Health Impacts of Kathmandu’s Air Pollution

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ABBREVIATIONS & ACRONYMS

ARI	Acute Respiratory Infection
BS	*Bikram Sambat* (Nepali year)
CEN	Clean Energy Nepal
CO	Carbon Monoxide
COH	Coefficient of Haze
COPD	Chronic Obstructive Pulmonary Disease
CO_2	Carbon Dioxide
CSE	Centre for Science and Environment
CWIN	Child Workers in Nepal
DANIDA	Danish International Development Agency
DHM	Department of Hydrology & Meteorology
DOTM	Department of Transport Management
ENPHO	Environment & Public Health Organization
ESPS	Environment Sector Programme Support
EV	Electric Vehicles
HMG	His Majesty's Government
HSU	Hartridge Smoke Unit
HC	Hydrocarbons
ITDG	Intermediate Technology Development Group
KCF	Kanti Children's Hospital
KEVA	Kathmandu Electric Vehicle Alliance
KVEECP	Kathmandu Valley Vehicle Emission Control Project
LPG	Liquefied Petroleum Gas
MOPE	Ministry of Population and Environment
$\mu g/m^3$	microgram per cubic meter
NAAQS	National Ambient Air Quality Standards
NESS	Nepal Environment and Scientific Services
NOx	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
OPD	Out-Patient Department
O_3	Ozone
PADCO	Planning and Development Collaborative International
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PH	Patan Hospital
PM	Particle Matter
PM10	Particle Matter less than 10 microns
PM2.5	Particle Matter less than 2.5 microns
ppm	Parts per million
SPM	Suspended Particulate Matter
SOx	Oxides of Sulphur
SO_2	Sulphur Dioxide
TSP	Total Suspended Particles
TUTH	Tribhuwan University Teaching Hospital
USEPA	United States Environment Protection Agency
VTP	Valley Traffic Police

WHO	World Health Organization

EXECUTIVE SUMMARY

Many international studies have shown that there are serious health risks associated with air pollution. According to the World Health Organization (WHO), air pollution is responsible for increases in outpatient visits due to respiratory and cardiovascular diseases, hospital admissions and mortality. WHO estimates that globally about 3 million people die each year due to air pollution out of which 800,000 premature deaths result from out door air pollution.

These figures indicate that Kathmandu's air quality is also likely to have serious public health implications. This study aims to compile and analyse available information on the health effects of Kathmandu's air pollution to support decision-makers as well as the public in understanding the relationship between pollution and health.

Fine Particles are Dangerous

Internationally, experts, as well as WHO, have recognized that fine particles are the most dangerous air pollutants as they can enter deep into the human body and they are often coated with toxic substances. WHO says there is not safe limit for the concentration of PM10 (particle matter less than 10 microns) or PM2.5 (particle matter less than 2.5 microns) in the air as even at low levels they can cause harm to human health. The main source of fine particles is combustion of fossil fuel, such as vehicle emission.

Diesel exhaust is especially deadly because diesel engines emit a large number of particles and more than 90 percent of these particles are less than 1 micron, which means that most of the particles go straight into the lungs. Scientists have also discovered the most dangerous carcinogen found till now in diesel exhaust.

Kathmandu's Polluted Air

Several studies have shown that Kathmandu's air is very polluted, particularly in the dry winter months and that the level of pollution is increasing. In the dry months, along busy roadsides, the PM 10 level is above the national standard on 99 percent of the days. Comparison of data collected by ENPHO in 1993 to data generated by the recently established air quality monitoring stations, indicates that the PM10 level in Putali Sadak has tripled in the last 10 years.

Studies have also indicated that vehicles are the main sources of air pollution in Kathmandu. Until recently, Himal Cement, brick kilns and vehicle exhaust were the main sources of pollution. Now, with the closure of Himal Cement and the introduction of environment-friendly brick kilns, vehicles are the main culprits.

The main reasons for the high level of vehicular emission are the large number of vehicles on congested streets, poor quality vehicles, poor quality fuels and lubricants, weaknesses in the emission inspection & maintenance system, and ineffective transport management. Over the past five years, number of vehicles in the Valley have been increasing at a rate of about 17 percent per year, which is almost four times higher than the population growth rate in the valley. Although the new vehicles are of EURO I standard, there are many old vehicles that emit large amounts of pollution and even the new vehicles produce emission when they are not maintained properly.

A study done by MOPE/ESPS indicates that PM10 emission from vehicles has increased by more than four times between 1993 and 2001 and now vehicle exhaust is responsible for 42 percent of the total PM10 emission in the Valley.

Results of emission test of in-use vehicles indicate that approximately 25 percent of the vehicles fail to meet the standards. Ensuring that "gross polluters" such as these do not operate in Kathmandu can have a significant impact on air quality.

Electric vehicles (EVs) can play a very important role in reducing emission loads in Kathmandu. Operating the existing trolley bus system can save approximately 3 tons of potentially carcinogenic particles from being released into Kathmandu's air every year. Although zero-emission EVs are very suitable for Kathmandu and the government says it wants to promote EVs, in practice EVs are not getting sufficient support and their numbers are decreasing. Therefore, a great opportunity to clean up Kathmandu's air is not being fully utilized.

Health Effects of Air Pollution

As the most common route for pollutants to enter the human body is by inhalation, the most common effect of air pollution is damage to the respiratory system. Exposure to air pollutants, can overload or break down natural defense mechanisms in the body, causing or contributing to respiratory diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Air pollution can also have adverse impacts on other important systems such as cardiovascular system and central nervous system.

A recent study indicates that a mere 10 $\mu g/m^3$ increase in PM2.5 can increase the risk of lung cancer by 8 percent, cardiopulmonary deaths by 6 percent and all deaths by 4 percent.

Several studies have shown that children, elderly and people with lung and heart diseases are more vulnerable to the health effects of air pollution.

Health effects of air pollution can be estimated by conducting epidemiological studies or experiments on animals and humans. Results from various epidemiological studies have been used to develop dose-response relationships to estimate the increase in morbidity or mortality due to increase in pollution level. Although the use of these relationships has its limitations, it can be valuable in providing a quantitative estimate of health effects.

Health Impacts in Kathmandu

Although no long-term epidemiological studies have been conducted in Kathmandu, a few studies have been done by conducting preliminary medical examination of a group of exposed population or by using dose-response relationships that have been developed elsewhere. These indicate that the health impacts of Kathmandu's air pollution can be quite severe.

A study done by World Bank estimated impacts on mortality and morbidity due to PM10 levels in 1990. The study estimated that Kathmandu's PM10 resulted in 84 cases of excess mortality, 506 cases of chronic bronchitis, 4,847 cases of bronchitis in children and 18,863 asthma attacks per year. Overall, Kathmandu's residents experienced over 1.5 million respiratory symptom days per year.

An analysis of the records of 369 Chronic Obstructive Pulmonary Disease (COPD) patients and 315 control patients admitted to Patan Hospital from April 1992 to April 1994 showed that the odds of having COPD are 1.96 times higher for Kathmandu Valley residents compared to outside valley residents. COPD, which is an irreversible damage of the lungs, is one of the main health effects of air pollution. The study also stated that over the past decade the proportion of COPD patients had increased by more than four folds and that COPD was the number one killer of adult patients in the hospital.

An analysis of hospital records from three major hospitals in Kathmandu indicates that the number of COPD patients admitted to hospitals, as well as the percent of COPD patients as a percentage of total medical patients has increased significantly in the last ten years.

Hospital records also indicate that the number of COPD patients is highest in the dry winter months, which is also when air pollution in Kathmandu is at its peak. These figures clearly indicate that that Kathmandu's air pollution is damaging the respiratory systems of Kathmandu's residents.

Unlike COPD cases, hospital records in Kathmandu do not indicate a significant increase in the number of asthma patients over the past 10 years. Although air pollution is known to be one of the factors that exacerbate asthma, there are several other factors that can trigger asthma attacks.

A survey of 331 patients with respiratory illnesses visiting the out-patient and emergency departments of major hospitals in Kathmandu indicate that most of them are from Kathmandu valley and belong to the age group of 51 to 75. Approximately, 80 percent of the respondents said public transportation was their most common mode of transportation. Although the sample size was not large enough to draw concrete conclusions, the survey does indicate that patients visiting the hospitals with respiratory problems are mostly elder residents of Kathmandu valley who are regularly exposed to air pollution.

Using dose-response functions, this study estimates that reducing PM2.5 level in Kathmandu Valley by just half (by 47.4 $\mu g/m^3$), will reduce daily mortality by 7 percent and hospital admissions by 24 percent. Similarly, reduction of PM2.5 level in Kathmandu Municipality by half (by 63.4 $\mu g/m^3$), will reduce mortality by approximately 10 percent and hospital admissions by 32 percent.

Reducing the annual average PM10 level in Kathmandu to international standards (50 $\mu g/m^3$) will avoid over 2000 hospital admissions, over 40,000 emergency room visits, over 135,000 cases of acute bronchitis in children, over 4,000 cases of chronic bronchitis and half a million asthma attacks. Overall, this means over 5 million restricted activity days and 32 million days with respiratory symptoms will be avoided. Currently the annual average PM10 level in Kathmandu is estimated to be 148 $\mu g/m^3$.

Financial Implications of Health Impacts

Although it is clear that pollution related health effects result in substantial direct as well as indirect financial losses, valuation of health effects (mortality and morbidity) in monetary terms is very difficult and controversial issue because of the many uncertainties and assumptions involved in this process.

A World Bank study has estimated the total cost of the health impacts of PM10 in Kathmandu in 1990 to be approximately Rs. 210 million. The study also found that reduction of vehicle exhaust emission is the most effective measure to reduce health damage. The study estimated that reduction of one kg of vehicle emission will result in saving Rs. 341 in terms of reduced health damage, whereas the saving due to reduction in domestic emission, which was next in the order of importance, was only Rs. 185.

Preliminary estimates indicate that reducing the annual average PM10 levels in Kathmandu to international standards (50 $\mu g/m^3$) will save approximately Rs. 30 million in just hospital admission costs. A previous study by World Bank showed that hospital admission cost is only 0.02 percent of the total cost of health effects of air pollution. Therefore, it is safe to assume that billions of rupees can be saved by the lowering Kathmandu's PM10 levels to that of international standards.

This clearly shows that the cost of pollution is very high and reducing vehicle emission is the most effective way of reducing this huge economic burden.

Recommendations

This study therefore strongly recommends immediate action to control Kathmandu's air pollution. MOPE has prepared national ambient air quality standards and expressed its commitment to meet these standards within three years. This is ambitious but not impossible, if MOPE can come up with a comprehensive action plan and the willingness to implement this action plan.

As fine particles are the main problem in Kathmandu's air, any future programme to control Kathmandu's air should focus on reducing concentration of fine particles. This means that diesel vehicles, one of the main sources of fine particles, need to be discouraged. Similarly, the rapid growth in the number of private vehicles needs to be controlled and "gross polluters" need to be taken off the road.

As Kathmandu is very suitable for the use of electric vehicles, these zero-emission vehicles should be promoted. An effective public transportation system based on EVs is the best alternative for polluting diesel vehicles and private vehicles in Kathmandu.

Although there are plenty of evidences linking air pollution to health effects, some further studies on health effects of air pollution should be done mainly to stimulate action from policy makers as well as the public. Simultaneously, a public awareness campaign is required to inform the public and decision-makers on the hazards of air pollution and possible mitigation measures.

1 INTRODUCTION

1.1 Background

Deterioration of ambient air quality has significant health implications. According to the World Health Organization (WHO), air pollution is responsible for increases in outpatient visits due to respiratory and cardiovascular diseases, hospital admissions, and mortality. WHO estimates that globally, 4 to 8 percent of pre-mature deaths are due to exposure to particulate matter in ambient and indoor environment. Similarly, 20 to 30 percent of all respiratory diseases appear to be cased by air pollution (WHO, 2000).

These figures indicate that the high level of pollution in Kathmandu's air is also having adverse impacts on the health of its residents. In fact, one can often feel the impacts of the pollution while walking or biking down a polluted street in Kathmandu. However, defining the nature of these health impacts and quantifying the impacts in terms of number of excess mortality and morbidity due to various diseases that have been caused by the air pollution is a more difficult task. Assessment of financial implications of these impacts then becomes even more difficult and controversial. The difficulty mainly arises because of the lack of reliable data related to air quality, health status, and hospital visits, and the lack of appropriate tools/models to analyse available data.

There is no doubt that the problem of air pollution in Kathmandu needs to be addressed immediately and technologies such as electric vehicles need to be promoted. The recently established air quality monitoring stations in Kathmandu are very much needed in collecting data on air quality. However, technical data on air quality alone is not enough to grab the attention of policy makers and the public. Relating the quality of the air to something that people are more sensitive to and can relate more easily to is essential to stimulate immediate action. In this regard, it becomes essential to explore the impact of air pollution on the health of the people and the economy, which are two issues that most people are genuinely concerned about.

A few studies have tried to estimate the health impacts of Kathmandu's air pollution. There is a need to evaluate these previous studies and also analyse data from hospitals and conduct epidemiological studies to get a better understanding of the nature and significance of the health impacts of Kathmandu's air pollution. This study aims to partially fulfill this need.

1.2 Objectives

The main objective of this study is to analyse the impacts of Kathmandu's air pollution on the health of people. The specific objectives are as follows:

- Identify impacts of vehicular pollution on human health
- Review previous studies done on Kathmandu's air pollution and its health impacts.
- Estimate the impact of the closure of Kathmandu's trolley bus system on pollution levels.
- Analyse hospital records to identify annual and seasonal variations and trends in respiratory illnesses and its relation to pollution levels.
- Conduct a short survey to gather information on patients with respiratory illnesses visiting outpatient and emergency departments of major hospitals.
- Evaluate financial implications of health impacts.

1.3 Methodology

The following activities were done in the process of conducting this study:

Review of literature

Available literature on the health impacts of air pollution, particularly in Kathmandu and other cities in the region were reviewed. The list of literature reviewed for this study is presented in the Reference Section.

Consultation with Experts

National and international experts were consulted to gather their opinion. In this process, the Team Leader attended a workshop in Delhi organized by Centre for Science and Environment (CSE) and CEN together with Ministry of Population and Environment (MOPE)'s Environment Sector Programme Support (ESPS) project organized a workshop to discuss the topic of health effects of air pollution.

Analysis of Kathmandu's Air Quality Data

The study team collected data from past efforts to monitor Kathmandu's air quality, as well as recent data generated by the six monitoring stations setup by MOPE/ESPS and analysed them to draw conclusions on the current status of Kathmandu's air quality and trends.

Estimate Vehicle Contribution to Air Pollution and the Impact of Trolley Bus

Based on available information, this study has assessed the contribution of vehicle emissions to Kathmandu's air pollution and also calculated the impact of the Tripureshwor-Suryabinayak Trolley Bus service.

Analysis of Hospital Records

This study analysed records of patients admitted to four major public hospitals in Kathmandu (Bir Hospital, Tribhuwan University Teaching Hospital, Patan Hospital, and Kanti Children's Hospital) over the past 10 years to see the trend in the number of people admitted with diseases related to air pollution. Although there are many diseases that can result from air pollution, the study focused primarily chronic obstructive pulmonary disease (COPD) and asthma.

Survey of Hospital Patients

A two-week survey of patients with respiratory problems visiting the out-patient and emergency departments of 3 major hospitals were conducted to get preliminary information on the background of these patients. Although the sample size was small due to the short duration of the survey, it did provide some general information of patients visiting the public hospitals.

Use of Dose-Response Relationships

Dose-response relationships developed by Ostro (1996) and WHO (2000) were used to estimate the health benefits of reducing PM10 levels in Kathmandu. In this process, the annual average PM10 concentration in the Valley was also calculated based on results obtained so far from the six monitoring stations in Kathmandu.

1.4 Scope & Limitations

Assessing health impacts of air pollution is a complex and sometimes controversial issue. Although many international studies have established certain health risks associated with different substances that cause air pollution, there are very few studies done in developing countries. This is mainly because of the difficulty in obtaining useful data and the time and cost associated with such studies. This study is definitely not a complete or comprehensive assessment of health impacts of Kathmandu's pollution or an academic research on the topic. It is a compilation of available information mainly aimed at supporting decision-making and raising public awareness on air quality in Kathmandu. Some of the main limitations of this study are as follows:

1. Because of the short duration (two months) of the study, it only focuses on compiling available materials on this issue and analysing them. This study has not conducted any major primary research on this topic.

2. Hospital records at public hospitals in Kathmandu are usually poorly managed and are often difficult to obtain. Although this study has obtained data directly from the information recording sections of the hospitals, it was not possible to obtain some data and sometimes the data may not reflect the actual situation. For example, there are many respiratory diseases and one patient may be suffering from more than one but hospitals only record the final “primary diagnosis” which refers to the principal acute reason for admission. Similarly, according to Dr. Mark Zimmerman at the Patan Hospital, COPD includes emphysema, chronic bronchitis and bronchiectasis with airway obstruction. This definition of COPD may be slightly different in other hospitals.

3. This study only analysed records of patients who had been admitted to the hospitals as records of other patients (outpatients and emergency patients) were not available.

4. The data obtained for this study is only from the large public hospitals. These days, many well-to-do Kathmandu residents prefer to visit private clinics or nursing homes. Therefore, the data from the major public hospitals may not give the complete picture.

5. As the survey of patients with respiratory illnesses was only done for two weeks, the number of samples is small and this does not permit a statistical analysis of the results. The results of the survey are therefore only meant to provide some general information on patients visiting outpatient department (OPD) and emergency departments of hospitals.

6. This study has used dose-response relationships that have been developed elsewhere to obtain quantitative estimates on health effects of Kathmandu's air pollution. The relationships may be a bit different for the case of Kathmandu but in the absence of local epidemiological studies, it is not possible to derive more accurate dose-response functions.

2 KATHMANDU'S AIR QUALITY

2.1 Why is Kathmandu Vulnerable to Air Pollution?

Although all major cities in the developing world suffer from air pollution, Kathmandu Valley is especially vulnerable to this problem. Natural conditions, such as the Valley's bowl shaped topography and climate, as well as man-made conditions that have resulted in rapid and haphazard growth, are responsible for this vulnerability.

Topography

Kathmandu is located in a valley in the mid-hills of Nepal. The Valley floor is relatively flat with an elevation of 1350 meters but it is surrounded by hills that rise up to 1950 meters. The bowl like topography restricts air movement and the pollutants generated in the Valley are often trapped within the valley. There are only a few passes where air enters or leaves the Valley. The relatively high elevation of the Valley also means that vehicles tend to generate more emissions in Kathmandu than at a place with a lower elevation.

Meteorology

The meteorological conditions in the Valley also make it vulnerable to air pollution. In the winter, due to a phenomenon called temperature inversion, cool air at night and early morning gets trapped near the ground under a layer of warm air. There is usually very little air circulation in the valley till afternoon and as a result, the pollutants remain trapped near the ground for a long time.

Although Kathmandu receives 1400 to 1900 mm of rain per year, about 80 percent of this rain falls during the monsoon season, which lasts three to four months between June to September. As a result, the remaining eight months are quite dry and this is when there is maximum pollutants in the air and very little rain to flush them down.

Kathmandu's Growth

The population of Kathmandu has been growing rapidly and there has been very little effort to control and manage this growth. Between 1991 and 2001, the population of the three districts of Kathmandu, Bhaktapur and Lalitpur grew by 56 percent, which is a rate of 4.5 percent per annum. This is more than two times the growth rate of the country as a whole, which was 2.2

percent. In 1991, 56 percent of the valley's population lived in cities, but ten years later this number had increased to 61 percent.

Table 2.1 Population Growth in Kathmandu Valley

DISTRICT	POPULATION (THOUSANDS)				ANNUAL GROWTH (%)		
	1971	1981	1991	2001	'71-'81	'81-'91	'91-'01
Kathmandu	354	427	668	1082	1.9	4.6	4.9
Lalitpur	122	165	222	338	3.1	3.0	4.3
Bhaktapur	110	144	173	225	2.7	1.8	2.7
Total	586	736	1063	1645	2.3	3.7	4.5

The rapid growth in population and expansion of the urban area is mainly due to migration from rural areas in search of employment and other facilities that a large city like Kathmandu offers. Years of Kathmandu centric development and the lack of appropriate programmes to address the critical issue of rural poverty are responsible for this situation. According to the 2001 census, 44.1 percent of the people living in the city of Kathmandu were not born there or are first generation migrants. This figure is very high compared to 30.1 percent first generation migrants in Nepal's urban areas as a whole.

Although urbanization itself is not bad because urban areas generate employment opportunities and economic development, unmanaged urban growth can invite many problems. In the case of Kathmandu, weak public institutions have been unable to manage the rapid urban growth and this has resulted in a host of problems. These include dense settlements with very little open space, mushrooming of polluting industries, poor road network, unmanaged transportation system and the lack of environment quality standards and legislation. All these conditions make the residents of Kathmandu very vulnerable to air pollution.

2.2 What is Causing Kathmandu's Air Pollution?

Past studies have indicated that the main causes of Kathmandu's air pollution are industries and vehicles. Some other sources are domestic cooking, refuse burning and resuspended dust on unpaved roads. The exact contribution of these sources towards air pollution is however not clear although some studies have tried to calculate emission from various sources.

In 1993, Shrestha and Malla estimated emission from different energy uses in Kathmandu and found that transportation sector was by far the largest emitter of pollutants. It was responsible for 57 percent of the total emissions, 60 percent of CO emissions and 79 percent of HC emissions. The study, however, estimates that the transport sector is responsible for only 7 percent of the particles.

Table 2.2 Estimated Emissions from Different Energy Uses in Kathmandu in 1993 (tons)

SOURCE	TSP	CO	HC	NO_X	SO_2	TOTAL
Transport	475	23693	11024	1353	133	36678
Household	2382	9867	1281	213	503	14246
Industrial	3574	5220	1492	628	1349	12263
Commercial	24	234	11	5	3	277
Total	6455	39014	13808	2199	1988	63464

Source: Shrestha & Malla, 1996

Adhikari (1997) estimated the total emission from the transportation sector in 1996 to be 31,378 tons. Of this, petrol vehicles contributed 90 percent of the total emissions and diesel vehicles contributed 10 percent. Diesel vehicles, which consisted of 12.5 percent of the total operating vehicle fleet in the valley, contributed more particles, NOx and SO_2, while petrol vehicles emitted more CO and HC.

A study done by the World Bank estimated that the contribution of vehicle exhaust to TSP was only 3.5 percent in 1993. In comparison, the contribution of Himal Cement, brick kilns, domestic fuel combustion and road resuspension towards the total TSP load in Kathmandu were 36 percent, 31 percent, 14 percent and 9 percent respectively. (See Section 3.3 for details)

Ten years later, however the situation in Kathmandu is quite different. In the past 10 years, Himal Cement has closed, the number of brick kilns have decreased and many people now use less polluting kerosene and LPG for cooking instead of biomass. In the mean time, the number of vehicles in the valley has more than tripled. This means that the emission from the vehicles has probably increased significantly, while emission from other sources has decreased over the past 10 years. As a result, vehicle is now the number one source of pollution in Kathmandu.

The main reason for the high level of vehicular emission is the large number of vehicles on congested streets, poor quality vehicles, poor quality fuels and lubricants, weaknesses in the emission inspection & maintenance system and a poorly managed transportation system.

2.3 Air Quality Monitoring in Kathmandu

Up until a year ago, assessment of Kathmandu's air quality had not been carried out systematically due to lack of an appropriate and specialised organisation to regularly monitor the Valley's air. As a result, historic data on Kathmandu's air quality is very scattered and irregular. Although occasional studies done by various agencies as well as individual researchers did provide some indicative pictures regarding major types of pollution, levels of pollutants and pollution prone areas, a comprehensive picture of the Valley's air pollution was lacking. These studies were usually of short duration and it is difficult to compare data from one study to another because of the difference in sampling equipment, sampling methodology and time of sampling.

Air quality monitoring started in Kathmandu in the 1980s with a few studies that indicated that air quality in Kathmandu might be a concern. Then in the 1990s, several studies were conduced by various government and non-government organizations. These studies attracted public attention to Kathmandu's deteriorating air quality and also stimulated some response from the government and donor agencies. Now in 2003, Kathmandu has a permanent air quality monitoring system, which is recording the status of ambient air at six different locations every day using state-of-the-art equipment and disseminating the results to the public.

First Attempts to Monitor Kathmandu's Air quality

Probably the first study on Kathmandu's air quality was done in 1980 when Bhattarai and Shrestha (1981) collected data on dust pollution at 18 spots. They concluded that the lead content in the collected samples were above reasonably accepted level of 0.6 parts of million (ppm). At the busy intersection of Maitighar, the lead level was found to be as high as 544 ppm.

In 1986, Davidson and Pandey showed that the concentration of SO_2, NO_3, organic carbon and lead at the curb of a busy Kathmandu street was comparable to those in urban areas in industrialised countries. In September 1987, a study done by the Ministry of Housing and Physical Planning measured the concentration of dust particles at three locations (Jhochhen, Singha Durbar and Lazimpat). The study concluded that the amount of dust in the air was between 6 to 11 times the relevant US standards. In 1990, CEDA carried out similar experiments in Kathmandu, Biratnagar and Pokhara and came up with similar conclusions.

Studies in the 1990s

In the early 1990s, more detail studies were done by ENPHO, UNDP funded Kathmandu Valley Vehicular Emission Control Project (KVVECP), World Bank funded URBAIR Project and several individual researchers as part of their thesis work.

In November 1992 and February 1993, ENPHO measured TSP, PM10, NO_2, SO_2, Pb, and CO at 20 sites in various parts of Kathmandu. In the first phase 24 hour averages were obtained from 9 sites and in the second phase, 9 hour averages were obtained from 11 sites. This provided important data on Kathmandu's air quality and also helped in identifying some of the pollution hotspots in Kathmandu.

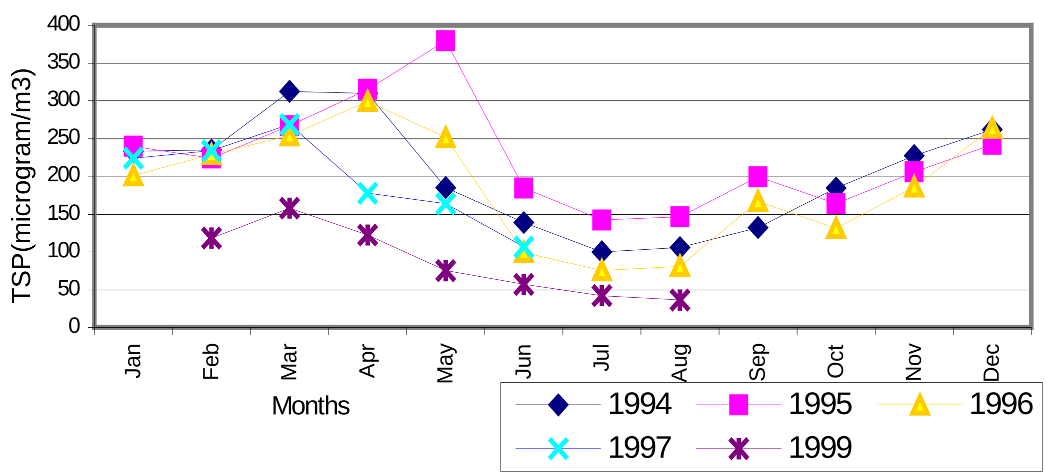
The study concluded that TSP was the main problem compared to the WHO guideline. In Phase 1, the average TSP measured was 308 $\mu g/m^3$ with the maximum concentration of 555 $\mu g/m^3$ recorded at Chabahil. This is much higher than the then WHO guideline of 120 $\mu g/m^3$. The PM10 levels recorded were also higher than WHO standards but to a lesser extent. The average PM10 recorded was 89 $\mu g/m^3$ while the maximum was 127 $\mu g/m^3$, again in Chabahil. The PM10 to TSP ratio was found to be only 0.28, which means that most of the particles were not small enough to enter the human body and affect human health. The concentration of gaseous pollutants (CO, NOx and SO_2) were below WHO standards (NESS, 2001).

Between September and December 1993, KVVECP measured TSP, PM10, NOx, SOx, CO, and Pb at 14 sites and came up with similar conclusions.

In a recent study done by ENPHO in Kalimati and Putalisadak, concentration of CO was recorded below 1 ppm and SOx concentration less than 13 $\mu g/m^3$ in both the sites throughout the monitoring period (ENPHO, 2001).

In 1994, the Department of Hydrology and Meteorology started taking TSP measurements at their office complex in Babar Mahal. Although only one parameter (TSP) was measured and there are several gaps in the data, the information generated by DHM is still valuable because this is the longest duration of air quality monitoring done till date. The results of TSP measurements by DHM are presented in Figure 2.1. The figure indicates that except for a few months during the monsoon (June, July, August), TSP levels are higher than the WHO guideline of 120$\mu g/m^3$. The data however do not indicate an increase in air pollution from 1994 to 1999 as would have been expected considering the increase in pollution sources such as vehicles.

Figure 2.1 Concentration TSP recorded by DHM



In 1996, the World Bank published its study on Air Quality Management in Kathmandu Valley. The study went further than just collecting data at different locations and utilized data collected by previous studies to calculate population exposure and spatial distribution of air pollution. In this process, the study used a dispersion model to estimate air pollution at different locations of the valley and the number of people exposed to various levels of pollution.

Between 1995 and 2000, several studies were done by NGOs and private labs such as LEADERS, NESS and Soil Test. Most of these studies were done as short-term campaigns to collect air quality data for a specific purpose rather than monitoring air quality in the long run.

In 1999-2000, with the support of DANIDA, NESS and NEFEJ monitored air pollution every day at different locations of Kathmandu and broadcasted the results over Radio Sagarmatha, a community FM station run by NEFEJ. Although only one-hour samples were taken the exercise was very useful in raising public awareness on the status of Kathmandu's air.

2.4 Air Quality Monitoring System

Recently, with the help of DANIDA, MOPE has established an air quality monitoring system in Kathmandu consisting of six monitoring stations. The number of monitoring stations is adequate for Kathmandu at present considering that the EU standard is at least one monitoring station per 250,000 people. The objectives of the monitoring system are to monitor compliance with air quality standards, assist in air quality research & management and raise public awareness. The locations of the monitoring stations are presented in Table 2.3.

Table 2.3 Locations of Monitoring Stations

LOCATION	CLASSIFICATION
Putali Sadak	Urban traffic
Patan Hospital	Urban traffic
Thamel	Urban traffic/residential
Bhaktapur	Urban background
TU, Kirtipur	Urban background
Matsyagaon	Valley Background

When the system is fully operational, each of the monitoring stations will be equipped to monitor PM10, PM2.5, TSP, CO, NO_2, SO_2 and Benzene. Right now, however, only PM10 is being monitored. The monitoring stations automatically collect 24-hour samples through the eight filters mounted three meter above ground. The samples are collected once a week and analysed in a local lab.

The results are placed on MOPE's web site (www.mope.gov.np), distributed to local media, and displayed on an electronic board in Basantapur. In order to make the results more understandable to the local people, MOPE is also considering to develop an Air Quality Index and to use simple descriptors with colour codes to describe the air quality. Proposed descriptors for air quality in Kathmandu are present in Table 2.4.

Table 2.4 Proposed Air Pollution (PM10) Descriptors for Kathmandu

DESCRIPTOR	COLOUR	PM10 (μg/m^3)
Good	Green	<60
Moderate	Yellow	60-119
Unhealthy	Orange	120-349
Very Unhealthy	Red	350-425
Hazardous	Purple	>425

MOPE has also developed National Ambient Air Quality Standards (NAAQS). The standard for PM10 is 120 μg/m^3. The government has said that it aims to meet the NAAQS within three years. Judging from the PM10 levels that have been recorded by the monitoring stations over the past year, achieving the 120 mark anytime soon will be major challenge, unless the government takes some bold decision and has the will to implement them.

Table 2.5 National Ambient Air Quality Standards

PARAMETER	UNITS	AVERAGING TIME	MAX. CONC.	TEST METHODS
TSP	µg/m3	Annual	-	
		24-hours*	230	High Volume Sampling
PM10	µg/m3	Annual	-	
		24-hours*	120	Low Volume Sampling
Sulphur Dioxide	µg/m3	Annual	50	Diffusive sampling based on weekly averages
		24-hours	70	To be determined before 2005.
Nitrogen Dioxide	µg/m3	Annual	40	Diffusive sampling based on weekly averages
		24-hours	80	To be determined before 2005.
Carbon Monoxide	µg/m3	8 hours	10,000	To be determined before 2005.
		15 minute	100,000	Indicative samplers **
Lead	µg/m3	Annual	0.5	Atomic Absorption Spectrometry, analysis of PM10 samples***

		24-hours	-	
Benzene	µg/m3	Annual	20	Diffusive sampling based on weekly averages
		24-hours	-	

*Note: 24 hourly values shall be met 95% of the time in a year. 18 days per calendar year the standard may be exceeded but not on two consecutive days.
**Note: Control by spot sampling at roadside locations: Minimum one sample per week taken over 15 minutes during peak traffic hours, i.e. in the period 8am – 10am or 3pm – 6pm on a workday.
***Note: If representativeness can be proven, yearly averages can be calculated from PM10 samples from selected weekdays from each month of the year.
Source: HMG, 2003

2.5 Current Status of Air Quality in Kathmandu

The data being generated from the six monitoring stations in Kathmandu gives a fairly good picture of the current status of air quality in Kathmandu. Although data is only available for the past nine months, this is sufficient to do a preliminary assessment of air quality in Kathmandu Valley.

The following conclusions can be drawn from analysing the data obtained so far from the monitoring stations:

PM10

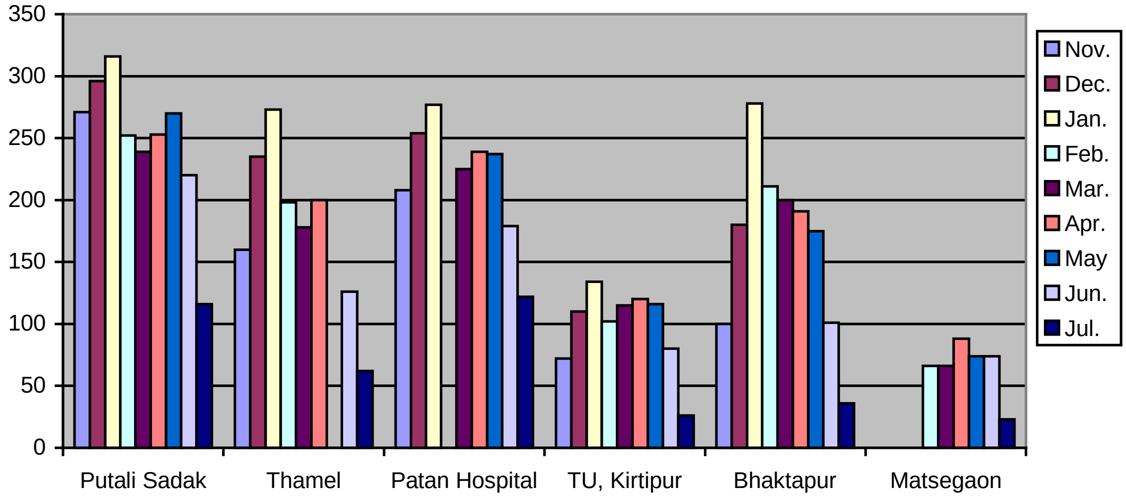
1. The PM10 level in Kathmandu is much higher than the NAAQS and other international standards, especially in urban areas such as Putali Sadak, Thamel and Patan Hospital. Even in a place like Matsyagaon, which is a village located 150 meters above the valley floor, with very few sources of pollution, the PM10 level occasionally exceeds the national standard.

2. Among the six areas being monitored, Putali Sadak is the most polluted. This is mainly because of the high traffic density in this area and the fact that tall buildings on either side of the road tends to have a canyon effect which does not allow pollutants to disperse easily.

3. In the dry season between November and May, the PM10 levels in Putali Sadak were above the national standard during 99 percent of the days. With the arrival of monsoon rains in mid-June, the PM10 has decreased significantly, but is still above national standard on many days.

4. Patan Hospital is the second most polluted area among those being monitored. This is again because the monitoring station is besides a busy road. The street in front of Patan Hospital, however, is not as crowded as Putali Sadak and the area as a whole is a bit more open thus allowing more dispersion than Putali Sadak.

Figure 2.2 Average Monthly PM10 Concentrations (μg/m³) from October 2002 to July, 2003



5. At the roadside stations in Putali Sadak and Patan Hospital, in the dry months, the air quality should be classified as "Unhealthy" in 9 out of 10 days, as "Very Unhealthy" during 6 to 7 percent of the days and as "Hazardous," which is the highest alert level, during 2 percent of the days.

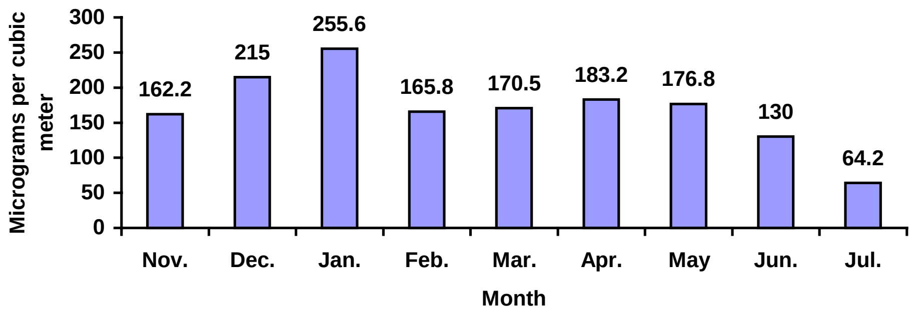
6. The PM10 level in the residential area of Thamel is also quite high even though this station is located on the top of a house. In the dry season, the PM10 concentration was above the NAAQS during 90 percent of the days. During these months the air can be classified as "Unhealthy" in 89 percent of the days and "Very Unhealthy" in 1 percent of the days. In other words, the air quality was good in only 10 percent of the days. This indicates that Kathmandu residents cannot escape the pollution even when they are in their homes.

7. The air is significantly better in Kirtipur (East Side of the valley) compared to Bhaktapur (West Side of the valley). In the dry months, the air in Kirtipur can be classified as "Unhealthy" in 40 per cent of the days while in Bhaktapur the air was "Unhealthy" in 82 percent of the days. This is probably due to the westerly winds taking pollutants from Kathmandu over to Bhaktapur.

8. There is a significant amount of seasonal variation in the level of PM10. The PM10 level is highest in January, which is the peak of the dry winter season, and is lowest in July, which is the peak of the monsoon season. During the monsoon, rains flush down the particles in the air and significantly reduce the pollution level. In January 2003, the average

PM10 concentration in Kathmandu Valley was 255.6 $\mu g/m^3$, but six months later in July 2003 the level had dropped to 64.2 $\mu g/m^3$. An additional factor that keeps the pollution level low during the monsoon is that the polluting brick kilns in Kathmandu do not operate during the monsoon.

Figure 2.3 PM10 in Kathmandu Valley (Monthly Average of the Six Stations)



9. The seasonal variation in air pollution is especially high in Bhaktapur. In the two months between November 2002 and January 2003, the PM10 level in Bhaktapur rose by 178 percent while during the same period the PM10 level in Putali Sadak, Patan Hospital and Thamel went up by only 16 percent, 33 percent and 70 percent, respectively. This is mainly due to two reasons: one is that most of Kathmandu's brick kilns, most of which are located around the city of Bhaktapur start operating in December, and other is the wind in Kathmandu, which flows east towards Bhaktapur, carrying with it a significant amount of particles from Kathmandu.

10. Because of the brick kilns and the westerly winds from Kathmandu, the air in Bhaktapur gets very polluted in the winter season. The average PM10 level in the month of January in Bhaktapur was higher than the levels in Thamel and Patan Hospital and only slightly lower than Putali Sadak. During this month, Bhaktapur had three days when the PM 10 level was above 350 $\mu g/m^3$, which is in the very unhealthy range.

11. In Kathmandu it is clear the vehicles are the main sources of air pollution. This can be verified by the following three observations:
    (I) Areas with heavy traffic (Putali Sadak and Patan Hospital) are the ones that are most polluted.
    (ii) Pollution levels drop on weekends when there fewer vehicles on the road. The average PM10 level on the 5 weekends (Saturdays and Sundays) in May, 2003 in Putali Sadak was 219.4 $\mu g/m^3$. However, in the same month, the average PM10 concentration on weekdays (Monday to Friday) was 290.4 $\mu g/m^3$, which is 32 percent higher than the concentration on weekends.
    (iii) Pollution levels are very low during Nepal Bandh when there are almost no vehicles on the road. When there was a Nepal Bandh on

April 23, 2003, the PM 10 level dropped by 30 percent from 332 to 231 μg/m^3 and then went up to 284 μg/m^3 again the next day.

12. As two of the six monitoring stations are located in rural areas while four are in urban areas, which is same ratio as the ratio of rural to urban population in the Valley, average PM10 level in the Valley can be estimated by averaging the results from the six stations.

Table 2.6 Average Monthly & Annual PM10 (μg/m^3) Levels in Kathmandu

MONTH	PUTALI SADAK	PATAN HOSP.	THAMEL	BHAKTA PUR	TU	MATSYA GAON	MONTHLY AVG.
Nov '02	271	208	160	100	72	66*	146.2
Dec '02	296	254	235	180	110	66*	190.2
Jan '03	316	277	273	278	134	66*	224.0
Feb '03	252	251*	198	211	102	66	180.0
Mar '03	239	225	178	200	115	66	170.5
Apr '03	253	239	200	199	120	88	183.2
May '03	270	237	163*	175	116	86	174.5
Jun '03	220	179	126	101	80	74	130.0
Jul '03	116	122	62	36	26	23	64.2
Aug '03	155*	144*	87*	52*	38*	34*	84.7
Sep '03	194*	165*	111*	68*	49*	45*	105.2
Oct '03	232*	187*	136*	84*	61*	55*	125.7
Annual Average	235	207	161	140	85	61	148.2

* Estimate based on measured data from other months

13. Although at present, data on daily PM10 levels are only available for the past nine months, the concentration of PM10 during the remaining three months (August to October) can be estimated. Because July is normally the month with the highest rainfall and lowest pollution level, the PM10 level is expected to increase steadily between July and November. Assuming a linear growth in PM10 concentration between July to November, the average annual PM10 level in Kathmandu Valley can be estimated to be 148 μg/m^3. Similarly, the average annual PM10 level in Kathmandu City (average of results from Putalisadak, a commercial area and Thamel, a residential area) can be estimated to be 198 μg/m^3.

PM2.5

It has now been realized that PM2.5 is more of a concern than PM10 because PM2.5 indicates the presence of smaller particles that can go deep into the human body and damage the lungs (WHO, 2000). Smaller particles also have a larger retention time in the air and they are often coated with toxic substances.

MOPE/ESPS monitored PM2.5 in Patan and Bhaktapur in Jan-Feb, 2003. In the Patan Hospital area, the average PM2.5 was recorded to be 166 μg/m^3

and the PM2.5 to PM10 ratio was estimated to be 0.64. Similar measurements done in Bhaktapur showed that the PM2.5 to PM10 ratio ranged from 0.7 to 0.9. These ratios are fairly high compared to other Asian cities where the ratio is about 0.5. The high PM2.5 to PM10 ratio indicates that most of the particles in Kathmandu's air are tiny particles that can go deep in to human body. This is a dangerous situation.

Smaller particles are generated from combustion sources such as vehicle emissions, particularly diesel exhaust. This means that vehicle emission must have a significant contribution to Kathmandu's air pollution. The high concentration of PM2.5 in Patan Hospital area is probably due to diesel exhaust as the monitoring station is located along a busy road near the Lagankhel bus station, which has many diesel vehicles.

The high concentration of PM2.5 in Bhaktapur, however cannot be from the immediate vicinity as the monitoring station is located in Durbar Square where there is no vehicular movement. The high PM2.5 must then be due to the particles that have been transported to the area by westerly winds from Kathmandu and the surrounding brick kilns. This indicates that the people living in the western part of the Kathmandu Valley suffer from the pollution generated in Kathmandu and the brick kilns.

Measurements of PM2.5 done in Bhaktapur in March, 2003 showed that the PM2.5 to PM10 ratio had gone down to 0.65, but the levels of PM2.5 were still high. The measurements also indicate that both PM10 and PM2.5 begin to decreases later in the month as it gets warmer.

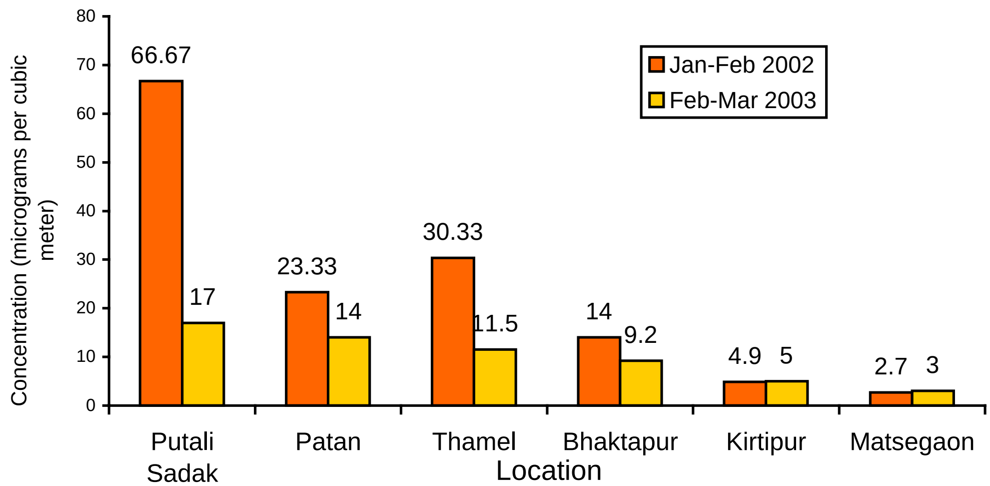
Benzene

Benzene concentration in the air is a major concern because it is a volatile organic compound and a known carcinogen that can cause leukemia or blood cancer. As the petrol used in Kathmandu's contains 3 to 5 percent benzene, petrol cars can emit benzene into the air, especially if the engine is not properly adjusted and if the car does not have a catalytic converter.

In Kathmandu, two attempts have been made to measure benzene concentration in the air, once in January-February 2002 and more recently in February-March 2003. The results from January-February 2002 were quite alarming as it indicated benzene concentration as high as 77 $\mu g/m^3$ in Putali Sadak in the second week of February and the average of three samples collected over a period of three weeks was 67 $\mu g/m^3$. Similarly, the average concentration at Chabahil, Thamel and Patan Hospital were 44, 30 and 23 $\mu g/m^3$ respectively. Considering the fact that the previous WHO guideline value for benzene concentration was 5 to 20 $\mu g/m^3$ and that now WHO has said there is no safe limit for benzene, these numbers are scary.

The second round of tests done in February-March, 2003 indicated a much lower concentration of benzene (see Figure 2.4). One possible reason for this drop in benzene level is Nepal Oil Corporation's claim that previously the petrol had 5 percent benzene but now it has only 3 percent. Although the results from the second round of tests indicate that the benzene concentration has gone down to within NAAQS, it is still too early to draw conclusions regarding benzene concentrations in Kathmandu's air.

Figure 2.4 Benzene Concentration in Kathmandu



NO_2 , SO_2 & other Gaseous Pollutants

Almost all studies done so far in Kathmandu indicate that the levels of NO_2 and SO_2 are not a major concern and are below WHO standards. The latest measurements of NO_2 and SO_2 were done by ESPS in February-March, 2003. As this was in the middle of the dry season, this is when the concentration is probably at its highest.

The results of the four-week monitoring showed that the NO_2 level was highest in Putali Sadak where it reached 50 $\mu g/m^3$ but at all the other stations the NO_2 levels were well below 50 $\mu g/m^3$. The high concentration of NO_2 at Putali Sadak is clearly due to vehicle emission but even at a place where vehicle emission is at its worst, the NO_2 level was within NAAQS.

The highest level of SO_2 level was recorded in Bhaktapur. Here the SO_2 level was higher than 50 $\mu g/m^3$ at all times and in one of the four weeks the SO_2 concentration slightly exceed the national standard of 70 $\mu g/m^3$. The high level of SO_2 in Bhaktapur is probably due to the use of high-sulphur coal in the brick kilns around Bhaktapur. In all the other stations the SO_2 levels remained below 50 $\mu g/m^3$ throughout the monitoring period, except during the second week of March when SO_2 levels at Patan Hospital area rose slightly above 50 $\mu g/m^3$.

These results indicate that at present, NO_2 and SO_2 concentrations in Kathmandu Valley are within national standards and need not be cause of major concern. As the SO_2 and NO_2 tests were done in the February and March when air pollution levels are high, it is safe to assume that the concentration of these gases will probably not exceed national standards at other times during the year as well.

Although the monitoring stations set up by MOPE/ESPS have not yet monitored the concentration of other pollutants such as carbon monoxide, ozone and lead, a few studies that have been done previously have indicated that the concentration of these pollutants in the air is not a major concern. Lead, which is a very dangerous substance, is probably not a major problem now because the main source of lead in the air is usually leaded petrol and since 1999 all the petrol used in Kathmandu is unleaded.

2.6 Air Quality Trends

In the absence of reliable historic data, it is difficult to tell exactly how the air quality has changed over the years and predict future scenarios. However, the existing data can give us some indication as to how much the pollution level in Kathmandu has increased over the years.

In November 1992, ENPHO had collected several 24-hour samples to monitor PM10, as well as other pollutants, at 9 sites in Kathmandu. One of these sites was Putali Sadak. At Putali Sadak, ENPHO had recorded the average PM10 concentration to be 92 $\mu g/m^3$. Ten years later, ESPS/MOPE found that the average 24-hour PM10 levels at Putali Sadak in November 2002 was 271 $\mu g/m^3$. These figures indicate that the PM10 level at Putali Sadak has increased by 3 times over the past ten years.

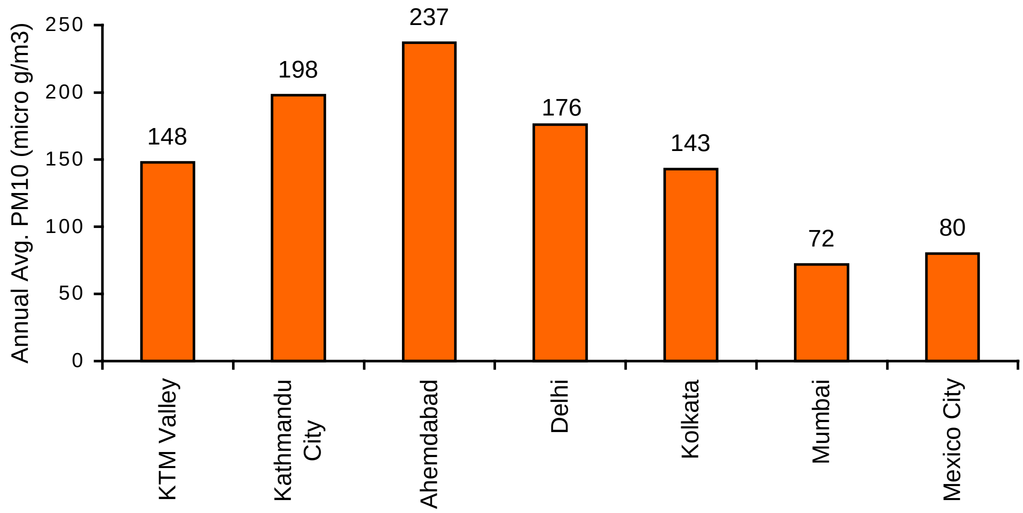
Over the last ten years, the number of brick kilns have gone down and Himal Cement, the main source of air pollution in Kathmandu has closed. Similarly, the number of wool dying factories, which produce some air pollution have also probably decreased because of the downfall in the carpet industry. Therefore, it is safe to say that pollution from the industrial sector in Kathmandu has most probably decreased over the past 10 years.

If industrial pollution has gone down, it must be vehicles that are responsible for increasing the pollution by three folds in the Putali Sadak area over the past 10 years. In the past 10 years, the number of vehicles registered in Kathmandu has also increased by about three folds from 72,037 to 224,098.

With the continuous increase in the number of vehicles, we can expect the PM10 levels in Kathmandu to continue to increase in the future unless serious efforts are made to introduce clean vehicles and get rid of the polluting ones. Kathmandu is already one of the most polluted cities in the world (see Figure 2.5). A recent report released by the Central Pollution Control Board of India Ahemdabad is the most polluted city in India and Delhi is the fifth most polluted city according to air quality data from 2003. PM10 levels in

Kathmandu are between the levels found in Ahemdabad and Delhi. The air quality in Mexico City, which was once considered a very polluted place, is now much better than Kathmandu.

Figure 2.5 Comparison of Kathmandu's Air Pollution With Other Major Cities



A rise in vehicle emission will also lead to rise in concentration of NO_2, CO, ozone and to some extent SO_2. Although the concentration of these pollutants is not an immediate concern as they are within national standards, they may become a problem in the future if vehicle emission is not controlled immediately.

Chapter Summary

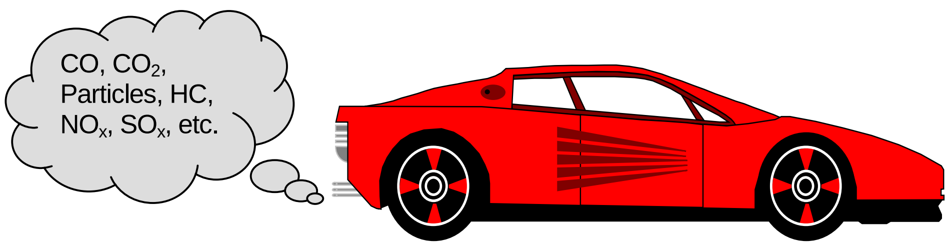
1. A combination of natural and man-made factors make Kathmandu Valley very vulnerable to air pollution.
2. Himal Cement Factory, brick kilns and vehicle emission used to be the main sources of air pollution in Kathmandu Valley. Now with the closure of Himal Cement and the introduction of environment-friendly brick kilns, vehicles are the main source of air pollution in the Valley.
3. Although several air quality related studies have been done in Kathmandu in the 1980s and 1990s, most of the data are scattered and irregular.
4. Less than a year ago, six permanent air quality-monitoring stations were established in Kathmandu which are now providing daily PM10 data.

5. PM10 levels in Kathmandu, particularly in the dry winter months, are extremely high. The PM10 levels are highest at the roadside stations of Putali Sadak and Patan Hospital, especially on week days, thus indicating the high contribution of vehicular emission to air pollution.
6. Some measurements of PM2.5 at these stations indicate that a very high portion (64 percent at Patan Hospital and 65 to 90 percent at Bhaktapur) of the PM10 is PM2.5. This indicates that combustion sources, such as vehicle emission, are the main source of PM10 in Kathmandu.
7. The annual average PM10 level in Kathmandu Valley is estimated to be 148 $\mu g/m^3$ and in Kathmandu city it is estimated to be 198 $\mu g/m^3$.
8. PM10 is the main pollutant of concern in the Kathmandu valley. Data collected by ENPHO in November, 1992 and by MOPE in November, 2002 in Putali Sadak indicates that over the past 10 years there has been a 3 fold increase in PM10 levels.
9. Concentration of benzene, a carcinogen, may also be a problem.
10. Concentration of other gaseous pollutants such as NO_2 and SO_2 are within national standards.

3 VEHICLE EMISSION AND IMPACT OF ELECTRIC VEHICLES

3.1 Emission from Vehicles

Almost all vehicles have internal combustion engines that use a mixture of petrol or diesel and air to produce power. The engine uses oxygen in the air to burn the hydrocarbon fuel. In an ideal system, the combustion would be complete and it would only generate carbon dioxide, water and nitrogen which remains unburnt. In practice, however, the combustion process is never complete and it produces various pollutants such as carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx) and particles. Although the total amount of pollutants other than carbon monoxide and carbon dioxide is generally less than one percent of the total exhaust, the cumulative impact of the pollutants can be very severe. Other than vehicle exhaust, some pollution, mainly hydrocarbons also results from the evaporation of fuel from the fuel tank and carburetor (about 15 percent of HC) and blow by from the engine crank case (about 20 percent of HC) (Watkins, 1991).



The combustion process is different in petrol and diesel engines and the emissions generated by these engines are also quite different. Emission also depends on several other variables such as type of engine (two-stroke or four stroke), the air to fuel ratio entering the engine, vehicle maintenance, fuel quality and quality, and quantity of lubricants used.

In petrol engines, air is mixed with petrol and then burnt. This generally results in high concentration of carbon monoxide and hydrocarbon in the emission, especially emission from two-stroke petrol engines. On the other hand, petrol engines produce very little particles, NOx and SOx.

In diesel engines fuel is sprayed from an injection nozzle into air that is under high temperature and pressure. Diesel engines always have excess air and as a result it produces very little carbon monoxide. However, as the air to fuel ration in the engine varies depending on location, the exhaust will contain hydrocarbons.

The main problem associated with diesel exhaust is that it has very high concentration of particles and NOx. The particles are especially dangerous because they are very tiny and their surface attracts hydrocarbons and other toxic substances that can damage lung tissue and even cause cancer and other deadly diseases. Diesel engines produce more oxides of nitrogen because these engines have excess oxygen and very high temperature. NOx is also harmful to human health and they also form ozone, which again damages the respiratory system. Diesel engines also generate more sulphur compounds.

DEADLY DIESEL

Until recently, diesel was considered to be a relatively clean fuel because it is 15 to 20 percent more fuel-efficient than petrol. But in the past 10 years diesel has taken a severe beating and now diesel exhaust is considered a deadly pollutant and a carcinogen.

The first alarm rang when experts found up to 100 times more particulate matter in diesel exhaust than petrol. Then researchers in the UK found that 90 percent of the particles emitted by diesel engines are very tiny or less than 1 micron. This means that almost all the particles in diesel exhaust, which are coated with toxic compounds such as polycyclic aromatic hydrocarbons (PAHs), are small enough to go deep into the human body.

This was followed by studies indicating that of all the air pollutants, fine particles are the most deadly. To make matters worse, in 1997, Japanese scientists discovered the most potent carcinogen found as of date, a new PAH called 3-nitrobenzathrone, in diesel exhaust. As a result, the California Air Resources Board (CARB) declared diesel exhaust to be toxic air contaminants and said that chronic exposure to just 1 $\mu g/m^3$ of diesel exhaust will lead to additional 300 cases of lung cancer per million people. The United States Environment Protection Agency (USEPA) has also labeled diesel exhaust as a potential carcinogen.

So far about 30 epidemiological studies have shown increased lung cancer risks of 20 to 89 percent associated with diesel exhaust (ADB, 2003).

Environmentalists all over the world are now campaigning to ditch diesel vehicles and some countries such as Brazil, Taiwan and Egypt have banned private diesel cars. French journalists and the famous Indian environmentalist Late Anil Agarwal called diesel vehicles "Engines of the Devil."

In Nepal, however, diesel continues to enjoy subsidies and driving a heavy diesel powered sports utility vehicles (SUVs) is the in-thing in town. Practically all international agencies and projects have them; when members of parliaments decided they all wanted duty free vehicles, most opted for one of these, and it is a must-have for anyone wanting to show off their wealth. Never mind that these gas-guzzling monsters are totally unsuitable for Kathmandu's congested streets.

Source: Based on Agarwal, 1999

In Nepal, diesel vehicles are often seen with a plume of black smoke following them. This is mainly because the vehicles are often overloaded and drivers adjust the injection pump to allow more fuel in to the engine so as to increase power. However, they manage to get only about 2 percent increase in power while the fuel consumption goes up by ten percent or more (J. Grunwald, Advisor, Vehicle Anti-Pollution Programme, Kathmandu, personal communication, 2003). This results in heavy pollution.

Pollution also results from the use of poor quality diesel. While in Europe the sulphur content in diesel has been reduced to 15 ppm, in Nepal we still import diesel with sulphur content of 1,000 ppm. Higher sulphur content results in higher concentration of sulphur oxides and particles in the exhaust.

Adulteration of diesel with kerosene is also a common practice in Nepal. Experiments done at the Vehicle Anti-Pollution Programme in Kathmandu and in other parts of the world has shown adulteration by itself does not significantly increase pollution. Adulteration, however does damage the engine and this may in the long run increase pollution.

Table 3.1 Comparison of Emission from Petrol and Diesel Vehicles

PETROL (WITHOUT CATALYTIC CONVERTER)	DIESEL
• More CO and CO_2 • Equal hydrocarbons	• Very high concentration of fine particles • Higher levels of NOx and SOx

Note: For petrol engines, 3-way catalytic converter, with oxygen sensor and feed-back control system, reduces CO, HC and NOx but increases CO_2. 3-way catalytic converter has not yet been applied to diesel. Various ways to reduce NOx and particles are being researched.

3.2 Number of Vehicles and their Growth in Kathmandu

Because of the concentration of economic activities within Kathmandu Valley and the rapid growth of population in the valley, the number of vehicles in the Valley is also very large and it is growing at an alarming rate. Vehicles registered in Bagmati Zone, which mainly consists of vehicles in Kathmandu valley, accounts for about 57 percent of the total vehicles registered in Nepal. At the end of the last fiscal year (mid July 2003), Bagmati zone had 224,068 registered vehicles (DoTM, 2003). This number, however, does not take into account the number of vehicles that have been scrapped or are not in use anymore.

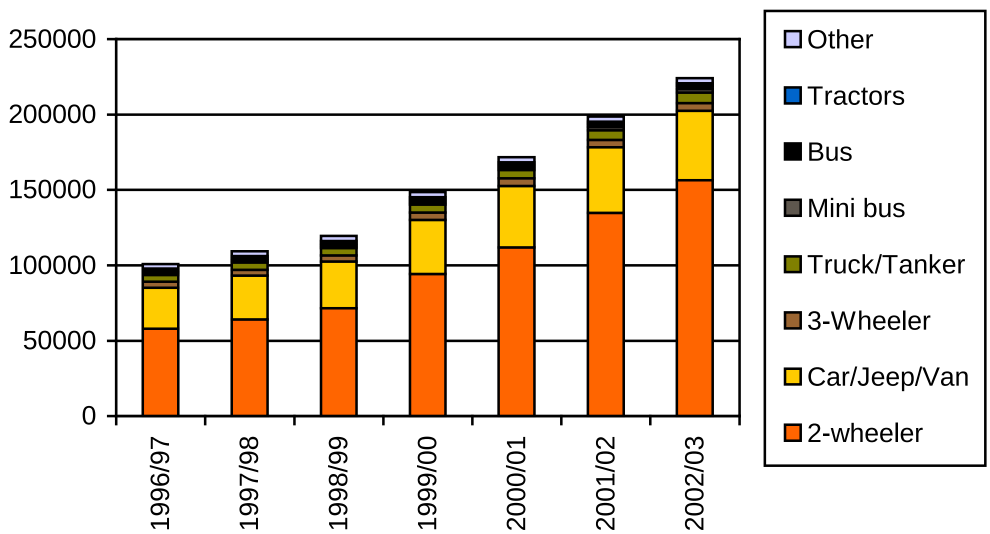
The total number of vehicles in Bagmati zone has increased by over 90 percent in the past five years. Although the growth of vehicles went down to 12.8 percent in the last fiscal year, in the past five years the average annual growth rate has been 17.4 percent, which is almost four times higher than the population growth rate in the valley. At this rate, the number of vehicles will double in about five years. Table 3.2 shows the total number of vehicles registered in Bagmati zone over the last five years. Similarly, Figure 3.1 shows that the increase in the number of vehicles have been most prominent in the past five years and this is mainly due to increase in two-wheelers and light vehicles, most of which are private vehicles.

Table 3.2 Number of Vehicles in Bagmati Zone

VEHICLE TYPE	1998/99	1999/00	2000/01	2001/02	2002/03
Bus	1403	1632	1744	1858	2061
Mini bus	1527	1610	1804	2172	2387
Truck/Tanker	4811	5295	5484	6274	6991
Car/Jeep/Van	30919	35993	40674	43409	45361
Pick-up	-	-	-	-	521
Micro bus	-	-	-	-	232
3-Wheeler	4262	4778	4949	5073	5073
2-wheeler	71612	94217	112000	134852	156410
Tractors	1672	1672	1673	1673	1677
Other	3311	3338	3350	3356	3385
Total	117836	148535	171678	198667	224068
% Increase in Total vehicles	7.6	26	15.6	15.7	12.8

Note: DOTM has added two new categories (pick up and microbuses) starting last fiscal year. Kathmandu did have pick-ups and microbuses in years prior to 2002/03 but they were registered under a different category.
Source: Department of Transport Management

Figure 3.1 Increase in Vehicles in Kathmandu Valley



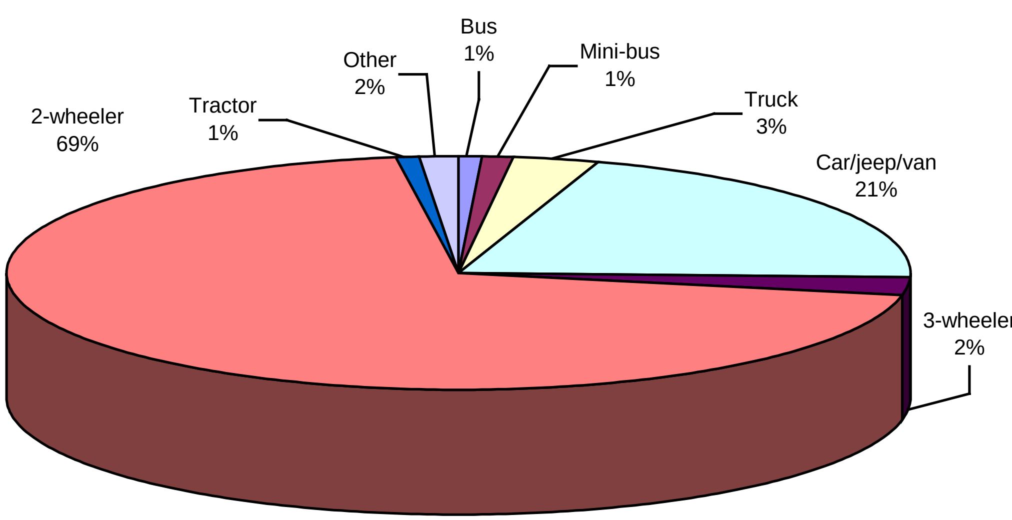
The rapid rise in vehicle numbers together with poor transportation infrastructure is causing serious problems of traffic congestion and air pollution. A study conducted by Department of Transport Management (DoTM), indicated that the number of vehicles in Kathmandu exceeded the Valley's carrying capacity by about 30,000 in 1999/2000 fiscal year. Since then more than 75,000 vehicles have been added to the streets of Kathmandu, while the road infrastructure has remained more or less constant. The total road network within the valley is 1339 km.

Besides the number of vehicles, the type of vehicles on the streets of Kathmandu is also a problem. Many vehicles in Kathmandu are old and poorly maintained which emit more pollutants. Old vehicles normally do not have emission control devices so they are more polluting than vehicles manufactured after emission standards have been introduced. Similarly, two stroke engines produce emission with higher concentrations of PM_{10}. Although the import of new two-stroke vehicles have been banned, there are still significant number of two-stroke two and three wheelers in town, which cause significant amount of pollution.

City of Motorcycles

The rate of increase in vehicle numbers is highest in the case of two-wheelers (motorcycles). This is mainly because of the affordability and convenience of such vehicles and the growing middle-class. Currently' there are 156,410 motorcycles registered in Bagmati zone, which is almost 70 percent of the total vehicle fleet (see figure 3.1) and the number of motorcycles has been increasing at the rate of 21.6 per cent per year in the last five years.

Figure 3.2 Types of Vehicles Registered in Bagmati Zone (15 July 2003)



Thanks to a government decision to ban the import of two-stroke engines in 1999, all motorcycles imported in Kathmandu now have four-stroke engines, which are better than two-strokes in terms of fuel efficiency and emissions. However, many old two-stroke motorcycles continue to operate in the valley. According to local dealers, both two-stroke and four-stroke motorcycles were equally popular before 1999. DoTM records indicate that there were 71,612 motorcycles in Bagmati zone in 1999. Assuming that about half of these motorcycles had 2-stroke engines, the number of two-stroke motorcycles in 1999 was about 36 thousand. As the number of motorcycles in Kathmandu has now increased to 156,410 (as of 15 July 2003), it can be estimated that approximately 20 percent of the two-wheelers in Kathmandu have two-stroke engines.

Indian motorcycles are the most popular brands in Kathmandu. In the past few years, however Chinese motorcycles, have managed to capture a significant portion of the market. As emission standards for motorcycles in India is one of the most stringent in the world, the emission from Indian motorcycles are probably fairly low. However, the same cannot be said about Chinese motorcycles. Chinese motorcycles have not yet been able to enter Indian market because they cannot meet the tight Indian standards (Roychowdhury, 2002).

In the future, policy makers need to introduce measures to control the rapid growth of two-wheelers on the streets of Kathmandu and pollution they create. Improving the effectiveness of public transportation system, making the use of two-wheelers and other private vehicles more expensive by levying pollution tax on the fuel and/or vehicles, and promoting cleaner two-wheelers such as electric scooters are some measures to achieve this.

Three-Wheelers

Three-wheelers, locally known as tempos, are the smallest public transport vehicles in Kathmandu and they come in two forms. One operates as a taxi that can carry up to three passengers and the other travels on fixed routes carrying 6 to 13 passengers. The three-wheeler taxis are all petrol operated and have two-stroke 145.45 cc engines from Bajaj Company in India. The fixed-route tempos are powered by petrol, LPG or electricity.

Currently, the three-wheeler vehicle fleet in Kathmandu consists of approximately 2,000 petrol vehicles, 550 LPG vehicles and 600 electric vehicles. Since November 1991, the government has banned the import of new petrol and diesel three-wheelers. Two-stroke three wheelers first arrived in Kathmandu about 30 years ago. As no new two-stroke three-wheelers have been imported in the last 10 years, the petrol-operated three-wheelers in Kathmandu are all between 11 to 30 years old. As emission standards were introduced in India only in 1991 and then updated in 1996, the three-wheelers in Kathmandu were not designed to meet any emission standards. Furthermore, with over 11 years of heavy use as public vehicles, many of these vehicles have been worn out. As a result, these vehicles are very polluting.

Quality of lubricants being used in vehicles is another cause for poor vehicle exhaust. Use of poor quality lubricants and wrong amount of lubricants causes significant increase in emission from two-stroke vehicles (Kojima et. al, 2000). A recent study by CEN indicated that about 98 percent of the two-stroke three-wheelers in Kathmandu are using various quantities of loose oil instead of the recommended quantity of 2T oil. The study also indicated that shifting to the use of 2 percent 2T oil instead of the current practice of using approximately 8 percent loose oil would reduce CO and HC emission by 44 and 45 percent respectively.

LPG & Electric Three-Wheelers

In 1999, following the ban of the highly polluting diesel three-wheelers, locally known as Vikrams, about 650 diesel three-wheelers were expelled from the Valley. This resulted in a dramatic rise in electricity and LPG operated three-wheelers. The number of electric three-wheelers jumped from about 200 in 1998 to almost 600 in the following year and the number of LPG three-wheelers increased from about 175 to about 300 in the same period. In the next two years, the number of LPG three-wheelers continued to increase but the number of EVs remained the same.

3.3 Emission Load of Vehicles

Studies have shown that vehicles are the main cause of air pollution in Kathmandu. Till a few years ago, emission from industries such as Himal Cement Factory and brick kilns were the main sources of pollution. However, with the closure of Himal Cement, introduction of new improved brick kiln technologies in Kathmandu and the rapid increase in vehicles, vehicular emission has emerged as the main polluter.

Several attempts have been made to calculate the total emission from various sources in Kathmandu Valley. Devkota (1992) and Shrestha and Malla (1993) calculated emission from various energy uses in the Valley. They did not however consider emission from non-energy uses such as resuspension from roads, dust from construction sites and refuse burning. World Bank's URBAIR project used these emission surveys as well as findings from other studies, to arrive at a more comprehensive inventory of emission sources in Kathmandu. The study also distributed the emission spatially within 1 km^2 grids based on location of point sources, distribution of population, cooking practices of urban and rural households and traffic activity distribution (Shah and Nagpal, 1997).

The URBAIR study concluded that particles were the main cause of concern in Kathmandu. The main sources of particulate pollution were Himal Cement (36% of TSP; 17% of PM10), brick kilns (31% of TSP; 28% of PM10), domestic fuel burning (14% of TSP; 25% of PM10), road dust (9% of TSP;

9% PM10), and vehicle exhaust (3.5% of TSP; 12% of PM10). According to this inventory although vehicle exhaust was a major cause of pollution, its contribution was less than other major sources such as Himal Cement, brick kilns, domestic fuel burning and road dust. This may be because of the relatively low emission factors used in calculating the emissions from vehicles. For example, the study used an emission factor of 2g/km to calculate emission from diesel buses and trucks because this is within the higher range of emission factors used in other cities. However, the same report mentions that "a diesel truck with a smoke meter reading of 85 HSU, as measured typically on Kathmandu trucks and buses, corresponds to an emission factor of roughly 8 g/km." This indicates that the emission factor of 2 g/km, used for calculating emission from diesel trucks and buses, probably underestimates the emission from these sources.

Although the URBAIR study estimates that the contribution of the transportation sector towards PM10 and TSP is less than some of the other sectors, the same study estimates that an increase in emission of 1 kg from traffic sources increases health damage by Rs. 570, but for domestic sources and brick kilns, the increase in 1 kg emissions raises the health costs by only Rs. 270 and Rs. 250 respectively. Therefore, the study concludes that reducing vehicle exhaust is the most effective way to reduce health costs.

More recently, the MOPE/ESPS has tried to update the URBAIR emission inventory. It has applied the same methodology to more recent data to come up with new figures. The results of the two inventories (see Table 3.3) indicate that vehicle exhaust is now the main source of PM10 in the valley. PM10 from vehicles increased by 471 percent between 1993 and 2001. Vehicles are now responsible for about 67 percent of the PM_{10} load (Gautam C, 2002).

Table 3.3 Comparison of Emission Inventory in 1993 & 2001

SOURCES	TSP (TONS/YR)			PM10 (TONS/YR)		
	1993	2001	% increase	1993	2001	% increase
Mobile Sources						
Vehicle Exhaust	570	1971	245	570	3259	471
Road Resuspension	1530	7008	358	400	1822	356
Subtotal	2100	8979	328	970	5081	424
Stationary Sources						
Industrial/commercial fuel	582			292		
Domestic fuel combustion	2328			1166		
Brick kilns	5180	6676	29	1295	1688	30
Himal Cement	6000	3612	-40	800	455	-43
Industrial boilers		28			15	
Refuse burning	385	687	78	190	339	78
Subtotal	14475	10904	-25	3472	2498	-28
TOTAL	16575	19884	20	4712	7580	61

Source: MOPE/ESPS, 2003

3.4 Emission Control Measures

The Nepalese government has introduced vehicle emission standards for new as well as in-use vehicles. The standards for in-use vehicles were introduced in 1995 and then revised in 1998, while standards for new vehicles were introduced in 2000.

Table 3.4 Emission Standards for In-Use Vehicles in Nepal

VEHICLE	STANDARD	
For Gasoline Vehicles	CO in %	HC in ppm
Four wheelers manufactured up to 1980 Four wheelers manufactured after 1981 Two and Three Wheelers	4.5 3.0 4.5	1000 1000 7800
LPG Vehicles		
Four Wheelers Three Wheelers	3 3	1000 7800
For Diesel Vehicles	Hatridge Smoke Unit (HSU)	
Vehicles manufactured up to 1994 Vehicles manufactured after 1995	75 65	

All new vehicles imported to Nepal must now meet the Nepal Mass Vehicle Emission Standards which are equivalent to the EURO I standards. However, in the absence of a system to test vehicles for their Type Approvals (TA) and Conformity of Production (COP), there is no guarantee, except the word of manufacturers, that new imported vehicles are of EURO I standards. In spite of this limitation, data from the DoTM indicates that new vehicles that are being imported these days are significantly cleaner than the older ones (Table 3.5). The test results also show that the improvement in emissions is much more significant in the case of petrol vehicles than diesel vehicles. This is because the EURO I standards for petrol vehicles require significant improvement in terms of emission control technology but in the case of diesel vehicles, the EURO I standards do not require major improvements in emission levels. Emission levels from diesel vehicles are improved significantly only when they get to EURO IV levels.

Table 3.5 Emission Test Results of EURO I and Non-EURO I Vehicles

POLLUTANT	RANGE OF MEASURED PARAMETERS	
	Vehicles imported before EURO I (1/1/2000)	Vehicles imported after EURO I
CO (%)	2 - 9	0.01 – 0.35
HC (ppm)	500 – 1000 & up to 10000*	10-220
HSU	60 – 95	22 - 61

* Two stroke two & three-wheelers
Source: Department of Transport Management

Although it is good that Nepal has enforced EURO I standards, it needs to move on and start tightening the standards. While other countries have moved towards EURO-IV emission norms, Nepal is still at EURO-I and so far there are no plans to move up the standards ladder.

To control emission from in-use vehicles in Kathmandu, there is a provision for emission testing and issuing of “green stickers” to vehicles that meet emission standards prescribed by the government. However, this system has not been very effective, as many drivers tamper with the air to fuel ratio to lower the emissions just before checking and even vehicles that do not comply with the emission standard are still free to ply all over Kathmandu valley, except a few streets.

Emission test results from the past eight years indicate that approximately 25 percent of the vehicles fail the tests (Table 3.6). Vehicles that fail the test are not issued the “green sticker” but they are allowed to come again to get their vehicles tested. Many vehicles do pass the test after they tamper with their engines and many people also claim that green stickers can be "bought." However, in spite of the potential discrepancies in the inspection system, the numbers still tell us that at least one fourth of the vehicles in Kathmandu do not meet the emission standards.

Table3.6 Emission Test Results of In-Use Vehicles in Kathmandu

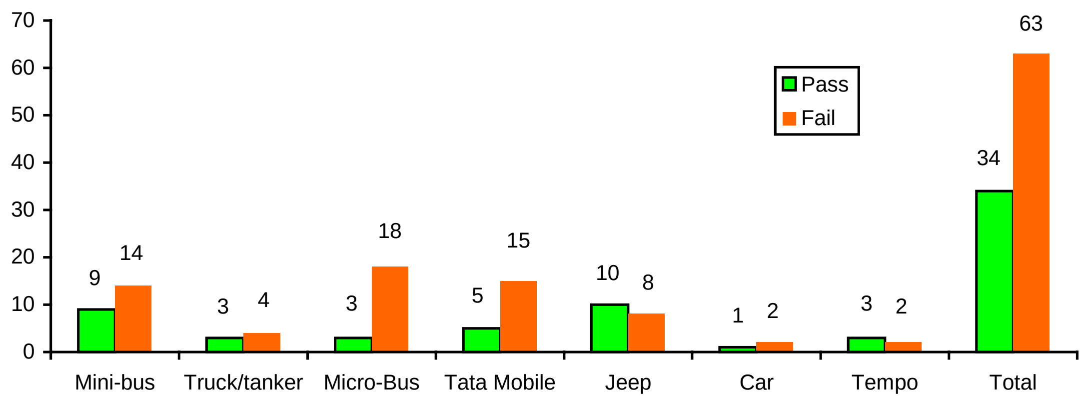
YEAR	VEHICLES TESTED	PASS	FAIL	% FAILED
1995/96	486	162	324	67
1996/97	41466	25220	16246	40
1997/98	31173	22984	8189	26
1998/99	28018	24240	3778	13
1999/00	42826	34255	8571	20
2000/01	34543	29034	5509	16
2001/02	33378	24462	8916	27
2002/03	32894	23698	9196	28
Total	244784	184055	60729	24.8

Source: Valley Traffic Police, 2003

Experiments done in some other cities like Bangkok indicate that 20 percent of the most polluting vehicles are responsible for about 50 percent of the pollution (Roychowdhury, 2000). If indeed 25 percent of the vehicles in Kathmandu are emitting more emission than the prescribed standards, significant improvement in air quality can be achieved by getting these "gross polluters" off the road.

Recently, from 5 June 2003, the traffic police started to conduct on the spot emission checks on vehicles that seem to polluting. In the first month of implementing this system, the police checked 97 vehicles and found that 65 percent do not meet the emission standards. The percent of vehicles that fail to meet the standards is more in the case of diesel vehicles than petrol. Over 70 percent of the diesel vehicles failed to meet the standards, while in the case of petrol vehicles, only 33 percent failed to meet the standards. An interesting point to note is that 18 of the 21 microbuses that were tested (86%) failed to meet the standards. Almost all microbuses in Kathmandu have been imported within the past five years. This shows that many of the new diesel microbuses from reputed companies are failing to meet the standards.

Figure 3.3 Results of On-the Spot Emission Tests Conducted in June 2003



3.5 Role of Electric Vehicles in Reducing Emissions

There is no doubt that zero emission electric vehicles (EVs) can have a significant impact in reducing Kathmandu's air pollution. Kathmandu is the city with the largest fleet of electric vehicles in public transportation and many experts have said that the city is ideal of electric vehicles because travel distances in the city are short and the traffic moves at a slow speed. The fact that EVs produces no emissions and they use local hydropower makes them even more attractive.

Kathmandu's trolley bus system was established in 1975 and untill 1990, they were operating profitably. Although, political interference and mismanagement has forced the closure of the trolley bus system in 2001, a study done by Winrock International Nepal has shown that they can operate profitably if they are well managed (Cemat, 2002). Another study done by Winrock International Nepal has also suggested that it is feasible to operate trolley buss around the Ring Road (Cemat, 1999). Expanding the trolley bus system throughout the Kathmandu Valley can play a major role in getting rid of the polluting diesel buses and encouraging more people to use public transportation.

How Much Pollution Can We Avoid By Reviving the Trolley Bus System?

According to Cemat (1999), Kathmandu's trolley bus system was providing its services to about 10,000 to 11,000 passengers per day with 14 buses before it closed down. Cemat also did a survey of passengers on diesel buses along the Suryabinayak–Kathmandu route and found that on average, a bus carries 89 people per trip.

Assuming that following the closure of the trolley bus system, all passengers who would have taken the trolley bus shifted to diesel buses, this would require 118 additional bus trips per day or 1,534 additional km of bus travel per day.

According to several international studies emission factors for heavy buses range from 0.75 to 2.1 g/km. However, based on relationship between smoke meter reading and mass emissions, Shah & Nagpal (1997) estimates that a diesel truck with a smoke meter reading of 65 and 75 HSU, as measured typically in Kathmandu, corresponds to emission factor of roughly 5g/km and 6.6 g/km respectively. This level of smoke is emitted when the vehicle is "smoking," which happens 25 to 50 percent of the time. If during rest of the time the emission factor is assumed to be 1 g/km, then the average emission factor for a diesel bus/truck in Kathmandu is calculated to be 2.5 to 3.7 g/km (Shah & Nagpal, 1997).

If the emission factor for a bus in Kathmandu is assumed to 3g/km, then the total amount of excess particles emitted due to the closure of the trolley bus system is 4.6 kg per day or 1.68 tons per year.

This calculation has been done using passenger numbers when only 14 buses are operational. If the number of trolley buses were to be doubled, as recommended by the Cemat study, then reviving the trolley bus service would result in saving more than 3 tons of particles per year.

As many studies have shown that diesel exhaust is potentially toxic and carcinogenic, the 3 tons of particles per year saved by the trolley bus system is not ordinary pollutant but rather 3 tons of toxic substance. Furthermore, a study in UK has shown that more than 90 percent of particles from diesel exhaust are less than 1 micron in size, which can enter deep into the human body. This means that reviving the trolley bus will ensure that about 3 tons of toxic particles do not enter the lungs of Kathmandu residents every year.

Furthermore, according to the URBAIR study (Shah and Nagpal, 1997), increase in one kg of pollution from traffic sources increases health damage by Rs. 541. Therefore, closure of the trolley bus system results in increased health damage of over Rs. 1.6 million per year.

Electric three-wheelers (Safa Tempo) have been successfully operating in the Kathmandu since 1995 and they are popular means of travel for the local people. Although the operating cost of the Safa Tempos are currently higher than the petrol and LPG tempos, the recent government decision to lower electricity tariff for EVs and the use of Nepalese batteries could significantly reduce the operating cost of these vehicles. In the future Safa Tempos, which are made locally, can replace most, if not all, small public vehicles in Kathmandu if government provides some support. This will have significant impact on reducing vehicle emissions

Although zero-emission electric vehicles such as trolley buses and Safa Tempos have proved that they are suitable for Kathmandu, since the year 2000, only fossil fuel vehicles are being added to the public transportation fleet of Kathmandu while the number of electric vehicles is slowly decreasing. Table 3.7 shows that in 1999, Safa Tempos consisted of about half of the small public vehicle fleet in Kathmandu but by 2002, its share in the market, in terms of available passenger seats had gone down to only 21 percent.

Table 3.7 Growth of Safa Tempos and Other Small Public Transport Vehicles in Kathmandu

VEHICLE	1999		2002	
	Number	Seats	Number	Seats
Safa Tempo	589	4712	589	4712
Others*	594	4712	1719	17788

* Petrol, diesel and LPG powered 3-wheelers, microbuses and mini-micro-buses
Source: ESPS/MOPE, 2003

The current state of electric vehicles in Kathmandu clearly indicates that although the government claims to be pro-EVs, in reality it is not utilizing the opportunities offered by EVs to improve Kathmandu's air quality and the health of citizens. As an EV-based public transportation system in Kathmandu will be replacing highly polluting diesel buses and microbuses, this will bring about significant environmental and health benefits to the citizens of Kathmandu. Therefore, immediate action is necessary to promote the use of EVs in Kathmandu.

Chapter Summary

Vehicle emission results from incomplete combustion of fuel. Emission from petrol vehicles normally has higher concentration of CO and CO_2 while diesel exhaust has higher levels of particles, NOx and SOx.

Diesel exhaust is particularly harmful to health because it is a potential carcinogen with very high concentration of fine particles that are coated with toxic substances like PAH.

In the past five years, the number of vehicles in Kathmandu valley have been growing at an alarming rate of about 17 percent per year, which is almost four times higher than the population growth rate.

Besides the number of vehicles, the type and condition of vehicles are also responsible for the growing vehicular emission. Kathmandu has a large number of old and two-stroke vehicles, which cause significant pollution and many of the vehicles, are not well maintained.

An emission inventory done by the World Bank in 1993 estimated that vehicles exhaust contributed 3.5 percent of TSP and 12 percent of PM10. A similarly inventory done MOPE/ESPS found that the emission from vehicles had increased by more than four times and vehicle exhaust was responsible for 10 percent of TSP and 43 percent of PM10.

The government has introduced emission standards for new as well as in-use vehicles. Although this is a good move, there are some problems in implementation of these standards.

Results of emission test of in-use vehicles indicate that approximately 25 percent of the vehicles fail to meet the standards. However these vehicles are not removed from the streets. Ensuring that “gross polluters” such as these do not operate in Kathmandu can have a significant impact on air quality.

EVs can play a very important role in reducing emission loads in Kathmandu. Operating the existing trolley bus system can save approximately 3 tons of potentially carcinogenic particles from being released into Kathmandu’s air.

Although zero-emission EVs are very suitable for Kathmandu and the government says it wants to promote EVs, in practice EVs are not getting sufficient support and their numbers are decreasing. Therefore, a great opportunity to clean up Kathmandu’s air is being lost.

4 Health Implications of Air Pollution

Globally, it is difficult to estimate how many people die prematurely or get sick due to air pollution because people are exposed to so many different pollutants in various concentrations over their lifetimes. However, WHO (2000) estimates that air pollution claims approximately 3 million lives each year. Of these, 800,000 people die prematurely every year due to lung cancer, cardiovascular and respiratory diseases caused by outdoor air pollution. Approximately 150,000 of these deaths are estimated to occur in South Asia alone (World Bank, 2003a). Other adverse health impacts include increased incidence of chronic bronchitis and acute respiratory illnesses, exacerbation of asthma and impairment of lung function.

Similarly, the US EPA estimates that people living in the most polluted cities in the US are 15 to 17 percent more likely to die prematurely than those living in cities with the cleanest air. This means that people living in the worst parts of Los Angeles will suffer from 5 to 10 year decrease in life expectancy compared to people living in cleaner cities (Cunningham and Saigo, 1999)

Health impacts of air pollution depend on various factors such as nature of pollutant, intensity and duration of exposure, age and prior health status. The impacts of various air pollutants, especial impacts of vulnerable groups and systems in the human body that are effected are described in the sections below.

4.1 Health Effects of Various Pollutants

Air pollution is the presence of any substance in the air in concentration sufficient to interfere with comfort, safety or with full use and enjoyment of property (Shrestha, 2002).

High levels of exposure to air pollutants produce symptoms of both upper and lower respiratory tract irritations engendering increased severity of respiratory diseases like asthma and chronic bronchitis. Air pollutants may also affect other systems in the body such as the cardiovascular system and the central nervous system.

Outdoor air pollution typically consists of a complex mixture of multiple pollutants. Air pollutants can be classified into suspended particulate matter (dust, fumes, mists, smokes) and gaseous pollutants (sulphur compounds, carbon monoxide, nitrogen compounds, organic compounds such as hydrocarbons, volatile organic compounds – VOC, polycyclic aromatic hydrocarbons – PAH, halogen derivatives, etc.). Secondary pollutants may be formed by thermal, chemical or photochemical reactions. For example, photochemical reactions between NOx and reactive hydrocarbons can produce ozone (O_3), formaldehyde (HCHO) and PeroxyAcetyl Nitrate (PAN).

Some of the main air pollutants and their effects on human health are presented in Table 4.1.

Table 4.1 Health Effect of Selected Air Pollutants

POLLUTANTS	HEALTH IMPACT
Particulate Matter	Acute respiratory infections (ARI), especially in children Damages lung's defense mechanisms and causes COPD, cardiovascular disease & lung cancer Triggers asthma Irritation in the eye Low birth weight Studies indicate that every 10 μg/m3 increase in PM10 increases • Non-trauma deaths by 0.8 % • Hospital admission for respiratory & cardiovascular diseases by 1.4 & 6% respectively • Emergency room visits by 3.1 % • Restricted activity days by 7.7% Previously, WHO guideline was 70 $\mu g/m^3$ (24 hr. average) but now it says there is no safe limit as even low levels can cause damage
Sulphur Dioxide	Acute mucus membrane irritant Exacerbates asthma & COPD WHO guideline: 125 $\mu g/m^3$ (24 hr.) and 50 $\mu g/m^3$ (annual mean)
Nitrogen Dioxide	Irritation of respiratory tract Severe exposure can result in death from pulmonary oedema Can increase susceptibility to viral infections such as influenza WHO guideline: 40 $\mu g/m^3$ (annual mean)
Carbon Monoxide	Fatal in large doses Aggravates heart disorders Effects central nervous system Impairs oxygen carrying capacity of blood WHO guideline: 100 mg/m^3 or 90 ppm for 15 minutes
Ozone	Reduced lung function; airway inflammation; bronchoconstrictions; exacerbation of asthma Eye irritation WHO guideline: 120 $\mu g/m^3$ for 8 hours
Lead	Extremely toxic: affects nervous system and blood; can impair mental development of children; causes hypertension WHO Guideline: 0.5 $\mu g/m^3$ (1 year average)
Benzene	Carcinogenic to humans; long-term exposure can result in bone marrow depression expressed in leucopenia and anemia; high concentration can result to structural and numerical chromosome aberrations. WHO guideline: No safe limit

Source: Agarwal et. al., 1996; WHO, 2000; WHO, 2001; Shrestha, 2002

Particulate Matter

The most significant health impact of outdoor air pollution has been associated with particulate matter and to a lesser extent, with ground level ozone (Cohen et. al., 2003; Holgate et. al., 1999 and World Bank 2002). In most cities in developing countries, particulate matter is a major concern because their concentration in the air is often very high. This is true for Kathmandu as well.

Particulate matter does not consist of one compound or element but rather, it is a complex mixture of different organic and inorganic substances that are present in the air as both liquid and solid. Primary particles are emitted directly by emission sources, whereas secondary particles are formed through reaction of gases in the atmosphere. Many of the substances that make up particulate matter are very harmful to human health. These include metals, PAH and VOC.

The effect of particles on human health varies depending on size and chemical composition. Particle size can vary between 0.005 microns (µm) to 100 microns. For comparison, the thickness of an average human hair is approximately 50 microns. All particles in the ambient air are collectively referred to as Total Suspended Particles (TSP). Particles that have an aerodynamic diameter of less than 10 µm are referred to as PM10. As these particles are small enough to enter the human respiratory system, they are also called respirable particulate matter. Similarly, particles that are smaller than 2.5 µm are referred to as fine particles or PM2.5. Coarse particles generally refer to particles with an aerodynamic diameter greater than 2.5 µm.

When particles in the air are inhaled by human beings, they are deposited in various regions of the respiratory system depending on the size of the particles. Particles that are greater than 10 microns are normally retained by the cilia in the nose and do not enter the respiratory tract. Therefore, particles larger than 10 microns do not cause much harm except some irritation in the nose or eye.

Fine particles are generated mainly by combustion and they consist of aerosols, unburned combustible material, semi-volatile organic compounds and organic metal vapours. Non-combustion sources such as road dust, contribute more to larger size particles. A study in done Mexico City in 1997 showed that PM2.5 consisted of about 50 percent carbonaceous aerosols, most likely from combustion sources, followed by 30 percent secondary aerosols, and 15 percent geological matter. PM10 on the other hand was found to be 50 percent geological matter, 30 percent carbonaceous aerosols and 20 percent secondary aerosols (World Bank, 2003c). This means that PM2.5 consists of higher percentage of harmful substances than PM10 and a higher PM2.5 to PM10 ratio indicates higher contribution of combustion sources, such as vehicle emission.

Smaller the Particles, Greater the Impact

The most severe health impacts are due to particles that are small enough to penetrate deep into the respiratory tract. In fact, the smaller the particle, more dangerous it becomes. This is because of three reasons:

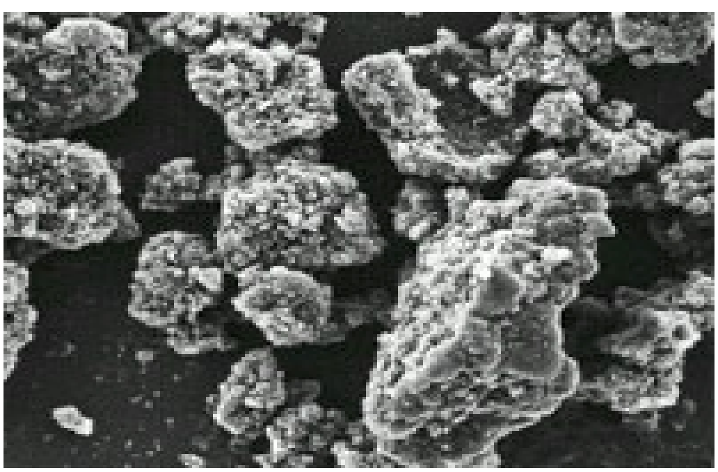
1. Smaller particles do not settle easily and therefore have a long residence time in the air and can travel far from their sources. Therefore, the possibility of inhaling fine particles is higher than coarse particles. The relative surface area and settling velocity of different categories of small particles are shown in Table 4.2.

Table 4.2 Characteristics of Particles of Various Sizes

PARTICLE DIAMETER (μM)	NO. OF PARTICLES IN 1 μG	SURFACE AREA (M^2/G)	SETTLING VELOCITY (CM/SEC)
0.01	2 trillion	6,000,000	0.000005
0.1	2 billion	600,000	0.00008
1.0	2 million	60,000	0.0035
2.5	120,000	24,000	0.02
10	2,000	6,000	0.3

2. Smaller particles have more surface area where harmful substances, such as PAH, can attach themselves. For example, diesel exhaust has many fine particles that are coated with PAH and other harmful substances. Figure 4.1 shows ultra-fine diesel particles that are less than 0.65 microns, with their great surface area. These can enter very deep into the alveoli or air sacks of our lungs. Some recent studies indicate that ultra-fine particles are highly toxic to the lungs, even when they comprise materials that are not toxic when present in larger particles (World Bank, 2002c).

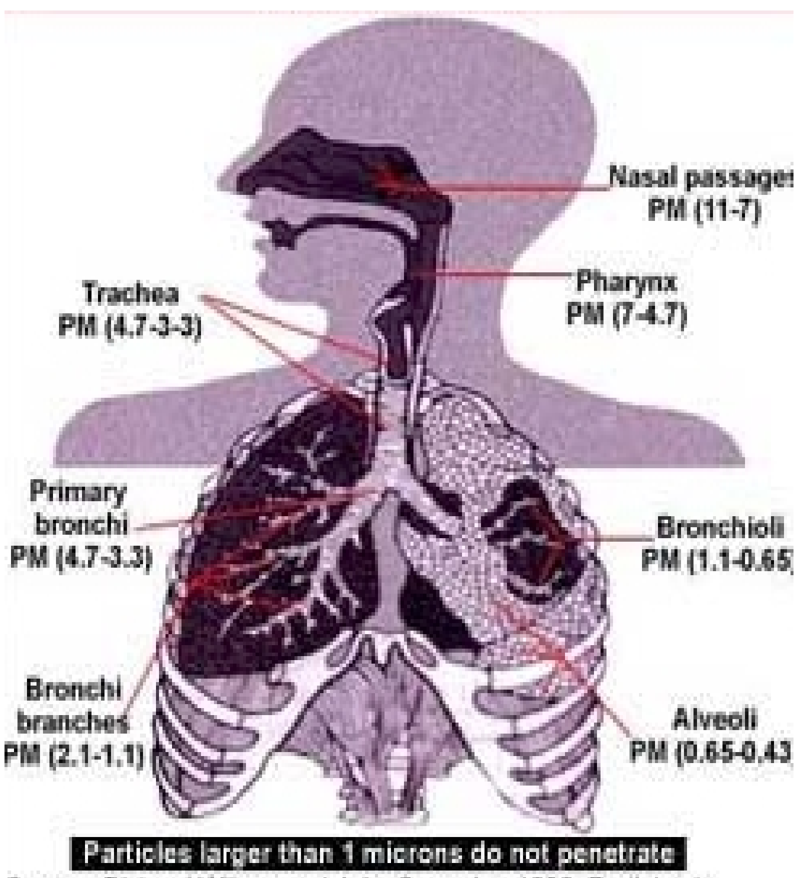
Figure 4.1 Very Fine Particles in Diesel Exhaust



Source: Centre for Science and Environment, www.cseindia.org

3. Smaller particles penetrate deeper into the human body. As mentioned earlier, particles that are larger than 10 to 11 microns are rejected by the cilia in the nose. Particles that are up to about 5 microns in size can go down as far as the pharynx, located just above our throat. Particles that are up to about 3 microns in size manage to go up to the trachea before movement of cilia sweeps the particles along with mucus upward from the windpipe to the mouth. Particles that are smaller than 2 or 3 microns (PM2.5) make it to the lower respiratory system, which consists of bronchi, bronchioli and the alveoli in the lungs. Particles that are smaller than about 0.65 microns go all the way to the alveoli and from there, some smaller particles enter the circulatory system that takes them to other vital organs in the body.

Figure 4.2 Penetration of Particles in the Human Body



Source: Richard Wilson and John Spengler, 1996, Particles in Our Air, Concentrations and Health Effects, Harvard University Press, Harvard, USA, p45

Note: The size of particulate matter (PM) is in microns.

Source: Centre for Science and Environment, www.cseindia.org

Carbon Monoxide

Carbon monoxide, which is mainly emitted from petrol vehicles is quickly absorbed by the lungs and carried in the blood. At high concentrations, CO is toxic and can be fatal. CO impairs the oxygen carrying capacity of blood and as a result, organs like the heart, central nervous system, and the fetus, which need a large supply of oxygen are affected. Potential health effects include hypoxia, neurological deficits, neurobehavioral changes and increases in daily mortality and hospital admissions for cardiovascular diseases (WHO, 2001).

Oxides of Nitrogen

Oxides of nitrogen are generally released as nitrogen oxide (NO) and gradually convert to nitrogen dioxide (NO_2) in the atmosphere. A number of studies indicate that children with long-term exposure to NO_2 exhibit increased respiratory symptoms, decreased lung function, and increased incidence of chronic cough, bronchitis and conjunctivitis (WHO, 2001).

Sulphur Dioxide

Inhaled SO_2 is highly soluble in aqueous surfaces of the respiratory tract. In the upper airways, it exerts an irritant effect. High concentrations can cause laryngo-tracheal and pulmonary oedema (Agarwal, et. al., 1996). SO_2 also results in exacerbation of asthma and COPD.

Ozone

Short-term exposure to high concentration of ozone aggravates pre-existing respiratory diseases such as asthma, and increases hospital admission and emergency room visits for respiratory distress (WHO, 2001). Ozone also causes eye, nose and throat irritation.

Lead

Lead is extremely toxic and affects neurological development in children. It also results in increased blood pressure and damage of gastro-intestinal tract and kidneys. Leaded petrol is the main source of lead in the air. As the petrol used in Kathmandu is now unleaded, lead concentration in the ambient air is probably not a major concern.

Benzene

Although Kathmandu now receives unleaded petrol, the petrol now contains benzene, another carcinogenic substance. It is estimated that about 50 percent of the benzene inhaled by the body is adsorbed (Agarwal et.al, 1996). Benzene is mainly distributed to tissues rich in fat, such as adipose tissue and bone marrow. The toxic effects of benzene include damage to the central nervous system, hematological and immunological effects. Benzene is a known carcinogen that causes and lung cancer and leukemia.

Polycyclic Aromatic Hydrocarbons (PAH)

PAH are a group of chemicals formed during incomplete combustion. PAH are known to be carcinogenic and mutagenic and are absorbed in the gut and lungs.

4.2 How does Air Pollution Cause Health Effects?

The most common route for pollutants to enter the human body is by inhalation. Other pathways include, direct absorption through the skin or contamination of food or water.

Impact on the Respiratory System

Human respiratory system has a number of mechanisms that provide protection from air pollution. Hairs in the nose filter out large particles. Sticky mucus in the lining of the upper respiratory tract captures smaller (but not the smallest) particles and dissolves some gaseous pollutants. Sneezing and coughing expel contaminated air and mucus when the respiratory system is irritated with pollutants. Cells of the respiratory tract are also lined with hundreds of thousands of tiny, mucus-coated hair like structure called cilia that continually wave back and forth, transporting mucus and the pollutants to the throat, where they are either swallowed or expelled.

Exposure to air pollutants, compounded by smoking, can overload or break down the natural defense, causing or contributing to respiratory diseases. Examples include lung cancer, asthma, chronic bronchitis and emphysema.

Because sulphates, SO_2, NO_2, and O_3 are strong oxidizing agents, they act as irritants that damage delicate tissue in the eyes and the respiratory passage. Fine particles also act as irritants. These irritants set in motion inflammatory responses that impair lung function and also trigger cardiovascular problems as the heart tries to compensate for the lack of oxygen by pumping faster and harder. If the irritation is really severe, so much fluid seeps into the lungs through damaged tissues that the victims actually drown. This happened to many victims of the Bhopal disaster in 1984 (Cunningham and Saigo, 1999).

4.3 Most Vulnerable Groups

Some people are more sensitive to air pollution than others. Generally, children, elderly and people with lung and heart diseases are more vulnerable to the health effects of air pollution.

Children

Children are more vulnerable to air pollution because they inhale more air, their natural defense mechanism is not as strong as adults, they often spend more time in outdoor environments, and because of their lower heights, there are closer to the tailpipes of vehicles than adults.

National Institute of Environmental Health Sciences in the US studied 110 ten-year old children who shifted to different cities with different levels of air pollution over a period of five years and found a strong association between annual average exposure to PM10 and the annual lung function growth rates. This shows that air pollution can impede lung function in children (Ghose, 2002).

In another study in Santiago, Chile scientists studied daily visit of children to primary health care clinics for upper and lower respiratory track symptoms for a period of two years. The study showed that a 50 $\mu g/m^3$ change in PM10 was associated with a 4 to 12 percent increase in lower respiratory symptoms for children under two and 3 to 9 percent increase for 3 to 15 year-old children (Ostro et. al., 1998).

In Kathmandu, a study done by CEN indicated that young children under the age of six who were attending a school located next to brick kilns suffered from more respiratory problems than similar children who went to school in an area without brick kilns. The study also showed that the absentee rate in the school next to the brick kilns was almost twice as high as the absentee rate in the school with a relatively clean environment (Tuladhar and Raut, 2002).

Elderly

In 2000, a Canadian study used three measurements of particulate matter: coefficient of haze (COH), total sulphate and PM2.5 and reported an association with respiratory diseases and other non-accidental diseases including diabetes. Additionally, COH was associated with increases in cancer deaths and sulphate was associated with mortality from coronary artery disease and cardiovascular diseases. All associations were generally stronger for those above 65 years (Ghose, 2002).

Asthmatics

Although asthma can have several causes, studies have shown that air pollution tends to trigger and aggravate asthma attacks and asthmatics are more vulnerable to other effects of air pollution. When an asthmatic encounters a “trigger” such as dust, cold air, or irritating chemicals, muscles around the bronchial tubes contract and secretory cells produce a thick mucus that block the airways. This results in wheezing and difficulty in breathing (Cunningham and Saigo, 1999).

A few studies have indicted that there is a link between PM10 concentration and asthma attacks. A ten-year study in Chicago found that asthmatics had double the risk of PM10-associated hospital admissions. Another study investigated the short-term health effects of particles in eight European cities and found that for each 10 $\mu g/m^3$ increase in PM10, asthma in children less than 14 years old increased by 1.2 percent and 1.1 percent in people between 15 and 64 years of age (Ghose, 2002).

Asthma attacks can also be triggered by SO_2 and ozone (WHO, 2000). Even moderate levels of SO_2 can affect asthmatics, especially asthmatics doing outdoor exercises.

Diabetics

Particles can increase the risk of heart disease for diabetics. A study done by Harvard School of Public Health investigated the association of PM10 with hospital admissions for heart and lung diseases in persons with or without diabetes in Cook County, Illinois. The study found that a 10 $\mu g/m^3$ increase in PM10 was linked with a 2.01 percent in crease in admissions for heart diseases with diabetes but only a 0.94 percent increase in persons without diabetes (Ghose, 2002).

4.4 Global Evidence on Health Effects of Air Pollution

People who are forced to breathe polluted air have known all along that this has adverse effect on health. However, it is only recently that scientists have begun to understand some of the complexities of air pollutants and unearth evidence on the exact nature of the effects and the severity of the problem.

The first recorded episode of health effects of air pollution was in Meuse valley of Belgium, where air pollution that got trapped at ground level for a week in December 1930 killed 60 people. In October 1948, half the population of 14,000 in Donora, Pennsylvania got sick and 20 died due to severe air pollution. The most notorious event, however, was the 1952 London Smog that killed 4000 people in one weekend. This triggered government action and research to control air pollution and its health effects.

Various epidemiological studies done in the 1990s showed that even at very low concentrations tiny particles can kill and the impact of air pollution is not limited to the respiratory system as all vital organs of the body, including the heart are affected. Scientists are still studying the details on how pollutants chemically and biologically affect various systems within the human body. But the fact that air pollutants, especially fine particles, are deadly and they can cause morbidity as well as mortality is well established. Previously, WHO had recommended 70 $\mu g/m^3$ as a guideline value for PM10 concentration but now it says there is no safe limit for PM10.

Two of the most influential (and controversial) studies so far have been the Six Cities Study done by Harvard University and a study done by American Cancer Society (ACS) (Ghose, 2002). The Harvard Study found that higher levels of fine and sulphate particles were associated with a 26 percent increase in mortality from all causes when comparing the most polluted to the least polluted city – a difference of 18.6 $\mu g/m^3$ for PM2.5 in six cities. Fine particles were also associated with mortality from cardiopulmonary diseases. The ACS study followed 552, 138 adults from 154 US cities from 1982 to 1989 and found higher levels of fine particles were associated with increased mortality from all causes and cardiopulmonary diseases. Higher sulphate levels were also associated with lung cancer (Dockery et. al, 1993).

One of the latest studies indicates that a mere 10 $\mu g/m^3$ increase in fine particles (PM2.5) can increase the risk of lung cancer by 8 percent, cardiopulmonary deaths by 6 percent and all deaths by 4 percent (Pope et. al, 2002 in Ghose 2002). The findings are based on sixteen years of research involving about 500,000 people and 116 metropolitan areas in the US. Arden Pope, one of the co-authors of the study, says that "the findings of the study provide the strongest evidence to date that long-term exposure to air pollution is an important risk factor for cardiopulmonary and lung cancer mortality" (Ghose, 2002).

4.5 Health Effects of Air Pollution in South Asia

The large, crowded and rapidly growing cities of South Asia face major problems related to air pollution and the health of the people living in cities is naturally affected by this pollution. There are, however, very few studies that have estimated or documented the extent of this impact.

In India, a few studies have been done in some large cities such as Delhi, Mumbai, Kolkata, Bangalore, Hyderabad and Chennai. One study shows that 7.5 to 10 percent of males in Delhi suffer from various respiratory diseases. Another says that 10 percent suffer from breathlessness and their lung function is way below expected levels.

In 2001, a study using questionnaires, health examinations and lung function tests (spirometry/peak flow meters) of 4141 individuals living within one km of permanent monitoring stations showed the following results (Chabra, 2003):

- Nearly 25 percent of the residents had chronic respiratory symptoms
- Smoking was by far the major determinant of respiratory morbidity
- Residents in more polluted areas have higher mucous hypersecretion
- Even apparently healthy residents of more polluted areas have poor lung function

Similarly, a seven-year study done in Kolkata revealed that symptoms of respiratory illness were found in 59 % of Kolkatans compared to 23% in rural controls. Similarly, lung function was found impaired in 37% of urban subjects against 18% in controls (Lahiri, 2003). Using these, along with many other findings of the study, Dr. Lahiri concludes that "the study has amply demonstrated adverse effect of urban air pollution on the respiratory health of the citizens." She further adds that "the damage is not restricted to the lung as all the vital organs of the body are affected. Important functional compartments like the immune, circulatory, metabolic and neurological systems are altered."

In Dhaka, Bangladesh, the SPM levels are about two times higher than the Bangladeshi standard of 200 $\mu g/m^3$ in residential areas and more than 10 higher than previous WHO guidelines of 120 $\mu g/m^3$ in commercial areas (Brandon, 1997). Using dose-response functions, Brandon estimates that just reducing Dhaka's air pollution to Bangladeshi standards could save 3,580 premature deaths and 87 million fewer respiratory symptom days.

Although there are few studies on health effects of air pollution in South Asia, available information indicates that the pollution, particularly particulate matter, in South Asian Cities is probably having a major impact on the health of the citizens.

4.6 How to Assess Health Effects of Air Pollution?

Health impacts consist of mortality (death) and morbidity (illness). Assessment of health effects of air pollution can be a very long, complex and expensive process because of the many variables involved.

Generally there are three approaches to study health effects: toxicological studies, controlled human exposure studies and epidemiological studies. Toxicological studies and controlled human exposure studies are done in controlled environments or labs by exposing a certain amount of pollutants for a certain duration to animals or humans, whereas epidemiological studies are done in the natural environment. Some of the main advantages and disadvantages of these approaches are presented in Table 4.4

Table 4.3 Advantages and Disadvantages of Various Approaches to Study Health Effects of Pollution

APPROACH	ADVANTAGE	DISADVANTAGE
Toxicological studies	Quick Dose-response can be studied Single pollutant effect can be studied	May not always be relevant to humans Only short-term effects can be studied
Controlled human exposure	Single pollutant effect can be studied Dose-response can be studied	Only short term effects can be studied Ethical constraints
Epidemiological studies	Close to real life situation Acute/chronic effects can be studied Risk factors can be analysed	Single pollutant effects cannot be studied Confounding factors not easy to control Time consuming Methodology & analysis requires careful considerations

Source: Chabra, 2003

Epidemiological studies try to estimate a statistical relationship between the frequency of specific health outcome observed in a population in its normal environment and air pollution concentrations. There are two types of epidemiological studies: time series and cross sectional. Time series studies examine changes in health outcome within a specific area as air pollution fluctuates over a long time. Cross sectional studies compare differences in health outcomes across different locations at a selected point or period of time. Time series studies have the advantage of reducing the problems associated with confounding or omitted variables (Ostro, 1996).

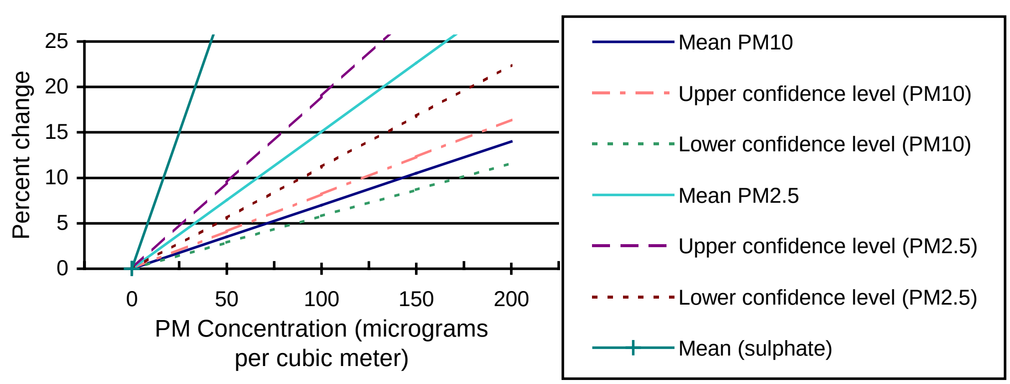
The results from epidemiological studies are often used to develop dose-response relationships to estimate the increase in morbidity or mortality due to increase in pollution level. Based on data from various epidemiological studies, most of which have been done in the US and Europe, several dose-response functions have been developed. Although the use of these relationships has its limitations, they can be valuable in providing a quantitative estimate of health effects.

WHO (2000) has developed the following relationships to estimate the relative increase in various health parameters as a function of PM concentration:

Percent change in daily mortality = 0.6 x mean sulphate
= (0.151 ± 0.039) x mean PM2.5
= (0.070 ± 0.012) x mean PM10

These relationships are shown graphically in Figure 4.3. According to these relationships, the mean PM10 levels were to increase by 10 $\mu g/m^3$, mortality will increase by approximately 0.7 percent. Similarly, if the PM2.5 concentration increases by 10 $\mu g/m^3$, mortality will increase by about 1.51 percent. The relationships show that increase in sulphate particles will have the biggest impact on mortality. An increase in 10 $\mu g/m^3$, of sulphate particles will increase mortality by 6 percent.

Figure 4.3 Percent Change in Daily Mortality as a Function of PM Concentration

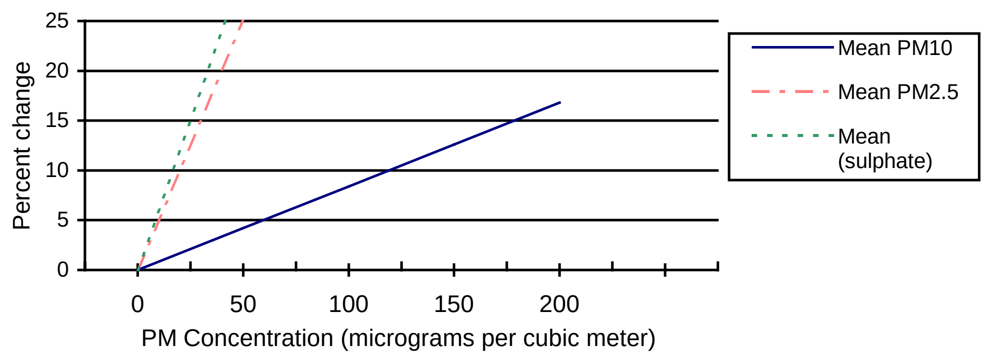


Source: WHO, 2000

WHO has also developed relationships between changes in PM concentration and percent change in hospital admission. These relationships are presented below and shown graphically in Figure 4.4. The relationships indicate that a change in 10 μg/m^3 of PM10 increases the hospital admission by 0.84 percent. However a similar increase in PM2.5 will increase hospital admission by 5 percent. This indicates that PM2.5 concentration has a much higher impact on health and hospital admissions than PM10.

Percent change in hospital admissions= 0.6 x mean (sulphate)
= 0.5 x mean PM2.5
= (0.084 $\pm$ 0.033) x mean PM10

Figure 4.4 Percent Change in Hospital Admissions as Function of PM concentration



Source: WHO, 2000

According to WHO (2000), these relationships can be "used with caution to estimate how many subjects would be affected over a short period of time with increased PM levels." WHO, however, does not recommend the use of these graphs and relationships for PM10 below 20 μg/m^3 or above 200 μg/m^3 and for PM2.5 below 10 μg/m^3 and above 100 μg/m^3.

Similarly, dose-response functions have also been developed to estimate changes in respiratory hospital admissions, emergency room visits, restricted activity days, lower respirator illness in children, asthma attacks, days with respiratory symptoms, and chronic bronchitis (Ostro, 1996). These functions are used to estimate the changes in the number of cases of these "health endpoints" due to changes in the PM10 levels. Table 4.5 shows three sets of dose-response functions to quantitatively estimate the health effects of PM10. The high, low and central functions have been derived by Ostro (1996) based on the findings of several epidemiological studies and used to estimate the health impacts of air pollution in Santiago, Chile. As Santiago Chile is quite similar to Kathmandu in many respects, these functions have also been used to estimate the health effects in Kathmandu. The results are presented in Chapter 5.

Table 4.4 Dose-Response Functions to Estimate Health Effects of PM10

HEALTH EFFECT	ESTIMATED NUMBER OF CASES PER YEAR		
	LOW	CENTRAL	HIGH
Respiratory health admission	0.66×10^{-5} $(PM_j)(Pop_j)$	1.2×10^{-5} $(PM_j)(Pop_j)$	1.56×10^{-5} $(PM_j)(Pop_j)$
Emergency room visits	1.18×10^{-4} $(PM_j)(Pop_j)$	2.35×10^{-4} $(PM_j)(Pop_j)$	3.53×10^{-4} $(PM_j)(Pop_j)$
Restricted activity days	$0.04\ (PM_j)(Pop18_j)$	$0.057\ (PM_j)(Pop18_j)$	$0.09\ (PM_j)(Pop18_j)$
Acute bronchitis in children	0.8×10^{-3} $(PM_j)(PopL18_j)$	1.6×10^{-3} $(PM_j)(PopL18_j)$	2.38×10^{-3} $(PM_j)(PopL18_j)$
Asthma attacks	$0.033(PM_j)(Pop_{aj})$	$0.059(PM_j)(Pop_{aj})$	$0.195(PM_j)(Pop_{aj})$
Respiratory symptoms	$0.091\ (PM_j)(Pop_j)$	$0.180\ (PM_j)(Pop_j)$	$0.273\ (PM_j)(Pop_j)$
Chronic bronchitis	3.0×10^{-5} $(PM_j)(PopG25_j)$	6.1×10^{-5} $(PM_j)(PopG25_j)$	9.3×10^{-5} $(PM_j)(PopG25_j)$

Note:
$PM10_j$ = Change in annual PM10 in area j
Pop_j = Population in area j
Pop18j = Population in area j 18 years of age and older
$PopL18_j$ = Population less than the age 18 in area j
Pop_{aj} = Asthmatic population in area j (5 percent of Popj)
$PopG25_j$ = Population greater than the age 25 in area j

Chapter Summary

As the most common route for pollutants to enter the human body is by inhalation, the most common effect of air pollution is damage to the respiratory system. Exposure to air pollutants, can overload or break down natural defense mechanisms in the body, causing or contributing to respiratory diseases such as lung cancer, asthma, chronic bronchitis and emphysema.

Air pollution can also have adverse impacts on other important systems such as cardiovascular system and central nervous system.

A recent study indicates that a mere 10 $\mu g/m^3$ increase in PM2.5 can increase the risk of lung cancer by 8 percent, cardiopulmonary deaths by 6 percent and all deaths by 4 percent.

The most significant health impacts of outdoor air pollution are associated with particulate matter. Particulate matter does not consist of one compound or element but rather, it is a complex mixture of different organic and inorganic substances, many of which are harmful to human health.

Smaller particles are more dangerous because they stay in the air for a longer time, they have a large surface area which is often coated with harmful substances and they can penetrated deeper into the human body.

Children, elderly and people with lung and heart diseases are more vulnerable to the health effects of air pollution.

Although there are relatively few studies on health effects of air pollution in South Asia, the findings of some Indian studies indicates that urban air pollution, particularly particulate matter, results in major health impacts.

Scientists have used results from epidemiological studies to develop dose-response relationships to estimate the increase in morbidity or mortality due to increase in pollution level. Although the use of these relationships has its limitations, it can be valuable in providing a quantitative estimate of health effects.

5 ASSESSMENT OF HEALTH EFFECTS OF KATHMANDU'S AIR POLLUTION

5.1 Review of Previous Studies

Very few studies have been done to evaluate the health impacts of Kathmandu's air pollution, mainly due to the lack of data on air quality and health status of citizens. Although no long-term epidemiological studies have been conducted in Kathmandu, a few studies have been done by conducting preliminary medical examination of a group of exposed population or by using dose-response relationships that have been developed elsewhere.

World Bank, 1997

Ten years ago, the World Bank supported Metropolitan Environmental Improvement Project (MEIP) project conducted a comprehensive study on the Valley's air pollution, which included for the first time an assessment of the health impacts of Kathmandu's air pollution. The study used dose-response relationships developed from research conducted in the US and combined it with estimated frequency distribution of PM10 exposure in Kathmandu, to estimate impacts on mortality and morbidity due to PM10. Although the use of these functions involves many assumptions and the results can only be speculative at best, it does provide some preliminary numbers. The findings of the health impact study are presented in Table 5.1.

Table 5.1 Health Impacts of PM10 in Kathmandu Valley in 1990

TYPES OF HEALTH IMPACT	NUMBER OF CASES
Excess Mortality	84
Chronic Bronchitis	506
Restricted Activity Days	475,298
Emergency Room Visit	1,945
Bronchitis in Children	4,847
Asthma Attacks	18,863
Respiratory Symptom Days	1,512,689
Respiratory Hospital Admissions	99

Source: Shah & Nagpal (eds.), 1997a

The study indicated that the PM10 in Kathmandu's air has a major impact on respiratory diseases such as bronchitis in children, chronic bronchitis and asthma attacks. Chronic bronchitis can lead to chronic obstructive pulmonary disease (COPD). The number of asthma attacks is particularly high because the study assumes that 20 per cent of the population suffer from asthma and the change in daily asthma attacks per asthmatic person is estimated at 0.0326 x (PM10 – 41).

The main limitations of the World Bank study are as follows:

- The dose-response relationship used was developed in the US based on epidemiological studies done there and the same relationships may not be valid for the case of Kathmandu.
- The value for annual average PM10 concentration for Kathmandu used in the relationship was calculated based on very few studies on Kathmandu's air quality that had been done at that time.
- The equation uses the figure of 41 $\mu g/m^3$ as a bench-mark for PM10, below which it is assumed that there will be no damage. Recent studies have however pointed out that there is no safe limit for PM10.

The World Bank report admits that "for practical and methodological reasons only a partial assessment and valuation of health impacts was possible."

Nepal Environmental and Scientific Services, 2001

A more recent study done by NESS for Nepal Health Research Council using the same dose-response model suggested that Kathmandu's PM_{10} pollution causes 92 premature deaths annually among children less than five years old and about 65,000 cases of respiratory problems (NESS, 2001). Although this study attempts to update the World Bank study, it suffers from the same limitations as the previous study.

Child Workers in Nepal, 1997

One of the first attempts to assess the health impacts of air pollution on a particular vulnerable group was a study done by an NGO, Child Workers in Nepal (CWIN). This study conducted a survey of 60 children working as conductors (*Khalaasi*) in tempos and examined the health (including chest X-ray and blood test) of 38 of these children (CWIN, 1997).

In the survey, 42% of the children said that they had been sick during work.

The health examination found that 84 % had eye problem, 82 % had chest pain, 58 % had headaches and nausea, 53 % suffered from fever, 66 % suffered from cough, cold and problems with the upper respiratory tract, and 45 % experienced difficulty in breathing. Similarly, 29% had pneumonia, tuberculosis, bronchitis and chest problems, 18 % had anemia, and 21 percent had skin problems.

The study also estimated that as these children work for about 14 hours each day hanging behind the tempos just above the emission pipes, they breathe 4,116 g of PM10, 1,255 g of NOx and 17,687 g of TSP each day. As these figures are much higher than the WHO guidelines, these children are dealing with major occupational hazards. The survey also indicated that 65 % of the children are below 14 years of age, which makes them more vulnerable to air pollution.

Student Dissertations, 2001 & 2002

Two students from St. Xavier's Campus have conducted dissertation work on health impacts of air pollution, as part of the B. Sc. Course on Environmental Science. Shakya (2001) studied health impacts on traffic police and Shrestha (2002) did a preliminary assessment of records on COPD patients from major hospital. As these are undergraduate level dissertation, they do not cover the subject in detail but they do provide some useful information on the topic.

Shakya conducted a questionnaire survey of 90 Traffic Police, unstructured interviews with 20 police, observations in the field and medical tests (carboxyhaemoglobin level test and flow meter test) of 15 traffic police. Some of the main findings of the survey are as follows:

Impact on nervous system:

- 73 percent said they suffered from headaches.
- 64 percent reported to suffer from forgetfulness.
- 58 percent suffered from dizziness
- 68 percent suffered from irritation, especially during peak traffic hours
- 74 percent of the respondents said they suffered from depression
- 69 percent suffered from the lack of concentration.

Impact on respiratory system:

- 62 percent were suffering from lowered resistance to influenza
- 26 percent suffered from asthma
- 77 percent suffered from sneezing and irritation of nose
- 87 percent suffered from cough and 22 percent were suffering excessively from this problem. This was found to be the most dominant problem. During the interviews several respondents complained about black sputum and during field observations also many police personnel were seen to be coughing, especially during the peak hours.
- 69 percent were suffering from throat pain

Impact on cardio-vascular system

- 52 percent were suffering from high blood pressure
- 48 percent suffered from rapid heartbeat
- 63 percent suffered from chest pain
- 39 percent suffered from anemia

Other

- 58 percent suffered from reddening of eyes and 71 percent reported burning sensation and watering of eyes. Similarly 51 percent suffered from reduction in vision. Eye problems were also mentioned in the interviews and observed in the field.
- 43 percent suffered from allergy and 41 percent suffered rashes

The levels of carboxyhaemoglobin in the blood was found to be between 0.001 to 0.3 percent, which is lower than the normal level i.e. 1 percent. The results of the flow meter test were all within the normal range.

Shrestha collected data from Bir Hospital, Patan Hospital, Kanti Hospital and TUTH and found that the records show an increasing number of patients diagnosed with respiratory problems over the past five years. Shrestha concludes that this increase in prevalence of respiratory illness is due to the rising level of particulate concentration in Kathmandu's air.

Intermediate Technology Development Group (ITDG), 2002

This study, which has not yet been finalized, focuses on the impact of fuel quality and traffic conditions in Kathmandu's air quality and also assesses the health impacts of air pollution.

The study conducted a survey of 300 people from urban areas (Battisputali, Kalimati, Sundhara) and control area (Budhanilkantha). While 35 percent of the respondents from the urban area said that they were either moderately or severely affected by air pollution, none of the respondents in the control areas said they were moderately or severely affected. In fact, 61% of the respondents in Budhanilkantha said that they were not affected at all, where as in urban Kathmandu, this number was only 10.3 %.

Similarly, in a survey of 15 traffic policemen, all of them said that air pollution is a direct threat to health and well-being and all of them reported that they experienced some ARI related symptoms.

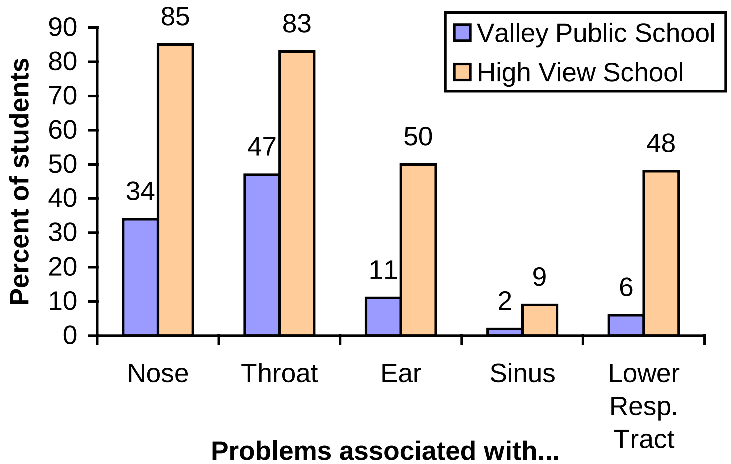
Clean Energy Nepal, 2002

Clean Energy Nepal, together with Pro Public, conducted a study on the impact of brick kilns on the health of children living next to the kilns. A survey of people living in an area with brick kilns as well as a control area indicated that people living near brick kilns are more likely to suffer from illnesses related to air pollution compared to similar people living in an area without kilns. Similarly, a medical examination of children attending school in an area with brick kilns (High View School in Tikathali) and a school in an area without kilns (Valley Public School) showed that the kilns adversely affected the health of young children (under the age of six) exposed to the pollution. The study also showed that the PM10 in the area with the kilns was about three times higher than PM10 levels in an area without the kilns. Some of the key findings of the survey are as follows:

- Out of 290 individuals surveyed, 54 percent from area with brick kilns reported symptoms of respiratory disorders compared to 41 percent in the control area.
- Elderly people were the most affected from respiratory disorders in both the areas. This was followed by children up to the age of four years.

Some of the key findings of the health examination of over 100 students under the age of six are presented in Figure 5.1.

Figure 5.1 Health Status of Students under the Age of 6 in High View School (Brick Kiln Area) and Valley Public School (Control Area)



Patan Hospital, 1993-1994

In 1993, an analysis of the records of all patients admitted to Patan Hospital found that in six years (2042 to 2048 BS), the proportion of admission for COPD as a percent of the total number of medical patients had tripled. In 2041-42 (1984-85) the proportion of COPD patients was 5.1 percent but in 2048 (1991) it had increased to 15 .2 percent (Zimmerman, 1993).

A few years later a more rigorous analysis of the records of 369 COPD patients and 315 control patients admitted to Patan Hospital from April 1992 to April 1994 found that the odds of having COPD are 1.96 times higher for Kathmandu Valley residents compared to outside valley residents (Zimmerman, personal communication, 2003). An unpublished report of the study stated that over the past decade the proportion of COPD patients had increased by more than four folds and that COPD was the number one killer of adult patients in the hospital.

5.2 Analysis of Hospital Records

An indication of the health impacts of Kathmandu's pollution may be obtained by analysing the records of major hospitals in Kathmandu to find the trend in the number of patients visiting the hospitals with air pollution related diseases.

For the purpose of this study, only the records of in-patients were analysed as these were the only records that were available. These figures are likely to indicate only the number of patients who have serious or chronic respiratory illnesses as normally people are not admitted to hospitals for simple problems like cough and throat inflammation.

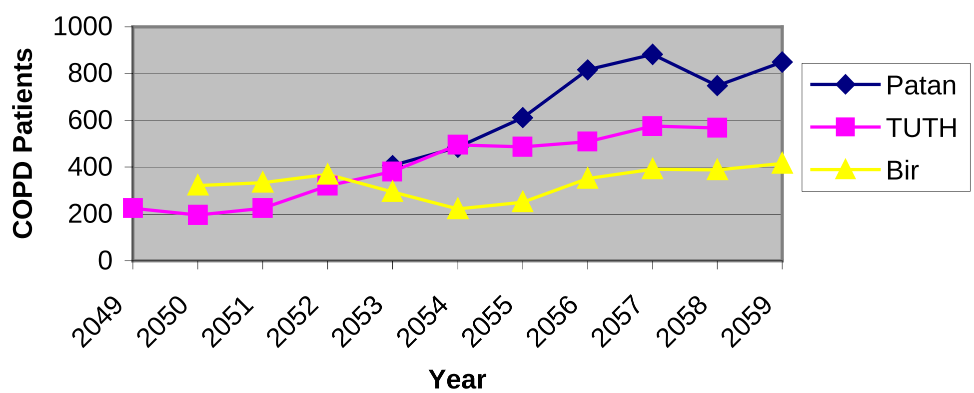
The major public hospitals in Kathmandu are Bir Hospital with approximately 400 beds, Tribhuwan University Teaching Hospital with over 400 beds, Patan Hospital with 300 beds, and Kanti Children's Hospital. Besides these large public hospitals Kathmandu also has many small and medium private hospitals and nursing homes which cater to the health needs of a fairly large number of people, particularly the richer people in society.

This study assessed the records of in-patients from the past ten years at three major hospitals in Kathmandu. The study only obtained records of in-patients that suffered from COPD and asthma. All the records were directly obtained from the hospital staff responsible for keeping these records.

COPD Patients over the Last 10 Years

The number of COPD in-patients in Kathmandu Valley's hospitals has increased over the past 10 years (See Figure 5.2). While in Patan Hospital the increase is most significant, the other hospitals recorded only moderate increases. In Patan Hospital, the number of COPD patients more than doubled within a period of six year from 407 patients in 2053 to 849 patients in 2059. In TUTH, as well the number of patients increased from more than doubled from 225 in the year 2049 to 568 in the year 2058. The increase was least prominent in the case of Bir Hospital where the number of COPD patients went up from 322 in 2050 to 416 in 2059, an increase of 29 percent.

Figure 5.2 Number of COPD Patients Discharged from Major Kathmandu Hospitals over the Past 10 years

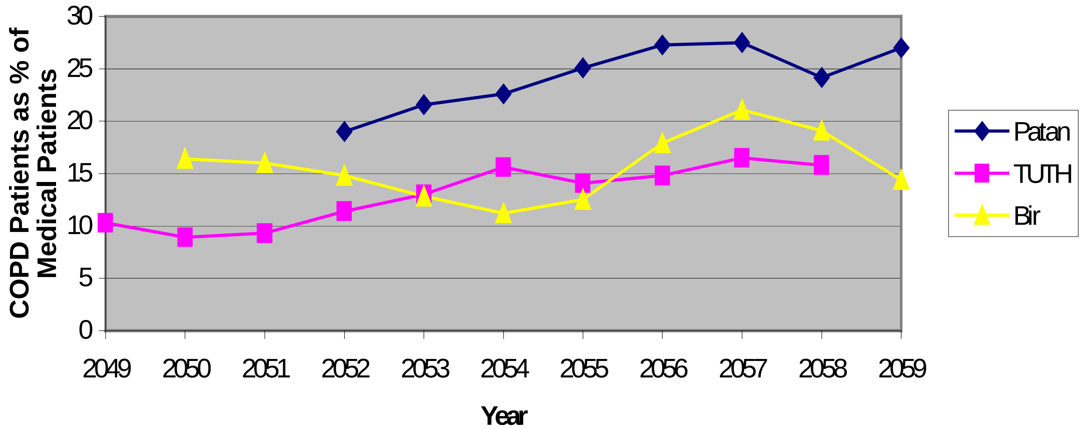


Note: The Nepali calendar is about 57 years ahead of the Gregorian calendar.

The records also indicated that COPD patients as a percentage of the total medical patients had also increased over the years. This indicates that the increase in the number of COPD patients is not just because of the overall increase in the number of patients visiting the hospitals.

The increase in the proportion of COPD patients over the past 10 years is shown in Figure 5.3. The increase is also highest in the case of Patan Hospital where in year 2052 BS, COPD patients represented 19 percent of the total medical patients but now, it is 27 percent. In TUTH, the proportion of COPD patients increased from 8.9 percent in 2050 to 16.5 percent in 2057. In Bir Hospital, the proportion of COPD patients actually decreased from 2050 to 2054, but since then it has increased.

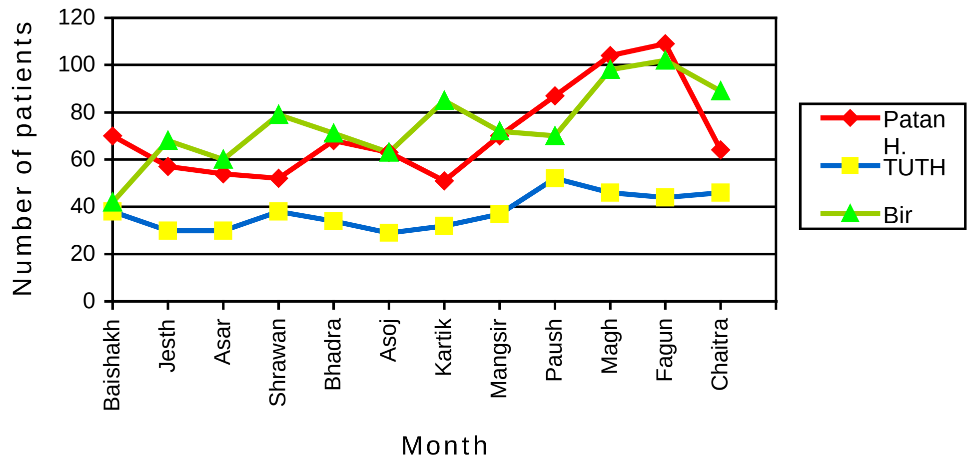
Figure 5.3 COPD Patients as a Percentage of Total Medical Patients



Overall the medical records for the past 10 years indicate that significant number of patients admitted to major hospitals is diagnosed with COPD and their numbers are increasing. On average, approximately 24 percent of the patients admitted to Patan Hospital are COPD patients. While this figure is 13 percent for TUTH and 15 percent for Bir Hospital.

Hospital records and interviews with doctors also clearly indicate that the number of COPD patients admitted to hospitals is highest in the winter season when the air pollution is also at its peak as indicated in Figure 5.4.

Figure 5.4 Number of COPD Patients Admitted to Major Hospitals in 2059

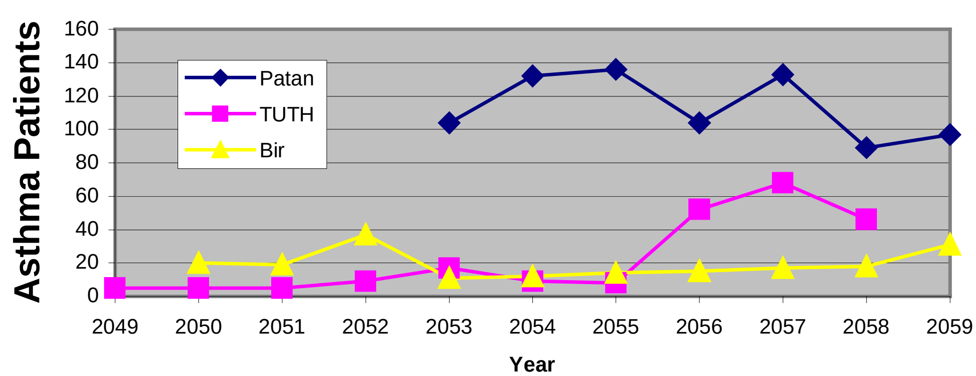


Note: The Nepali Month of Baishakh falls in April-May.

Analysis of Records of Asthma Patients

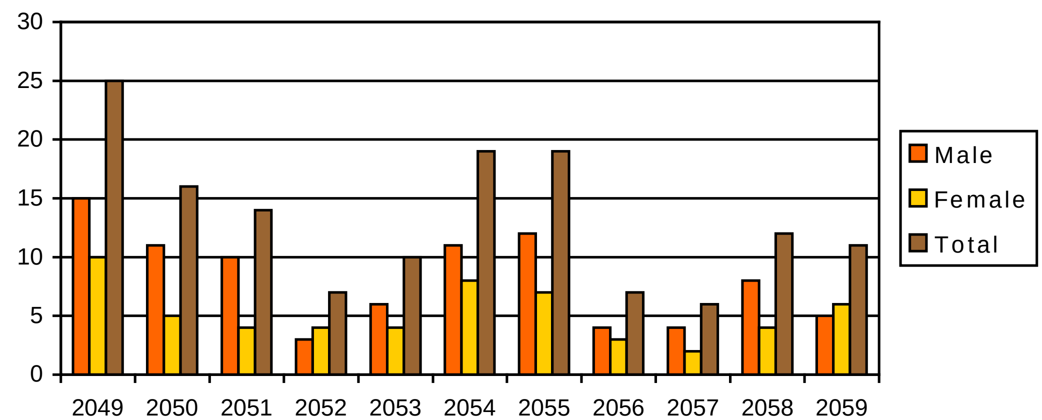
This study also collected data of asthma patients admitted to hospitals in Kathmandu Valley (See Figure 5.5). The data does not show any significant increase over the past 10 years. Several international studies have shown that air pollution exacerbates asthma attacks and it is clear that air pollution in Kathmandu Valley has increased significantly over the past 10 years. A study done by World Bank has also estimated that PM10 levels in Kathmandu would result in 18,863 asthma cases per year (Table 5.1). Hospital records in Kathmandu, however, do not indicate a link between the growing air pollution and the number of asthmatics admitted to hospitals. This may be partially because many asthmatics stay indoors during the winter and take medication if they get asthma attacks instead of being admitted to hospitals.

Figure 5.5 Number of Asthma Patients admitted to Hospitals



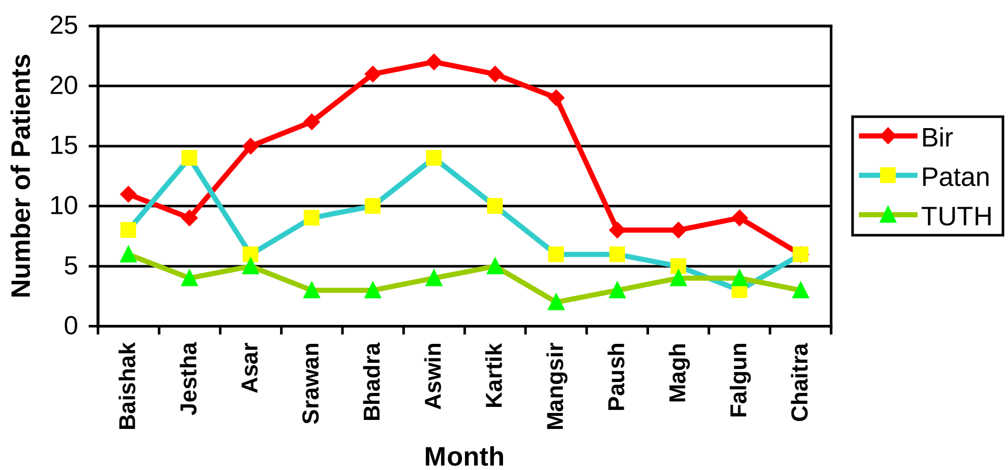
Analysis of hospital records at Kanti Children's Hospital also did not find a clear trend in the number of asthmatic children admitted to the hospital over the past 10 years. Figure 5.6 shows that the number of children with asthma admitted to Kanti Hospital has in fact decreased over the past 10 years.

Figure 5.6 Number of Asthma Patients Admitted to Kanti Hospital



The monthly data on asthmatic patients being admitted to hospitals also does not indicate any clear trend. In fact, data from Patan Hospital and Bir Hospital indicate that the number of asthma patients admitted to hospital is highest in the summer/monsoon season. One possible reason for this is that asthma attacks are triggered by air pollution, as well as pollen, dust and other allergens, which may be higher in the summer. The figures indicate that asthma has several causes other than air pollution.

Figure 5.7 Number of Asthma Patients Admitted to Hospitals in 2059



5.3 Survey of Hospital Patients

In order to get some preliminary information on patients visiting the outpatients and emergency units of the major hospitals, a quick survey was conducted in TUTH, Bir Hospital and Kanti Hospital. The questionnaire survey was administered to patients with respiratory illnesses visiting the hospitals' emergency and outpatients unit during a two-week period in April 2003. A total of 331 patients were surveyed, out of which 179 were in TUTH, 64 in Bir Hospital and 88 in Kanti Children's hospital.

The questionnaire asked for information on age, sex, address, occupation, most common mode of transportation used, smoking habit and respiratory illness. Some of the main limitations of the survey are as follows:

- As the duration of the survey was only two weeks, the total sample size was too small to do a statistical analysis.

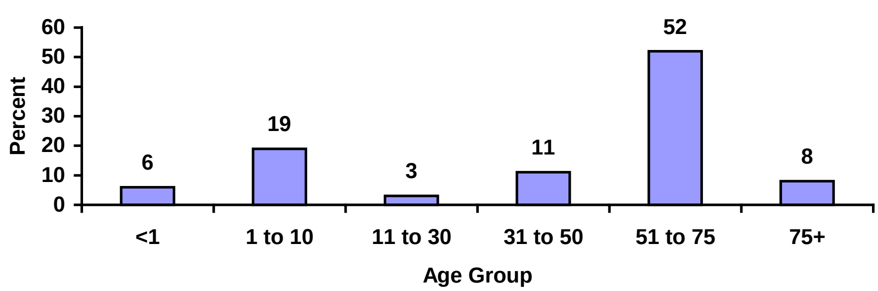
- It is often difficult to diagnose the illness at the time of the survey.

- The survey was only conducted in three hospitals. Although these are three major public hospitals in Kathmandu including the largest children's hospital, the patients visiting the hospitals do not necessarily represent the general population of Kathmandu. Many of the well-to-do Kathmandu residents visit private clinics and nursing homes, especially for outpatient services. Similarly, many people from outside Kathmandu Valley visit the large hospitals that were surveyed.

Because of the limitations involved in the survey, the findings and conclusions drawn from the survey are speculative and may not be evidence-based. Listed below are some of the findings of the survey:

More than 50 percent of the patients were in the 50 to 75 years age category and children below 10 years accounted for more than 20 percent. This indicates that older people and children are more vulnerable to respiratory illnesses. Studies done in other parts of the world have also indicated that the elderly and children are more vulnerable to the impacts of air pollution.

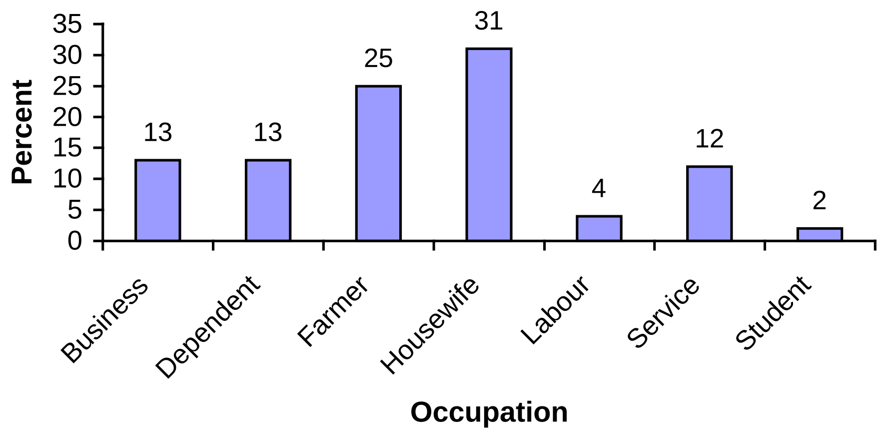
Figure 5.8 Age Distribution of Surveyed Patients



The survey indicated that 69 percent of the respondents were from Kathmandu Valley. Although this shows that most of the patients visiting the hospitals with respiratory problems are from Kathmandu, this information by itself is not very useful because at the moment we do not have information to compare this data with proportion of patients with non-respiratory illnesses who are from Kathmandu valley.

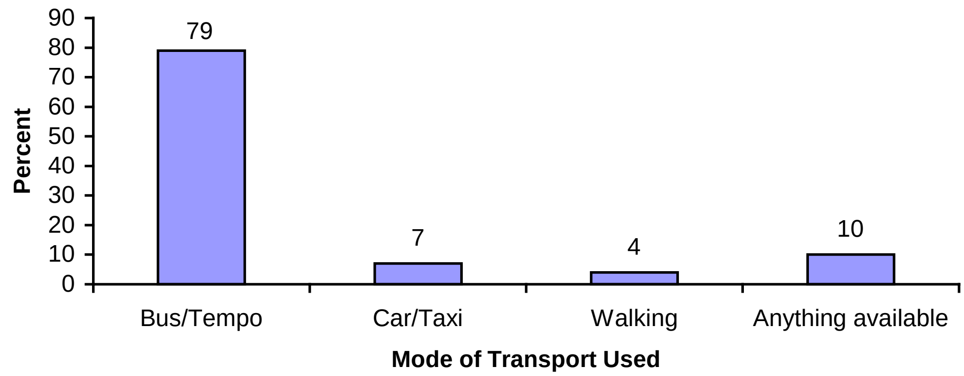
Most of the patients were either housewives or farmers. Housewives accounted for 31% while 25% of the patients surveyed were farmers.

Figure 5.9 Occupation of Surveyed Patients



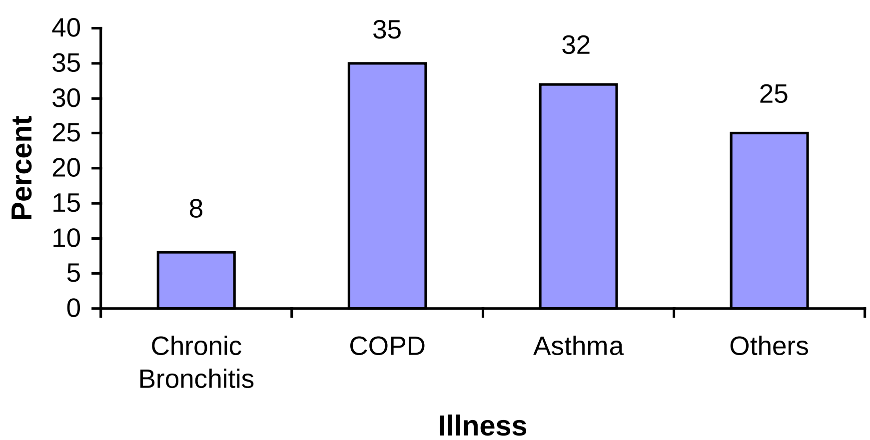
Most respondents were using public transportation such as buses and Tempos on a regular basis. This indicates that the economic status of most of the respondents is fairly low and many are exposed to vehicle emission on a regular basis.

Figure 5.10 Mode of Transportation Used by Survey Respondents



The survey categorized respiratory illness to four classifications, namely, chronic bronchitis, COPD, asthma and others. COPD and asthma have the highest occurrence in the patients, 35% and 32% respectively. Illnesses other than chronic bronchitis, COPD or asthma were chest infection and acute respiratory infection, mostly in children under the age of 10. It was also seen that 72% of the COPD patients and 65% of the asthma patients use bus or tempo as their major means of transport.

Figure 5.11 Main Illnesses of the Surveyed Patients



5.4 Application of Dose-Response Functions in Kathmandu

One way to estimate the potential health impacts of Kathmandu's air pollution is to apply dose-response functions that have been developed elsewhere. The URBAIR study first attempted to this by using some scattered data on air quality from 1990 and a dispersion model to find out population exposed to various levels of pollutants. Although this provided some indications on potential health impacts, the study had to deal with many limitations such as applicability of the function in Kathmandu and the lack of data.

The same functions used by the URBAIR study cannot be used now because, the functions assumed that there was a threshold limit for PM10, below which there would be no impacts. WHO has now said that there is no safe limit for PM10 and even at low levels particles can damage health. Furthermore, most recent studies indicate that PM2.5 is a better predictor of health effects than PM2.5.

Dose-response functions can however be used to estimate the change in health effects caused by a change in PM10 concentrations as shown in Figures 4.3 and 4.4. This requires information on baseline PM10 conditions.

The current annual PM10 concentration in Kathmandu Valley can be estimated based on available data. The existing monitoring stations provide data on PM10 levels at six different locations in Kathmandu Valley from November 2002 to present (July, 2003), which means data from three months are missing. As July is usually the month with the highest rainfall and lowest PM10 levels in Kathmandu, we can assume that the PM10 levels in the valley will start to increase from July to November. Assuming that this increase follows a linear pattern, the PM10 levels for the months of August, September and October can be estimated. Furthermore, two of the six stations are located in rural areas while four are in urban areas, which is same ratio as the ratio of rural population to urban population in the Valley. Therefore, taking an average of the results from the six stations will give a reasonable estimate of the average exposure level in the valley. Similarly, the average exposure to PM10 levels in Kathmandu municipality can be calculated by taking the average of the results from Putali Sadak and Thamel as these represent commercial and residential areas in the city.

Using the assumptions and calculations mentioned above, the average annual PM10 level in Kathmandu Valley comes out to be 148 $\mu g/m^3$, and the average annual PM10 level for Kathmandu municipality comes out to be 198 $\mu g/m^3$. Furthermore, preliminary studies on PM2.5 levels in Kathmandu indicate that about 64 percent of the PM10 is PM2.5. Assuming 64 percent of the average annual PM10 is PM2.5, then the average annual PM2.5 concentration in Kathmandu Valley and Kathmandu municipality comes out to be 94.7 $\mu g/m^3$ and 126.7 $\mu g/m^3$ respectively.

Using the average annual PM10 and PM2.5 values and the functions shown in Figure 4.3 and Figure 4.4, we can draw the following conclusions:

- If we were to reduce the PM2.5 level in Kathmandu Valley by half (by 47.4 μg/m^3), we can expect to see a reduction in daily mortality by 7 percent and hospital admissions by 24 percent.

- Similarly, if we reduce the PM2.5 level in Kathmandu Municipality by half (by 63.4 μg/m^3), the daily mortality will to go down by approximately 10 percent and hospital admissions will reduce by 32 percent.

- If we could reduce the PM2.5 levels in Kathmandu Valley to USEPA standards (15 μg/m^3), then we would reduce mortality by 12 percent and hospital admissions by 40 percent.

The NAAQS does not mention any standard value for annual average PM10. In many other countries (including India and the US) the standard for annual average PM10 is 50 μg/m^3. If we assume that the current population of Kathmandu Valley is 1.8 million, then the health benefits of reducing the average annual PM10 concentration in Kathmandu to 50 μg/m^3 can be estimated using dose-response functions developed by Ostro (1996). The functions are presented in Table 4.4 and the results are presented in Table 5.2.

Table 5.2 Estimated Health Benefit of Reducing Kathmandu Valley's Annual Average PM10 to 50 μg/m^3

HEALTH EFFECT	NUMBER OF CASES AVOIDED
Respiratory hospital admissions	2,117
Emergency room visits	41,454
Restricted activity days	5.2 million
Acute bronchitis in children	135,475
Asthma attacks	0.5 million
Days with Respiratory symptoms	32 million
Chronic bronchitis	4,304

Assumptions:
Total population of Kathmandu in 2003 is approximately 1.8 million
Percent of population over 18 years is 52 percent (same as national average in 2001)
Percent of population that has asthma is 5 percent
Percent of population over 25 years is 40 percent (same as national average in 2001)

The results indicate that the estimated health benefits of reducing Kathmandu's PM10 levels to international standards are enormous. The results are also much higher than the estimated health effects calculated by the URBAIR study using PM10 levels in 1990. The difference is mainly due to the increase in population and pollution levels.

Chapter Summary

Although no long-term epidemiological studies have been conducted in Kathmandu, a few studies have been done by conducting preliminary medical examination of a group of exposed population or by using dose-response relationships that have been developed elsewhere.

The URBAIR study done by World Bank used dose-response relationships developed from research conducted in the US and combined it with estimated frequency distribution of PM10 exposure in Kathmandu, to estimate impacts on mortality and morbidity due to PM10 levels in 1990. The study estimated that Kathmandu's PM10 resulted in 84 cases of excess mortality, 506 cases of chronic bronchitis, 4,847 cases of bronchitis in children and 18,863 asthma attacks per year. Overall, Kathmandu's residents experienced over 1.5 million respiratory symptom days per year.

More recently, NESS did a similar study and estimated that Kathmandu's PM10 resulted in about 65,000 cases of various respiratory problems per year.

A few studies have shown the impact on certain vulnerable groups such as traffic police, children working as conductors in Kathmandu's three-wheelers and children living near brick kilns.

An analysis of the records of 369 COPD patients and 315 control patients admitted to Patan Hospital from April 1992 to April 1994 showed that the odds of having COPD are 1.96 times higher for Kathmandu Valley residents compared to outside valley residents. The study also stated that over the past decade the proportion of COPD patients had increased by more than four folds and that COPD was the number one killer of adult patients in the hospital.

An analysis of hospital records from three major hospitals in Kathmandu indicates that the number of COPD patients admitted to hospitals, as well as the percent of COPD patients as a percentage of total medical patients has increased significantly in the last ten years.

Hospital records also indicate that the number of COPD patients is highest in the dry winter months, which is also when air pollution in Kathmandu is at its peak.

Hospital records in Kathmandu do not indicate a significant increase in the number of asthma patients over the past 10 years. Although air pollution is known to be one of the factors that exacerbate asthma, there are several other factors that can trigger asthma attacks.

A survey of 331 patients with respiratory illnesses visiting the out-patient and emergency departments of major hospitals in Kathmandu indicates that most of them are from Kathmandu valley and most are in the age group 51 to 75. Approximately, 80 percent of the respondents said public transportation was the most common mode of transportation for them. Although the sample size was not large enough to draw concrete conclusions, the survey does indicate that patients visiting the hospitals with respiratory problems are mostly elder residents of Kathmandu valley who are regularly exposed to air pollution.

Using dose-response functions, we can estimate that reduction of PM2.5 level in Kathmandu Valley by half (by 47.4 $\mu g/m^3$), will reduce daily mortality by 7 percent and hospital admissions by 24 percent. Similarly, reduction of PM2.5 level in Kathmandu Municipality by half (by 63.4 $\mu g/m^3$), will reduce mortality by approximately 10 percent and hospital admissions by 32 percent.

Reducing the annual average PM10 level in Kathmandu to international standards (50 $\mu g/m^3$) will avoid over 2000 hospital admissions, over 40,000 emergency room visits, over 135,000 cases of acute bronchitis in children, over 4,000 cases of chronic bronchitis and half a million asthma attacks. Overall this means over 5 million restricted activity days and 32 million days with respiratory symptoms will be avoided.

6 ECONOMIC VALUATION OF HEALTH IMPACTS

6.1 Approaches used for Valuation of Health Impacts

Valuation of health effects is a very difficult and often controversial issue because of the many uncertainties and assumptions involved in this process. Although it is clear that pollution related health effects result in substantial direct as well as indirect financial losses, it is difficult to value these losses in monetary terms. Yet, this type of information is very valuable for decision-making and public education campaigns.

Economic valuation of health impacts may be divided into two components: valuation of mortality (death) and valuation of morbidity (illnesses)

Valuing Reduction in Morbidity (Illnesses)

The value of avoiding an illness episode, such as asthma attack, consists of the following four components (World Bank, 2003b):

- Value of the work time lost due to the illness episode (by the victim as well as the caretaker)
- Medical cost of treatment
- The amount the victim or his/her guardian would pay to avoid the pain and suffering associated with the illness
- Value of the leisure time lost due to the illness (by the victim as well as the caretaker)

There are various ways to calculate the value of the four components. Generally patients are asked what were the cost of treatment and the length of time they were sick. The cost due to loss in work time is calculated by using local wage rates. The cost of suffering is more difficult to estimate. Normally this is estimated by asking people what they are willing to pay to avoid the pain and discomfort caused by the illness. This may be difficult in the case of serious illnesses such as cancer and heart attack. The cost of medical treatment is often referred to as direct cost and the other components are referred to as indirect costs.

Valuing Premature Mortality

Dose-response relationships are often used to estimate how many fewer people are likely to die if air pollution is reduced. This number is referred to as the number of statistical lives. Value of premature mortality is calculated by establishing a value for statistical life (VSL) depending on local circumstances. Shah and Nagpal (1997) describes two broad methods are used to estimate VSL. One is the human capital approach, which values an individual's life according to the net present value of his/her future productivity. The second is the willingness to pay (WTP) approach, which measures the value society places on individual distinct from an individual's wage-earning capacity (Shah and Nagpal, 1997). Normally the first approach gives a lower value than the second approach.

Several modifications of these broad methods are also possible. For example, in the US a value of US$ 3 million per statistical life is derived using the WTP approach. Although such a value is not readily transferable from one country to another, an approximation can be derived by correcting the US figure by a factor of the purchasing power parity in Nepal, divided by the purchasing power in US. According to Shah and Nagpal, 1997 using this method the VSL in Nepal will be Rs.6.4 million. Using the human capital approach, Shah and Nagpal estimate the VSL in Nepal to be Rs. 340,000, which is very different from Rs. 6.4 million.

6.2 Valuation Health Effects due to Kathmandu's Air Pollution

The first attempt to calculate the value of health effects of Kathmandu's air pollution was done by a World Bank study (Shah and Nagpal, 1997). The study estimated the health effects of PM10 in Kathmandu and also attempted to calculate the value of these impacts. The study estimated that the total cost of the health impacts of PM10 in Kathmandu in 1990 to be approximately Rs. 210 million.

Table 6.1 Valuation of Health Impacts in Kathmandu

TYPES OF HEALTH IMPACT	NO. OF CASES	VALUE (NRS.)	
		Specific	Total (x 10^3)
Excess Mortality	84	340,000	28,644
Chronic Bronchitis	506	83,000	41,988
Restricted Activity Days	475298	56	26,617
Emergency Room Visit	1945	600	1167
Bronchitis in Children	4847	350	1,697
Asthma Attacks	18,863	600	11,318
Respiratory Symptom Days	1,512,689	50	75,634
Respiratory Hospital Admissions	99	4160	415
Total			209,051

Source: Shah & Nagpal, 1997

Since 1990, the number of vehicles in Kathmandu has increased by four folds thus increasing the total pollution load in the valley. As mentioned earlier, ESPS/MOPE estimates that the PM10 emission from vehicles must have increased by almost four folds and the total PM10 emission load in Kathmandu has almost doubled.

The number of people exposed to Kathmandu has also increased significantly, over the last 13 years. According to the national census of 2001, Kathmandu's population increased by 54 percent between 1991 and 2001.

As urban population growth rate is much higher than the rural population growth rate, it can be assumed that much of this growth happened in urban Kathmandu and therefore the number of people exposed to high pollution levels has significantly increased.

Therefore the total economic value of health effects due to Kathmandu's pollution must have also increased significantly.

NESS did a similar assessment in 2001 and concluded that the respiratory problems caused by air pollution costs the country about Rs. 30 to 55 million per year. Although this figure does not include the cost of change in mortality, chronic bronchitis, and asthma attacks, this is much less than the estimate calculated by Shah and Nagpal (1997). This is because of some errors in calculations and the low unit rates used during the calculations. For, example the study estimates that the change in respiratory symptom days will be only 322, which must be a mistake because the cases of chronic bronchitis itself are over 10,000. The World Bank study estimates the change in respiratory symptom days to be about 1.5 million.

The World Bank study has also attempted to calculate the marginal contribution of various sources towards total particulate pollution and in this process estimated marginal cost/benefit of various sources of pollution. The report concludes that "an analysis of the marginal impacts of emission increase and reduction by source categories showed that the health impacts are mostly affected by development in the transport sector, while domestic sources and brick manufacturing rank second in this respect."

The study estimated that reduction of one kg of vehicle emission will result in saving Rs. 341 in terms of reduced health damage, whereas the saving due to reduction in domestic emission, which was next in the order of importance, was only Rs. 185. Similarly the study states that an increase in one kg of emission from traffic sources (vehicle emission and resuspension) will increase health damage by Rs. 570, whereas the increase in damage due to domestic sources and brick kilns was only Rs 270 and Rs. 250 respectively.

The World Bank study concludes that reduction of vehicle exhaust emission is the most effective measure to reduce health damage due to air pollution.

Estimation of Hospital Costs

This present study has not done a complete valuation of the health effects due to Kathmandu's air pollution because of the many uncertainties involved. Discussion with personnel from public hospitals, however, indicate that on average, a person with COPD admitted to the general ward of a public hospital in Kathmandu will have to spend approximately Rs. 1200 per day on room charge, medication and food. Similarly, an asthma patient in the general ward will have to spend about Rs. 1500 per day. Naturally, the cost in the private wards and in the private hospitals will be much more expensive.

Preliminary results from a survey done by ITDG (2002) indicated that the average direct cost of treatment for respiratory illnesses in Kathmandu's public hospitals was Rs. 9,921 and the average indirect cost was estimated to be Rs. 4400. The total cost per hospital admission is therefore estimated to be Rs. 14,321. Results of dose-response calculations (Table 5.2) indicate that reducing Kathmandu's PM10 level to international standards can avoid 2117 cases of hospital admissions. Therefore, the avoided cost of hospital treatment by reducing Kathmandu's PM10 levels to international standards is about Rs. 30 million. This is not the entire cost of health effects of Kathmandu's air pollution because it does not include cost of emergency room visits, restricted activity days, respiratory symptom days, treatment at home and excess mortality.

In the World Bank study, the cost of hospital admission was only 0.2 percent of the total cost of PM10 pollution (Table 6.1). The study estimated the cost of respiratory hospital admission to be only Rs. 415,000 compared to the total cost of Rs. 210 million. Therefore, the present estimate of Rs. 30 million for avoided cost of hospital admission indicates that the total benefit of reducing Kathmandu's PM10 levels to international standards will be much higher.

Chapter Summary

Although it is clear that pollution related health effects result in substantial direct as well as indirect financial losses, valuation of health effects (mortality and morbidity) in monetary terms is a difficult and often controversial issue because of the many uncertainties and assumptions involved in this process.

A World Bank study estimated the total cost of the health impacts of PM10 in Kathmandu in 1990 to be approximately Rs. 210 million.

The study also found that reduction of vehicle exhaust emission is the most effective measure to reduce health damage. The study estimated that reduction of one kg of vehicle emission will result in saving Rs. 341 in terms of reduced health damage, whereas the saving due to reduction in domestic emission, which was next in the order of importance, was only Rs. 185.

Preliminary estimates indicate that reducing the annual average PM10 levels in Kathmandu to international standards (50 $\mu g/m^3$) will save approximately Rs. 30 million in just hospital admission costs. The World Bank estimates showed that hospital admission cost was only 0.02 percent of the total cost of health effects of Kathmandu's air pollution in 1990. Therefore, it safe to assume that billions of rupees can be saved by the lowering Kathmandu's PM10 levels to that of international standards.

The preliminary studies on financial implications of air pollution clearly show that the cost of pollution is very high and reducing vehicle emission is the most effective way of reducing this huge economic burden.

7 CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

The following conclusions can be drawn from this study:

1. The level of PM10 in Kathmandu's air is extremely high, especially in the dry winter months. In these months the air in urban Kathmandu, especially along roadsides, can be classified as either "very unhealthy" or even "hazardous."

2. The concentration of fine particles (PM2.5) in the air is also very high. The high PM2.5 to PM10 ratio suggests that most of the pollution is from combustion sources, such as vehicles.

3. Vehicles are the main source of air pollution in Kathmandu and the pollution from this source is increasing at an alarming rate. Now with the closure of Himal Cement and the introduction of new environment-friendly brick kilns, the need to control vehicle emission becomes even more urgent.

4. Air pollution is a major cause of mortality and morbidity all over the world. Among substances that can pollute the air, fine particles are considered to be the most deadly. These particles are often coated with toxic substances and they can enter deep into the lungs and other parts of the body.

5. As the level of fine particles is very high in Kathmandu, the associated health impacts are also expected to be high.

6. As the most common route for pollutants to enter the human body is by inhalation, the most common effect of air pollution is damage to the respiratory system. Exposure to air pollutants, can overload or break down natural defense mechanisms in the body, causing or contributing to respiratory diseases such as lung cancer, asthma, chronic bronchitis and emphysema.

7. Children, elderly and people with lung and heart diseases are more vulnerable to the health effects of air pollution.

8. One of the main sources of fine particles is diesel exhaust. Studies have established that diesel vehicles emit up to 100 times more particles than petrol vehicles and 90 percent of these are less than 1 micron in size. Diesel exhaust has also been labeled as carcinogenic. As Kathmandu also has a large number of diesel vehicles (buses, mini-buses, micro-buses and private cars) there needs to be a concerted effort to control the pollution from these sources.

9. Electric vehicles (trolley buses and battery operated vehicles) can be a good replacement for the diesel (as well as petrol and LPG) vehicles in Kathmandu. Just rehabilitating the existing trolley bus system can save about 3 tons of carcinogenic particles from being released into Kathmandu's air.

10. A few sporadic studies that have been done to study the health effects of air pollution in Kathmandu suggests that the Valley's air pollution is having a major impact on the health of the residents and the economy as a whole.

11. A study of 369 COPD patients and 315 control patients admitted to Patan Hospital between 1992 and 1994 concluded that that the odds of having COPD are 1.96 times higher for Kathmandu Valley residents compared to outside valley residents

12. Analysis of records from Patan hospitals, TUTH and Bir Hospital in Kathmandu indicate that the number of COPD patients admitted to the hospitals shows an increasing trend over the last 10 years. In Patan Hospital, the number of COPD patients have almost doubled in the past five years.

13. The number of COPD patients as a percent of total medical patients has also increased in the hospitals indicating that the increase in COPD patients is not just because of an increase in the total number of patients. In Patan Hospital, currently about 27 percent of Medical patients are COPD patients. This number used to be 5.1 percent in 1985 and 15.2 percent in 1991.

14. Hospital records also show that the number of COPD patients is highest in the winter months when the air pollution in Kathmandu is also at its peak.

15. Analysis of hospital records regarding asthma patients does not give clear picture regarding the trend in asthma patients admitted to hospitals. The number of asthma patients has fluctuated annually over the past ten years and they cannot be related to Kathmandu's pollution. Analysis of seasonal variation in asthma patients also does not show any clear trends. In one of the hospitals, the number of asthma patients was higher in the summer/monsoon months when the air pollution is low.

16. Although this study could not find a relationship between Kathmandu's growing air pollution and the number of asthma patients, a number of international studies have concluded that air pollution exacerbates asthma attacks.

17. Survey of patients visiting the out-patient and emergency department of major public hospitals with respiratory problems indicate that most of the patients are from Kathmandu Valley, almost 80 percent regularly use public transportation and most are in the 50 to 75 age group. Although

the number of patients surveyed is too small to draw concrete conclusions, it does indicate that most of the patients visiting Kathmandu's public hospitals with respiratory problems are elder residents of Kathmandu Valley who are regularly exposed to air pollution.

18. Reduction of PM2.5 level in Kathmandu Valley by half (by 47.4 $\mu g/m^3$), will reduce daily mortality by 7 percent and hospital admissions by 24 percent. Similarly, reduction of PM2.5 level in Kathmandu Municipality by half (by 63.4 $\mu g/m^3$), will reduce mortality by approximately 10 percent and hospital admissions by 32 percent.

19. Reducing the annual average PM10 level in Kathmandu to international standards (50 $\mu g/m^3$) will avoid over 2000 hospital admissions, over 40,000 emergency room visits, over 135,000 cases of acute bronchitis in children, over 4,000 cases of chronic bronchitis and half a million asthma attacks. Overall this means over 5 million restricted activity days and 32 million days with respiratory symptoms will be avoided.

20. Preliminary studies on financial implications of air pollution clearly shows that the cost of pollution is very high and reducing vehicle emission is the most effective way of reducing this huge economic burden.

7.2 Recommendations

Based on the conclusions mentioned above, this study recommends the following actions:

1. As air pollution is a serious threat to the health and well-being of Kathmandu Valley residents, actions to control air pollution must be implemented immediately. At present, MOPE is implementing some measures to control air pollution but they are not done in a planned manner and are insufficient considering the rapid increase in pollution levels. MOPE has expressed its commitment to meet the standards within three years. This is very ambitious but not impossible if MOPE takes some bold decisions and has the will to implement it. This study therefore strongly recommends MOPE to come up with a comprehensive and convincing action plan designed to meet the NAAQS within the next three years. As particles are the number one problem in Kathmandu, the action plan should be targeted at bringing down the concentration of fine particles in Kathmandu's air.

2. Electric trolley buses should be promoted as an alternative to diesel buses in Kathmandu. For this the existing trolley bus system should be revived immediately and steps should be taken to expand the trolley bus service in partnership with the private sector.

3. As diesel exhaust is very dangerous for health and it is the main source of fine particles, diesel vehicles should be avoided to the extent possible. For this, government should introduce economic tools, such as fuel tax, to

discourage the use of diesel vehicles and at the same time promote cleaner alternatives such as electric vehicles.

4. As the number of vehicles in Kathmandu is rising at an alarming rate, the government should promote efficient and clean public transportation to control vehicle numbers. Simultaneously, the use of private vehicles should be discouraged by making ownership and operation of private vehicles more expensive.

5. Studies done in various cities have shown that about 20 percent of highly polluting vehicles are generally responsible for about 50 percent of the pollution. Therefore steps need to be taken immediately to weed out the "gross polluters." The existing emission testing system can identify gross polluters, now the government has to have the will to get rid of them.

6. Although there are enough evidences linking air pollution and health impacts, some further studies should be done on the health effects of air pollution in Kathmandu. These should be short studies aimed at stimulating action from policy makers and the general public.

7. Public awareness campaigns are required to inform the people about the hazards of air pollution and what they can do to avoid and minimize air pollution. The campaign should have the following objectives:

    - Highlight the alarming situation of air pollution in Kathmandu and its health impacts.
    - Inform policy makers and the general public on steps that need to be taken to reduce air pollution.
    - Encourage citizens to raise their voices against air pollution in the Valley and exert pressure on the government to take effective action.
    - Encourage vehicle owners to regularly maintain their vehicles and reduce the use of their vehicles to the extent possible
    - Discourage the use of polluting vehicles, such as vehicles with two-stroke engines and diesel vehicles.
    - Encourage the use and promotion of clean vehicles such as electric vehicles and non-motorized transportation.

"Protect Our Children's Right to Clean Air"

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ANNEX 1 SCOPE OF WORK

To identify the air pollution related health impacts and to assess relationship between the specific cases (health conditions) with level of air pollution in Katmandu the study will:

1. Collect historical data on air pollution levels in Kathmandu specifically vehicular contribution to air pollution.
2. Identify any adverse dermatological conditions caused by air pollution (air pollution due to vehicular emissions).
3. To identify the affects of vehicular emissions on the public health, references may be made to similar cities in Indian subcontinent, if sufficient data is not available.
4. Study and present the findings of increased impacts of pollution since the Kathmandu-Baktapur Trolley has stopped running. (This would be based on an assessment of additional pollution due to replacement of the electric trolley by other forms of transportation on this route.)
5. Collect data form Patan Hospital for the period of, but limiting to, the last 10 years. If data is available, collect data from Bir Hospital, TUTH, Teku Hospital and Kanti Children's Hospital. A trend analysis is done for possible correlation with hospital visits and pollution levels in Kathmandu. The data will include patients who visited the emergency or the outpatient department for any (not limiting to) of the following air pollution related complaints: i) acute exacerbation of asthma, ii) chronic obstructive airway disease iii) acute coronary events.
6. For a specified period during the duration of this study: Collect data from Bir Hospital, TUTH, and Kanti Children's Hospital. The data will include the information of all the patients who come to the Emergency Department or the Out Patient Department (OPD) with any of the following: i) acute exacerbation of asthma, ii) chronic obstructive airway disease iii) acute coronary events. The information of a patient will include occupation, current address, place of work, and mode of transportation.
7. Where possible gather available data on the financial impacts of such health problems (i.e., number of work days missed, patients' medical expenses i.e. costs incurred as an admitted and/or non-admitted case, etc.).
8. Coordinate with the Ministry of Population and Environment/Environment Sector Program Support Project (MOPES/ESPS) to collect data from the existing air monitoring centers.
9. Statistical analysis of the data (including disaggregation of data by gender, socioeconomic status and age, as much as is possible.
10. Present trends and identify contributing factors related to any increases in respiratory problems (acute exacerbation of asthma, chronic obstructive

airway disease, acute coronary events) during the worse periods of pollution levels in the Valley.

11. Present and publish the findings of the study.
12. It is expected that the study will take around 60 professional working days to complete.

ANNEX 2 AIR QUALITY DATA (NOVEMBER 2002 TO JULY 2003)

November, 2002							
Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
11/1/02	N/A	N/A	N/A	119	N/A	170	145
11/2/02	N/A	N/A	N/A	108	N/A	163	136
11/3/02	N/A	N/A	N/A	100	N/A	184	142
11/4/02	N/A	N/A	N/A	105	N/A	190	148
11/5/02	N/A	N/A	N/A	104	N/A	171	138
11/6/02	N/A	N/A	N/A	72	N/A	124	98
11/7/02	N/A	N/A	N/A	78	N/A	128	103
11/8/02	N/A	N/A	N/A	93	N/A	136	115
11/9/02	N/A	N/A	N/A	93	N/A	137	115
11/10/02	N/A	N/A	N/A	100	N/A	150	125
11/11/02	N/A	N/A	N/A	77	N/A	109	93
11/12/02	N/A	N/A	N/A	71	N/A	98	85
11/13/02	N/A	N/A	N/A	46	N/A	57	52
11/14/02	N/A	N/A	N/A	73	N/A	109	91
11/15/02	N/A	N/A	N/A	72	N/A	121	97
11/16/02	N/A	N/A	N/A	83	N/A	126	105
11/17/02	N/A	N/A	N/A	83	N/A	165	124
11/18/02	N/A	N/A	N/A	74	N/A	146	110
11/19/02	N/A	N/A	N/A	95	N/A	158	127
11/20/02	N/A	N/A	N/A	106	N/A	161	134
11/21/02	N/A	N/A	N/A	119	N/A	214	167
11/22/02	N/A	N/A	N/A	126	N/A	185	156
11/23/02	N/A	N/A	N/A	125	N/A	176	151
11/24/02	N/A	N/A	N/A	114	N/A	171	143
11/25/02	N/A	N/A	N/A	150	N/A	231	191
11/26/02	N/A	N/A	N/A	121	185	196	167
11/27/02	256	N/A	N/A	115	222	209	201
11/28/02	287	N/A	N/A	127	217	205	209
11/29/02	286	N/A	N/A	135	220	221	216
11/30/02	256	N/A	N/A	124	198	200	195
Monthly Avg.	271	N/A	N/A	100	208	160	136
December, 2002							
Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
12/1/02	257	N/A	N/A	126	200	176	190
12/2/02	262	N/A	N/A	133	213	179	197
12/3/02	267	N/A	N/A	151	229	197	211
12/4/02	304	N/A	N/A	112	240	222	220
12/5/02	297	N/A	N/A	121	231	213	216
12/6/02	288	N/A	N/A	120	205	203	204

12/7/02	254	N/A	N/A	133	286	240	228
12/8/02	263	N/A	N/A	114	255	177	202
12/9/02	267	N/A	N/A	111	227	178	196
12/10/02	284	N/A	N/A	132	206	196	205
12/11/02	278	N/A	N/A	125	232	205	210
12/12/02	310	N/A	N/A	129	222	216	219
12/13/02	301	N/A	N/A	141	205	210	214
12/14/02	261	N/A	N/A	146	194	200	200
12/15/02	291	N/A	N/A	144	205	194	209
12/16/02	271	N/A	N/A	147	227	209	214
12/17/02	281	N/A	N/A	177	261	236	239
12/18/02	277	N/A	N/A	187	262	240	242
12/19/02	346	N/A	N/A	226	311	273	289
12/20/02	333	N/A	N/A	215	281	270	275
12/21/02	284	N/A	N/A	207	245	225	240
12/22/02	350	N/A	N/A	202	259	286	274
12/23/02	359	N/A	N/A	212	264	328	291
12/24/02	367	N/A	N/A	273	365	302	327
12/25/02	345	N/A	N/A	261	339	308	313
12/26/02	339	N/A	N/A	256	317	286	300
12/27/02	342	N/A	N/A	215	320	291	292
12/28/02	310	N/A	N/A	254	290	247	275
12/29/02	204	N/A	N/A	265	245	291	251
12/30/02	N/A	N/A	N/A	284	283	278	211
12/31/02	N/A	N/A	N/A	278	275	N/A	138
Monthly Avg.	296	N/A	N/A	181	255	236	242
January, 2003							
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
1/1/03	N/A	N/A	65	145	157	240	121
1/2/03	407	N/A	111	210	283	270	320
1/3/03	435	N/A	133	245	309	348	294
1/4/03	303	N/A	112	279	296	261	250
1/5/03	349	N/A	115	261	299	289	263
1/6/03	340	N/A	114	271	330	305	272
1/7/03	295	N/A	130	261	299	281	253
1/8/03	343	N/A	102	248	282	249	245
1/9/03	290	N/A	114	236	264	247	230
1/10/03	318	N/A	118	244	297	300	255
1/11/03	266	N/A	129	248	242	259	229
1/12/03	301	N/A	138	244	254	291	246
1/13/03	313	N/A	128	250	303	287	256
1/14/03	305	N/A	117	254	289	266	246
1/15/03	328	N/A	128	300	317	309	276
1/16/03	321	N/A	131	297	356	306	282
1/17/03	305	N/A	136	298	139	298	235
1/18/03	319	N/A	129	298	N/A	295	260
1/19/03	325	N/A	136	347	N/A	302	278

1/20/03	349	N/A	131	317	N/A	303	275
1/21/03	307	N/A	124	337	N/A	266	259
1/22/03	283	N/A	138	292	N/A	257	243
1/23/03	296	N/A	164	299	N/A	250	252
1/24/03	318	N/A	157	314	N/A	279	267
1/25/03	317	N/A	172	368	N/A	269	282
1/26/03	314	N/A	221	323	N/A	310	292
1/27/03	374	N/A	206	362	N/A	303	311
1/28/03	416	N/A	269	384	N/A	369	360
1/29/03	221	N/A	118	270	N/A	85	174
1/30/03	210	N/A	90	200	N/A	176	169
1/31/03	237	N/A	98	236	N/A	198	192
Monthly Avg.	317	N/A	135	279	277	273	254
February, 2003							
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
2/1/03	132	N/A	55	90	N/A	106	96
2/2/03	201	N/A	91	166	N/A	156	154
2/3/03	313	N/A	95	215	N/A	256	220
2/4/03	464	N/A	146	258	N/A	309	294
2/5/03	324	N/A	114	259	N/A	234	233
2/6/03	282	N/A	89	240	N/A	246	214
2/7/03	260	N/A	101	233	N/A	222	204
2/8/03	245	N/A	109	230	N/A	212	199
2/9/03	298	N/A	102	268	N/A	231	225
2/10/03	278	N/A	96	238	N/A	203	204
2/11/03	292	N/A	103	252	N/A	241	222
2/12/03	274	N/A	102	252	N/A	222	213
2/13/03	259	N/A	121	261	N/A	223	216
2/14/03	275	N/A	127	288	N/A	243	233
2/15/03	266	110	159	302	N/A	245	216
2/16/03	260	104	152	265	N/A	234	203
2/17/03	291	108	168	284	N/A	245	219
2/18/03	283	84	137	284	N/A	213	200
2/19/03	88	24	36	103	N/A	102	71
2/20/03	213	32	53	148	N/A	127	115
2/21/03	227	41	82	178	N/A	184	142
2/22/03	224	50	75	165	N/A	188	140
2/23/03	232	54	92	186	N/A	181	149
2/24/03	234	56	81	175	N/A	150	139
2/25/03	198	72	99	161	N/A	127	131
2/26/03	167	69	82	109	N/A	112	108
2/27/03	217	55	90	141	N/A	135	128
2/28/03	277	N/A	110	173	N/A	197	189
Monthly Avg.	253	66	102	212	N/A	198	181

March, 2003							
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
3/1/03	304	55	112	280	157	263	195
3/2/03	354	75	168	308	154	278	223
3/3/03	327	62	124	276	205	217	202
3/4/03	268	68	130	218	N/A	211	179
3/5/03	307	86	164	249	N/A	233	208
3/6/03	306	141	197	280	399	266	265
3/7/03	253	52	151	240	378	228	217
3/8/03	224	83	125	234	231	186	181
3/9/03	234	91	138	218	276	203	193
3/10/03	N/A	94	143	230	300	214	196
3/11/03	N/A	72	140	257	272	212	191
3/12/03	N/A	69	100	202	204	165	148
3/13/03	260	32	69	119	180	124	131
3/14/03	216	45	88	189	260	157	159
3/15/03	205	56	96	176	225	142	150
3/16/03	220	57	107	199	180	163	154
3/17/03	145	40	87	163	170	139	124
3/18/03	235	40	90	164	201	147	146
3/19/03	275	60	127	180	231	174	175
3/20/03	242	77	121	226	273	183	187
3/21/03	250	97	133	211	258	194	191
3/22/03	222	96	128	222	194	182	174
3/23/03	194	92	107	198	206	152	158
3/24/03	145	60	87	142	166	124	121
3/25/03	155	41	77	104	182	127	114
3/26/03	188	54	94	165	225	130	143
3/27/03	172	44	97	140	212	161	138
3/28/03	332	57	107	185	241	167	182
3/29/03	201	64	100	178	196	128	145
3/30/03	208	42	68	108	164	117	118
3/31/03	270	55	94	144	202	148	152
Monthly Avg.	240	66	115	200	226	179	170
April, 2003							
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
4/1/03	224	63	102	158	217	157	154
4/2/03	216	82	119	171	222	163	162
4/3/03	282	92	129	178	241	188	185
4/4/03	202	56	81	129	167	127	127
4/5/03	165	47	69	139	143	125	115
4/6/03	239	45	76	168	156	151	139
4/7/03	272	65	117	200	232	181	178
4/8/03	329	74	130	236	263	228	210
4/9/03	350	102	165	261	313	236	238
4/10/03	307	115	186	289	356	290	257

4/11/03	366	124	195	309	309	271	262
4/12/03	316	138	185	250	315	269	246
4/13/03	320	134	148	233	286	255	229
4/14/03	197	72	126	162	227	148	155
4/15/03	222	58	121	170	260	137	161
4/16/03	250	73	114	146	354	162	183
4/17/03	213	50	108	128	243	166	151
4/18/03	226	87	121	178	N/A	205	163
4/19/03	277	103	127	206	N/A	228	188
4/20/03	142	73	87	162	N/A	88	110
4/21/03	248	100	148	228	N/A	185	182
4/22/03	332	121	126	241	N/A	235	211
4/23/03	231	122	121	231	186	248	190
4/24/03	284	132	114	209	291	334	227
4/25/03	305	122	108	240	250	324	225
4/26/03	235	100	121	213	236	266	195
4/27/03	203	62	127	156	211	37	133
4/28/03	157	71	60	100	91	N/A	96
4/29/03	N/A	N/A	80	117	145	N/A	114
4/30/03	N/A	N/A	100	148	285	N/A	178
Monthly Avg.	254	89	120	192	240	200	179
May, 2003							
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
5/1/03	N/A	N/A	102	126	264	N/A	164
5/2/03	N/A	N/A	64	134	159	N/A	119
5/3/03	N/A	N/A	99	148	250	N/A	166
5/4/03	272	N/A	100	137	181	N/A	173
5/5/03	364	189	200	241	331	N/A	265
5/6/03	427	N/A	209	295	378	N/A	262
5/7/03	415	N/A	227	318	386	N/A	269
5/8/03	455	298	194	325	395	N/A	333
5/9/03	251	75	162	208	296	N/A	198
5/10/03	243	83	100	161	187	N/A	155
5/11/03	221	71	87	124	213	N/A	143
5/12/03	176	54	73	105	220	N/A	126
5/13/03	192	60	96	124	196	N/A	134
5/14/03	251	62	109	157	237	N/A	163
5/15/03	241	63	103	159	210	N/A	155
5/16/03	253	64	92	143	235	N/A	157
5/17/03	160	61	86	133	177	N/A	123
5/18/03	213	50	91	140	183	N/A	135
5/19/03	200	63	N/A	133	220	N/A	123
5/20/03	245	73	N/A	155	225	N/A	140
5/21/03	268	80	109	164	210	N/A	166
5/22/03	172	45	52	106	152	N/A	105
5/23/03	204	47	70	125	227	N/A	135
5/24/03	187	64	73	108	148	N/A	116

5/25/03	164	80	88	135	178	N/A	129
5/26/03	305	100	129	184	229	N/A	189
5/27/03	348	136	166	208	256	N/A	223
5/28/03	332	N/A	145	190	227	N/A	179
5/29/03	324	N/A	N/A	243	252	N/A	164
5/30/03	385	N/A	N/A	298	299	N/A	196
5/31/03	295	N/A	N/A	208	232	N/A	147
Monthly Avg.	270	87	116	175	237	N/A	177
			June, 2003				
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
6/1/03	285	120	122	188	234	N/A	190
6/2/03	208	102	114	156	199	N/A	156
6/3/03	264	83	114	147	261	N/A	174
6/4/03	137	N/A	50	69	173	88	103
6/5/03	241	N/A	66	88	230	108	147
6/6/03	295	N/A	82	113	185	120	159
6/7/03	218	75	70	105	136	118	120
6/8/03	225	47	42	93	183	104	116
6/9/03	250	52	60	103	181	133	130
6/10/03	244	135	138	174	203	189	181
6/11/03	381	196	184	236	303	262	260
6/12/03	450	226	228	219	330	312	294
6/13/03	461	243	245	258	350	312	312
6/14/03	203	88	110	143	183	177	151
6/15/03	283	82	91	119	226	164	161
6/16/03	160	67	77	74	209	114	117
6/17/03	244	55	67	83	220	131	133
6/18/03	162	45	61	79	180	108	106
6/19/03	201	28	31	68	129	82	90
6/20/03	156	30	37	49	120	69	77
6/21/03	165	30	38	46	94	72	74
6/22/03	82	27	28	42	131	65	63
6/23/03	117	31	34	43	87	67	63
6/24/03	78	30	38	46	108	59	60
6/25/03	144	35	34	44	111	79	75
6/26/03	129	34	44	50	116	87	77
6/27/03	N/A	33	53	53	135	90	73
6/28/03	N/A	27	31	39	100	110	61
6/29/03	226	35	45	47	107	96	93
6/30/03	165	56	68	74	172	105	107
Monthly Avg.	221	75	80	102	180	127	131
			July, 2003				
Date	**Putalisadak**	**Matsyagaon**	**TU**	**Bhaktapur**	**Patan Hospital**	**Thamel**	**Ktm. Avg.**
7/1/03	115	37	43	61	124	69	75
7/2/03	133	43	44	55	137	75	81

7/3/03	149	28	28	37	131	54	71
7/4/03	40	25	32	36	85	44	44
7/5/03	117	29	35	37	121	61	67
7/6/03	149	21	23	32	107	59	65
7/7/03	226	21	19	33	95	80	79
7/8/03	90	17	17	27	57	45	42
7/9/03	36	21	19	28	87	38	38
7/10/03	126	19	26	38	158	64	72
7/11/03	170	20	19	33	194	73	85
7/12/03	98	22	23	36	155	58	65
7/13/03	148	27	33	34	97	62	67
7/14/03	113	22	25	32	81	59	55
7/15/03	189	30	28	35	116	70	78
7/16/03	108	31	38	71	181	66	83
7/17/03	84	28	28	31	117	53	57
7/18/03	63	25	33	33	130	50	56
7/19/03	81	28	32	35	78	71	54
7/20/03	104	20	24	31	106	88	62
7/21/03	134	20	25	36	153	63	72
7/22/03	118	19	32	39	197	61	78
7/23/03	167	17	19	35	113	65	69
7/24/03	129	35	28	46	112	84	72
7/25/03	136	24	23	36	151	98	78
7/26/03	87	13	17	26	77	55	46
7/27/03	98	18	24	41	159	58	66
7/28/03	102	21	30	33	190	72	75
7/29/03	122	20	20	32	134	57	64
7/30/03	77	11	16	24	98	42	45
7/31/03	88	13	16	23	57	48	41
Monthly Avg.	116	23	26	36	123	63	65

Note: The unit for all the data is $\mu g/m^3$
Averages have been calculated using available data only
Ktm. Avg.: Average of the six monitoring stations
Monthly Avg.: Monthly average value for each monitoring station
N/A: Not available

Source: Ministry of Population & Environment / Environment Sector Programme Support (www.mope.gov.np)