Final report

on

Assessment of Ambient Air Quality in Selected Urban Areas of Nepal

(With Estimated Burden of Disease)

Submitted by:

Ambient Air Quality Study Team

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Nepal Health Research Council (NHRC)
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List of Abbreviation

ADB	:	Asian Development Bank
AFs	:	Attributable Fractions
ARI	:	Acute Respiratory Infection
BS	:	Bikram Sambat
CBS	:	Central Bureau of Statistics
CEN	:	Clean Energy Nepal
CNG	:	Compressed Natural Gas
CO	:	Carbon monoxide
COPD	:	Chronic Obstructive Pulmonary Disease
DALYs	:	Disability Adjusted Life Years
DANIDA	:	Danish International Development Agency
DCSI	:	Department of Cottage and Small Industries
DoHS	:	Department of Health Services
DoTM	:	Department of Transport Management
EBD	:	Environmental Burden of Disease
EIA	:	Environmental Impact Assessment
ENPHO	:	Environment and Public Health Organisation
EPA	:	Environmental Protection Agency
ESPS	:	Environment Sector Programme Support
EVs	:	Electric Vehicles
GBD	:	Global Burden of Disease
GDP	:	Gross Domestic Product
HCs	:	Hydrocarbons
HMG/N	:	His Majesty's Government of Nepal
HSU	:	Hartridge Smoke Unit
IF	:	Impact Fraction
IQ	:	Intelligence Quotient
JICA	:	Japanese International Cooperative Agency
KEVA	:	Kathmandu Electric Vehicle Alliance
KMC	:	Kathmandu Metropolitan City
KVVECP	:	Kathmandu Valley Vehicular Emission Control Project
LEADERS Nepal	:	Society for Legal and Environmental Analysis and Development Research
LPG	:	Liquefied Petroleum Gas
LRTI	:	Lower Respiratory Tract Infection
MoPE	:	Ministry of Population and Environment
N_2O	:	Nitrous Oxide
NAAQS	:	National Ambient Air Quality Standards
NEDA	:	1-Naapthyl ethylenediamine dihydrochloride
NESS	:	Nepal Environmental & Scientific Services
NHRC	:	Nepal Health Research Council
NO	:	Nitric Oxide
NO_2	:	Nitrogen Dioxide
NOC	:	Nepal Oil Corporation
NOx	:	Nitrogen Oxides
O_3	:	Ozone

OEHHA	:	Office of Environmental Health Hazard Assessment
PAH	:	Polycyclic Aromatic Hydrocarbon
PAN	:	Peroxyacetyl Nitrate
Pb	:	Lead
PM	:	Particulate Matter
PM_{10}	:	Particulate matter of size less than 10 micron
$PM_{2.5}$	:	Particulate matter of size less than 2.5 micron
SO_2	:	Sulphur Dioxide
SPM	:	Suspended Particulate Matter
TCM	:	Tetrachloratemercurate
TSP	:	Total Suspended Particle
TU	:	Tribhuwan University, Kirtipur
TUTH	:	Tribhuwan University Teaching Hospital
UNEP	:	United Nations Environment Programme
URTI	:	Upper Respiratory Tract Infection
VDC	:	Village Development Committee
VTP	:	Valley Traffic Police
WHO	:	World Health Organisation

Symbols and Units

μg	:	Microgram
$\mu g/m^3$	:	Microgram per Cubic Meter
μm	:	Micro meter
^0C	:	Degree Centigrade
ng/m^3	:	Nanograms per Cubic Meter
nm	:	Nanometre
NRs	:	Nepalese Rupees
km	:	Kilometre

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Rashmi Singh Rana
Team Leader

Executive Summary

Air pollution is a growing problem in the world. In urban areas, air pollution is caused due to the increasing use of fossil fuels. Studies have shown that air pollution has a proven linkage with the human health damage. According to a recent estimate on increase in daily mortality, on a global scale 4 to 8 percent of premature deaths around the globe are due to the exposure to particulate matters. It is estimated that air pollution in South Asian cities causes nearly 100,000 premature deaths per year and over a billion work days of lost or reduced productivity.

In case of Kathmandu valley, vehicles has been found to be number one source of air pollution and this problem is further devastating due to the growing number of vehicles on the narrow roads. There has been some studies in past to assess the health impact due to urban air pollution. These studies, done in case of Kathmandu, have identified PM_{10} as major threat to public health and already the concentration has been in the level that is higher than the national as well as health based guidelines.

Assessment of Ambient Air Quality outside Kathmandu valley

The TSP and PM_{10} levels in the ambient air at Birgunj exceeds several times of the national standard. Average level of PM_{10} remained higher than the national standard in the ambient air of this city. Average PM_{10} levels in Bhanuchok, Ranighat and Addarshnagar were found 380 $\mu g/m^3$, 358 $\mu g/m^3$, & 220 $\mu g/m^3$ respectively. However, Birgunj was found to be least polluted with all kinds of gaseous pollutants. Observed levels of NOx, SOx and CO in all locations of this city were found very low than the recommended safe level. In case of Pokhara, it also possesses high degree of air pollution particularly due to the presence of high levels of TSP and PM_{10}. The observed average level of TSP and PM_{10} except the station Hallchok, Lakeside was also found higher than the NAAQS level. Like Birgunj, gaseous pollutants were found very low than the set NAAQS limit.

Assessment of Air Quality in Kathmandu valley

Kathmandu being the capital city of Nepal has observed rapid urban growth and population inflow for last few years. The valley is especially vulnerable to air pollution due to an exploding population inflow, rapid urbanisation, valley centric industrialisation and significant increase of vehicular transport in narrow streets. Furthermore, the bowl like topography of the valley restricts wind movement and retains the pollutants in the atmosphere.

Annual average of the PM_{10} in Kathmandu's air from March 2003 to February 2004 was calculated to be 132.88 $\mu g/m^3$. The most polluted monitoring site was found out to be Putalisadak with annual average of PM_{10} to be 209.01 $\mu g/m^3$. Similarly, least polluted site was Matsyagaon.

Monthly average shows the decrease in concentration from the month May and reach minimum during July to September and after October the concentration again starts increasing. Besides the particulate matter, gaseous air pollutants in Kathmandu valley are within the guideline value. However, recent studies have found that concentration of benzene and polycyclic aromatic hydrocarbon (PAH) has been a major concern in Kathmandu's air.

Analysis of air pollution related diseases

The yearly trend of COPD patients in the public hospitals of Kathmandu shows the increment in the number of patients. The seasonal variation of COPD patients coincide with the PM_{10} concentration in Kathmandu. During the dry winter season, the PM_{10} concentration was found higher, and the COPD patients number also shows the same trend.

Environmental Burden of Disease

The disease burden of a population, and how that burden is distributed across different subpopulations (e.g. infants, women), are important pieces of information for defining strategies to improve population health. For policy-makers, disease burden estimates provide an indication of the health gains that could be achieved by targeted action against specific risk factors. In case of outdoor air pollution, we can say the achievement of health gains meeting the national ambient air quality standard.

This study used the WHO's guideline to assess the burden of disease due to outdoor air pollution; *Outdoor air pollution: Assessing the environmental burden of disease at national and local levels*.

In case of Kathmandu valley, the attributable burden due to current PM_{10} concentration in Kathmandu valley against the baseline concentration of 10 µg/m^3 was found out to be 1926 cases of premature mortality per year (lower and upper bounds of 1184 and 2973, respectively). Similarly, the number of cases of premature mortality from short-term exposure to current PM_{10} concentration in Kathmandu valley which could be avoided if the government could reduce the ambient PM_{10} concentration to national standard, was calculated to be 212 cases of premature mortality per year, with upper and lower boundary to be 127 and 338 respectively.

Policy regulation related to air pollution in Nepal

Although there is no particular law or act focusing solely on air pollution control in Nepal like Clean Air Act, there are some provisions made in few other laws regarding it. For the past few years, government has started realising outdoor air pollution as a major threat to the public health and environmental problem in Kathmandu valley and other few urban & tourist centres.

Government has set the national standard for ambient level of six classic air pollutants. Although at most of the air quality monitoring stations, the average value frequently crossed the standard value for PM_{10}, a major problem in the Kathmandu's air, the government has set target to meet the standard value by May 2006.

To achieve the goal of reducing urban air pollution, government has implemented some policies to reduce emission from vehicles as well as industries. However, implementation and enforcement of these policies is another story.

Recommendations

There is urgent need to extend the regular air quality monitoring programme in other cities of Nepal and assess the impact due to it. Air pollution in Kathmandu valley, specially, particulate matter has been a serious threat to human health. Therefore, while addressing the problem of air pollution, the cost of human health should also be kept in mind by the policymakers.

A detail burden of disease study in major urban areas of Nepal is required to assess the health impact due to urban air pollution in these cities at the national level. Similarly, due to the absence of epidemiological studies in Nepal, researchers are bound to use the risk factor developed in other parts of the world. Therefore, we recommend to have epidemiological studies due to air pollution.

To combat the increasing threat due to the ambient air pollution in urban areas, holistic policy measures should be taken which could be done by the formulation and implementation of Clean Air Act.

1. Introduction

Due to the rapid urbanisation & industrialisation, urban areas in recent years have brought home numerous environmental problems. Also, due to the number of vehicles growing within the urban areas, air pollution has been a common problem associated with urbanisation. This study, entitled "*Assessment of Ambient Air Quality in Selected Urban Areas of Nepal*", aims to assess the ambient air quality in selected urban areas of Nepal. At first, although, we intended to assess ambient air quality of 10 major urban areas of Nepal, due to the resources constrains, we landed up for the study on two cities outside Kathmandu valley only. But we expect this study would help any future studies as this is the first study outside Kathmandu valley for two seasons and 24 hour averaging time.

Although, ambient air pollution has numerous impacts, this study intend to find out the possible health effects to the people residing in urban areas. We have used the "Environmental Burden of Disease (EBD)" approach to quantify the health impact due to urban air pollution, especially particulate matter of size less than 10 micro meter (PM_{10}) in Kathmandu valley.

This chapter provides background information to the study via a general description of Nepal, concept about air pollution, sources of urban air pollution (in Kathmandu valley), major air pollutants and its health significance.

1.1 Background information - Nepal

Nepal is a small landlocked country lies between 26°22' N latitude and 80°12' E longitude. It has a total land area of 147,181 sq. km. It is bordered by China from North and India from South, East and West and elevation ranges from 90 to 8848 meters. The average length being 885 km east to west and the average breadth is 193 km from north to south. Geographically, the country is divided in three regions; Mountain, Hill and Terai accommodating 7.44 and 49 percent of the population respectively. The snow clad High Himalayas in the Northern Belt, the Mountainous Region embracing Mahabharata Range in the middle with long terraced slopes leading to fertile valleys and subtropical plain land in the down south. There are 5 development regions and 75 administrative districts. Districts are further divided into smaller units, called Village Development committee (VDC) and Municipality. Currently, there are 3914 VDCs and 58 Municipalities in the country.

Economic growth of the country has not improved markedly over time to over take population growth. As the country estimated population growth is 2.3 per annum, the gain achieved by developmental activities has been concealed by growing population. Little over half (57 percent) of the population of working age reported economically active in 1991 and among them 81 percent were engaged in agricultural activities(CBS, 2002).

Population of Nepal increased from 15 million in 1981 to 18.5 million in 1991 and 23.1 million in 2001 fixing a annual growth rate of 2.2 percent in 1991- 01 decade. Population density for the year 2001 is estimated to be 157 persons per square km.

Climate

With varied topography and altitude featured diversity in the weather and climate. Nepal, in general, has four seasons: spring (March - May), summer (June-August), autumn (September - November) and winter (December - February). The climate variation depends upon geographical location from sub-tropical to alpine types.

Climatically, the southern belt of Nepal, the Terai, experiences warm and humid climate. It is the hottest part of the country where summer temperature rises as high as 40^0C.The middle mountain region has climate with mild and pleasant weather throughout the year. The temperature in this region during the summer ranges around 25 to 27^0C. And subzero to 12^0C. in the mountain and valleys. The northern Himalayan region has an alpine climate. The valley of Kathmandu-the capital city has very pleasant climate with average summer and winter temperatures of 19^0 to 27^0C and 2 to 12^0C.

Degree of rainfall also varies with the seasons. Nepal enjoys widespread rainfall during the monsoon period i.e. from June to August. The eastern parts of the country receive maximum rainfall. The winter is rather dry in most parts of the country. Annual rainfall varies around 300mm in the northern and the western areas to over 2500 mm in the eastern region.

Looking at the health problems of the people who visited hospital, Acute Respiratory Infection (ARI) comes to second position (see table 1 for details). As ARI is cased due to the alleviated air pollution level both at indoor and outdoor environment, it implies that there is substantial role of air pollution in health burden to the people of Nepal.

Table 1: Ten Leading Diseases (Total New Visits as a Percentage of Total Population), Fiscal Year 2058/59

Diseases/conditions	Percentage of Total population
Skin Diseases	5.76
ARI	3.44
Diarrhoeal Diseases	3.38
Intestinal Worms	2.76
Pyrexia unknown origin	2.30
Gastritis	2.20
Ear Infection	1.56

Chronic Bronchitis	1.20
Abdominal Pain	1.05
Sore Eye & Complains	1.02

Source: Annual Report, DoHS, 2058/59

1.2 Air pollution

Clean air is vital for human survival. A human body requires approximately 25 kg of air everyday to sustain its requirement of oxygen, meaning that a human being breaths nearly 22,000 times, or about 9 litre, per day. This figure reflects the importance of air to human beings and any contamination in the air will have a direct impact on our health.

Pure air consists of oxygen (21 percent), nitrogen (78 percent) and a number of other gases and water vapour. Any contamination, natural or anthropogenic, to pure air is known as air pollution and the causing agent is known as air pollutants. In general, the term "air pollution" refers to the accumulation of any substances in the air in sufficient concentration to effect man, animals, vegetation or other materials. Although not all impurities in the air will cause harm, they may harm adverse health impact according to the nature, concentration, and duration of exposure. Normally anthropogenic air pollutants causing harm to one's well-being are Suspended Particulate Matter (SPM), Sulphur Dioxide (SO_2), Nitrogen dioxide (NO_2), Carbon monoxide (CO), Lead (Pb), Ozone (O_3) and Hydrocarbons (HCs)(Rao and Rao, 1989).

Air pollution is a growing problem in the world. In urban areas, air pollution is caused due to the increasing use of fossil fuels. Unmanaged urban settlements and modernisation has only compounded the problem as more people are exposed to the pollutants, which adversely impact their health. It is estimated that air pollution in South Asian cities causes nearly 100,000 premature deaths per year and over a billion work days of lost or reduced productivity (ADB, 2001).

There are three broad sources of air pollution from human activities: Stationary sources, Mobile Sources, and Indoor sources (WHO, 2000). Air pollution in the urban part of the world due to the vehicular and industrial contribution has become a major risk to the people residing. According to a recent estimate on increase in daily mortality, on a global scale 4 to 8 percent of premature deaths around the globe are due to the exposure to particulate matters. Moreover, around 20-30 percent of all respiratory diseases appear to be caused by ambient and indoor air pollution (WHO 2000). Furthermore, the WHO estimates that every year 800,000 people die prematurely from lung cancer, cardiovascular and respiratory diseases caused by outdoor air pollution (World Bank, 2003a).

Looking at the figure below in the table 2 describing the environmental risks to the human health, it can be inferred that urban outdoor air pollution is one of the major risks to the human health and Asian countries are more effected by it with the higher share in the world Globally, urban air pollution caused around 799,000 death per year and only in Asia around 487,000 people die due to it.

Table 2 : Premature deaths due to environmental factors

Environmental Risks	Global Estimate	Asian Estimate	Asia as a percent of Global
Unsafe Water	1,730,000	730,000	42 percent
Urban Outdoor Air	799,000	487,000	61 percent
Indoor Air	1,619,000	1,025,000	63 percent
Lead	234,000	88,000	37 percent

Source: WHO, 2002

However, the acute effects of the air pollution in urban areas have caused noted effects to residents. In the air pollution study history, there has been few notable air pollution episodes (table 3) which led to the policy makers think about health hazards of the air pollution in urban population. The 1952 London episode was the worst one, resulting in an estimated 4,000 deaths in five days.

Table 3 : Notable air pollution episodes

Location	Date	Pollutants	Deaths
London, England	Dec 9-11, 1873	SO_2	650
London, England	Jan 20-29, 1880	SO_2	1,176
Meuse Valley, Belgium	Dec 1-5, 1930	SO_2 (up to 100 mg/m^3)	63
Donora, USA	Oct 26-31, 1948	SO_2 (up to 5 mg/m^3)	20
London, England	Nov 26-30, 1948	SO_2 (particles)	700
Poza Rica, Mexico	Nov 24, 1950	H_2S	22
London, England	Dec 5-9, 1952	SO_2 (particles) up to 4 mg/m^3	4,000
London, England	Dec 5-9, 1955	SO_2 (particles) up to 2 mg/m^3	1,000
New York, USA	Nov 24-30, 1966	SO_2 (particles)	168

Source: World Bank, 1997a

1.2.1 Principal air pollutants

Air pollutants can be classified as either primary or secondary depending on the their process of formation. Primary pollutants are substances directly produced by a process, such as ash from a volcanic eruption or the carbon monoxide gas from a motor vehicle exhaust. Secondary pollutants are not emitted from the source. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ozone - one of the many secondary pollutants that make up photochemical smog.

Primary pollutants produced by human activity include:

- oxides of sulfur, nitrogen and carbon
- organic compounds, such as hydrocarbons (fuel vapour and solvents)
- particulate matter, such as smoke and dust
- metal oxides, especially those of lead, cadmium, copper and iron
- odours
- toxic substances.

Secondary pollutants include some particles formed from gaseous primary pollutants and compounds in photochemical smog, such as nitrogen dioxide, ozone and peroxyacetyl nitrate (PAN) (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Sulfur dioxide

Sulfur dioxide in the atmosphere arises from both natural and human activities. Natural processes which release sulfur compounds include decomposition and combustion of organic matter; spray from the sea; and volcanic eruptions. The main human activities producing sulfur dioxide are the smelting of mineral ores containing sulfur and the combustion of fossil fuels. Sulfur dioxide dissolves in water to form sulfuric acid. This is a corrosive substance that damages materials and the tissue of plants and animals. (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Particulate matter

Not only are there gaseous pollutants, there are also solid or liquid particles that may be suspended in the air. Referred to as 'particulate matter', these particles range in size up to 50 micrometres (µm) in diameter and may reduce visual amenity and adversely impact health. Examples of particles in the air include dust, smoke, plant spores, bacteria and salt. Particulate matter may be a primary pollutant, such as smoke particles, or a secondary pollutant formed from the chemical reaction of gaseous pollutants.

Human activities resulting in particulate matter in the air include mining; burning of fossil fuels; transportation; agricultural and hazard reduction burning; the use of incinerators; and the use of solid fuel for cooking and heating.

Particulate matter can be usefully classified by size. Large particles usually settle out of the air quickly while smaller particles may remain suspended for days or months. Rainfall is an important mechanism for removing particles from the air. The size of a particle also determines its potential impact on human health. Larger particles are usually trapped in the nose and throat and swallowed. Smaller particles may reach the lungs and cause irritation there (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Oxides of nitrogen

The main oxides of nitrogen present in the atmosphere are nitric oxide (NO), nitrogen dioxide (NO_2) and nitrous oxide (N_2O).
The major human activity which generates oxides of nitrogen is fuel combustion, especially in motor vehicles. Oxides of nitrogen form in the air when fuel is burnt at high temperatures. This is mostly in the form of nitric oxide with usually less than 10 percent as nitrogen dioxide. Once emitted, nitric oxide combines with oxygen ('oxidises') to form nitrogen dioxide, especially in warm sunny conditions.

These oxides of nitrogen may remain in the atmosphere for several days and during this time chemical processes may generate nitric acid, and nitrates and nitrites as particles. These oxides of nitrogen play a major role in the chemical reactions which generate photochemical smog. Nitrogen dioxide is also a respiratory irritant which may worsen the symptoms of existing respiratory illness (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Carbon monoxide

Carbon monoxide is an odourless, colourless gas produced by incomplete oxidation (burning). As well as wildfires, carbon monoxide is produced naturally by oxidation in the oceans and air of methane produced from organic decomposition. In cities, the motor vehicle is by far the largest human source, although any combustion process may produce it.

Carbon monoxide usually remains in the atmosphere for a month or two. It is removed by oxidation to form carbon dioxide, absorption by some plants and micro-organisms, and rain. When inhaled, carbon monoxide binds to the oxygen-carrying site on the blood's haemoglobin, which reduces oxygen transport in the body. At high concentrations it is very toxic, causing headaches, dizziness, reduced ability to think, and nausea (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Ozone

Near the ground, ozone is a colourless, gaseous secondary pollutant. It is formed by chemical reactions between reactive organic gases and oxides of nitrogen in the presence of sunlight. Ozone is one of the irritant secondary pollutants in photochemical smog and is often used as a measure of it. Ozone is strongly oxidising and can irritate the eyes and the respiratory tract. It also damages plants.

The formation of ozone in the upper levels of the atmosphere or 'stratosphere' is by a different process. Ozone there is not regarded as a pollutant because it is produced naturally. It is important in absorbing harmful ultraviolet radiation and preventing it from reaching the earth (http://www.epa.nsw.gov.au/envirom/princairpol.htm).

Lead

The major source of lead in the air is leaded fuel used in motor vehicles. The introduction of unleaded fuel in 1985 has resulted in a substantial decrease in the concentration of lead in the air. Lead is a heavy metal and, when present in the body, can impair brain function, especially in children (http://www.epa.nsw.gov.au/envirom/princairpol.htm). In case of Nepal, leaded gasoline has been banned from 26 December 1999 (UNEP, 2001). Therefore, we did not monitor the lead presence in the atmosphere assuming the decrease in the concentration.

1.2.2 Major sources of air pollution

Air pollution comes from different sources both natural and anthropogenic. Anthropogenic sources include: vehicles, industries, power plants, dry cleaners, and even windblown dust etc. Air pollution can threaten the health of human beings, trees, lakes, crops and animals, as well as damage the ozone layer and buildings. Air pollution also can cause haze, reducing visibility in national parks and wilderness areas.

In case of Kathmandu valley, there has been mainly two major studies which describes the sources of air pollution. One inventory was done by the World Bank back in 1997 and another was done recently by the ESPS. According to ESPS inventory conducted in 2001, total annual PM_{10} and total suspended particles (TSP) load in Kathmandu valley is 7580.5 and 19,884.2 tons respectively. This is significantly higher than a previous inventory done by World Bank in 1997, when the total annual load was estimated to be 4,712 and 16,575 tons for PM_{10} and TSP respectively. These figures indicate that over the past five years or so, there has been a 60 percent increase in the PM_{10} (World Bank, 1997b).

The main cause of this increase is the remarkable increase in the number of vehicles. A comparison of the two inventories indicates that PM_{10} from vehicle exhaust has increased from 570 tons to 3,259.6 tons and TSP from vehicles has increased from 1530 tons to 7,008.01 tons respectively. Overall, in the 1997 inventory, vehicles were responsible for about 20 percent of the PM_{10} but the latest inventory indicates that vehicle emission contributes 67 percent of the PM_{10} in Kathmandu valley (Gautam, 2002).

Vehicular Emission

Vehicle emission is a major source of air pollution in Kathmandu. This is mainly because of the large number of vehicles on congested streets, poor quality vehicles, poor quality fuels and weaknesses in the emission inspection system. Till fiscal year 2002/03, Kathmandu valley had 224,098 registered vehicles and this number is increasing at about 16 percent per year. A study conducted by Department of Transport Management (DoTM), indicated that the number of vehicles in Kathmandu had already exceeded the valley's carrying capacity by about 30,000 in 1999/2000 fiscal year. For these 224,098 and other vehicles registered outside Kathmandu valley but being operated within the valley, there exists a total road network of only 1339 km. This is causing serious problems of traffic congestion and air pollution.

Table 4 shows the total number of vehicles registered in Bagmati zone (mainly plying within Kathmandu valley) over the last seven years. This table indicates that there is a very small increase in the number of buses and 3-wheelers which are the main public transport vehicles, but phenomenal increases in the number of car/jeep/van and two-wheelers, almost all of which are private vehicles.

Table 4: Total number of vehicles registered in Bagmati Zone over last seven years

Vehicle Type	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03
Bus	1163	1298	1403	1632	1744	1858	2061
Mini bus	1468	1500	1527	1610	1804	2172	2387
Truck/Tanker	4483	4759	4811	5295	5484	6274	6991
Car/Jeep/Van	27153	28915	30919	35993	40674	43409	45361
3-Wheeler	3844	3925	4262	4778	4949	5073	5073
2-wheeler	58029	64142	71612	94217	112000	134852	156410
Tractors	1672	1672	1672	1672	1673	1673	1677
Other	3020	3278	3311	3338	3350	3356	4138
Total	100831	109489	117836	148535	171678	198667	224098

Source: Department of Transport Management

Clearly, the dramatic rise in the number of private vehicles is a cause of concern, as public vehicles tend to emit less pollution per passenger. Within the private vehicle category, the most significant increase is in the number of two-wheelers (CEN/ENPHO, 2003).

Industrial Emission

Industries situated within the valley, using poorly maintained and old technology, are also responsible for air pollution. Most polluting industries are situated at the south and southwest parts of the valley. Unfortunately, southwest wind in the valley helps to blow air pollutants from remotely situated industries to the urban area (Raut, 2002).

Emission load from the industrial sector in the Kathmandu valley in 1993 was estimated to be 3574 tons of TSP, 5220 tons of CO, 1492 tons of

Hydrocarbon, 628 tons of Nitrogen Oxides (NOx) and 1349 tons of Sulphur Dioxide (SO_2) per year (Shrestha and Malla, 1995).

Now that the Himal Cement factory (previously number one polluting industry) is closed, the brick kilns are the main polluting industry in the Valley. There are about 125 brick kilns operating in Kathmandu valley out of which 113 are bull's trench type, 9 are clap kiln type and 3 Hoffmann kilns (ENPHO, 2001). As the brick manufacturing process in Bull's Trench and Clamp Kiln is very poor and inefficient, the amount of smoke spewing from these kilns is very high. Due to its polluting nature, this technology has even been banned in India, the place of its origin. A study carried out by Clean Energy Nepal in Tikathali VDC in Lalitpur and Jhaukhel VDC in Bhaktapur indicate the air pollution in brick kiln affected areas are three times higher than normal. In Tikathali the concentration of PM_{10} during the brick-making season was found to be 602.16 $\mu g/m^3$ while in the off-season it was only 217.95 $\mu g/m^3$. Similarly, in Jhaukhel, PM_{10} concentration in an area with brick kilns was found to be 568.78 $\mu g/m^3$ while it was only 158.33 $\mu g/m^3$ at Sipadol area, a valley background (Tuladhar and Raut 2002).

1.2.3 Health impact of selected air pollutants

Major air pollutants contributing to the human health damage are the Particulate matters, sulphur dioxide, nitrogen dioxide, carbon monoxide, ozone, lead, and benzene. These air pollutants have adverse impact on the human health according to their nature, concentration and period of time exposed to it. Major identified human health damage by the selected air pollutants can be summarised as:

Pollutants	Major health impacts
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 % • Hospital admission for respiratory & cardiovascular diseases by 1.4 & 6% respectively • Emergency room visits by 3.1 % • Restricted activity days by 7.7%
Sulphur Dioxide	Acute mucus membrane irritant; Exacerbates asthma & COPD
Nitrogen Dioxide	Irritation of respiratory tract Severe exposure can result in death from pulmonary oedema Can increase susceptibility to viral infections such

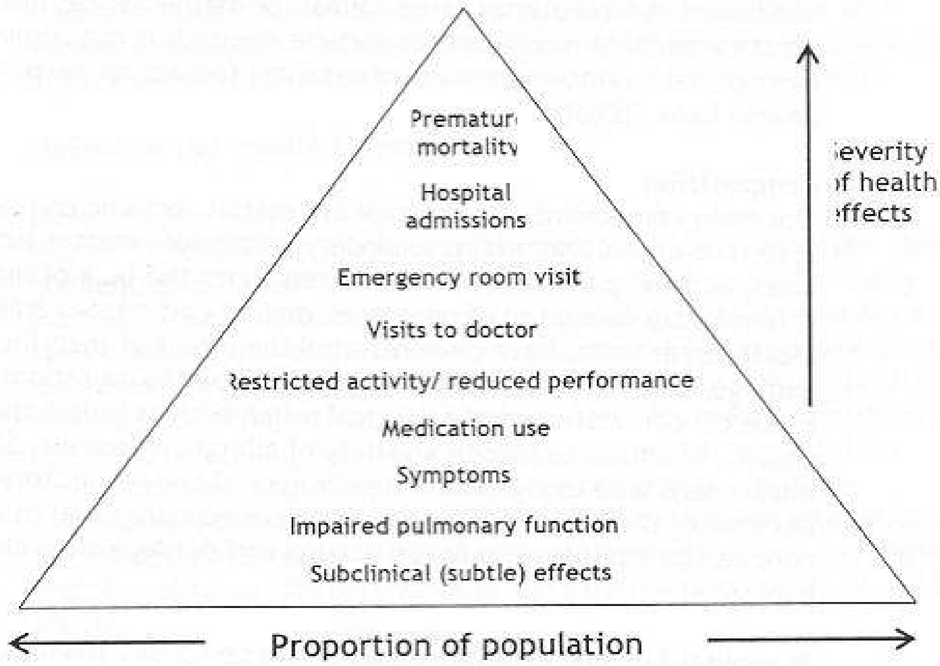
	as influenza
Carbon Monoxide	Fatal in large doses Aggravates heart disorders Effects central nervous system Impairs oxygen carrying capacity of blood
Ozone	Reduced lung function; airway inflammation; bronchoconstrictions; exacerbation of asthma Eye irritation
Lead	Extremely toxic: affects nervous system and blood; can impair mental development of children; causes hypertension
Benzene	Carcinogenic to humans; long-term exposure can result in bone marrow depression expressed in leucopenia and anemia; high concentration can result to structural and numerical chromosome aberrations.

Particulate Matter (PM):

There is strong evidence linking urban air pollution to acute and chronic illnesses and premature death, and these adverse health impacts in turn carry high economic costs to society. The evidence correlating air pollution and health impacts is especially strong for particulate matter (PM).

Why is PM so Damaging to Health?
Epidemiological studies from different parts of the world, conducted by different groups of researchers using different data sets and analysis techniques, have generated results that confirm the magnitude of PM health impacts. While a statistical association has been found between adverse health effects and PM_{10}, recent studies using $PM_{2.5}$ data have shown an even stronger association between health outcomes and particles in this size range. Evidence that smaller particles are more harmful is further supported by medical and toxicological research, which is increasingly focused on understanding the role of particle size (in the fine and ultrafine range) and composition in PM toxicity (World Bank, 2003b).

Figure 1: Air pollution and health effects pyramid



Size and number

Size determines how different particles deposit in different parts of the respiratory tract. Studies have shown that particles of different size vary in their respiratory tract deposition, movement, clearance, and consequent retention time in the human body. Ultrafine particles tend to behave more like gases and hence travel to the lower region of the lungs as compared to larger particles which tend to get deposited in the upper or middle region of the respiratory tract. Particles larger than about 10 microns in diameter are deposited almost exclusively in the nose and throat, whereas particles smaller than 1 micron are able to reach the lower regions of the lungs. The intermediate size range gets deposited in between these two extremes of the respiratory tract.

Ultrafine particles are highly toxic to the lungs, even when they comprise materials that are not toxic when present in larger particles. The mechanisms for toxicity of ultrafine particles are still under investigation, but several observations may be made. For a given mass, the number of particles and the total surface area increase dramatically with decreasing particle size. If toxic components are adsorbed on the surface of ultrafine particles, the level of interaction between the lungs and the surface of ultrafine particles is likely to increase with increasing surface area. It is not immediately clear, however, why the adverse impact of non-toxic particles should also increase with decreasing particle size and increasing surface area.

The particle size and particle number may be more relevant indicators than particle mass: the smaller the particle, the greater the fraction of particles deposited in airways and lungs, and the greater the surface area available for interaction with biological systems. Most of the research, however, on the role of particle size and number has been conducted in laboratories using animals or mathematical models. In practice ambient monitoring of particle numbers is not common; rather, most of the monitoring the world over still focuses on particle mass (World Bank, 2003b).

Composition

The main components of urban PM are metals, organic compounds, materials of biologic origin, secondary particulate matter (sometimes as ions), and the particle core which often forms the bulk of urban PM and is frequently composed of pure or elemental carbon. Several studies, mostly on animals, have demonstrated the effect of metallic PM on lung damage. Organic compounds are known to lead to mutations and even cause cancer. Materials of biological origin such as fungal spores and pollen are known to induce a variety of allergic responses. Sulfate and nitrate ions lead to significant impairment of the respiratory tract because of their acidic potential. Carbonaceous material in the particle core can by itself lead to lung irritation and damage after chronic exposure.

In general fine and ultrafine particles are composed mainly of particles with a carbon core that contains a variety of metals, organic compounds, and secondary particulates. The surface area of the elemental carbon core is considerably increased by its porous nature, greatly enhancing the adsorption probability of airborne substances such as organic compounds.

While particle composition is known to play an important role in inducing adverse health effects, much less is known about its role compared to that of particle size and mass. The strongest evidence of the role of particle composition comes from studies investigating the effects of metallic particles on health. More recently, studies have started focusing on the impact of organic compounds associated with fuel combustion, such as those contained in particles produced by diesel-powered vehicles.

A recent study by the U.S. Environmental Protection Agency (EPA) highlighted the likely cancer risk from diesel emissions, declaring it as a potential carcinogen. The diesel particles, many of which are smaller than 1 micron in diameter, have a carbonaceous core with a large surface area to which various organic compounds are adsorbed, including carcinogenic polycyclic and nitro-polycyclic hydrocarbons. Diesel particles have also been shown to adsorb allergens from grass pollen, thus potentially increasing allergen deposition in the respiratory tract. The composition of PM varies with factors such as the nature of sources and/or geographical location. For example, the particle composition in the northeastern part of the United States, which has a high concentration of coal-based thermal power plants, is dominated by secondary sulfate particles linked to sulfur dioxide emissions from the power plants. As a result, the health effects of inhaled particles may also be affected by their composition. This suggests that more epidemiological studies based on $PM_{2.5}$ and smaller particles with varying compositior are needed to see whether there is a significant impact of particulate composition on health (World Bank, 2003b).

Mechanism of Health Effects

Dose
While ambient concentrations are normally used as a proxy for linking ambient air pollution to health effects, it is the dose that actually matters. Dose is defined as the quantity of material that reaches a target. Knowledge of the dose of PM delivered to a target site or sites in the respiratory tract is important for understanding possible health effects associated with human exposure to ambient PM. The effect, however, of varying dose and potential duration of the effect are functions of the retention and clearance of particles from the respiratory tract, which in turn are affected by the characteristics of the inhaled particles (size, number, and composition) and the physical and physiological characteristics of the exposed population (World Bank, 2003b).

Lung defences
The adult human lung, with a surface area of 40-120 square meters, comes in contact with between 10,000 and 20,000 litres of ambient air daily. The lung has evolved a multilayered defence mechanism to counter inhaled particles, and it responds to particulate pollution with the same defence mechanism as it does to pollens and spores. The first layer of defence is a barrier of cells and fluids that the foreign matter must penetrate before it enters the tissues of the body. Fluid secretion, such as mucus lining the airways, is an important part of the first layer that essentially traps and removes the larger particles. Coughing, activated by the presence of particles, also helps in the removal process. If the particles infiltrate the first layer of defence, "scavenger" cells come into play. These cells ingest the particles and attempt to destroy them. If the burden of foreign matter overwhelms this line of defence, as can occur in response to inhaled particles, the lung defences may be weaker from subsequent attacks (World Bank, 2003b).

Specific health effects
The PM damage to lung defenses manifests itself in the form of health effects such as acute respiratory infection (both upper and lower respiratory tract infections), chronic obstructive lung disease (especially bronchitis), asthma attacks, cardiovascular disease, and lung cancer. Further, recent research has increasingly shown that particles can also affect other parts of the body, including the nervous system, by physically moving out of the airways and into the blood stream. Thus particle deposition in airways can set off a chain of events, potentially affecting parts of the body other than just the respiratory tract. As can be expected, the changes in the body are likely to be more severe in cases where the body's defences are already weak or previously

damaged. Hence, certain population subgroups, such as the elderly, children, and individuals with existing respiratory or cardiovascular diseases, are at increased risk from exposure to PM (World Bank, 2003b).

The science of health impacts of particulate matter is quite complex. After more than two decades of research, however, answers to some of the key research questions regarding the science of health effects of PM are beginning to emerge.

- While a large body of studies links adverse health effects to particles less than 10 microns in diameter (PM_{10}), the latest evidence strongly indicates that the fine (less than 2.5 microns) and ultrafine (less than 0.1 micron) fractions of PM are most harmful because of their ability to penetrate deeply into the lungs.
- Small particles with toxic materials adsorbed onto surface are especially damaging. Ultrafine particles, however, have been found to have adverse health effects even when they comprise substances that are not harmful when present in larger particles.
- For a given mass, the surface area and particle number increase dramatically as the particle size decreases. As a result, a smaller mass of PM_{10} which happens to consist primarily of ultrafine particles can be more damaging than a greater mass of PM_{10} but with a significant fraction falling in the coarse range.
- Certain plausible mechanisms by which PM affects human health have been identified, strengthening evidence from epidemiological studies.

Sulphur Dioxide (SO_2):

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

Exacerbation of symptoms among panels of selected sensitive patients seems to arise in a consistent manner when the concentration of SO_2 exceeds 250 $\mu g/m^3$. At low levels of exposure (mean annual levels below 50 $\mu g/m^3$; daily levels usually not exceeding 125 $\mu g/m^3$) effects on mortality (total, cardiovascular and respiratory) and on hospital emergency admissions for total respiratory causes and chronic obstructive pulmonary disease (COPD), have been consistently demonstrated.

Nitrogen Dioxide (NO_2):

As a class of compounds, the oxides of nitrogen are involved in a host of environmental concerns that adversely impact human health and welfare. Nitrogen dioxide (NO_2)has been linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics, and decreased pulmonary function. It has been shown that even short-term NO_2 exposures have resulted in a wide-range of respiratory problems in school children; cough, runny nose and sore throat are among the most common.

Nitrogen oxides (NOx) also contribute to acid deposition, which damages trees at high elevations and increases the acidity of lakes and streams, which results in severe damage to aquatic life. Finally, NOx emissions can contribute to increased levels of particulate matter by changing into nitric acid in the atmosphere and forming particulate nitrate (ADB, 2003).

Carbon Monoxide (CO):

Carbon monoxide (CO) - an odourless, invisible gas created when fuels containing carbon are burned incompletely - poses a serious threat to human health. Fetuses and persons afflicted with heart disease are especially at risk. Because the affinity of blood haemoglobin is 200 times greater for carbon monoxide than for oxygen, CO hinders oxygen transport from the blood into the tissues. Therefore, more blood must be pumped to deliver the same amount of oxygen (ADB, 2003).

Carbon monoxide, which is mainly emitted from petrol vehicles is quickly absorbed by the lungs and carried in the blood. When it reaches the lungs, it is being absorbed by haemoglobin to form carboxy-haemoglobin, results in reduction of bloods purity. At high concentrations, CO is toxic and can be fatal. CO impairs the oxygen carrying capacity of the blood and as a result, organs like 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 due to cardiovascular diseases (WHO, 2000).

Ozone:

Short term exposure to high concentration of ground level ozone concentration aggravates pre-existing respiratory diseases such as asthma and increase hospital admission and emergency room visits for respiratory distress (WHO, 2000). Ozone also causes eye, nose and throat irritation.

Lead:

Over the past century, a range of clinical, epidemiological and toxicological studies have continued to define the nature of lead toxicity, to identify young children as a critically susceptible population, and to investigate mechanisms of action of lead toxicity. In summary, lead effects many organs and organ systems in the human body, with sub-cellular changes and neurodevelopmental effects appearing to be the most sensitive. The most substantial evidence from cross-sectional and prospective studies of populations with lead levels generally below 25 µg/decilitre of blood relates to decrements in intelligence quotient (IQ).

Existing epidemiological studies do not provide definite evidence of a threshold. Below the range of about 10-15 µg/decilitre of blood, the effects of confounding variables and limits in the precision of analytical and psychometric measurements increase the uncertainty attached to any estimate of effect. However, there is some evidence of an association below this range. Animal studies provide support for a causal relationship between lead and nervous system effects, reporting deficits in cognitive functions at lead levels as low as 11-15 µg/decilitre of blood, which can persist well beyond the termination of lead exposure (ADB, 2003).

Benzene:

Benzene is known to be carcinogenic to humans and no safe level of exposure has been recommended. The most significant adverse effect of benzene on human beings has been characterised as haematotoxicity, genotoxicity and carcinogenicity. Long-term benzene exposure can result in bone marrow depression expressed in leucopenia and anaemia. Similarly, it has also been found that high benzene concentration can result to structural and numerical chromosome aberrations.

Health based air quality guidelines

World Health Organisation (WHO) has prepared a guideline value for the major air pollutants that effects the human health.

Following are the guidelines for major air pollutants:

1. It is recommended that a value of 500 µg/m^3 should not be exceeded over averaging periods of 10 minutes for SO_2.
2. A one-hour guideline of 200 µg/m^3 is proposed by the WHO for NOx.
3. The guideline value for CO are 100 mg/m^3 for 15 minutes, 60 mg/m^3 for 30 minutes, 30 mg/m^3 for 1 hour and 10 mg/m^3 for 8 hours.
4. A guideline value for ambient air of 120 µg/m^3 for a maximum period of eight hours per day has been established for ground level Ozone.
5. Long term average exposures to low particulate matter levels, starting at about 10 µg/m^3 of fine particulate matter (PM_{10}), were associated with reduction in life expectancy. WHO has realised that the available information does not allow a judgement to be made of concentrations below which no effects would be expected. Thus the WHO has not set any guideline value to PM_{10}.

Source: WHO, 2000

1.2.4 National ambient air quality standard - Nepal

MoPE/ His Majesty's Government of Nepal (HMG/N) has set national standard for 7 major air pollutants in the ambient air. The ministry aims to meet this National Ambient Air Quality Standard (NAAQS) in case of all air pollutants within three years from the time of enforcement, which was June 2003. Detail of the standard is presented in Table 5.

Table 5 : National Ambient Air Quality Standards 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
		24-hours	-	

Source: Ministry of Population and Environment, 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 8am - 10am or 3pm - 6pm 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.

2. Air pollution and health impact studies in Nepal

This chapter describes the previous studies on urban outdoor air pollution and its health implications in Nepal conducted by various institutions. However, there has been very few studies on the health implications of urban outdoor air pollution. Out of which, almost all of these studies have been done for Kathmandu valley. There has been few studies on the impact of indoor air pollution on human health in rural part of the country.

LEADERS Nepal conducted a survey of air pollution among children in Kathmandu based on the secondary data collected from Kanti Children Hospital, the only public hospital of children in Kathmandu. Cases like pneumonia, URTI, ARI, Asthma, Bronchitis, Chest infection, LRTI, Koch disease, wheezing cough and chest and Post measles pneumonia was considered for analysis. Both indoor and outdoor patients for the year 1996/97 were used for the analysis.

From the preliminary screening of medical records from the hospital it had been found that urban residents exceeded the number of respiratory related cases in the hospital compared to that from the rural areas from Kathmandu.

2.1 The World Bank Study

The World Bank in 1997 conducted a detail study on different aspects of air quality management of Kathmandu valley under the Urban Air Quality Management Strategy in Asia. The report also assessed health impact due to urban outdoor air pollution in Kathmandu especially due to PM_{10}. It has estimated health impacts using dose-response relations derived in US and air quality model developed for Kathmandu Valley. Key data are excess mortality totalling 85 cases, and the number of respiratory symptom days at about 1.5 million.

According to the study, valuation of health impacts due to the PM_{10} in Kathmandu's air was over NRs. 200 million in 1990. It was also estimated that among the sources of air pollution, traffic sources (exhaust emissions and resuspension) might have the largest impact on health. The study has found the health impact in Kathmandu valley due to PM_{10} as presented in the table 6. The study revealed that PM_{10} in Kathmandu's air has a major impact on respiratory diseases.

Table 6 : Health impacts due to PM_{10} in Kathmandu Valley

Types of Health Impact	Number of Cases
Excess Mortality	84
Chronic Bronchitis	506
Restricted Activity Days	475298
Emergency Room Visit	1945
Bronchitis in Children	4847

Asthma	18863
Respiratory Symptom Days	1512689
Respiratory Hospital Admissions	99

Source: World Bank, 1997b

2.2 Kathmandu Electric Vehicle Alliance (KEVA)/(CEN & ENPHO)

A study conducted by Clean Energy Nepal (CEN) and Environment and Public Health Organisation (ENPHO) for KEVA in September 2003 entitled "Health Impacts of Kathmandu's Air Pollution" revealed that reduction of $PM_{2.5}$ level in Kathmandu by half of the existing (by 47.4 $\mu g/m^3$), will result in reduction in daily mortality by 7 percent and hospital admissions by 24 percent. Similarly, the study suggested that reduction in the annual average PM_{10} level in Kathmandu to international standard (50 $\mu g/m^3$) will avoid over 2000 hospital admissions, over 40,000 emergency room visits, about 135,000 cases of acute bronchitis in children, over 4,000 cases of chronic bronchitis and half a million asthma attacks. The study further found out that the number of COPD patients admitted to three major hospitals in Kathmandu as well as the percent of COPD patients as a percentage of total medical patients has increased significantly in the last ten years (CEN/ENPHO, 2003).

2.3 NHRC/NESS

Nepal Environmental & Scientific Services (NESS) Pvt. Ltd. has indicated in a study entitled "Determination of Health Risk Effects of PM_{10} on Residents in Major Urban Areas, Specially Women and Children" carried out for Nepal Health Research Council that based on the available database on air quality, in Kathmandu valley nearly 9.133 children of age less than five years die prematurely due to the PM_{10}. Similarly, about 65000 cases of respiratory problems related to PM_{10} occur annually in Kathmandu with the worth over NRs. 30 to 35 million as a direct economic cost (NHRC/NESS, 2001).

2.4 Clean Energy Nepal (CEN), Health Impact due to Brick Kilns

Air pollution caused by brick kilns situated within the Kathmandu valley has adverse impact on the health of local people. The PM_{10}, emitted from these brick kilns has direct relation to the human health, as these particulates are small enough to pass through the nose and enter the respiratory system causing problems such as asthma and bronchitis. To assess the health impact due to these brick kilns, a health check-up conducted under a study "*Environmental and Health Impacts of Kathmandu's Brick Kilns*" carried out by Clean Energy Nepal. The health check up programme showed that young children studying at High View School, located next to the kilns in Tikathali, suffer more from respiratory problems than students at Valley Public School in Lamatar, which does not have brick kilns in its immediate vicinity. When a doctor examined over 100 children, under the age of five, in these schools, only 3.85 percent of the examined children at Valley Public School showed signs of abnormality of lower respiratory tract, where as in High View School, this number was 50.85 percent (Tuladhar and Raut, 2002).

2.5 JICA study

A research carried out by the Japanese International Cooperative Agency (JICA) has shown that 10 to 20 percent of the people living in the city areas of the Kathmandu valley are suffering from asthma. Similarly, about 30 percent of the people in the Himalayan region also suffer from asthma, according to a research conducted a few years ago by Mrigendra Health Clinic. The reasons for this are that the people use firewood to cook food and to keep their houses warm. The research carried out in different parts of the Himalayan region found that smoke and cold are the main causes of asthma in the cold places. In urban areas, vehicular emission, air pollution and congestion could cause this disease, while fire, smoke, dust, and smoking habit give rise to it in rural areas (The Rising Nepal, 2003).

3. Methodology

This chapter provides information on the methodologies used in this study. In case of air quality data, we have conducted monitoring in two cities outside Kathmandu valley for two different seasons. However, in case of Kathmandu, there is air quality monitoring system present and we have used the data for analysis.

To assess the health impacts due to air pollution, we have used WHO's recent guideline to assess burden of disease due to outdoor air pollution. Chapter 8 provides detail about the methodology to assess the burden of disease and in chapter 9, we have tried to use the methodology in case of Kathmandu valley due to outdoor PM_{10}. We have not done assessment for cities outside Kathmandu valley due to lack of annual average data as our monitoring in these cities was only for two times at a particular site and that does not represent the annual average value.

3.1 Desk study - literature review

Within the allocated time of the study period, different national as well as international studies have been reviewed. Main purpose of the literature survey was to gather the previous scattered study on health impact due to air pollution in Nepal's urban areas and also to choose a appropriate model to quantify the health impact due to air pollution. Similarly, as the environmental burden of disease due to the outdoor air pollution is relatively new issue, international studies was an asset to this study for further direction.

In case of Kathmandu, as there is already a mechanism to monitor ambient level of air pollution in six different locations, the secondary data generated from these stations were used to calculate the health impact due to air pollution and give a view on level of ambient air pollution.

3.2 Field study - air quality monitoring

To quantify the ambient level of air pollution in selected urban areas of Nepal, ambient air quality monitoring has been conducted in two different season, one during rainy season and another during post rainy season. Emphasis was given for the out of Kathmandu study as there are very few such studies exits on outside Kathmandu cities.

Major urban air pollutants namely; Particulate matter of size less than 10 micro meter (PM_{10}), Total suspended particulate matter (TSP), Soot, Carbon monoxide (CO), Sulphur dioxide (SO_2) and Nitrogen dioxide (NO_2) were monitored in two cities, namely Pokhara and Birgunj; one located in midhills and another in terai region of the country.

Methodology of the air quality monitoring

Three air quality monitoring spots were selected in each city which were the high traffic area, industrial area and residential cum commercial area within the city. Likewise to identify the variation on air quality depending on the season, it was decided to monitor the ambient air quality of these two cities in two distinct seasons. Consequently air quality monitoring was carried-out at two seasons one at the post monsoon season and another at post winter season. Twenty-four hours air quality monitoring in each spot was carried out for all air pollutants except carbon monoxide, which was monitored for fifteen minutes especially during rush hour of the day. These monitoring were conducted at ground level and at respirable height. The methodology adopted for these six-air quality detriments are given below.

PM_{10}: PM_{10}, the most significant health parameter was measured by the use of High Volume Air Sampler (Envirotech). Known volume of ambient air was sucked at constant rate through an ignited, conditioned and weighted glass filter. Based on the aerodynamic principle, the particles of respirable size were collected in filter. After twenty-four hours sampling, the filter was again conditioned in laboratory atmosphere for forty-eight hours and weighted again. From the increased in filter weight and the total volume of the air sucked, the levels of the thoracic dust were calculated.

Total Suspended Particulates (TSP): Depending on the size of particles, the high volume air sampler is capable to separate out the coarse particles and the respirable one. The non-respirable particles were simultaneously collected in a special cup at the moment of PM_{10} collection. The quantity of the collected dust was then estimated gravimetrically. From the weight of the non-respirable particles, the level of non-respirable particles in the atmosphere was found out. The summation of the both respirable and non- respirable particles concentration gives the level of total suspended particles (TSP).

Soot: Estimation of the soot was made in the respirable dust (PM_{10}). The glass fibre filter after estimating the PM_{10} was ignited at 500^0C for one hour. The ignited filter, after cooling and conditioning was weighted again in order to find out the loss of weight during ignition. The loss of weight along with the volume of air sucked gives the level of volatiles (mostly soot) contained in the atmosphere.

Carbon Monoxide (CO): Estimation of the existing intermittent CO level of particular spot was made by the use of indicator Doppler tube. Ambient air was sucked through the calibrated indicator tube for fifteen minutes with fixed rate of suction. After fifteen minutes of suction, the developed colour on tube was compared with the standard colour chart to identify the level of CO.

Sulfur Dioxide (SO_2): Level of sulfur dioxide in ambient air was estimated by West and Gake method. In this method air was bubbled through an absorbent solution i.e., sodium tetrachloratemercurate (TCM) solution. Sulfur Dioxide is absorbed by TCM solution taken in an impinger to form a complex, which on treating with pararosiline and formaldehyde forms intense red- violet colour. The intensity of the developed colour is measured using spectrophotometer at wavelength 560nm. From the obtained absorbency, the concentration of sulfur dioxide in sample is determined.

Nitrogen Dioxide (NO_2): Nitrogen Dioxide from air is absorbed by alkaline solution of sodium arsenite (Absorbent) where it forms sodium nitrite which on treating with sodium peroxide, sulphanilamide, and N-(1-naapthyl) ethylenediamine dihydrochloride (NEDA) solution develops red colour. The intensity of the developed colour measured spectrophotometrically at 540 nm. From the measured absorbency, concentration of the analyte is determined.

3.3 Environmental burden of disease due to outdoor air pollution

To assess health impact due to urban air pollution, especially due to PM_{10} environmental burden of disease concept was used. EBD was calculated using the relation developed by Dr. Bart Ostro in "*Outdoor air pollution: Assessing the environmental burden of disease at national and local levels* ". See chapter 8 for detail of the guideline and chapter 8 for the application in Kathmandu valley.

3.4 Expert consultation (National as well as International)

Different national as well as international experts were consulted during the study period for the ambient air pollution and its health impact modalities, literatures. Similarly, consultations was also done with the medical doctors regarding the health impact of urban air pollution.

3.5 Analysis of air pollution related disease records

Annual report of the Department of Health Services has been reviewed for the records of number of people suffered from air pollution related diseases. Acute Respiratory Infection (ARI) data of Kathmandu valley (Kathmandu, Lalitpur and Bhaktapur) has been analysed in yearly trend.

Hospital records was also analysed to see the number of patients admitted to the hospital suffering from air pollution related diseases, specially COPD. Similarly, past records were also seen to witness the trend of the air pollution related patient admission.

4. Scope and limitations of the study

4.1 Scope of the study

There has been very few studies on status of urban air pollution in cities outside Kathmandu valley. However, still these studies did not conducted the monitoring for 24 hours (which is standard time). To fill this gap, we decided to monitor the air quality parameters for 24 hours and for two seasons. Previous studies have shown that there is variation in the pollutants concentration seasonally. Although, air quality monitoring was done for only two times and one day in site, this study helps to get the picture of ambient air quality of cities outside Kathmandu, namely Pokhara and Birgunj.

This study also aims to give a view on health impact of outdoor air pollution in Kathmandu valley. This type of research is first of its kind using the EBD concept for health impact study in Nepal, which is an emerging issue to work on environmental health policy is most of the countries. This study will be a guide to further studies to be carried out using burden of disease concept in case of outdoor air pollution and give a way how we should proceed on such studies.

Outcome of this study will be useful for the policymakers working in health as well as urban air pollution sector while formulating country's plans and policies. This study will also be useful for academics, journalists and students, among others.

4.2 Limitations of the study

There were following limitations to the study.

1. Although, it was intended to monitor outdoor air pollution in major urban areas of Nepal, we could only monitor the air quality for two cities outside Kathmandu valley due to budget limitations.
2. Even the monitoring was limited to three days in each city for a season. Averaging those data could not give a picture of the air quality of the city and compare it with other city like Kathmandu.
3. To conduct a detail health impact study, the allocated 5 months for the study was not enough.
4. There were not proper database of hospital records outside Kathmandu.
5. To find out the EBD, we had to used the risk factors developed elsewhere as in case of our country we did not have any detail epidemiological studies on impact of outdoor air pollution.
6. Due to the two time monitoring only, we could not be able to come-up with annual average in cities outside Kathmandu valley. Therefore, as the burden of disease concept requires annual average of air pollutant, we could not assess the burden of disease for cities outside Kathmandu valley.

5. Assessment of Ambient Air Quality outside Kathmandu valley

This chapter describes the assessment of air quality in cities outside Kathmandu valley. Air quality monitoring was carried out in two cities of the country, namely Pokhara and Birgunj. Pokhara is a city situated in mid-hills of country whereas Birgunj is situated in Terai plain lands.

For the representative sampling from the urban areas, two cities outside Kathmandu valley was chosen; one of which was in terai land and another in midhills. Similarly, for the air quality data to be comparable with the national standard, 24 hour monitoring was carried out. Similarly, three sites were chosen again to make the representative sample; first in busy road, second in industrial and third in residential area.

5.1 Air Quality Monitoring outside of Kathmandu (Birgunj and Pokhara)

Estimation of the levels and types of pollutants prevailing in a particular area requires the monitoring of air quality parameters. Thus, air quality monitoring is the main source of information in assessing the exposure of the population to ambient air pollution. Particularly, either the complete lack of such air quality information or paucity of relevant data outside of Kathmandu, it is being impossible to assess the air qualities impacts elsewhere than Kathmandu. Consequently, to assess the ambient air quality of the urban centres of the Kingdom; air quality monitoring was carried out within the Birgunj and Pokhara cities of the country.

Furthermore, the air quality of a particular environment can be varied severely depending on the prevailing metrological conditions and season; despite the sources of pollution and their emission factors remain the same. Thus, the air that meets the set standards at one season or time may not comply at another season or time. Hence it is necessary to identify the variation in air quality of any environment at different seasons in order to investigate the average annual exposure of the population or to state the average air quality of a specific environment.

To identify the air quality of Pokhara and Birgunj cities, air quality monitoring was carried out at two different seasons, once at the post monsoon season, which was conducted from October 15 to October 25, and another at post winter season that was conducted from February 14 to 22. Total six classical air quality pollutants were under investigation during these monitoring which were PM_{10}, TSP, Soot, NOx, SOx, and CO.

5.2 General Description of the Monitoring Cities and Locations

The weathers conditions and the dominant sources of pollution those were prevailed during the monitoring in each spot briefly described below.

Birgunj

Birgunj is the city situated in the Terai plains of Nepal, at the close proximity of Indian border. This strategic location makes Birgunj a frequent destination for business travellers, executives of foreign projects and agencies, overland tourists, pilgrims and other visitors. There is a dry port being constructed in Birgunj at present. It signifies the importance of Birgunj as a strategic trade and transit junction between Nepal and India, and elsewhere also. It is also a rapidly growing industrial city and has been playing an active role in the economic development of the country.

Birgunj not only is the headquarter of Parsa district but also is of the Narayani Zone of Nepal. The city exhibits temperate type of climate. Max. 37^0 C in summer and 8^0 C in winter. The latest population census indicates that the current population of this city is about 200,000.

To assess the ambient air pollution of the Birgunj city, three air quality-monitoring spots were selected with in the city, which were Bhanuchowk, Addarsha Nagar and Ranighat. The general descriptions of the monitoring locations are as follows:

a) **Bhanuchowk:** This spot represents the heaviest traffic areas of the city. Indeed, this is the bus park area and all busses for different destinations of the country departure from here. The traffic density is high in this spot and the dominant vehicles fleeting during monitoring were buses, trucks, minitrucks, light vehicles and motorcycles. Considerable numbers of Riksha and Tanga were also plying in this spot. The weather during monitoring period was clean and sunny. The observed temperatures in post monsoon were ranged from 24^0 C to 37^0 C whereas in the post winter seasons it was ranged from 19-34^0 C. Most of time the ambient air was remained stagnant and mild air was observed only for sometimes during monitoring. The dominant source of the pollution in this area was the vehicles. Both the emission as well as the resuspension of the fugitive dust generated by the fleeting vehicles significantly contributed for the observed levels of TSP and PM_{10} in this location.

b) **Ranighat:** This area represents the industrial area with in the sub-metropolis where a number of rice mills are located. The road of this area is unpaved and dusty. The major modes of transport of this area were Riksha, Tanga, truck and tractor. The minimum temperature observed during monitoring at post monsoon was 24^0 C and that of maximum temperature recorded was 35^0 C. Similarly the observed temperature at later season was ranged from 20-33^0 C. A mild wind was experienced during most of the monitoring time at this location that was blown west to east. The days during both monitoring periods were clean and sunny. The dominant sources of air pollutants in this area were the emission from the rice mills, vehicles and resuspension of the road dust. Various activities such as loading and unloading of the rice and its husks also contributed considerably for the observed TSP and PM_{10}.

c) **Addarshanagar:** This area represents the commercial/residential area of the city. Various commercial activities of the city are concentrated in this area. Moderate type of vehicular movement was observed during monitoring. The major type of vehicles that were fleeting in this area were buses, light vehicles and motorcycles. Riksha was the most dominant mode of transport for the people of this area. The maximum temperature observed during post monsoon was 34^0 C whereas the minimum it was 23.5^0 C. In the post winter season observed temperature data indicates that the ambient temperature of this location was varied from 20-33^0 C. Clean and sunny weather was prevailed in both monitoring periods. Except a mild wind blowing sometimes, most of the time the atmosphere was quite calm during both monitoring. Vehicular emission and the fugitive dust emission from the road were the dominant sources of the air pollution. Various commercial activities prevailing in this area were also responsible to hike the pollution level.

Pokhara

Pokhara, a major tourist destination of Nepal, located at the middle part of the country. The Pokhara valley stands on an elevation of about 827 meters above sea level. Besides of its natural beauty, Pokhara is famous for mountain views, and is a gateway to one of the most famous trekking areas, the Annapurna Region.

But due to the rapid urbanisation, Pokhara, a scenic valley, is being environmentally deteriorated. Population growth is a major challenge here. In recent years, urban population in Pokhara is growing at the rate of 8 percent per year. Such high urbanization rate causing over pressure on natural resources, infrastructure and land thereby creating various environmental problems in this city. Air pollution is one of the major environmental problems of this beautiful city experienced in recent years.

To investigate existing ambient air quality of this beautiful city, air quality monitoring was carried out at three locations, which were Mahendrapool, Industrial estate and Lakeside. The brief description of these three locations is made below:

a) **Mahendrapool:** This is one of the heavy traffic areas of the city. This area is not only the high traffic area but also is a major commercial area of the city too. Considerable numbers of vehicles fleet in the roads of this area. Dominant vehicles of this area were buses, minibuses, cars, jeeps, vans and motorcycles. As far as the prevailing weather condition is concerned, the weather at post monsoon season was fine and sunny whereas in the post winter it was cloudy and partial raining. The maximum temperature observed during post monsoon season was 29^0 c and the minimum temperature observed was 16^0 C. Similarly the maximum temperature recorded during post winter season was 25^0 C whereas the minimum it was 11.5^0 C. Moderate wind was blowing at most of the time however the wind direction was not unidirectional. The major sources of pollution were the vehicular emission as well as the resuspension of the road dust by vehicles. Beside that the burning of the waste residue and other commercial activities were also responsible for the air pollution.

b) **Industrial Estate:** This spot is located within the industrial estate and from the vicinity of which the Prithivi highway passes. There are all together 72 industries of all kinds ranging from food processing , textile; constructional and paper are located within this estate. During post monsoon season the temperature recorded was ranged from 16.5-29.5 ^{0} C whereas the temperature recorded at post winter season was between 13-25^0 C The weather in both season was clear and sunny, however, it was rain just two days earlier of the monitoring day in post winter season. The major sources of the pollution were the industrial emission as well as the vehicular emission from the nearby highway.

c) **Lakeside (Halchowk):** This is the tourist area of the city and various commercial activities related to tourism are concentrated in this area. Comparatively very less number of the vehicles was observed from this area. Light vehicles, motorcycles and city buses were the dominant fleeter on the road. The temperature during post monsoon was varied from minimum of 16 to maximum of 28.5^0 C whereas the temperature at post winter season was 13-22^0 C. The weather was clean and sunny. Moderate air was blown in most of the monitoring time of the post monsoon season. The major sources of pollution in this area were the domestic fuel burning, vehicular emission and other commercial activities.

5.3 Air quality monitoring data

To assess the ambient air quality, air quality monitoring in two different seasons were conducted at three spots in each city. The spots selected for Birgunj were Bhanuchok, Rajghat and Addarsha Nagar whereas the spots selected for Pokhara were Mahendrapool, Industrial estate and Hall Chowk (Lakeside). The data for PM_{10}, TSP, Soot, NOx, SOx, and CO obtained from the monitoring conducted in post monsoon season for the ambient air of Birgunj and Pokhara cities is depicted in table 7. Similarly the data obtained from the air quality monitoring at post winter season is depicted in table 8.

Table 7: Air Quality Monitoring Result (Post Monsoon)

Parameters	Unit	Sample ID					
		1	2	3	4	5	6
TSP	(μg/m³)	1099.1	1612.5	572.2	438.0	487.1	312.5
PM_{10}	(μg/m³)	303.0	332.8	179.1	145.1	149.3	101.2
SO_2	(μg/m³)	2.65	1.49	0.48	0.87	0.36	0.17
NO_2	(μg/m³)	16.38	9.18	8.13	10.52	5.98	7.59
CO	(μg/m³)	3584	1792	896	1792	896	<896
Soot	(μg/m³)	154.2	144.8	87.9	50.8	64.5	45.5

Table 8: Air Quality Monitoring Result (Post Winter)

Parameters	Unit	Sample ID					
		1	2	3	4	5	6
TSP	(μg/m³)	1466	1252	521	620	300	306
PM_{10}	(μg/m³)	457	384	261	185	111	117
SO_2	(μg/m³)	3.71	<0.3	0.32	0.66	<0.3	0.45
NO_2	(μg/m³)	4.53	1.82	2.41	2.40	1.18	<0.8
CO	(μg/m³)	1792	896	896	1792	896	<560
Soot	(μg/m³)	231	182	178	74	39	60

Where:

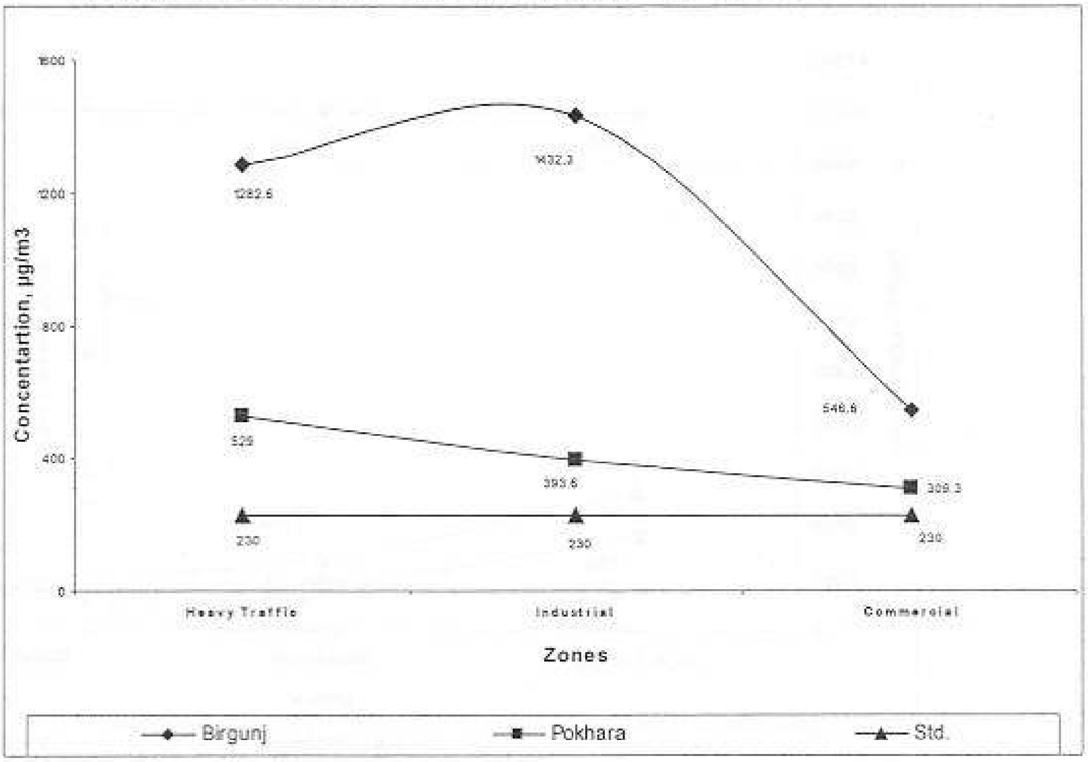
1 = Bhanuchowk (Birganj) 2 = Ranighat (Birganj)
3 = Adarshanagar (Birganj) 4 = Mahendrapul (Pokhara)
5 = Ind-Estate (Pokhara) 6 = Hall Chowk, Lakeside (Pokhara)

5.4 Assessment of the air quality of Birgunj and Pokhara

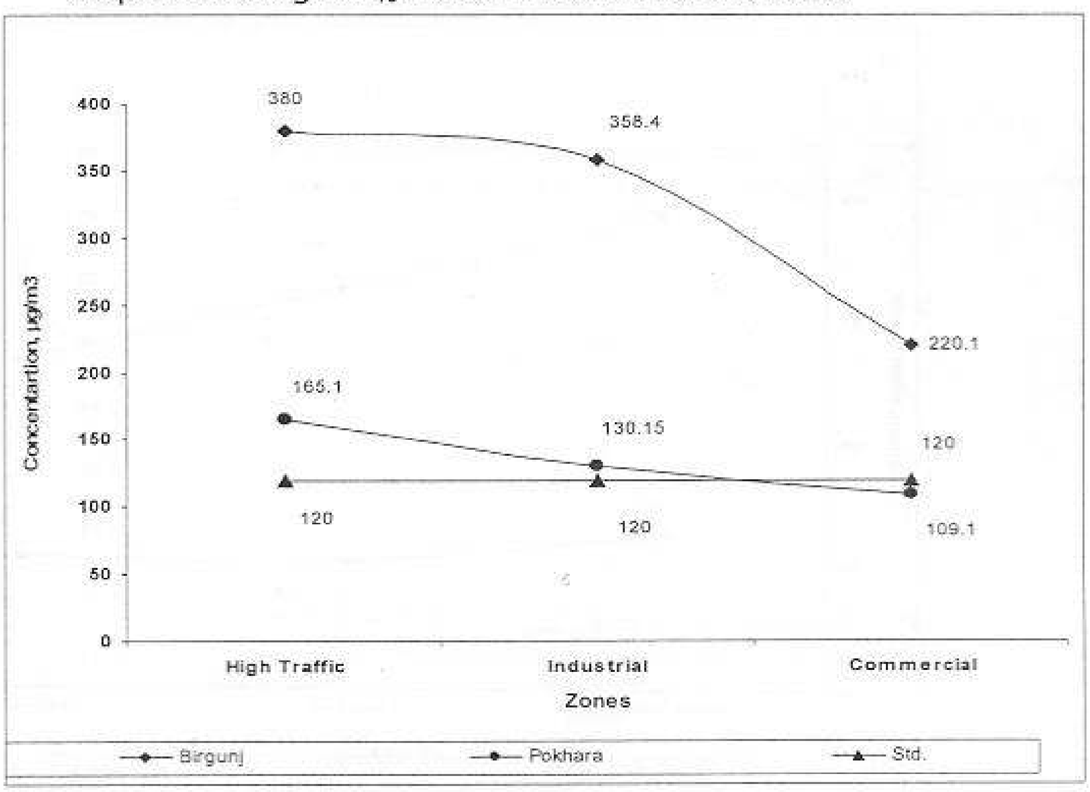
Based on the air quality data obtained from these monitoring, assessment of the prevailing air quality of these two cities and their possible implications are made here.

5.5 Air quality data analysis - with reference to sampling site

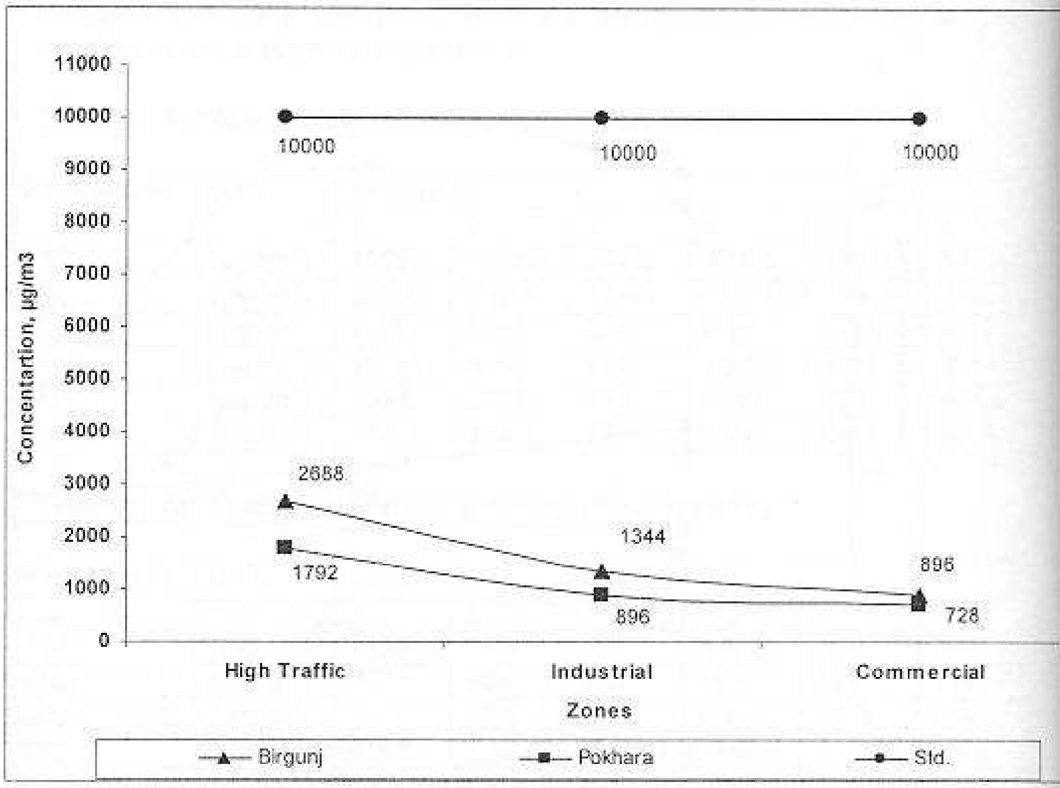
Graph 1 : Average TSP Concentration in Various Zones



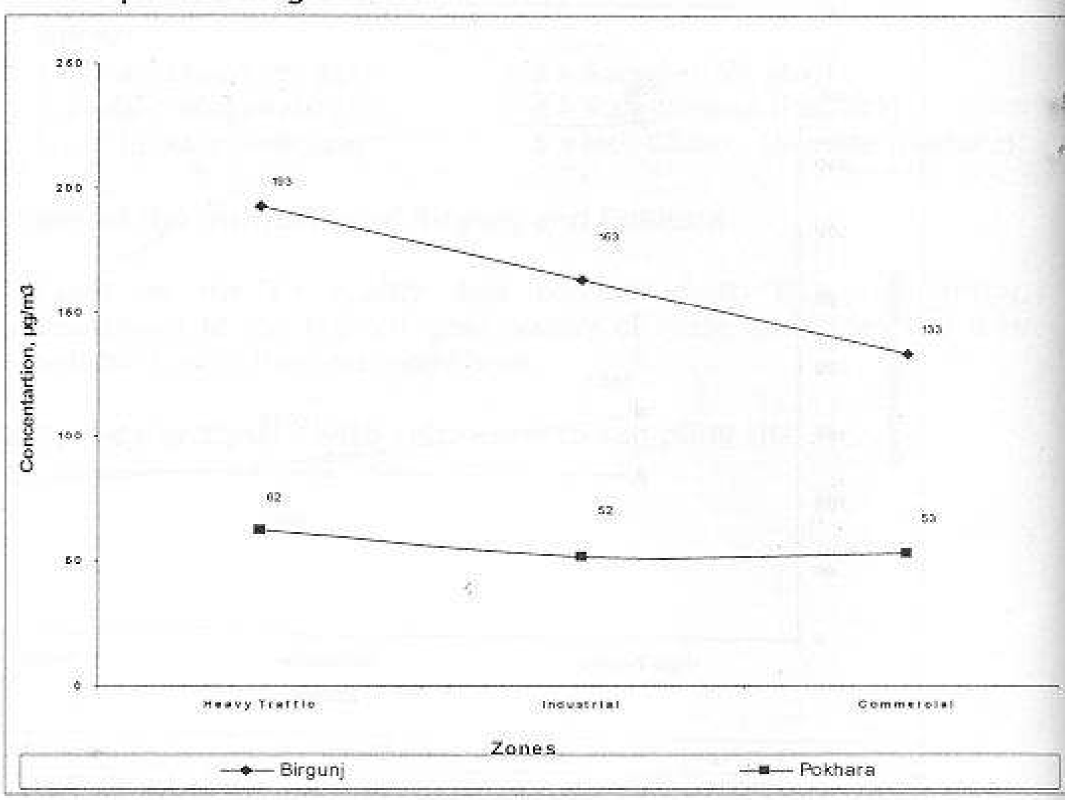
Graph 2 : Average PM_{10} Concentration in Various Zones



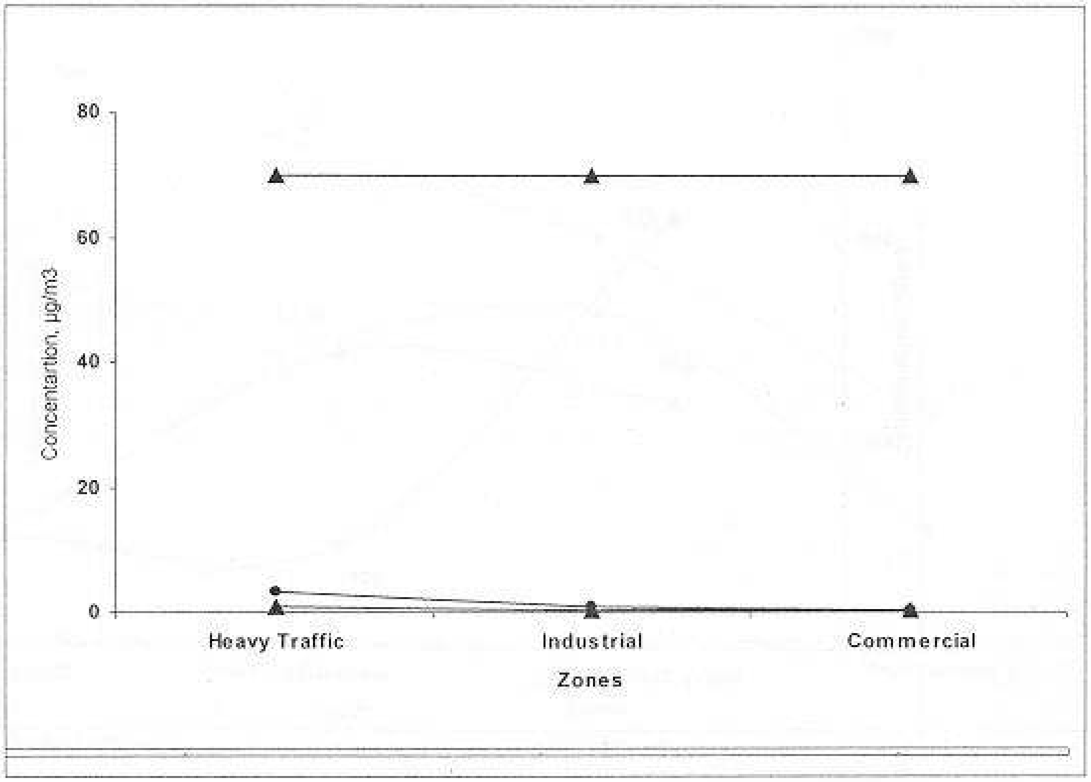
Graph 3 : Average CO concentration in Various Zones



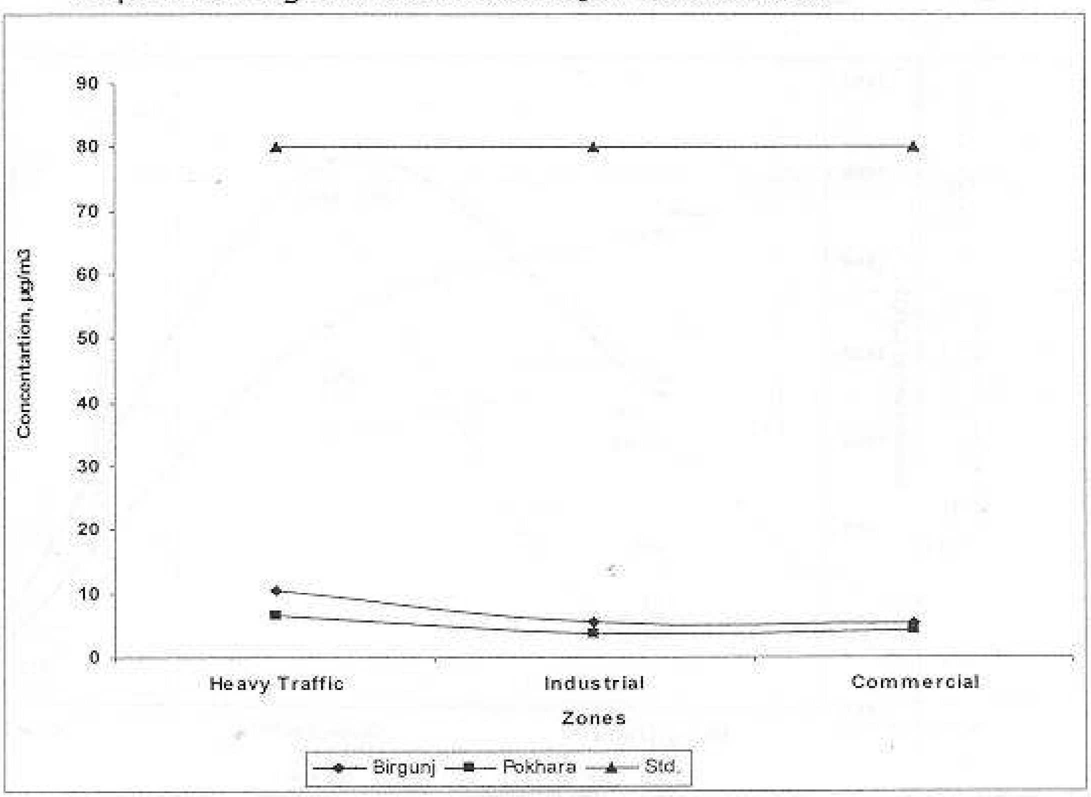
Graph 4: Average Soot Concentration in Various zones



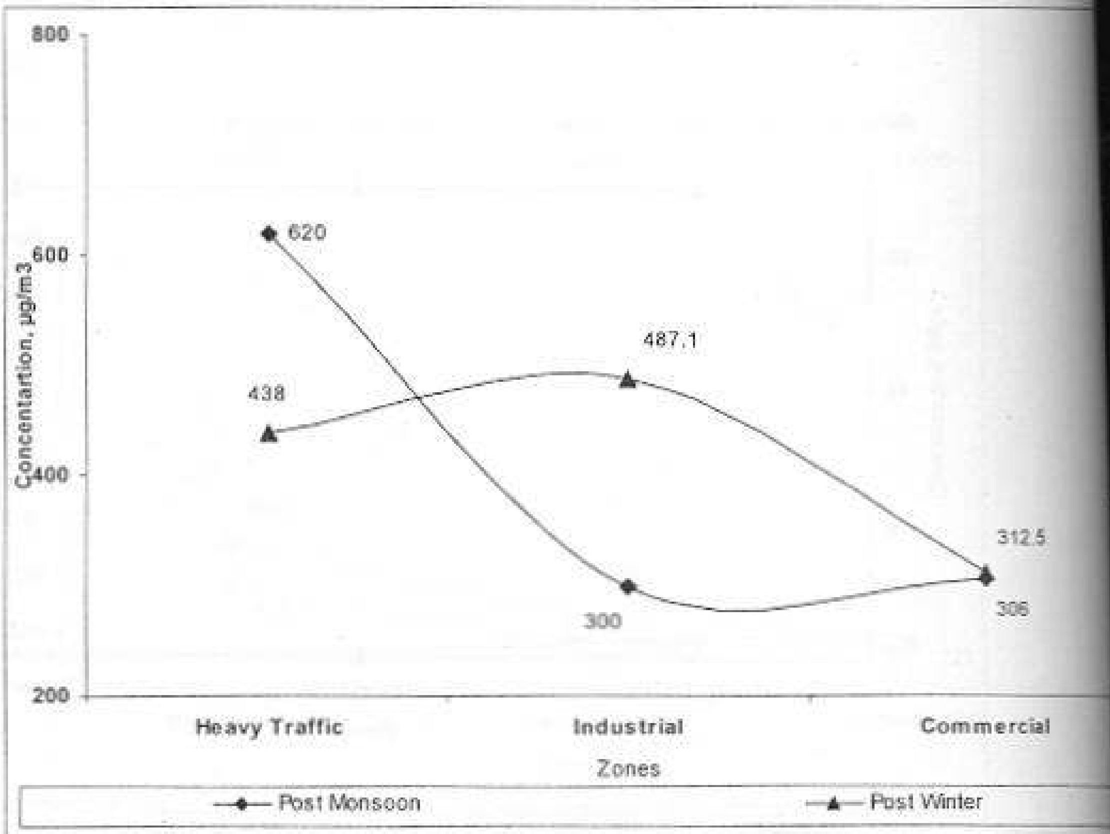
Graph 5: Average SO_2 Concentration in Various Zones



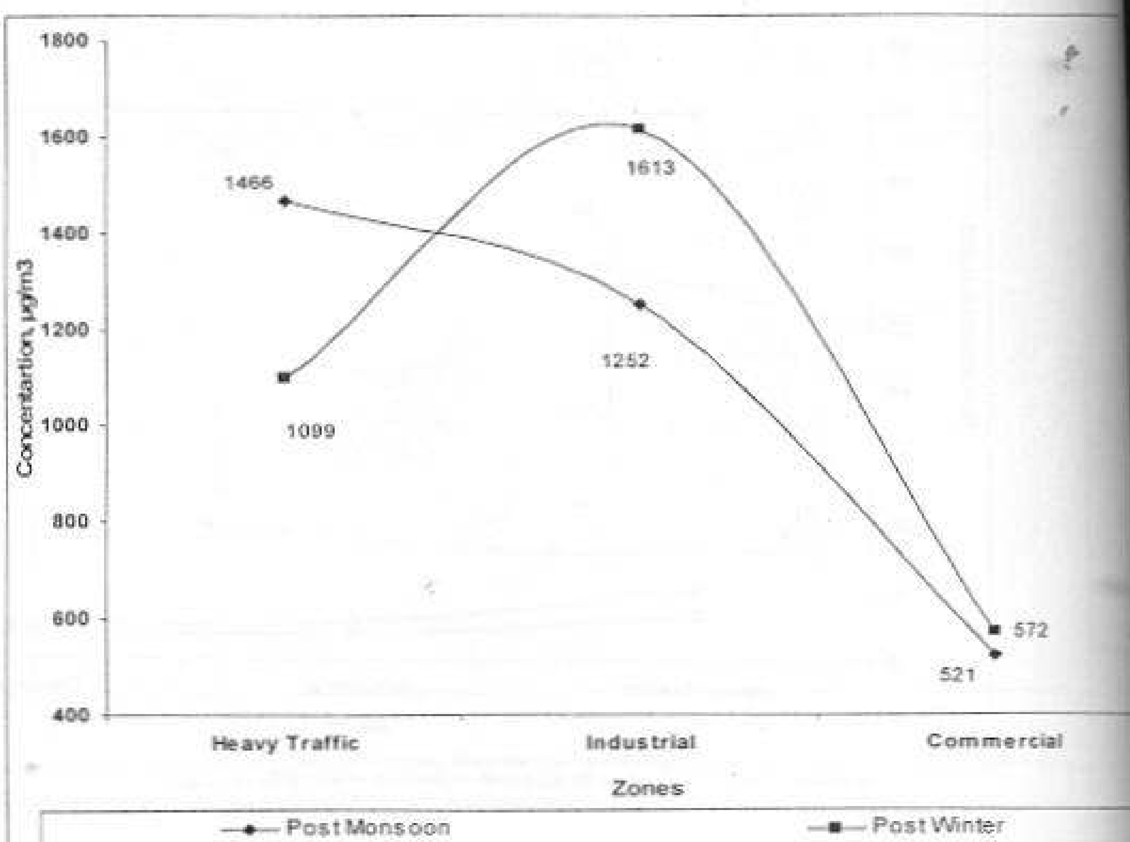
Graph 6: Average Concentration NO_2 in Various Zones



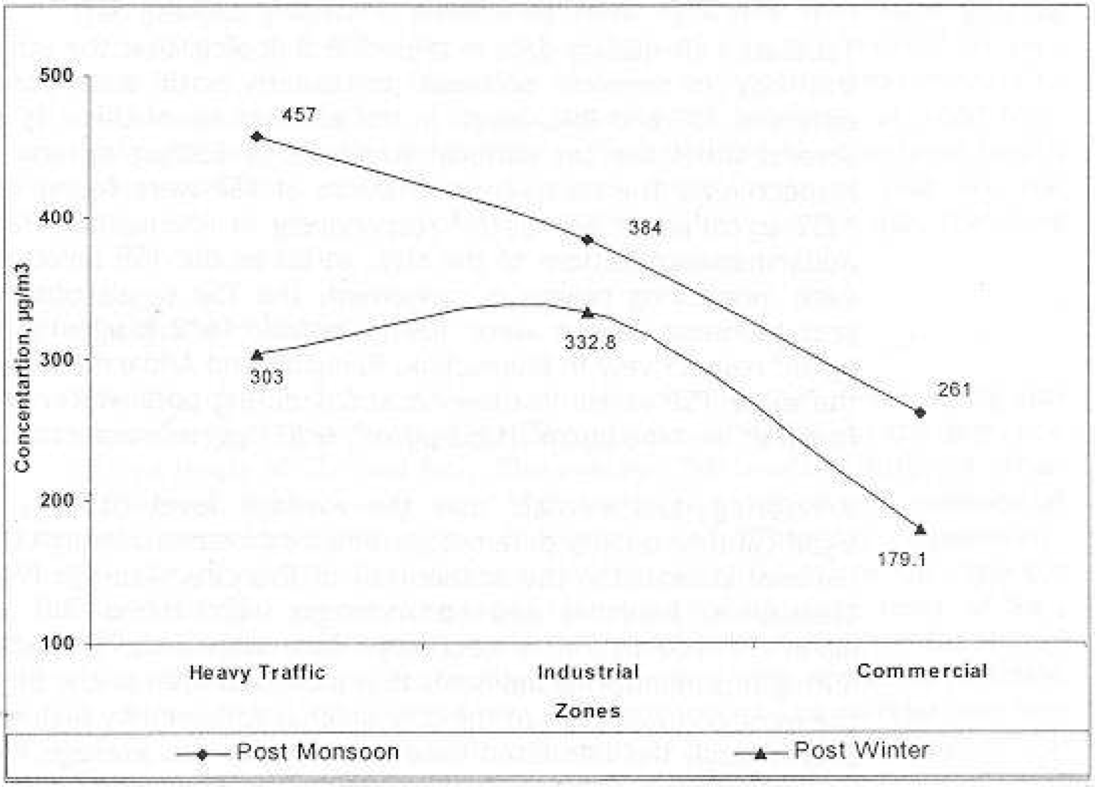
Graph 7: Seasonal Variation of TSP in Various Zones, Pokhara



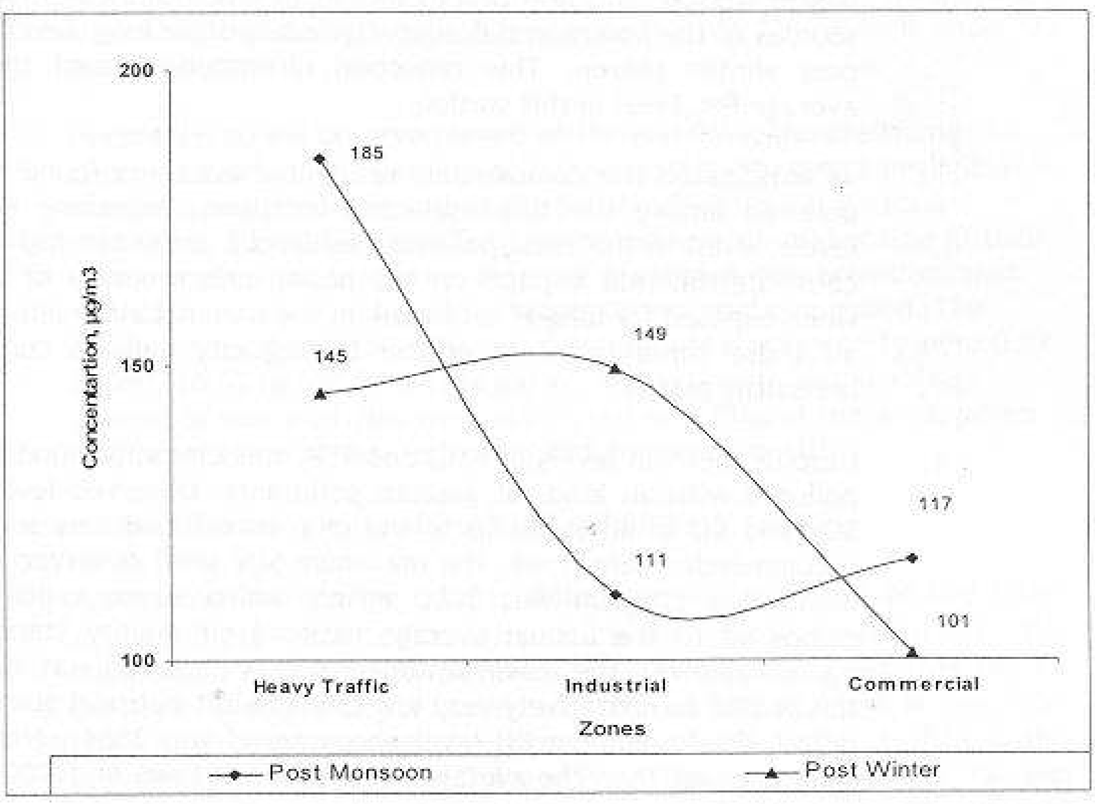
Graph 8: Season-wise Variation of TSP in Various Zones, Birgunj



Graph 9: Season-wise Variation of PM_{10} in Various zones, Birgunj



Graph 10: Season-wise Variation of PM_{10} in Various Zones, Pokhara



5.5.1 Air Quality of the Birgunj City

Tabulated air quality data in table 7 & 8 depicts that the atmosphere of this city is severely polluted particularly with dust particles. The observed TSP and PM_{10} levels in the ambient air of this city exceeds by several times the set national standards of 230 µg/m^3 and 120 µg/m^3 respectively. The mean concentrations of TSP were found 1282 µg/m^3, 1432 µg/m^3, and 547 µg/m^3 respectively in Bhanuchok, Ranighat and Addarshanagar stations of the city. As far as the TSP level measured in each monitoring season is concerned, the TSP levels observed in the post monsoon season were 1099.1 µg/m^3, 1612.2 µg/m^3, and 572.20 µg/m^3 respectively in Bhanuchok, Ranighat and Addarshanagar. Whereas the same TSP levels in these locations during post winter season were found to be 1466 µg/m^3, 1252 µg/m^3, & 521 µg/m^3 respectively.

Monitoring data reveals that the average level of PM_{10}, the most significant air quality parameter, remained excessively high than the set national standard in the ambient air of this city. Average PM_{10} levels in Bhanuchok, Ranighat and Addarshnagar were found 380 µg/m^3, 358 µg/m^3, & 220 µg/m^3 respectively. Both PM_{10} and TSP data obtained during this monitoring indicates that Industrial area of the Birgunj city is the most polluted area of the city which is followed by high traffic area. Even though the tabulated data depicts that the average PM_{10} level at Ranighat is less than the observed PM_{10} at Bhanuchok this is not the real. Apparently low level of the PM_{10} is due to the shifting of the monitoring station a little bit far from the pollution sources in post winter season. This anti-propinquity of the monitoring station from the sources of the pollution subsequently reduced the PM_{10} level during the post winter season. This reduction ultimately caused the reduced average PM_{10}level in this station.

As anticipated the commercial/ residential area was found to be least polluted among the three selected locations. Prevailing PM_{10} & TSP levels, even in the least polluted residential area, are high enough to cause detrimental impacts on the health and property of the people when exposed for long-time. Based on the national air quality descriptor all these three locations of the Birgunj city can be considered as unhealthy places.

Despite the high levels of PM_{10} and TSP, this city still found to be least polluted with all kinds of gaseous pollutants. Observed levels of NOx, SOx and CO in all locations of the city were found very low than the recommended safe level. The maximum SOx level observed during this monitoring program was 3.71 µg/m^3, which seems quite negligible compared to the annual average national air quality standard of 80 µg/m^3. Likewise the maximum level of NOx observed was 16.38 µg/m^3 this is also comparatively very low than the set national standard of 70 µg/m^3. The maximum CO level encountered was 3584 µg/m^3 and this level is lower than the average recommended level of 10000 µg/m^3 for eight hours.

The gaseous pollutant monitoring data indicates that such gaseous pollutants in the atmosphere of the Birgunj city are existed in very trace levels, which are incapable to cause any detrimental impacts to the exposed population. Significant level of soot was recorded from the ambient air of the Birgunj city. Though there is no defined health based guideline of the soot particles, high levels of soot are the indicatives of presence of high levels of volatile compounds that may possibly be noisome.

5.5.2 Air Quality of the Pokhara City

The data obtained during this monitoring reveals that Pokhara city also possesses high degree of air pollution particularly due to the presence of high levels of TSP and PM_{10}. The average TSP levels in different urban settings of Pokhara city i.e., high traffic, industrial and commercial zones were found 529 $\mu g/m^3$, 394 $\mu g/m^3$, and 309 $\mu g/m^3$ respectively. The prevailing TSP level seems to be high in all locations than the set NAAQS of 230 $\mu g/m^3$. Similarly, the observed average level of PM_{10} except the station Hallchok, Lakeside, was found beyond the set NAAQS level of 120 $\mu g/m^3$. In contrast to the observed high degree of pollution in other two locations of the city, the residential/ commercial area was found to be least polluted with all kinds of air pollutants including TSP and PM_{10}. Besides, the observed level of PM_{10} in this area remained within the set NAAQS limit during this monitoring. Based on the observed PM_{10} level and using national air quality descriptor, Mahendrapool and the Industrial Estate of this city can be categorised as the unhealthy places whereas the Lakeside area can be kept under the healthy places.

In contrast to the observed levels of TSP and PM_{10}, the prevailing concentrations of the gaseous pollutants in this city seems negligible and are at very low levels than the set NAAQS limit. All gaseous pollutants, SOx, NOx, and CO all are of less concerned because of their extremely low concentration than the significant concentrations that may cause detrimental health impacts on exposed population. The maximum levels of SOx, NOx, and CO observed from this city were 0.87 $\mu g/m^3$, 10.52 $\mu g/m^3$, and 1792 $\mu g/m^3$, respectively. Considerable amount of soot particles were associated with PM_{10} of this area, which may possibly cause deleterious impact on human health.

5.5.3 Comparison of the air quality of Pokhara and Birgunj

Assessment of the air quality data depicts that both of the cities are severely polluted with particulate matters. However, the comparison of air quality between these two cities shows that the air quality of Pokhara city is better than that of Birgunj. Both of the cities have been experiencing the same type of air problem that is the prevalence of high levels of TSP and PM_{10}. The average levels of TSP and PM_{10} in Birgunj are almost double than that of Pokhara. The PM_{10} level in all locations of the Birgunj exceeds the NAAQS level whereas the PM_{10} level in residential area of the Pokhara city remains with in the NAAQS level. Similar scenario of the soot particles can be seen in these cities. Observed soot level in the ambient air of the Birgunj remains almost two folds higher than that of the Pokhara.

As far as the observed levels of the other gaseous pollutants is concerned, the levels of all gaseous pollutants i.e., NOx, SOx, & CO in both cities are very low. However the obtained data of these pollutants reveals that Birgunj city exhibits higher levels of gaseous pollutants than the Pokhara city.

5.5.4 Comparison of the pollution levels among the different urban settings of Pokhara and Birgunj cities

Comparison of the pollution levels of the different urban settings i.e. high traffic, industrial and residential cum commercial areas of both cities indicates that the industrial and high traffic areas exhibit high levels of pollutants. Compared to the high traffic and industrial areas, the residential/commercial areas possess low levels of pollutants in these cities. However the trend of the pollution in both cities is not the same. Highest levels of TSP and PM_{10} were found in the industrial area of the Birgunj city, which was followed, by high traffic area. The lowest level of pollution was observed from the residential/commercial area. In contrast to the observed trend of the Birgunj, the highest level of the TSP and PM_{10} were found in the high traffic area of the Pokhara city, which was followed, by the industrial area. Like that of the Birjung, the lowest level of the pollution was observed from the residential/ commercial areas of the Pokhara city also. The trend of the other gaseous pollutants shows that the degree of these pollutants remained highest in the high traffic areas that were followed by industrial and commercial cum residential areas successively but the NO_2 level in Lakeside Pokhara particularly during post monsoon season. The NO_2 level during post monsoon season at commercial cum residential area of Pokhara (Hall Chowk) was found higher than the industrial area.

5.5.5 Comparison of the air quality between two seasons i.e. between post monsoon and post winter seasons

Comparison of the air quality data obtained from two distinct seasons indicates that except few exceptions, the pollution level was found to be increased during winter season than that of the post monsoon season. The data tabulated reveals that PM_{10} level in all locations of the Birgunj city has been increased in the post winter season whereas the observed level of TSP in Ranighat and Addarshanagar was found to be decreased. However this reduction is not merely caused by the influence of the meteorological conditions or season and rather it was caused by the change in monitoring points in these two locations. In post monsoon season the measurement was made at very close vicinity of the road whereas in the post winter season it was shifted a little bit far from the road. In contrast to the TSP and PM_{10} levels, observed levels of all gaseous pollutants were low during the post winter season than that of the post monsoon season. The level of PM_{10} was found to be increased in Pokhara city during the post winter season except in the industrial estate. The TSP level was found to be increased in the winter in Mahendrapool of Pokhara whereas the TSP level in industrial Estate and in Lakeside was found to be decreased during this season. However this reduction in dust particles was caused by prevailing rain. Moderate rainfall was observed during air quality monitoring at Mahendrapool. Prevailing rain precipitates down the suspended particulate particles from the air as well as reduces the resuspension process of the dust from the road or ground as a result of which the observed level of particulate matters virtually seen reduced than the post monsoon season. As far as the other gaseous pollutants are concerned their levels have been reduced significantly during the post winter season.

6. Assessment of Air Quality in Kathmandu valley

This chapter describes air quality assessment of Kathmandu valley. There has been few studies in the past in Kathmandu valley for air quality assessment and also few air quality monitoring intermittently. However, from last year a continuous air quality monitoring programme is being carried out in the valley and the data are being disseminated to the public. We made use of the data for the assessment.

Kathmandu being the capital city of Nepal has observed rapid urban growth and population inflow for last few years. The city is situated in mid-hill region of Nepal within the Kathmandu valley along with 4 other smaller municipalities and about a hundred VDCs.

Kathmandu valley is situated between the latitudes 27 32' 13" and 27 49' 10" north and longitudes 85 11' 31" and 85 31' 38" east. It covers an area of about 667 square kilometre and its mean elevation is about 1350m, above sea level (KMC, 2001).

Population growth in Kathmandu has been critical because of centralisation and migration of the rural people to the capital for different opportunities. Overall country's population growth is 2.27 percent where as in Kathmandu population growth during the same span has been recorded as 4.83 percent. Kathmandu valley has population approximate to 1645091 (this is sum of three districts, namely Kathmandu, Bhaktapur and Lalitpur) according to 2001 census.

The valley is especially vulnerable to air pollution due to an exploding population inflow, rapid urbanisation, valley centric industrialisation and significant increase of vehicular transport in narrow streets. Furthermore, the bowl like topography of the valley restricts wind movement and retains the pollutants in the atmosphere. This is especially bad during the winter season when thermal inversion, where cold air flowing down from the mountains is trapped under a layer of warmer air, creates a lid, which keeps the pollutants, sealed within the valley.

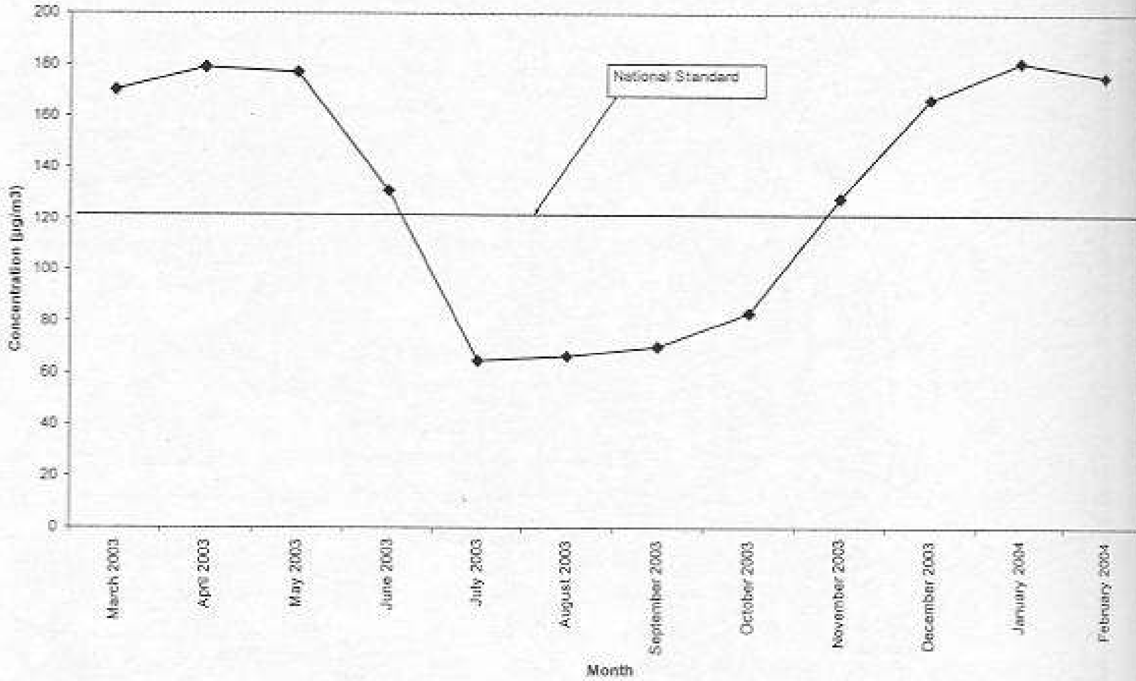
Map 1: Air quality monitoring stations in Kathmandu valley

Source: Environment Sector Programme Support, ESPS
Note: 1: Putalisadak; 2: Patan Hospital; 3: Thamel; 4: Bhaktapur; 5: TU, Kirtipur; 6: Matsyagaon

Realising the need to continuously monitor the valley's air, a DANIDA funded project, ESPS is supporting MoPE to continuously monitor air quality at six locations around the valley (See the map for location of these monitoring stations). So far, the PM_{10} concentration at these locations are being disseminated through the website and weekly average by the electronic display located in central city area.

Annual average of the PM_{10} in Kathmandu's air from March 2003 to February 2004 was calculated to be 132.88 $\mu g/m^3$. This value is higher than the Nepalese ambient air quality standard. However, the standard has been set for the daily average, it is more important to look at the number of days that crossed the daily average standard at respective monitoring locations. The graph below (Graph 11) gives a view of monthly PM_{10} concentration variation averaged for all monitoring locations in Kathmandu valley.

Graph 11: Monthly PM_{10} variation in Kathmandu valley



The above graph (average concentration of PM_{10} of Kathmandu valley) shows that concentration of PM_{10} has been gradually starts decreasing from the month May and comes to a minimum level during July. Similarly, from October, it again starts increasing. During the month July till October, the mean PM_{10} concentration of Kathmandu valley is below the national standard. This decrease in the PM_{10} concentration is mainly due to two major factors. One is due to the rain and another is that during the rainy season brick kilns do not operate.

Usually monsoon starting from June/July flushes away the dust in the air and also the road dust which eventually comes to ambient level due to resuspension. Similarly, Bull's trench brick kilns, a major part of the brick industry do not operate during rainy season. According to the inventory conducted by ESPS in 2001, brick kiln was responsible for 67 percent of total PM_{10} in Kathmandu (Gautam C, 2002).

Following conclusions can be drawn from the analysis of the PM_{10} data obtained from these six monitoring locations:

1. Annual average of PM_{10} at the six monitoring locations was calculated to be 132.88 $\mu g/m^3$ from March 2003 to February 2004.

2. Calculating Location-wise , the most polluted site was found out to be Putalisadak. Annual average of PM_{10} at Putalisadak was calculated to be 209.01 $\mu g/m^3$. Similarly, least polluted site was

Matsyagaon where the annual PM_{10} average was found out to be 53.57 μg/m³ (detail in chart).

3. Looking at annual average of PM_{10} at the respective locations, it reveals that annual average of PM_{10} concentration at the four monitoring locations are higher than the national standard (which is 120 μg/m³), these locations are Putalisadak, Bhaktapur, Patan Hospital and Thamel. At other two locations, namely, Matsyagaon and TU, the annual average is below the standard value.

4. Looking at monthly average of the PM_{10} concentration at different locations (graph 13), it clearly shows the decrease in concentration starting from the month May and reach minimum during July to September. After October the concentration again starts increasing. This clearly shows the role of rain and operation of brick kilns during winter season to increase the pollution level (CEN/ENPHO, 2003).

5. Monthly average of PM_{10} at Putalisadak most of the time crossed the national standard. Concentration was little lower than standard during July (detail in graph 14).

6. In case of Matsyagaon, a valley background location, monthly averages are always below the standards (graph 15). Also at TU monitoring site, concentration are below the standard value. Only during the month of April the monthly average is almost equal to the standard (graph 16).

7. Monitoring location situated at Bhaktapur showed the same trend like other locations. Monthly averages of PM_{10} were found higher than the standard value during March to May. However, during the June to November concentration were found below the standard and after December it again crossed the standard (graph 17).

8. Patan hospital area is also a place with higher PM_{10} concentration throughout the year. Monthly averages crossed national standard almost all the month except August and October when the concentration is almost near to the standard value (graph 18).

9. In case of Thamel, a residential area, the concentration were below standard during July to October with data missing for May. During rest of the months, it crossed the standard value (graph 19).

10. Table 9 gives the value of the totals days that crossed the national standard for PM_{10} concentration in respective monitoring locations. Out of the 365 days, at Putalisadak, PM_{10} concentration were higher than standard in 291 days and 17 days of data were missing. During rest of the 57 days, the concentration were below the standard. Putalisadak shows the highest number of days crossing

the national standard out of the total six monitoring locations. Patan Hospital area comes to the second position, where total of 275 days the PM_{10} concentration were found higher than the national standard.

11. At Matsyagaon, a valley background location, concentration of PM_{10} were higher than the national standard for 15 days with 18 days of data missing. Rest of the 333 days, the concentration were found within the national standard. Out of the monitoring locations, this location was found to be least polluted.

12. At TU monitoring location, PM_{10} concentration were higher than standard for 65 days with 9 days of data missing. However, at this location, the concentration was within the standard for 292 days.

13. Bhaktapur and Thamel area showed almost 50 percent of the days when the PM_{10} concentration was higher than standard and almost 50 percent within the standard. At Bhaktapur, 165 days were with the PM_{10} concentration higher than the standard with 3 days of data missing and 198 days within the standard value. Similarly, at Thamel, concentration of PM_{10} was found crossing the national standard for 185 days with 44 days of data missing and 137 days within the standard value.

Graph 12: Annual average of PM_{10} at different location

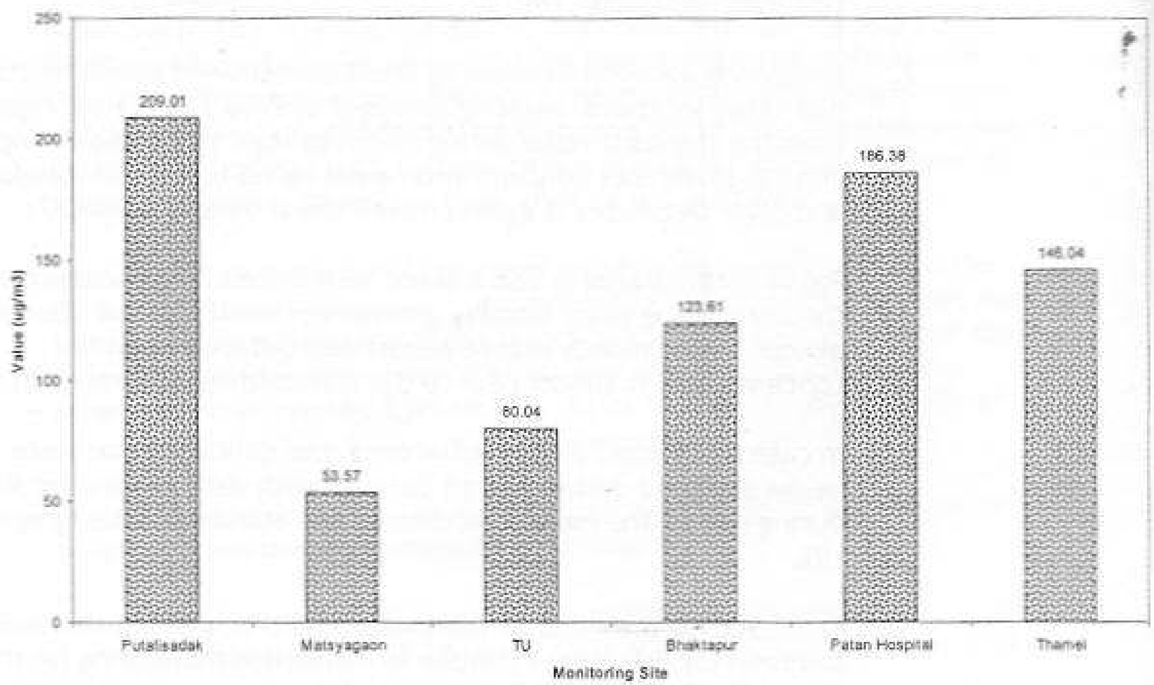


Table 9: Number of days concentration of PM_{10} above the national standard

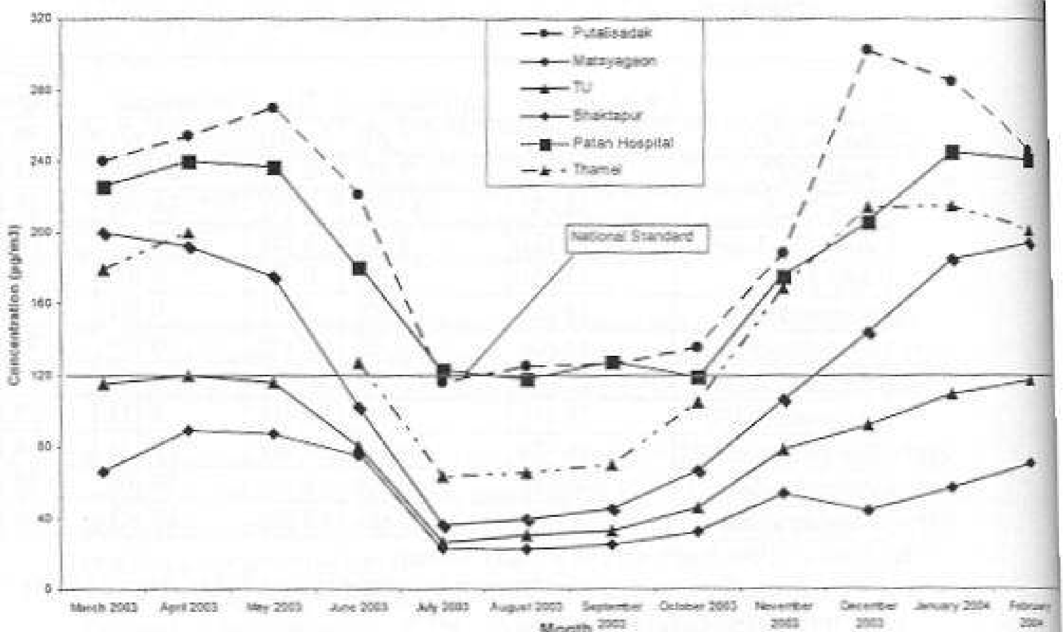
	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel
March 2003	28 (3)	1 (0)	14 (0)	28 (0)	29 (2)	30 (0)
April 2003	28 (2)	7 (2)	16 (0)	28 (0)	24 (5)	27 (3)
May 2003	28 (3)	3 (10)	8 (5)	28 (0)	31 (0)	0 (31)
June 2003	25 (2)	4 (3)	5 (0)	8 (0)	22 (0)	8 (3)
July 2003	13 (0)	0 (0)	0 (0)	0 (0)	15 (0)	0 (0)
August 2003	18 (0)	0 (0)	0 (1)	0 (0)	11 (0)	0 (0)
September 2003	18 (0)	0 (0)	0 (0)	0 (0)	17 (0)	0 (0)
October 2003	19 (0)	0 (0)	0 (0)	0 (0)	13 (0)	9 (0)
November 2003	29 (1)	0 (1)	0 (1)	4 (1)	29 (1)	28 (1)
December 2003	26 (5)	0 (2)	1 (2)	19 (2)	28 (2)	28 (2)
January 2004	30 (1)	0 (0)	8 (0)	30 (0)	30 (0)	30 (0)
February 2004	29 (0)	0 (0)	13 (0)	20 (0)	26 (3)	25 (4)

Note: figure in parentheses represents the total days of data missing for the respective month

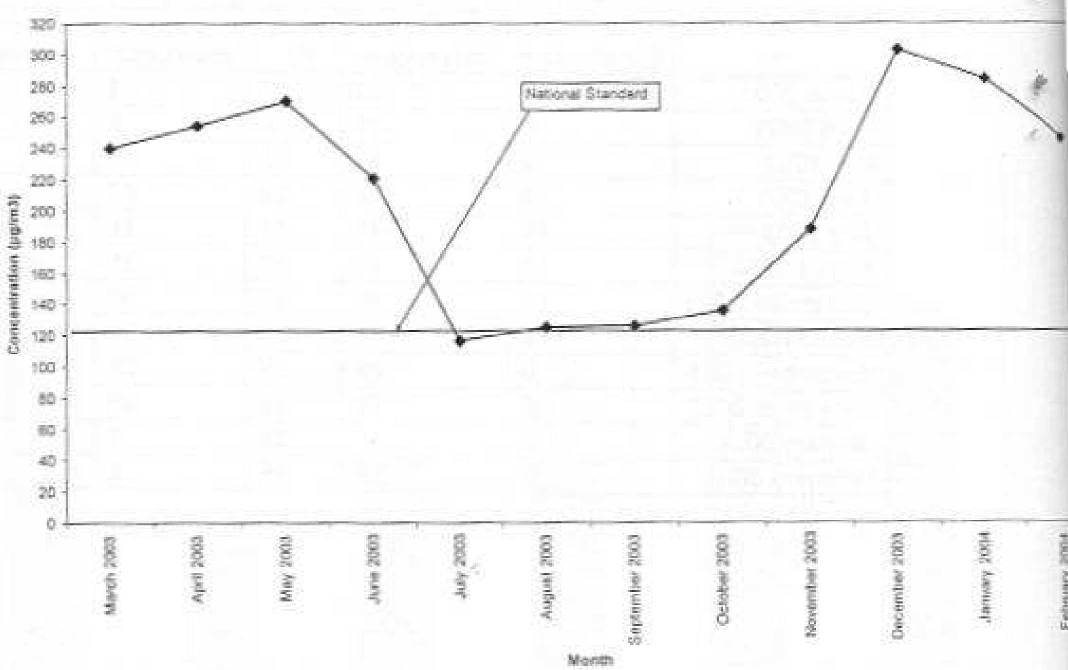
Table 10: Number of days equals to or within national standard

	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel
March 2003	0	30	17	3	0	1
April 2003	0	21	14	2	1	0
May 2003	0	18	18	3	0	0
June 2003	3	23	25	22	8	19
July 2003	18	31	31	31	16	31
August 2003	13	31	30	31	20	31
September 2003	12	30	30	30	13	30
October 2003	12	31	31	31	18	22
November 2003	0	29	29	25	0	1
December 2003	0	29	28	10	1	1
January 2004	0	31	23	1	1	1
February 2004	0	29	16	9	0	0

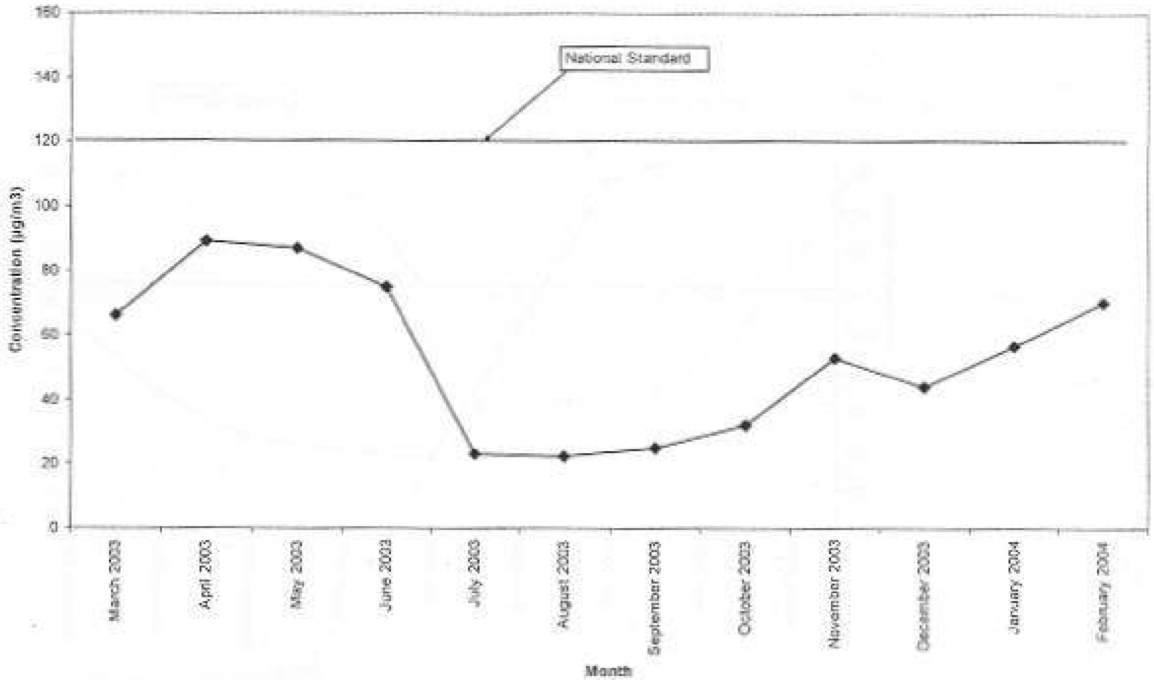
Graph 13: Monthly variation of PM_{10} at different monitoring sites



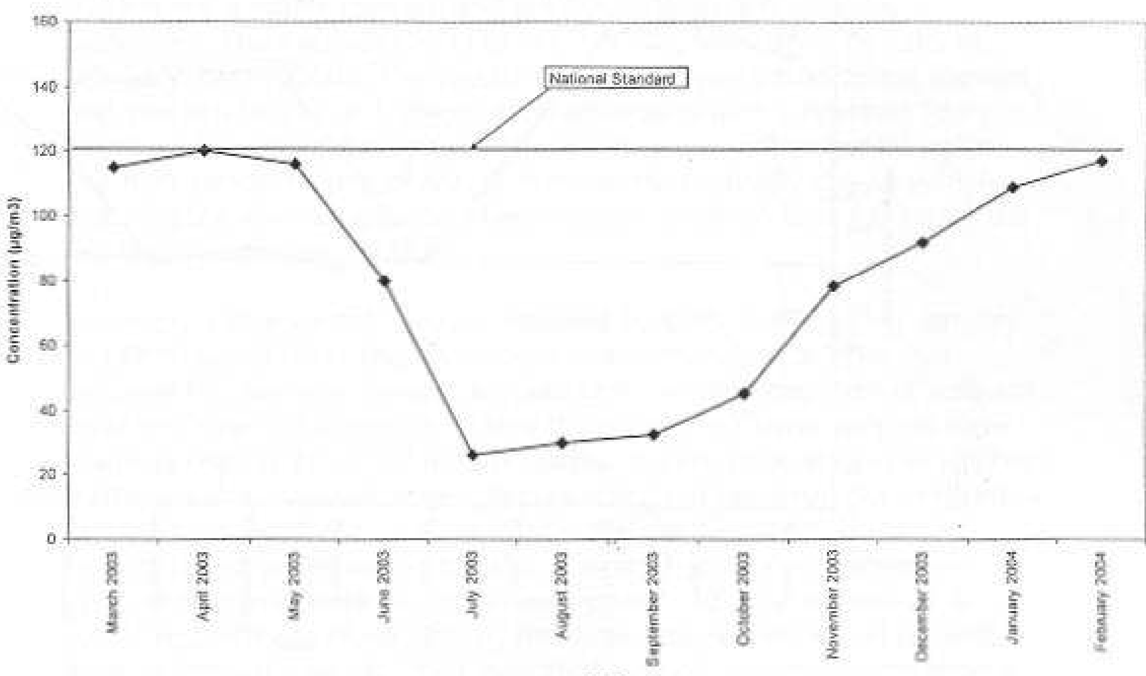
Graph 14: Monthly variation of PM_{10} at Putalisadak



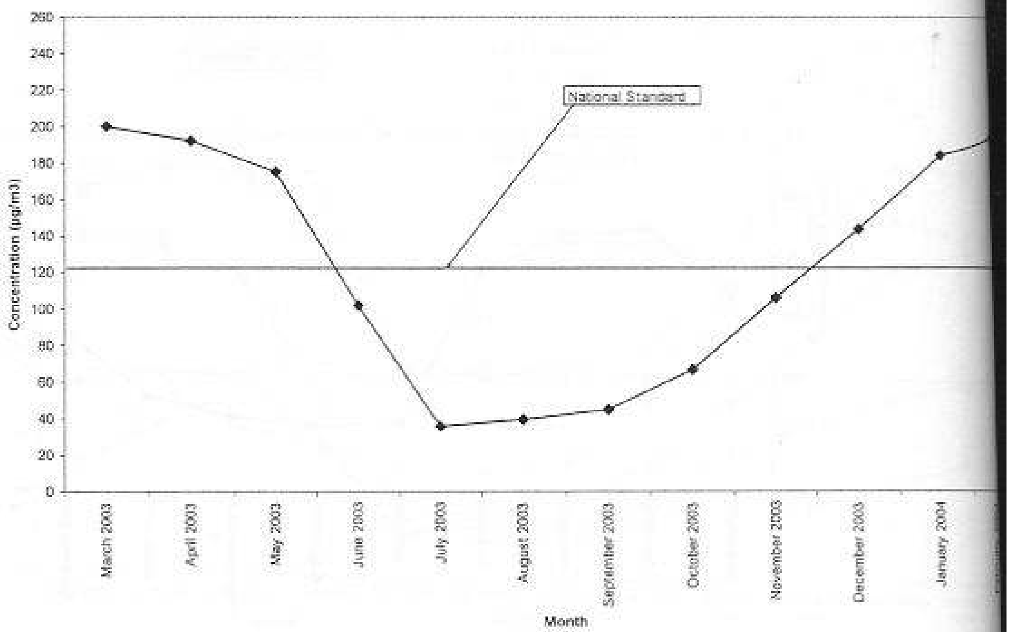
Graph 15: Monthly variation of PM_{10} at Matsyagaon



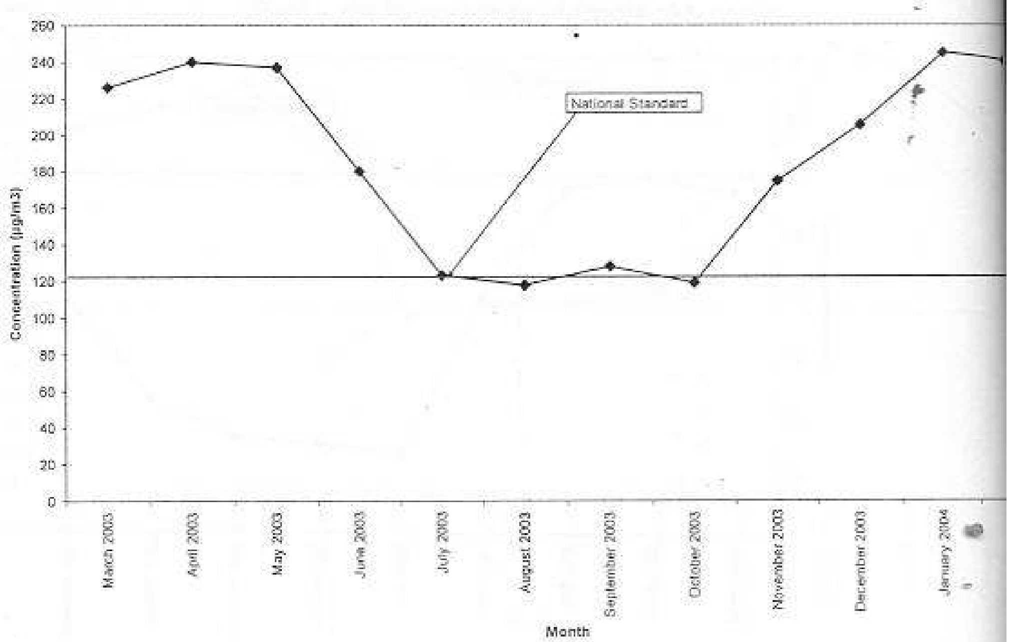
Graph 16: Monthly variation of PM_{10} at TU



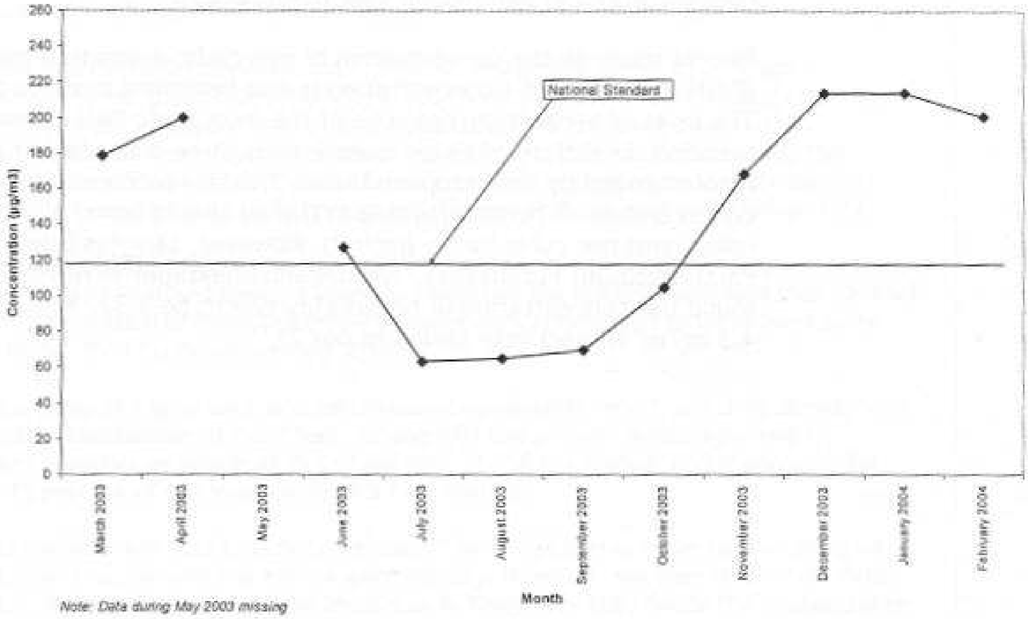
Graph 17: Monthly variation of PM_{10} at Bhaktapur



Graph 18: Monthly variation of PM_{10} at Patan Hospital



Graph 19: Monthly variation of PM_{10} at Thamel



Besides the particulate matter, other gaseous air pollutants in Kathmandu valley are within the guideline value (Raut, 2002). Almost all studies done so far in Kathmandu indicate that the levels of NO_2 and SO_2 are not a major concern and are below WHO and national guidelines. The measurements of NO_2 and SO_2 were done by ESPS in February-March, 2003. The results of the four-week monitoring showed that the NO_2 level was highest in Putalisadak where it reached 50 $\mu g/m^3$ but at all the other stations the NO_2 levels were well below 50 µg/m3. The high concentration of NO_2 at Putalisadak is clearly due to vehicle emission but even at a place where vehicle emission is at its worst, the NO_2 level was within NAAQS.

However, a three-week study conducted by ESPS/MoPE during January and February 2002 at the 7 locations in Kathmandu indicated that benzene has become a major air pollutant. Weekly averages of ambient level benzene concentrations using the passive diffusive method were found as high as 77 $\mu g/m^3$ in Putalisadak. Putalisadak, known as the high traffic area, accounted very high concentration however, Matsyagaon, a valley background has very low concentration. Similarly, other high concentration zones were Chabahil, Paknajol and Patan, where average value of benzene were found to be 44 $\mu g/m^3$, 30.3 $\mu g/m^3$ and 23.3 $\mu g/m^3$ respectively (Raut, 2003). However, the second round of tests done in February-March, 2003 indicated a much lower concentration of benzene. One possible reason for this drop in benzene level is Nepal Oil Corporation's claim that previously the petrol had 5 percent benzene but now it has 3 percent only. Although the results from the second round of tests indicate that the benzene concentration has gone down to within NAAQS, it is still early to draw conclusions regarding benzene concentrations in Kathmandu's air (Raut, 2003).

Recent study on the concentration of polycyclic aromatic hydrocarbon (PAH) shows that it s concentration is also becoming a major concern. The level of benzo[a]pyrene, one of the most toxic PAH known to mankind, in Kathmandu's air is more than three times higher than levels recommended by the European Union. The EU recommends that the concentration of benzo[a]pyrene in the air should be no higher than 1 nanograms per cubic meter (ng/m^3). However, samples taken from Patan Hospital, Putalisadak, Thamel and Bhaktapur in November 2003 found the concentration of benzo[a]pyrene to be 2.32, 3.16, 3.23, and 4.3 ng/m^3 respectively (detail in Box 2).

Box 2

Concentration of Toxic PAH in Kathmandu's Air is Three Times Higher Than EU Norms

A recent study done by Rossanna Bossi, a senior research scientist at Denmark's Department of Atmospheric Environment, has found that the level of benzo[a]pyrene, one of the most toxic polycyclic aromatic hydrocarbon (PAH) known to mankind, in Kathmandu's air is more than three times higher than levels recommended by the European Union. This was disclosed today at a seminar organized by the Environment Sector Programme Support (ESPS) project of Ministry of Population and Environment.

In November, 2003, Bossi had taken two samples from five different monitoring stations in Kathmandu and analysed them in Denmark. Based on the results, Bossi said that, "annual mean concentration of benzo[a]pyrene in Kathmandu is expected to be at least three times higher than EU recommended level."

PAH is a group of highly toxic and carcinogenic compounds, which primarily results from incomplete combustion of fossil fuel. Among PAH compounds, benzo[a]pyrene is commonly used as an indicator as its toxicity is one of the highest and it accounts for about 75 percent of carcinogenicity of a PAH mixture.

The EU recommends that the concentration of benzo[a]pyrene in the air should be no higher than 1 nanograms per cubic meter (ng/m^3). However, samples taken from Patan Hospital, Putalisadak, Thamel and Bhaktapur in November 2003 found the concentration of benzo[a]pyrene to be 2.32, 3.16, 3.23, and 4.3 ng/m^3 respectively. The only place where the concentration was below the EU recommended level was in Matsyagaon, which is a village located in the south-eastern part of Kathmandu Valley, about 150 meters above the valley floor.

The high level of PAH in Bhaktapur is probably due to the transport of Kathmandu's PAH towards Bhaktapur due to westerly winds. Because benzo[a]pyrene attaches itself to fine particles that are emitted from incomplete combustion, they are easily transported by the wind and they enter the body when the particles are inhaled.

Bossi also said that diesel vehicles and two stroke engines are probably the main sources of PAH in Kathmandu. Bossi had also measured the PAH levels on September 18, 2003, which was a Nepal Bandh day when there were very few vehicles on the streets. She found that the PAH level on the Bandh day was about one fifth of the level recorded during a normal week-day in November. This clearly indicates that polluting vehicles are the main source of toxic chemicals in Kathmandu's air.

Source: CEN, 2004a

7. Analysis of air pollution related disease records

7.1 Air pollution related disease rates

Table 11: Incident of ARI in per 1000 population and children under five years of age in Kathmandu valley

S. No.	Year (BS)	ARI/1000 of population			Children under five years of age		
		Kathmandu	Lalitpur	Bhaktapur	Kathmandu	Lalitpur	Bhaktapur
1.	2052/53	29	109	67	5341	5764	4282
3.	2054/55	38	119	122	7786	9691	4236
4.	2055/56	69	102	103	7828	7888	4044
5.	2056/57	75	103	90	10332	7821	3686
6.	2057/58	69	132	72	12158	8294	2922
8.	2059/60	92	181	135	21485	15505	5822

7.2 Hospital Data analysis of Kathmandu's hospitals

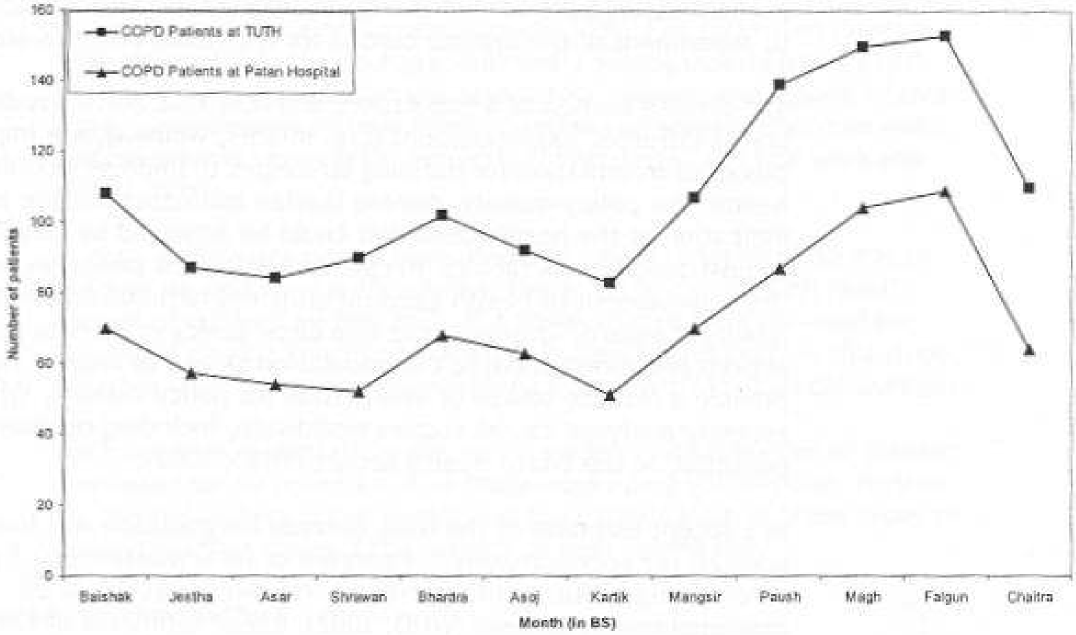
In 1993, an analysis of the records of all patients admitted to Patan Hospital found that in six years (2042 to 2048 BS), the proportion of admission for COPD as a percent of the total number of medical patients had increased by three folds. In 2041- 42 BS (1984-85) the proportion was 5.1 percent but in 2048 (1991) it had increased to 15.2 percent (Zimmerman, 1993). According to a hospital data analysis done by LEADERS Nepal in 1998 in the hospitals, urban residents have more respiratory diseases than rural residents (LEADERS 1998).

There are four major public hospitals in Kathmandu namely, Bir Hospital, Tribhuwan University Teaching Hospital (TUTH), Patan Hospital, and Kanti Children's Hospital. Besides these public hospitals there are also few other small hospitals and nursing homes run by the private sector.

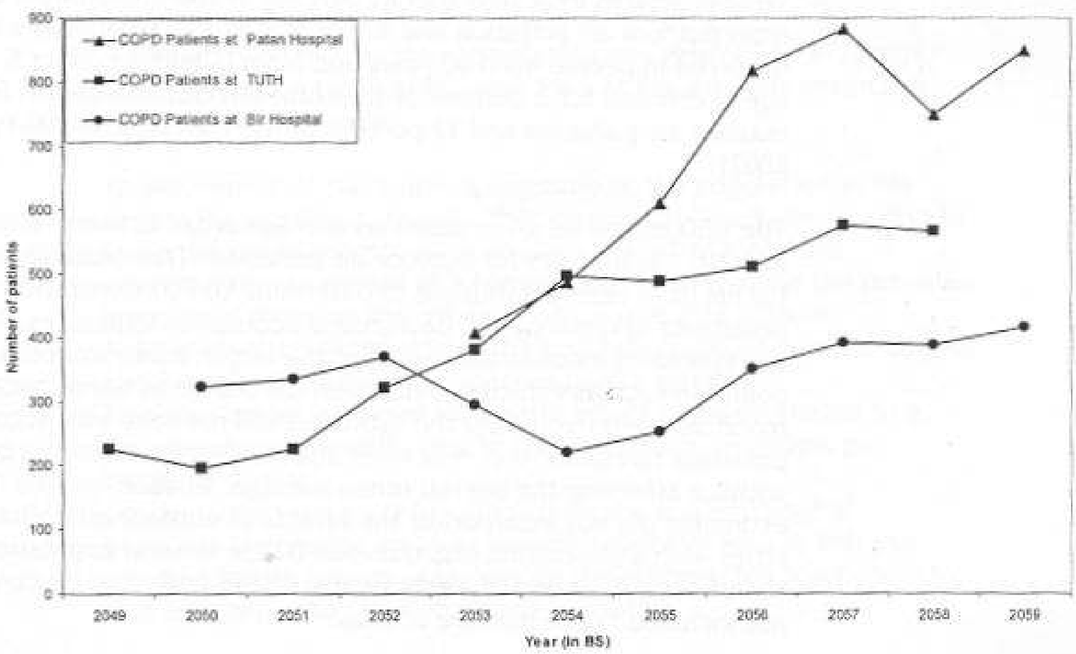
The study only obtained records of in-patients that suffered from COPD and uses the number of the patients with COPD to get the yearly trend (graph 21). The trend shows the increment in the number of patients getting admitted to these public hospitals due to COPD. However, this study did not take account the increase in number of patients with the population increase in Kathmandu valley, the increasing trend of the COPD patients in urban areas is obviously a major concern. The trend also did not tell us the story how many patients were got the COPD due to exposure to ambient air pollution. Again due to lack of reliable air pollution data historically, we did not correlate the number of COPD patients with the urban air pollution in Kathmandu valley. In future, with at least five years air pollution data in hand, we could do detail correlation between air pollution and COPD patient numbers.

But the monthly or seasonal variation of COPD patients somewhat coincide with the PM_{10} concentration in Kathmandu. During the dry winter season, when the PM_{10} concentration was found higher, the COPD patients number also shows the same trend (see graph 20 for details).

Graph 20: Monthly variation of COPD patients in two major hospitals in Kathmandu



Graph 21: Yearly trend of COPD patients in Kathmandu's major public hospitals



8. Environmental Burden of Disease (EBD) concept

This chapter provides some aspects on EBD concept. It also provides the background to the general method for assessing the disease burden of specific environmental risk factors. EBD studies assess the disease burden attributable to environmental risk factors, and are closely linked to assessment of the disease burden for individual diseases and injuries.

The disease burden of a population, and how that burden is distributed across different subpopulations (e.g. infants, women), are important pieces of information for defining strategies to improve population health. For policy-makers, disease burden estimates provide an indication of the health gains that could be achieved by targeted action against specific risk factors. In case of outdoor air pollution, we can say the achievement of health gains meeting the national ambient air quality standard. The measures also allow policy-makers to prioritize actions and direct them to the population groups at highest risk. To help provide a reliable source of information for policy-makers, WHO recently analysed 26 risk factors worldwide, including outdoor air pollution, in the World Health Report (WHO, 2002).

In a recent estimate of the GBD, outdoor air pollution was found to account for approximately 1.4 percent of total mortality, 0.5 percent of all disability-adjusted life years (DALYs) and 2 percent of all cardiopulmonary disease (WHO, 2002). These estimates of the total disease burden were based solely on the effects of PM on mortality in adults and children. Because the epidemiological studies suggested that mortality impacts were likely to occur primarily among the elderly, the WHO estimates indicated that 81 percent of the attributable deaths from outdoor air pollution and 49 percent of the attributable DALYs occurred in people aged 60 years and older. Children under 5 years of age accounted for 3 percent of the total attributable deaths from outdoor air pollution and 12 percent of the attributable DALYs (WHO, 2002).

The GBD estimates were based on average urban concentrations of PM_{10} and $PM_{2.5}$ as markers for outdoor air pollution. Traditionally, monitors for PM have been established to determine the concentration of pollutants in regional and background population exposures. As such, the estimates incorporated some of the larger urban sources of pollution such as vehicles, industries. On the other hand, because the monitors were fixed-site, the estimates did not take into account pollution 'hot spots' that may have affected segments of the population, without affecting the overall urban average. In addition, the GBD estimates did not incorporate the effects of outdoor air pollution in cities with a population less than 100 000 or in rural populations, nor the effects of other pollutants such as ozone and toxic air contaminants not included in the mixture of PM_{10}.

For the quantitative assessment of health effects, $PM_{2.5}$ and PM_{10} are selected because these exposure metrics have been used in epidemiological studies throughout the world. In addition, over the past two decades, epidemiological studies spanning five continents have demonstrated an association between mortality and morbidity, and daily, multi-day or long-term (a period of more than a year) exposures to concentrations of pollutants, including PM. The estimated mortality impacts are likely to occur predominantly among elderly people with pre-existing cardiovascular and respiratory disease, and among infants. Morbidity outcomes include hospitalisation and emergency room visits, asthma attacks, bronchitis, respiratory symptoms, and lost work and school days.

In case of Kathmandu (we have used this city only for the EBD due to outdoor air pollution in this study), there has few studies on health impact of outdoor air pollution. But these studies have not used the burden of disease concept to quantify human health cost. In this study, we have used the guideline developed by the WHO for EBD calculations.

We have tried to initiate study on the environmental burden of disease from outdoor air pollution. This study would be a guideline for further studies in this sector and would lead to multiplication of these types of studies in other cities of the country as well in long run.

8.1 Summary of the method

According to the guideline prepared by Dr. Bart Ostro, to quantify the environmental burden of disease due to outdoor air pollution, following methods can be used by a city.

For a given city or region, the quantitative assessment of the health impact of outdoor air pollution, using PM_{10} or $PM_{2.5}$ measurements, is based on four components:

1. An assessment of the ambient exposure of the population to PM (either PM_{10} or $PM_{2.5}$), based either on existing fixed-site monitors or on model-based estimates. In addition a 'goal' or threshold concentration is needed as a comparison, to determine the potential benefits of reducing the risk factor by a specified amount.
2. A determination of the size of the population groups exposed to PM_{10} and $PM_{2.5}$, and the type of expected health effect.
3. The baseline incidence of the health effect being estimated (e.g. the underlying mortality rate in the population, in deaths per thousand people).
4. Concentration-response functions from the epidemiological literature that relate ambient concentrations of PM_{10} or $PM_{2.5}$ to selected health effects, and provide the attributable fractions (AFs) that are then used to estimate the following:

- the number of cases of premature mortality from all causes from short-term exposure to PM_{10}.
- the number of cases of premature mortality and DALYs (cardiopulmonary and lung cancer) attributed to long-term exposure to $PM_{2.5}$, for people >30 years old.
- the number of cases of premature mortality and DALYs (from all causes) attributed to the short-term exposure to PM_{10}, for children younger than five years old.

The outcomes, exposure metrics, and relative risk functions are summarized in Table 12.

Table 12: Recommended health outcomes and risk functions used to calculate the EBD

Outcome and exposure metric	Relative risk function[a]	Suggested ß coefficient (95% CI)	Subgroup
All-cause mortality and short-term exposure to PM_{10}[b]	RR = exp[ß (X -Xo)]	0.001 (0.0006, 0.0016)	All ages
All-cause mortality and short-term exposure to PM_{10}	RR = exp[ß (X-Xo)]	0.00166 (0.00034, 0.0030)	Age <5 years
Cardiopulmonary mortality and long-term exposure to $PM_{2.5}$	RR = [(X+1)/(Xo+1)] ß	0.15515 (0.0562, 0.2541)	Age >30 years
Lung cancer and long-term exposure to $PM_{2.5}$	RR = [(X+1)/(Xo+1)] ß	0.23218 (0.08563, 0.37873)	Age >30years
Lower respiratory illness and short-term exposure to PM_{10}	RR = exp[ß (X-Xo)]	0.00491 (0.0036, 0.0062)	Age <19 years

[a] X = current pollutant concentration ($\mu g/m^3$) and Xo = target or threshold concentration of pollutant ($\mu g/m^3$).
[b] Not used in DALY calculations and should not be added to the other mortality estimates.

Time-series studies examine daily changes in air pollution (typically based on 24-hour average concentrations) in relation to daily counts of mortality. Studies of the acute effects of PM exposure typically involve daily observations over several months or years.

The analysis involves multivariate regression models that control for potentially confounding factors that may vary over time and be associated with mortality. Studies of the effects of PM often examine whether daily counts of mortality or cause-specific hospitalisations are correlated with daily concentrations of PM, after controlling for the effects of other covariates and potential confounders. Such factors include temporal and meteorological variables (e.g. day of the week, extremes in temperature, humidity or dew point), co-pollutants, and longer-term trends represented by seasonal changes or population growth. Well designed time-series studies can have several methodological strengths, including:

- a large sample size (up to eight years of daily data), which increases the sensitivity of the statistical analysis for detecting effects;
- data are collected for a range of population demographics, baseline health characteristics and human behaviours, which makes the results more widely applicable;
- the exposures are 'real-world' and avoid the need to extrapolate to lower concentrations, or across species.

However there are certain limitations of the time-series studies, these include:

- the difficulty in determining actual pollutant concentrations to which people are exposed;
- the potential for misclassifying the exposure;
- there can be co-variation among pollutants, which makes it difficult to attribute an effect to a single pollutant.

Based on the existing evidence, it is proposed that the total number of cases of premature mortality be calculated for the EBD. To date, however, no evidence has been provided about the amount of life shortening involved with each fatality associated with short-term exposure. Therefore, these calculations are used only to provide an estimate of the number of premature deaths per year, not years of life lost (YLL) or DALYs.

Based on available evidence, a reasonable central estimate of the EBD for mortality due to short-term exposure is a 1 percent increase per 10 $\mu g/m^3$ PM, with a range of 0.6-1.5 percent. This range reflects the evidence from a variety of cities and averaging times (including single and multi-day lags). Therefore, the relative risk (RR) can be specified as:

$$RR = \exp[ß(X - Xo)] \quad \textit{(Equation 1)}$$

where:
ß = 0.001 (range 0.0006-0.0015).
X = current concentration of PM_{10} ($\mu g/m^3$).
Xo = target or threshold concentration of PM_{10} ($\mu g/m^3$).

The current concentration will be determined from existing monitoring data, model estimates, or best judgement. The target concentration can be either the background concentration (i.e. the level that would exist without any man-made pollution, which is approximately 10 $\mu g/m^3$ PM_{10}), other regulatory target such as national standard 120 $\mu g/m^3$ for PM_{10} (in case of Nepal). Comparing current and background exposure levels is one step in calculating the attributable burden (i.e. the total health impact of the risk factor). If current pollution levels are compared with regulatory targets, for example, this leads to the health burden that would be avoided if the regulatory goal will be met. The relative risk estimate can be applied to the entire population (i.e. all ages) and over the full range of PM_{10} concentrations, since the relationship appears to be linear throughout the full range of PM_{10} concentrations (Ostro, 2004). An estimate of all-cause mortality associated with short-term exposure to PM_{10} was not included in the GBD calculations (WHO, 2002), since the number of life-years lost (and therefore DALYs) cannot be determined for each of the premature deaths. For the EBD calculation, however, estimates of premature mortality associated with short-term exposures can be used as an alternative to DALYs, and used as a basis for comparing short-term and long-term effects of pollutant exposure. Short-term estimates should not be added to long-term estimates, however, since that would involve some double counting of the mortality cases. A summary of the relative risk function and model parameters for all-cause mortality from short-term exposure is provided in Table 12.

One significant uncertainty associated with this outcome relates to differences in the distribution of mortality causes in different cities, countries or regions. Presumably, most of the 'all-cause' mortality resulting from exposure to PM is associated with cardiovascular and pulmonary disease. Therefore, in an area with a relatively low proportion of cardiopulmonary mortality (e.g. in developing countries with relatively more mortality from malnutrition and diarrhoea), it is more likely that the short-term impact of air pollution will be overestimated. This is the result of applying the percentage increase in mortality due to air pollution, to a mortality rate that includes relatively more non-cardiopulmonary disease. However, existing studies from developing countries suggest that an increase in mortality of about 1 percent per 10 $\mu g/m^3$ PM is a reasonable approximation, and that the likely effect lies within the range that has been proposed for calculating the EBD (Ostro, 2004).

Combining the estimates reviewed for different studies, using a fixed-effects model that weights each estimate by the inverse of its standard error, we estimate that a 10 $\mu g/m^3$ increase in ambient PM_{10} concentration results in a 1.66 percent (95 percent CI = 0.34.3.0) increase in daily mortality from acute respiratory infections in children 0-5 years of age. Thus, the linear exposure model (Equation 1 and Table 12) should be used to quantify the relative risks for this endpoint with ß -0.00166 and a 95 percent CI of 0.00034-0.0030 (Ostro, 2004).

8.2 Calculating the disease burden

The relative risk (RR) for each included health outcome can be calculated using the risk functions in Table 12. Once the relative risks have all been determined, the AF (or impact fraction, IF) of health effects from air pollution for the exposed population can be calculated by:

$$AF = \frac{\Sigma P_i RR_i - 1}{\Sigma P_i RR_i} \quad \textit{(Equation 2)}$$

where:
Pi = the proportion of the population at exposure category 'i', including the unexposed (i.e. Σ Pi RRi becomes ($P_1RR_1 + P_2RR_2 + ... + P_{unexposed} \times 1$)).

RRi = the relative risk at exposure category 'i', compared to the reference level.

Equation 2 takes into account various population groups exposed at different levels of pollutants. In the case of the population of only one city with only one exposure level, this formula simplifies to Equation 3 (i.e. Pi becomes 1, as the total population is exposed, and only one relative risk value would apply):

$$AF = \frac{RR - 1}{RR} \quad \textit{(Equation 3)}$$

To estimate the impact of changing the exposure from one distribution to another, for example through a public-health intervention, a more general formula than Equation 2 could be used (Equation 4). This formula can be used to estimate the fraction of the disease burden attributable to the risk factor, as compared to some 'alternative' or counterfactual level, which might be the minimum that can be feasibly achieved in a given time frame.

$$IF = \frac{\Sigma P_i RR_i - \Sigma P_i' RR_i}{\Sigma P_i RR_i} \quad \textit{(Equation 4)}$$

where:

Pi = the proportion of the population at exposure category 'i".

Pi' = the proportion of the population in exposure category 'i' after an intervention or other change.

RRi =the relative risk at exposure category 'i' compared to the reference level.

To calculate the expected number of mortality cases due to air pollution (E), the AF is applied to the total number of deaths:

$E = AF \times B \times P$ *(Equation 5)* where:

E = the expected number of deaths due to outdoor air pollution.

B = the population incidence of the given health effect (i.e. deaths per 1000 people).

P = the relevant exposed population for the health effect.

The AF is based on relative risks derived from epidemiological studies and from the change in PM being evaluated. B is obtained or approximated from available health statistics, and P is obtained from census or other data for the area under study.

9. EBD application in Kathmandu valley

In this chapter, we have tried to apply the environmental burden of disease concept in case of Kathmandu valley due to PM_{10} concentration. We have used WHO Environmental Burden of Disease Series, No. 5, *Outdoor air pollution: Assessing the environmental burden of disease at national and local levels* (Ostro, 2004) as a reference to carry out the burden of disease assessment.

Kathmandu valley constitutes five municipalities and it has population approximate to 1.65 million (this is sum of three districts, namely Kathmandu, Bhaktapur and Lalitpur) according to 2001 census. Crude Mortality rate data from the statistical pocket book, Central Bureau of Statistics, 2002 were used to determine the existing mortality rate (which is calculated to be 0.0101). The ß-coefficients used in the models are detailed in Table 12.

Before calculating the disease burden due to outdoor air pollution in Kathmandu, we have made few assumptions.

1. Out estimation for the annual average of PM_{10} concentration was derived from the air quality monitoring conducted by ESPS. Averaging PM_{10} concentration of all six monitoring locations for the one year period could give the overall exposure concentration to the people living within the Kathmandu valley.
2. We, therefore, used the EBD model to calculate the mortality due to short-term exposure to PM_{10}.
3. We assumed the mortality rate of Kathmandu valley is equal to that of national.
4. As the monitoring sites in Kathmandu valley has been distributed throughout the valley (covering both rural as well as urban centres), we assumed that the annual mean of these six sites will give an average value for PM_{10} concentration that the overall population of the valley is being exposed to.
5. We assumed that sum of the population living in three districts; Kathmandu, Bhaktapur and Lalitpur will give the population living within Kathmandu valley, although there is certain percentage of these population living just in another part of the valley.

There are few limitations while conducting this EBD study in case of Kathmandu valley, which we could not avoid due to different factors. They are:

1. Due to the lack of epidemiological studies in case of urban air pollution in Kathmandu valley, we were bound to use the ß coefficient developed elsewhere.
2. Due to the lack of mortality rate due to cardiovascular related disease for Kathmandu valley, we could not do assess the burden of disease due to the long-term exposure to $PM_{2.5}$.

3. Due to the short time of the study, we could not be able to assess the burden of disease to the different subpopulation such as children under five years of age, elderly, women etc.

We used three different baseline concentrations - a background concentration of 10 $\mu g/m^3$ for PM_{10}, the proposed European Union target limit value for 2010 of 20 $\mu g/m^3$ for PM_{10} and the Nepalese NAAQS of 120 $\mu g/m^3$ for PM_{10}. These three baseline concentrations were used to determine the burden of disease at three different scenario.

The background concentration as baseline concentration will help to calculate the current attributable burden, while the national standard used to calculate a targeted reduction in the burden if we could meet the national standard for PM_{10}. The European Union target limit would suggest a value that being strict on AAQS enforcement, how much will be the attributed burden due to current PM_{10} concentration which could be avoided if we meet the European Union standard.

Scenario 1 (baseline concentration for PM_{10} = 10 $\mu g/m^3$)

From Equation 1, the relative risk for effects of short-term exposure to PM_{10} concentration of 132.88 µ g/m³ is:

$RR = \exp[\beta(X - Xo)] = \exp[0.001(132.82 - 10] = 1.13068$

Using Equation 3, the AF for the change to 10 $\mu g/m^3$ is:

$AF = (1.13068 - 1) / 1.13068 = 0.11558$

The expected total number of cases of premature mortality from short-term exposure to PM_{10} is the product of the AF, the population and the baseline rate. Therefore, the impact of the current ambient level of PM_{10} (138.82 $\mu g/m^3$), relative to a concentration of 10 $\mu g/m^3$, is:

$E = (0.11558)(0.0101)(1.65 * 10^6) = 1926$ cases of premature mortality per year, with upper and lower boundary to be 1184 and 2973.

If we assume a baseline concentration of 10 $\mu g/m^3$ for PM_{10}, the estimated effect is 1926 cases of premature mortality per year (lower and upper bounds of 1184 and 2973, respectively). This is value gives the picture of the attributable burden due to current PM_{10} concentration or the total health impact of the risk factor.

Scenario 2 (baseline concentration for PM_{10} = 20 $\mu g/m^3$)

From Equation 1, the relative risk for effects of short-term exposure to PM_{10} concentration of 132.88 µ g/m³ is:

$RR = \exp[\beta(X - Xo)] = \exp[0.001(132.82 - 20] = 1.1194$

Using Equation 3, the AF for the change to 20 $\mu g/m^3$ is:

AF = (1.1194 - 1) / 1.1194 = 0.10669

The expected total number of cases of premature mortality from short-term exposure to PM_{10} is the product of the AF, the population and the baseline rate. Therefore, the impact of the current ambient level of PM_{10} (138.82 $\mu g/m^3$), relative to a concentration of 20 $\mu g/m^3$, is:

E = (0.10669)(0.0101)(1.65 * 10^6) = 1778 cases of premature mortality per year, with upper and lower boundary to be 1091 and 2752.

This scenario gives the number of cases of premature mortality from short-term exposure to PM_{10} in Kathmandu valley which could be avoided if we could be strict enough on the air quality standard enforcement to meet the European Union's target for 2010.

Scenario 3 (baseline concentration for PM_{10} = 120 $\mu g/m^3$)

From Equation 1, the relative risk for effects of short-term exposure to PM_{10} concentration of 132.88 μ g/m^3 is:

RR = exp[ß(X - Xo)] = exp[0.001(132.82 - 120] = 1.0129

Using Equation 3, the AF for the change to 120 $\mu g/m^3$ is:

AF = (1.0129- 1) / 1.0129 = 0.01274

The expected total number of cases of premature mortality from short-term exposure to PM_{10} is the product of the AF, the population and the baseline rate. Therefore, the impact of the current ambient level of PM_{10} (138.82 $\mu g/m^3$), relative to a concentration of 120 $\mu g/m^3$, is:

E = (0.01274)(0.0101)(1.65 * 10^6) = 212 cases of premature mortality per year, with upper and lower boundary to be 127 and 338.

This scenario give the number of cases of premature mortality from short-term exposure to current PM_{10} concentration in Kathmandu valley which could be avoided if the government could reduce the ambient PM_{10} concentration to national standard, which it has promised to meet within three years of the standard setting date. Although, there is high difference in the calculated number of cases of premature mortality due to current concentration over national standard and background concentration, at least at this point we could expect to avoid 212 cases of premature mortality per year reducing the annual mean of PM_{10} to national standard.

Policy regulation related to air pollution in Nepal

Although there is no particular law or act focusing solely on air pollution control in Nepal like Clean Air Act, there are some provisions made in few other laws regarding it. These laws have been made with emphasis on other issues, however, there are certain points that deals with air pollution, especially urban air pollution.

Below are some of these acts, laws and policies that address the air pollution problems nationwide:

a. The Constitution of the Kingdom of Nepal, 1990

The state give priority to the protection of environment and take special measures for preventing further damage due to physical development activities.

b. Industrial Enterprises Act,1992

This Act grants a reduction of up to 50 percent on the taxable income of any industry invested in pollution minimisation equipment or processes.

c. Vehicles and Transport Management Act, 1993

This Act has been enacted with a view to manage and regulate the traffic and provide convenient and effective transportation facilities to the public. Section14(1) has made compulsory to register any vehicle that is purchased or imported and 14(2) prohibits the use of vehicles without registration. Section 17 authorizes to test the vehicles according to the criteria prescribed under section 23 of the Act. This includes:

- Mechanical condition of the vehicle
- Amount of pollution discharged by the vehicles
- Life span of the vehicles
- Make or appearance of the vehicles

According to this section 23, the government has set the emission standard to check vehicular emission in Kathmandu valley. The government specified; smoke density of diesel engine should not exceed 65 Hartridge smoke unit (HSU) and CO emitted by petrol engine vehicles should not exceed 3 percent by volume. However, later this limit has been brought down to 75 HSU and 4.5 percent by volume respectively.

d. Environment Protection Act, 1996

In order to give effect to constitutional mandates, special "Environment Protection Act 1996" (enforced from June 24, 1997) & "Environment Protection Rules 1997 (enforced from June 26, 1998) have brought into existence. These Act & Rules have made provisions dealing with pollution control, IEE & EIA, conservation of national heritage etc. The main thrusts of the Act and the Regulation are pollution control and environment assessment. Regarding environmental pollution prevention and control, a pollution control permit system is conceived in the regulation. Further procedural approaches are still unclear, but according to the Environment Protection Regulations, MoPE limit its activity to formulate the environmental standards, and the other concerned line agencies should execute them. A provision of a revolving fund for pollution control, environment, heritage conservation, awareness creation, research and award business exists in the regulation.

Sec. 7 provides for pollution control as follows:

Prevention & Control of Pollution:

A person shall not cause pollution or allow pollution to be caused in a manner which is likely to have significant adverse impact on the environment or harm human lie or public health or shall not emit, discharge sound, beat, radioactive from any machine, industrial enterprise or any other place above the prescribed standard.

If it is found that a person has been significantly adversely effecting the environment, relevant agency may impose necessary conditions in relation to that or may prohibit from doing such act. The Ministry may, by publishing a notification in the Nepal Gazette, prohibit the use of such matter, fuel, equipment or plant whose use has significantly adversely effected the environment or is likely to have significant adverse impact on the environment.

Other provision elating to prevention & control of pollution shall be as prescribed.

In Sec. 8 of the Act, the appointment & qualifications of the Environment Inspector has been provided. The responsibility of the said Inspector is to supervise whether abatement or control of pollution is done in accordance with the Act or regulation.

Sec. 12 of the Act empowers the relevant person designated by the Secretariat or the Agency to collect sample of air, water etc. discharged by any industry or body or vehicle for examination. Similarly, sec. 15 empowers HMG/N to give concessions & incentives to industry & bodies for pollution control. Besides, the prescribed office may prohibit the work with immediate effect & impose a fine upto an amount of one hundred thousand rupees if there is a violations of the Act or rules (Sec. 18).

Sec. 24 empowers the HMG to frame rules including for matters relating to sources of pollution, standards, prevention & control of pollution.

Furthermore, there is several other legislation, which has provision for air pollution control, but these statues remain to be implemented effectively. These are Town Development, Act, 1988; Kathmandu Valley Development Authority Act, 1988; Labour Act, 1991; Municipality Act, 1991; Pesticide Act, 1992; Industrial Enterprises Act, 1992; Water Resources Act, 1992; Electricity Act 1992; and Financial Act, 1993, NEPAP 1993.

However, for the past few years, government has started realising outdoor air pollution as a major threat to the public health and environmental problem in Kathmandu valley and other few urban & tourist centres. In line with this realisation, it has taken few steps to curb the air pollution in urban areas with special respect to Kathmandu valley.

Government has set the national standard for ambient level of six classic air pollutants. Although at most of the air quality monitoring stations, the average value frequently crossed the standard value for PM_{10}, a major problem in the Kathmandu's air, the government has set target to meet the standard value within 3 years from the date of standard setting (which was June 2003).

To achieve the goal of reducing urban air pollution, government has implemented some policies to reduce emission from vehicles as well as industries.

Response of HMG/N through policy and program to curb the air pollution problem in Kathmandu valley:

Vehicles

Tail pipe Emission Standard for Diesel and Petrol vehicle

Considering the problem of vehicular emission in Kathmandu, Kathmandu Valley Vehicular Emission Control Project (KVVECP) in 1992 conducted emission test for diesel and petrol vehicles operating in Kathmandu. Out of vehicle tested, the results of petrol vehicle showed that 51 percent four wheelers, 77 percent three-wheelers and 62 percent two wheelers were found to be within the limit of 3 percent of CO exhaust emission. It found that only 4.8 percent of diesel vehicles were within the smoke level of 65 HSU and 13.8 percent in the range of 66-75 HSU. Based on these findings the project recommended emission limit of 75 HSU for diesel vehicle under free acceleration condition and 3 percent CO by volume for gasoline during idle condition. Later His Majesty's Government introduced limits for vehicular emission to be 65 HSU for diesel and 3 percent CO for gasoline vehicle and enforced this limit for the first time in June 1995. But only after two and half years government relaxed the diesel smoke to 75 HSU for the vehicles manufactured till 1994 and CO limit for gasoline vehicle to 4.5 percent for four wheeler manufactured till 1980. This emission standard is only valid in Kathmandu and in other city emission test for vehicle is not in practice.

Inspection and Maintenance Program

With the introduction of tailpipe emission standard, the Valley Traffic Police (VTP) was playing a vital role in inspecting vehicle at its emission testing station inside the VTP office complex till recently. As a general procedure, green stickers are issued to the vehicles that pass emission test and red stickers for those vehicles that does not pass the prescribed emission limit. Vehicles with red sticker are restricted or denied entry into the government offices, airport area and in main core city centres. Recently this vehicle emission testing is being carried out by DoTM.

Nepal Vehicle Mass Emission Standard, 1999

In 2000, MoPE introduced the Nepal Vehicular Mass Emission-2056 for new vehicles, which is similar to the European Emission - I (EURO - I) Norm. Along with the decision of banning diesel three wheelers from Kathmandu valley, Government has also decided to ban import of two stroke two wheelers (Raut, 2002).

Clean Fuel Program

Considering the problem of lead in the petrol, for the first time in 1997, Nepal Oil Corporation (NOC) introduced unleaded gasoline in Kathmandu. For two years unleaded gasoline was only available in one petrol pump but at present almost all petrol pumps provide unleaded gasoline for the consumer in Kathmandu valley. Nepal imports all the fossil fuel from India and presently available unleaded fuel is similar to that of Unleaded gasoline that is available in India. Apart from the lead in petrol, from the quality data of fuel available from NOC, an improvement in the constituent such as sulfur in the gasoline could also been seen. The levels of lead and sulfur requirement in gasoline, for example has been tightened from 0.15 to 0.013 and 0.20 to 0.10 respectively, from 1995 to 2000. It indicates that there has been gradual improvement in fuel quality that is imported in country but no body knows how much fuel is adulterated with in a country.

Vehicle Phase Out Program:

MoPE in the later part of 2000 announced a ban in all public vehicles older than 20 years and all two stroke three wheelers in Kathmandu valley effective from 16 November 2001. This decision however has not been implemented so far. The government has, however, banned the import of new two-stroke vehicles since 1999 (Tuladhar, 2001).

This was another bold step taken after banning of about 600 diesel three wheelers from Kathmandu Valley. Similarly HMG/N has also announced to ban the operation of diesel three wheelers effective from the same date from all other sub-metropolitan, municipalities, sub-municipalities, and cities where at present previous expulsed three wheelers from Kathmandu are plying.

Cleaner Vehicle Program

Along with Electric vehicles (EVs), LPG operated vehicles are also seen running with the banner of zero emission vehicle in Kathmandu.

Along with Electric vehicles (EVs), Liquefied Petroleum Gas (LPG) operated vehicles are also seen running with the banner of zero emission vehicle in Kathmandu. There are altogether 650 EVs and about 1000 three and four-wheel LPG vehicles presently plying in the street of Kathmandu valley. EV movement in Nepal took its root in the year 1989, when Nepal felt an impact of trade and transit embargo from India. Considering the energy security aspect, as Nepal is endowed with large amount of water resources and there is potentiality of generating hydro energy, Electric vehicle has always been the choice of people here. With the announcement of banning of diesel three wheelers from Kathmandu number of EVs spurt and totalled to 650.

To promote Cleaner Fleet the Fiscal Act introduced in the year 1999, provides tax incentives for the production of electricity, gas and battery operated vehicles or for the import of the necessary parts of such vehicles in country. This policy has not only facilitated the growth of EVs in country but providing similar facilities to LPG vehicle also has caused for the increment of number of LPG operated vehicles. Since the operating cost for LPG vehicle is quite cheaper compare to EVs, this has caused to increase the number LPG operated vehicle in Kathmandu. At present all the LPG vehicle are using LP Gas that is imported for the means of cooking. Presently available LPG is mixture of Propane and Butane at 19 percent and 79 percent respectively, with little addition of smelling agent Ethyl mercaptan. The reason to add Ethyl mercaptan is to signal out the warning in case of leakage. Though it has been proven that LPG provides less air quality benefits than CNG, primarily because the hydrocarbon emissions are more photochemical reactive and also because they emit more carbon monoxide, government of Nepal has not announced publicly the emission standard for LPG vehicle. The 1000 LPG driven vehicle providing transportation services to the commuters in Kathmandu is siphoning out the fuel from Kitchen meant for the cooking purposes.

Industries

In March 2002, Industrial Promotion Board of HMG/N, decided that after a year and half the government will ban brick kilns that use outdated Bulls Trench Kiln technology in Kathmandu valley. These brick kilns of which most of them are traditional Bull's Trench Kilns was one of the major sources of air pollution in the valley and was prime pollution source in industrial sources after the closure of Himal Cement Factory. The Board has also decided to start the legal and administrative work to change existing polluting industries towards the cleaner options. The Board further ordered the Department of Cottage and Small Industries (DCSI) to close down the brick kilns, which are operating without registration (illegal kilns). In the fiscal year 2000/2001, DCSI conducted action against 33 illegally operating brick kilns in Kathmandu valley and fined them a total of NRs. 3.65 million (DCSI, 2002). At the same time, government had announced to stop registration for new Bull's Trench Brick Kilns in Kathmandu valley.

After the government's decision to shift towards cleaner technologies, brick kiln entrepreneurs looked at the various environment friendly brick making technologies. Due to the fact there are now some of the brick kilns operating in new technology. Till now, over 60 kilns have adopted new and less polluting technologies replacing the old ones (CEN, 2004b).

10. Conclusion and recommendations

Outdoor air pollution has been identified as one of the major threat to public health, specially to the urban population. In case of Nepal too, outdoor air pollution has been found a major environmental chaos in urban areas. Whether it is Kathmandu or other urban cities, particulate matter is a major problem in the air. Other gaseous pollutants have been found within the guideline value.

Following conclusions can be made from this study:

1. Air pollution is a major area of concern in urban cities of Nepal, where particularly, particulate matter is higher in the concentration that threats the public health.
2. In case of Kathmandu valley, vehicles are the major sources of air pollution along with brick industries.
3. There is seasonal variation in the PM_{10} concentration in Kathmandu. Dry winter periods are polluted period of the years when in high traffic areas, PM_{10} concentration crosses the national standard almost all time.
4. During the short term study in two cities, Birgunj and Pokhara, it shows the similar trend like Kathmandu where high traffic area is most polluted. Out of these cities, Birgunj is more polluted than Pokhara where again the problem of particulate matter is prevailing.
5. Annual mean of PM_{10} in Kathmandu was calculated to be 132.88 $\mu g/m^3$ from March 2003 to February 2004.
6. In case of Kathmandu valley, Putalisadak was found out to be the most polluted site. Annual average of PM_{10} at Putalisadak was calculated to be 209.01 $\mu g/m^3$ whereas, least polluted site was Matsyagaon where the annual PM_{10} average was found out to be 53.57 $\mu g/m^3$.
7. Besides the particulate matter, other gaseous air pollutants in Kathmandu valley were found within the guideline. However, certain harmful pollutants such as Benzene and PAH has become a major concern in high traffic area.
8. The attributable burden due to current PM_{10} concentration in Kathmandu valley against the baseline concentration of 10 $\mu g/m^3$ was found out to be 1926 cases of premature mortality per year (lower and upper bounds of 1184 and 2973, respectively).
9. Similarly, the number of cases of premature mortality from short-term exposure to current PM_{10} concentration in Kathmandu valley which could be avoided if the government could reduce the ambient PM_{10} concentration to national standard, was calculated to be 212 cases of premature mortality per year, with upper and lower boundary to be 127 and 338.
10. Analysis of hospital records revealed that there is increase in number of patients being suffered from COPD in Kathmandu's public hospitals. Similarly, the seasonal variation of COPD patients also coincide with the PM_{10} concentration in Kathmandu. During

the dry winter season, when the PM_{10} concentration was found higher, the COPD patients number also shows the same trend.

11. There are some laws and regulations that deals with the urban air pollution control. Also the government has initiated some of the policy measures to curb the urban air pollution with emphasis to Kathmandu valley. Still they have not been effective as per the expectations.
12. While most of the focus is in Kathmandu valley, other urban areas of Nepal are also following the foot trails of Kathmandu and bringing home the problem of urban air pollution.

Based on the study findings, we recommend following actions from the concerned authorities:

1. There is urgent need to extend the regular air quality monitoring programme in other urban cities of Nepal and assess the impact due to it, as the focus has been in Kathmandu valley only.
2. Air pollution in Kathmandu valley, specially, particulate matter has been a serious threat to human health. There is urgent need to address the problem.
3. While addressing the problem of air pollution, the cost of human health should also be kept in mind by the policymakers.
4. In case of Kathmandu valley, vehicles are the major cause of air pollution. Therefore, we recommend to find out bottlenecks on the vehicular emission control and work towards reduced emission from vehicles.
5. A detail burden of disease study in major urban areas of Nepal is required to assess the health impact due to urban air pollution.
6. While calculating the EBD based on the WHO guideline, due to the absence of epidemiological studies in Nepal, we used the risk factor developed in other parts of the world. Therefore, we recommend to have epidemiological studies due to air pollution.
7. There is absence of proper hospital database with reference to air pollution related disease. This is almost nil in case of hospitals outside Kathmandu valley. Therefore, we recommend to develop such mechanism.
8. To combat the increasing threat due to the ambient air pollution in urban areas, holistic policy measures should be taken which could be done by the formulation and implementation of Clean Air Act.
9. Although, there are few laws existing which deals with air pollution problem, implementation of these laws has not been very effective. Therefore, focus should also be given towards the enforcement of these laws.

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12. Annex - 1: Air Pollution data of Kathmandu valley (PM_{10})

[MARCH 2003 TO FEBRUARY 2004]

March, 2003

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

April, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
4/1/2003	224	63	102	158	217	157	154
4/2/2003	216	82	119	171	222	163	162
4/3/2003	282	92	129	178	241	188	185
4/4/2003	202	56	81	129	167	127	127
4/5/2003	165	47	69	139	143	125	115
4/6/2003	239	45	76	168	156	151	139
4/7/2003	272	65	117	200	232	181	178
4/8/2003	329	74	130	236	263	228	210
4/9/2003	350	102	165	261	313	236	238
4/10/2003	307	115	186	289	356	290	257
4/11/2003	366	124	195	309	309	271	262
4/12/2003	316	138	185	250	315	269	246
4/13/2003	320	134	148	233	286	255	229
4/14/2003	197	72	126	162	227	148	155
4/15/2003	222	58	121	170	260	137	161
4/16/2003	250	73	114	146	354	162	183
4/17/2003	213	50	108	128	243	166	151
4/18/2003	226	87	121	178	N/A	205	163
4/19/2003	277	103	127	206	N/A	228	188
4/20/2003	142	73	87	162	N/A	88	110
4/21/2003	248	100	148	228	N/A	185	182
4/22/2003	332	121	126	241	N/A	235	211
4/23/2003	231	122	121	231	186	248	190
4/24/2003	284	132	114	209	291	334	227
4/25/2003	305	122	108	240	250	324	225
4/26/2003	235	100	121	213	236	266	195
4/27/2003	203	62	127	156	211	37	133
4/28/2003	157	71	60	100	91	N/A	96
4/29/2003	N/A	N/A	80	117	145	N/A	114
4/30/2003	N/A	N/A	100	148	285	N/A	178
Monthly Avg.	**254**	**89**	**120**	**192**	**240**	**200**	**179**

May, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
5/1/2003	N/A	N/A	102	126	264	N/A	164
5/2/2003	N/A	N/A	64	134	159	N/A	119
5/3/2003	N/A	N/A	99	148	250	N/A	166
5/4/2003	272	N/A	100	137	181	N/A	173
5/5/2003	364	189	200	241	331	N/A	265
5/6/2003	427	N/A	209	295	378	N/A	262
5/7/2003	415	N/A	227	318	386	N/A	269
5/8/2003	455	298	194	325	395	N/A	333
5/9/2003	251	75	162	208	296	N/A	198
5/10/2003	243	83	100	161	187	N/A	155
5/11/2003	221	71	87	124	213	N/A	143
5/12/2003	176	54	73	105	220	N/A	126
5/13/2003	192	60	96	124	196	N/A	134
5/14/2003	251	62	109	157	237	N/A	163
5/15/2003	241	63	103	159	210	N/A	155
5/16/2003	253	64	92	143	235	N/A	157
5/17/2003	160	61	86	133	177	N/A	123
5/18/2003	213	50	91	140	183	N/A	135
5/19/2003	200	63	N/A	133	220	N/A	123
5/20/2003	245	73	N/A	155	225	N/A	140
5/21/2003	268	80	109	164	210	N/A	166
5/22/2003	172	45	52	106	152	N/A	105
5/23/2003	204	47	70	125	227	N/A	135
5/24/2003	187	64	73	108	148	N/A	116
5/25/2003	164	80	88	135	178	N/A	129
5/26/2003	305	100	129	184	229	N/A	189
5/27/2003	348	136	166	208	256	N/A	223
5/28/2003	332	N/A	145	190	227	N/A	179
5/29/2003	324	N/A	N/A	243	252	N/A	164
5/30/2003	385	N/A	N/A	298	299	N/A	196
5/31/2003	295	N/A	N/A	208	232	N/A	147
Monthly Avg.	**270**	**87**	**116**	**175**	**237**	**N/A**	**177**

June, 2003

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

July, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg
7/1/2003	115	37	43	61	124	69	75
7/2/2003	133	43	44	55	137	75	81
7/3/2003	149	28	28	37	131	54	71
7/4/2003	40	25	32	36	85	44	44
7/5/2003	117	29	35	37	121	61	67
7/6/2003	149	21	23	32	107	59	65
7/7/2003	226	21	19	33	95	80	79
7/8/2003	90	17	17	27	57	45	42
7/9/2003	36	21	19	28	87	38	38
7/10/2003	126	19	26	38	158	64	72
7/11/2003	170	20	19	33	194	73	85
7/12/2003	98	22	23	36	155	58	65
7/13/2003	148	27	33	34	97	62	67
7/14/2003	113	22	25	32	81	59	55
7/15/2003	189	30	28	35	116	70	78
7/16/2003	108	31	38	71	181	66	83
7/17/2003	84	28	28	31	117	53	57
7/18/2003	63	25	33	33	130	50	56
7/19/2003	81	28	32	35	78	71	54
7/20/2003	104	20	24	31	106	88	62
7/21/2003	134	20	25	36	153	63	72
7/22/2003	118	19	32	39	197	61	78
7/23/2003	167	17	19	35	113	65	69
7/24/2003	129	35	28	46	112	84	72
7/25/2003	136	24	23	36	151	98	78
7/26/2003	87	13	17	26	77	55	46
7/27/2003	98	18	24	41	159	58	66
7/28/2003	102	21	30	33	190	72	75
7/29/2003	122	20	20	32	134	57	64
7/30/2003	77	11	16	24	98	42	45
7/31/2003	88	13	16	23	57	41	41
Monthly Avg.	**116**	**23**	**26**	**36**	**123**	**63**	**65**

August, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
8/1/2003	126	16	21	33	112	60	61.33
8/2/2003	65	21	22	30	55	47	40
8/3/2003	139	22	27	34	118	68	68
8/4/2003	156	22	33	40	188	85	87.33
8/5/2003	92	27	34	43	170	66	72
8/6/2003	118	22	28	38	114	74	65.66
8/7/2003	123	26	30	33	130	75	69.5
8/8/2003	276	17	25	29	88	64	83.16
8/9/2003	193	21	29	39	110	73	77.5
8/10/2003	155	25	31	38	119	67	72.5
8/11/2003	123	23	37	48	103	63	66.16
8/12/2003	116	23	28	79	87	56	64.83
8/13/2003	126	22	28	46	135	74	71.83
8/14/2003	155	33	37	51	202	82	93.33
8/15/2003	203	30	34	48	165	71	91.83
8/16/2003	131	30	35	43	126	73	73
8/17/2003	94	24	35	30	118	57	59.66
8/18/2003	40	12	17	33	49	42	32.16
8/19/2003	36	14	15	29	59	39	32
8/20/2003	80	22	28	42	74	58	50.66
8/21/2003	130	18	39	48	181	93	84.83
8/22/2003	133	22	32	46	211	79	87.16
8/23/2003	102	17	16	31	124	58	58
8/24/2003	130	20	29	31	148	72	71.66
8/25/2003	107	26	33	36	107	62	61.83
8/26/2003	138	24	31	39	91	71	65.66
8/27/2003	144	22	36	40	92	61	65.83
8/28/2003	153	22	25	32	117	67	69.33
8/29/2003	117	27	51	35	108	58	66
8/30/2003	114	22	N/A	41	82	58	63.4
8/31/2003	60	19	33	28	71	46	42.83
Monthly Average	**125**	**22.29**	**29.96**	**39.13**	**117.87**	**65.12**	**66.74**

September, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
9/1/2003	125	23	32	31	105	56	62
9/2/2003	93	20	24	34	79	54	50.66
9/3/2003	140	21	24	36	122	69	68.66
9/4/2003	167	25	29	34	110	64	71.5
9/5/2003	142	20	26	39	131	54	68.66
9/6/2003	97	25	34	43	139	60	63.33
9/7/2003	158	22	26	39	117	65	71.66
9/8/2003	146	22	29	47	145	73	77
9/9/2003	139	25	34	49	117	82	74.33
9/10/2003	102	26	38	48	161	72	74.5
9/11/2003	121	32	35	49	178	68	80.5
9/12/2003	150	34	34	45	140	79	80.33
9/13/2003	81	24	27	42	123	54	50.14
9/14/2003	91	28	34	44	166	55	69.66
9/15/2003	132	24	32	36	188	56	78
9/16/2003	142	24	38	41	216	81	90.33
9/17/2003	152	25	34	46	156	88	83.5
9/18/2003	46	21	22	33	52	42	36
9/19/2003	67	24	26	40	60	63	46.66
9/20/2003	57	22	24	34	72	56	44.16
9/21/2003	97	21	22	38	74	57	51.5
9/22/2003	142	29	35	52	172	86	86
9/23/2003	112	27	33	47	86	60	60.83
9/24/2003	72	23	36	54	69	65	53.16
9/25/2003	197	29	51	71	140	87	95.83
9/26/2003	220	26	47	61	163	104	103.5
9/27/2003	196	21	26	55	111	95	84
9/28/2003	157	26	40	46	159	93	86.83
9/29/2003	161	33	46	63	182	90	95.83
9/30/2003	83	23	30	42	96	63	56.17
Monthly average	**126.16**	**24.83**	**32.26**	**44.63**	**127.63**	**69.7**	**70.50**

October, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
10/1/2003	168	22	34	54	126	95	83.17
10/2/2003	147	19	33	47	148	93	81.17
10/3/2003	121	28	40	61	113	89	75.33
10/4/2003	106	32	41	56	114	87	72.67
10/5/2003	108	27	34	47	78	87	63.5
10/6/2003	91	31	34	45	101	88	65
10/7/2003	97	32	35	46	101	94	67.5
10/8/2003	99	30	34	42	103	77	64.16
10/9/2003	92	25	28	37	83	61	54.33
10/10/2003	107	22	28	40	97	64	59.66
10/11/2003	109	27	40	49	98	91	69
10/12/2003	143	30	46	61	125	106	85.16
10/13/2003	148	29	44	68	135	114	89.66
10/14/2003	143	36	54	74	148	121	96
10/15/2003	156	42	55	77	150	122	83.66
10/16/2003	155	38	54	82	129	122	96.66
10/17/2003	159	34	48	78	111	115	90.83
10/18/2003	127	38	46	68	109	115	83.83
10/19/2003	151	32	51	86	115	116	91.83
10/20/2003	189	35	63	92	138	140	109.5
10/21/2003	185	32	57	86	116	142	103
10/22/2003	173	45	65	105	138	142	111.33
10/23/2003	186	45	66	102	175	139	118.83
10/24/2003	205	58	90	109	182	160	134
10/25/2003	172	57	66	87	123	129	105.66
10/26/2003	114	36	39	78	111	98	79.33
10/27/2003	93	20	24	43	76	74	55
10/28/2003	91	20	31	38	94	68	57
10/29/2003	108	20	32	59	102	85	67.66
10/30/2003	124	25	49	67	120	102	81.16
10/31/2003	130	26	43	75	131	108	85.5
Monthly average	135.38	32.03	45.29	66.42	119.03	104.64	83.26

November, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
11/1/2003	121	42	63	91	146	114	96.16
11/2/2003	172	66	86	112	181	157	129
11/3/2003	190	69	102	124	209	196	148.33
11/4/2003	189	58	84	124	186	183	137.33
11/5/2003	195	61	90	116	161	180	133.83
11/6/2003	191	71	96	131	174	198	143.5
11/7/2003	197	74	105	117	214	190	149.5
11/8/2003	186	64	85	114	152	174	129.16
11/9/2003	171	56	81	99	170	172	124.83
11/10/2003	NA	NA	NA	NA	NA	NA	NA
11/11/2003	167	56	70	96	180	146	119.16
11/12/2003	174	50	78	91	178	165	122.66
11/13/2003	232	45	85	102	163	175	133.66
11/14/2003	192	45	66	103	163	186	125.83
11/15/2003	175	44	72	93	140	173	116.16
11/16/2003	166	65	63	77	179	145	115.83
11/17/2003	192	41	72	99	159	156	119.83
11/18/2003	189	46	68	105	168	143	119.83
11/19/2003	192	37	71	104	167	182	125.5
11/20/2003	220	40	73	112	170	210	137.5
11/21/2003	193	53	87	106	193	157	131.5
11/22/2003	176	56	79	108	153	157	121.5
11/23/2003	180	49	72	99	187	149	122.66
11/24/2003	200	44	66	108	187	185	131.66
11/25/2003	189	47	69	117	189	167	129.66
11/26/2003	191	50	71	91	193	132	121.33
11/27/2003	217	52	81	108	186	176	136.66
11/28/2003	192	48	75	103	149	157	120.66
11/29/2003	184	55	79	105	169	165	126.16
11/30/2003	209	56	80	121	199	192	142.83
Monthly Average	**187.65**	**53.1**	**78.24**	**106.07**	**174.65**	**168.34**	**128.0**

December, 2003

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
12/1/2003	235	62	104	121	215	215	158.66
12/2/2003	248	62	96	114	224	218	160.33
12/3/2003	278	52	91	110	201	180	152
12/4/2003	200	48	67	98	182	151	124.33
12/5/2003	243	56	92	117	208	190	151
12/6/2003	276	70	114	134	202	225	170.16
12/7/2003	227	76	95	134	211	173	152.66
12/8/2003	245	68	85	124	194	179	149.16
12/9/2003	231	37	60	97	159	162	124.33
12/10/2003	251	32	63	96	181	159	130.32
12/11/2003	226	36	66	106	201	181	136
12/12/2003	265	36	70	104	211	186	145.33
12/13/2003	336	36	77	126	218	214	167.83
12/14/2003	N/A	32	80	128	206	232	135.6
12/15/2003	N/A	44	96	136	223	238	147.4
12/16/2003	N/A	82	121	155	304	287	189.8
12/17/2003	356	47	112	115	238	259	187.33
12/18/2003	338	42	84	124	231	217	172.66
12/19/2003	303	34	81	162	232	233	174.66
12/20/2003	285	41	92	149	238	198	167.16
12/21/2003	297	42	82	159	244	208	172
12/22/2003	278	36	74	132	217	217	159
12/23/2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/24/2003	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12/25/2003	323	32	83	160	231	260	181.5
12/26/2003	322	49	96	140	251	215	178.83
12/27/2003	245	54	110	156	208	195	161.33
12/28/2003	239	26	56	75	101	118	102.5
12/29/2003	282	43	90	124	198	204	156.83
12/30/2003	360	54	92	157	193	236	182
12/31/2003	347	49	114	195	256	271	205.33
Monthly Average	302.57	43.86	91.57	143.86	205.43	214.14	166.9

January, 2004

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
1/1/2004	340	44	90	183	236	263	192.66
1/2/2004	314	51	87	156	292	220	186.66
1/3/2004	260	42	102	169	234	224	171.83
1/4/2004	262	55	103	177	234	226	176.16
1/5/2004	280	57	105	164	264	195	177.5
1/6/2004	330	47	106	169	249	231	188.66
1/7/2004	326	45	97	200	242	241	191.83
1/8/2004	366	49	116	232	298	255	219.33
1/9/2004	344	50	107	205	299	248	209.66
1/10/2004	295	51	110	202	273	237	194.66
1/11/2004	316	60	125	172	271	256	200
1/12/2004	279	57	112	207	271	264	198.33
1/13/2004	277	56	104	206	260	212	185.83
1/14/2004	N/A	45	105	206	192	196	144.4
1/15/2004	182	51	101	184	198	183	144.33
1/16/2004	320	81	130	151	229	204	193.5
1/17/2004	287	65	113	197	226	223	183
1/18/2004	313	69	123	227	330	234	216
1/19/2004	285	63	133	214	265	216	196
1/20/2004	270	69	124	221	271	221	196
1/21/2004	244	67	119	195	199	180	167.33
1/22/2004	251	59	102	179	212	137	156.66
1/23/2004	195	65	140	219	204	170	165.5
1/24/2004	139	33	66	100	118	104	93.3
1/25/2004	343	34	77	153	217	190	169
1/26/2004	309	61	89	149	267	233	184.66
1/27/2004	254	57	81	143	229	177	156.83
1/28/2004	248	57	106	149	261	208	171.5
1/29/2004	294	81	126	175	220	215	185.16
1/30/2004	297	66	113	167	236	227	184.33
1/31/2004	317	71	168	247	300	256	226.5
Monthly average	**284.57**	**56.71**	**109.03**	**184.45**	**245.06**	**214.39**	**181.52**

February, 2004

Date	Putalisadak	Matsyagaon	TU	Bhaktapur	Patan Hospital	Thamel	Ktm. Avg.
2/1/2004	365	49	136	202	290	234	212.66
2/2/2004	186	45	93	160	187	151	137
2/3/2004	222	43	86	167	225	185	154.66
2/4/2004	173	64	81	127	210	162	136.16
2/5/2004	187	64	83	109	172	137	125.33
2/6/2004	227	62	90	151	221	168	153.16
2/7/2004	223	67	108	182	207	180	161.66
2/8/2004	255	73	115	206	251	219	186.5
2/9/2004	263	58	122	240	274	225	197
2/10/2004	308	62	112	203	251	219	192.5
2/11/2004	279	48	114	223	249	N/A	182.6
2/12/2004	192	46	92	168	187	N/A	137
2/13/2004	286	52	123	203	299	N/A	178.6
2/14/2004	217	66	114	171	265	N/A	166.6
2/15/2004	280	66	128	174	256	194	183
2/16/2004	311	64	110	210	261	256	202
2/17/2004	217	69	120	210	213	216	174.16
2/18/2004	288	81	146	295	333	265	234.66
2/19/2004	318	83	157	244	291	301	232.33
2/20/2004	239	69	114	188	273	195	179.66
2/21/2004	231	92	131	213	256	190	185.5
2/22/2004	232	70	115	172	192	175	159.33
2/23/2004	260	93	131	200	277	197	193
2/24/2004	238	110	135	190	214	204	181.83
2/25/2004	196	98	143	206	175	192	168.33
2/26/2004	220	93	129	213	N/A	186	168.2
2/27/2004	222	97	129	207	N/A	182	167.4
2/28/2004	245	77	118	180	N/A	188	161.6
2/29/2004	248	68	122	205	233	205	180.16
Monthly Average	**245.79**	**69.96**	**117.14**	**193.76**	**240.85**	**201.04**	**175.61**

Note: The unit for all the data is μg/m³
Averages have been calculated using available data only
Ktm. Avg. : Average of the six monitoring stations
Monthly Avg.: Monthly avg. Value for each monitoring station
NA: Not available
Source: Ministry of Population & Environment/ Environment sector programme support { www.mope.gov.np}

13. Annex - 2: Photograph of the air quality monitoring outside Kathmandu

Photo 1: Air Quality Monitoring at Bhanuchowk (Birganj)

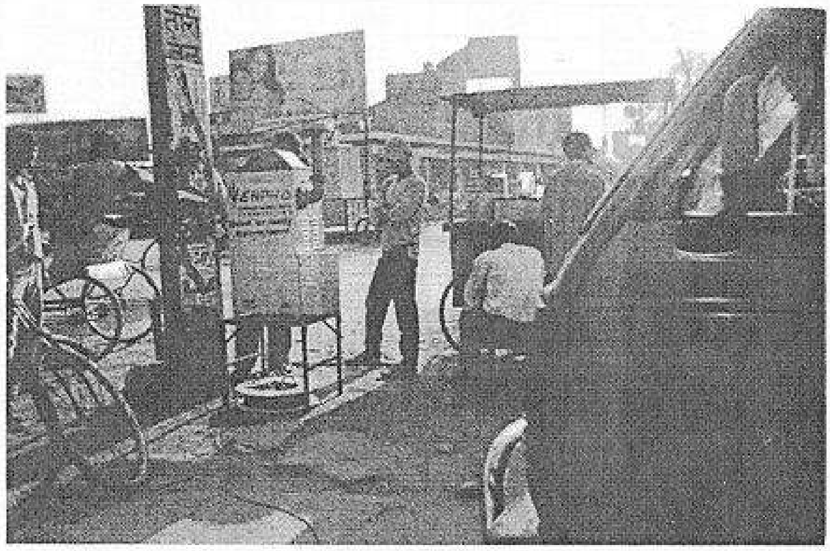

Photo 2: Air Quality Monitoring at Ranighat (Birganj)

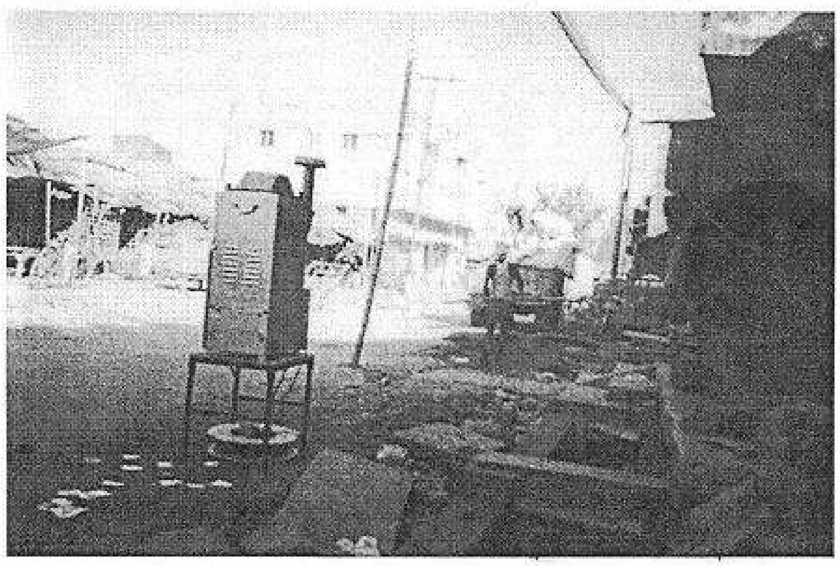

Photo 3: Air Quality Monitoring at Adarshanagar (Birganj)

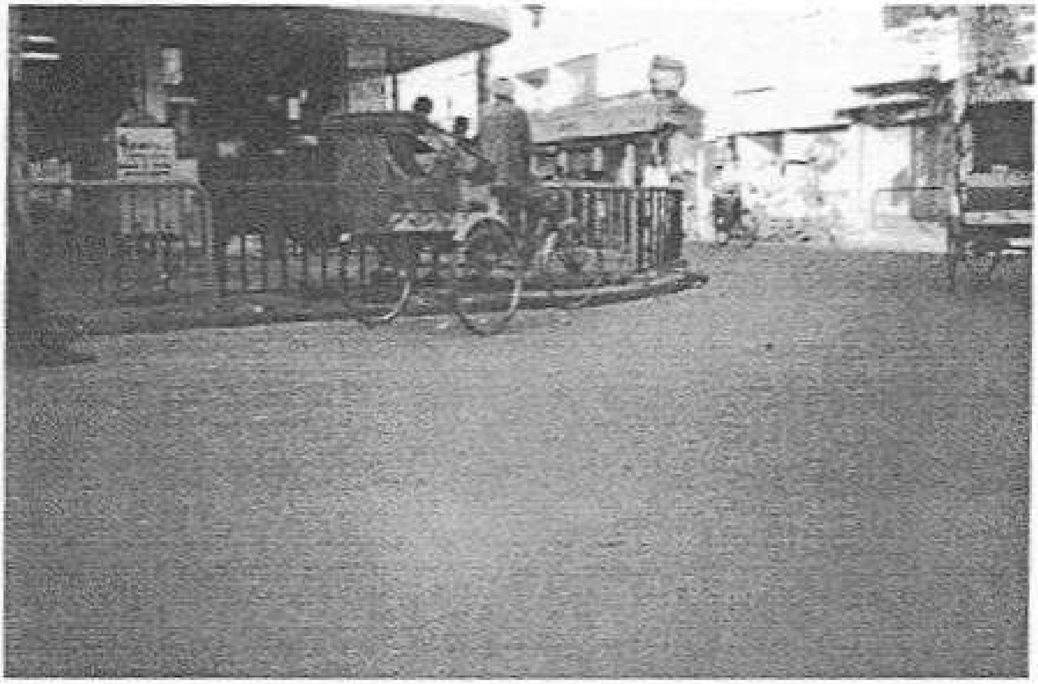

Photo 4: Air Quality Monitoring at Mahendrapul (Pokhara)

Photo 5: Air Quality Monitoring at Industrial Estate (Pokhara)

Photo 6: Air Quality Monitoring at Hall Chowk, Lakeside (Pokhara)

14. Annex - 3: Photograph of the air quality monitoring stations of Kathmandu valley

Photo 7: Air Quality Monitoring station at Putalisadak

Photo 8: Air Quality Monitoring station at Matsyagaon

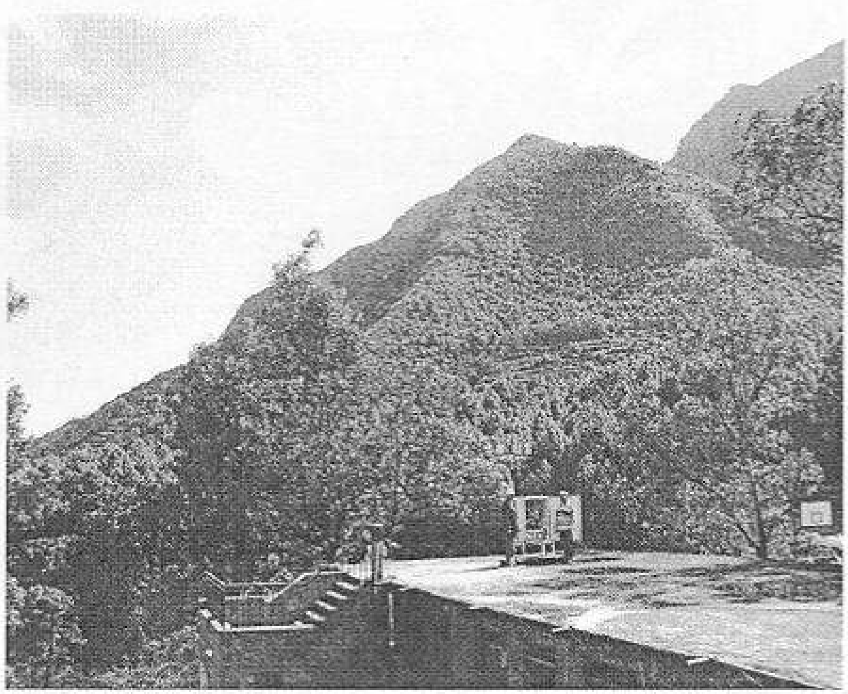

Photo 9: Air Quality Monitoring station at TU, Kirtipur

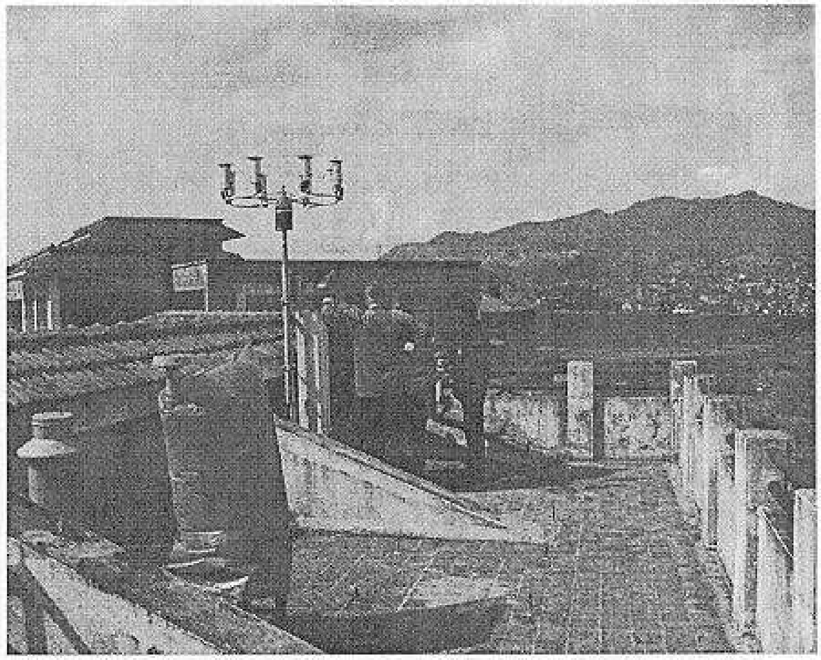

Photo 10: Air Quality Monitoring station at Bhaktapur

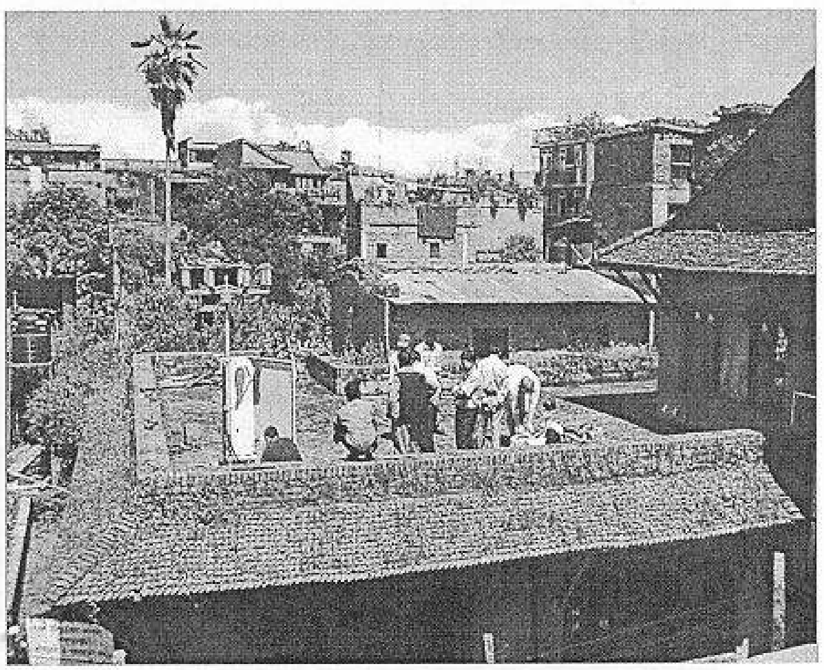

Photo 11: Air Quality Monitoring station at Patan Hospital

Photo 12: Air Quality Monitoring station at Thamel

Photo source: Environment Sector Programme Support