	1.	1.	2.	1.	21.	3.	3.	59.	56.	8.	6.	3.	6.	13.	3.	5.	2.	2.	2.	2.	10.	7.	1.	1.
J= 7	.	.	.	.	1.	2.	11.	2.	3.	3.	6.	24.	33.	16.	5.	7.	3.	4.	4.	1.	1.	1.	2.	1.	8.	10.	4.
J= 6	.	.	1.	1.	1.	1.	6.	2.	3.	1.	8.	7.	39.	5.	11.	4.	2.	2.	5.	2.	1.	1.	1.	1.	1.	1.	5.
J= 5	.	.	.	.	2.	1.	5.	5.	2.	.	5.	9.	9.	29.	9.	4.	2.	3.	2.	1.	.	.	.	.	.	.	.
J= 4	.	.	.	1.	1.	9.	8.	1.	1.	.	3.	8.	4.	31.	4.	3.	3.	4.	2.	.	.	.	.	.	.	.	.
J= 3	.	.	.	.	1.	5.	1.	1.	1.	.	3.	7.	6.	3.	27.	1.	1.	1.	.	.	.	.	.	.	.	.	.
J= 2	.	.	.	.	1.	3.	.	1.	1.	.	.	6.	3.	2.	9.	16.	3.	1.	.	.	.	.	.	.	.	.	.
J= 1	.	.	.	.	1.	1.	1.	1.	1.	.	.	.	1.	1.	1.	5.	7.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 6: Suspended particle ("TSP") emissions from ***resuspension from roads****, Kathmandu Valley.*
Winter half year emissions, 1992/93. Constant emissions, calculated as kg/hour.
Unit: 10^{-2} kg/hour per km^2 grid.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
J=21	.	.	.	.	.	.	302.	529.	831.	755.	755.	467.	467.	779.	623.	467.	312.	233.	473.	.	.	315.	315.	.	706.	.	.
J=20	.	79.	.	.	.	.	151.	378.	453.	604.	604.	779.	934.	934.	779.	779.	467.	156.	315.	473.	630.	353.	483.	353.	353.	353.	.
J=19	.	158.	79.	79.	79.	79.	154.	381.	227.	378.	984.	779.	467.	1406.	703.	550.	629.	315.	473.	315.	696.	455.	391.	706.	353.	706.	.
J=18	.	158.	236.	158.	158.	158.	158.	158.	1214.	1811.	1242.	1209.	2070.	1992.	704.	1817.	1956.	788.	1103.	510.	455.	521.	706.	706.	706.	1059.	.
J=17	.	79.	394.	394.	315.	394.	394.	158.	1933.	1811.	3478.	2186.	1992.	1992.	983.	3004.	1483.	630.	473.	521.	521.	521.	433.	746.	706.	1412.	353.
J=16	.	.	315.	315.	236.	315.	472.	315.	1305.	1993.	2341.	2038.	3431.	2500.	2503.	500.	630.	789.	575.	521.	616.	281.	241.	80.	80.	433.	433.
J=15	.	277.	554.	355.	296.	551.	630.	472.	435.	2693.	4510.	1854.	2748.	2612.	2332.	1330.	2346.	698.	521.	536.	321.	321.	361.	281.	200.	281.	321.
J=14	.	692.	692.	554.	831.	592.	630.	1657.	2014.	3138.	2649.	2966.	2249.	3170.	2217.	1647.	633.	688.	877.	1052.	562.	361.	321.	321.	401.	396.	457.
J=13	.	554.	692.	692.	1108.	1067.	788.	1231.	2014.	2721.	2495.	2076.	2207.	1840.	3503.	475.	650.	1413.	1667.	1296.	642.	401.	401.	1598.	600.	369.	556.
J=12	.	692.	831.	1108.	1108.	854.	2036.	721.	721.	3096.	2315.	2893.	3385.	3091.	1346.	492.	1167.	2000.	1333.	1121.	1872.	1425.	1238.	3094.	829.	347.	417.
J=11	.	277.	831.	860.	878.	962.	1443.	962.	1322.	3269.	2108.	5530.	2502.	1142.	558.	643.	1215.	1191.	1024.	2137.	1928.	2752.	2179.	2221.	243.	278.	487.
J=10	.	138.	499.	481.	962.	1203.	591.	899.	658.	1912.	2258.	2240.	1876.	1017.	1017.	811.	763.	763.	667.	1144.	572.	1218.	286.	383.	278.	417.	556.
J= 9	.	.	241.	241.	721.	361.	110.	439.	420.	978.	1283.	1708.	1708.	763.	1272.	1017.	826.	953.	763.	763.	381.	238.	381.	191.	417.	556.	417.
J= 8	.	.	55.	175.	175.	230.	165.	220.	327.	300.	800.	120.	907.	692.	382.	700.	1526.	382.	540.	286.	286.	191.	238.	143.	139.	139.	70.
J= 7	.	.	55.	55.	110.	220.	110.	165.	327.	400.	760.	721.	1441.	1937.	548.	844.	382.	508.	429.	95.	143.	143.	191.	95.	35.	104.	35.
J= 6	.	.	110.	110.	165.	137.	165.	220.	329.	100.	900.	840.	1200.	604.	1291.	450.	254.	254.	636.	238.	95.	95.	95.	95.	83.	70.	.
J= 5	.	.	.	55.	220.	110.	220.	220.	220.	.	540.	1080.	721.	441.	1028.	484.	242.	323.	271.	127.	.	.	48.	48.	48.	.	.
J= 4	.	.	.	110.	165.	165.	165.	110.	165.	.	310.	960.	420.	480.	282.	323.	323.	484.	242.	.	.	.	.	.	.	.	.
J= 3	.	.	.	27.	110.	55.	110.	137.	165.	.	300.	840.	721.	360.	240.	162.	162.	162.	.	.	.	.	.	.	.	.	.
J= 2	.	.	.	55.	82.	165.	55.	160.	77.	.	50.	721.	360.	240.	360.	81.	.	.	.	.	.	.	.	.	.	.	.
J= 1	.	.	.	27.	110.	110.	82.	82.	100.	.	.	.	60.	120.	120.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 7: Suspended particle ("TSP") emissions from ***domestic and industrial fuels****, (excl. brick and cement industry), Kathmandu Valley.*
Winter half year emissions, 1992/93. Constant emissions, calculated as kg/hour.
Unit: 10^{-3} kg/hour per km^2 grid.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
J=21	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=19	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=18	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=17	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=16	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=15	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=14	.	.	.	.	.	.	1740.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J=12	.	2610.	.	2610.	1740.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2610.	4350.	870.	.	3480.	1740.	.	.
J=11	.	.	.	.	.	5220.	870.	.	.	.	.	.	.	.	.	.	.	4350.	870.	870.	1740.	.	.	3480.	.	.	.
J=10	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2610.	.	.	.	.
J= 9	.	.	.	.	.	.	.	.	2610.	.	.	4350.	1740.	1740.	.	.	1740.	870.	.	.	.	.	3480.	1740.	.	.	.
J= 8	.	.	.	.	.	.	.	.	.	.	.	2610.	3480.	870.	5220.	.	870.	.	.	.	.	.	.	1740.	.	.	.
J= 7	.	.	.	.	.	.	.	.	.	.	2610.	6960.	2610.	5220.	6960.	.	.	.	.	.	.	.	.	.	.	.	.
J= 6	.	.	.	.	.	.	.	.	.	.	.	.	2610.	8700.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 5	.	.	.	.	.	.	.	.	.	.	.	.	2610.	870.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 4	.	.	.	.	.	.	.	.	.	.	.	.	870.	870.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
J= 1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27

Figure 8: Suspended particle ("TSP") emissions from ***Bull's trench brick kilns****, Kathmandu Valley.*
Winter half year emissions, 1992/93. Constant emissions, calculated as kg/hour.
Unit: 10^{-2} kg/hour per km^2 grid.

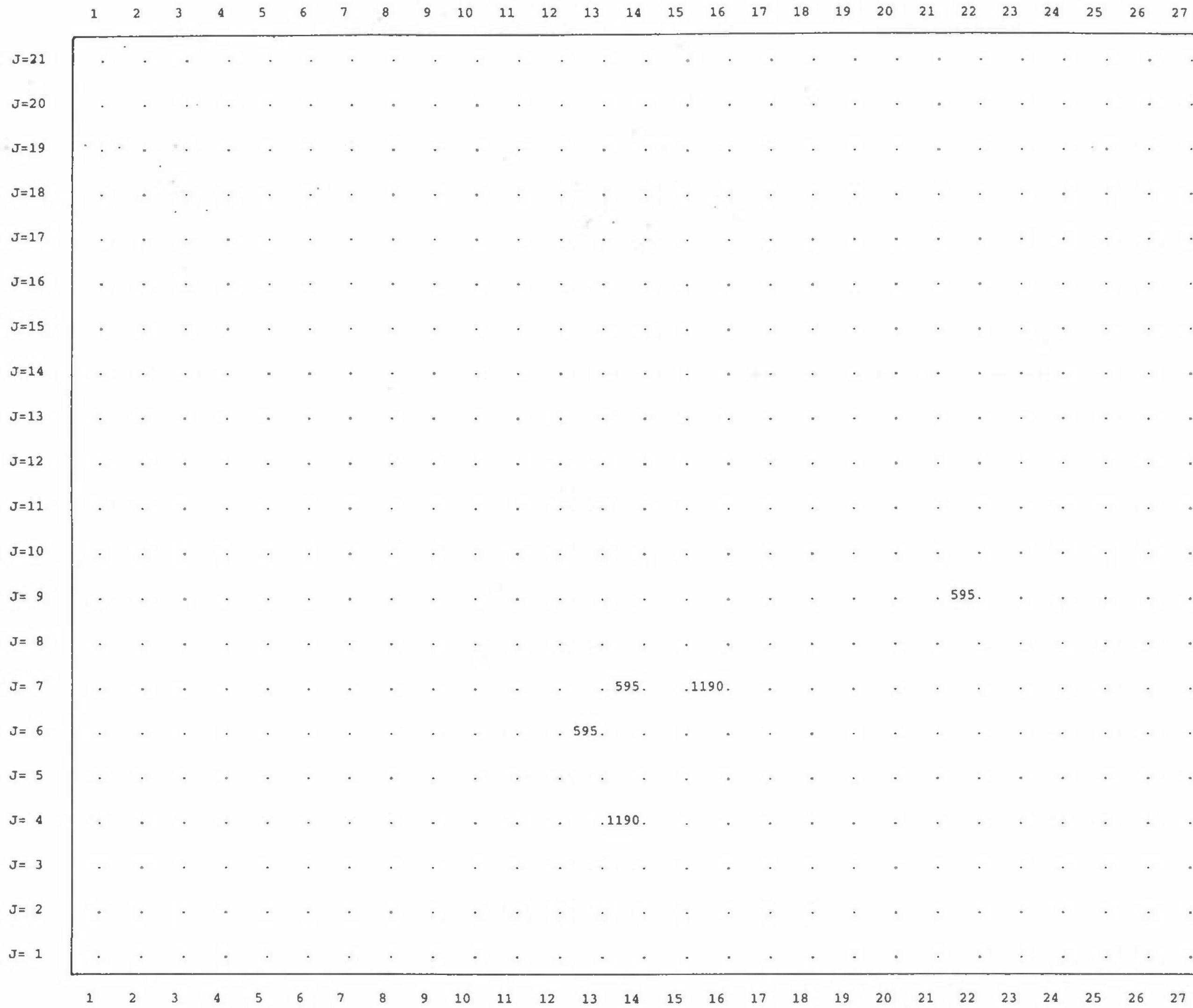

*Figure 9: Suspended particle ("TSP") emissions from **Chinese (Hoffman Bhatta) brick kilns**, Kathmandu Valley.*
Winter half year emissions, 1992/93. Constant emissions, calculated as kg/hour.
Unit: 10^{-2} kg/hour per km^2 grid.

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Appendix 4

Emission Factors, Particles

Contents

Emission Factors, Particles

1. Introduction

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

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

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

2. Motor vehicles

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

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

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

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

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

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

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

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

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

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

Comments

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

Gasoline:

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

Diesel:

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

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

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

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

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

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

3. Fuel combustion

Oil

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

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

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

S: Sulphur content in % by weight

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

4. References

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Appendix 5

Spreadsheet for Calculating Effects of Control Measures on Emissions

1 Emissions spreadsheet

The spreadsheet is shown in Figure 1. (Example: TSP emissions, Kathmandu Valley, Base Case Scenario, 1993.) Figure 2 shows emission contributions in absolute and relative terms.

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

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

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

The columns and rows of the worksheet are as follows:

Columns

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

Emissions spreadsheet, Kathmandu Valley
TSP, Base case, 1993

	Emission factor	Amount	Base-case Emissions	Control measures			Modified emissions	Relative emissions per category	Relative emissions total
POINT SOURCES									
	q (kg/t)	F (10E3 t/a)	qF (tonnes)	fq	fF	f-	qF fq fF f (10E3 tonnes)	(dqF fq fFf) (percent)	(dqF fq fFf)tot (percent)
Himal Cement Dry kiln			2000	1.00	1.00	1.00	2000		33.3
Clinker Cooler			0	1.00	1.00	1.00	0		0.0
Dryers, grinders, etc.			4000	1.00	1.00	1.00	4000		66.7
Quarry			0	1.00	1.00	1.00	0		0.0
			0	1.00	1.00	1.00	0		0.0
			0	1.00	1.00	1.00	0		0.0
Sum large point sources			**6000**				**6000**		**100.0**
Modified emissions/emissions, point sourc.							1		
DISCRETE AREA SOURCES									
Local Brick									
Chinese kilns		146.0		1.00	1.00	1.00	0.00	0.0	0.0
Coal	20.00	9.1	182.00	1.00	1.00	1.00	182.00	3.5	1.7
Bull Trench kilns			5000.00	1.00	1.00	1.00	5000.00	96.5	47.3
Coal		42.0		1.00	1.00	1.00	0.00	0.0	0.0
Fuel wood		5.7		1.00	1.00	1.00	0.00	0.0	0.0
Other (mainly rice husk)		15.8		1.00	1.00	1.00	0.00	0.0	0.0
Sum discrete area sources			**5182.00**				5182	**100.0**	**49.0**
Modified emissions/emissions, discr. area sourc.							1		
DISTRIBUTED AREA SOURCES									
Vehicles	q (g/km)	T (10E6 vehkm/a)	TSP (t/a)	fq	fT	f-	qT fq fTf (10E3 tonnes)	(dqT fq fTf) (percent)	(dqT fq fTf) (percent)
Gasoline exhaust									
Cars, taxis	0.20	192	38.4	1	1	1	38.4	6.7	0.4
3-wheelers (TC)	0.50	135	67.5	1	1	1	67.5	11.8	0.6
2-wheelers (MC)	0.50	215	107.5	1	1	1	107.5	18.8	1.0
Sum gasoline		542	213.4				213.4		2.0
Modified emissions/emissions, gasoline							1.0		
Diesel exhaust									
Jeeps	0.9	76	68.4	1	1	1	68.4	12.0	0.6
Minibuses	1.5	15	22.5	1	1	1	22.5	3.9	0.2
Buses	3.0	15	45.0	1	1	1	45.0	7.9	0.4
Trucks	3.0	38	114.0	1	1	1	114.0	20.0	1.1
Tractors	0.9	24	21.6	1	1	1	21.6	3.8	0.2
3-wheelers (TC)	1.5	57	85.5	1	1	1	85.5	15.0	0.8
Sum diesel		225	357.0				357.0		3.4
Modified emissions/emissions, diesel							1.0		
Sum total vehicle exhaust		767	570.4				570.4	100.0	5.4
Modified emissions/emissions, total vehicle exhaust							1.00		
Resuspension from roads	2.0	767	1534.0	1	1	1	1534.0		14.5
Sum total vehicles (exh.+resusp.)			**2104.4**				2104.4		19.9
Modified emissions/emissions, total vehicles (exh. + resusp.)							1.00		
Fuel combustion	q (kg/t)	F (10E3 t/a)	qF (tonnes)	fq	fF	f-	qF fq fF f (10E3 t/a)	(dqF fq fFf)fuel (percent)	(dqF fq fFf)tot (percent)
Iindustrial/commercial									
Diesel HSD	0.28		0.00	1.00	1.00	1.00	0.00	0.0	0.0
Fuel oil LDO			0.00	1.00	1.00	1.00	0.00	0.0	0.0
Coal	10.00	4.8	48.00	1.00	1.00	1.00	48.00	1.7	0.5
Charcoal	20.00	1.0	20.00	1.00	1.00	1.00	20.00	0.7	0.2
Fuelwood	3.60	17.2	61.92	1.00	1.00	1.00	61.92	2.1	0.6
Agri. residue	10.00	45.0	450.00	1.00	1.00	1.00	450.00	15.5	4.3
Kerosene/LPG	0.06	1.0	0.06	1.00	1.00	1.00	0.06	0.0	0.0
Sum industrial			579.98				579.98		5.5
Modified emissions/emissions, industrial							1.00		
Domestic									
Fuel wood	15.00	122.1	1831.50	1.00	1.00	1.00	1831.50	63.0	17.3
Agri. residue	10.00	45.4	454.00	1.00	1.00	1.00	454.00	15.6	4.3
Anim. waste	10.00	3.0	30.00	1.00	1.00	1.00	30.00	1.0	0.3
Kerosene	0.06	35.0	2.10	1.00	1.00	1.00	2.10	0.1	0.0
LPG	0.06	4.0	0.24	1.00	1.00	1.00	0.24	0.0	0.0
Charcoal	20.00	0.5	10.00	1.00	1.00	1.00	10.00	0.3	0.1
Sum domestic			2327.84				2327.84		22.0
Modified emissions/emissions, domestic							1.00		
Sum fuel combustion			**2907.82**				**2907.82**	100.0	27.5
Modified emissions/emissions, fuel							1.00		
Miscellaneous	q	M	qM	fq	fM	f-	qM fq fM f	(dqM fq fMf)misc (percent)	(dqM fq fMf)tot (percent)
Refuse burning	37	10.4	384.8	1	1	1	384.8	100.0	3.6
Construction									
Resuspension, open surfaces									
Sum miscellaneous			**384.8**	1	1	1	**384.80**	100.0	3.6
Modified emissions/emissions, misc.							1.00		
Sum total distributed area sources			**10579.02**				10579.02		100.00
Modified emissions/emissions, distr. area sources							1.00		

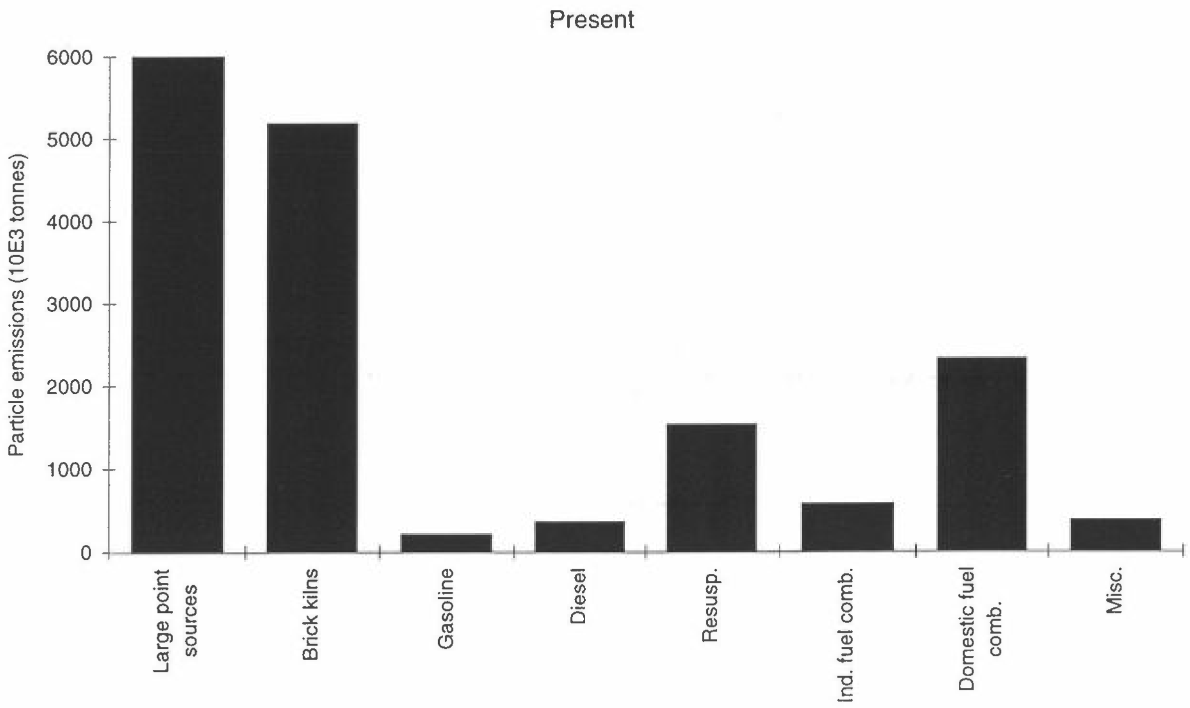
Figure 1: URBAIR spreadsheet for emissions calculations.

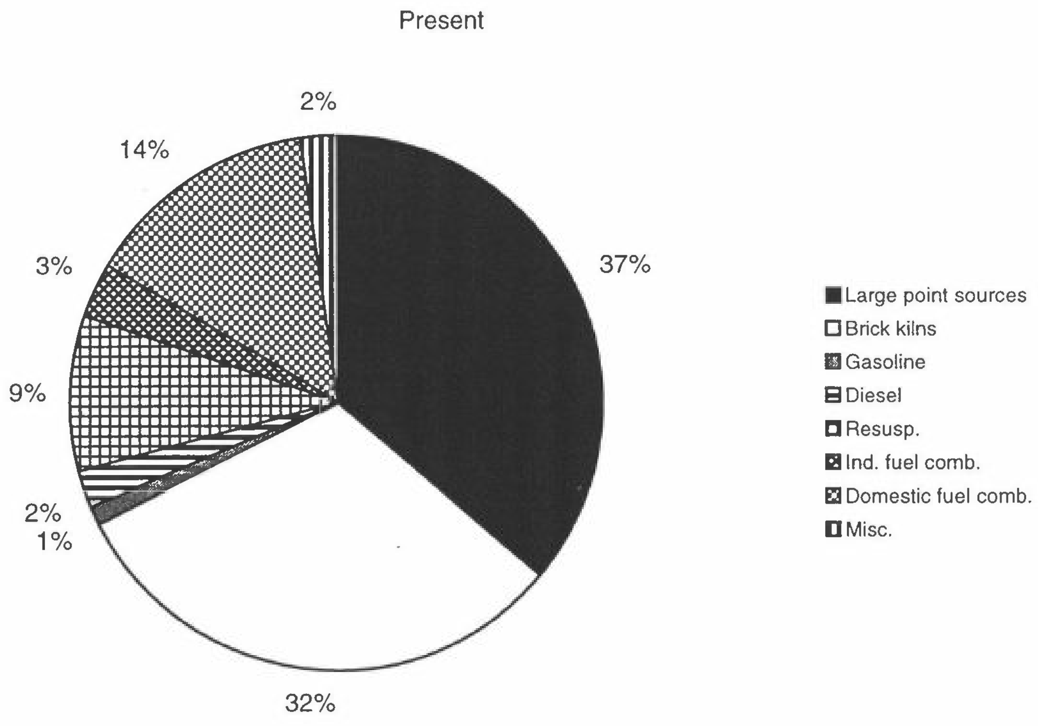
e)	qFfqfFf-	Modified emissions, due to control measures.
f)	d(qFfqfFf-)	Relative emission contributions from each source, per source category: - vehicles - fuel combustion - industrial processes - miscellaneous
g)	d(qFfqfFf)	Relative emissions contributions, all categories summed.

Rows

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

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


Present
Particle emissions (10E3 tonnes)
6000
5000
4000
3000
2000
1000
0
Large point sources
Brick kilns
Gasoline
Diesel
Resusp.
Ind. fuel comb.
Domestic fuel comb.
Misc.


Present
2%
14%
3%
9%
2%
1%
37%
32%
Large point sources
Brick kilns
Gasoline
Diesel
Resusp.
Ind. fuel comb.
Domestic fuel comb.
Misc.

Appendix 6

Project Descriptions, Local Consultants

Contents

Project Description regarding Air Quality Assessment

18 May 1993 ANNEX 2

Project Description

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

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

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

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

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

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

- Dispersion modelling: Reports describing studies and results

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

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

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

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

Project Description regarding Damage Assessment and Economic Valuation

Project Description

This Project Description describes the work to be carried out under the Contract of 19 May 1993 between Norwegian Institute for Air Research (NILU) and [redacted].

URBAIR

Topics for research

A. Physical Impacts

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

2. Decide on the acceptability of dose - effect relationships from USA (tables 5.7 - 5.9).
   a. Mortality: 10 µg/m³ TSP leads to 0.682 (range: 0.48-0.89) percentage change in mortality.
   b. Work loss days (WLD): 1 µg/m³ TSP leads to 0.00145 percentage change in WLD.
   c. Restricted activity days (RAD): 1 µg/m³ TSP leads to 0.0028 percentage change in RAD per year.
   d. Respiratory hospital diseases (RHD): 1 µg TSP leads to 5.59 (range: 3.44-7.71) cases of RHD per 100,000 persons per year.
   e. Emergency room visits (ERV): 1 µg/m³ TSP leads to 12.95 (range: 7.1-18.8) cases of ERV per 100,000 persons per year.
   f. Bronchitis (children): 1 µg/m³ TSP leads to 0.00086 (range: 0.00043-0.00129) change in bronchitis.
   g. Asthma attacks: 1 µg/m³ TSP leads to 0.0053 (range: 0.0027-0.0079) change in daily asthma attacks per asthmatic person.
   h. Respiratory symptoms days (RSD): 1 µg/m³ TSP leads to 1.13 (range: 0.90-1.41) RSD per person per year.
   i. Diastolic blood pressure (DBP): change in DBP = 2.74 ($[\text{Pb in blood}]_{new}$ - $[\text{Pb in blood}]_{old}$) with [Pb in blood] is blood lead level (µg/dl).
   j. Coronary heart disease (CHD): change in probability of a CHD event in the following ten years is $[1 + \exp - \{ - 4.996 + 0.030365(DBP_1)\}]^{-1}$ –

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

   k. Decrement IQ points: IQ decrement = 0.975* change in air lead (µg/m³).

Calculation example.

Let population be 10 million people.

Let threshold value of TSP be 75 µg/m³ (the WHO standard).

Let the concentration TSP be 317 µg/m³.

--> Concentration - threshold = 317 - 75 = 242 = 24.2 10 µg/m³.

--> Change in mortality = 24.2 * 0.682 = 16.5%.

Let crude mortality be 1% per year.

--> Crude mortality = 100,000 people per year.

--> Change in mortality due to TSP = 16.5% of 100,000 people = 16,500 people per year.

3. For those close -effect relationships that are acceptable, base value must be gathered, e.g.:

   a. crude mortality

   b. present work days lost

   etc.

B. Valuation

1. Mortality.

   a. Willingness to pay.

   In USA research has been carried out on the relation between risks of jobs and wages. It appeared that 1 promille of change in risk of mortality leads to a wage difference of ca. $1000. If this figure is applicable to all persons of a large population (say 10 million), the whole population values 1 promille change in risk of mortality at $1000 * 10 * 10^6 = $ 10 billion. An increase in risk of 1 promille will lead to ca. 10,000 death cases, so per death case the valuation is $ 1 million. It should be decided if in other countries, e.q. cities, this valuation should be corrected for wage differences (e.g. if the average wage is 40 times lower than in USA, the valuation of 1 death case is $25,000). If this approach is acceptable, the only information needed is average wage.

   b. Production loss.

   If the approach of willingness to pay is not acceptable, the alternative is valuing human life through production loss, i.e. foregone income of the deceased. Again, the information needed is average wage. Moreover, information is needed on the average number of years that people have a job. However, those without a job should also be assigned a value. An estimate of the income from informal activities can be an indication. Otherwise a value derived from the wages (e.g. half the average wage) can be a (somewhat arbitrary) estimation.

2. Morbidity.

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

3. Willingness to pay to prevent a day of illness.

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

4. IQ points.

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

C. Other impacts

1. Buildings.

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

2. Monuments.

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

D. Remark

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

E. Technological Reduction Options

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

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

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

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

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

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URBAIR Urban Air Quality Management Strategy in Asia KATHMANDU VALLEY Appendices	NILU PROJECT NO. O-92117
AUTHOR(S) Prepared by Steinar Larssen, Frederick Gram and Ivar Haugsbakk Norwegian Institute for Air Research (NILU), Kjeller, Norway Huib Jansen and Xander Olsthoorn Instituut voor Milieuvraagstukken (IVM) Vrije Universiteit, Amsterdam, the Netherlands Anil S. Giri, Royal Nepal Academy of Science and Technology (RONAST) Kathmandu, Nepal Madan L. Shrestha, Dpt. of Hydrology and Meteorology, Min. of Water Resources, Kathmandu, Nepal	CLASSIFICATION * A CONTRACT REF. Mr. Jitendra Shah

REPORT PREPARED FOR: International Bank for Reconstruction and Development (the World Bank)
Asian Techn. Dept., 1818 NW, Wash. D.C., 20433 USA

ABSTRACT

The main 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.

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

NORWEGIAN TITLE

KEYWORDS

Air Pollution	Management	Kathmandu Valley

ABSTRACT (in Norwegian)

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