AIR POLLUTION IN KATHMANDU VALLEY A THREAT TO ENVIRONMENTAL SUSTAINABILITY AND HUMAN HEALTH

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Abstract

Air pollution problems are increasing in the Kathmandu valley with high levels of particulate matter, currently posing the greatest threat to environmental sustainability and human health. The sources of this air pollution are varied and mainly include vehicular exhaust, industrial emissions and refuse burning. The valley's topography also encourages the formation of temperature inversions, especially in winter months, which allow air pollutants to build up to high levels. For these reasons, Kathmandu valley is classified as a High Air Pollution Potential Zone. Most of Nepal's economic and business activities are centered in the valley which is becoming environmentally stressed due to the high population pressure, unmanaged industrial establishments and the increasing number of vehicles. Rapid urbanization, industrialization, poorly maintained vehicles and a lack of public awareness are contributing to deterioration in ambient air quality in Kathmandu valley. At the same time, air quality management in Nepal is somewhat limited. This is due to the lack of coordination amongst the various agencies responsible and the lack of a coherent legislative or policy framework.

As such, the present study attempts to discover the relationship between air pollution, environmental sustainability and human health. This study also analyzes the steps taken by different agencies dealing with air pollution for management of ambient air quality of Kathmandu valley. The respondents are interviewed in six different spots where the PM_{10} monitoring stations are located. Perceptions of respondents towards air pollution are obtained using questionnaire method. The present status of air pollution is shown through different case studies, literature review and field survey. Recent photographs of study area are mirrors which reflect the actual situation.

For fulfilling the objectives of the study, air quality data of one year (May 2005 to April 2006) are analyzed which was obtained from MOPE. Moreover, this study focuses only on PM_{10} data. This is followed by analyzing hospital records of different major hospitals in Kathmandu valley, especially COPD records, to find the trend in the number of patients visiting the hospitals with air pollution related diseases. The increasing numbers of vehicles in such narrow streets of Kathmandu valley, reasons behind unplanned urbanization in valley etc are also analyzed. Additionally, vehicular emission test results showed the increasing faulty vehicles that run on streets of Kathmandu are about 30 percent.

The PM_{10} level in Kathmandu is much higher than the NAAQS and other international standards. Among the six areas being monitored, Putalisadak is the most polluted. The level of PM_{10} in Kathmandu's air is extremely high, especially in the dry winter months. Vehicles are the main sources of air pollution. 25 percent of the vehicles in Kathmandu are emitting more emission than the prescribed standards. One of the main sources of fine particles is diesel exhaust. As the level of fine particles is very high in Kathmandu, the associated health impacts are also expected to be high. Air pollution in Kathmandu valley is having a major impact on the health of the residents and the economy as a whole. Analysis of records from

Patan hospital, TUTH and Bir Hospital in Kathmandu indicate that the number of COPDpatients admitted to the hospitals shows an increasing trend over the past years. 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. Cost of pollution is very high and reducing vehicle emission is the most effective way of reducing this huge economic burden.

Electric vehicles can be a good replacement for the diesel (as well as petrol and LPG) vehicles in Kathmandu. Diesel vehicles should be avoided to the extent possible. 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. Improvement is needed in the vehicle inspection and maintenance system. Alternative energy sources, which are more efficient, less polluting, and cost effectiveness should be promoted. There should be use of non-motorized vehicles. 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.

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Abbreviations and Acronyms

%	Percentage
&	And
<	Less than
>	Greater than
^{o}C	Degree Centigrade
ARI	Acute Respiratory Infection
BS	Bikram Sambat (Nepali year)
CEN	Clean Energy Nepal
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COH	Coefficient of Haze
COPD	Chronic Obstructive Pulmonary Disease
CWIN	Child Workers in Nepal
DANIDA	Danish International Development Agency
DHM	Department of Hydrology and Meteorology
DOTM	Department of Transport Management
ENPHO	Environment and Public Health Organization
ESPS	Environment Sector Programme Support
EVs	Electric Vehicles
Fig.	Figure
HAPs	Hazardous Air Pollutants
HC	Hydrocarbon
HLF	Himalayan Light Foundation
HSU	Hartridge Smoke Unit
KEVA	Kathmandu Electric Vehicle Alliance
KMC	Kathmandu Metropolitan City
LEADERS	Society for Legal and Environmental Analysis and Development Research
LPG	Liquefied Petroleum Gas
MOPE	Ministry of Population and Environment
µg/m3	microgram per cubic meter
NAAQS	National Ambient Air Quality Standards
NESS	Nepal Environment and Scientific Services
NO_X	Oxides of Nitrogen
NO_2	Nitrogen Dioxide
NRs.	Nepalese Rupees
OPD	Out-Patient Department

O_3	Ozone
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PH	Patan Hospital
PM	Particulate Matter
PM_{10}	Particulate Matter less than 10 microns
$PM_{2.5}$	Particulate Matter less than 2.5 microns
ppm	Parts per million
SPM	Suspended Particulate Matter
SO_X	Oxides of Sulphur
SO_2	Sulphur Dioxide
TSP	Total Suspended Particles
TUTH	Tribhuvan University Teaching Hospital
USEPA	United States Environment Protection Agency
VOCs	Volatile Organic Compounds
VTP	Valley Traffic Police
WB	World Bank
WHO	World Health Organization

CHAPTER I
INTRODUCTION

1.1 Background of the Study

Air quality in our surrounding is deteriorating day by day in recent years by air pollution from various sources. Pollution is one of the major problems of developing countries like Nepal due to unsystematic urbanization, industrialization, heavy population pressure and above all the vehicular emission on narrow streets. Pollutants affect human health as well as visibility.

The major sources of air pollution are industries, vehicles, domestic emissions etc. Kathmandu Valley with typical bowl shaped topography has been alarmingly polluted due to the vehicular emission and dust particles. Kathmandu Metropolitan City has 2-6 times or higher dust particles concentration than normally accepted level set by WHO.

Concentration of pollution also depends largely on meteorological parameters such as wind speed, direction, temperature and precipitation.

Air pollution means the presence, in the outdoor atmosphere, of one or more contaminants such as dust, fumes, gas, mist, odour, smoke or vapour in quantities, with characteristics, and of durations such as to be injurious to human, plant or animal life or to property or which unreasonably interfere with the comfortable enjoyment life and property.

Generally, in nature, the air is never found clean. It is obviously, due to natural and anthropogenic pollution. Gases such as SO_X, NO_X, CO_X are continuously released into atmosphere through natural activities e.g. volcanic activity, vegetation decay and forest fires.

Besides, tiny particles of solids or liquids are distributed throughout the air by wind, volcanic explosions and other similar natural disturbances. In addition to these natural pollutants, there are man-made pollutants, gases, mist, particulates and aerosols resulting from chemical and biological processes used by man. Air pollutants are present in atmosphere in concentration that disturb the dynamic equilibrium in atmosphere and thereby affect man and his environment.

The severity of air pollution in a given area is dependent upon climate, topography, population density, number and types of industrial activities and organisms and materials affected.

There are two major types of pollutants – primary pollutants and secondary pollutants.

Primary pollutants are those occurring in harmful concentration which is added directly to air. Secondary pollutants are those formed in atmosphere through chemical reaction.

The major air pollutants are those produced in significant amounts and those having documented health and/ or other environmental effects. They include CO_X, SO_X, NO_X, hydrocarbons and above all – the particulate matter.

Particulate Matter:

It covers a wide range of finely divided solids or liquids dispersed into the air. Respiratory system may get damaged directly by particulate material. It also damages vital photosynthetic system of plants by covering the leaves, plugging stomata and reducing absorption of CO_2 and sunlight.

SO_x:

It results acid rain and is one of the principle air pollutants. Environmental effect of SO_2 includes acidification of soil, lakes and rivers. SO_2 is also responsible for corroding buildings, monuments and art works.

NO_X:

It results asthma, acute bronchitis. Atmospheric NO_X plays a key role in reducing visibility and contributes to acid aerosol formation. Nitrous oxide can absorb infrared radiation and may enhance global warming. It is resulted due to combustion of fossil fuels and through motor vehicles. Also use of explosives and welding processes, tobacco smoking, oil stove etc emits NO_X.

CO:

It is produced by incomplete combustion of fossil fuels like petroleum and coal and other carbonaceous materials. Its major source is petrol powered motor. People in developing countries who rely on biomass for cooking, heating are likely to be exposed to higher level of CO.

Table 1.1: WHO Guideline Values for Air Quality

Parameter	WHO Guidelines
A) Dust	
Suspended Particulate Matters	120 µg/m^3
Carbon	3.5 µg/m^3
Mercury	20 µg/m^3
Lead	0.15 µg/m^3
Arsenic	0.2 µg/m^3
Cadmium	0.05 µg/m^3
B) Gases	
NO_2	150 µg/m^3
SO_2	125 µg/m^3
CO	10 µg/m^3
CO_2	9000 µg/m^3

Source: www.who.org

MOPE has also developed National Ambient Air Quality Standards (NAAQS). The standard for PM_{10} is 120 µg/m3. The government has said that it aims to meet the NAAQS within three years. Judging from the PM_{10} 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 1.2: National Ambient Air Quality Standards (NAAQS) for Nepal

Parameters	Units	Averaging Time	Concentration in Ambient Air, maximum	Test Methods
TSP (Total Suspended Particulates)	µg/m3	Annual	-	
		24-hours*	230	High Volume Sampling
PM_{10}	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 PM_{10} samples****
		24-hours	-	-
Benzene	µg/m3	Annual	20*****	Diffusive sampling based on weekly averages

Parameters	Units	Averaging Time	Concentration in Ambient Air, maximum	Test Methods
		24-hours	-	-

Source: www.mope.gov.np

*Note: 24 hourly values shall be met 95 percent of the time in a year. 18 days per calendar year the standard may be exceeded but not on two consecutive days.

**Note: 24 hourly standards for NO_2 and SO_2 and 8 hours standard for CO are not to be controlled before MOPE has recommended appropriate test methodologies. This will be done before 2005.

***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 8 am – 10 am or 3 pm – 6 pm on a workday. This test method will be re-evaluated by 2005.

****Note: If representativeness can be proven, yearly averages can be calculated from PM_{10} samples from selected weekdays from each month of the year.

*****Note: To be re-evaluated by 2005.

1.2 Statement of the Problem

Air pollution has emerged as a potential threat to the residents of Kathmandu, Nepal. This problem was predicted long ago by *Fleming (1970)* when he stated “air pollution may become a serious problem for the Kathmandu Valley in the future, the combination of the ‘basin effect’ with the lack of much air movement in the valley predisposes the region to troubles”. He could foresee that improperly placed factories would contribute significantly to air pollution in Kathmandu. He even proposed programs targeted to control excess pollution.

Thirty years have passed since *Fleming* accurately predicted the future. Currently, Kathmandu, the capital city of Nepal, is a rapidly growing urban center. Since the early 1990s, the population inhabiting the Kathmandu metropolitan area has increased by several hundred thousand people, as has the process of industrialization and motorization. As Kathmandu has grown, so too has the problem of air pollution. The combustion of fuel by vehicles and industries has produced significant amounts of atmospheric pollution across this urban center. With this increase in pollution there is a growing potential health risk for people living in the valley.

Traditionally, symptoms of daily exposure to unhealthy levels of pollution include reduction in lung function, chest pain, and cough (Gold et al., 1999). Prolonged exposure may lead to respiratory infection and lung inflammation, with the most drastic result being irreversible change in lung structure and chronic respiratory illness. Those most prone to pollution related affliction are children, because of their under-developed defense mechanism, and the elderly, due the enhancement of preexisting respiratory diseases (Gold et al., 1999).

From a human geography perspective, it is clear that the large population of automobile users and industry within the Kathmandu Valley is a significant anthropogenic source of pollutants and aerosols.

However, the occurrence of high concentrations of lower atmospheric pollution across Kathmandu is critically dependent upon the physical geography of the region. A major contributing factor to this pollution problem is the physical setting of Kathmandu, which lies in a valley and is surrounded by high mountain ranges. This setting limits the diffusion of pollutants from the immediate area, contributing to long periods of continual air pollution hazards. In order to properly address pollution policy, there needs to be a better understanding of how the pollution process evolves and the causes of variation at different spatio-temporal scales. As such, climatological factors are important causal considerations. The boundary layer dynamics of air pollution are determined by meteorological factors. Such factors as wind direction and speed, precipitation, and mixing height play an important role in determining pollutant levels in an ambient atmosphere. Given a change in meteorological factors, air pollution may vary greatly month-to-month and season-to-season.

Particulate matter is a primary concern in Kathmandu Valley. Kathmandu is venerable to particulate matter concentration as most of the time the particulate matter concentration exceeds the prescribed value recommended by the World Health Organization (WHO) guideline value for ambient air quality, whereas other criteria pollutants (i.e. sulfur oxides SO_X, nitrogen oxides NO_X and carbon monoxide CO) are well below the WHO guideline values for criteria air pollutant concentrations (URBAIR, 1997; LEADERS Nepal, 1998; LEADERS Nepal, 1999; NESS, 1999; LEADERS Nepal, 2000).

So to conclude, due to its bowl shaped topography, Kathmandu Valley is vulnerable to air pollution. Rapid urbanization, improper location of industries, population growth, narrow roads and street etc are the reasons behind excessive pollution out here. The major contributing factor is vehicular emission.

In recent years, rapid urbanization of Kathmandu Valley has increased the level of fuel consumption significantly. With the subsequent increase in fuel consumption sources as automobiles, industries, domestic sectors, the quality of air effluents thrown into the atmosphere has also increased drastically. Because of this, air quality in Kathmandu Valley is deteriorating day by day.

Hence, this study is primarily focused on the status of ambient air quality in Kathmandu valley and its health impacts on the people residing here.

1.3 Significance of the Study

In present days, air pollution has become an emerging problem for human health and environmental sustainability.

The research carried out here deals with the problems faced by people in Kathmandu Valley, the reasons behind such alarming pollution and of course, its solutions to make the city clean, green and neat. It is human beings that pollute his surrounding knowingly or unknowingly, so it is of great importance to aware them about long term and short term effects of pollution so that they may live longer in clean environment.

Vehicular traffic congestion, unplanned urbanization, industrialization and its improper placement, no sewage treatment facilities, increasing population pressure on limited resources and undoubtedly the Maoist insurgency are the reasons behind such great number of people in Kathmandu Valley in recent years and thereof pollution out here.

1.4 Objectives of the Study

The general objective of the study is to analyze the air pollution situation in the Kathmandu Valley.

The specific objectives are listed as below:

1. To analyze the causes and consequences of air pollution in the Kathmandu Valley.
2. To analyze the concentration of PM_{10} in the ambient air at different spots within the Kathmandu Valley
3. To compare air pollution levels between busy traffic flow and traffic-free area of the Kathmandu Valley.

4. To show the relationship between air pollution and environmental sustainability.
5. To show the effects of air pollution on human health.

1.5 Limitation of the Study

The present study is limited to Kathmandu Valley only.

Basically, data collected for this study is based on secondary data. Therefore, the validity of the study would depend upon the reliability of the collected information and data obtained from different sources.

In this research, only PM_{10} parameter has been taken as the pollution indicator. However, other parameters may be contributing significantly for polluting air, but these parameters have not been included.

Impact of the meteorological factor e.g. wind direction and speed, precipitation, mixing height, temperature inversion etc has not been considered which might have significant role in the dispersal of air pollutants.

This study only analyzes the records of the COPD patients who have been admitted to the hospitals whereas records of the other patients (outdoor as well as emergency patients) were not available.

This study just gives an indication of the impact of Kathmandu’s pollution on public health on the bases of some of the literature reviewed concerning the respiratory disease. Medical study concerning the respiratory diseases has not been conducted.

Because of the short duration of the study, it only focuses on compiling available materials on relevant issue and analyzing them. This study has not conducted any major primary research on this topic.

1.6 Organization of the Study

Chapter one gives the brief introduction of air pollution and pollutants including Kathmandu’s ambient air quality too. It lists the WHO guidelines and NAAQS for air quality. The statement of the problem, objectives of the study, significance, limitations together with expected outcomes are also listed in chapter one.

Chapter two is the review of literature. It has reviewed air pollution from different aspects as its sources, meteorological factors, health impacts, legislations etc.

Chapter three provides the methodology adopted for the study to be carried out.

Chapter four provides brief explanation about the study area. It provides information of Kathmandu valley regarding geography, weather, climate, population, urbanization, traffic volume, road network, industrial growth, energy use and consumption pattern etc.

Chapter five links air pollution with environmental sustainability. Furthermore, it explains the sources of air pollution and emission control measures.

Chapter six links air pollution with human health. It provides detailed information regarding effects of various pollutants including financial implications of health impacts.

Chapter seven tabulates, analyses and interprets all the data collected from the study area with the help of questionnaire, interviews, field visit and observation. It also analyses secondary data obtained from various sources.

Chapter eight summarizes the research work performed. It develops a clear view about the study in the form of conclusions and recommendations provided so as to be aware of air pollution and its threat to environmental sustainability and human health.

Finally, there are references which the researcher has referred while carrying out his entire research work. There are also annexes which includes location and photographs of the study area showing the status of air pollution. It also includes the questionnaire used to generate data for entire research work and monthly average air quality data from January 2003 to April 2006.

CHAPTER II
LITERATURE REVIEW

2.1 The National View of Air Pollution

Nepal displays extreme variations in natural environment ranging from tropical plain to alpine heights, traditionally classified into three major geographical regions: the Terai plains, Hill and Mountain regions. The environmental aspects of terai (below 300m) include large-scale deposition forms and increasing deforestation for land colonization. It has extensive fertile land that supports the large population. The hill region (300-3000m), the traditional zone of Nepalese settlement also has a large population subsisting mainly on agriculture. Much of natural vegetation has been cleared for cultivation or grazing. Natural process of erosion are active both in the form of slow degradation and catastrophic landslides. The mountain region (above 3000m) is a marginal area for human occupancy, where glacial and pre-glacial processes of erosion predominate. The sparse population subsists on agriculture, pastoralism and trade (www.keva.org.np).

Urban growth in terms of area, human population, industry, transport etc. has been recognized as a worldwide phenomenon. The WHO estimates that almost one half of world population is now living in and around urban centers of the world. Such concentration of human activities in small areas exerts severe strain on the available natural resource of the region. Consequently, the release of pollution loads to the environment is outstripping the carrying capacities of almost all major urban centers of the world leading to a series of environment related problem. In Nepal also, the situation is not different but rather worse. The scale of activities here is comparatively much lower but the extent of negative impact is greater simply because of almost total lack planning, regulation and control.

Along with increasing industrial and commercial activities, pressures on the existing infrastructures, roads, sewerage, drainage, solid waste management and existing transportation are grown with as increasing incidence of environmental deterioration (www.keva.org.np).

As pollution regulation and management is not stringent in Nepal. There is no reliable treatment of sewerage, no strict controls on vehicular exhaust levels or pollution – prone industries, no effective regulation of pesticide use, no systematic monitoring of water quality and very little laboratory facilities. Thus, the existing environmental issues in Nepal have become prominent topics of concern for the last few years.

The major environmental problems evident in the urban areas are physical congestion, air pollution, water pollution, lack of cleanliness, loss of open spaces and loss of cultural property. Whereas water pollution can be linked with domestic waste, solid waste and industrial waste and there their collection, treatment and discharge management and practices, air pollution can be seen as a fall-out of industrial emissions, household energy usage pattern, vehicular emission and microclimate (www.keva.org.np).

The quality of ambient air is basically a localized problem (IUCN, 1991). Presently, the core areas of major urban centers such as Kathmandu Valley, Birgunj, and Biratnagar etc. have been facing the visible threat of air pollution due to increasing number of vehicles and pollution prone industries.

Kathmandu, the capital of Nepal is the focus of all major facets of a country, namely economic, tourism, culture, politics, administration and natural environment. The expanding city of Kathmandu has resulted in population growth through continuous migration. As the result of it, the city population is dramatically increased. The population census of 1991 showed that the urban population of Kathmandu is 6,61,836 with the growth rate of 5.99 (www.keva.org.np).

Air pollution has emerged as the most visible components of environmental degradation in Kathmandu valley for the last couple of years. The valley is especially vulnerable to air pollution due to its bowl- like topography, exploding population inflow, rapid urbanization, valley centric industrialization and significant increase of vehicular transport in narrow streets. The bowl like topography restricts wind movement and retains the pollutants in the atmosphere especially during the period of thermal inversion over Kathmandu, where cold air flowing down from the mountains is trapped under a layer of warmer air, which acts like a lid over a bowl (www.keva.org.np).

On an average, a human body requires 30lb of air everyday to sustain its requirement of oxygen (Environmental Pollution & Protection, 1995). This fact suggests that air pollution is indeed of great immediate concern than any other aspect of pollution. What makes air quality particularly vulnerable is that air unlike water or other waste cannot be reprocessed practically at some central locations and subsequently distributed for use. Air may get rejuvenated through photosynthetic process and cleared through precipitation, but these natural processes are limited in their effectiveness in urban areas. It is therefore seems evident that the protection of air quality is a vital consideration.

At present, not only natural factors, but also anthropogenic activities have also added large amount of macro and micro pollutants to the atmosphere, triggering the environmental problem. Though long-term data on pollution are lacking, available information reveals that the nature and extent of air pollution has a serious dimension in major urban areas and in some industrial sites in Nepal. Various studies done so far also indicate (1) Industrial hot spot area (2) types of major pollutants and (3) extent of concentration. But most of the study has been concentrated in the valley (www.keva.org.np).

The Himal Cement plant at Chobhar in Kathmandu has attracted considerable public attention for its dust emission, which can be seen from any point of the valley. Dust was emitted from the limestone crusher, saw mill, raw materials storage yard and limestone excavation processes (IUCN, 1991) ENPHO reported maximum PM_{10} and TSP concentration in the nearby areas showed of 206 µg/m3 and 402 µg/m3 respectively. But the gaseous pollutants such as SO_2 and NO_2 were within the WHO guidelines. It is estimated to discharge 6000 MT of dust particulate per year. But now, Himal Cement Factory has been closed and not in operation.

Brick manufacturing by Bull's trench kilns owing to their process of material handling, firing technology, energy efficiency and also by virtue of consumption of substantial amount of dirty fuels, are potentially significant sources of atmospheric emissions. As the industries are located in a valley at the outskirts of the urban centers, impact of air pollutants released from these industries is visibly felt. The exact quantification of air pollutant is, however difficult without stack monitoring. Secondary information estimates that tons of dust particles, SO_2, NO_2, hydrocarbon, carbon monoxide and fluoride are emitted in the atmosphere. Out of a total of 179 operational commercial brick kilns in Kathmandu valley in 1994, 172 industries were the Bull's trench kiln type (NESS, 1995). Among the remaining, six were semi-mechanized Hoffmann's kiln and one vertical shaft kiln.

The rural areas are engulfed by heavy indoor air pollution. According to the survey, the main source energy consumed by households in Nepal consists of traditional source: firewood, animal dung and litters (CBS, 1996). Use of traditional source of energy for cooking and heating purpose in poorly ventilated dwelling has been aggravating indoor air pollution.

Vehicular emission is another principle contributor to air pollution. This is further magnified by leaded, substandard and adulterated fuel; narrow streets and poor traffic management, practice of importing old vehicles and poor vehicle maintenance (Joshi, 1993). Since 1999, unleaded petrol has been introduced in Kathmandu Valley. In the recent past vehicular population in large towns like Kathmandu, Patan, Birjunj, Biratnagar has been increasing very rapidly. The registered Vehicle of 1997/98 shows, out of 211,097 numbers of vehicles in whole Nepal, the registered vehicles in Bagmati zone itself is 140,000 which means another 27percent increase over the last two years (CBS, 1998). In proportionate to the vehicle fleet increase, the consumption of petrol and diesel in the country have also risen considerably about 51percent for petrol and 54percent for diesel during the last four years (NOC).

According to the data (1997/98) petrol and diesel consumption was 46939 kl and 302063 kl respectively. Out of those national consumption Figures, the estimated consumption Figures for the valley were 80 percent petrol and 27 percent diesel. The total road length in the valley in which the vehicles ply is estimated to be around 995 km (Nepal district profile, 1997) out of which 401 km is black-topped, 246 km gravel and 348 km earthen. Shrestha and Malla (1993) have done emission inventory load by adopting the energy consumption technique.

The finding study showed total annual emission load from transportation sector is 12,422 tons. Likewise other study done by URBAIR showed total annual emission of TSP from vehicle exhaust is 570 tons.

Various analyses have demonstrated that major cities of Nepal as well as Kathmandu’s air exhibits unacceptable levels of suspended particulate, lead and other pollutants that pose significant risk to human heath. The number of clear days per year in Kathmandu has been consistently decreasing in the past two decades. According to the study (Shrestha, 1994) the number of foggy days in Kathmandu has increased from about 38/year in 1970 to more than 60/year in 1994.

Deterioration of public health, especially due to increase in the respiratory and skin diseases has become a serious concern in the Kathmandu valley. The prevalence of chronic bronchitis was reported to be the highest in Jumla, 24 percent whereas in mid-hills region of urban Kathmandu it was 8.8 percent (Pandey and Basnet, 1988). Overall impact of population is higher in women than in man, as women spend about 20 percent of their time in cooking related activities. Indoor pollution of industries also poses a considerable threat to the health workers in some industries. Most common diseases prevalent were headache, respiratory problem and abdominal disorders.

Impact of Himal Cement on soil, water, vegetation and health was studied by ENPHO (1999). The soil of this region has become hard due to calcium deposition and this affects germination of seeds. The leafy vegetables like mustard, cabbage etc. were found injured due to dust deposition on the leaf surface. After 2-3 days of dust deposition holes appear on the leaf surface. The vegetable is not palatable around this area due to dust. Closing of stomatal pores due to the deposition of dust brings wilting and drooping of vegetable leaves. This has been observed in most dust prevalent area. The straw of rice, wheat and barley is not palatable for livestock. Cows and buffaloes suffer from diseases if they are fed on straws for a long time. Poor visibility and poor sunlight in winter also attributes to thick smoke and dust from the factory.

Health impact from Himal Cement was studied in the nearby villages. Out of 683, the total population, 0.87 percent was suffering from pneumonia, 8.19 percent person from bronchitis and 5.27 percent from asthma. In the survey, 0.14 percent is suffering from cataract, 7.75 percent from vision problems, 5.85 percent from conjunctivitis and 0.14 percent from night blindness. Similarly, skin problems like scabies, ringworm and wounds were 0.58 percent, 0.87 percent and 1.61 percent respectively. Other type of skin problem was 4.87 percent.

Exposure to vehicular exhaust leads to increase prevalence of various diseases viz. irritation, respiratory tract infection, bronchitis and asthma. Leaded gasoline, which is often adulterated, is available in Kathmandu and the large percentage of heavy vehicles runs on diesel. This can cause substantial damage to health and welfare of the people who are exposed to the resulting emission. Furthermore, leaded gasoline emits lead to the air resulting in a significant cause of decreased IQ among children, increased incidence of high blood pressure among adults and can be highly detrimental to unborn children.

Air pollution in Kathmandu is also causing damage to many historical buildings that represents the cultural heritage of the valley. Acid formed as a result of various sulphurous and nitrous oxides reacting with water can damage fine wood carving, marble and metallic exteriors common to many historical buildings of Nepal. The damage to cultural heritage not only deprives the residents of proud past, it also can negatively impact on tourist trade, an important contributor to the valley’s economy (Adhikari, 1998).

An October 1993 article in Newsweek painted a pessimistic, but accurate image of the air pollution situation in Kathmandu valley. Such negative publicity could have an adverse impact on tourism. In the early 1990’s, foreign currency revenues amounted to approximately US$60 million a year. Although no ’dose-effect’ relationship of air pollution and tourism are available, it can be assumed that an approximately 10 percent decrease in tourism could lead to a loss of to US$6 million for Nepal. This is a very significant amount of foreign exchange for a country that has a negative balance of trade (URBAIR, 1996).

To sum it up existing environmental issues in the country have become prominent topics of concern for the last few years. Amid aggravating environmental conditions, notably soil erosion, deforestation and water as well as air pollution and their severe impacts on ecological balance, economic growth and human health certainly is of growing concern.

Environmental problems are stemming primarily from ecological incompatible human activities pursued in the endeavor of fulfilling material needs (CEDA, 1993). So is in the case of air pollution. The economic cost of air pollution due to loss in human health potential, loss in tourism and damage to cultural heritage is significant, running into millions of dollars annually (Adhikari, 1998). Thus, Nepal urgently needs to prepare a comprehensive framework for policies to address the problems of pollution.

2.2 Air Pollution and Its Sources

Kathmandu valley being a capital of Nepal is a centre for all major administration, trade and industry. Different studies have suggested that air quality degradation of the valley is accelerating from bad to worse. Principal source of air pollution is vehicular and industrial emissions. URBAIR (1997) pointed out that Brick Kilns contribute 32 percent of total pollution in the valley, rest are vehicles and other industries. There are altogether 125 brick kilns, which are all located in suburb of the valley and most of them are in Laltipur district.

2.3 Air Pollution and Human Health

Government of Nepal, Ministry of Health recognizes ARI as one of the major public health problems in Nepal among the children of <5 years of age. The national control of ARI program is an integral part of primary health care and has been accorded high priority by MoH. Total new cases of ARI reported in the year 1998/1999 was 468266 and fatality rate 1.6 per 1000 children and it is the topmost killer disease of Nepalese children (DoHS, 1999)

Particulate matter consists of solid particles or liquid droplets (aerosols) small enough to remain suspended in the air. Such particles have no general chemical composition and may, in fact, be very complex. Examples include soot, smoke, dust, asbestos fiber, and pesticides, as well as some metals (including mercury, iron, copper, and lead). We can characterize particulate matter by size. Particles with a diameter of 10 micrometers (μm) or less are known as PM_{10} (Pepper *et al.*, 1996).

Air pollution in cities has been linked to increased rates of mortality and morbidity in developed and developing countries. The effects have been documented in places like the United States (e.g., Dockery and Pope, 1994; Schwartz, 1994 & 1995; Pope *et al.*, 1995; Li and Roth, 1995; Theresa *et al*., 2000; Samet *et al*., 2000; Therese *et al*., 2000; Andrew *et al*, 2001), Europe (e.g., Kunzi *et al*., 2000), and Australia (e.g., Goldberg, 2001). In contrast, research on effects of air pollution on health in developing countries is less advanced (Murray *et al*., 2001). Some of the studies that have been conducted have shown a relation between air pollution and air borne health problems in Mexico (e.g., Hernandez *et al*., 1997), Taiwan (e.g., Hwang et.al, 2002), India (e.g., Smith, 1996) and Nepal (e.g., URBAIR, 1996; LEADERS Nepal, 1998).

Since particulate matter can be inhaled, this pollutant has been found to impair many respiratory functions. Among the many pollutants highlighted for adverse health effects, particular attention has been focused on fine particulates recently (Dockery and Pope, 1994; Schwartz, 1994 & 1995; Pope *et al*., 1995; Li and Roth, 1995). Well-documented air pollution episodes throughout recent history have linked air pollution with an increased mortality rate among individuals with cardiovascular and respiratory disease (e.g. Donaldson *et al*., 2000; Anderson *et al*., 2000). Although the components of air pollution that cause adverse health effects in these individuals are unknown, a small proportion by mass (but a large proportion by number) of the ambient air particles are ultra fine, i.e., less than 10 μm in diameter (PM_{10}) (Donaldson *et al*., 2000; Anderson *et al*., 2000). This ultra-fine component of particulate matter for which there is toxicological evidence to support this contention may mediate some of the adverse health effects reported in epidemiological studies (Donaldson *et al*., 2000; Anderson *et al*., 2000).

Studies conducted in 20 cities in the United States indicated that there is evidence that links the level of fine particulate matter in the air with the increased risk of cardiovascular and respiratory illnesses (Samet *et al*., 2000). As an example, epidemiological investigations have established an association between exposure to particulate matter and human health in the Utah Valley (Ghio, 2001). A study undertaken in Montreal, Quebec also showed an association of variations in concentrations of particulates in the ambient air with daily variations in cause-specific daily mortality (Goldberg, 2001).

A study by Therese *et al*. (2000) was conducted to evaluate the association between mortality in elderly individuals and particulate matter (PM) of varying aerodynamic diameters (in micrometers; PM_{10}, $PM_{2.5}$, and PMCF - PM_{10} minus $PM_{2.5}$), and selected particulate and gaseous phase pollutants in Phoenix, AZ, using daily data from 1995-1997. This study showed that the total mortality was significantly associated with CO and NO_2 ($p < 0.05$) and weakly associated with SO_2, PM_{10}, and PMCF ($p < 0.10$). In this same study, cardiovascular mortality was significantly associated with CO, NO_2, SO_2, $PM_{2.5}$, PM_{10}, PMCF ($p < 0.05$), and elemental carbon levels. Factor analysis in this study revealed that both combustion-related pollutants and secondary aerosols (sulphates) were associated with cardiovascular mortality (Therese *et al*., 2000). It is estimated that mortality rates increase on average by 0.7 percent per 10 $\mu g/m^3$ increase in PM_{10} concentrations, with greater effects at sites with higher ratios of 2.5 µm particulate matter (Levy *et al*., 2000).

In a separate study, Dockery and Pope (1994) reported that with each 10 $\mu g/m^3$ increase in concentration of particulate matter of less than 10 µg in diameter there is an estimated 0.06-1.6 percent increase in mortality.

A different study was conducted to estimate the impact of outdoor (total) and traffic related air pollution on public health in Austria, France and Switzerland (Kunzli *et al*., 2000). This study showed that air pollution caused 6 percent of the total mortality (more than 40,000 attributable cases) per year. About half of all mortality caused by air pollution was attributed to motorized traffic. Air pollution in these countries also accounted for more than 25,000 new cases of chronic bronchitis (adults); more than 290,000 episodes of bronchitis (children); more than 0.5 million asthma attacks; and more than 16 million person-days of restricted activities (Kunzli *et al*., 2000).

2.4 Air Pollution and Meteorology

The study of the linkages between weather and air pollution can be traced back to the late 1940s and early 1950s in the United States and Europe. At the time scientists were interested in understanding this phenomenon, especially after the tragic incidents that took place in Donora, Pennsylvania and in London, England. In 1952, smog that had built up in the atmosphere of London due to the mixing of smoke and fog and in the absence of proper dispersion of pollutants by the wind killed several thousand people. With the build-up of a high pressure zone above London and the flow of wind in the opposite direction due to an anticyclone, the wind's low velocity (almost calm) held accumulated gases, ash, and unburned coal suspended in the atmosphere of London (Battan, 1966; Kupchella and Hyland, 1989).

A similar disaster occurred again in London in 1956 taking the lives of another thousand people (Kupchella and Hyland, 1989). The incident in London was preceded by an equally tragic incident in Donora, PA in 1948. In this case, a combination of polluting gases and particles, a thermal inversion in the lower atmosphere, and a stagnant weather system prohibited the dispersion of atmospheric pollutants in the highly industrialized valley of Donora. Hence air pollution accumulated to such levels that several thousand people become ill, a great many required hospitalization and twenty died (Hoecker, 1949, Battan, 1966; Kupchella and Hyland, 1989; Nebel and Wright, 2000).

Since then, various studies have been carried out to establish the linkage between air pollution and weather pattern in different parts of the world. For example studies completed in Donora (Harold et. al, 1949), Nashville (Turner, 1961), Stockholm (Bringfielt, 1971), Bangi, Malaysia (Sani, 1987), California (Chow *et al*., 1998), Turkey (Tayanc, 2000), Ahmedabad, India (Lal *et al*., 1999), Hong Kong (Chan *et al*., 1997; Chan and Kwok, 2000), and Phoenix, AZ (Ellis *et al.*, 1999, 2000), demonstrate some linkage between different meteorological factors and air pollution.

Several things can happen once pollutants are in the troposphere. Wind currents often transport pollutants, and they may undergo chemical transformation before being deposited on the Earth's surface. The time needed for this cleaning process may vary from a few hours to several days. Larger particulate matter with a diameter of 10 µm or larger generally settle out of the atmosphere in less than a day. Particles with diameter of less than 10 µm can remain suspended in the air for weeks. Soluble gases and particles may be washed away by precipitation. Sometimes the removal of pollutants like sulphates and nitrates by rainfall can result in acid precipitation. The wind may blow away these pollutants to some other locations and then the problem of air pollution may become one of a regional concern. Also, the mixing of pollutants into the upper atmosphere may dilute the concentrations near the Earth's surface, but this can cause long-term changes in the chemistry of the upper atmosphere, including the ozone layer (Oren, 2001).

The ability of the atmosphere to accept, disperse and remove pollutants is strongly related to its various physical dynamic properties. Atmospheric winds, for example, determine the pathways and speeds at which pollutants are transported away from sources. Another physical process, the condensation of water vapor into rain and fog droplets, scavenges water-soluble pollutants from the atmosphere, ultimately determining the rate of their removal. In addition, the vertical variation of temperature greatly influences atmospheric stability and hence the turbulent mixing of polluted air with clean air (Pepper *et al*. 1996).

The importance of meteorological factors in the transport and diffusion stage of the air pollution cycle is well recognized. Meteorological factors such as wind speed, precipitation and mixing height all play important roles in determining the pollutant levels for a given rate of pollutant emission (Tayanc, 1999).

Polluted atmospheres commonly assume a well-marked physical configuration around urban areas, which are dependent upon environmental lapse rates and particularly the presence of inversions and wind speed (Barry and Chorley, 1992). The entering of pollutants from the ground surface, their residence in the atmosphere, and the formation of secondary pollutants is controlled not only by the rate of emission of the reactants into the air from the source, but also by wind speed, turbulence level, air temperature, and precipitation. Thus, it is often important to understand the physical processes leading to an observed concentration of pollutants at a given point.

2.4.1 Pollutant Transformation and Removal

Once pollutants enter the atmosphere they move with the wind. Chemical reactions often occur between the pollutants and other atmospheric chemical species forming secondary compounds. Although the pathways and rates of many of these chemical reactions are poorly understood, they are an important factor affecting the fates of many air pollutants (Pepper *et al*., 1996; Oren, 2001).

Pollution leaves the atmosphere in any of three ways: gravitational settling, dry deposition and wet deposition. Gravitational settling removes most particles whose diameters are greater than about 1 µm. Particles less than 1 µm in diameter are often small enough to stay in the atmosphere for long periods. Particles greater than about 10 µm in diameter quickly settle out (Pepper *et al.*, 1996). Dry deposition is a mass transfer process that results in adsorption of gaseous pollutants by plants and soil. Plant uptake of pollutant is dependent upon uptake of the pollution through stomata openings in plant leaves. Dry deposition to bare soil involves not only turbulent transport of pollutants in air above the soil; it also involves soil microorganisms that take up such pollutants as carbon monoxide (Pepper *et al*., 1996). In terms of wet deposition, rain is a very effective remover of gases and small particulates (Sani, 1987; Pepper *et al*., 1996). Raindrops increase in size as they fall toward the ground, and thus they increasingly capture more pollutants. Raindrops, in effect, scavenge pollution as they fall through the air. The ability of rain to remove pollutants depends upon the rainfall intensity, the size and electrical properties of the drops, the solubility of the polluting species (Pepper *et al.*, 1996).

Collection efficiency depends in a complicated way upon the sizes and surface properties of the collector and of the collected particles (Mason, 1957; McDonald, 1963; Berg, 1963). Similarly, the scavenged volume also depends upon the size of the precipitation drops (Shaw and Mun, 1971). A uniform rainfall of 1.9 mm per hour over a 15 minute period, for example, has been shown to be able to scavenge about 28 percent of the 10 µm particles from a volume of air through which the rain passed (Greenfield, 1957). However, for particles of 2 µm and smaller, the scavenging through precipitation becomes insignificant (Bach, 1972; Kupchella and Hyland, 1989).

2.4.2 Terrain Influences and Mountain Valley Breeze

The problem of pollution dispersion in an urban area of complex topography is becoming better understood, primarily because of concern over air quality in Phoenix, AZ and Los Angeles, CA, USA (Barry and Chorley, 1992; Berman *et al*., 1995; Lu and Turco, 1995; Ellis *et al.*, 1999, 2000).

A classic example is Los Angeles, where surrounding topography restricts the transport of pollution away from the urban area. When a weak background synoptic circulation combines with a valley air temperature inversion and surrounding orographic blockade, the result is often a lack of dispersion of significant lower atmospheric pollutants away from the urban center (Berman *et al*., 1995, Lu and Turco 1995; Ellis *et al.,* 1999, 2000).

Generally, in mountainous regions, mountain-valley breezes develop along mountain slopes. During the day, sunlight warms the valley walls, which in turn warm the air in contact with them. The heated air being less dense than the air of the same altitude above the valley, rises as a gentle upslope wind known as a valley breeze. At night the flow reverses. The mountain slopes cool quickly, chilling the air in contact with them. The cooler, denser air glides down slope into the valley because of gravitational force, providing a mountain breeze (Ahren, 1991; Barry and Chorley, 1992; Danielson, 1998).

Such a wind pattern gives rise to distinct diurnal process by which lower atmospheric pollutants are transported away from the source by one set of winds and again brought back to same area by another set of winds. Taken together, the up-slope and down-slope transport of pollutants produce a distinct pattern of “sloshing”, affecting a particular area in a valley twice daily (Ellis *et al.*, 1999). Similar diurnal process has been reported in Phoenix, AZ (Green and Sellers, 1964; Sellers and Hill, 1974; Davis and Gay, 1993, Ellis *et al*., 1999).

Effects of mountain-valley breezes on air pollution have been studied in the vicinity of Freiburg, Germany (Baumbach and Vogt, 1999). This study revealed that when the mountain-valley wind system develops in November, most of the air pollutants emitted in Freiburg during the daytime are transported to the Black Forest by the valley wind during the daytime, and then returned to Freiburg at night with the mountain wind blowing from the Black Forest (Baumbach and Vogt, 1999).

Reviews of theoretical and empirical approaches to the problem of meteorological influences on pollution concentrations suggest that wind speed, atmospheric stability and precipitation are important variables. The Donora investigation conducted to correlate the concentration of atmospheric pollutants in Monongahela Valley, PA and meteorological factors established this relationship (Harold *et al*., 1949). In this study, the greater percentage of higher values for all contaminants was found in the wind speed range of 0-3 miles per hour (1.35 ms^{-1}). The average value for the inversion samples show a greater than two fold increase for sulphur dioxide, total sulphur and total particulate matter and a large increase for zinc, lead and cadmium, over the average value of the other samples taken during the “test period” (Harold *et al*., 1949).

Turner (1961), found that stability, wind speed and degree days explained 50 percent of variation in SO_2 and smoke in Nashville, TN, while Bringfielt (1971) found temperature, wind speed and mixing depth explained a 70 percent variance in SO_2 in Stockholm. In their study, Ellis *et al*. (2000) found an association of high, moderate and low ozone concentrations with a wind regime that appears to be the product of a mesoscale thermodynamic circulation in Phoenix. A study of particulate matter and meteorology in Bangi, Malaysia showed that there is a positive correlation between wind speeds and suspended particulate concentration.

Similarly, the analysis of pollution concentration for days “with rain” suggested rainfall has a scavenging effect (Sani, 1987). Meteorological conditions such as relative humidity (RH), rainfall and prevailing wind direction were found to affect the mass concentration of TSP, PM_{10} and coarse particulates in urban areas of Hong Kong (Chan and Kwok, 2000). Owen and Tapper (1977), on the other hand, found only a weak correlation between individual meteorological parameters and pollution levels (Sani, 1987).

2.4.3 Seasonal, Weekdays and Diurnal Variation of Ambient Air Quality

On a climatological basis, the normal progression of diurnal and annual cycles of weather conditions and the diurnal and annual cycles of pollutant emissions result in a reasonably orderly and predictable diurnal pattern of air pollution in cities (Munn and Katz, 1959; Halliday and Kemeny, 1964; McCormick, 1970; Lanfredi and Macchiato, 1998). Besides anthropogenic sources in urban areas, most of the variables involved in air pollution dynamics are variables of meteorological or climatological concerns (Lanfredi and Macchiato, 1998).

Usually, most primary pollutants (e.g., SO_2, CO, NO_X and particulates) show two diurnal peaks, one occurring sometime after sunrise between 07:00 and 10:00 local standard time (LST), and the other in the evening between 19:00 and 22:00 LST (McCormick, 1970). The double maxima appear to be due to the optimum relative coincidence in the change in emission and dissipation rates of air pollutants during those hours (Munn and Katz, 1959, and Halliday and Kemeny, 1964). Secondary pollutants formed by photochemical reactions in the atmosphere show one diurnal maximum early in the afternoon (McCormick, 1970).

A study of air pollution in California showed the concentration of ozone and its precursor gases varied by sampling site, time, and day, and the ozone episode (Chow *et al*., 1998). It was found that the nitrates occurred mainly in the gas phase during the daytime, when temperature exceeded 25^oC and in particulate phase during the nighttime, when the temperature decreased to less than 10^oC. At most of the sites, which were separated by hundred of kilometers, diurnal patterns of ozone, nitrogen oxide, PAN, nitric acid and total particle nitrate were similar, showing evidence of both photochemical conversion and the transport of polluted air masses (Chow *et al*., 1998).

A study done in Hong Kong showed large size particles had an apparent seasonal variation, with a greater concentration level in winter and a lower concentration in summer. The dry continental winter monsoon and the wet oceanic summer monsoon were found to be the dominant factors (Chan and Kwok, 2000). Similarly, surface ozone and its precursors in rural and urban areas of Hong Kong showed seasonal, temporal and spatial variation patterns (Chan *et al*., 1997). The seasonal alternation of the prevailing oceanic and continental air masses, in addition to the climate system associated with the Asian monsoon system, was found as the governing factor for the temporal pattern in Hong Kong (Chan *et al*., 1997).

The surface measurements of ozone and its precursor gases (NO_X, CO, and CH_4) in an urban site of Ahmedabad, India showed diurnal variations. The boundary layer processes and meteorology in Ahmedabad played an important role in combination with the effect of local emission (Lal *et al*., 1999).

Though extensive studies have not been carried out in Kathmandu to link air pollution with different meteorological parameters, in the absence of a comprehensive database, sporadic studies have been carried out showing seasonal variation (LEADERS Nepal, 1998; DHM, 1998), diurnal variation, and weekend vs. weekday scenarios of particulate matter (LEADERS Nepal, 1999). Similarly, a study has been conducted to demonstrate the diurnal variation of ozone concentration (Dhakal, 2000). A study of aerosol distribution and its outlet from Kathmandu has also been completed recently (Dhaubhadel, 2000).

2.5 Past Air Pollution Studies Done on Kathmandu

Due to the absence of an air quality-monitoring network, air quality assessment has not been carried out systematically in Nepal. However, some institutions are becoming involved, and studies have recently been carried out to monitor the air quality situation in Kathmandu.

These studies have reveled that in most of the instances, PM_{10} and total suspended particulates (TSP) are found to be greater than acceptable WHO guideline values (TSP 150 μgm^{-3} and PM_{10} 10-70 μgm^{-3} for 8 hours). Other pollutants NO_X and SO_X are noted as well below the prescribed threshold limits of WHO (URBAIR, 1997; LEADERS Nepal, 1999; NESS, 1999; UNEP, 2001).

Very little research has been done to assess CO and ozone pollution. The study conducted by Devkota (1993) and ENPHO (1993), shows that the concentration of CO is well below the prescribed or safety value recommended by WHO. A study of ozone was carried out at different time intervals at Tribhuvan University at Kirtipur, Kathmandu (Dhakal, 2000). One study showed that ozone concentrations have increased since 1994, and it is expected that there will be a 42.25 percent increase in ozone concentration in the next 10 years from the year 2000. The same study has also shown a seasonal variation in ozone concentration, with February and March attaining the maximum concentration. The ozone concentration has also been observed to exhibit a diurnal variation with the highest concentration at about 12:00 to 14:00 LST. It has also been observed that meteorological phenomena like clouds, rainfall, and temperature influence ozone build up and dispersion (Dhakal, 2000).

Currently the Department of Hydrology and Meteorology is monitoring ambient air at least twice a week in Kathmandu. On the average, winter days are more polluted than summer days based on the amount of TSP in the valley atmosphere (DHM, 1999). Similar conditions have also been found in other recent studies (e.g., LEADERS Nepal, 1998; NESS, 1999).

The study by LEADERS Nepal (1998) also provided evidence that rainfall plays a very important role to reduce high incidence of dust particulates. The effect of wind has also been studied to some extent in Kathmandu (Dhaubhadel, 2000). High concentrations of pollutants are observed before noon and then decreases during the afternoon. The decreasing trend from morning to late afternoon is the result of increasing wind speed through the same time period. The persistent westerly and southwesterly winds flush urban pollutants from the valley (Dhaubhadel, 2000).

In the same study, abnormal air pollution episodes over the valley were observed from 7th March to 16th April 1999. Above normal temperatures were observed during this episode. It is thought that abnormal air pollution episodes are caused by the absence of precipitation for periods of more than six months (Dhaubhadel, 2000).

Despite recent efforts to carry out studies on air pollution, in the absence of a quality ambient air pollution database, very little is known regarding the problem of air pollution in Kathmandu.

2.6 Air Pollution and Legislation

Deteriorating air quality is a growing concern in most countries, including Nepal. Many factors are responsible for changing air quality and this varies from location to location. Indoor air quality is significantly affected by firewood burning while outdoor air quality is affected by vehicular pollution, industrial exhausts, mining activities, construction work and the nature of handling of construction materials, road conditions and weather. While factors such as weather are not amenable to policy changes, policy directives can influence most of the other factors to a significant extent. The practical difficulties as well as the effectiveness of implementation of policy decisions are another dimension of the problem. Time and again, different policies have been implemented and some like the removal of Viram tempos was a bold move that help to remove to some extent a significant source of pollution while others like the green sticker have not been very effective. Similarly, the introduction of unleaded petrol was also an important move. There are other policies such as subsidy on cooking stoves or biogas that have helped to improve air quality significantly (IUCN, Nepal, 2004).

CHAPTER III
RESEARCH METHODOLOGY

3.1 Research Design

The present study has been carried out both on the basis of exploratory and descriptive research design. It is somehow technical too.

It is exploratory because the study focused on to investigate the causes and consequences of air pollution, its effects on human health and surrounding environment. On the other hand, it tries to describe the relationship between man, environment and resources i.e. the concept of sustainable development to reduce population pressure on limited resources which is one of the reasons behind air pollution. It also analyzes the steps taken by relevant agencies to mitigate with air pollution problems. The main theme of the present research is to generate awareness among the inhabitants of Kathmandu about air pollution, its causes and potential health hazards, also the mitigation measures to be adopted.

It is somehow technical too because some lab experiments were carried out to show air pollution status in Kathmandu Valley.

3.2 Rationale for the Selection of the Study Area

Kathmandu Valley is the Capital of Nepal. Decentralization, being, just the concept and limited only to paper works over here in Nepal, the capital Kathmandu valley is being centralized day to day. Present day Maoist insurgency on other development regions, it is believed only the capital city to be safe so nearly half the population of Nepal today live in Central development region and especially Kathmandu valley.

Kathmandu valley too, has not sufficient infrastructures, sewage management systems, roads and traffic to accommodate such great number of people and therefore resulted pollution day by day. Present day, in Kathmandu valley there is much more pollution level than that set by WHO for air quality.

The narrow streets, increasing trend of vehicles and their emission, weak legislations and policies to control air pollution, people's unawareness, increasing industrialization, fuel use pattern in household and unplanned urbanization led Kathmandu valley prone to the different hazards of air pollution.

Present study, though mostly based on secondary data sources, the researcher aims to provide valuable effort towards raising awareness towards air pollution and its hazards to the inhabitants of Kathmandu valley for their better tomorrow.

3.3 Sampling Procedure

Mostly congested and heavily polluted spots were taken as sample place. Information was obtained by interviewing respondents. Stratified Random sampling was done. Kathmandu Valley was divided into 6 different strata and a total of 60 respondents were interviewed, 10 from each strata. It is because, MOPE has established air quality monitoring stations, one in each, in 6 sites around Kathmandu Valley namely, Putalisadak, Patan Hospital, Thamel, Bhaktapur, TU Kirtipur and Matsyagaon. And these are the places where researcher found the respondents to fill up the questionnaire.

3.4 Nature and Sources of Data Collection

Present study is based on primary as well as secondary data in order to meet the stated objectives of the study.

Primary data was obtained from field survey using questionnaire; observation and interview. The respondents were interviewed, filled up questionnaires and field survey was done. Also some lab experiments were done for some primary data regarding air quality.

Secondary data was collected from books, journals, dissertation, brochures, newspapers, magazines, TUCL and other relevant materials available from else where. The various websites are also surfed for obtaining data regarding air pollution. The institutions and agencies dealing with air pollution as CEN, ENPHO, LEADERS Nepal, IUCN, KEVA, MOPE, DoTM, MoH, DHM etc are visited to get relevant data.

3.5 Data Collection Tools and Techniques

Basically, secondary data has been used for the present study. The available literatures on air pollution were reviewed. The list of literature reviewed for this study has been presented in the Reference Section. The websites of different NGOs, INGOs and institutions dealing with different aspects of air pollution has also been surfed.

The MOPE's website has been surfed for air quality data of the six air quality monitoring stations. The air quality data of past one year i.e. from May 2005 to April 2006 has been used in this study. This study also analyzes the previous yearly and monthly data of different stations.

This study has also analyzed the records of patients admitted to major public hospitals in Kathmandu (Bir Hospital, Tribhuvan University Teaching Hospital and Patan Hospital) over the past 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 on chronic obstructive pulmonary disease (COPD).

To generate the primary data, the structured questionnaire, semi or unstructured interviews and observation as well as focus group discussion methods were applied.

3.5.1 Questionnaire Survey

Structured questionnaire was prepared to generate the realistic and accurate data. The respondents were requested to fill up the questionnaire. In case of the respondents who could not fill up the questionnaire, the questions were asked to the respondents and answers were filled up to collect the required data.

3.5.2 Key Informant Interview

The primary data was also collected from key informant using the semi or unstructured interview method. The interview was taken as cross checking for data obtained from questionnaire. The key informants were roadside pedestrians, those who spend most time roadsides as shopkeepers, those who used bike most of the time etc.

The informants were interviewed on the present status, causes and consequences of pollution in Kathmandu valley and this is the best method to give appropriate recommendations for planners, policy makers and relevant agencies.

3.5.3 Field Visit and Observation

The study area was visited and the level of pollution was observed. The photographs (see annexes) show the pictorial representation of the actual ambient air quality of Kathmandu valley and the sources of pollutants.

3.5.4 Focus Group Discussion

Focus group discussion is a most in this research work to discuss the problems, people living in Kathmandu are facing, due to air pollution and their solution to let them breathe clean air(*noted that: health is wealth*). For environmental conservation, local people should be aware and focus group discussion fulfills this category. It also helps to provide the required data and recommendations to related agency.

3.6 Data Processing and Analysis

After the data was collected from field survey, data was thoroughly checked and edited wherever necessary. Various softwares were used for data analysis. Simple statistical tools like tables, graphs, percentage, measures of central tendency, dispersion, correlation, regression analysis etc were done for data analysis. Descriptive method was used for qualitative data.

The secondary data was also analyzed and interpreted in the same way.

CHAPTER IV
THE STUDY AREA

4.1 Country Background

Nepal covering an area of 147, 181 sq. km and an average north-south width of 193km and east-west length of 850 km consists of three main physiographic regions, viz mountains, hills and terai (plains). Of the country's total area, the mountain and hill regions together account for nearly 77 percent while the Terai region accounts for the remaining 23 percent of the area. But in terms of population, the terai region had 48.4 percent of the country's estimated total population of 26 million and the mountains and hills, the rest.

The general environmental conditions of the country can be considered under two headings: environmental resources and social and economic driving forces. The country has diverse environmental resources; water, forests, land, biodiversity, climate and weather. The country has enormous hydropower potential. Forests still occupy the largest proportion of the land area. The diverse climate conditions make it possible to grow a wide variety of agricultural crops. With the diverse climate conditions, together with the forests, the country is rich in biodiversity.

Due to the lack of capital and human resources, commitment on the part of the government and awareness among the general mass of the people, the country has not been able to utilize these vast resources to the extent desired. The resources are deteriorating instead. Landslides, soil erosion, deforestation, forest fires and so on have caused the land to deteriorate, water sources to dwindle away, rivers to flood, biodiversity to deplete and people to migrate into urban areas and elsewhere.

Urban areas have developed haphazardly creating acute problems of solid waste, water pollution, air pollution, noise pollutions and others. The country has a broad-based population structure indicating a high fertility rate. The gainful population is increasing and is quite large compared to the availability of employment opportunities.

Roads, the backbone of industrial development and social, economic, political and spatial integration, have not yet reached all parts of the country and therefore, most of the human settlements cannot be reached by road. The existing infrastructure facilities, including roads, electricity, health, schools and water are inadequate, not only for the needs of the people but also in terms of use of existing resources.

The country's 2001 state of environment thus addresses five key environmental issues:

- Forest depletion
- Soil degradation
- Solid waste management
- Uncontrolled growth of population
- Poor management and use of resources

These are the major reasons for environment deterioration.

4.2 Background of the Kathmandu Valley

4.2.1 Geography

Like other growing urban centers throughout the world, the Kathmandu metropolitan area is particularly susceptible to episodes of high concentrations of lower atmospheric pollution. The physical geography of the area is as important as human aspects in producing this particular environmental problem.

Kathmandu Valley is the administrative as well as financial capital of Nepal. Kathmandu valley is in the political Bagmati Zone and three districts, Kathmandu, Lalitpur and Bhaktapur fall in the valley. The valley is an oval shaped, flat-bottomed basin improperly ventilated. The valley occupies about 351 square kilometer and is situated at an altitude of 1300 m to 1350 m. The highest hill surrounding the valley is Phulchoki (2785 m) in the southeast, Sivapuri (2713m) in the north, Chandragiri (2250 m) in the southwest and Nagarjun (2100m) in the western corner. Surrounding hills are covered with shrubs at higher altitudes and in some places slightly to moderately dense forests. The city itself is located between 20^o 34'N and 27^o 50' N and 85^o 11' E and 85^o 32' E. The urban part of valley includes altogether five municipalities namely Kathmandu Metropolitan City, Lalitpur sub-metropolitan City, Bhaktapur Municipality, Madhyapur-Thime Municipality and Kirtipur Municipality. Rural Kathmandu is quickly diminishing and is now confined to some outlying areas within the valley. The cross section of the Kathmandu Valley, oval in shape is about 20 km from north to south and 30 km from east to west.

4.2.2 Weather and Climate

Kathmandu Valley is influenced by the Indian monsoon. The general pattern is characterized by a hot season in May and June, followed by a well-defined monsoon during July, August and September, and an almost rainless, cold winter in December, January and February.

Kathmandu has an annual rainfall of 1740 mm (DHM, 2003). The normal onset date for rainfall is 12 June for Kathmandu (Yogacharya, 1998). Wind is ordinarily light throughout the year, but there is a strong wind in and around the hot season. The temperature in Kathmandu drops below freezing in winter and in summer it may rise to 35^{o}C. The mean annual temperature in Kathmandu is 18^{o}C. The coldest month is January with a mean temperature of 10^{o}C. The warmest months are July and August, with an average temperature of 24^{o}C. Fog is common in the morning during the months of October to February (Pandey, 1987, Yogacharya, 1998).

The climate condition of Kathmandu valley depends on the prevailing wind regime from central Asia and the northern hemisphere's cold pole. In the summer and early autumn the prevailing wind regime in Kathmandu valley is the southwest monsoon. In the winter the prevailing winds are more westerly. The high mountains in the north present the outbreak of cold Siberian winds form the northeast. The wind pattern is dominated by weak winds. Because of the high occurrence of calm and low winds speeds, the dispersion conditions in Kathmandu are poor. The mean annual air temperature in Kathmandu is 19^{o}c. The coldest month is January, with a mean temperature of 11^{o}c. The warmest month is July with an average rainfall of 27mm. The driest months are November/December when the average rainfall is less than 1mm. (Shrestha, 2001)

A high altitudinal variation with extreme diurnal radiation leads to a potentially strong cooling system in the night and a warming in the day. During the dry season, cooling in the morning and late afternoon, cause the formation of deep inversion layers. When the inversion layer is deep enough, insulation may not break through the inversion (Pandey, 1987). This situation of temperature inversion may last for several days, especially during the winter period. The atmosphere then acts like a cover over the city and the concentration of pollutants may build up considerably due to poor atmospheric dilution (Pandey, 1987). Due to topographical specificity, once the pollutants have entered into the valley, they cannot easily escape and may remain into the atmosphere for extended period of time.

Due to this topography and wind pattern, Kathmandu valley has been subjected to temperature inversion especially during winter period which is the dry season, when atmosphere acts as a lid over the city and the air pollutants have built up considerably.

4.2.3 Population and Urbanization

The city of Kathmandu has experienced rapid urbanization in recent years. Like most cities around the world, urbanization in Kathmandu is due to the economic activity and the career opportunities. Thus, over the past years Kathmandu Valley has witnessed a substantial change in population.

The valley alone accommodates nearly 1.3 million people out of 20.2 million people living in Nepal (CBS, 1996).The population of Kathmandu valley, which grows at an average annual rate of 4.6 percent in 1970's, went up to 6 percent growth rate in 1980's. The population of Kathmandu is estimated to be more than one million, making one of the most populous cities in South Asia region. The migrant population is from mountain, hill and terai in search of jobs, education and other opportunities. (Shrestha, 2001)

Presently, the Maoist insurgency is the major reason behind such heavy population pressure in Kathmandu Valley. Others include centralization, better facilities and so on.

Table 4.1: Population Data, Kathmandu Valley

Year	Kathmandu District	Bhaktapur District	Lalitpur District	Total
1971	3,53,757	1,10,157	1,54,998	6,18,912
1981	4,22,237	1,59,767	1,84,341	7,66,345
1991	6,75,341	1,72,952	2,57,086	11,05,379
2001	10,81,845	2,25,461	3,37,785	16,45,091

Source: CBS, Population Census, 1981, 1991, 2001.

The total land area of the Kathmandu is 4770 hectare (ha) (Mathema et al., 1992). Out of the total land area only 221 hectare are committed as open space (Tudikhel, Swayambhu, Bhadrakali, and the Airport Golf course. In all, 62 percent of the land in Kathmandu is built -up urban land (MSUD/DHUD, 1989).

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.

4.2.4 Traffic Volume and Road Network

With industrial and economical development, transportation has become an important requirement in urban Kathmandu. The number of vehicles in this city is ever increasing, and in the 1990s alone, the number of vehicles increased by 4.2 fold (LEADERS Nepal, 1999). According to the Department of Transport Management, the number of vehicles in the Bagmati zone has increased to 171,678 by the end of fiscal year 2001/02 which is a very high number considering the small road network in Kathmandu Valley. In Nepal it is not precisely known what percentage of registered vehicles are actually operated (Adhikari, 1999). However, it appears that almost all the vehicles in Bagmati zone run on the streets of Kathmandu (CEN, 2001). During the last fiscal year alone 23,143 vehicles entered the streets of Kathmandu. Among these, 77 percent were motorcycles. Cars and two – wheelers have been dominating the total fleet in Nepal and now comprise about 22 percent and 51 percent of the total vehicle fleets, respectively (Adhikari, 1999).

By in large road vehicle fleet, using fossil fuel accounts for the major ambient air pollution in Kathmandu. It is estimated that 51 vehicles ply per km of road in Kathmandu (Shrestha, 2001).

A study done by LEADERS Nepal has concluded that vehicles are responsible for the increased concentration of respirable particulate matter at different traffic intersections (LEADERS Nepal, 1999). Approximately 36.5 percent of the vehicles running in the streets of Kathmandu valley fail to comply with the emission standards set by His Majesty’s Government of Nepal (Bastola, 1998).

Listed below in Table 4.2 is the total number of vehicles registered in the Bagmati zone over past years. The large number of vehicles and their movement has caused adverse impacts on the air quality of the Kathmandu Valley.

Table 4.2: Vehicle Registration Data, Bagmati Zone

Vehicle Type	2000/01	2001/02	2002/03	Upto mid-July 2003/04
Bus	1744	1858	2061	16549
Mini bus	1804	2172	2387	
Truck/Tanker	5484	6274	6991	26067
Car/Jeep/Van	40674	43409	45361	73474
Pick-up	-	-	521	-
Microbus	-	-	232	-
3-Wheeler	4949	5073	5073	7215
2-wheeler	112000	134852	156410	270949
Tractors	1673	1673	1677	31856
Other	3350	3356	3385	3979
Total	171678	198667	224068	430089
% increase in Total vehicles	15.6	15.7	12.8	91.95

Source: Department of Transportation Management (2005)

Note: DoTM has added two new categories (pick-up and microbuses) starting 2002/03. Kathmandu did have pick-ups and microbuses in years prior to 2002/03 but they were registered under a different category.

Despite the heavily increasing number of vehicles, the total length of road networks in Kathmandu Valley is insufficient (Ghimire, 1998).

Table 4.3: Road Status in Kathmandu Valley

(A)

District	Major Urban Center	Road Type (Km)			Total (Km)
		Black Topped	Graveled	Earthen	
Kathmandu	Kathmandu	299	144	85	528
Lalitpur	Patan	84	48	158	290
Bhaktapur	Bhaktapur	59	50	16	125

Source: Ghimire, 1998

(B)

Municipality	Roads, Km	Total area, ha	Road (Km)/ area (sq. km)	Road (Km)/ 1,00,000 people
Kathmandu	705	4830	14.59	95
Lalitpur	383	1547	24.75	220
Bhaktapur	172	688	25.00	229
Madhyapur	11	1147	0.95	21
Kirtipur	110	1400	7.85	255
Kathmandu Valley	1381	9612	14.36	127.75

Source: http://www.iges.or.jp/en/ue (upto July 2004)

The roads in urban Kathmandu have not been altered to accommodate the increasing number of vehicles. Thus, most motorable roads in Kathmandu are too narrow for the dense traffic with only 3.65m per vehicle. This Figure is for the total urban road network. However, if only black top surfaced road is considered, per vehicle road space is only 2.81m (LEADERS Nepal, 2000). Since Kathmandu has an insufficient and sub-standard road network, the transport or the vehicle-related air pollution has been linked not only with types and condition of vehicles, but also with the infrastructure to accommodate them properly (Adhikari, 1999).

4.2.5 Industrial Growth

Urbanization has helped the city to diversify the economy by facilitating the growth of the industrial base. But at the same time, these industries are a major source of pollutant emissions in the Kathmandu Valley. Industrial development has been growing at a rapid rate in the last decade. Kathmandu Valley accommodates 25 percent of the total units of the industries in the country (UNEP, 2001). Out of 125 industries identified as point sources of pollution in the country, 105 industries have air pollution problems (NECG, 1990).

According to a study done to estimate total amount of air pollutants, 3156 industries were found to be in the category of air polluting industries, out of which Kathmandu Valley accommodates 47.5 percent of them (Devkota and Neupane, 1994). Studies have shown that brick and cement industries are the main industrial polluter (Devkota and Neupane, 1994; URBAIR, 1996).

The major air pollutants of the cement industry are particulate and gaseous wastes such as SO_2, NO_X, CO_2 and CO emitted from stacks. Himal Cement located inside the valley alone emits as much as 400 tons/year of dust (NECG, 1990). Presently, Himal Cement is closed and not in operation.

4.2.6 Energy Use and Consumption Pattern

Nepal's total energy demand is estimated to be 8.205 million TOE (tons of oil equivalent) i.e. about 15GJ per capita in 2002. Out of the total energy consumption, 89.05 percent is consumed by the residential sector and the rest by other sectors. 85.27 percent of the energy demand is met from traditional sources such as fuel wood, agricultural residues, animal dung. The remaining 14.24 percent is met from commercial sources such as petroleum products 9.24 percent, coal 3.53 percent and electricity 1.47 percent. All petroleum products are imported into Nepal, of which considerable amount is used for automobiles, followed by industry. Renewable energy source accounts 0.48 percent of total energy consumption in 2002.

The total consumption for Kathmandu is divided into domestic use, vehicle fleet and industry. For domestic use, fuel wood has been replaced by kerosene and Liquidified Petroleum Gas (LPG), coal is used mainly in the brick and cement industry. The coal and other energy sources used to fire the bricks in these industries have been major sources of air pollution emissions which significantly degrade air quality of the valley. The increase in the number of smaller industries using fuel oil, high-speed diesel (HSD) and agricultural refuse, although less significant for air pollution than big industries, but has significant local air pollution exposure, especially in semi-urban Kathmandu. Tobacco smoking also comes under this category of air pollution.

4.2.7 Health Impact

Each winter and late summer, high concentrations of lower atmospheric pollutants pose a threat to the health of the residents of the Kathmandu Valley, Nepal (LEADERS Nepal 1998; LEADERS Nepal, 1999). Because of the potential threat to human health, high levels of lower atmospheric pollution across the Kathmandu, urban area have been a focus of Nepalese scientists and local government agencies over the past decade. A citizen's report published by LEADERS Nepal in 1998 indicates a rise in incidence of respiratory disorders, the reporting of eye, throat and skin problems, and incidence of cardio-vascular related problems among people living in Kathmandu.

A preliminary study has shown that urban residents exceed the number of respiratory-related cases treated in hospitals, compared to that from the rural areas in Kathmandu. One possible reason for the increased numbers could be linked with the deteriorating ambient air quality (LEADERS Nepal, 1999). Acute respiratory disease (ARI) is one of the top five diseases reported in Nepal (UNEP, 2001).

In Kathmandu, Lalitpur and Bhaktapur (the three major municipalities inside the Kathmandu Valley) 16.5 percent (156,483 patients) of all hospital visits from 1996-97 were reported to be for respiratory problems (DOH, 1997). Acute respiratory disease is also the leading cause of death among young children, accounting for more than 30 percent of the deaths in children less than five years of age (Niraula, 1998).

A strong correlation was also found between the prevalence of chronic bronchitis and indoor smoke pollution in Nepal (Pandey and Basnet, 1987). Previous studies have suggested that the high mortality rate due to PM_{10} was about 85 cases in a population of approximately 1 million in Kathmandu (URBAIR, 1996).

CHAPTER V

AIR POLLUTION – A THREAT TO ENVIRONMENTAL SUSTAINABILITY

5.1 Environment

Environment is the natural world of land, sea, air, plant and animals that exist around us. In Laymen's term – everything around us is environment. The environment etymologically means surroundings. Environment consist a wide range of resources like air, water, soil which are vital elements for the existence of all forms of life in the earth. More conveniently, environment can be defined as "All conditions and influences surrounding and affecting the organism or groups of organisms of the biosphere".

Environment can be divided into: lithosphere, biosphere and atmosphere.

Atmosphere is an insulating blanket of air around the earth. It is a thin and fragile membrane, which mediates between the ocean and land tropics and one ecosystem to another. Atmosphere supports life on earth by doing following things:

- ⇨ It is a reservoir of oxygen
- ⇨ It serves distribution of moisture, lighting, cloud, wind, rain, snow and fires
- ⇨ It shields the earth from the lethal concentration of UV radiation.

Total mass of earth's atmosphere is approximately 5.1×10^{15} tons consisting of gases, spores and suspended particles. Air is a mixture of gases. Composition of dry unpolluted air by volume is as follows:

Table 5.1: Composition of Gases in Atmosphere

Gases	Concentration	Gases	Concentration
Nitrogen	78.084%	Methane	1.3-1.6 ppm
Oxygen	20.946%	Krypton	1.14 ppm
Argon	0.934%	Hydrogen	0.5 ppm
Carbondioxide	340 ppm	Nitrous Oxide	0.25-0.35 ppm
Neon	18.18 ppm	Xenon	0.87 ppm

Source: www.questia.com

5.2 Sustainability and Sustainable Development

People all over the world are increasingly worried not only about their own and their children's future but also atmospheric and water pollution, a rapid extinction of plant and animal species, emerging specter of global warming and climate change. Nuclear war remains a long-term threat to our survival. The constraints imposed by depletion of natural resources and pollution caused by the conversion of resources have brought humanity to crossroads. There is also inequitable distribution of benefits of development. Desertification, deforestation and droughts have created urbanization, unemployment and lack of housing is steadily increasing. Therefore we need to replace our traditional notion of security by a new and global concept – "Sustainable Development".

The report on "Our Common Future" defined Sustainable development as meeting the needs and aspirations of the present generation without compromising the availability of future generations to meet their needs.

It requires political reform, access to knowledge and resources and a more just and equitable distribution of wealth within and between nations. Sustainable development is thus a strategy to enhance global security.

Sustainable development is a phenomenon wherein the demand of the present generation is optimally satisfied without compromising the vital needs of future generations. Concept of Sustainable Development stresses on the need for utilizing country's bio-physical resources in the most productive manner without 'damaging' or 'depleting' these resources.

Sustainable Development does not degrade the quality of environment and therefore sustains human progress not just in a few places and not just for a few years.

Broader notions of Sustainable Development are:

- Improving health care, education and overall social well-being
- Emphasizing participation of people at grass-root level in decision making process
- Enhancing Human Resource and technical know-how

A resource use rate is sustainable when it can be maintained over long-run without impairing the fundamental ability of the natural resource base to support future generations. However, sustainability does not mean that resources must remain untouched. Instead, what it means is that, their rates of use should be set so that they do not jeopardize future generations.

Concept of Sustainable Development appears to have evolved out of realization and recognition of the crucial linkages between population (Society), Resource (Economy) and Environment.

Figure 5.1: Relationship between Population, Resource and Environment

Such linkage comprises a trilateral interaction process in which each factor affects the other two, directly or indirectly. E.g. high population increase will put pressure on limited sources which degrade the environment directly or indirectly. These two negative consequences will in turn lower the quality of human life and eventually threaten human survival.

During 1970s, development related concepts such as growth with equity, redistribution with growth etc were emerged. It emphasized that along with economic growth, benefits of the growth must be fairly distributed among people of all categories.

During 1980s, it is taken development as a multidimensional concept. Development should encompass improvements in both material and social well-being of all people. Investments are required in all sectors such as agriculture, industry and not just in one or two sectors. The most important realization was that the development must be sustainable because rapid population growth rates made difficulties in poverty alleviation, employment creation and living standard.

It was then during end of 1980s that the development and environment were started being taken to be mutually interdependent and reinforcing. Protection of environment and promoting economic development started being considered a common challenge. Sustainable Development lies in integrating these two.

Hence, concept of Sustainable Development implies:

- ⇨ Maintenance and sustainable utilization of functions (goods and services) provided by natural ecosystem and biospheric processes. (Vellinga et al, 1995)
- ⇨ Maximizing biological system goals (genetic diversity, biological production), economic system goals (meeting basic minimum needs, equity) and social system goals (social justice, people's participation) simultaneously. (Barbier, 1987)
- ⇨ Improving the quality of human life while living within the carrying capacity of supporting ecosystems. (IUCN, UNEP and WF for Nature, 1991)

So, Sustainable Development is all about progress, growth, generation of wealth and use of resources.

Sustainable Development includes two key elements

- ⇨ Meeting the needs particularly of those people who have been left far behind in the process of growth and development.
- ⇨ Imposing limits to use of resources of our environment so as to protect their resource base at local, regional, national and global levels.

Sustainability refers to the idea that the course of action which reduces the long-run productive capabilities of natural and environmental resource base should be avoided. Sustainability means that the future production possibility curve (PPC) is not adversely affected by what is done today. It however does not mean that we must maximize environmental quality today because that implies zero output of goods and services. What it actually means is that, environmental impacts need to be sufficiently reduced today to avoid shifting future production possibility curve (PPC).

Sustainability follows that environmental protection and economic development are complementary rather than antagonistic processes. It chiefly involves preserving the natural environment upon which people and economies depend so heavily.

Figure 5.2: Production Possibility Curve, Today and in 50 Years

In Figure 5.2, there are two curves – PPC today and PPC in 50 years. In PPC today Figure, the initial environment quality is at e1 and the production of market goods is at c1 level. Nowadays, we are increasing the market goods to the level of c2 in the cost of destruction of environment which is shown by e2. This means we are achieving the economic growth in the cost of environmental destruction.

If the present condition prevails then in next 50 years the environment will degrade from e2 to e3. Also instead of increasing the market goods, it will lower down to c3 i.e. we have both the lower economic development and degrading environmental quality, if this is the condition.

The goal of sustainability implies a restructuring of international cooperation in the economic and environmental spheres. This restructuring must take into account some strategic imperatives:

- ⇨ Reviving growth: Poverty undermines people's capacity to use resources widely;
- ⇨ Urgently finding patterns of growth that are less energy intensive;
- ⇨ Meeting the essential needs of the expanding population of the developing world;
- ⇨ Achieving a sustainable and stabilized world population level;
- ⇨ Conserving and enhancing the resource base. Alternative means of production and consumption must be sought, so as to reduce the pressure on resources;
- ⇨ Reorienting technologies to meet the challenges of increased consumption and lowered use of resources;
- ⇨ Merging environmental and economic concerns in decision making at all level.

Achieving sustainability means to maintain the following:

- ⇨ Continuation of human species on earth.
- ⇨ Stable/ reduced human population.
- ⇨ Provision of basic needs of all human.
- ⇨ Maintenance of biodiversity.
- ⇨ Reduced rate of usage of non-renewable resources.
- ⇨ Reduced rate of output of non-reusable or intractable wastes.
- ⇨ Increased reliance on stable/ sustainable rates of usage of renewable resources.
- ⇨ Quality goods and services rather than quantity.
- ⇨ Global redistribution of means of production.
- ⇨ Satisfaction of non-material needs of all human beings.
- ⇨ Stabilization of basic ecological processes.

5.3 Air Pollution

5.3.1 Introduction

Air pollution can be defined as the disequilibrium condition of ambient air quality by the introduction of foreign elements from either anthropogenic or natural sources. According to WHO (1996), "Air pollution is limited to situation in which the outer ambient atmosphere contains materials in concentrations which are harmful to human beings and their environment".

Air pollution is the presence of one or more chemicals in the atmosphere in quantities and duration that cause harm to humans, other forms of life, and materials. In other words, air pollution is a chemical in the wrong place in the wrong concentration. For example, ozone is a natural and important component of the stratosphere, where it shields the earth from most of the life destroying ultraviolet radiation emitted by the sun. In the troposphere however, even trace amounts of ozone formed in urban smog damage plants, the respiratory systems of humans and other animals, and materials such as rubber.

As clean air in the troposphere moves across the earth's surface, it collects the products of natural events (dust, storms and volcanic eruptions) and human activities (emissions from cars and smokestacks). These potential pollutants, called *primary pollutants*, are mixed vertically and horizontally and are dispersed and diluted by the churning air in the troposphere. While in the troposphere, some of these primary pollutants may react with one another or with the basic components of air to form new pollutants, called *secondary pollutants*. Long-lived primary and secondary pollutants can travel great distances before they return to the earth's surface as solid particles, droplets, or chemicals dissolved in precipitation.

Pollutants are also found indoors from infiltration of polluted outside air and from various chemicals used or produced inside buildings. Risk analysis experts rate indoor and outdoor air pollution as high-risk human health problems. Air pollution is not new, but it has increased significantly since the industrial revolution.

In developed countries, most pollutants enter the atmosphere from the burning of fossil fuels in both power plants and factories (stationary sources) and in motor vehicles (mobile sources). Motor vehicles produce more air pollution than any other human activity. In car-clogged cities like Los Angeles, Sao Paulo, Bangkok, Rome and Mexico City, more vehicles are responsible for 80-88 percent of the air pollution. According to the WHO, more than 1.1 billion people – one of every five persons – live in urban areas with air that is unhealthy to breath.

Because they contain large concentrations of cars and factories, cities normally have higher air pollution levels than rural areas. However, prevailing winds can spread long-lived primary and secondary air pollutants from emissions in urban and industrial areas to the countryside and to other downwind urban areas.

5.3.2 Sources of Kathmandu's Air Pollution

Past studies have indicated that the main sources of Kathmandu's air pollution are industries and vehicles. Some other sources are domestic cooking fuels, 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.

i) Industries

Several industries in the valley, in particular, the hundreds of coal burning brick kilns, emit a substantial quantity of smoke and dust into the atmosphere. In 1998, about 150 brick kilns were estimated to be in operation in the Kathmandu valley. Smoke emissions from these kilns are particularly high during the major brick production season from November to May - the driest months when the effects of air pollution are heightened. There are no wet or electrostatic scrubbers in these kilns, and consequently, smoke, ash particles and brick dust are directly released into the atmosphere. An IUCN survey in 1990 found that more than half of all industrial units in Kathmandu had no pollution control measures. These industries included cement, textiles, soap and chemicals, bricks, feed and foam plants in the valley.

ii) Household Smoke and Other Factors

Many households in Kathmandu still use biomass, particularly firewood, for cooking and heating. Only limited households have started to cook with LPG, a less polluting fuel. The households using LPG are also distracted towards gas due to high cost. Presently one cylinder of gas costs NRs. 900 which is very high for middle class families. In addition, the solid waste in the valley is regularly burned in an attempt to destroy waste at source.

Lack of dust control mechanisms during the construction of buildings and physical infrastructure, small industrial and business activities and cumulative dirt in the sidewalks also contribute to air pollution. Traffic congestion and the severe shortage of public open space and greenery in the urban area exacerbate the impacts of air pollution. The bowl-shaped physiography and the resulting thermal inversion effect in the atmosphere heighten the air pollution by trapping the foul air within the valley's immediate atmosphere. The releases from all these sources have created a high level of air pollution in the Kathmandu valley, the pollution becoming increasingly severe in the last decade.

iii) Vehicular Emission

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 5.2: 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 and 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, NO_X and SO_2, while petrol vehicles emitted more CO and HC.

Table 5.3: 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 NO_X and SO_X

Source: www.cen.org.np

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

A study done by the WB 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.

Ten years later, however the situation in Kathmandu is quite different. In the past 10 years, Himal Cement has been closed, the number of brick kilns has 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.

Figure 5.3: Vehicular Emission

MOPE/ESPS has tried to update the URBAIR emission inventory. The results of the two inventories indicate that vehicle exhaust is now the main source of PM_{10} in the valley. PM_{10} from vehicles increased by 471 percent between 1993 and 2001. Vehicles are now responsible for about 67 percent of the PM_{10} load (Gautam, 2002).

Table 5.4: Comparison of Emission Inventory in 1993 and 2001

Sources	PM_{10} (Tons/year)		
	1993	2001	% increase
Mobile Sources			
Vehicle Exhaust	570	3259	471
Road Resuspension	400	1822	356
Sub-total	970	5081	424
Stationary Sources			
Industrial/ Commercial fuel	292		
Domestic fuel combustion	1166		
Brick Kilns	1295	1688	30
Himal Cement	800	455	-43
Industrial boilers		15	
Refuse burning	190	339	78
Sub-total	3472	2498	-28
Total	4712	7580	61

Source: MOPE/ ESPS, 2003

5.4 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 5.5: Emission Standards for In-Use Vehicles in Nepal

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

Source: www.cen.org.np

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 5.6).

Table 5.6: 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 & upto 10000*	10 – 220
HSU	60 – 95	22 – 61

Source: Department of Transport Management

* Two stroke two and three wheelers

The test results also show that the improvement in emissions is much more significant in 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.

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 (from 1995/96 to 2002/03) indicate that approximately 25 percent of the vehicles fail the tests (Table 5.7). 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.

Table 5.7: Emission Test Results of In-Use Vehicles in Kathmandu

Year	Vehicles Tested	Pass	Fail	% Failed
1995/96	486	162	324	67.00
1996/97	41466	25220	16246	40.00
1997/98	31173	22984	8189	26.00
1998/99	28018	24240	3778	13.00
1999/00	42826	34255	8571	20.00
2000/01	34543	29034	5509	16.00
2001/02	33378	24462	8916	27.00
2002/03	32894	23698	9196	28.00
Total	244784	184022	60729	24.80

Source: Valley Traffic Police Office, 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 percent) 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.

CHAPTER VI
AIR POLLUTION AND HEALTH RELATED ISSUES

6.1 Our Respiratory System

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.

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

Years of smoking and exposure to air pollutants can overload or break down these natural defenses, causing or contributing to respiratory diseases. Examples are:

i) *Lung cancer*,
ii) *Asthma* (typically an allergic reaction causing sudden episodes of muscle spasms in bronchial walls, resulting in acute shortness of breath),
iii) *Chronic bronchitis* (persistent inflammation and damage to the cells lining the bronchi and bronchioles, causing mucus buildup, painful coughing, shortness of breath),
iv) *Emphysema* (irreversible damage to air sacs or alveoli leading to abnormal dilation of air spaces, loss of lung elasticity and acute shortness of breath.

6.2 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.

i) 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 environment, and because of their lower heights, they 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 PM_{10} 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 µg/m3 change in PM_{10} was associated with a 4-12 percent increase in lower respiratory symptoms for children under two years and 3-9 percent increase for 3-15 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).

ii) Elderly

In 2000, a Canadian study used three measurements of particulate matter: coefficient of haze (COH), total sulphate and $PM_{2.5}$; 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).

iii) 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 PM_{10} concentration and asthma attacks. A ten-year study in Chicago found that asthmatics had doubled the risk of PM_{10}-associated hospital admissions. Another study investigated the short-term health effects of particles in eight European cities and found that for each 10 µg/m3 increase in PM_{10}, 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.

iv) Diabetics

Particles can increase the risk of heart disease for diabetics. A study done by Harvard School of Public Health investigated the association of PM_{10} with hospital admissions for heart and lung diseases in persons with or without diabetes in Cook County, Illinois. The study found that a 10 µg/m3 increase in PM_{10} was linked with a 2.01 percent increase in admissions for heart diseases with diabetes but only a 0.94 percent increase in persons without diabetes (Ghose, 2002).

6.3 Health Effects of Various Pollutants

i) 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 WB 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 PM_{10}. About 1600 fine particles with a diameter of 10 microns could fit inside the dot above the letter *i*. 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 $PM_{2.5}$. 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 $PM_{2.5}$ consisted of about 50 percent carbonaceous aerosols, most likely from combustion sources, followed by 30 percent secondary aerosols, and 15 percent geological matter. PM_{10} on the other hand was found to be 50 percent geological matter, 30 percent carbonaceous aerosols and 20 percent secondary aerosols (WB, 2003c). This means that $PM_{2.5}$ consists of higher percentage of harmful substances than PM_{10} and a higher $PM_{2.5}$ to PM_{10} ratio indicates higher contribution of combustion sources, such as vehicle emission.

Inhaling suspended particulate matter aggravates bronchitis and asthma, and long-term exposure can contribute to development of chronic respiratory diseases and cancer. Invisible fine particle especially those less than 10 microns (or micrometers) emitted by incinerators, motor vehicles, radial tires, wind erosion, wood-burning fireplaces and power and industrial plants are especially hazardous.

Such tiny particles are not effectively captured by modern air pollution control equipment, and they are small enough to penetrate the respiratory systems natural defenses against air pollution. They can also bring with them droplets or other particles of toxic or cancer-causing pollutants that become attached to their surfaces. Once lodged deep within the lungs, these fine particles can cause chronic irritation and can trigger asthma attacks, aggravate other lung disease, causing lung cancer and interfere with the blood's ability to take in oxygen and release CO_2. This strains the heart, increasing the risk of fatalities from heart disease.

Exposure to particulate air pollution is much worse in most developing countries, where urban air quality has generally deteriorated. The WB estimates that if particulate levels were reduced globally to WHO guidelines, between 300,000 and 700,000 premature deaths per year could be avoided.

ii) Carbon Monoxide (CO)

About 90 percent of the CO – a colorless, odorless, poisonous gas – in the troposphere comes from natural sources. Most of this is produced by reaction in the upper troposphere between methane (emitted mostly by the anaerobic decay of organic matter in swamps, bogs and marshes) and oxygen. Because this CO is diluted by the turbulent air flows in the troposphere, it does not build up to harmful levels.

However, the remaining 10 percent of the CO added to the atmosphere come form the incomplete burning of carbon containing chemicals. Cigarette smoking is responsible for the largest human exposure to CO, but this gas is also released by motor vehicles, kerosene heaters, woodstoves, fireplaces and faulty heating systems. In urban and heavily industrialized areas, outdoor CO levels from such sources (mostly motor vehicles) can be 50-100 times higher than worldwide averages from natural CO emissions and can reach harmful levels inside motor vehicles in heavy traffic.

CO reacts with hemoglobin in red blood cells and thus reduces the ability of blood to carry oxygen. This impairs perception and thinking, slows reflexes, and causes headache, drowsiness, dizziness and nausea. CO can also trigger heart attacks and angina attacks in people with heart disease. It can damage the development of fetuses and young children and aggravate the condition of people suffering from chronic bronchitis, emphysema and anaemia. Exposure to high levels of CO causes collapse, coma, irreversible damage to brain cells and even death.

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).

Carbon monoxide detector (similar in size to smoke detector) is a good safety investment for homeowner.

iii) Sulphur dioxide (SO_2)

SO_2 causes some constriction of the airways in healthy people and severe restriction in people with asthma. Chronic exposure causes a condition similar to bronchitis. Sulphur dioxide and suspended particles react to form far more hazardous acid sulphate particles, which are inhaled more deeply into the lungs than SO_2 and remain there for long periods. According to the WHO, 625 million people are exposed to unhealthy levels of SO_2 from fossil fuel burning.

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.

iv) Nitrogen Oxides (especially NO_2)

NO_2 can irritate the lungs, aggravate the condition of people suffering from asthma or chronic bronchitis, cause conditions similar to chronic bronchitis and emphysema, and increases susceptibility to respiratory infections, such as the flu and common colds (especially in young children and elderly people). Recent evidence from test animals indicates that NO_2 exposure may also encourage the spread of some cancers – especially *malignant melanoma* throughout the body.

Oxides of nitrogen are generally released as nitrogen oxide (NO) and gradually converted 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).

v) Volatile Organic Compounds

Many volatile organic compounds such as benzene and formaldehyde and toxic particulates such as lead, cadmium, PCBs and dioxins can cause mutations, reproductive problems or cancer.

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.

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) 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.

vi) Ozone

Inhaling ozone, a component of photochemical smog, causes coughing, chest pain, shortness of breath and eye, nose and throat irritation. It also aggravates chronic diseases such as asthma, bronchitis and emphysema and heart trouble and reduces resistance to cold and pneumonia.

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.

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.

Table 6.1: Health Impact 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 PM_{10} increases - Non-trauma deaths by 0.8 percent - Hospital admission for respiratory & cardiovascular diseases by 1.4 & 6 percent respectively - Emergency room visits by 3.1 percent - Restricted activity days by 7.7 percent Previously, WHO guideline was 70 µg/m3 (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 µg/m3 (24 hr.) and 50 µg/m3 (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 µg/m3 (annual mean)
Carbon Monoxide	Fatal in large doses Aggravates heart disorders Effects central nervous system Impairs oxygen carrying capacity of blood WHO guideline: 100 µg/m3 or 90 ppm for 15 minutes
Ozone	Reduced lung function; airway inflammation; bronchoconstrictions; exacerbation of asthma Eye irritation WHO guideline: 120 µg/m3 for 8 hours
Lead	Extremely toxic: affects nervous system and blood; can impair mental development of children; causes hypertension WHO Guideline: 0.5 µg/m3 (1 year average)
Benzene	Carcinogenic to humans; long-term exposure can result in bone marrow depression expressed in leucopenia and anaemia; 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

Thus it is clear that the major air pollutants contributing to human health damage are particulate matters, SO_2, NO_X, CO, ozone, lead and benzene.

In case of Kathmandu, as levels of SO_2, NO_X, CO, ozone, lead and benzene are generally found to be within international standards, the main pollutant of concern is the concentration of particulate matter in the air. Among the particles, the level of fine particles that can enter the human body is of special concern. Particles less than 10 microns (PM_{10}) can enter through the upper respiratory tract and particles less than 2.5 microns ($PM_{2.5}$) can reach the lungs.

The fine particles can cause long term damage to the lungs. 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, they are often coated with toxic substances and they remain in the air for a long time.

A recent study indicates that a mere 10 µg/m3 increase in $PM_{2.5}$ can increase the risk of lung cancer by 8 percent, cardiopulmonary deaths by 6 percent and all deaths by 4 percent.

WHO says there is no safe limit for the concentration of PM_{10} or $PM_{2.5}$ 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 vehicular emission.

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

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. Furthermore, these particles are coated with toxic substances. Scientists have also discovered the most dangerous carcinogen found till now in diesel exhaust. Diesel exhaust can therefore cause cancer.

6.4 Health Impacts of Kathmandu's Air Pollution

Information regarding health impact is very limited. URBAIR 1996 was the first scientific study done regarding health impact assessment. The study showed that 50 percent of the population was exposed to a TSP concentration above the WHO Air Quality Guideline (AQG) (90 µg/m3 annual average) and some 4 percent of the population was exposed to TSP concentration above 2 x WHO AQG (180 µg/m3).

These were the residents in the brick kiln areas and drivers and roadside residents of the roads with the most heavy traffic. The prominent diseases were chronic bronchitis in adults and asthma in children.

A study done by LEADERS (1999) from a city hospital, showed that respiratory infections increased from 10.9 percent of the total outpatient visits (5,67,378) in 1996 to 11.6 percent of the total outpatient visits (7,11,581) in 1998. The other health impacts observed were eye irritation and infection during dry months.

The environment impact is hard to substantiate. Some observes that dust particles have caused an adverse impact on vegetation growth as well as low visibility and low degree of incoming sunlight.

Air pollution can affect our health in many ways with both *short-term* and *long-term* effects. Different groups of individuals are affected by air pollution in different ways. Some individuals are much more sensitive to pollutants than are others. Young children and elderly people often suffer more from the effects of air pollution. People with health problems such as asthma, heart and lung disease may also suffer more when the air is polluted. The extent to which an individual is harmed by air pollution usually depends on the total exposure to the damaging chemicals, i.e. the *duration of exposure* and the *concentration of the chemicals* must be taken into account.

Examples of *short-term effects* include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Other symptoms can include headaches, nausea, and allergic reactions. Short-term air pollution can aggravate the medical conditions of individuals with asthma and emphysema. In the great "Smog Disaster" in London in 1952, four thousand people died in a few days due to the high concentrations of pollution.

Long-term health effects can include chronic respiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver or kidneys. Continual exposure to air pollution affects the lungs of growing children and may aggravate or complicate medical conditions in the elderly. It is estimated that half a million people die prematurely every year in the United States as a result of smoking cigarettes.

Research into the health effects of air pollution is ongoing. Medical conditions arising from air pollution can be very expensive. Healthcare costs, lost of productivity in the workplace and human welfare impacts cost billions of dollars each year.

i) Past Studies

Many studies have shown that deterioration of ambient air quality has significant health implications. According to the WHO, air pollution is responsible for about 3 million pre-mature deaths each year. Out of this, approximately 800,000 are due to outdoor air pollution. WHO also 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 caused by air pollution. (WHO, 2000) Approximately 150,000 of these deaths are estimated to occur in South Asia alone (WB, 2003a). Other adverse health impacts include increased incidence of chronic bronchitis and acute respiratory illnesses, exacerbation of asthma and impairment of lung function.

These Figures indicate that Kathmandu's air pollution is also having adverse impacts on public health. Kathmandu's PM_{10} level is several times higher than national and international standards. In fact, one can often feel the impacts of the pollution when 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 is a more difficult task. Assessment of financial implications of these impacts then becomes even more difficult. The difficulty mainly arises because of the lack of reliable data related to air quality, health status, hospital visits and the lack of appropriate tools/models to analyze the data.

Several studies have shown that Kathmandu's air is much polluted; particularly in the dry winter months and that the level of pollution is increasing. In the dry months, along busy roadsides, the concentration of PM_{10} is above the national standard on 99 percent of the days. Comparison of data collected by ENPHO in 1992 to data generated by the recently established air quality monitoring stations indicates that the PM_{10} level in Putalisadak has more than tripled in the past years.

Studies have also indicated that vehicles are the main sources of air pollution in Kathmandu. 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 and maintenance system and ineffective transport management. Over the past years, number of vehicles in the valley has been increasing at an alarming rate. Although 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 indicates that PM_{10} emission from vehicles has increased by more than four times between 1993 and 2001 and now vehicle exhaust is responsible for 43 percent of the total PM_{10} emission in the Valley.

Although no long-term epidemiological studies have been conducted in Kathmandu, a few studies have indicated that the health impacts of Kathmandu's air pollution can be quite severe.

The results of a study done by WB to estimate impacts on mortality and morbidity due to PM_{10} levels in 1990 are presented in the table below:

Table 6.2: Health Impacts Due to Kathmandu's PM_{10} in 1990

Health Impact	No. of Cases	Value (NRs. 1000)
Excess mortality	84	28,644
Chronic bronchitis	506	41,988
Restricted activity days	475,298	26,617
Emergency room visits	1,945	1,167
Bronchitis in children	4,847	1,697
Asthma	18,863	11,318
Respiratory symptom days	1,512,689	75,634
Respiratory hospital admissions	99	415
Total		209,051

Source: WB, 1997

A study done by NESS for Nepal Health Research Council using the same dose-response model used by WB study, 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).

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.

In the survey, 42 percent of the children said that they had been sick during work. The health examination found that 84 percent had eye problem, 82 percent had chest pain, 58 percent had headaches and nausea, 53 percent suffered from fever, 66 percent suffered from cough, cold and problems with the upper respiratory tract, and 45 percent experienced difficulty in breathing. Similarly, 29 percent had

pneumonia, tuberculosis, bronchitis and chest problems, 18 percent had anaemia, 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 PM_{10}, 1,255 g of NO_X 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 percent of the children are below 14 years of age, which makes them more vulnerable to air pollution (CWIN, 1997).

Various studies have also shown the adverse health impacts of air pollution on vulnerable groups such as children living in polluted areas, traffic police and road side vendors. A health check-up conducted by CEN and Pro-Public showed that young children studying at a school near brick kilns in Tikathali VDC of Lalitpur District suffered more from respiratory problems than students at a similar school but with no brick kilns in its vicinity.

ii) Hospital Records

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

COPD, which is an irreversible damage of the lungs, is one of the main health effects of air pollution. COPD is 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 percentage of total medical patients has increased significantly in the last few years. In Patan Hospital, the number of COPD patients has doubled in the past few years.

Hospital records also indicate that the number of COPD patients is highest in the dry winter months, which is the time 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.

The number of COPD in-patients in Kathmandu Valley's hospitals has increased over the past years. 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 double within a period of six year from 407 patients in

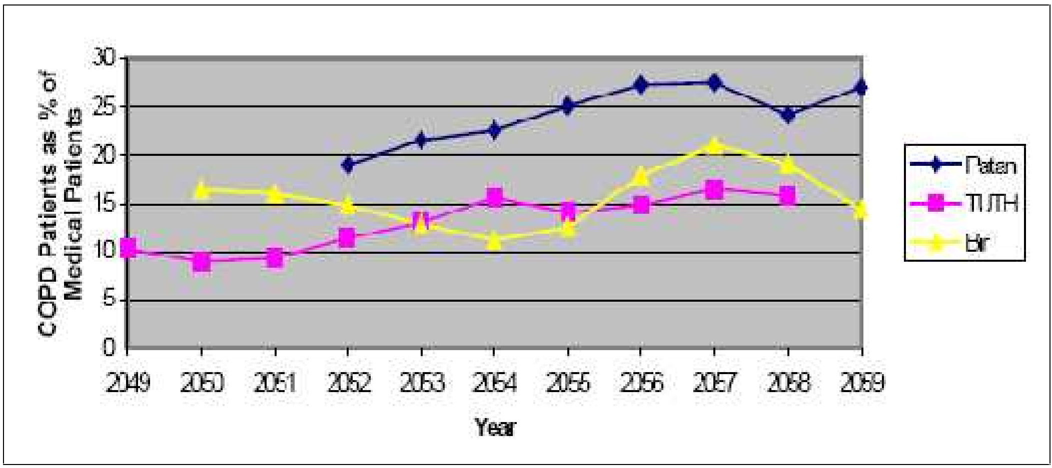
2053 to 849 patients in 205. In TUTH, as well, the number of patients increased more than double from 225 in the year 2049 to 568 in the year 2058. The increase was least prominent in the case of Bir Hospital where the number of COPD patients went up from 322 in 2049 to 416 in 2059, an increase of 29 percent.

Figure 6.1: Number of COPD Patients Discharged from Major Hospitals in Kathmandu over Past Years

The records also indicated that COPD patients as 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 from BS 2049 to BS 2059 is shown in Figure 6.2. 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 6.2: COPD Patients as percentage of Total Medical Patients



Overall 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 6.3.

Figure 6.3: Number of COPD Patients Admitted to Major Hospitals (BS 2059)

iii) Dose – response Function

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 PM_{10}, below which there would be no impacts. WHO has now said that there is no safe limit for PM_{10} and even at low levels particles can damage health. Furthermore, most recent studies indicate that $PM_{2.5}$ is a better predictor of health effects than PM_{10}.

Dose-response functions can however be used to estimate the change in health effects caused by a change in PM_{10} concentrations. Using the average annual PM_{10} and $PM_{2.5}$ values, we can draw the following conclusions:

- ⇨ If we were to reduce the $PM_{2.5}$ level in Kathmandu Valley by half (by 47.4µg/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 $PM_{2.5}$ level in KMC 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 $PM_{2.5}$ 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 PM_{10}. In many other countries (including India and the US) the standard for annual average PM_{10} 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 PM_{10} concentration in Kathmandu to 50 µg/m^3 can be estimated using dose-response functions developed by Ostro (1996).

Table 6.3: Estimated Health benefit of reducing Kathmandu valley's Annual Average PM_{10} to 50µg/m3

Health Effect	Cases Avoided
Respiratory hospital admission	2117
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	4304

Source: CEN Fact Sheet

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 PM_{10} levels to international standards are enormous. The results are also much higher than the estimated health effects calculated by the URBAIR study using PM_{10} levels in 1990. The difference is mainly due to the increase in population and pollution levels.

6.5 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 a difficult and controversial issue because of the many uncertainties and assumptions involved in this process. 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)

The first attempt to calculate the value of health effects of Kathmandu's air pollution was done by a WB study (Shah and Nagpal, 1997). The study estimated the health effects of PM_{10} in Kathmandu and also attempted to calculate the value of these impacts. The study estimated that the total cost of the health impacts of PM_{10} in Kathmandu in 1990 to be approximately NRs. 210 million.

Table 6.4: Valuation of Health Impacts in Kathmandu

Types of Health Impact	No. of Cases	Value (NRs.)	
		Specific	Total (× 10^3)
Excess Mortality	84	340000	28644
Chronic Bronchitis	506	83000	41988
Restricted Activity Days	475298	56	26617
Emergency Room Visit	1945	600	1167
Bronchitis in Children	4847	350	1697
Asthma Attacks	18863	600	11318
Respiratory Symptom Days	1512689	50	75634
Respiratory Hospital Admissions	99	4160	415
Total			209051

Source: Shah and Nagpal, 1997

Since 1990, the number of vehicles in Kathmandu has increased by four folds thus increasing the total pollution load in the valley. ESPS/MOPE estimates that the PM_{10} emission from vehicles has increased by almost four folds and the total PM_{10} emission load in Kathmandu has almost doubled. The number of people exposed to Kathmandu has also increased significantly, over the past years. Population census of 2001 shows that 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 NRs. 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 low unit rates used during the calculations.

The WB 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 NRs. 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 NRs. 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 NRs. 570, whereas the increase in damage due to domestic sources and brick kilns was only Rs 270 and NRs. 250 respectively.

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

Hospital Cost:

A person with COPD admitted to the general ward of a public hospital in Kathmandu will have to spend approximately NRs. 1200 per day on room charge, medication and food. Similarly, an asthma patient in the general ward will have to spend about NRs. 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 NRs. 9,921 and the average indirect cost was estimated to be NRs. 4,400. The total cost per hospital admission is therefore estimated to be NRs. 14,321. Results of dose-response calculations indicate that reducing Kathmandu's PM_{10} level to international standards can avoid 2117 cases of hospital admissions. Therefore, the avoided cost of hospital treatment by reducing Kathmandu's PM_{10} levels to international standards is about NRs. 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 WB study, the cost of hospital admission was only 0.2 percent of the total cost of PM_{10} pollution. The study estimated the cost of respiratory hospital admission to be only NRs. 415,000 compared to the total cost of NRs. 210 million. Therefore, the present estimate of NRs. 30 million for avoided cost of hospital admission indicates that the total benefit of reducing Kathmandu's PM_{10} levels to international standards will be much higher.

CHAPTER VII

DATA TABULATION, ANALYSIS AND INTERPRETATION

To generate awareness among inhabitants of Kathmandu valley towards air pollution is the most essential thing to do in present time. The primary data generated for the purpose of study is based on questionnaire survey, field visit and observation. For this purpose, 6 sites were selected namely, Putalisadak, Patan Hospital, Thamel, Bhaktapur, TU Kirtipur and Matsyagaon. These are the same places where MOPE has established air quality monitoring stations, one in each. Altogether 60 questionnaires were filled up with the pedestrians found there, 10 in each place and the data is tabulated, analyzed and interpreted as follows:

7.1 About the Respondents

The respondents selected for the purpose of the study include every age group, each gender and every educational status. However, the respondents of age group 20-30 are maximum, which may be due to the reason that they may have completed their study and searching for job because they are the most active age group. This is also that age group which migrates in urban centers in search of employment, better opportunities and further study. Kathmandu being the administrative as well as financial capital of Nepal, urbanization in Kathmandu is due to the economic activity and the career opportunities.

Table 7.1: Age Composition of Respondents

(No. of Respondents= 60)

Age Group	No. of Respondents	Percentage (%)
<20	15	25.00
20-30	28	46.67
30-40	10	16.67
>40	7	11.67
Total	60	100.00

Source: Field Survey, 2006

Table 7.2: Gender Composition of Respondents

(No. of Respondents= 60)

Sex	No. of Respondents	Percentage (%)
Male	37	61.67
Female	23	38.33
Total	60	100.00

Source: Field Survey, 2006

Table 7.3: Educational Level of Respondents

(No. of Respondents= 60)

Education	No. of Respondents	Percentage (%)
< SLC	11	18.33
SLC	13	21.67
Intermediate(any faculty)	14	23.33
Bachelor (any faculty)	17	28.33
Masters (any faculty)	5	8.33
Total	60	100.00

Source: Field Survey, 2006

7.2 Migration: An Unsolved Problem

Migration is an important component of population analysis. Migration is defined as the movement of people from one place to another. Shryock and Siegal (1975) defined Migration as "a form of geographic or spatial mobility involving a change of usual residence between clearly defined units. It should be noted that in present definition temporary movements are not included. Migration has a profound effect on structure, composition and growth of population in a country therefore it is an important area of population studies.

The trend of internal migration has been increasing in Nepal. In 1971, 445,128 people migrated within the country, which accounted for 3.9 percent of the total population. It increased to 929,585 in 1981, comprising 6.2 percent of total population. Hence, in the decade the volume of migration increased by 108.8 percent. In 1991, volume of internal migration increased by 32.1 percent as compared to a decade back, to make the number of migrants to 1,228,356, which is 6.6 percent of total population.
(www.mope.gov.np/population/demographic.php)

Table 7.4: Migration Status of the Respondents

(No. of Respondents= 60)

Residence	No. of Respondents	Percentage (%)
Kathmandu	32	53.33
Outside Kathmandu	28	46.67
Total	60	100.00

Source: Field Survey, 2006

Table 7.4 shows that Kathmandu valley is already overpopulated due to migration showing 47 percent respondent are migrated from other places within the country. The major reason behind such migration is Maoist insurgency, higher education, better facilities, employment opportunities, centralization of administrative, political and other all sectors etc.

It is estimated that the valley alone accommodates nearly 1.3 million people out of 20.2 million people living in Nepal (CBS, 1996).The population of Kathmandu valley, which grows at an average annual rate of 4.6 percent in 1970's, went up to 6 percent growth rate in 1980's. The population of Kathmandu is now estimated to be more than one million, making one of the most populous cities in South Asia region. The migrant population is from mountain, hill and terai in search of jobs, education and other opportunities. (Shrestha, 2001)

Table 7.5: Years Spent in Kathmandu

(No. of Respondents= 28)

Years	No. of Respondents	Percentage (%)
<1 year	2	7.14
1-5 years	16	57.14
5-10 years	6	21.43
>10 years	4	14.29
Total	28	100.00

Source: Field Survey, 2006

Table 7.5 shows that migration in Kathmandu Valley is the recent phenomenon. It is around 5 or more years that people began to heavily migrate in Kathmandu valley.

7.3 Perception of Respondents Towards Kathmandu Valley

Table 7.6: Changes Seen in Kathmandu

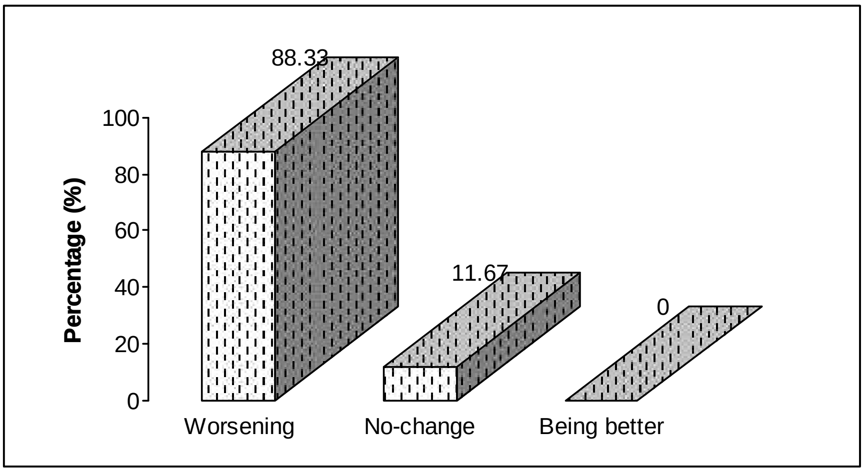
(No. of Respondents= 60)

Changes	No. of Respondents	Percentage (%)
Being better	0	0.00
Worsening	53	88.33
No-change	7	11.67
Total	60	100.00

Source: Field Survey, 2006

Table 7.6 shows the perception of respondents towards changes seen in Kathmandu valley, which indicates that 88 percent of respondents feel that Kathmandu valley is worsening day by day. Worsening in the sense, there is heavy population pressure; pollution in terms of air, water, noise, land; poorly managed infrastructures, no drinking water facilities, increasing unemployment rate, political instability and many more.

Figure 7.1: Changes Seen in Kathmandu



Based on: Table 7.6

Table 7.7: Feeling About the Environment of the Kathmandu Valley

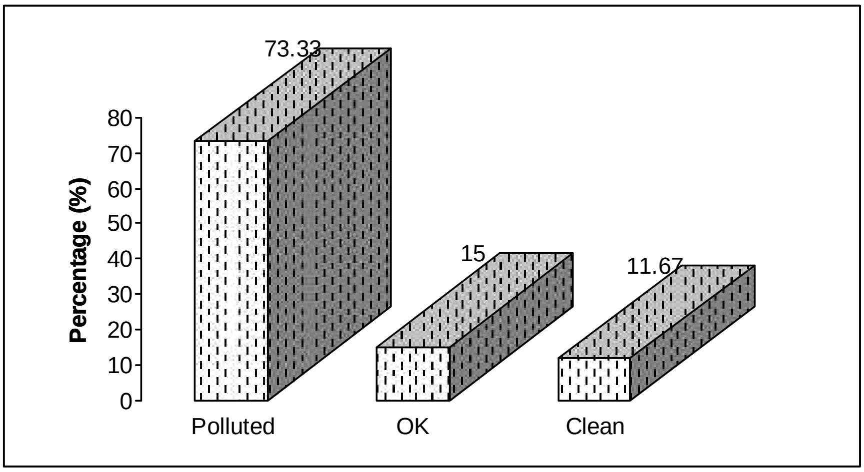
(No. of Respondents= 60)

Feeling	No. of Respondents	Percentage (%)
Polluted	44	73.33
OK	9	15.00
Clean	7	11.67
Total	60	100.00

Source: Field Survey, 2006

Table 7.7 shows the perception of respondents towards environment in Kathmandu valley, which indicates that 73 percent of respondents feel that Kathmandu is a polluted city. One can feel the pollution even when walking a street of Kathmandu valley. The unmanaged sewage in roads, drainage pipes mixed in rivers and dust and fumes from vehicular emission etc are enough to reflect the image of Kathmandu. About 27 percent respondents felt Kathmandu valley to be clean and Ok. This is due to the sites being selected. Respondents interviewed at Matsyagaon and TU Kirtipur and even some people of Bhaktapur felt that the environment is Ok. But they also agree that the environment is becoming worsening day by day.

Figure 7.2: Feeling About the Environment of the Kathmandu Valley



Based on: Table 7.7

It is very interesting to show that not even a single person in Kathmandu valley agrees that there has been planned urbanization. Everyone feel that Kathmandu is unplanned and too congested.

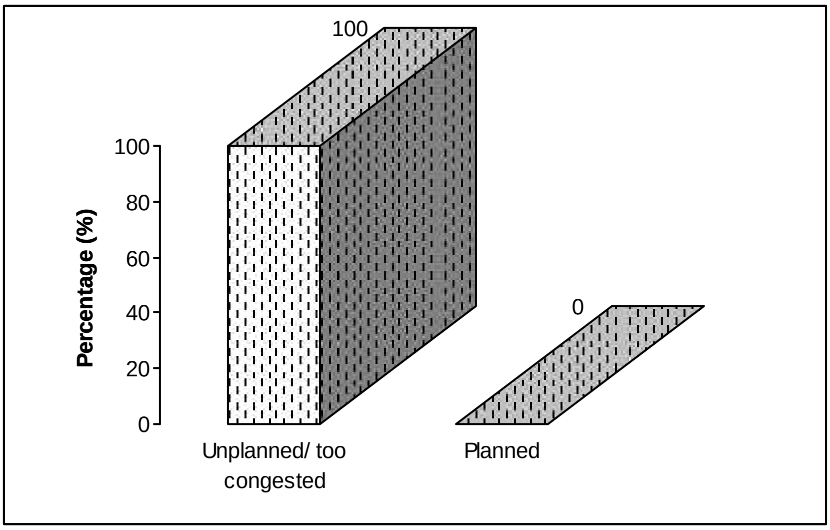
Table 7.8: Feeling About the Urbanization of the Kathmandu Valley

(No. of Respondents= 60)

Feeling	No. of Respondents	Percentage (%)
Planned	0	0.00
Unplanned/ too congested	60	100.00
Total	60	100.00

Source: Field Survey, 2006

Figure 7.3: Feeling About the Urbanization of the Kathmandu Valley



Based on: Table 7.8

7.4 Air Pollution Causes and Consequences

Table 7.9 shows the cause of air pollution in Kathmandu Valley for respondents, which indicates that the vehicular emission is prime factor involved in it. Secondly, industrialization and at last unplanned urbanization comes, according to respondents.

Table 7.9: Cause of Air Pollution in Kathmandu Valley for Respondents

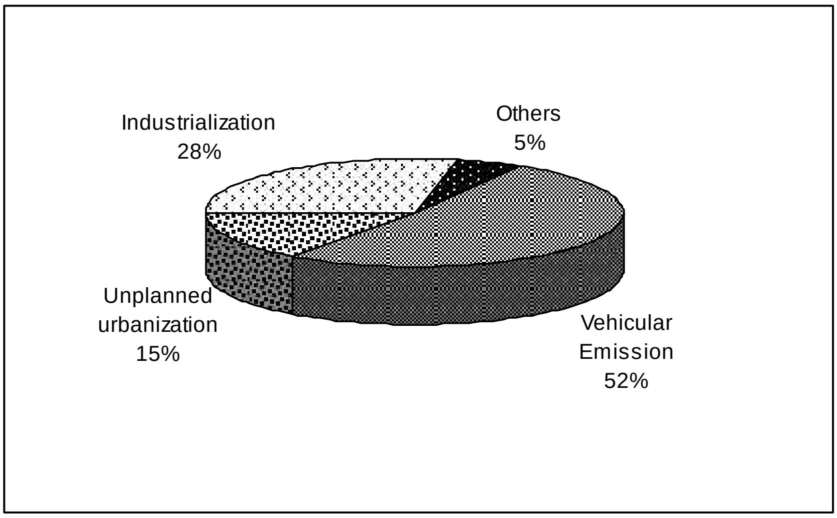
(No. of Respondents= 60)

Reason	No. of Respondents	Percentage (%)
Vehicular Emission	31	51.67
Unplanned urbanization	9	15.00
Industrialization	17	28.33
Others	3	5.00
Total	60	100.00

Source: Field Survey, 2006

Note: Others include unawareness, no legislation and government steps, topography of Kathmandu valley etc.

Figure 7.4: Cause of Air Pollution in Kathmandu Valley for Respondents



Based on: Table 7.9

Table 7.10 shows the most polluted area of Kathmandu valley felt by respondents. 73 percent of the respondents voted Putalisadak to be the most polluted followed by Patan Hospital, Bhaktapur and Thamel. Putalisadak and Patan Hospital are the urban traffic area. This result can be verified by the PM_{10} data available from MOPE too.

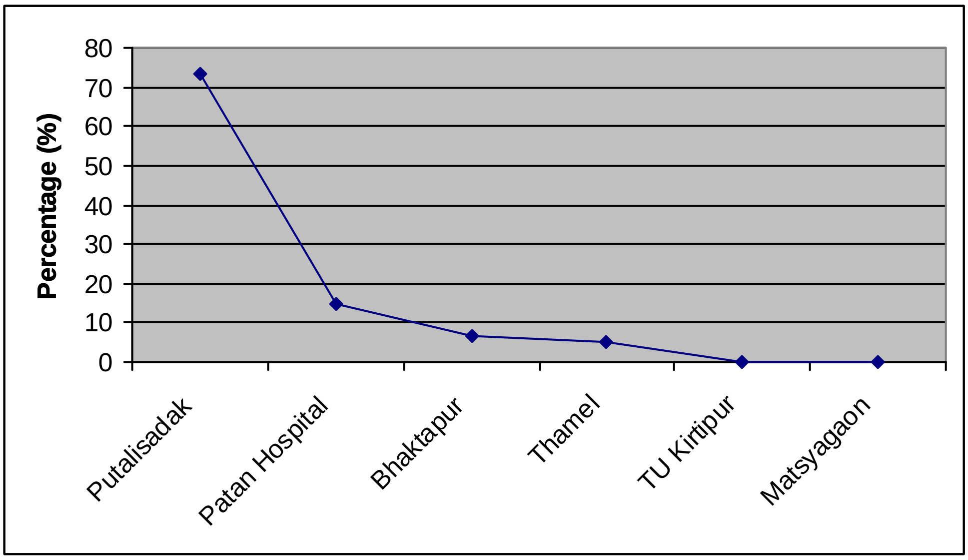
Table 7.10: Most Polluted Area of Kathmandu Valley for Respondents

(No. of Respondents= 60)

Area	No. of Respondents	Percentage (%)
Putalisadak	44	73.33
Patan Hospital	9	15.00
Thamel	3	5.00
Bhaktapur	4	6.67
TU Kirtipur	0	0.00
Matsyagaon	0	0.00
Total	60	100.00

Source: Field Survey, 2006

Figure 7.5: Most Polluted Area of Kathmandu Valley for Respondents



Based on: Table 7.10

In the polluted roads and streets of Kathmandu valley, one can often see people wearing mask or spectacles while walking or biking. Due to security reasons, traffic police has banned on the use of visors on helmets which forced people to wear specs. Without specs, no one can imagine driving a bike on the streets of Kathmandu. In comparison to use of specs, it is rather less, that people use mask. Mostly the respondents don't use mask due to hesitation. From Table 7.11, it can be seen that 85 percent respondents use mask or specs while traveling.

Table 7.11: Respondents Visiting Pattern

(No. of Respondents= 60)

Wearing 'Mask or Spec'	No. of Respondents	Percentage (%)
Yes	18	30.00
No	9	15.00
Sometimes	33	55.00
Total	60	100.00

Source: Field Survey, 2006

Table 7.12 shows that around 63 percent respondents do have one or more vehicles in their home. Mostly used vehicle by respondent is motorcycle, so does Kathmandu have. Kathmandu is also called the city of motorcycles.

Table 7.12: No. of Vehicles, Respondents Do Have

(No. of Respondents= 60)

No. of Vehicles	No. of Respondents	Percentage (%)
0	22	36.67
1	26	43.33
2 or more	12	20.00
Total	60	100.00

Source: Field Survey, 2006

Table 7.13 shows the smoking pattern of respondents, which indicates around 63 percent people are smokers. This means that 63 percent of population is potential to be affected by indoor air pollution. Smoking in non-ventilated room increases the risk of different diseases including lung cancer because cigarette smoking is the prominent source of CO.

Table 7.13: Smoking Pattern of Respondents

(No. of Respondents= 60)

Smoke	No. of Respondents	Percentage (%)
Yes	17	28.33
No	22	36.67
Occasionally	21	35.00
Total	60	100.00

Source: Field Survey, 2006

When people think about air pollution, they usually think about smog, acid rain, CFC's, and other forms of outdoor air pollution. But do we know that air pollution also can exist inside homes and other buildings? It can, and every year, the health of many people is affected by chemical substances present in the air within buildings. Smoking is one of them.

According to the EPA and public health officials, cigarette smoke, formaldehyde, asbestos and radioactive Radon-222 gases are the four most dangerous indoor air pollutants. The health risks from exposure to such chemicals are magnified because people spend 70-98 percent of their time indoors. Danish and EPA studies have linked pollutants found in buildings to dizziness, headaches, coughing, sneezing, nausea, burning eyes, chronic fatigue and flu-like symptoms – known as the sick building syndrome.

Due to air pollution, people are suffered from different health related problems. Generally, children, elderly and people with lung and heart diseases are more vulnerable to the health effects of air pollution. 20 to 30 percent of all respiratory diseases appear to be caused by air pollution. (WHO, 2000)

Table 7.14: Health Problems of Respondents

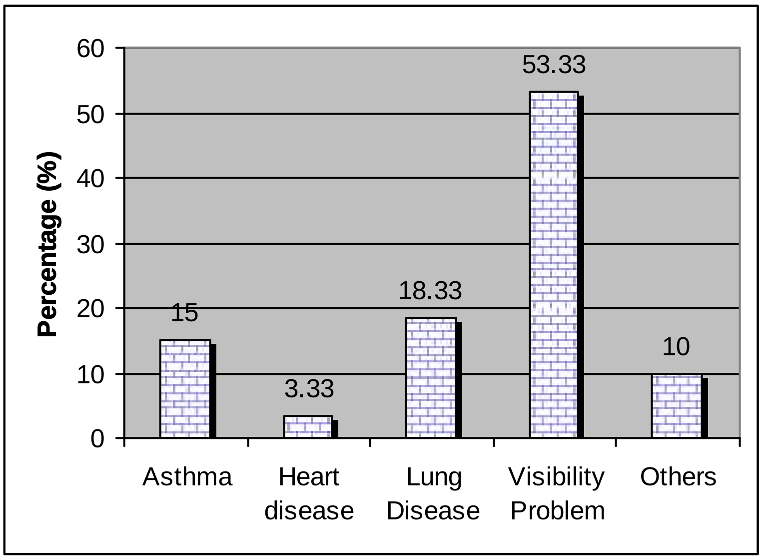
(No. of Respondents= 60)

Health problems	No. of Respondents	Percentage (%)
Asthma	9	15.00
Heart disease	2	3.33
Lung Disease	11	18.33
Visibility Problem	32	53.33
Others	6	10.00
Total	60	100.00

Source: Field Survey, 2006

Table 7.14 shows the health problems faced by respondents due to Kathmandu's air pollution. 53 percent of the respondents are suffered by visibility problem which is due to intolerable concentration of TSP in ambient air of Kathmandu. The lung disease, asthma, heart diseases and many other health problems are faced by inhabitants of Kathmandu due to air pollution.

Figure 7.6: Health Problems of Respondents due to Kathmandu's Air Pollution



Based on: Table 7.14

7.5 Air Quality Monitoring Stations

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 7.15.

Table 7.15: Locations of Monitoring Stations

Location	Classification
Putalisadak	Urban traffic
Patan Hospital	Urban traffic
Thamel	Urban traffic/residential
Bhaktapur	Urban background
TU, Kirtipur	Urban background
Matsyagaon	Valley Background

Source: www.mope.gov.np

When the system is fully operational, each of the monitoring stations will be equipped to monitor PM_{10}, $PM_{2.5}$, TSP, CO, NO_2, SO_2 and Benzene. Right now, however, only PM_{10} 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 analyzed 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 color codes to describe the air quality. Proposed descriptors for air quality in Kathmandu are present in Table 7.16.

Table 7.16: Proposed Air Pollution (PM_{10}) Descriptors for Kathmandu

Descriptor	Color	PM_{10} ($\mu g/m^3$)
Good	Green	<60
Moderate	Yellow	61-120
Unhealthy	Orange	121-350
Very Unhealthy	Red	351-425
Hazardous	Purple	>425

Source: www.mope.gov.np

7.6 Status of Ambient Air Quality

7.6.1 PM_{10} Data

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.

Table 7.17 shows the trend of yearly average of PM_{10} monitored by each monitoring stations of Kathmandu valley. It shows that year 2002 was very much polluted year. In that year, air quality of Putalisadak, Bhaktapur, Patan Hospital and Thamel area was unhealthy whereas air quality was good for Matsyagaon and moderate for Kirtipur. After that, the air quality was becoming good till 2005 but it became worst in 2006 till date. The very reason is the 19 day long strike in the month of April. The firing of tear gas, burning of tyres and Flame rally (Mashal Julus) and all those used in strike polluted the air of Kathmandu to maximum, noted that the ambient air quality of Putalisadak was very unhealthy.

Table 7.17: Yearly Trend of PM_{10} in Each Air Quality Monitoring Stations

Location	Yearly Average (μg/m³)				
	2002	2003	2004	2005	2006
Putalisadak	293	208	203	202	345*
Matsyagaon	N/A (50.1)	50	56	44	72*
TU Kirtipur	70	80	78	65	104*
Bhaktapur	140	131	111	96	181*
Patan Hospital	248	180	190	202	269*
Thamel	178	149	139	124	179*

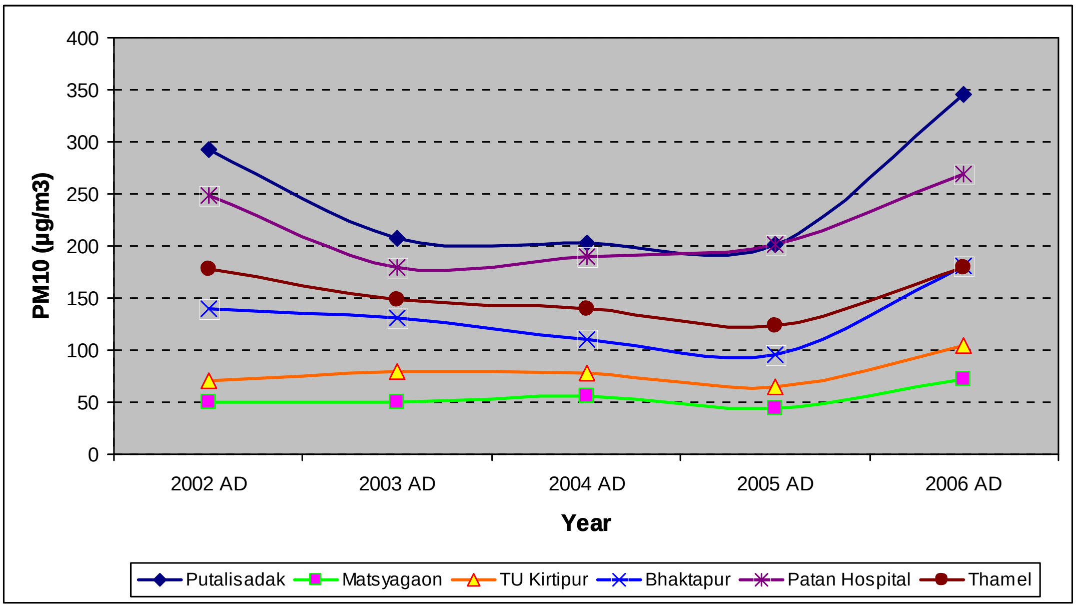
Source: Compiled from www.mope.gov.np

Note:

* means that the average data is calculated by researcher using available data only

The data on parenthesis is the data calculated by researcher using monthly average and yearly average for previous years

Figure 7.7: Yearly Trend of PM_{10} in Each Air Quality Monitoring Stations



Based on: Table 7.17

For the purpose of showing the status of ambient air quality of Kathmandu valley, the researcher collected the one-year data from May, 2005 to April 2006. The data is listed in Table 7.18 which shows monthly average, yearly average and Kathmandu average.

Table 7.18: Air Quality Data, May 2005 – April 2006

Month	Putalisadak	Matsyagaon	TU Kirtipur	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
May, 2005	238	54	70	109	213	120	134
June, 2005	184	52	57	78	211	103	114.17
July, 2005	118	15	18	30	177	52	68.33
Aug, 2005	118	19	21	32	113	56	59.83
Sep, 2005	151	21	25	47	144	70	76.33
Oct, 2005	126	22	22	51	114	75	68.33
Nov, 2005	224	36	46	96	168	123	115.5
Dec, 2005	330	47	78	152	224	182	168.83
Jan, 2006	330	70	118	171	280	221	198.33
Feb, 2006	N/A (303)	N/A (61)	N/A (100)	N/A (180)	N/A (253)	N/A (187)	N/A (181)
Mar, 2006	362	74	101	209	256	178	196.67
Apr, 2006	478	111	145	N/A (179)	303	121	193*
Yearly Average	241.73*	47.36*	63.73*	97.5*	200.27*	118.27*	128.14*

Source: Compiled from www.mope.gov.np

Note:

The unit for all the data is µg/m3

Yearly Average: Yearly average value for each monitoring station

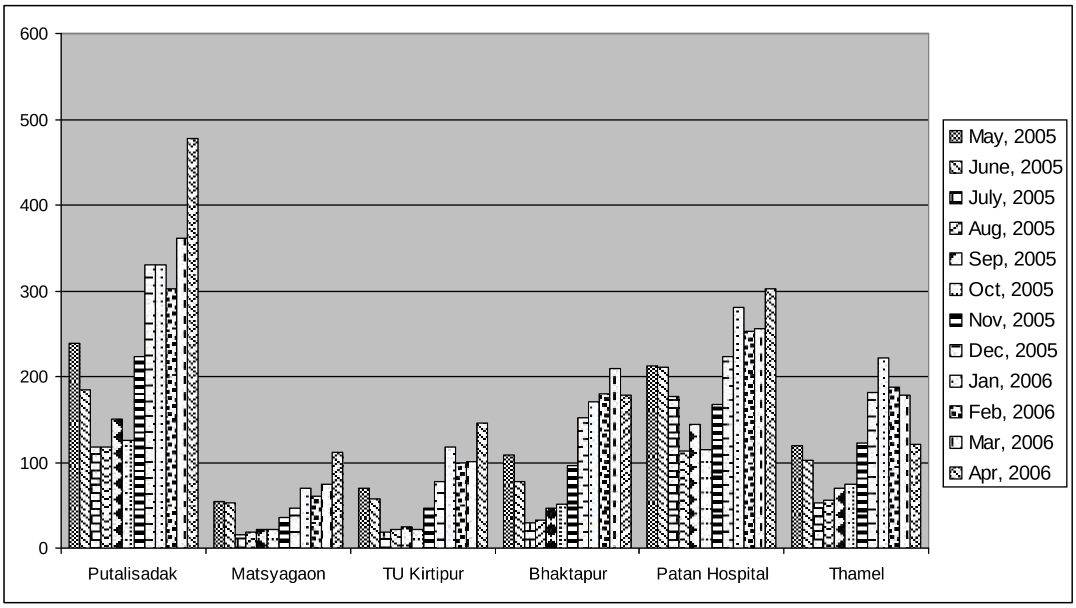
N/A: Not available

Ktm. Avg.: Monthly Average PM_{10} in six monitoring stations in Kathmandu valley.

* means that the average data is calculated by researcher using available data only.

The data on parenthesis is the data calculated by researcher using monthly average and yearly average for previous years.

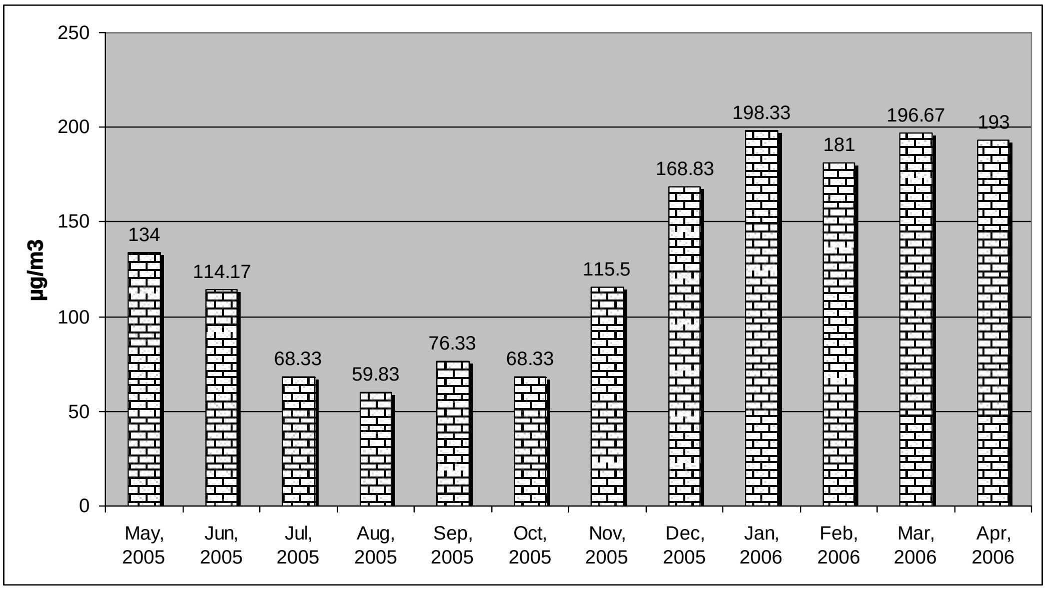
Figure 7.8: Average Monthly PM_{10} Concentrations (µg/m3) from May, 2005 – Apr, 2006



Based on: Table 7.18

Figure 7.8 shows the average monthly PM_{10} concentrations (μg/m^3) from May, 2005 to April, 2006. The Figure reflects the situation that Putalisadak and Patan Hospital area are much polluted. Almost every month the average PM_{10} level exceeds NAAQS. During dry seasons, PM_{10} level at Thamel and Bhaktapur area also exceeds NAAQS. Matsyagaon and TU area are fairly unpolluted by total suspended particles.

Figure 7.9: PM_{10} in Kathmandu Valley (Monthly Average of the Six Stations)



Based on: Table 7.18

Figure 7.9 shows the average PM_{10} in Kathmandu valley calculated by the average of six stations in particular month. This shows that during winter, the average PM_{10} level of Kathmandu becomes the highest. This is the driest season and makes residents more vulnerable to the effects of air pollution. Highest level of pollution is measured in January and lowest in August.

Table 7.19: Percentage of Unhealthy Days in Kathmandu During Dry Seasons

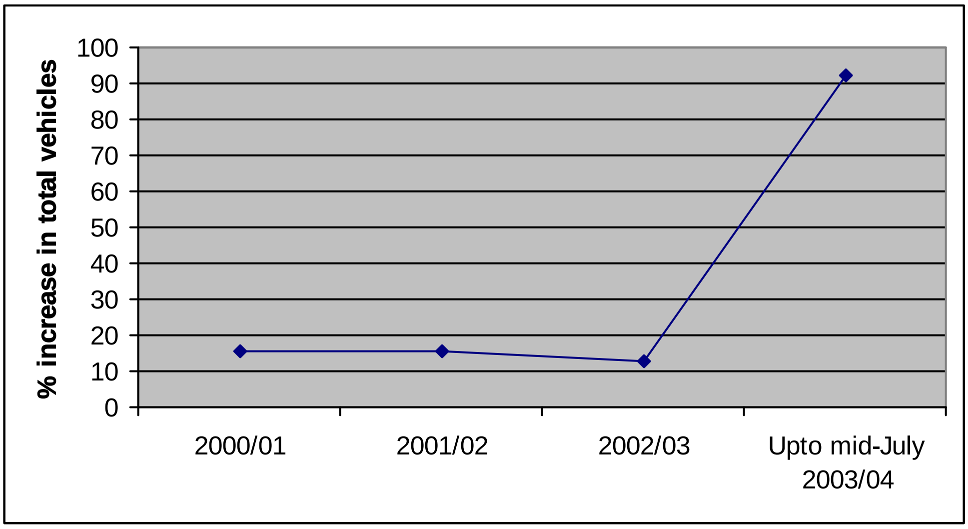
Descriptor	PM_{10} (μg/m3)	During Dry seasons (Nov, 2005 to May, 2006)					
		Putalisadak	Matsyagaon	TU Kirtipur	Bhaktapur	Patan Hospital	Thamel
Good	<60	-	42.86	14.29	-	-	-
Moderate	61-120	-	57.14	71.43	28.57	-	14.29
Unhealthy	121-350	100.00	-	14.29	71.43	100	85.71
Very Unhealthy	351-425	28.57	-	-	-	-	-
Hazardous	>425	-	-	-	-	-	-

Based on: Researcher's Calculations

7.6.2 Vehicular Emission

As stated above in previous chapters, vehicular emission is the number one source of air pollution for Kathmandu valley.

Figure 7.10: Percentage Increase in Total Vehicles (2000/01 to mid – July 2003/04)

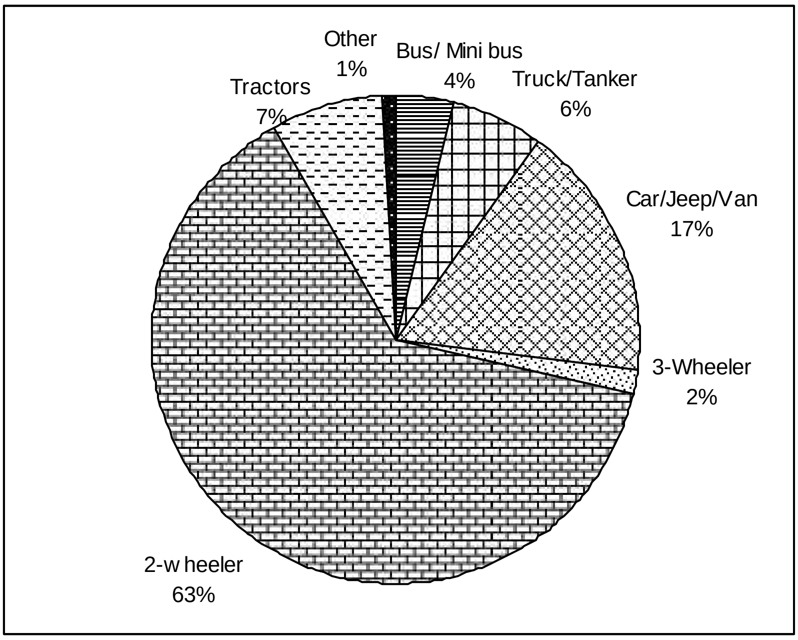


Based on: Table 4.2

Figure 7.10 shows the percentage increase in total vehicles from 2000/01 to mid-July 2003/04. The percentage increase was 15.6 in 2000/01 which increased to 15.7 in the following year but decreased to 12.8 in 2002/03. Thereafter, it increased drastically to 91.95 percent increase in total vehicles just upto mid-July 2003/04. This is the major reason behind air pollution in Kathmandu valley that the city accommodates such huge number of vehicles than its carrying capacity.

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. In 2003, there were 156,410 motorcycles registered in Bagmati zone, which increased to 270,949 just upto mid-July 2003/04. This is 73.23 percent increase over past year. The number of motorcycles had been increasing at the rate of 20.4 percent per year in 2001/02 whereas it was just 15.98 percent for 2002/03.

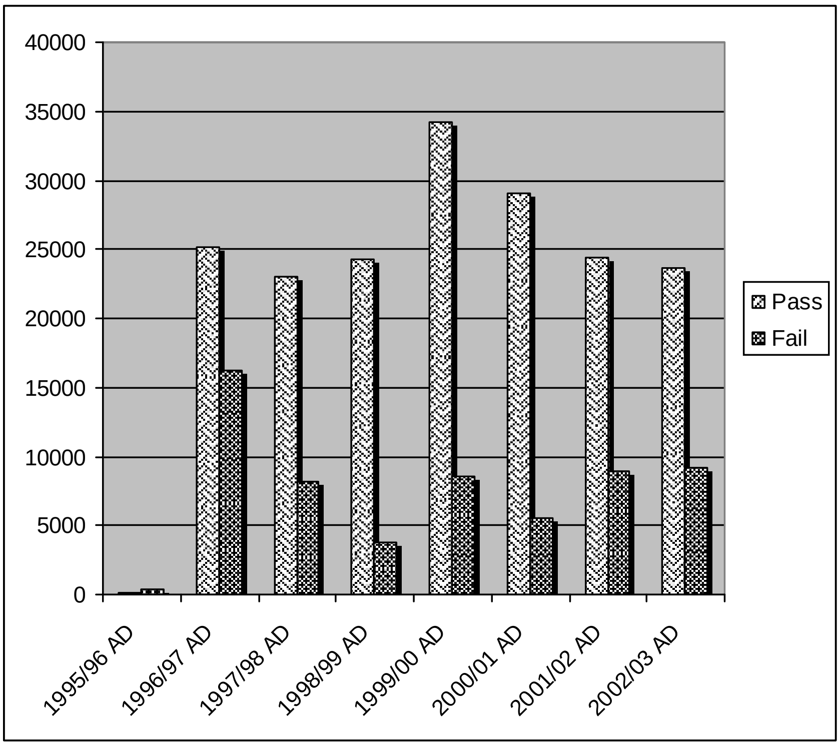
Figure 7.11: Types of Vehicles Registered in Bagmati Zone, as of mid-July 2003/04



Based on: Table 4.2

Figure 7.11 shows that of the total vehicles registered in Bagmati zone upto mid-July 2003/04, 63 percent are two-wheelers (motorcycles).

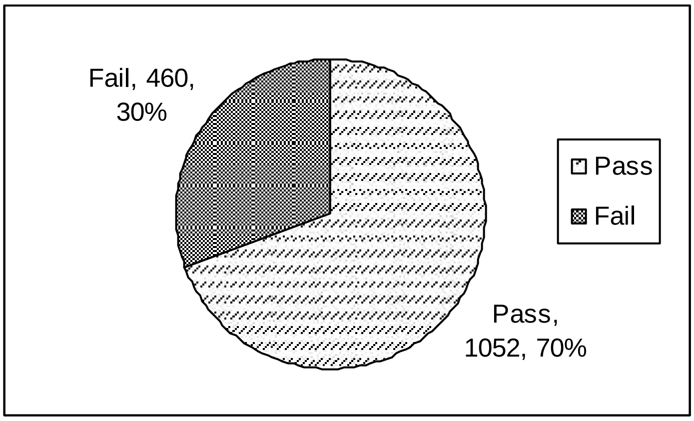
Figure 7.12: Emission Test Results of In-Use Vehicles in Kathmandu (1995/96-2002/03)



Based on: Table 5.7

Figure 7.12 shows the emission test results from the past eight years (from 1995/96 to 2002/03). It indicates that approximately 25 percent of the vehicles fail the tests (Table 5.7). This means that 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.

Figure 7.13: Results of Emission Tests Conducted in May 2006



Based on: Data Obtained from VTP Office

Figure 7.13 shows the emission test conducted by VTP in the month of May, 2006. Altogether 1512 vehicles were tested of which 30 percent failed to meet the standards.

7.6.3 COPD Records

The health impacts of Kathmandu's pollution can be obtained by analyzing the records of major hospitals in Kathmandu.

Table 7.20 shows the number of COPD patients of the major hospitals namely PH, BH and TUTH. It is seen that there is increasing trend of number of COPD patients in those hospitals.

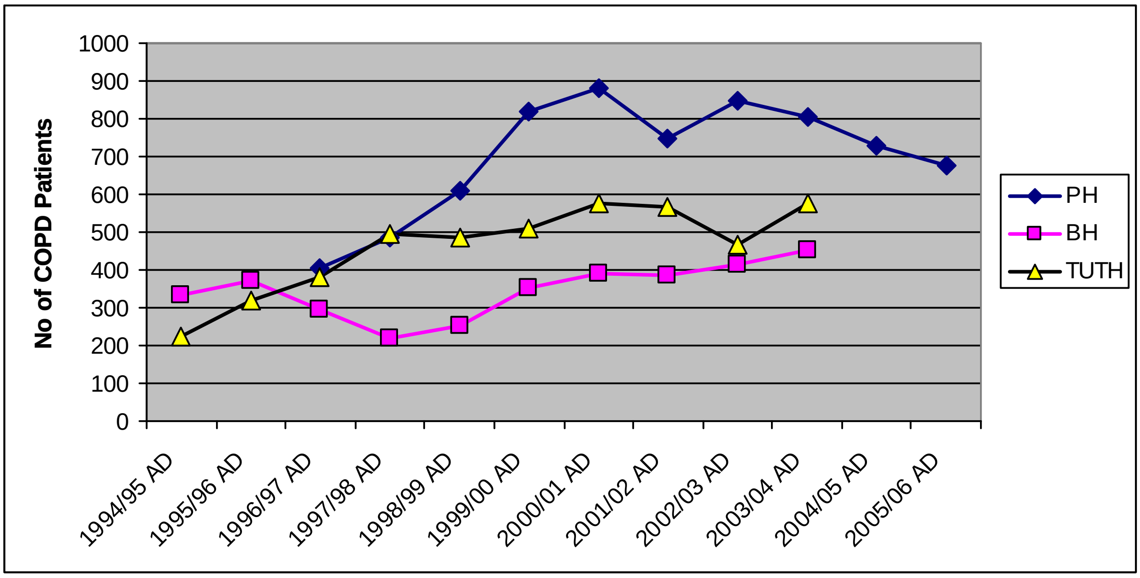
Table 7.20: Records of COPD Patients in Major Hospitals of Kathmandu Valley 1994/95 – 2005/06

Year	COPD Patients		
	PH	BH	TUTH
1994/95	-	335	225
1995/96	-	370	320
1996/97	407	294	381
1997/98	486	221	496
1998/99	611	251	487
1999/00	817	351	510
2000/01	882	391	576
2001/02	749	388	568
2002/03	849	416	467
2003/04	803	454	575
2004/05	730	-	-
2005/06	678	-	-

Source: Medcial Record Section of the respective hospitals

Note: PH means Patan Hospital, BH means Bir Hospital and TUTH means Tribhuvan University Teaching Hospital

Figure 7.14: Yearly Trend of COPD Patients of the Major Hospitals in Kathmandu



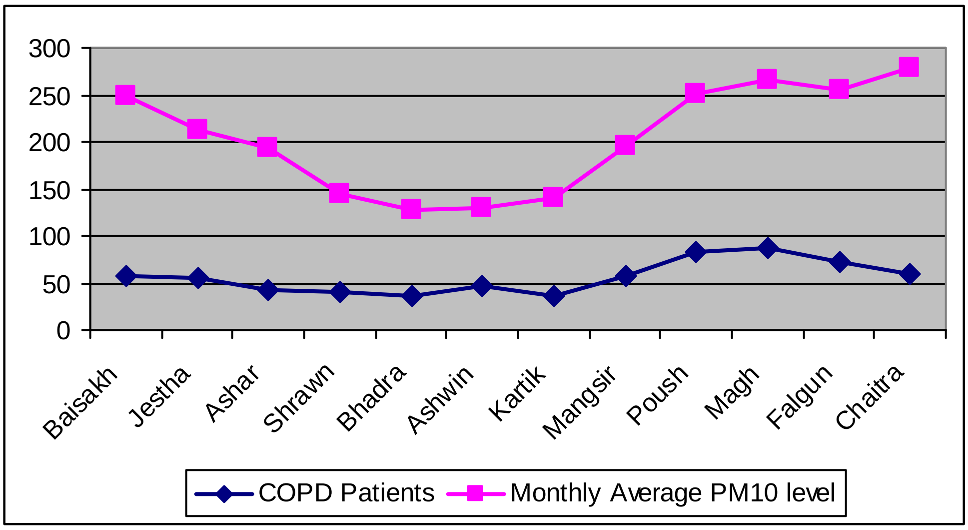
Based on: Table 7.20

Table 7.21 shows the monthly variation of COPD patients of Patan Hospital and PM_{10} level at Patan Hospital Air Quality Monitoring Station for the year BS2062. Figure 7.15 clearly indicates that monthly variation of COPD patients of Patan Hospital is directly proportional to the PM_{10} level at Patan Hospital Air Quality Monitoring Station i.e. with the increase in PM_{10} level; there is increase in the number of COPD patients visiting the hospital.

Table 7.21: Monthly Variation of COPD Patients (Patan Hospital) and PM_{10} Level at Patan Hospital Air Monitoring Station (2005/06)

Months (BS 2062)	COPD Patients	Monthly Average PM_{10} level
Baisakh (mid Apr – Mid May)	58	249.0
Jestha (mid May – Mid Jun)	56	212.0
Ashar (mid Jun – Mid Jul)	43	194.0
Shrawn (mid Jul – Mid Aug)	40	145.0
Bhadra (mid Aug – Mid Sep)	36	128.5
Ashwin (mid Sep – Mid Oct)	46	129.0
Kartik (mid Oct – Mid Nov)	37	141.0
Mangsir (mid Nov – Mid Dec)	58	196.0
Poush (mid Dec – Mid Jan)	84	252.0
Magh (mid Jan – Mid Feb)	87	266.5
Falgun (mid Feb – Mid Mar)	73	254.5
Chaitra (mid Mar – Mid Apr)	60	279.5

Figure 7.15: Linkage between Monthly Variation of COPD Patients (Patan Hospital) and PM_{10} Level at Patan Hospital Air Monitoring Station (2005/06)



Based on: Table 7.21

Box 1: Case Study from www.virtualtourist.com

Researcher visited the website www.virtualtourist.com, which was designed for providing information regarding Nepal to the tourists. On the tab, 'Travel Guides/ Nepal: Pollution Reviews', researcher finds something what tourists say about Kathmandu's pollution. Here is what researcher saw:

Pollution: In Kathmandu, the air...
Written by klchong on August 25, 2002.
In Kathmandu, the air pollution was quite serious. The exhaust gases generated by vehicles and dust filled in the air. Each time we came back to hotel after walking around the city, we found that our skins and clothes were covered by a black layer. If you have any respiratory problem, please take extra care.

Pollution: City Pollution
Written by SumTingWong on September 13, 2003
City, i.e. Kathmandu/Patan, pollution levels are horrendous. The burning of pollutant fossil fuels fills the air with thick gray smog. Most of this is caused from old car exhausts. Some traffic police wear masks to avoid breathing in all the smog. City pollution isn't strictly air pollution. Littering is a huge problem in Nepal, as many places don't even have trashcans. Pollution in Nepal, as in every nation, is sickening. Try not to add to the pollution. Take electric taxis and do not to litter.

Pollution: Chaotic traffic on the roads
Written by victorwkf on September 14, 2003.
Traffic on the roads is often chaotic in Nepal. To make matters worse, there are also animals such as cows walking on the road, plus there are many pot-holes. Therefore driving in Nepal can be an adventure in itself!

Pollution: air pollution
Written by tenshi25 on February 7, 2005.
Air pollution in Kathmandu is pretty bad, I felt like as if I was standing on the top of the factory chimney facing down. Don't forget to pack some masks, you will need it.

CHAPTER VIII

SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1 Summary

i) Status of Ambient Air Quality in Kathmandu Valley

Rapid urbanization, industrialization, poor maintenance of road, poorly maintained vehicles and public unawareness is responsible for deteriorating ambient air quality in Kathmandu valley. The main emission sources of air pollutants are:

- ⇨ smoking vehicles of all types
- ⇨ re-suspension of street dust and litter
- ⇨ black smoke plumes from numerous bricks kilns
- ⇨ refuge burning

The major air pollutant is total suspended particles (TSP) and PM_{10}, due to the following main sources:

For TSP: re-suspension from roads, brick kilns, domestic fuel combustion, diesel vehicles, gasoline vehicles.

For PM_{10}: Diesel vehicles, gasoline vehicles, re-suspension, domestic fuel, brick kilns.

ii) Management of Urban Air Pollution in Kathmandu Valley

Government of Nepal has taken many noteworthy initiatives to curb growing air pollution problems caused by the transport sector. A number of programmes have been introduced through various national five-year development plans, new rules and regulations have been formulated and implemented, and new institutions have been set up and strengthened. Here are some of the policy responses to air quality change.

National Policy

National Five-year Plans

The share of the transport and communication sectors in the national GDP increased from 6.8 percent in 1996/97 to 7.7 percent in 2001/02, with an annual growth rate of 8.7 percent. With the increased importance of the transport sector, the government sought to address many problems arising out of the rapid growth of this sector. Road transportation was accorded high priority sector during the Seventh Five Year Plan (1985-1990). Particular emphasis was laid on planning the expansion of trolley bus services in and outside of the capital, although the idea never materialized. The National Conservation Strategy of 1988 prepared the establishment of air and water quality monitoring and evaluation systems.

Similarly, in the Eighth Plan (1992-1997), the emphasis was on developing alternative transport systems. A detailed engineering study for the expansion of trolley bus services continued to receive priority but it was not implemented during this period also. A total of 134km of roads were constructed to help reduce the pressure of urban congestion. Ten new trolley buses were introduced on the Kathmandu-Bhaktapur trolley bus service. A traffic pollution control system (pollution tests and use of pollution free vehicles) was initiated to minimize the adverse environmental impact due to the transportation system. The period also saw Environmental Impact Assessment (EIA) being made mandatory in the formulation and implementation of projects. EIA guidelines for the forestry and industrial sectors were formulated and implemented.

The Ninth Plan (1997-2002) accorded priority to the repair and maintenance, extension and management of roads. Similarly, it identified reduction of vehicle-induced pollution as a priority area. It stipulated the enforcement of mandatory and voluntary measures of pollution control by fixing emission and effluent standards. A twenty-year transport management Master Plan was formulated to strengthen the traffic and transport system. The possibilities of using appropriate types of vehicles along narrow hill roads were also explored. Special arrangements were to made for the prevention of road accidents and for ensuring road and transport safety. The Ninth Plan also committed to specifying air pollution standards. Suitable programmes were to be conducted for the use and development of pollution free vehicles and polluting vehicles were to be gradually discouraged. Special attention was to be paid to minimizing environmental damage in the design, construction, maintenance, repair and rehabilitation work related to the transport system, including the use of appropriate technology, and local human and material resources.

The Tenth Plan (2002-2007) has once again stressed the need for clean transport systems. It has envisioned the extension of trolley bus and ropeway systems. However, these programmes have been listed as third priority projects. The plan has also listed urban pollution control as an objective and has mentioned the need for pollution control programmes and public awareness programmes. Although these programs have not been spelled out in detail, they have been mentioned as first priority programmes and budget estimates for these programmes have also been provided.

Other policies include:

- ⇨ Nepal Environmental Policy and Action Plan (NEPAP), 1993
- ⇨ National Transport Policy, 2058 BS

National Legislation

The Constitution of the Kingdom of Nepal, 1990

Article 26 (4) of the constitution of the Kingdom of Nepal stipulates that:

“The state shall give priority to protection of the environment and also to the prevention of its further damage due to physical development activities by increasing the awareness of the general public about environment cleanliness and the state shall make arrangement for the special protection of the rare wildlife, the forests and the vegetation”.

With the above provisions, some constitutional responsibilities and duties have been vested upon the state for safeguarding the environment against further damage.

Other legislations include:

- ⇨ Industrial Enterprises Act, 1992
- ⇨ Vehicle and Transport Management Act, 1993
- ⇨ Nepal Petroleum Product Act, 1993
- ⇨ Environment Protection Act (EPA), 1997, and the Environment Protection Rules (EPR), 1997
- ⇨ Civil Aviation Act, 1958 BS
- ⇨ Local Self Governance Act, 1999
  (The LSGA, 1999 clearly stipulates that the municipality must assist in the task of controlling water, air and sound pollution in the municipal area and protect the environment)

Air Quality Standards

These include:

- ⇨ In-Use Vehicle Emission Standards, 1995
- ⇨ Nepal Mass Vehicle Emission Standards, 2056 BS
- ⇨ National Ambient Air Quality Standards (NAAQS), 2003

Institutional Framework

MOPE, established on 22nd September 1995, is primarily responsible for the formulation and implementation of policies, plans and programs. MOPE is also responsible for preparing environment related Acts, Rules and guidelines; conducting environmental surveys, studies and research; disseminating information; and carrying out public awareness programmes. It also carries out monitoring and evaluation, human resource development, and acts as a national and international focal point in the population and environment domain.

Government of Nepal/ National Planning Commission (NPC), and Environment Protection Council (EPC) are responsible for coordinating all environment related activities. Similarly, the Environment Conservation Committee of the House of Representatives is mainly responsible for monitoring activities of Government of Nepal on environment and other policy directives. Added that, DoTM, MoH, DHM, VTP, KMC etc are also helping for air quality monitoring and evaluation.

Besides, there are various national and international NGOs, local clubs and CBOs that are working to raise public awareness, and conducting environmental quality monitoring and emission inventories. These include WB, WHO, CEN, ENPHO, LEADERS Nepal, IUCN and KEVA.

iii) Steps taken to improve Kathmandu's air

Government of Nepal

- 1991 Ban on import of new three-wheelers
- 1995 Tail pipe emission standards & checking of vehicle emission
- 1997 Incentives for electric vehicles
- 1999 Import of unleaded fuel
- 1999 Removal of 600 diesel three-wheelers from Kathmandu
- 2000 EURO I norms for new vehicles
- 2000 Ban on import of new two-stroke two wheelers
- 2004 Two-stroke three wheelers to be removed from Kathmandu
- 2005 Bull Trench Brick Kilns to be banned in Kathmandu

Private Sector

- Investment of more than NRs. 450 million in operating 600 electric three-wheelers locally called SAFA Tempos

Municipalities

- Public education and infrastructure improvement

NGOs

There are several non-governmental organizations involved in research, advocacy, public awareness, and pilot project demonstration work related to air pollution control.

- Air quality monitoring & research (ENPHO, LEADERS)
- Public awareness & advocacy (CEN, Pro-Public, Martin Chautari)
- Development of Electro-vehicle (HLF)

International Organizations

- International organizations like DANIDA with its Environment Sector Program Support (ESPS) project, IUCN, International Center for Integrated Mountain Development (ICIMOD) are now working in air quality monitoring, promotion of electric vehicles and promoting cleaner production in industries
- ESPS (Environment Sector Program Support) is assisting Government of Nepal in monitoring air pollution, promoting electric vehicles, strengthening institutions and demonstrating new brick kiln technologies.
- Winrock International, together with other partners of Kathmandu Electric Vehicle Alliance (KEVA), is promoting electric vehicles
- Renewable Energy Programme Support Office (REPSO Nepal) of Winrock International is assisting in promotion and development of alternative fueled vehicles.
- SDC is promoting cleaner brick kilns

8.2 Conclusion

Studies have clearly shown that air pollution is a threat to environmental sustainability and human health. The health effects of Kathmandu's air pollution and its cost are very high. As vehicles are the most prominent contributor to air pollution, reducing vehicle emission is the most effective way of minimizing air pollution and huge economic burden thereof.

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 polluting vehicles need to be taken off the road.

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

PM_{10}:

- ⇨ The PM_{10} level in Kathmandu is much higher than the NAAQS and other international standards, especially in urban areas such as Putalisadak, 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 PM_{10} level occasionally exceeds the national standard.

- ⇨ Among the six areas being monitored, Putalisadak 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.

- ⇨ In the dry season between November and May, the PM_{10} levels in Putalisadak were above the national standard in all days. It is very unhealthy in 16.6 percent of the days. With the arrival of monsoon rains in mid-June, the PM_{10} has decreased significantly, but is still above national standard on 60 percent of the days.

- ⇨ 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 Putalisadak and the area as a whole is a bit more open thus allowing more dispersion than Putalisadak.

- ⇨ At the roadside stations in Putalisadak and Patan Hospital, in the dry months, the air quality should be classified as “Unhealthy” in almost 100 percent of the days, as “Very Unhealthy” during 14 percent of the days and as “Hazardous”, which is the highest alert level, during 7 percent of the days.

- ⇨ The PM_{10} 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 PM_{10} concentration was above the NAAQS in all days. During these months the air can be classified as “Unhealthy” in 86 percent of the days. In other words, the air quality was moderate in only 14 percent of the days. This indicates that Kathmandu residents cannot escape the pollution even when they are in their homes.

⇨ 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 14 percent of the days while in Bhaktapur the air was “Unhealthy” in 71 percent of the days. This is probably due to the westerly winds taking pollutants from Kathmandu over to Bhaktapur.

⇨ There is a significant amount of seasonal variation in the level of PM_{10}. Basically, the PM_{10} 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. 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. During the monsoon, rains flush down the particles in the air and significantly reduce the pollution level. But here, the condition is a lit different.

In August 2005, the average PM_{10} concentration in Kathmandu Valley was 59.83 $\mu g/m^3$ (lowest), but in January 2006 the level had raised to 198.33 $\mu g/m^3$ (highest). In April 2006, Putalisadak, Matsyagaon, TU Kirtipur and Patan Hospital air quality monitoring stations recorded the PM_{10} level to be 478, 111, 145 and 303 $\mu g/m^3$ respectively, which was the highest recorded value in the 1 year data taken by researcher. This is due to the 19 day long strike so called ‘Loktantrik Jana Andolan 2006’. During these days, though vehicles were not running in streets, there were too many tear gases firing, burning of tyres, flame rallies which polluted these areas the most.

⇨ The level of PM_{10} 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”.

Vehicular Emission:

⇨ In Kathmandu it is clear that the vehicles are the main sources of air pollution. This can be verified by the following three observations:

i) Areas with heavy traffic (Putalisadak and Patan Hospital) are the ones that are most polluted.

ii) Many studies have shown that pollution levels drop on weekends when there are fewer vehicles on the road.

iii) Pollution levels are very low during Nepal Bandh when there are almost no vehicles on the road.

- ⇨ 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.

- ⇨ 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, microbuses and private cars) there needs to be a concerted effort to control the pollution from these sources.

- ⇨ 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.

Human Health:

- ⇨ 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.

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

- ⇨ 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.

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

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

- ⇨ 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 past years. In Patan Hospital, the number of COPD patients has almost doubled in the past five years.

- ⇨ 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.

- ⇨ 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.

- ⇨ 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.

8.3 Recommendations

Based on the conclusions mentioned above, this study recommends the following actions for improvements in the pollution situation.

- ⇨ 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.

- ⇨ 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. Operating the existing trolley bus system can save approximately three tons of potentially carcinogenic particles from being released into Kathmandu's air every year.

- ⇨ As Kathmandu is very suitable for the use of electric vehicles (EVs), they need to be promoted. An effective public transportation system based on EVs is the best alternative for polluting diesel vehicles and private vehicles in Kathmandu. This will result in major health benefits for the residents of Kathmandu.

- ⇨ 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.

- ⇨ 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.

- ⇨ Improve the road condition in Kathmandu.

- ⇨ 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.

- ⇨ Improve the vehicle inspection and maintenance system.

- ⇨ Introduction of environment-friendly brick kilns can also significantly reduce the amount of pollutants in dry winter season.

- ⇨ Alternative energy sources, which are more efficient, less polluting, and cost effectiveness should be promoted to replace. For example, use of methane gas from landfill site to brick industries.

⇨ Facilitate the use of non-motorized vehicles. The priority should be given to ecological modes of transport as walking and cycling. Building bicycle lanes and pavements could facilitate this.

⇨ 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.

⇨ 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.

Based on the review and observation done for this study, air pollution condition in the Kathmandu Valley, the following seem to be the areas relevant for further research.

Role of EVs in reduction of air pollution.
Role of other pollutants other than PM_{10} such as $PM_{2.5}$, Benzene, NO_X , SO_X & other Gaseous Pollutants in contributing air pollution.
Health impacts of Kathmandu's air pollution.
Indoor air pollution: Causes and Consequences etc.

Box 2: Why Kathmandu Needs EVs?

1. No emission.
2. Low noise level.
3. Appropriate for Kathmandu where streets are narrow, traffic speed is low and travel distances are short.
4. Batteries can be recycled.
5. They use off peak electricity because the batteries are charged at night.
6. Tourist attraction.
7. Government gets revenue from the sale of electricity.
8. Being a local industry, it provides jobs to the local people.
9. EV technology represents an example of how a hydroelectricity rich country like Nepal can utilize its resources to promote sustainable development and reduce dependence on imported fossil fuels.

Source: www.cen.org.np

Box 3: Future Trend of EVs

In the future we can expect to see expansion of the trolley bus system, new types of EVs and improved batteries, provided that the government supports the development of this industry.

A new model of the Safa Tempo, which will be more attractive and efficient than the existing one, will soon be on the streets of Kathmandu.

Himalayan Light Foundation (HLF), has recently modified a milk float from the UK to make a new electric-bus. According to the manufacturers, the electro-bus has a capacity to carry 14 passengers and can go at a speed of approximately 45 km/hr.

A private company has also tried to import electric cars called "Reva" from India. According to manufacturers, the car has a range of 80 km (fully loaded) per charge. The cars are currently stuck at the customs due to lack of government support.

In the future, there are also possibilities for introducing electric motorcycles, cycles and hybrid vehicles (operated by petrol and electricity) in Kathmandu. With improvements in vehicle and battery technologies, it is expected that electric vehicles will be cheaper and more popular in the future.

Adopted from: CEN fact sheet

Box 4: Ten Steps for Better Air Quality

1. Improve public transportation system.
2. Improve road network and other transportation infrastructure.
3. Expand the trolley bus system.
4. Promote environment friendly transportation such as electric vehicles, bicycles & walking.
5. Ban the use of polluting vehicles.
6. Ensure the use of clean fuel.
7. Effective planning to reduce transport demand.
8. Introduce economic tools (tax and subsidies) to promote clean technologies.
9. Improve the vehicle emission inspection and maintenance system.
10. Raise awareness on proper vehicle maintenance.

Source: www.cen.org.np

Box 5: Case Study from www.nsc.org

Researcher visited the website of National Safety Council, www.nsc.org which has listed some measures to control air pollution, especially meant for new drivers.

How Can I Reduce My Contribution to Air Pollution?

There are many ways to reduce air pollution. People can contribute significantly to cleaning the air if they take (or do not take — as the case may be) certain simple actions to reduce air pollution.

Since vehicles contribute greatly to air pollution by emitting CO, NO_X, ozone, VOCs, HAPs, CFCs, and particulate matter, each driver who makes personal changes in driving habits contributes to the reduction of air pollution.

Limit driving, use public transportation, walk, use carpools, bike, or so forth. These are the best ways an individual can help reduce air pollution!

If you must drive, then try to follow these guidelines:

- Avoid high speeds.
- Buy a vehicle with high miles per gallon.
- Do not overfill or top off your gasoline tank.
- Do not refuel on high ozone days — try to refuel after dark.
- Drive a newer vehicle; the new models generally pollute less.
- Drive alternative vehicles or alternatively fueled vehicles, such as electric vehicles.
- Drive smoothly and avoid lengthy idling.
- If the vehicle is a pre-1995 model, have a professional convert the air conditioning from the dangerous CFC R-12 to the safer R-134a to reduce your contribution to the ozone hole.
- Keep your car well maintained, especially the emissions control system.
- Keep tires properly inflated.
- Maintain your vehicle's air conditioning system — do not allow it to leak.
- Make fewer trips in your vehicle — plan routes to avoid traffic.
- Reduce fuel use as often as possible — a vehicle's shape and design features can affect its fuel use.

Here are other actions individuals can take to reduce air pollution:

- Defer lawn and gardening chores that use gasoline-powered equipment on high ground-level ozone days.
- Eat organically grown food, or at least less pesticide-dependant foods.
- Limit dry cleaning.
- Postpone using oil-based paint and solvents on high ground-level ozone days.
- Reduce consumption of electricity — conserving reduces emissions of SO_2, NO_X, VOCs and particulate matter into the air.
- Start charcoal with an electric or chimney-type fire starter instead of lighter fluid.
- Reduce, Reuse, Recycle — less consumption of products will reduce all types of air pollution!

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ANNEXES

ANNEX- 1: LOCATION OF THE STUDY AREA AND AIR QUALITY MONITORING STATIONS IN KATHMANDU VALLEY

ANNEX- 2: EXPERIMENT

TITLE: DETERMINATION OF THE AMOUNT OF DUST FALL (PARTICULATE MATTER) IN THE SPECIFIC AREA OF KATHMANDU VALLEY.

REQUIREMENTS: measuring cylinder, watch glass, beaker, glycerine

THEORY:

Today with the increase in human population, amount of waste materials produced by human activities has greatly increased. The persistent nature of wastes has worsened the problem and biosphere has been a natural victim. Our atmosphere consists of a number of gases, variety of particulate matters with a number of substances; human activities have been introducing a lot of undesirable and harmful materials which pollute the atmosphere. Major parts of particulate matter in the environment are contributed by dust particles from various sources.

Dust-fall measurement provides a rough estimation of atmospheric pollution.

PROCEDURE:

A dust trap was made by putting glycerine on watch glass and was exposed to atmosphere for 1 hour. The initial weight of the watch glass was taken before exposing it to the atmosphere and then final weight of watch glass was taken after exposing to atmosphere. The glycerine containing watch glass was kept at different places on the roof of Tri-Chandra Campus building. Differences between the initial and final weight of watch glass give the total weight of dust particles.

OBSERVATION:

S.No.	(By the Researcher, in 2057-02-29)			(By the Researcher, in 2063-02-07)		
	Initial weight (gm) A	Final weight (gm) B	Weight of dust fall B-A	Initial weight (gm) A	Final weight (gm) B	Weight of dust fall B-A
Watch glass 1	37.64	37.67	0.03	41.58	41.66	0.08
Watch glass 2	36.55	36.55	0	42.36	42.45	0.09
Watch glass 3	35.5	35.5	0	40.27	40.34	0.07
Watch glass 4	37.97	37.98	0.01	41.44	41.53	0.09
Beaker 1	75.37	75.39	0.02	78.22	78.3	0.08
Beaker 2	49.35	49.38	0.03	75.63	75.72	0.09

RESULT & DISCUSSION:

Previously in 2057 BS, the dust fall measured by researcher gave positive results in watch glass 1, watch glass 4, beaker 1 and beaker 2 as 0.03 $mg/cm^2/hr$, 0.01 $mg/cm^2/hr$, 0.02 $mg/cm^2/hr$ and 0.03 $mg/cm^2/hr$ respectively. It was so because the place where these apparatus were placed was on roadside. But in case of watch glass 2 and 3, no dust fall occurred as they were placed near trees of campus ground and air might have blown the dust particles from that area.

Recently the researcher performed same experiment that he did earlier. He took similar apparatus and placed those apparatus around various sides of the campus building. As before, the results were positive showing 0.08 $mg/cm^2/hr$, 0.09 $mg/cm^2/hr$, 0.07 $mg/cm^2/hr$, 0.09 $mg/cm^2/hr$, 0.08 $mg/cm^2/hr$ and 0.09 $mg/cm^2/hr$ dust fall in watch glass 1, watch glass 2, watch glass 3, watch glass 4 and beaker1, beaker 2 respectively.

As Tri-Chandra Campus is situated at the centre of Kathmandu City and the air pollutants (particulate matter as well as gases) is in high amount from the increasing number of vehicles (added that the researcher found drastically increasing number of vehicles: refer Figure 7.10; also 30 percent vehicles that ply on streets of Kathmandu failed on emission test: refer Figure 7.13) on the roads of Kathmandu, there is no doubt about the maximum dust fall at those areas.

CONCLUSION:

Hence, the experiment proves that the air pollution around Kathmandu valley has increased three to four folds in just past 6 years. If the present situation prevails, in near future the environment of Kathmandu will be so polluted that it will not be a place to live in.

ANNEX- 3: QUESTIONNAIRE FOR PUBLIC SURVEY

1) Respondent:

Name: …………………… ……………………

Age: ……………

Gender: ✂ Male ✂ Female

Education: ✂ < SLC ✂ SLC ✂ Intermediate (any faculty)

✂ Bachelor (any faculty) ✂ Masters (any faculty)

Occupation: ………………………

Permanent Address: ………………………..

2) *If your permanent address is outside Kathmandu, how long have you been living here?*

……………………. (years)

3) *What changes have you seen in the past?*

✂ Being better ✂ worsening ✂ no change

4) *How do you feel about the environment?*

✂ Polluted ✂ OK ✂ Clean ✂ No Change

5) *For you, what is the cause of air pollution?*

✂ Vehicular traffic ✂ Unplanned urbanization ✂ Industrialization ✂ Other (specify)………

6) *Among these areas which one do you think is the most polluted?*

✂ Putalisadak ✂ Matsyagaon ✂ Kirtipur ✂ Bhaktapur ✂ Patan Hospital ✂ Thamel

7) *How many vehicles do you have?* …………

8) *Do you wear 'mask' or 'specs' while traveling?* ✂ Yes ✂ No

9) *Do you know that the vehicles are the major contributors to air pollution?* ✂ Yes ✂ No

If yes, then what have you done to pollute less? …………………………………………

10) *What should be done to reduce vehicular traffic?* ....

11) *Do you smoke?* ✂ Yes ✂ No

12) *Do you have any health problems which may be due to air pollution?*

✂ Asthma ✂ Heart disease ✂ Lung disease ✂ Visibility problem ✂ Others (specify)…………

13) *How do you feel about urbanization of Kathmandu valley?*

✂ Planned ✂ unplanned/ too congested

14) *What may be the reasons behind such heavy population pressure in Kathmandu?*

…………………………………………………………………………………………………

………………………………………………………………………………………………....

15) *What would you suggest to overcome the pollution problem in Kathmandu?*

…………………………………………………………………………………………………

………………………………………………………………………………………………....

ANNEX- 4: AIR QUALITY DATA, MONTHLY AVERAGE (JANUARY 2003 TO APRIL 2006)

Months	Putalisadak				Matsyagaon			
Years	2003	2004	2005	2006	2003	2004	2005	2006
January	317	285	280	330	N/A	57	60	70
February	253	246	264	N/A (254)	66	70	48	N/A
March	240	287	255	362	66	108	50	74
April	254	241	N/A	478	89	91	102	111
May	270	230	238		87	79	54	
June	220	185	184		69	48	52	
July	116	113	118		23	29	15	
August	125	116	118		22	16	19	
September	126	117	151		25	24	21	
October	135	147	126		32	30	22	
November	188	218	224		53	48	36	
December	286	254	330		47	46	47	

Months	TU Kirtipur				Bhaktapur			
Years	2003	2004	2005	2006	2003	2004	2005	2006
January	135	109	110	118	279	184	150	171
February	102	117	82	N/A	212	194	134	N/A
March	115	151	83	101	200	219	124	209
April	120	122	121	145	192	154	192	N/A
May	116	99	70		175	138	109	
June	80	49	57		102	80	78	
July	26	29	18		36	36	30	
August	30	22	21		39	28	32	
September	32	35	25		45	42	47	
October	45	44	22		66	57	51	
November	78	77	46		106	100	96	
December	88	76	78		129	114	152	

Months	Patan Hospital				Thamel			
Years	2003	2004	2005	2006	2003	2004	2005	2006
January	277	245	270	280	273	214	222	221
February	N/A	241	265	N/A	198	201	161	N/A
March	226	280	238	256	179	224	148	178
April	240	230	285	303	200	161	193	121
May	237	211	213		N/A	153	120	
June	180	162	211		122	76	103	
July	123	136	177		63	61	52	
August	118	139	113		65	55	56	
September	128	123	144		70	67	70	
October	119	137	114		105	91	75	
November	175	179	168		168	151	123	
December	215	198	224		208	197	182	

ANNEX- 5: PHOTOGRAPHS

Unplanned Urbanization and Air Pollution in the Kathmandu Valley

A Sample of Air Quality Monitoring Station located at TU, Kirtipur

Vehicular Emission

Heavy Traffic in the streets of the Kathmandu Valley

Air Pollution from Brick Kilns

Resuspension of Dust Particles in the streets of Kathmandu Valley

Without mask and specs, it is very troublesome to travel in streets of Kathmandu valley.

Way People do Strike in Kathmandu Valley: By Burning Tyres

Safa Tempos: A Very Good Example of EVs