Final Report

on

Development of procedures and the assessment of EBD of local levels due to major environmental risk factors

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AF	Attributable Fraction
BoD	Burden of Disease
CDR	Crude Death Rate
CMR	Child Mortality Rate
CO	Carbon Monoxide
COPD	Chronic Obstructive Pulmonary Disease
DALYs	Disability Adjusted Life Years
DoHS	Department of Health Services
EBD	Environmental Burden of Disease
ENPHO	Environment and Public Health Organization
E. Coli	Escheria Coli
ESPS	Environmental Sector Program Support
GLM	Generalized Linear Model
HMG	His Majesty's Government
IF	Impact Fraction
JAICA	Japan International Co-operation Agency
MLD	Million Liters per Day
MOH	Ministry Of Health
MOPE	Ministry of Population and Environment
MPN	Most Probable Number
NESS	Nepal Environmental & Scientific Services
NHRC	Nepal Health Research Council
NOx	Nitrogen Oxide
NWSC	Nepal Water Supply and Sewerage Corporation
OPD	Out Patient Department
PM	Particulate Matter
PAH	Polycyclic Aromatic Hydrocarbon
RONAST	Royal Nepal Academy for Science and Technology
SAARC	South Asian Association for Regional Co-operation
SO2	Sulfur Dioxide

SPM	Suspended Particulate Matter
TB	Tuberculosis
TSP	Total Suspended Matter
TU	Tribhuvan University
SEAR-D	South East Asian Region with Mortality Stratum D
WHO	World Health Organization
YLD	Years Lived with Disability

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Acknowledgement

The present study on "Development of procedures and assessment of environmental burden of disease (EBD) of Local levels due to major environmental risk factors" is a part of ongoing NHRC programs on environmental health issues and conducted with support from World health Organization (WHO), Nepal.

The study is conducted to develop a comprehensive procedural guidelines for the assessment of EBD of local levels and also to carry out the assessment of EBD due to environmental risk factors, namely ambient air pollution and bacterial contamination of water supplies in Kathmandu Valley. Despite of many limitations, the report has come up with the assessment of EBD due the given risk factors, which is dependent upon the local data compiled from various secondary sources. It is believed that the output of the study will be helpful to all of those concerned and will add valuable impetus for further research in the area.

The study team would like to express sincere thanks to Dr. Anil Kumar Mishra, Former member secretary and Dr. Shanker Pratap Singh, Member secretary, NHRC for providing the opportunity to conduct the present study. Thanks are also go to Mr. Sharad Adhikari, WHO representative for the continuous technical as well as financial support to the project. The team acknowledges to Mr. Meghnath Dhimal, Researcher officer of NHRC for his valuable suggestions for the finalization of the report. The team would also like to thank Mr. Santosh Shrestha, NHRC for his suggestions during the study period. Since the study is based upon the secondary data compiled from various secondary sources, special thanks goes to all those who have provided vital information for the study including hospital personnel.

STUDY TEAM

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Executive Summary

There is direct relation ship between environment and health. The magnitude of health problems is increasing day by day due to the exposure of various types of environmental risk factors. Among them, two of the major environmental risk factors under investigation are ambient air pollution and bacterial contamination of water supplies in Kathmandu Valley. The study has been conducted to assess how much serious is the impact of the two risk factors on environmental burden of disease in the valley. This has been assessed by quantifying the proportion and amount of environmental disease burden that can be attributed to the risk factors.

The health effects incorporated regarding ambient air pollution are Chronic Obstructed Pulmonary Disease (COPD), Pneumonia, Acute Respiratory Infections (ARI), Asthma, Bronchitis and Lung cancer. Similarly, those incorporated for bacterial contamination of water supplies are Cholera, Typhoid, Bacillary Dysentery and other Diarrhoeal Diseases**.** In order to gain some perspective on the dimensions of the environment-related health loss in Kathmandu Valley, the present study has estimated Environmental Burden of Disease (EBD) for the health effects that can be attributed to the two risk factors for the period 2003 to 2004 based upon local data made available by secondary sources.

Methodology

The assessment of EBD is based upon the local data available from secondary sources and therefore some adjustments were made accordingly. The methodology is described in the following main steps:

- Data compilation from secondary sources
- Exposure – response modeling
- Estimation of EBD attributable to the given risk factors

Compilation of environmental health data / indicators based on health effects

In order to build exposure – response models, data on health effects which are assumed to be linked to the given environmental risk factors was compiled from the leading hospitals in Kathmandu Valley for the years 2003 and 2004. The hospitals are Bir Hospital (Kathmandu), TU Teaching hospital (Kathmandu), Patan hospital (Lalitpur), Bhaktapur hospital (Bhaktapur)and Sukraraj tropical & infectious disease hospital (Kathmandu). Daily hospital records were used to develop models to compute EBD due to ambient air pollution except for Lung cancer morbidity where monthly data was used. In order to develop models to calculate EBD due to bacterial contamination of water supplies, monthly data on hospital morbidities and exposure was used. Meanwhile for mortality assessment, census household survey data, 2001 was used.

The total disease burdens are based upon Crude Death Rate of Nepal (CDR), hospitals inpatient records and data available in the Annual Report of Department of Health Services (DoHS). In the absence of prevalence rates for the study population, inpatient hospital admissions and out

patient department (OPD) hospital visits were substituted for disease specific mortalities and morbidities.

Compilation of environmental data / indicators based on exposure

Previous monitoring results in Kathmandu Valley have shown that the valley ambient air is polluted with suspended dust particles (particulate matter) with altogether 193 days exceeding the daily Nepal ambient air quality standard for the year 2004. Majority of the studies conducted all over the world has also used particulate matter to assess the health effects due to ambient air pollution. Consequently, the present study has taken particulate matter (PM_{10}) as the parameter for the assessment ambient air quality. Data has been compiled for PM_{10} on daily basis monitored from the 6 fixed stations installed within Kathmandu Valley for the years 2003 and 2004. Meanwhile, the assessment of exposure for bacterial contamination of water supplies has been done by considering total coliform count in water samples from different sources such as tap water, well, spout etc. collected from different parts in Kathmandu valley. Data on water quality was provided by various secondary sources including NWSC.

Exposure-response modeling regarding ambient air pollution as the risk factor

Quantification of health effects associated with ambient air pollution was accomplished by building exposure-response models based upon time series data and is exposure based approach. The Generalized Linear Model (GLM) with Log link function known as the Poisson regression was used as the statistical model which has dependent variable as a count variable measuring daily (or monthly) health effect counts. Daily time series data was compiled on ambient air pollution assessed by PM_{10} for population exposure calculations. Data on daily average temperature was included in the models as the confounding variable along with seasonal variables. The corresponding health effect data was also compiled on daily basis from the leading hospitals within Kathmandu Valley and included as dependent variables in the models. The main objective of application of the model is to estimate the amount of increase in relative risks of the selected health effects and percent increase in health effects for certain degree rise in the level of exposure assessed by PM_{10}. The estimated relative risks are then used to find the attributable fractions and then EBD attributable to ambient air pollution regarding PM_{10}. In addition, lower and upper confidence limits have been computed with 95% confidence interval.

Exposure-response modeling regarding bacterial contamination of water supplies as the risk factor

The relationship between morbidity and exposure was modeled using monthly data on the selected health effects and exposure to bacterial contamination of tap water supply through the application of the Poisson Model. Bacterial contamination in water is assessed by total coliform content of water supplies across Kathamndu Valley for water borne disease morbidity assessment. However, for exposure-response modeling, only bacterial contamination in tap water with 442 sample determinations could be used since time series data on bacterial contamination of other supply sources such as well, tube well, spout etc. was unavailable for modeling. Also, total coliform content data for water supplies from other sources like well, deep well and spout water are utilized for EBD calculations even though not used during

exposure-response modeling. 228 such data were used of which 90 was from spout water, 86 from well water and 52 from deep well water. Exposure data on total coliform contents was categorized to 4 distinct categories (grades) with respect the level of total coliform contamination. Grade scores were used for numerical representation of grade of water sample with respect to total coliform content for statistical modeling.

EBD regarding mortality due to bacterial contamination of water supplies is accomplished with the help of exposure as well as health effect data obtained from population census, 2001 in which a 10 % sample of households was selected separately for collecting information on various variables including disease specific mortality since 12 months prior to the survey, household characteristics such as source of water supplies and sanitation situation beside other variables not included in the census itself. Exposure scenarios with respect to water supplies and sanitation situation were categorized according to the nature of water supplies of the sampled households such as tap water, tube well water, river water etc. and the nature of household sanitation situation such as availability or non availability of toilet facilities. Relative risks of the exposed group of scenarios were computed as compared to relatively unexposed group of population such as deep well water users having toilet facility. Consequently, the exposure-response modeling with computation of relative risks and impact fraction is scenario based approach.

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Estimation of EBD attributable to the given risk factors

The basic approach for estimating the environmental burden of diseases is common to every environmental risk factor. For each risk factor, following data was utilized to assess the environmental burden of diseases:

- Distribution of risk factor exposure within the study population.
- The exposure - response relationship for the risk factors.
- The total burden of diseases in terms of mortality and morbidity which depended upon mortality rates, disease incidence rates and the total exposed population for the study area.

The Burden of Disease attributable to a given risk factor when exposed populations are compared with unexposed populations is given by the following simplified expression of the impact fraction:

$$IF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$$

where,

IF = Impact fraction

P_i = Proportion of the population in exposure category i, including the unexposed

RR_i = Relative risk at exposure category i compared to the reference level

The equation accounts various population groups exposed at different levels of pollutants. In the case of the population with only one category of exposure classification, the above expression further simplifies with a single relative risk measure to:

$$AF = \frac{RR - 1}{RR}$$

Where, AF = Attributable fraction

To estimate the fraction of disease burden attributable to a risk factor for any define population, the total disease burden for the population (in deaths / total hospitalizations / total OPD visits) is multiplied by the attributable fraction. The attributable burden is therefore, given by:

Attributable burden = Attributable Fraction x total burden
= Attributable fraction x Population incidence of the health effect
x Total exposed population

Main Findings

General

The findings are based upon data collected for the year 2003 and 2004. Monthly hospital inpatient data showed high resemblance in pattern for COPD admissions with average monthly ambient PM_{10} concentration levels. The pattern showed high values in winter months as compared to other months for both COPD as well as average ambient PM_{10} concentration levels. The monthly variation pattern showed moderate and low resemblance regarding respiratory and pneumonia admissions. Similarly, monthly hospital inpatient data showed high resemblance in pattern for diarrheoal and enteric fever admissions with average monthly grade score of bacterial contamination in Kathmandu valley tap water. Warm and rainy season showed high values for both admission cases as well as tap water grade scores on bacterial contamination as compared to other seasons.

Regarding gender and age differences of the inpatients, both sexes are found to be evenly distributed, COPD admissions are mostly aged persons, pneumonia patients are evenly distributed above and below 50 years of age, high percentage of diarrheoal patients are adults and only small percent of enteric fever patients are old aged. Considering place of residence of the inpatients, the hospital records showed that more than 80% of the hospital inpatients were valley residents. This implies that the health effect assessments made in the study with respect to exposure to ambient air pollution in Kathmandu Valley can be said to be representative of the valley resident inpatients.

Results on the assessment of EBD due to ambient air pollution

The selected health effects included in exposure-response modeling are all cause mortality, respiratory mortality and morbidity including COPD, Asthma, Bronchitis, Lung cancer and Pneumonia. These four diseases have been included in the present data analysis under respiratory category for both morbidity as well as mortality data.

Positive associations have been found between various health effects and ambient air pollution. The estimated [1]percent increase in all cause mortality, respiratory mortality, respiratory hospital admissions, COPD hospital admission and lung cancer hospital admissions per 10 $\mu g/m^3$ increase in PM_{10} are 0.69 %, 3.48 %, 1.92 %, 3.22 % and 3.06 % respectively. The corresponding relative risks for average ambient PM_{10} exposure above the threshold limit (10 $\mu g/m^3$) are 1.0856, 1.5178, 1.2609, 1.4722, and 1.4437 respectively. Similarly, the estimated attributable fractions are 0.0788 (7.88%), 0.3411 (34.11%), 0.2609 (26.09%), 0.3207 (32.07%),

[1] All estimates are central estimates in executive summary

and 0.3073 (30.73%) for all cause mortality, respiratory mortality, respiratory hospital admissions, COPD hospital admission and lung cancer hospital admissions respectively. The coefficients of PM_{10} are found to be statistically significant for respiratory morbidity and COPD morbidity and insignificant for others at 95% confidence level.

EBD attributable to ambient air pollution exposure with respect to PM_{10} has been calculated for 20 $\mu g/m^3$ and 10 $\mu g/m^3$ baseline PM_{10} level. Total deaths or burden has been estimated by taking population of Kathmandu valley for 2004 as 18,40,111 and CDR as 9.22 per 1000 population. Morbidities have been expressed in terms of total hospital admissions and OPD visits in the absence of population prevalence rates. Out of total 16966 deaths, 1337 cases of deaths can be attributed to ambient air pollution regarding PM_{10} taking threshold limit as 10 $\mu g/m^3$ for PM_{10} for the year 2004. Similarly, out of 236 respiratory deaths, 3188 respiratory hospital admissions, 15948 COPD and 122 lung cancer hospital admissions, 81, 660, 5115 and 37 cases can be attributed to the risk factor for the year 2003/2004[2].

Results on the assessment of EBD due to bacterial contamination of water supplies

Positive associations have also been found for various health effects and bacterial contamination in water. The coefficients of coliform grade score are found to be statistically significant for all the morbidities considered for modeling at 95% confidence level. According to exposure-response modeling for morbidity, 71.3% of the diarrheoal morbidity, 72.4% of the gastro-enteritis morbidity and 74.2% of the enteric fever morbidity can be attributed to bacterial contamination of water supplies in Kathmandu Valley. Similarly, out of 38053 diarrheoal hospitalizations and OPD visits, 2511 gastro-enteritis hospitalizations and 6588 enteric fever hospitalizations and OPD visits, 27120, 1817 and 4889 cases can be attributed to bacterial contamination of water supplies for the year 2003 / 2004.

According to statistical modeling based upon different exposure scenarios on water borne disease mortality, 42% of the total diarrheoal deaths, 47.15% of the total diarrheoal deaths among children aged below 5 and 41.92% of the total enteric fever deaths can be attributed to unsafe water supplies only. Similarly, 84.6% of the diarrheoal deaths and 47.9% of the enteric fever deaths can be attributed to unsafe water supply and sanitation. It may be noted that water supplies and sanitation situations would be regarded as unsafe to human health mainly in the presence of bacterial contamination in water.

Lastly, only very few cases of waterborne deaths have been recorded in the hospitals from where data has been complied in the present study. Therefore, the corresponding total disease burdens are also very few for the reference year. Out of 3 recorded diarrheoal deaths and 4 enteric fever deaths, only 1 case each can be attributed to unsafe water supply. Similarly, out of the same totals, all 3 cases and 2 cases can be attributed to unsafe water supply and sanitation regarding diarrheoal and enteric fever deaths respectively for the year 2060 BS.

Concluding Remarks

- Data compiled from various secondary sources on environmental health data based upon health effects and exposure were useful and productive in developing exposure-response

[2] 2003 / 2004 is equivalent to fiscal year 2060 / 2061 BS

models which statistically link the responses on health effects to environmental exposures and subsequent computation of EBD due the given risk factors.

- Positive associations were detected between the health effects and environmental exposures regarding the given risk factors.
- More than 20% of the health effects can be attributed to ambient air pollution regarding PM_{10} as the air pollution parameter for all the health effects considered except in the case of all cause mortality for which 7.9% can be attributed.
- More than 70% of the health effects can be attributed to bacterial contamination of water supplies regarding water borne morbidities.
- About 85% of the diahrreoal deaths and about 48% of the enteric fever deaths can be attributed to unsafe water supply and sanitation.
- The assessment of EBD is dependent upon the local data available from the secondary sources.
- Some assumptions and substitutions were made as they were necessary for the computation of EBD within Kathmandu Valley

CHAPTER 1

INTRODUCTION

1.1 Environment and Health

There is a direct relationship between human being, environment and health. Environmental health comprises those aspects of human health, including quality of life that is determined by physical, social and psychological factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling and preventing those factors in the environment that can potentially affect adversely the health of present and future generation. (WHO 1993)

The magnitude of the health problems are increasing day by day due to various environmental risk factors. There are many environmental risk factors among them two main environmental factors are the concern of this study: These include ambient air pollution and bacterial contamination of water. Due to these risk factors many men, women and children are suffering from various types of diseases.

The ambient air pollution beside indoor air pollution is considered as a major risk factor associated with various respiratory ailments such as asthma, chronic obstructed pulmonary disease (COPD), bronchitis, lung cancer and acute respiratory infection (ARI) etc. Bacterial contamination of water is a leading cause of typhoid/paratyphoid, cholera, diarrhoeal diseases such as bacillary dysentery, and Rota virus diarrhea in infants etc. Both types of risk factors kill many children, old men and women especially in developing countries.

1.2 A brief introduction of Nepal and Kathmandu valley (The study area)

Geographically Nepal is located between 80° 4''and 88°12" east longitude and 26º 22" to 30º 27''north latitude. It is an independent, sovereign, and landlocked country bordered by china to the north and India to the east, south, and west. It is approximately 885km in length and its mean width is 193 km with a total land area of 147,181 sq. km. The elevation of the country ranges from 60m above the sea level to the highest point on the earth, Mt Everest at 8848meter, all within the distance of 150 kilometer with climatic conditions ranging from sub tropical to arctic.

Politically Nepal is divided into 5 development regions, 14 zones and 75 districts. Further the district is divided into village development committee and municipalities. Currently there are 3914 village development committee and 58 municipalities. The country comprises of three parallel ecological regions, namely, the mountains in the north, the hills at the centre and the terai belt in the south, each representing 35, 42, and 23 percent of the total area respectively. The country is a potpourri of ethnic groups and sub groups who speak over 90 languages and dialects. Nepali is the national language. Nepal enjoys the distinction of being the only Hindu kingdom in the world. However there is a harmonious blending of Hinduism and Buddhism.

Kathmandu valley is the heart of the kingdom and capital of Nepal, which is located at 27º42" north and 88º36"east at an altitude of 1336m above the sea level and cover the areas of 218 sq miles. The valley is surrounded with high mountains ranging from 5000ft to

9000ft.According to the census report 2001 the total population of valley is1645091, among them 863263are males and 781828 are females. The annual maximum and minimum temperature recorded in this city is 10º-24ºC. During the December the minimum temperature goes to freezing 2ºC and in the month of June maximum temperature goes to 36ºC.

1.3 Air and Water Pollutants and Health Effects

Increased health care utilization (hospitalization, physician and emergency room visits), Increased respiratory illness (symptoms, infections, and asthma exacerbation), Reduction in life-span, Potential increased risk of developing cancer, Decreased breathing capacity, Lung inflammation, Potential immunological changes, decreased tolerance for exercise, etc are the adverse health effects associated with air pollution which are diverse in nature.

1.3.1 Air Pollutants

A brief introduction to air pollutants and their health effects are given below.

Benzene

Benzene (98%) is commercially derived from petrochemical and petroleum refining industries. It is a by-product of various combustion processes, such as forest fires and the burning of wood, garbage, organic wastes, and cigarettes (IARC, 1982a; *Fishbein*, 1984; *Wester et al.*, 1986; *Hattemer-Frey et al.*, 1990); it is also released to the air from crude oil seeps and volatilizes from plants (*Brief et al., 1980*). It is commercially used in chemical production (ethyl benzene – Styrofoam andplastics, cumene (resins), cyclohexane (nylon and synthetic fibers) as well as in rubbers, gums, lubricants, dyes, pharmaceuticals and agrichemicals. Benzene is also a natural component of crude and refined petroleum to maintain high-octane levels and anti knocking properties. The major environmental sources include automobile exhaust, automobile refueling, hazardous waste sites, underground storage tanks that leak, waste water from industries that use benzene, chemical spills, chemical manufacturing sites, and petrochemical and petroleum industries (*Fishbein*, 1992; *Edgerton and Shah*, 1992).

The major effects due to the exposure to benzene are Anemia or other blood disorders, Arthritis, Asthma, emphysema, Diabetes, Kidney disease, Respiratory allergies, Skin rashes, Urinary tract disorders. The acute inhalation leads to the effects of Drowsiness, Dizziness, Fast heart rate, Headache, Tremors, Confusion Unconsciousness, and Death.

EPA benzene guideline value for Maximum Contaminant Level is 0.4ppb in air. But OSHA 8 hours day / 40 hour week limit for air exposure is 1ppm with a short-term limit of 5ppm (ATSDR fact sheet about Benzenewww.atsdr.cdc.gov/tfacts3.pdf).

PAH

The term 'polycyclic aromatic hydrocarbons' commonly refers to a large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms. Average concentrations of 1-30 ng/m^3 of individual PAH were detected in the ambient air of various urban areas. More than 100 PAH have been identified in atmospheric

particulate matter (*Lao et al., 1973; Lee et al., 1976a*) and in emissions from coal-fired residential furnaces (*Grimmer et al., 1985*), and about 200 have been found in tobacco smoke (*Lee et al., 1976b, 1981*). The domestic activities that may result in significant emissions of PAH emissions are vehicle traffic, tobacco smoking, broiling and smoking of foods, and refuse burning.

The chemicals commonly found with PAHs may be the cause of short-term symptoms such as eye irritation, nausea, vomiting, diarrhea and confusion. Possible long-term health effects caused by exposure to PAHs may include cataracts, kidney and liver damage and jaundice. Some people who have breathed or touched mixtures of PAHs and other chemicals for long periods of time have developed cancer.

Comprehensive work on the carcinogenicity of PAH shows that 17 of the 33 studied are, or are suspected of being, carcinogenic. The best-characterized PAH is benzo [a]pyrene, which has been studied by all current methods in seven species. PAH that have been the subject of 12 or more studies are anthanthrene, anthracene, benz [a]anthracene, chrysene, dibenz [a,h]-anthracene, dibenzo [a,i]pyrene, 5-methylchrysene, phenanthrene, and pyrene.

Particulate Matter, (PM)

Some particles are directly emitted into the air. They come from a variety of sources such as cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, stone crushing, and burning of wood. Inhalability and deposition characteristics of particles less than 10 micrometers in size (PM_{10}), which could potentially damage the lower respiratory tract and the gas-exchange region of the lung were the contributors to PM-related health effects in sensitive populations.

Particulate matter is associated with serious health effects and increased hospitals admissions and emergency room visits for people with heart and lung disease. Many scientific studies have linked breathing PM to a series of significant health problems including aggravated asthma, increase in respiratory symptoms like cough and difficult or painful breathing, chronic bronchitis, premature death and decreased lung function.

Carbon Monoxide, (CO)

The high affinity of CO to bond with oxygen-carrying proteins (hemoglobin and myoglobin) results in reduced oxygen supply in the bloodstream of exposed individuals through the formation of carboxyhemoglobin (COHb). It is that reduced oxygen supply which appears to be responsible for the toxic effects of CO which are typically manifested in the oxygen-sensitive organ systems. People with deficient blood supply to the heart (ischemic heart disease) are known to be susceptible to the effects of CO.

Nitrogen Oxides, (NOx)

NO_x causes a wide variety of health impacts because of various compounds and derivatives in the family of nitrogen oxides, including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. Human health concerns include effects on breathing and the respiratory system, damage to lung tissue, and premature death. Small particles penetrate

deeply into sensitive parts of the lungs and can cause or worsen respiratory disease such as emphysema and bronchitis, and aggravate existing heart disease.

1.3.2 Water Pollutants

Microbial (Coli form Bacteria & E. Coli) contamination in drinking water

Due to lack of required amount of municipal water supply system, the city dwellers have been continuously dependent upon the groundwater. Groundwater is depleted through the shallow wells. These shallow wells are polluted through infiltration either with the municipal sewage or local safety tanks, poor sanitation, etc. The microbial contamination in the dry seasons is creeping up.

The main drinking water pipelines and sewage pipes are placed side by side hence leading to contaminate the drinking water. Most of the groundwater and few tap water from Water Supply Corporation are contaminated with microorganisms (coliforms) in the valley. The inadequate chlorination in the reservoir, the old pipelines, pressure drop due water suction during flow from local people, etc are the major causes for the microbial contamination in the NWSC supply. If ammonia or iron is present in water, the chlorine species undergoes the by - products formation leading to the scarcity of chlorine content to disinfect the microorganisms. The water quality parameters like iron and ammonia in the valley's groundwater is high which may bring the ultimate growth of microbes either in oxic or anoxic conditions. The mean daily-contaminated water intake of 1 liter (WHO) per day pertinently leads to ingest larger population of microbes and the respondent are at high risk from the microbial borne diseases.

Increased health care utilization (hospitalization, physician and emergency room visits), Increased respiratory illness (symptoms, infections, and asthma exacerbation), Reduction in life-span, Potential increased risk of developing cancer, Decreased breathing capacity, Lung inflammation, Potential immunological changes, decreased tolerance for exercise, etc are the adverse health effects associated with air pollution which are diverse in nature.

Coliform Bacteria & E. Coli

The E. coli belongs to enterobacteriaceae family. Among them enteropathogenic, enteroinvasive, enterotoxigenic and verocytotoxin producing pathogenic E. coli types are responsible for diarrhea. Enterobacteriacae strains of E. coli produce dysentery by a mechanism similar to that found with shihella sps. These organisms invade the colonic mucosa and cause bloody diarrhea. The enterotoxigenic E. coli can cause cholera like syndrome in infants, children and adults. Verocytotoxic E. Coli cause disease ranging from mild diarrhea to haemorrhagic colotis characterized by blood-strained diarrhea, usually without fever, but accompanied by abdominal pain. It is a also cause of the haemolytic uraemic syndrome, commenst in infants and young children, and characterized by acute renal failure and haemolytic anaemia.

Groundwater is depleted through the shallow wells. These shallow wells are polluted through infiltration either with the municipal sewage or local safety tanks, poor sanitation, etc. The microbial contamination in the dry seasons is creeping up. The main drinking water pipelines and sewage pipes are placed side by side hence leading to contaminate the

drinking water. Most of the groundwater and few tap water from Water Supply Corporation are contaminated with coliforms in the valley. In order to reduce the risk of microbial regrowth in the distribution system, it is desirable to maintain a free residual chlorine level of 0.2 to 0.5mg/l. The inadequate chlorination in the reservoir, the old pipelines, etc is the major cause for the microbial contamination in the NWSC supply. The water quality parameters like iron and ammonia in the valley's groundwater is high which may bring the ultimate growth of microbes either in oxic or anoxic conditions. The mean daily-contaminated water intake of 1 liter (WHO) per day pertinently leads to ingest larger population of microbes and the respondent are at high risk from the microbial borne diseases.

Specific Diseases Outcomes

Due to bacterial contamination of water following diseases are associated;
Typhoid
Bacillary Dysentery
Diarrhea
Typhoid & Paratyphoid

1.4 Burden of disease perspectives in Nepal

The concept of burden of disease was developed by the World Bank and the WHO in (World Bank 1993).The approach is based on a new indicator, Disability Adjusted life Years (DALYs), which combines potential years of life lost as a result of death at a given age and years of life lived with disability. It provides new insights into the link between the nature and extent of illness in a society on the one hand and the desirable resource allocation for health sector activities and the prioritization of health care interventions on the other.

According to 2001 population census, out of the total deaths in Nepal (12 months preceding the census), 6.93% died from Asthma / bronchitis, 4.53% from cholera / diarrhea, 4.19% from pneumonia, 2.90% from heart diseases and 0.96% from typhoid. In 2002/2003, reported incidence of ARI among children aged below 5 was found to be 289 per 1000 for Nepal. Among the reported ARI cases, percent of pneumonia cases were 40.8. Similarly, incidence of diarrhea was found to be 200 per 1000 less than 5 year old children in the same fiscal year (Annual report, 2002/2003, Department of Health services, Ministry of Health, Nepal).

The yearly trend of COPD patients in the public hospitals of Katmandu shows the increment in the number of patients. The seasonal variation of COPD patients coincide with the PM10 concentration variation in Kathmandu. During the dry winter season the PM concentration has been found higher and the COPD patients number also shows the same trend (NHRC 2004 assessment of ambient air in selected urban areas of Nepal).

The burden of disease (BoD) study indicates that the overall pattern of morbidity in Nepal (1996) is dominated by infectious disease, nutritional disorders, and problems related to reproduction. Table (1) shows selected health indicators for Nepal at a glance.

Table 1 Selected indicators of Nepal

S. N.	Selected Indicators	Rate per 1000	Reference year
1.	Infant Mortality Rate (IMR)	64.4	2004
2.	Child Mortality Rate (CMR)	91.2	2004
3.	Crude Death Rate (CDR)	9.22	2004
	Access to toilet facilities	**Percentage**	
4.	Nepal	47.0	2001
	Kathmandu	93.2	2001
	Lalitpur	81.7	2001
	Bhaktapur	91.4	2001
	Access to improved source of drinking water		2001
5.	Nepal	82.0	2001
	Kathmandu	90.3	2001
	Lalitpur	84.8	2001
	Bhaktapur	82.4	2001

Source: Nepal in figures, 2004, CBS and District level indicators of Nepal, CBS, 2003

In the assessment of BoD, the diseases were classified into three major groups. Among them group (I) diseases like infectious diseases, maternal and perinatal disorders which contribute 68% estimated burden of diseases in Nepal. The group (II) comprises degenerative and non communicable diseases which contribute 23% of the estimated burden. Mortality and morbidity rates especially among women and children are alarmingly high compared to countries of similar socioeconomic status. Furthermore, 80% of the under-five deaths are due to Group I causes, particularly perinatal conditions, acute respiratory infections, diarrhoea and measles. It is highly significant that for each age category between birth and 44 years (0-4 years, 5-14 years and 15-44 years) females lose approximately 25% more DALYs than males (Table 2).

Table 2 DALYs lost per 1000 by age and sex in Nepal

Age Range	Male	Female	Female / Male
0 - 4	976	1207	1.24
5 - 14	118	146	1.24
15 - 44	177	223	1.26
45 - 59	314	269	0.86
60+	484	452	0.93
Total	2069	2297	1.11

Source: Strategic Analysis to Operationalise the 2nd Long Term Plan, HMG 2000

Following table (3) shows the incidence of selected water borne and air borne diseases pattern in national level and Kathmandu valley. In the valley, the number of new cases of

typhoid / paratyphoid and diarrhoeal diseases were 5581 and 35421 respectively in 2003 / 2004. Similarly, the reported cases for ARI and COPD were 49361 and 14058 respectively.

Table 3 Burden of diseases

Morbidity Status	Waterborne Diseases		Air borne Diseases	
	Typhoid / Paratyphoid	Diarrhoeal Diseases	ARI	COPD
National	215064	949630	1069660	347144
Kathmandu	2699	19518	24100	7478
Lalitpur	1695	10039	16222	4568
Bhaktapur	1187	5864	9039	2012
Valley Total	5581	35421	49361	14058

Ref.: Annex (III), Annual Report 2003 / 2004, Department of Health Services, Kathmandu Nepal.

Less than five year age group is vulnerable to diarrhoeal diseases and ARI. In this category age group, the stated cases for diarrhoeal diseases and ARI in the valley per thousand were 236 and 300 respectively (Table 4).

Table 4 Incidence of diseases per 1000 < 5 years old, 2001 / 2002

Districts	Diarrhoeal	ARI
Kathmandu	80	92
Lalitpur	110	141
Bhaktapur	46	67

Ref.: Annex (III), Annual Report 2001 / 2002, Department of Health Services, Kathmandu Nepal.

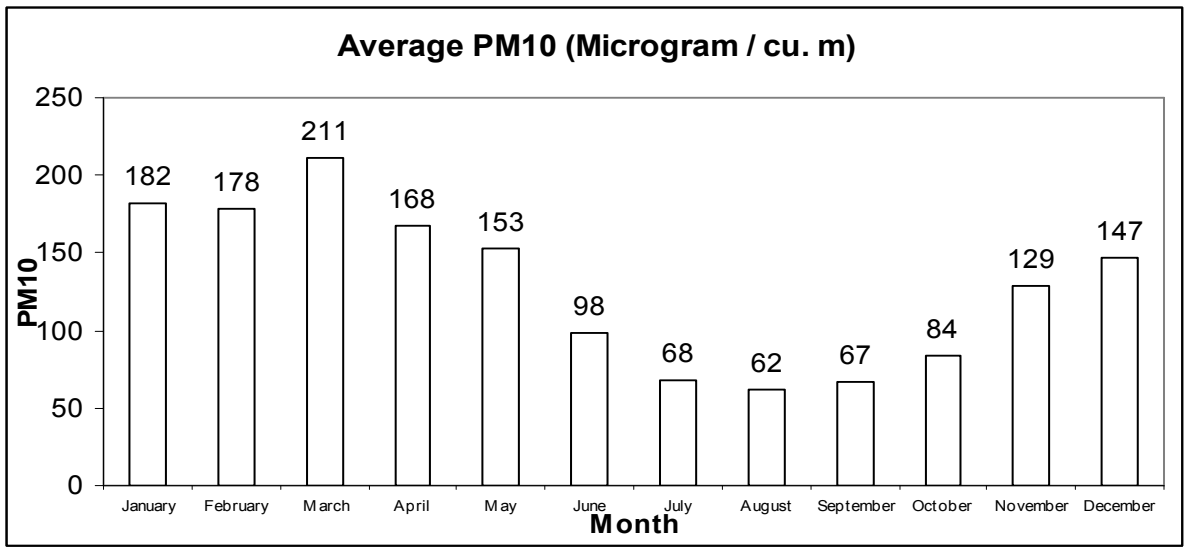
1.5 Air pollution and burden of disease

The major air pollutants in the bowl shaped valley are total suspended particulate matter (TSP), respirable particulate matter, nitrogen oxides (NOx), sulfur dioxide (SO_2), carbon monoxide (CO), benzene (C_6H_6), and polycyclic aromatic hydrocarbons (PAH) emitted from various pollution sources. Regarding ambient air pollution and respective health effects, the particulate matter, benzene and PAH concentration is more concerned. Mostly the cumulative health effects have been observed due to these pollutants. The mean values for nitrogen oxide, sulfur dioxide and carbon monoxide were found to be 27, 26 and 1878 $\mu g/m^3$ in Kathmandu Valley ambient air for 24 hours averaging period (Ref.: NHRC/NESS 2001), which are within the WHO guideline values.

Average monthly variation of PM_{10} in the year 2004 within Kathmandu valley monitored by the 6 fixed stations is shown below. Average for the whole year, 2004 is 129 $\mu g/m^3$. According to Nepal ambient air quality standards the 24 hr. average and annual mean standards for PM_{10} are 120 $\mu g/m^3$ and 50 $\mu g/m^3$ respectively. The values for monthly averages indicate that the average is highest in March and decreases in the following

months with lowest average in august and increases thereafter. Database shows that daily averages exceeding the standard for PM_{10} are altogether 193 days of which mostly fall in winter months.

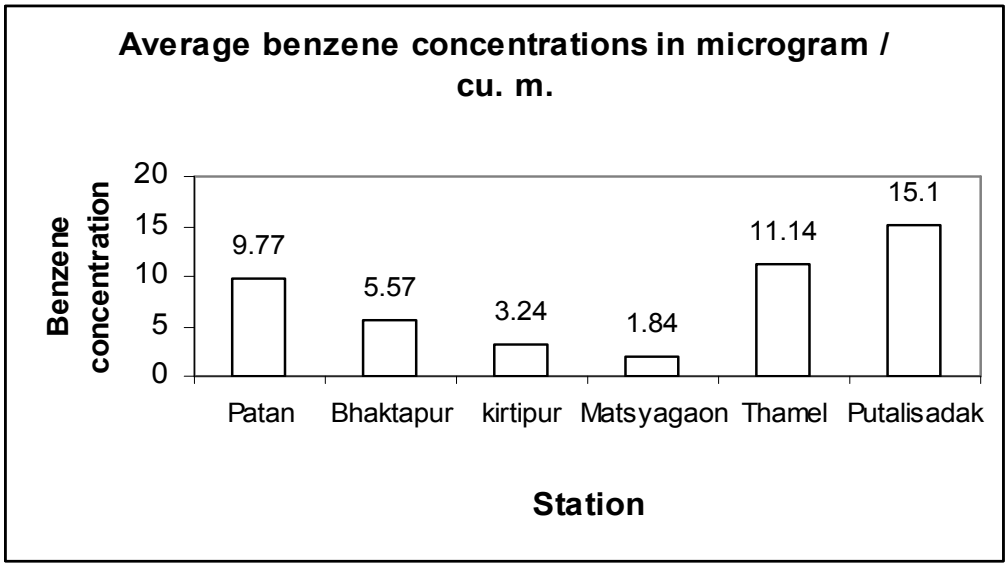
Figure 1



Raw data source: MOPE, missing values have been replaced by nearest adjacent values.

Bar diagram on average benzene concentrations for different locations within Kathmandu (calculated from some 2003 / 2004 monitoring results) is shown below.

Figure 2



Source: NESS, 2004

The particulate matter damages the defense mechanism of lungs resulting ARI in children, COPD, asthma, Low birth weight, Eye irritation etc. Sulfur dioxide, oxide of nitrogen also irritates respiratory tract and causes COPD and asthma. Carbon monoxide affects our heart. High concentration of ozone helps to reduce the function of lung. The toxicity of lead affects the nervous system. It also helps to impair the mental development of the children.

According to WHO report on global burden of disease in 2002, among the top 10 leading causes of deaths in the world, Ischemic heart diseases, Lower respiratory infection, chronic obstructive pulmonary disease, diarrhoeal diseases and trachea, bronchus and lung cancers ranked first, third, fifth, seventh and ninth accounting 12.6%, 6.6%, 4.8%, 3.1% and 2.2 % of the total deaths respectively. Among these diseases, ischemic heart disease, lower respiratory infection, chronic obstructive pulmonary disease and lung cancers have been linked to air pollution where as diarrhoeal diseases has been linked to unsafe water, sanitation and hygiene.

In developing countries with high mortality, lower respiratory infections, ischemic heart disease, and COPD ranks first, third, fifth and ninth accounting for 10%, 9.3% and 2.8% of the total deaths respectively. Similarly, among 10 leading causes of burden of disease expressed in DALYs in these parts of the world, lower respiratory infection, diarrhoeal diseases and ischemic disease ranks second, fourth and eight as percent of total DALYs respectively (Global burden of disease 2002, Data sources, methods and results, WHO, February, 2004).

In addition, 0.5% of DALYs and 1.4% of deaths have been attributed to urban air pollution globally (Environmental burden of disease series no.1, WHO, 2003).

The number of patients being admitted to Patan Hospital with chronic Obstructive Pulmonary Disease (COPD) has doubled in the past five years. Similarly, the percentage of COPD patients as a percentage of the total patients being admitted to the hospital increased from a 19 percent in 2052 to 27 percent in 2059. Similar hospital admission trend of COPD can be observed in the other major hospitals in the valley as well. (Bhusan Tuladhar, Breathing Kathmandu's Air can be Dangerous ENHPO Magazine, 2004).

1.6 Microbial contamination in drinking water and BOD

Nepal is ranked among the countries with the poorest health profile in the world. Lack of safe drinking water supply and sanitation facilities have resulted in worsening public health conditions, deteriorating quality of life and increased economic costs.
The high incidence of water-related diseases has contributed significantly to low productivity in Nepal. In urban centers others than Kathmandu have access to piped water supply and systematic solid waste management has yet to be established even in the largest metropolitan areas. Sanitation related- diseases account for 72 per cent of total ailments and diarrhea continues to be one of the leading causes of childhood deaths in Nepal.
NWSC is providing water supply to about 80% of the valley urban population through its volume production of 150 million liter per day (MLD) and 100 MLD during wet months and dry months respectively. The production is 56 MLD less in wet season and 104 MLD less in dry season. Consequently, the municipal water supply in the valley is insufficient. Due to this the inhabitants are directly or indirectly dependent upon the alternative raw sources of water like groundwater, stone tap or surface water, which are contaminated with

coliforms and faecal coliforms. The ingestion of this type of water may result typhoid / paratyphoid, dysentery, cholera and other diarrhoeal diseases.

In developing countries with high mortality due to diarrhoeal diseases ranks fifth accounting 5.5% of the total deaths. The vast majority of diarrhoeal disease in the world (88%) has been attributed to unsafe water, sanitation and hygiene. Approximately 3.1% of deaths (1.7 million) and 3.7% of DALY's (54.2 million) world wide are attributable to unsafe water, sanitation and hygiene. Of this burden, about one-third occurred in Africa and one-third in SEAR-D. In these areas, as well as in EMR-D and AMR- D, 4–8% of all disease burdens are attributable to unsafe water, sanitation and hygiene. Over- all, 99.8% of deaths associated with this risk factor are in developing countries, and 90% are deaths of children.

1.7 Objectives of the study

Development of procedures and the assessment of Environmental Burden of Diseases (EBD) of local levels due to major environmental risk factors namely

a. Bacterial contamination of water under supply
b. Ambient air pollution within Kathmandu valley

1.8 Limitations

1.8.1 Subsistence of complexity

People are depicted continuously to mixed environmental factors and the interactions between these factors are often not well - known and cannot be modeled in burden of disease calculations. The combined impact on the level of disability is likely to be different from the impact of a single disease if diseases occur together.

1.8.2 Proposition of different choices

Various judgments are attributed in disease burden calculations. These make a difference to priorities for action. Different assumptions should be used to calculate EBD rather than targeted verdicts. For instance, mortality rate for the study population such as CDR is not available but known only in the national level.

1.8.3 Lacking of secondary data

We have not maintained and familiar with scientific documentation system for epidemiological register ranging from simple health problems to the health effects of social and cultural dislocation due to microbial contamination in water and pollutants in breathing air. The deficiency of appropriate data and its dithering retrieval the quantitative measures for exposures and outcomes should be simply overlooked. For instance, disease specific prevalence rates may not be available for the study population. For the reason, some extrapolations may be required from the studies conducted elsewhere.

CHAPTER 2

LITERATURE REVIEW

According to the given schedule and work plan the first step of the study has been to review the electronic and published related documents and books. Aims of the literature review are to identify related documents and study reports and guidelines especially prepared by WHO, and other UN agencies. Literature review is also expected to provide the data of previous study and the trend of morbidity and mortality due to environmental risk factor which is needed for EBD calculation. Summary of literature review is given below.

2.1 WHO EBD Assessment Series

The assessment series provide an introduction to the environmental factors that pose a risk to health. The outlined general methods are used to estimate the disease burden of these factors. The first published WHO GBD concept constituted the comprehensive set of estimates on mortality and morbidity. The series incorporates the GBD concept of *Murray & Lopez 1996*, NBD concept of *Mathers et al, 2001* and other related risks by *Ezzali et al, 2003*. A GBD uses a summary measure of population health, DALY to combine estimates of the years of life lost and years lived with disabilities.

An original estimate for 1990 examined water, sanitation, and hygiene in terms of Diarrhoeal and selected parasitic diseases, based on the partial attribution of their disease burden to the risk factor (1). It was found that the worldwide risk factor accounted for 5.3% of all deaths and 6.8% of all DALYs.

World Health Organization has undertaken assessment of the global burden of disease for the year 2000 on the basis of articulated goals for the GBD 1990 with the following major objectives:

- To develop internally consistent estimates of mortality from 135 major causes of death disaggregated by age and sex, for the world and major geographic regions.
- To quantify the burden of premature mortality and disability by age, sex, and region for 135 major causes or groups of causes.
- To analyze the contribution to this burden of major physiological, behavioral, and social risk factors by age, sex and region.

Eight different age groups are used to undertake in GBD 2000 assessment. Regarding to the levels of child and adult mortality stratum for 191 WHO member states, the world has been divided into 14 sub regions from existing six WHO regions. They are AFRO, AMRO, EMRO, EURO, SEARO and WPRO respectively. Some member states have been reclassified into further sub regions with similar epidemiological / geographic / ethnic patterns. In SEARO - D sub region, the calculated attributable DALYs by risk factors were 34.14% and 19.24% for unsafe water, sanitation and hygiene; and urban air pollution respectively.

To maximize the epidemiological homogenecity, the WHO member states have been reclassified into seventeen epidemiological sub regions with similar epidemiological / geographic / ethnic patterns providing each group with separate region code that ranges from 1 to 17. The burden disease assessment comprises the YLD calculation. (YLD = IDWL; where I is the number of incident causes in the reference period, DW is the disability weight and L is the average years of disability.

WHO/ Annette Pruss, David Kay, Lorna Fewtrell, and Jamie Bartram (estimated the disease burden from water, sanitation, and hygiene at the global level taking into account various outcomes. They estimated the disease burden from these factors to be 4.0% of all deaths and 5.7% of the total disease burden occurring worldwide. Their estimation was based on the disease burden for 14 regions corresponding to those of the WHO Report 2000.

In 2001 assessment, the DALYs were calculated for burden of diseases by cause, sex and mortality stratum in south - East Asia. On this basis the DALYs estimated for low child / low adult mortality stratum were 4% for respiratory infections, 3.8% for lower respiratory infections and 0.09% for upper respiratory infections. Similarly, the estimation for high child / high adult mortality stratum were 8.5%, 8.28% and 0.13% respectively. The estimated DALYs for Diarrhoeal diseases in the same region were 0.38% in low child / low adult mortality stratum and 1.7% in high child / high adult mortality stratum. In case of low child / low adult mortality stratum, the DALYs for respiratory diseases, chronic obstructive pulmonary diseases and asthma were 2366, 895 and 543 respectively. Similarly, for high child / high adult mortality stratum, the DALYs were 14042, 6441 and 3630 respectively for above-mentioned diseases.

2.2 Key studies on health effects due to ambient air pollution

Various studies conducted at different parts of the world have demonstrated associations between a range of health effects and daily, multi-day or long term (one year to several years) changes in the concentrations of different air pollutants mainly particulate matter. The health effects associated with PM in epidemiological studies include mortality, lung cancer, hospitalization for respiratory and cardiovascular diseases, emergency room visits, asthma exacerbation, respiratory symptoms, restrictive activity days, loss of schooling etc. As mentioned in the global estimates (WHO, 2002), the EBD estimates for outdoor air pollution are based upon the following health outcomes:

- Mortality related to short term and long term exposure
- Morbidity related to short term and long term exposure

Mortality related to short term exposure

Several multi-city studies and more than 100 single-city studies have been published on the association between daily exposure to PM and mortality. Among the first of the multi-city studies on mortality, Schwartz et al. (1996) examined the data from the Harvard Six Cities study. Consistent associations were reported between daily mortality and daily exposures to PM_{10} and $PM_{2.5}$ with 0.8% (95% CI = 0.5 – 1.1) increase in daily mortality, all cause per 10 $\mu g/m^3$ of PM_{10}. In the study of 10 USA cities, Schwartz (2000a) examined the daily effects of PM_{10} and reported that a 10 $\mu g/m^3$ increase in the pollutant was associated with a 0.7%

increase in daily mortality. In a study involving 29 European cities reported an association of 0.6 % increase in mortality per 10 μg/m^3 increase in PM_{10} (Katsouyanni et. Al., 2001). Combined results of 88 largest cities of USA (NMMAPS) and 20 largest cities (Samet et. Al.) studies indicated an association between mortality and PM of approximately 0.5% per 10 μg/m^3 of PM_{10}. More recent studies used an alternative statistical model and found an association of 0.27% per 10 μg/m^3 of PM_{10} (Dominici et. Al., 2002).

Some of the studies have also been conducted in cities outside of the US and European cities and in developing countries and reported the effect estimates similar to those found for US and European cities. Combined results of the studies conducted in Asia shows an association of 0.41% (95% CI 0.25 – 0.56) increase in all cause mortality per 10 μg/m^3 increase in PM_{10} (HEI report, Health effects of outdoor air pollution in developing countries of Asia: A literature review, 2004)

Mortality related to long term exposure

Several air pollution studies have used a prospective cohort design in which a group of individuals are selected and followed over a long period of time usually several years to examine the effects of long term exposure to PM. Dockery et. al. (1993) followed approximately 8000 individuals in six cities of USA over a 15 year period and found an association between total and cardiovascular mortality and PM. The estimated mortality effects of long term exposure to PM_{10} is approximately 4 – 7 % increase per 10 μg/m^3 increase in PM_{10} which is much higher than the short term increase. Such studies provide a basis for calculating the reductions in life expectancy associated with PM exposure.

Morbidity

Many epidemiological studies have reported associations between PM and a range of morbidity outcomes such as

Hospitalization of respiratory and cardiovascular diseases
Emergency room visits
Asthma exacerbation
Acute and chronic bronchitis
Restriction in activities
Work loss
School absentees
Respiratory symptoms
Decreased lung function

Most of the studies showing associations between hospital admissions for respiratory and cardiovascular diseases have been conducted in USA, Europe and very few outside these regions. For instance, across cities of USA a 10 μg/m^3 increase in PM_{10} was associated with about 1% increase in cardiovascular admissions (Schwartz, 1999). Time series models have also provided association between daily PM and hospitalization for respiratory diseases. For example, in Santiago, Chile, association between PM_{10} and urgent care visits for lower respiratory symptoms were reported for children under age 2 years and for children 2 – 14 years (Ostro et al., 1999b).

In Los Angeles, PM_{10} exposure was associated with daily reporting of cough, shortness of breath and wheeze among Afro – American children with current physician diagnosed Asthma (Ostro et al., 2001). A study of daily effects of air pollution on 321 nonsmoking adults in three cities in Southern California reported associations between lower respiratory symptoms and PM (Ostro et al., 1993).

2.3 EBD assessment in national context

The World Health Report 2002 identified the top ten risks including smoke and unsafe water, sanitation and hygiene, globally and regionally, in terms of the burden of disease they cause. These risks account for more than one-third of all deaths worldwide. About, 1.7 million deaths a year worldwide were attributed to unsafe water, sanitation and hygiene, mainly through infectious diarrhea. Nine of ten such deaths are in children naturally all of the deaths are in developing countries.

Relative to people in other parts of the country, residents of rural and remote areas in Nepal have lower life expectancy and suffer more from chronic and acute illness. The major causes of sickness and death in Nepal are infectious diseases, maternal and perinatal ailments, and nutritional deficiencies, which accounts for 50 percent of all deaths. About 80 percent deaths among children fewer than five years old accounts due to intestinal infectious diseases, other bacterial diseases, pneumonia, and perinatal factors. More than half of the disease burden in Nepal is borne by children under five. Death and illness among 15 to 44 years olds account for nearly a quarter of DALYs lost. That burden is borne disproportionately by women. (World Bank, report No. 19613: Nepal Operational Issues and Prioritization of Resources in the Health Sector, June 2000)

WHO / NHRC organized a study on ambient air pollution: Assessing the EBD at National and Local Levels, 2004. This study highlighted 1926 cases of premature mortality per year in case of Kathmandu valley with upper and lower boundary at 1184 and 2973 respectively against the base line concentration of $10\mu g/m^3$ regarding PM_{10}. The BoD due to other pollution parameters has not been studied yet.

CHAPTER 3

PROCEDURAL GUIDELINES FOR THE ASSESSMENT OF EBD

3.1 Main steps

The procedure for the assessment of Environmental Burden of Disease (EBD) due to the two specific risk factors, namely bacterial contamination of water supplies and ambient air pollution is summarized in the following main steps.

I Data compilation from secondary sources
II Data generation from epidemiological survey
III Exposure – response modeling
IV Estimation of EBD attributable to the given risk factors

3.2 Data compilation from secondary sources

Available data should be compiled from the secondary sources needed for EBD calculations. The types of data to be compiled and their respective targeted secondary sources are described below.

3.2.1 Demographic data / indicators

The total burden of disease (BoD) assumed to be associated with environmental risk factors under consideration and expressed in terms of mortality, morbidity or DALYs should be collected at the initial stage for an EBD study. This can be accomplished through the compilation of demographic data on population, mortality represented by crude death rate (CDR), infant mortality rate (IMR), age / sex specific death rates, disease specific death rates etc. and morbidity by disease prevalence and incidence rates, total hospitalization cases etc. Age and gender specific values and indicators are preferable. However, the collection of disease prevalence rates, incidence rates or DALYs for the health effects associated with risk factors may not be readily available for the population under investigation. In such a case, it will be more difficult to carry out accurate EBD assessments if little is known about the health problems related to the environmental risk factors. A separate health survey may be required in such a situation or if the population under study has similar epidemiological, socioeconomic and cultural characteristics to the population for which the estimates are known, then they may be used and likely to provide good preliminary estimates for the assessment of EBD attributable to the given risk factors.

The targeted sources for demographic data compilation are Central Bureau of Statistics (CBS), Ministry of Health (MOH), Ministry of Population and Environment (MOPE), WHO reports on BoD and EBD etc.

3.2.2 Environmental health data / indicators

Environmental health indicators are both environmental as well as health indicators which can be linked together by an expression. Generally two types of environmental health indicators can be distinguished: those based on exposure and those based on health effects

3.2.2.1 Environmental health data / indicators based on exposure

Data compilation should be done on exposure indicators related to the risk factors such as levels of air pollutants regarding suspended air particulates and other gaseous emissions and bacterial contamination of water supplies across the study area (within Kathmandu Valley in the present study) and for the given reference period (e. g. 2003 / 2004). Time series, area specific and source specific data are required for population exposure calculations.

Ambient air pollution data

The principal air pollutants which exceed the WHO or national standards in the study area should be collected for EBD assessment studies. In case of Kathmandu Valley, previous air quality monitoring by MOPE show that the main pollutant which exceed the WHO / national standard is found to be suspended particulate matter (SPM). It is therefore recommended to collect the air pollution data on Particulate matter of size less than 10 micron (PM_{10}) or Particulate matter of size less the 2.5 micron ($PM_{2.5}$) for the EBD study within Kathmandu Valley. Consideration of other gaseous pollutants such as NO_2, SO_2, CO, Benzene would also be necessary to model health effects due to air pollution if they are near or above the international / national standards.

Water Quality Data

Bacterial contamination in water should be assessed by measurement of coliform content (E Coli / total coliform) in the water samples collected from different sources, locations and time periods for the study area.

Meteorological data

Data on temperature and humidity are usually included in the models as confounding variables besides air pollution data for building time series models for assessing short term health effects due to air pollution. Consequently, information on these variables should be considered during exposure – response modeling. Time series and area specific data will be required for exposure – response relationship modeling. The targeted secondary source for meteorological data is Department of Meteorology, HMG, Nepal.

3.2.2.2 Environmental health data / indicators based on health effects

In order to build exposure – response models, data on health effects which are assumed to be linked to the given environmental risk factors, namely ambient air pollution and bacterial contamination in water supplies in this particular EBD study should be collected from hospitals, nursing homes or health research centers etc. Data from hospital death records, hospital admission records and emergency room visit records should be compiled for the reference period under consideration.

Health effects that have been associated with the given risk factors are given below.

- Mortality and Morbidity due to the following diseases caused by bacteria

a. Typhoid/Paratyphoid (enteric fever)
b. Bacillary Dysentery
c. Cholera
d. Other Diahhoreal diseases caused by various types of bacteria (For example E Coli Diarrhea, Rota virus Diarrhea in infants)

- Mortality and Morbidity due to ambient air pollution

a. All cause (non-accidental) mortality
b. All respiratory diseases
c. All cardio vascular diseases
d. Asthma
e. Lung cancer
f. COPD / Bronchitis
g. Birth defect, low birth weight
h. Pneumonia

3.2.2.3 Representation of DALY as the population health indicator

Conventional demographic measures are based upon either mortality such as CDR or morbidity such as prevalence rates. The measures do not account mortality and morbidity in a single indicator but deals separately. One measure which takes account of both mortality and morbidity in a single indicator is Disability Adjusted Life Years (DALYs).

The EBD studies done in recent years elsewhere, particularly by WHO have considered DALYs as the main population health indicator. The indicator measures life years lost due to death and life years lived with the disability. The measure therefore has basically needs two components namely, YLL (Years of life lost due to death) and YLD (Years lived with the disability from health outcomes). If necessary data are available for computation of DALYs, then it should definitely represent as the main health effect indicator in any EBD calculations.

In the present study, the computation of DALY will be done only if necessary data inputs are available. However, estimation of DALYs for Nepal and subsequently Kathmandu Valley can also be done by extrapolating the values from WHO SEARD region.

3.2.2.4 Computation of DALY

The DALY combines in one measure the time lived with disability and time lost due to premature mortality as follows:

DALY = YLL + YLD where YLL for a given cause, age or sex is:
YLL = N x L where N is the number of deaths and L is the standard life expectancy at age of death (in years).

Time lost due to premature mortality is a function of death rate and the duration of time lost due to a death at each age. Since, death rates are incidence rates, we can use mortality by death incidence rate in a population.

To estimate YLD for a population, the number of disability cases is multiplied by the average duration of disability and a weight factor that reflects the severity of the disability or disease on a scale from 0 representing the perfect health and 1 for death.
The computational expression for YLD is:

YLD = I x DW x L where I is the number of incidence cases and L is the average duration of disability in years.

3.2.3 Reference period of data compilation

Daily data of ambient PM_{10} and benzene concentrations are available from the fixed monitors installed within Kathmandu Valley (ESPS, MOPE) from 2003 onwards. This means that hospital data on health outcomes may be compiled from then onwards so that the reference period of data collection would be 2 years at the most. The reference period of data compilation for exposure-response modeling should be at least one year for the EBD computation attributed to ambient air pollution. As far as data collection on bacterial contamination in water supplies is concerned, it may be collected for the same reference period as well. However, it is recommended to collect data for a reference period of several years if data can be made available.

3.3 Data generation and risk assessment from epidemiological study

A separate epidemiological survey for the study population will be needed if the required data are not available or missing from the secondary sources and from the past health/epidemiological surveys for the study population. A separate conduction of such a survey can provide vital inputs on disease incidence, prevalence and relative risks for statistical modeling of exposure and response relationships particularly for the computation of attributable burden from the risk factor, namely bacterial contamination of water sources though information on air pollution related health outcomes and exposure scenarios can also be gathered.

If such a survey is not feasible, then estimates on relative risks on total or disease specific mortality and morbidity should be extrapolated from the study done else where. Since, the present EBD study is based upon available secondary data compilation, a separate epidemiological survey is not feasible. As a result, some estimates on relative risks and other relevant environmental health indicators will be extrapolated from studies done else where necessary for EBD calculations.

3.3.1 Types of epidemiological studies for the assessment of environmental risks

Essentially there are three broad types of epidemiological study design:

- descriptive studies
- analytical or observational studies
- experimental or intervention studies.

3.3.1.1 Descriptive studies

These examine the distribution of disease and possible determinants of disease in a defined population, and can often lead to suggestions of important risk factors. They aim to identify changes in morbidity and/or mortality in time or to compare the incidence or prevalence of disease in different geographical areas or between groups of individuals with different characteristics. Descriptive studies generally use routinely collected health data, such as infectious disease notifications, and are cheap and quick to carry out. Descriptive studies are useful in generating hypotheses about the causes of certain disease patterns, but are not useful for testing hypotheses concerning the effect of particular exposures on particular disease outcomes.

3.3.1.2 Analytical studies

These are planned investigations designed to test specific hypotheses, and can be categorized into four groups:

- ecological
- cross-sectional studies
- cohort studies
- case-control studies.

3.3.1.3 Ecological studies

These examine associations between exposures and health outcomes using groups of people, rather than individuals, and often use surrogate measures of exposure, e.g. place and time of residence. Such a study would compare an aggregate measure of exposure (such as average exposure or the proportion of the population exposed) with an aggregate measure of health outcome in the same population. They are sometimes included under descriptive studies also. In Thailand, for example, the seasonal variation in the reported incidence of acute diarrhea in selected areas was examined in relation to rainfall and temperature records for the same areas (Pinfold *et al.* 1995). The authors found that the incidence of diarrhea appeared to be inversely related to a sharp seasonal decrease in temperature. Rainfall did not appear to have a direct effect on the relative incidence of acute diarrhea. The lack of ability to link individual exposure to individual disease risk and to control for possible confounders are major disadvantages of this approach and severely limit its usefulness in many settings, especially where the exposure changes over time and space and where there are many risk factors for the disease outcome of interest.

3.3.1.4 Cross-sectional studies

In a cross-sectional study exposure and health status are ascertained simultaneously on one occasion, and prevalence rates (or incidence over a limited recent time) in groups varying in exposure are compared. Careful measurement and statistical control of confounding variables is important to assess the effect of other risk factors for the outcome on observed prevalence. The usefulness of this study and other past cross-sectional studies has been limited by its failure to control for confounding variables and to document the type and extent of exposure of potentially exposed persons (Blum and Feachem 1985). A cross-sectional study can only provide information on the association between an exposure and

disease, and the temporal relationship between exposure and disease cannot be established. Other problems include the need for large sample sizes (for infections where prevalence is low), and potential bias due to exposure and disease misclassification. However, the advantages are that such studies are relatively cheap and can provide meaningful results where exposure and confounding factors are measured carefully.

3.3.1.5 Cohort studies

In a cohort study the population under investigation consists of individuals who are at risk of developing a specific disease or health outcome. These individuals will then be observed for a period of time in order to measure the frequency of occurrence of the disease among those exposed to the suspected causal agent as compared to those not exposed. During the follow-up period, data are acquired on the symptoms experienced by the two cohorts using questionnaire interviews. . The problem with this approach is that the aggregation of exposure and subsequent assignment of the same exposure to many people produces a large degree of non-differential misclassification bias, which biases the measure of association. Cohort studies are useful for the study of relatively common outcomes and for the study of relatively rare exposures e.g. risks from occupational exposure to wastewater (Shuval *et al*. 1989). Careful classification of exposures and outcomes is needed, as is the measurement and control for confounding factors. The disadvantages are that the studies are often complex and difficult to manage, the time span is often at least a year (to take into account seasonality of disease incidence) and the studies can therefore be expensive.

3.3.1.6 Case-control studies

Case-control studies examine the association between exposure and a health outcome by comparing individuals already ill with the disease of interest (i.e. cases) and a control group who are a sample of the same population from which the cases were identified. Gorter *et al*. (1991) used a case-control study design to examine the effects of water supply and sanitation on diarrhoeal disease in Nicaragua. They compared over 1200 children with diarrhea with a similar number of controls (children of a similar age with illnesses other than diarrhea). They found a statistically significant association between water availability and diarrhea morbidity. Children from homes with water supplies over 500 meters from the house had incidence rates of diarrhea 34% higher than those of children from houses with their own water supply. This relationship remained significant after controlling for confounding factors. The advantages of case-control studies are that they require smaller sample sizes, fewer resources, require less time and less money, and sometimes are the only way to study rare diseases. The difficulties are in appropriate study design to minimize bias, including the selection of appropriate controls and the control of confounding variables and minimizing recall bias.

3.3.1.7 Experimental or intervention studies

These differ from the observational techniques outlined above in that the investigators determine who will be exposed. A key part of the experimental design consists of randomizing a single cohort into two groups. The process of randomization attempts to ensure the same distribution of various intra-individual traits and potential confounders between study groups so that they are as comparable as possible. One group is then assigned to exposure to the factor under study; the other group is the control and the health

outcomes for the groups are compared. Randomization of subjects is important to minimize the potential for confounding or selection bias. In terms of determining causality this type of study is generally considered to be the most powerful. It is equivalent to the randomized controlled trial used in testing the impact of drugs and other medical interventions. Its use in examining environmental exposures has been limited because of ethical concerns, since many exposures of interest are potentially detrimental.

3.4 Exposure-response relationship modeling

The development of exposure response models through the application of some standard statistical modeling techniques is vital in EBD studies. Calculation of coefficients of the health outcomes due to the specified risk factors and relative risks are obtained through these models.

3.4.1 Exposure-response relationship modeling for the assessment of EBD due to ambient air pollution

Quantification of health effects associated with ambient air pollution in time series modeling is described below.

- The assessment of EBD attributable to ambient air pollution will be exposure based approach if time series modeling is applied. The exposure–response relationships should be developed through the application of time series models by recording daily variation of ambient air pollutants, such as suspended particulate matter and corresponding health outcomes in terms of total mortality, disease specific mortalities and morbidities obtained through the recording of daily hospital admissions, emergency room visits from various hospitals and other heath service providers such as nursing homes within the study area.

  An appropriate statistical model used to determine the health effects due to ambient air pollution is the Generalized Linear Model (GLM) with Log link function known as the Poisson regression. The model can be expressed as

$$\eta = \beta^t X$$

  where,
  η = Log {E(Y)} , Y is the dependent variable on health effects
  β = Vector of regression coefficients and
  X = Vector of explanatory variables including confounding variables
  such that $\beta^t X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p$ for p number of independent variables in the model.

  Time series models have distinct advantage over other models such as based upon cross sectional data since individual cofactors like smoking habit, nutrition, behavior are unlikely to be confounders in these models since they are not generally associated day to day with daily change in pollutant concentrations. The potential confounders that vary with time are weather and seasonal variables and therefore should be included in such models.

- Secondly, we can extrapolate the existing model estimates derived from those developed by epidemiological studies conducted elsewhere particularly those developed by WHO for the local assessment of EBD. However, such extrapolations have their own limitations such as

the demographic pattern of the study area and the area from where the models were actually developed could be substantially different from one another. Nevertheless, if the hospital data bases are weak or are not available for the study, extrapolations can still provide reasonable estimates for the local assessment of EBD. In present study also, if such data could not be obtained from secondary sources then coefficients and relative risks from other studies may be used for EBD calculations.

Similarly, quantification of health effects associated with bacterial contamination in water can be obtained as follows.

3.4.2 Exposure-response relationship modeling for the assessment of EBD due to bacterial contamination of water supplies

The assessment of EBD attributable to bacterial contamination of water supplies may be scenario based approach or exposure based approach.

In scenario based approach, population under investigation is categorized by parameters that influence the bacterial contamination in water such as source variation of water supplies, variations of sanitation situation across the study population, location variation within the study population and time variation of the analyzed samples. This implies that the study population would be divided in to pre-defined exposure scenarios. For instance, such exposure scenarios would divide the population in to categories namely, households with access of piped water supplies, households depending upon other sources such as well, stone spout, river etc. The health outcomes of the pre-identified exposure scenarios can be obtained from cross-sectional survey of the study population or may be obtained from the previous studies conducted for the study area.

The health outcome data on mortality and morbidity data can also be obtained from hospital / nursing home records and that of level of bacterial contamination in water supplies which are source as well as location specific can be obtained from concerned governmental or non governmental departments and organizations. Here, however the main issue is to link the exposure and outcome data with reference to a common variable, if available from the mentioned secondary sources. The common variable may be, for instance the area location of the water samples analyzed that matches with the location of the admitted patients with diahrreol disease. Once a linkage is established, relative risks of the high risk categories compared to low risk categories can be computed. The application of the above mentioned procedure depends solely upon the availability of the common variable that can link exposure and outcome data which may be difficult to obtain in real practice and depends upon the hospital data bases. If such information is lacking then a separate epidemiological study should be conducted to find out the relative risks of contaminated water on health effects compared to uncontaminated water. For the purpose either household survey or survey based on the hospital patients will be required to link between exposure situation and health effects of the study population.

In exposure based approach, time series models can be applied for exposure- response modeling similar to those applied in case of ambient air pollution. This modeling approach has already been described above.

The extrapolation of the relative risk values of the exposed and unexposed or relatively unexposed group of individuals with regard to the bacterial contamination of water supplies from epidemiologic studies conducted elsewhere is also one of the options that can be adopted in this study. However, before accepting these values, the justification on the suitability of the extrapolation should be critically examined.

3.5 Estimation of EBD attributable to the given risk factors

The basic approach for estimating the environmental burden of diseases is common to every environmental risk factor. For the EBD calculation, information on the local epidemiology of disease will be most required. For each risk factor, following data are required to assess the environmental burden of diseases:

- The distribution of risk factor exposure within the study population.
- The exposure - response relationship for the risk factors.
- The DALYs lost to disease for the risk factor of interest (mortality rates, disease incidence, etc.)

- Computation of attributable fraction (AF) or impact fraction (IF) as in the case of scenario based approach due to the specific risk factors will be done by standard methodology as mentioned in WHO literatures. Attributable fractions/impact fractions will be computed for total mortality and morbidity and also for the related diseases. Computation of DALY (Disability Adjusted Life Years) will also be explored and will be adopted if necessary data are available. Attributable disease burdens due to chosen risk factors will be computed for mortality, morbidity and DALYs if possible.

- The distribution of the risk factors within the study population and the development of exposure response model are combined together into an impact fraction or attributable fraction which is then applied to the disease estimates to find the attributable burden to a given risk factor

The Burden of Disease attributable to a given risk factor when exposed populations are compared with unexposed populations is given by the following simplified expression of the impact fraction :

$$IF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$$

where,

IF = Impact fraction

P_i = Proportion of the population in exposure category i, including the unexposed

RR_i = Relative risk at exposure category i compared to the reference level

The equation accounts various population groups exposed at different levels of pollutants. In the case of the population with only one category of exposure classification, the above expression further simplifies with a single relative risk measure to:

$$AF = \frac{RR - 1}{RR}$$

To calculate the fraction of disease attributable to a risk factor for any defined population, the total disease burden for the population (in deaths or DALYs) is multiplied by the attributable fraction. The attributable burden is therefore, given by:

Attributable burden = Attributable Fraction x total burden
= Attributable fraction x Population incidence of the health effect x Total exposed population

For instance, to calculate attributable burden of total annual deaths attributable to a given risk factor, the computing expression would be:

Attributable Burden = Attributable fraction x (Crude death rate / 1000) x Total exposed population

If there is evidence that the exposure distribution or the relative risks differ between subpopulations (such as by age or gender), then the impact fraction should be calculated separately for each subpopulation:

Attributable burden (age, sex) = Impact Fraction x total burden(age, sex)

If the exposure-response relationships are different for mortality and morbidity, the impact fractions should be calculated separately for YLL and YLD. For example, if the case fatality rate for diarrhoeal disease caused by exposure to unsafe water, sanitation or hygiene is different from that for the average diarrhoeal disease, then the impact fraction should be different for mortality than for DALYs and incidence. This is due to the fact that the relative risks for diarrhoea incidence and diarrhoea mortality would be different.

A couple of graphical representations for calculating the EBD using an exposure-based approach and scenario-based approach are shown below.

Figure 3 EBD from exposure-based approach

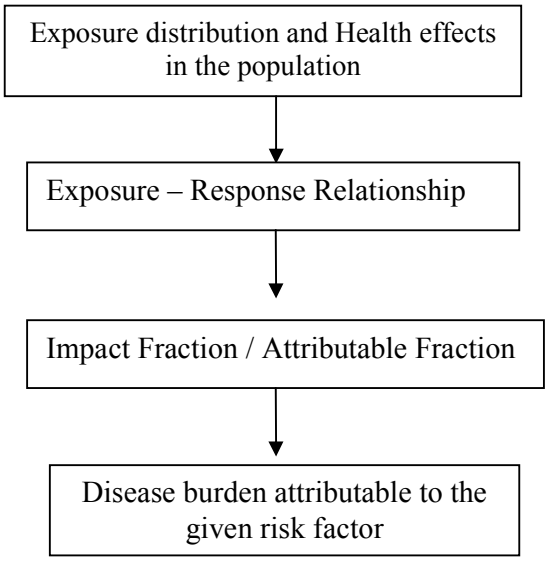
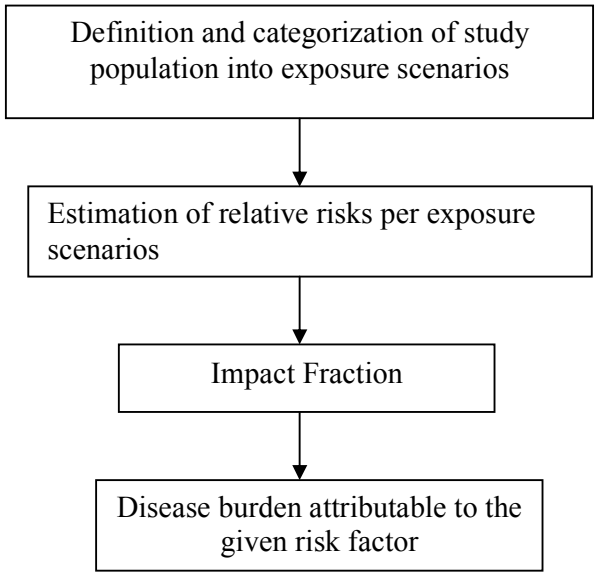


Figure 4 EBD from scenario-based approach



3.6 Uncertainties involved EBD studies

A certain level of uncertainty may exist in any research design or study**.** The present study is no exception to this. The uncertainty around BoD and EBD estimates can be influenced by many factors, including the following:

- The exposure assessment of the environmental risk factors may not be accurate. For instance, the number of people exposed to a particular or range of exposure levels may not be accurately estimated and cannot be practically feasible to be estimated with high degree of accuracy. The exposure – response relationships may be influenced by this to a certain extent.

- With lack of information on total disease burden for the study population, some assumptions will have to be taken at the cost of uncertainty.

- The risk of uncertainty associated with extrapolation of coefficients of exposure – response relationships cannot be denied. But this could be a reasonable solution for an EBD calculation under existing circumstances of poor country data bases available for the study population.

  As there is no straight forward mechanism to capture uncertainty around the best available estimate, a more approximate approach may be chosen. For instance, “high” and “low” estimates can be obtained from the lower and upper level of confidence interval for the relative risks obtained from surveys and models used.

CHAPTER 4

PROCEDURE ADOPTED FOR THE ASSESSMENT OF EBD IN THE PRESENT STUDY

4.1 Main steps

The procedure adopted for the assessment of Environmental Burden of Disease (EBD) due to the two specific risk factors, namely bacterial contamination of water supplies and ambient air pollution is summarized in the following main steps. To certain extent, the procedure is based upon the availability of local data from secondary sources.

I Data compilation from secondary sources
II Exposure – response modeling
III Estimation of EBD attributable to the given risk factors

4.2 Data compilation from secondary sources

Available data has been compiled from different secondary sources needed for EBD calculations. The reference period for data compilation has been 2003 and 2004. The period has been restricted to these years mainly because of the time limitation of the present study. The types of data compiled and their respective secondary sources are described below.

4.2.1 Demographic data / indicators

Demographic and population data has been compiled as follows.

- Population data for the study population and reference period
- Crude Death rate for Nepal. Deaths rates for Kathmandu valley were not available.
- Incidence rates on pneumonia and diarrheoal diseases

The sources for demographic data compilation are Central Bureau of Statistics (CBS), Ministry of Health (MOH), Ministry of Population and Environment (MOPE).

4.2.2 Environmental health data / indicators based on exposure

The assessment of exposure to the given environmental risk factors has been accomplished by compilation different exposure data relating ambient air pollution, bacterial contamination of water supplies and temperature for the study population Daily time series data has been collected for exposure-response modeling in the case of ambient air pollution. For bacterial contamination of water supplies, monthly data has been compiled.

Ambient air pollution data

Under the consideration of the principal air pollutants which exceed the WHO or national standards in the study area, time series data on PM_{10} has been collected and used for exposure-response modeling. Data on $PM_{2.5}$ could not be used for exposure-response modeling since it was available only for occasional periods. Consideration of including

other gaseous pollutants was ruled out since their average ambient concentrations are still within WHO limits and also because their daily time series values were unavailable for time series modeling. As a result, the present EBD assessment has included only PM_{10} as the parameter indicator of the ambient air pollution. Also, it is to be noted that almost all of the studies conducted at different parts of the world has included PM_{10} as the ambient air pollution parameter for time series modeling of health effects due to ambient air pollution.

Daily time series concentration values of ambient PM_{10} were obtained from ESPS, MOPE for 2003 and 2004. Daily averages obtained from the six fixed monitoring stations within Kathmandu Valley at Thamel, Putalisadak, Patan Hospital, Kirtipur, Bhaktapur and Matsyagaon were used for modeling.

Water Quality Data

Bacterial contamination of water supplies has been assessed by measurement of total coliform content in water samples. Sufficient data on E Coli was not available for modeling and therefore was excluded as the parameter in the process of modeling.

Altogether, 442 tap water values collected from different parts of Kathmandu Valley on total coliform content is used for building exposure response models. These were obtained from NWSC for the year 2003 / 2004 (2060 BS) Also, total coliform content data for water supplies from other sources like well, deep well and spout water are utilized for EBD calculations even though not used during exposure-response modeling. 228 such data were used of which 90 was from spout water, 86 from well water and 52 from deep well water. The data is taken from monitoring of ground water quality in Kathamndu Valley, ENPHO, 1999.

For descriptive assessment of water quality within Kathamndu Valley, data available from other sources like NESS, CEMAT etc. have been used. The list of sources visited is given below.

Sources for secondary data for bacterial water quality assessment

a. Nepal Water Supply Corporation
b. Kathmandu Metropolitan
c. ENPHO
d. United Nations International Children's Emergency Fund
e. JAICA
f. Nepal Water Supply and Sanitation Fund Board
g. WHO
h. NESS
i. Department of water supply
j. RONAST
k. Melamchi water project

l. CEMAT

Meteorological data

Data on temperature was used as one of the confounding variable in the models built regarding the ambient air pollution risk factor. Data monitored at International Airport, Kathamdu during 2003 and 2004, was used in the present analysis.

4.2.3 Environmental health data / indicators based on health effects

In order to build exposure – response models, data on health effects which are assumed to be linked to the given environmental risk factors, namely ambient air pollution and bacterial contamination in water supplies in this particular EBD study was collected from the leading hospitals in Kathmandu Valley. Data from daily hospital records was used to develop models to compute EBD due to ambient air pollution except for Lung cancer morbidity where monthly data was used. In order to develop models to calculate EBD due to bacterial contamination of water supplies, monthly health data on health outcomes based upon morbidity and exposure was utilized. Meanwhile for mortality due to bacterial contamination of water supplies, census household survey data, 2001 was used. The household data provided information on access to water supply and sanitation facility and deaths related to bacterial contamination one year prior to the census survey.

For the present EBD study, the following data was collected from the leading hospitals in Kathmanu Valley.

- Mortality and Morbidity due to the following diseases caused by bacteria

  e. Typhoid/Paratyphoid (enteric fever)
  f. Bacillary Dysentery
  g. Cholera
  h. Other Diahhoreal diseases caused by various types of bacteria (For example E Coli Diarrhea, Rota virus Diarrhea in infants)

- Mortality and Morbidity due to air pollution

  a. All cause (Non accidental) Mortality
  b. Asthma
  c. Lung Cancer
  d. COPD / Bronchitis
  e. Pneumonia

Sources of Mortality and Morbidity data

a. Patan Hospital
b. Bhaktapur Hospital
d. Bir Hospital
e. Sukra Raj Tropical Hospital
g. Epidemiology and Disease Control Division, Teku
h. TU Teaching Hospital
j. District Public Health office Kathmandu, Lalitpur & Bhaktapur

K. Department of Health Services

Representation of health effects in DALYs could not be carried out because of the lack of sufficient information for its computation. Data collection format is given in annex.

As far as total disease burden is concerned, total all cause mortality was computed from CDR, disease specific mortalities was computed from cause specific hospital deaths and morbidities were computed from total cause specific hospitalization cases.

4.3 Exposure-Response Modeling

Details of exposure-response modeling is described in the two following sections separately for the risk factor ambient air pollution and bacterial contamination of water supplies

4.3.1 Exposure-response relationship modeling for the assessment of EBD due to ambient air pollution

Quantification of health effects associated with ambient air pollution was accomplished by building exposure-response models based upon time series data. The detailed procedure is given below.

- The assessment of EBD attributable to ambient air pollution is exposure based approach. The exposure–response relationships was developed through the application of time series models by recording daily variation of ambient air pollutants assessed by PM_{10} and corresponding health outcomes in terms of total mortality, disease specific mortalities and morbidities obtained through the recording of daily hospital admissions from various leading hospitals.

- The statistical model used to determine the health effects due to ambient air pollution is the Generalized Linear Model (GLM) with Log link function known as the Poisson regression. The model can be expressed as

$$\eta = \beta^t X$$

where,

η = Log {E(Y)} , Y is the dependent variable on health effects

β = Vector of regression coefficients and

X = Vector of explanatory variables including confounding variables such that $\beta^t X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p$ for p number of independent variables in the model.

The confounding variables incorporated in the model are temperature and seasonal variables expressed in terms of sines and cosines. Some values on beta coefficient were extrapolated from studies conducted world wide and compiled by WHO.

4.3.2 Exposure-response relationship modeling for the assessment of EBD due to bacterial contamination of water supplies

The assessment of EBD attributable to bacterial contamination of water supplies was both scenario based approach for mortality assessment and exposure based approach for morbidity assessment.

In scenario based approach, population under investigation is categorized by parameters that influence the bacterial contamination in water such as source variation of water supplies and variations of sanitation situation across the study population. This implies that the population was divided in to pre-defined exposure scenarios. For instance, such exposure scenarios would divide the population in to categories namely, households with access of piped water supplies, households depending upon other sources such as well, stone spout, river etc. Data on exposure scenarios and health effects on cause specific mortality was taken from census survey, 2001 by CBS. Relative risks were estimated for various exposure scenarios as compared to relatively unexposed scenarios.

In exposure based approach, time series models were applied for exposure-response modeling similar to those applied in case of ambient air pollution. Monthly data was used instead of daily data based upon the availability of data from secondary sources. This modeling approach has already been described above.

4.4 Estimation of EBD attributable to the given risk factors

The basic approach for estimating the environmental burden of diseases is common to every environmental risk factor. For the EBD calculation, information on the local epidemiology of disease was required. For each risk factor, following data was utilized to assess the environmental burden of diseases:

- The distribution of risk factor exposure within the study population.
- The exposure - response relationship for the risk factors.
- The total burden of diseases in terms of mortality and morbidity which depended upon mortality rates, disease incidence rates and the total exposed population for the study area.

- Computation of attributable fraction (AF) or impact fraction (IF) as in the case of scenario based approach due to the specific risk factors was done by standard methodology as mentioned in WHO literatures. Attributable fractions/impact fractions were computed for total mortality and morbidity and also for the related diseases.

- The distribution of the risk factors within the study population and the development of exposure response model are combined together into an impact fraction or attributable fraction which is then applied to the disease estimates to find the attributable burden to a given risk factor

The Burden of Disease attributable to a given risk factor when exposed populations are compared with unexposed populations is given by the following simplified expression of the impact fraction :

$$IF = \frac{\sum P_i RR_i - 1}{\sum P_i RR_i}$$

where,

IF = Impact fraction
P_i = Proportion of the population in exposure category i, including the unexposed
RR_i = Relative risk at exposure category i compared to the reference level

The equation accounts various population groups exposed at different levels of pollutants. In the case of the population with only one category of exposure classification, the above expression further simplifies with a single relative risk measure to:

$$AF = \frac{RR-1}{RR}$$

Where, AF = Attributable fraction

To calculate the fraction of disease attributable to a risk factor for any define population, the total disease burden for the population (in deaths / total hospitalizations / total OPD visits) is multiplied by the attributable fraction. The attributable burden is therefore, given by:

Attributable burden = Attributable Fraction x total burden
= Attributable fraction x Population incidence of the health effect x Total exposed population

4.5 Limitations and assumptions made for EBD assessment

- The annual average PM_{10} concentration for Kathmandu Valley is based upon the annual averages monitored from the 6 fixed stations within the valley and assumed that the true average population exposure to PM_{10} is equal to the average obtained from the stations for the reference year.
- It is assumed that the mortality rate (CDR) for Kathmandu valley is equal to that of the national value.
- EBD due to ambient air pollution is computed from the short term health effects due PM_{10} and long term effects have been excluded as it generally takes many years to generate necessary data for quantification of health effects which is beyond the scope of the present study.
- As population prevalence rates were unavailable for the health effects under consideration, hospital admissions and OPD visits were used for the computation of total disease burden although these values are most likely to under estimate the true population burden values.
- Assessment of EBD under the consideration of DALYs could not be achieved since population data necessary for its computation for the population under study was not available.
- The database system was not uniform between the hospitals due to which the collected data also were not consistent.

CHAPTER 5

FINDINGS

The findings of the study is described and presented in various sections given below.

5.1 Environmental health data / indicators based on health effects

Five leading hospitals in Kathmandu valley were visited for the compilation of mortality and morbidity records for the year 2060 / 2061. The hospitals were Bir Hospital (Kathmandu), Patan Hospital (Lalitpur), TU teaching hospital (Kathmandu), Sukraraj Tropical & Infectious Disease Hospital (Kathmandu) and Bhaktapur hospital (Bhaktapur). Hospital inpatient records were collected for daily deaths from all non accidental cause, daily hospital admissions for the diseases namely COPD, Asthma, Bronchitis, Pneumonia, Lung cancer, Diarrheoal diseases such as Cholera, Dysentery, Gastroenteritis and Enteric fever and cause specific death records of the same diseases mentioned above. Data was compiled for one whole year from each of the hospitals.

Data on all cause mortality was obtained from Bir hospital and TU Teaching hospital for the year 2060 (2003/2004). Disease specific mortality and morbidity data were obtained from all the 5 hospitals visited for data compilation as shown in table5 below. Day to day data was obtained for hospital admission date and discharge date from all the hospitals except Sukraraj Tropical and Infectious Disease Hospital which provided data on only monthly basis. Some hospitals provided information on age, gender and address of the inpatients as well.

The differences in data compilation with regard to diseases between hospitals were mostly unavoidable since some hospitals did not observe the particular type of patients. For example, Bir hospital and TU teaching hospital did not have inpatients with diarrheal diseases. The differences in data compilation with regard to age, gender and address of the inpatients were entirely due to differences in mode of record keeping between hospitals. Due to this some provided information and some did not. The difference in starting month of a year for data compilation was also due to the same reason as above since the annual records started from the month of Baishak (Bir, TU teaching and Sukraraj hospital) in some hospitals and from shrawan (Patan, Bhaktapur hospital) for others.

In the year 2003/2004 (2060/2061 BS) 12,807 cases of air and water borne diseases were admitted in the leading hospital of Kathmandu Valley. Among these cases 288 died. The highest number of morbidly was observed in Sukra Raj Tropical hospital and the number of mortality was high in Patan hospital. Data regarding age and address of the morbidity and mortality were not available from all the hospital (Table 5).

Table 5 The morbidity and mortality data of five leading hospital of Kathmandu valley

Hospital	Admissions	Reference Year	Total Cases	Total Mortality Cases	Information on Age and Gender	Information on Address
Bir	COPD, Bronchitis, Pneumonia, Broncho-pneumonia, Asthma, Lung Cancer, Enteric fever	2060 (2003 / 2004)	772	98	Provided	Not Provided
TU Teaching	COPD, Pneumonia, Lung cancer, Enteric fever	2060 (2003 / 2004)	808	56	Provided	Provided
Patan	COPD, Asthma, Pneumonia, Lung Cancer, Enteric fever, gastroenteritis, Dysentery, Cholera	Shrawan 2060 – Ashad 2061 (2003 / 2004)	2,285	100	Not Provided	Provided
Sukraraj	COPD, Asthma, Pneumonia, RTI / LTRI, Gastroenteritis, Dysentery, Enteric fever	2060 and 2061 (2003 / 2005)	8,739	30	Provided	Not Provided
Bhaktapur	COPD, Asthma, ARI, Lung cancer, Enteric fever, Diarrhea, Dysentery, Cholera	Shrawan 2060 – Ashad 2061 (2003 / 2004)	203	4	Provided	Provided
Total			12,807	288		

Data on total burden of disease in terms of CDR, hospitalizations and OPD visits assumed to be associated with the environmental risk factors have been compiled and presented below. The data was compiled from total values obtained from the 5 leading hospitals of Kathmandu valley and data obtained from DoHS.

Table 6 Total disease burden of selected health effects

Health Effect	Indicator	Cause	Value	Population	Reference Year	Source
Mortality	CDR	All cause	9.22	Nepal	2004	Nepal in Figures, 2004, CBS
Mortality	Hospital Deaths	Respiratory	236	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	Respiratory	3188	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	COPD	1890	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	Lung Cancer	122	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	Diarrhea	2632	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	Gastro-enteritis	2511	KTM Valley	2003/2004	Hospital Records
Morbidity	Total Admissions	Enteric fever	1007	KTM Valley	2003/2004	Hospital Records
Morbidity	Total OPD Visits	Respiratory	32914	KTM Valley	2003/2004	DoHS
Morbidity	Total OPD Visits	COPD	14058	KTM Valley	2003/2004	DoHS
Morbidity	Total OPD Visits	Lung Cancer	NA	KTM Valley	2003/2004	DoHS
Morbidity	Total OPD Visits	Diarrhea	35421	KTM Valley	2003/2004	DoHS
Morbidity	Total OPD Visits	Gastro-enteritis	NA	KTM Valley	2003/2004	DoHS
Morbidity	Total OPD Visits	Enteric fever	5581	KTM Valley	2003/2004	DoHS

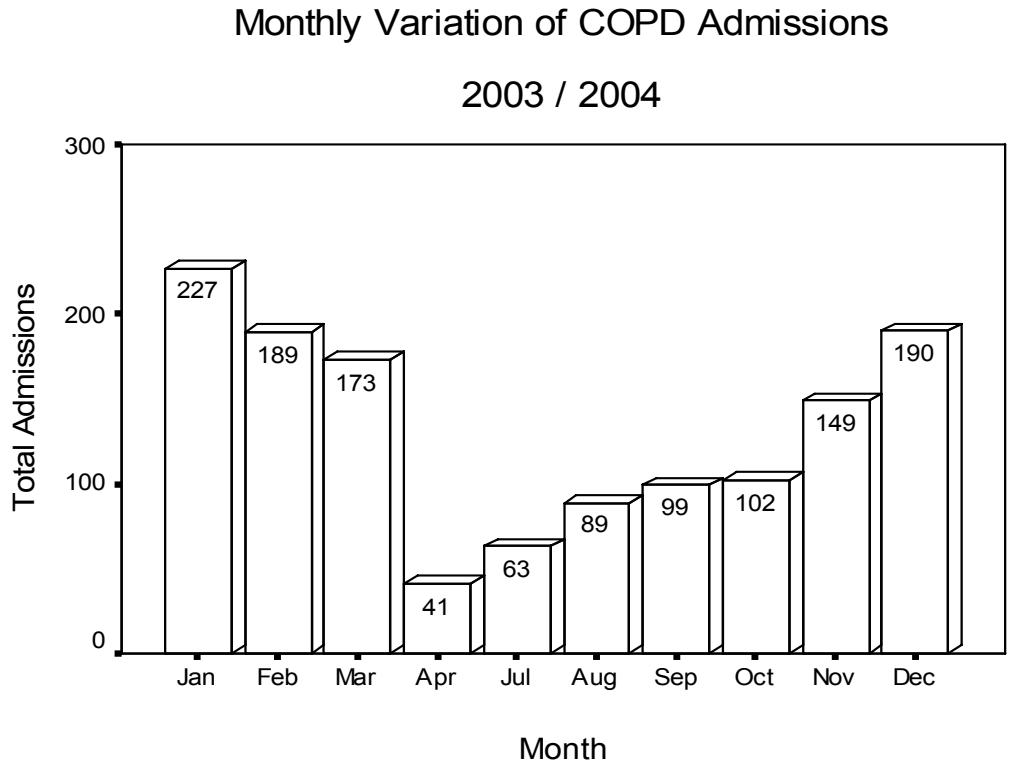
Monthly COPD hospital admissions

In the given table 7 and bar diagram shows the monthly variation of COPD admission. The numbers of chronic obstructed pulmonary diseases were relatively high in the month of November, December, January, February and March as compared to other months. Meanwhile, the number decreased in August, September, October and April. In winter, people are exposed to fumes and suspended air pollutants at higher level than summer, so that the cases COPD may have increased.

Table 7 Monthly hospital admissions of COPD in leading hospital of Kathmandu valley for 2003 /2004

Admission Month	Bir Hospital	Patan Hospital	Bhaktapur Hospital	TU Teaching Hospital	Total
January	53	107	9	58	227
February	48	78	13	50	189
March	45	90	8	30	173
April	32	65	6	16	119
May	54	58	5	46	163
June	44	52	9	53	158
July	27	50	7	38	122
August	24	23	8	34	89
September	20	38	9	32	99
October	26	44	5	27	102
November	35	62	9	43	149
December	47	96	3	44	190
Total	455	763	91	471	1780

Figure 5



5.1.2 Monthly Pneumonia hospital admissions

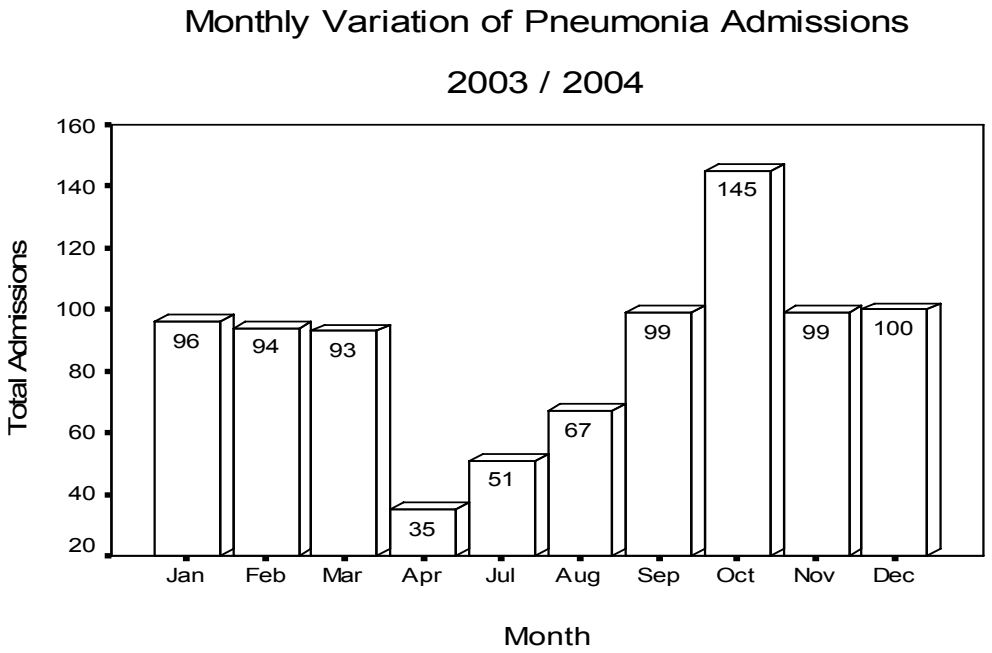
Pneumonia, Bronchitis and Asthma are also respiratory tract related diseases. In the given tables (8 & 9) and bar diagrams show the monthly variation of pneumonia, bronchitis and asthma admissions. The highest number of pneumonia cases were admitted in the Patan

hospital (871), while the number is lowest (9) in the Bhaktapur hospital. The number of pneumonia cases were less in Bir hospital (116) and (166) in TU Teaching hospital as compared to Patan hospital. Pneumonia cases were higher in the month of October and May. While the numbers decreased in the months of June, July, August, September, October and April. In the same way, cases of bronchitis and asthma were increased in the month of October, January and September. In winter people are more exposed to fumes and suspended air pollutants so that respiratory tract related diseases may increase (Table 8, 9)

Table 8 Monthly hospital admissions of Pneumonia in leading hospital of Kathmandu valley for 2003 /2004

Admission Mo nth	Patan Hospital	Bir Hospital	TU Teaching Hospital	Bhaktapur hospital	Total
January	72	10	13	1	96
February	61	20	13	0	94
March	66	10	14	3	93
April	72	2	10	1	85
May	73	9	22	1	105
June	64	6	13	0	83
July	72	13	10	1	96
August	50	11	6	0	67
September	73	10	14	2	99
October	123	8	14	0	145
November	81	6	12	0	99
December	64	11	25	0	100
Total	871	116	166	9	1162

Figure 6

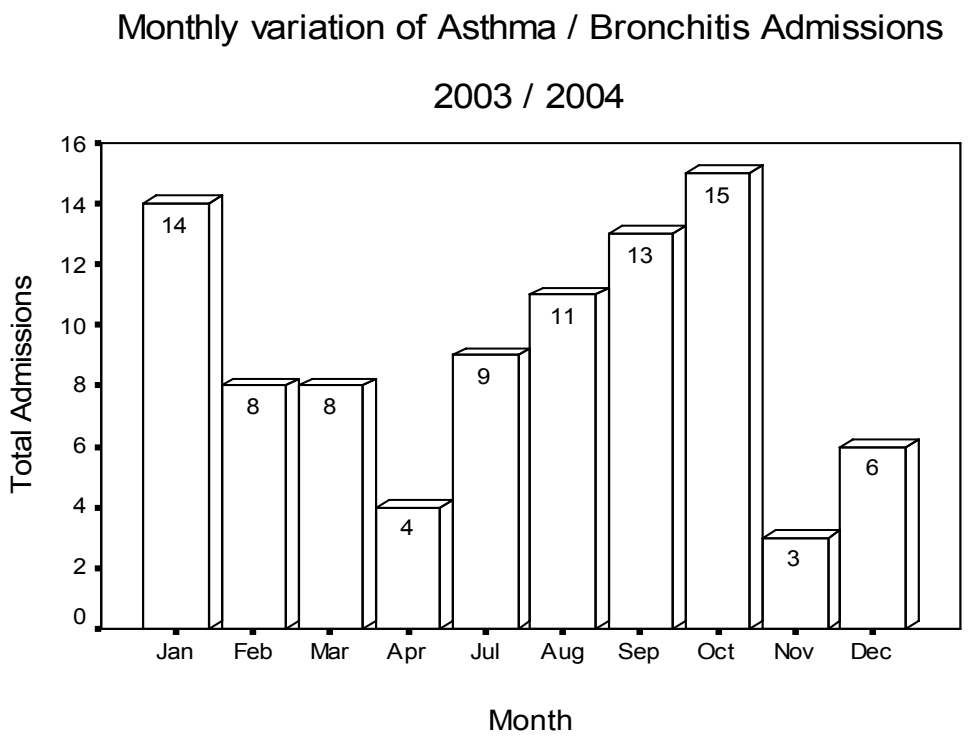


5.1.3 Monthly Asthma and Bronchitis hospital admissions

Table 9 Monthly hospital admissions of Asthma / Bronchitis in leading hospital of Kathmandu valley 2003 /2004

Admission Month	Asthma		Bronchitis	Total
	Patan Hospital	Bhaktapur Hospital	Bir Hospital	
January	7	0	7	14
February	6	3	1	10
March	8	0	0	8
April	3	1	3	7
May	3	0	5	8
June	11	1	2	14
July	4	0	7	11
August	3	3	5	11
September	4	2	7	13
October	9	0	6	15
November	2	0	1	3
December	3	0	3	6
Total	63	10	47	120

Figure 7



5.1.4 Monthly hospital admissions of Water Borne diseases

In the year 2003/2004 there were 32 cases of cholera, 89 cases of bacillary dysentery, 2511 gastro entestinal tract infection, 1007 enteric fever, and 2632 diarrhoeal diseases were found in the leading hospital of Kathmandu valley. The highest numbers of diarrhoeal diseases were recorded in the month of Shravan, Ashad Bhadra and Jestha. In the same way enteric fever was recorded 126 in Ashad, 116 in Jestha and 101in the month of Baisakh. The data shows other gastro intestinal infection is also increased in the same period. It is because of the shortage of water supply in the month of Chaitra, Baisakh and mid of the Jestha. During this period people do not get sufficient water for drinking, washing vessels and to maintain basic sanitation. By the mid of Jestha to Ashad Shravan and Bhadra due to heavy rainfall most of the water supply system is contaminated by various types of micro organism and the water borne diseases are increased in Kathmandu valley (Table 10).

Table 10 Monthly variation of Water Borne Diseases in leading hospital of Kathmandu Valley 2060 /61 (2003 /2004)

Month	Cholera	Dysentery	Gastro-intestinal tract infection	Enteric Fever	Diarrheoal
Baishak	3	8	268	101	279
Jestha	3	15	329	116	347
Ashad	1	17	372	126	390
Shrawan	5	2	429	167	436
Bhadra	13	10	350	131	373
Aswin	4	5	249	99	258
Kartik	0	2	87	96	89
Manshir	0	4	47	46	51
Poush	0	2	41	24	43
Magh	0	8	54	26	62
Fagun	1	6	88	27	95
Chaitra	2	10	197	48	209
Total	32	89	2511	1007	2632

In the given table 11, the prevalence of gastro enteritis, bacillary dysentery, enteric fever, COPD, asthma, pneumonia and RTI/LRI in the Sukraraj Tropical hospital has been shown. The number of gastro enteritis cases were 2262, bacillary dysentery 36 and enteric fever440. In the same way the total number of COPD were 110, asthma 4 and pneumonia 12. In the year The number of gastro enteritis increased 2262 (2061) to 5416 in the year 2062. In the same year bacillary dysentery cases were remained constant and the numbers of other disease other were decreased.

Figure 8

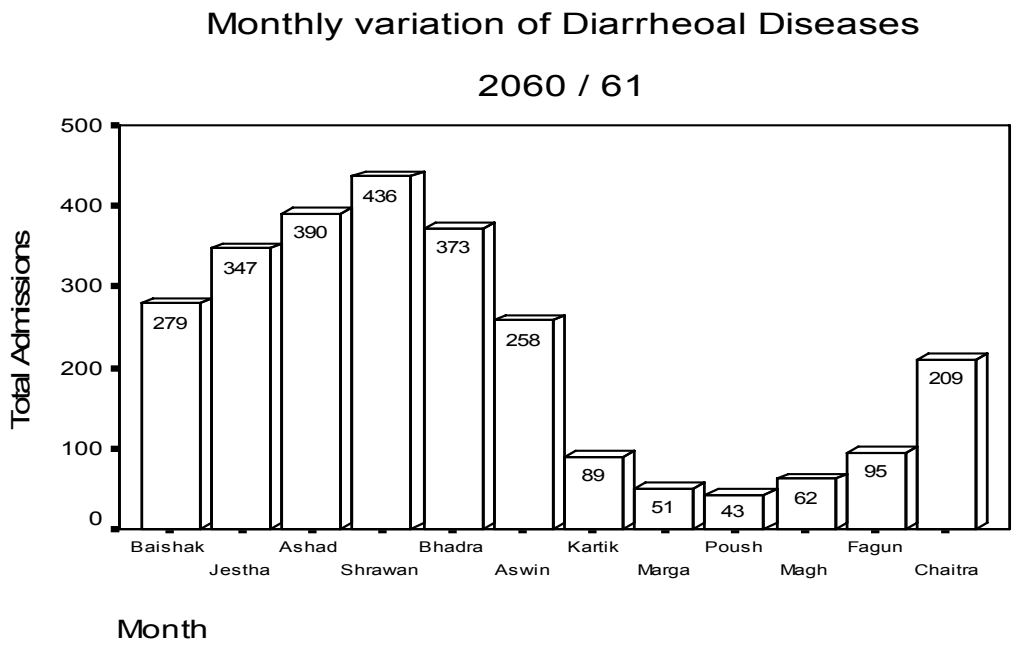


Table 11 Hospital Morbidity Data of Tropical & Infectious Diseases in Sukraraj Tropical Hospital in the year 2060 and 2061

Year	Month	Gastro enteritis	Bacillary Dysentery	Enteric fever	COPD	Asthma	Pneumonia	RTI/LTRI	Total
2060	Baishak	229	2	41	7	0	2	1	282
	Jestha	253	6	42	16	0	3	5	325
	Ashad	335	6	64	13	2	0	6	426
	Shrawan	416	0	74	6	0	2	4	502
	Bhadra	339	3	70	4	0	1	2	419
	Aswin	235	5	53	10	2	2	5	312
	Kartik	80	1	31	6	0	1	1	120
	Manshir	41	4	19	13	0	0	3	80
	Poush	31	1	11	13	0	0	2	58
	Magh	36	2	9	8	0	1	1	57
	Fagun	80	1	9	6	0	0	2	98
	Chaitra	187	5	17	8	0	0	2	219
	Total	2262	36	440	110	4	12	34	2898
2061	Baishak	749	4	21	6	0	2	0	782
	Jestha	1742	6	26	4	1	0	0	1779
	Ashad	1069	1	16	8	0	0	3	1097
	Shrawan	514	4	46	2	0	1	2	569
	Bhadra	386	3	34	11	0	1	3	438
	Aswin	338	0	41	2	1	0	7	389
	Kartik	158	2	28	6	0	1	3	198
	Manshir	70	0	21	1	0	2	0	94
	Poush	79	2	18	1	0	0	1	101

	Magh	75	4	11	6	0	1	3	100
	Fagun	106	7	10	6	1	0	2	132
	Chaitra	130	4	20	3	2	1	2	162
	Total	5416	37	292	56	5	9	26	5841
Total	Baishak	978	6	62	13	0	4	1	1064
	Jestha	1995	12	68	20	1	3	5	2104
	Ashad	1404	7	80	21	2	0	9	1523
	Shrawan	930	4	120	8	0	3	6	1071
	Bhadra	725	6	104	15	0	2	5	857
	Aswin	573	5	94	12	3	2	12	701
	Kartik	238	3	59	12	0	2	4	318
	Manshir	111	4	40	14	0	2	3	174
	Poush	110	3	29	14	0	0	3	159
	Magh	111	6	20	14	0	2	4	157
	Fagun	186	8	19	12	1	0	4	230
	Chaitra	317	9	37	11	2	1	4	381
	Total	7678	73	732	166	9	21	60	8739

The monthly variation of water borne diseases shows the highest number (490) in the month of Shravan, Bhadra (412), and Ashad (405) in the year 2061. The numbers of same diseases were increased than 2061. The given bar chart shows that Their were 774 cases of water borne diseases in the month of Baisakh. The number of cases increased in Jestha 1774, Ashad 1086 and in Shravan 564. This data shows the trend of water borne diseases is increasing every year.

Figure 9

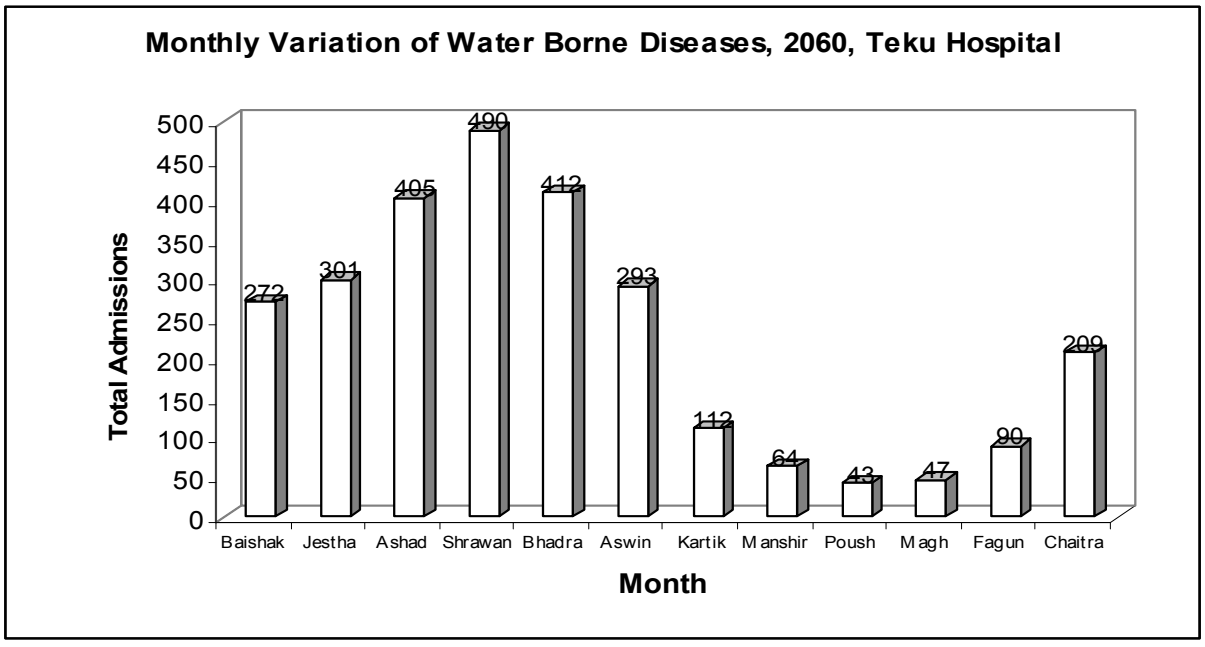
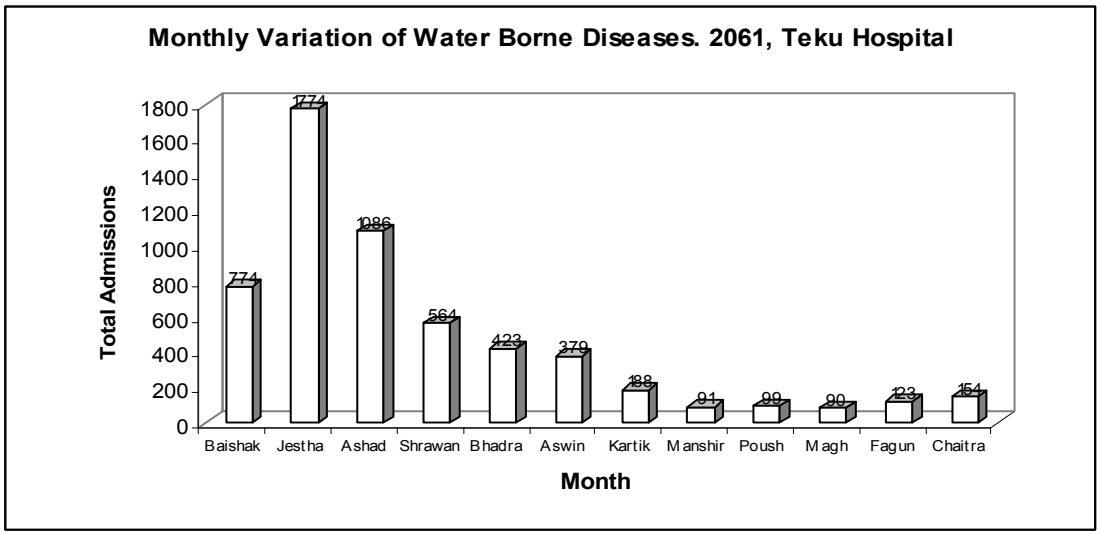


Figure 10



5.1.5 Age and Gender specific data

Several hospitals (4) provided information on gender and age. Among COPD hospitalizations, 46.7 % were males and 53.3% were females. Similarly, among pneumonia inpatients 56.4% were males and 43.6% were females; among diarrheoal inpatients, 54.9% were males and 45.1 were females; among Enteric fever inpatients, 55.6 were males and 44.4 were females.

Among COPD inpatients, an overwhelming 87.3 were aged 50 or above. Similarly among pneumonia inpatients, 49.5% were aged below 50; among diarrheoal inpatients only 20.1% were below age 20; among enteric fever 87.7% were aged below 50.

The above figure suggest that gender difference among hospital inpatients for both air borne as well as water borne diseases are not significantly different and evenly distributed. If we examine the age difference among the inpatients, we find that COPD patients are mostly old aged; pneumonia patients are evenly distributed below and above age 50; enteric fever inpatients are mostly young or middle aged and among diarrheoal patients only one fifth are aged below 20.

5.1.6 Inpatient record by place of residence

Only two hospitals provided information on place of residence of the hospital inpatients. Among Patan hospital inpatients, 86.2% and among TU teching hospital inpatients, 82.3% were Kathamndu Valley residents excluding the non response cases which is very small (0.4%). This implies that the health effect assessments made in the study with respect to exposure to ambient air pollution in Kathmandu valley can be said to be representative of the valley resident inpatients.

5.2 Environmental data / indicators based on exposure

Data compilation was conducted on exposure related to the risk factors such as levels of air pollutants regarding suspended air particulates and other gaseous emissions and bacterial contamination of water supplies across the study area (within Kathmandu Valley) and for the given reference period (e. g. 2003 / 2004). Time series and area specific data were compiled for population exposure calculations.

5.2.1 Ambient air pollution data

Daily data was collected on PM_{10} as observed by the 6 fixed stations across Kathmandu valley for the year 2003 and 2004. Data on Benzene concentration was also compiled. Similarly, data on other gaseous pollutants such as SO_2, NO_X etc were also not considered since they were within the WHO limit and did not pose serious to valley inhabitants. Data on air pollutant concentrations was provided from ESPS, MOPE (Table 12, 13, 14 & 15)

Table 12 Monthly Average PM_{10}, 2003

Month	Putalisadak	Patan	Thamel	Kirtipur	Matsyagaon	Bhaktapur	Mean
January	314.97	285.14	273.16	134.65	91.10	278.65	231.95
February	252.64	232.71	198.00	102.39	68.19	211.57	177.63
March	242.32	228.36	178.55	115.13	66.35	200.16	171.81
April	251.27	240.01	194.25	120.37	91.70	191.87	181.58
May	264.68	237.19	190.71	116.38	105.19	175.32	179.10
June	215.57	179.87	122.23	80.07	69.37	101.60	128.12
July	116.03	122.52	62.65	26.42	23.39	36.32	64.55
August	125.00	117.87	65.13	29.97	22.29	39.13	66.86
September	126.17	127.63	69.70	32.27	24.83	44.63	70.87
October	135.39	119.03	104.65	45.29	32.03	66.42	83.80
November	182.50	174.66	168.34	78.24	53.10	106.07	128.01
December	282.39	214.81	207.87	87.65	46.87	129.35	161.49
Total	208.88	189.66	152.15	80.24	57.12	131.40	136.05

Table 13 Monthly Average PM_{10}, 2004

Month	Putalisadak	Patan	Thamel	Kirtipur	Matsyagaon	Bhaktapur	Mean
January	283.19	245.06	214.39	109.03	56.71	183.74	182.02
February	245.79	239.21	202.69	117.14	69.97	193.76	178.09
March	286.84	280.26	224.26	150.74	108.26	220.13	211.75
April	241.37	230.03	161.27	120.70	91.93	165.67	168.49
May	230.00	211.45	153.29	98.77	78.61	147.06	153.20
June	185.27	161.73	69.30	50.47	47.70	75.53	98.33
July	113.32	135.97	61.29	32.19	27.42	36.42	67.77
August	116.48	138.90	54.65	21.81	14.52	27.48	62.31
September	116.63	122.93	67.00	34.67	19.90	41.53	67.11
October	147.16	136.74	90.97	44.23	29.58	56.90	84.26
November	218.03	178.80	150.93	76.80	47.83	100.03	128.74
December	252.42	197.71	197.42	75.71	45.55	113.71	147.09
Total	202.95	189.81	137.20	77.55	53.09	113.25	128.98

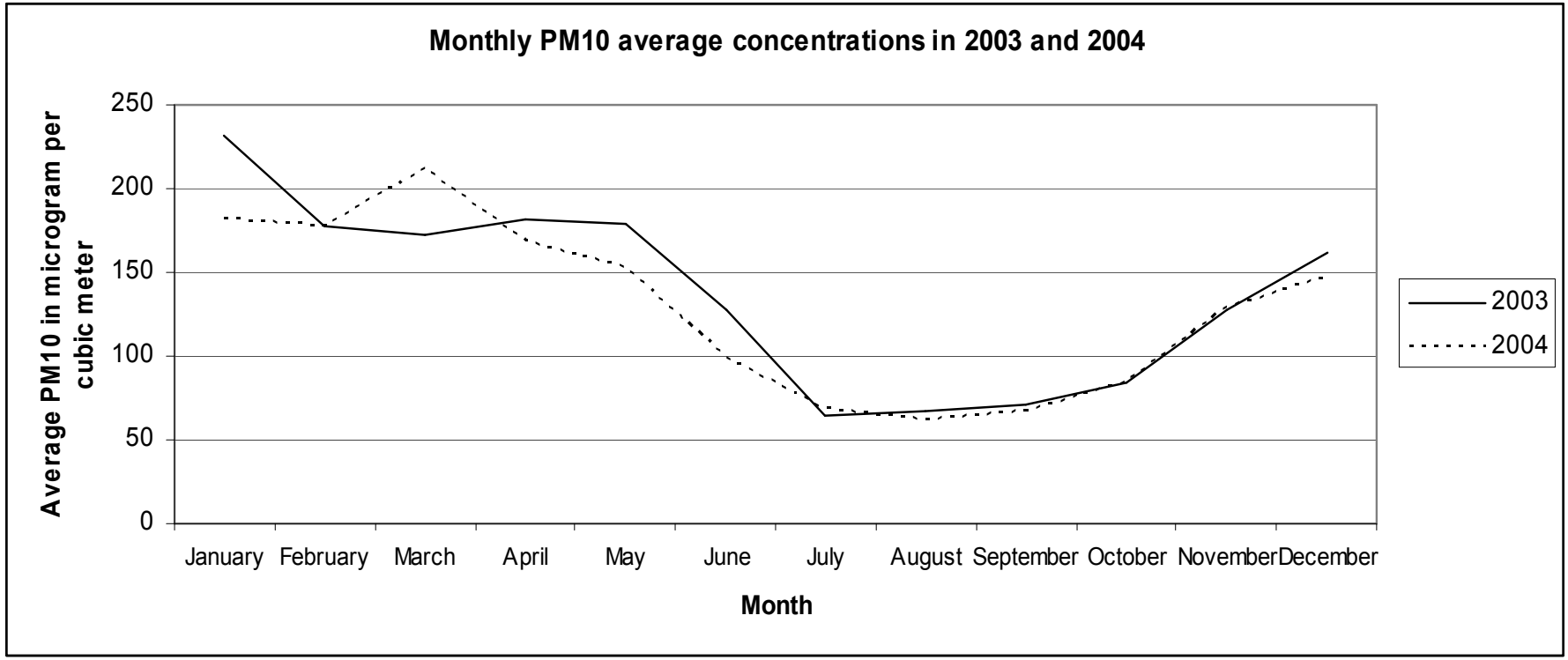
Table 14 Monthly Average PM_{10} , 2003 and 2004

Month	Putalisadak	Patan	Thamel	Kirtipur	Matsyagaon	Bhaktapur	Mean
January	299.08	265.10	243.77	121.84	73.62	231.19	206.57
February	249.16	236.08	200.39	109.89	69.11	202.51	177.87
March	264.58	254.31	201.40	132.94	87.31	210.15	191.78
April	246.32	235.02	177.76	120.53	91.82	178.77	175.04
May	247.34	224.32	170.36	106.81	90.98	161.19	164.76
June	200.42	170.80	95.77	65.27	58.53	88.57	113.23
July	114.68	129.24	61.97	29.31	25.40	36.37	66.16
August	120.74	128.39	59.89	25.82	18.40	33.31	64.54
September	121.40	125.28	68.35	33.47	22.37	43.08	68.99
October	141.27	127.89	97.81	44.76	30.81	61.66	84.03
November	200.27	176.76	159.49	77.51	50.42	103.00	128.38
December	267.40	206.26	202.65	81.68	46.21	121.53	154.29
Total	205.91	189.74	144.61	78.88	55.08	122.30	132.46

Table 15 Monthly Average Concentration of Benzene in Kathmandu Valley, 2003 / 2004

YEAR	MONTH	PUTALI	PATAN	THAMEL	BHAKT	KIRTIPUR	MATSYA	BENZENE
2003	July	14.20	10.03	9.12	2.65	1.61	1.23	6.03
	August	13.68	10.37	8.17	2.73	1.60	1.10	5.82
	September	14.48	9.95	9.82	3.01	1.82	1.31	6.23
	October	13.67	7.86	10.01	3.81	2.24	1.59	5.90
	November	13.92	8.56	12.22	5.23	3.04	1.80	6.59
	Total	13.99	9.35	9.87	3.49	2.06	1.41	6.11
2004	January	16.72	10.32	13.76	8.66	4.47	2.12	7.90
	February	13.44	9.33	10.13	7.80	3.80	1.71	6.40
	March	15.17	9.74	10.39	7.15	4.09	2.25	6.94
	April	16.10	9.85	13.27	7.66	4.72	2.50	7.74
	Total	15.36	9.81	11.89	7.82	4.27	2.15	7.25
Total	January	16.72	10.32	13.76	8.66	4.47	2.12	7.90
	February	13.44	9.33	10.13	7.80	3.80	1.71	6.40
	March	15.17	9.74	10.39	7.15	4.09	2.25	6.94
	April	16.10	9.85	13.27	7.66	4.72	2.50	7.74
	July	14.20	10.03	9.12	2.65	1.61	1.23	6.03
	August	13.68	10.37	8.17	2.73	1.60	1.10	5.82
	September	14.48	9.95	9.82	3.01	1.82	1.31	6.23
	October	13.67	7.86	10.01	3.81	2.24	1.59	5.90
	November	13.92	8.56	12.22	5.23	3.04	1.80	6.59
	Total	14.60	9.56	10.77	5.41	3.04	1.73	6.62

Figure 11


Monthly PM10 average concentrations in 2003 and 2004
Average PM10 in microgram per cubic meter
250
200
150
100
50
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
2003
2004

5.2.2 Water Quality Data

Bacterial contamination in water has been assessed by measurement of total coliform content in the water samples collected from tap , well, deep well and spout at different locations and time period across Kathmandu Valley. Data on water quality was provided by NWSC, NESS, JICA, CEMAT, ENPHO, NHRC studies. However, other potential secondary sources were also visited but data could not be obtained regarding coliform content in water supplies.

Data provided by NWSC on total coliform content in tap water samples collected from various parts of Kathmandu Valley was used for exposure response modeling. Altogether 442 tap water sample data with coliform content was provided. Similarly, 228 sample data of water quality from other sources measured by ENPHO is also utilized for EBD calculations.

Table 16 shows that the percentage of D grade water samples regarding total coliform content were higher in summer months than winter months. Table 17 shows the distribution of water samples according to their grades with regard to the supply sources.

Table 16 Frequency Distribution of Tap Water Quality, 2060 in Kathmandu Valley

Month	A		B		C		D		Total
	FREQ	%	FREQ	%	FREQ	%	FREQ	%	FREQ
Baishak	13	40.6	3	9.4	7	21.9	9	28.1	32
Jestha	17	19.5	0	0.0	8	9.2	62	71.3	87
Ashad	16	29.1	0	0.0	6	10.9	33	60.0	55
Shrawan	16	29.6	3	5.6	6	11.1	29	53.7	54
Bhadra	20	47.6	1	2.4	3	7.1	18	42.9	42
Aswin	11	35.5	0	0.0	5	16.1	15	48.4	31
Kartik	10	29.4	3	8.8	5	14.7	16	47.1	34
Manshir	7	21.9	13	40.6	6	18.8	6	18.8	32
Poush	10	45.5	1	4.5	9	40.9	2	9.1	22
Magh	8	44.4	1	5.6	6	33.3	3	16.7	18
Fagun	8	66.7	0	0.0	3	25.0	1	8.3	12
Chaitra	15	65.2	1	4.3	0	0.0	7	30.4	23
Total	151	34.2	26	5.9	64	14.5	201	45.5	442

Table 17 Frequency Distribution of Water Quality by type of Source, 1999 in Kathmandu Valley

	Spout		deep		well	
Grade	Frequency	Percent	Frequency	Percent	Frequency	Percent
A	3	3.33	12	23.08	3	3.49
B	11	12.22	19	36.54	13	15.12
C	21	23.33	17	32.69	17	19.77
D	19	21.11	4	7.69	15	17.44
E	36	40.00	0	0.00	38	44.19
Total	90	100.00	52	100.00	86	100.00

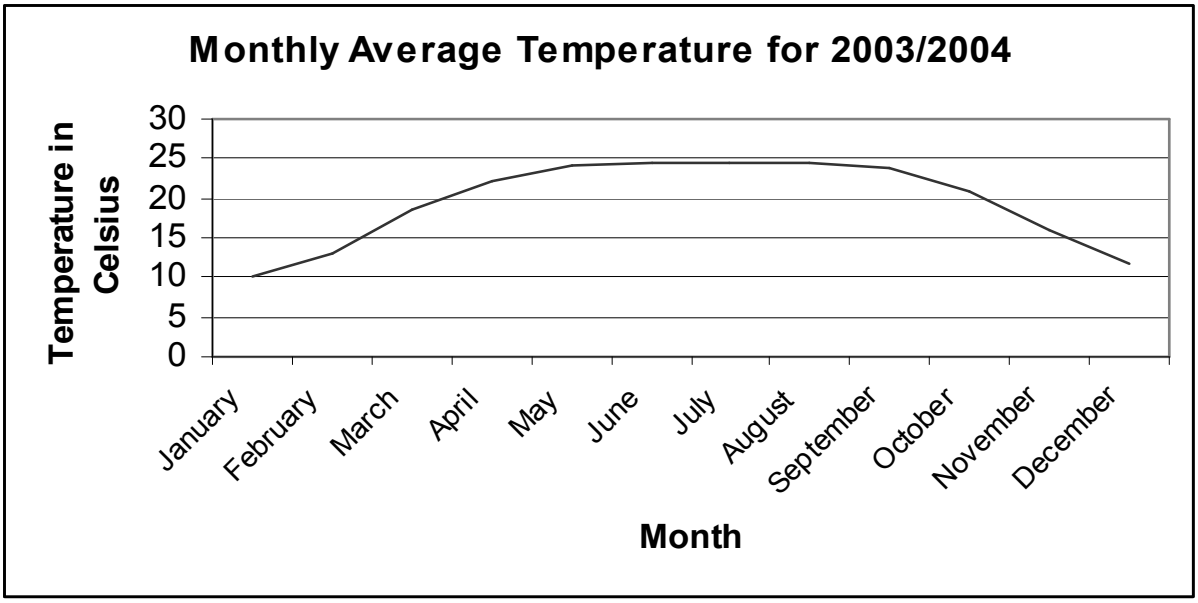
5.2.3 Meteorological data

Data on temperature has been included in the models as a confounding variable besides air pollution data for building time series models for assessing short term health effects due to air pollution. Mean daily temperature for Kathmandu Valley was collected from Tribhuvan International Airport readings.

Table 18 Monthly Average Temperature, Airport, 2003 / 2004

Month	Mean Temperature	Standard Deviation
January	10.14	1.10
February	13.16	2.88
March	18.51	2.20
April	22.03	2.76
May	24.04	2.45
June	24.58	2.15
July	24.57	2.11
August	24.61	1.35
September	23.72	1.57
October	20.99	1.76
November	16.06	2.11
December	11.74	2.07
Total	19.51	2.04

Figure 12



5.3 Results of the assessment of EBD due to ambient air pollution

Results of the assessment of EBD attributable to ambient air pollution are presented in the following sections.

5.3.1 Exposure-Response Modeling

The exposure–response relationships are developed through the application of statistical models based upon time series data on population exposure to environmental pollution and corresponding health effects. The assessment of exposure to ambient air pollution has been done by accounting exposure to ambient PM_{10} pollution since particulate pollution has been regarded as the single most important pollutant whose values are found to exceed both the national as well as international standards in Kathmandu valley. Data on ambient PM_{10} was obtained from ESPS, MOPE recorded by six fixed stations within the valley for the year 2003 and 2004. On the other hand data on selected health effects was obtained from hospital records of daily inpatients from various leading hospitals of Kathmandu Valley for one year period (2003 / 2004). Data on both exposure as well as health effects were compiled on daily basis. The selected health effects assumed to be associated with ambient particulate pollution and included in exposure-response modeling are all cause mortality, respiratory mortality and morbidity including COPD, Asthma, Bronchitis, Lung cancer and Pneumonia. Similarly, meteorological data on daily temperature of Kathmandu Valley recorded at Tribhuvan International airport is used as confounding variable in the models built.

The statistical model used to determine the health effects due to ambient air pollution is the Generalized Linear Model (GLM) with Log link function known as the Poisson regression. The model has been utilized in many studies linking ambient air pollution and health effects. It has the count variable which is the daily total counts on the selected health end points of the hospital inpatients as the dependent variable. The explanatory variables are daily average PM_{10} level included as the main explanatory variable and average temperature, its quadratic term and periodic variables expressed in sine and cosine are included as the confounding variables. The quadratic term of temperature is included in order to capture the curvilinear association between the response variable and the temperature if present. Meanwhile, sine and cosine terms are included in the model to adjust for seasonal variation.

It is to be noted that in such time series models individual characteristics such as smoking and nutrition do not vary daily and cannot be included as confounding variables. The confounding variables are only the time varying variables such as weather and seasonal variables, for instance daily average temperature, humidity etc. This particular linear model has been used since exposure to ambient PM_{10} has been found to be linearly associated with health effects even at fairy high level of PM_{10} (150 $\mu g/m^3$). The main objective of application of the model is to find the amount of increase in relative risks of the selected health effects and percent increase in health effects for certain degree rise in the level of exposure assessed by PM_{10}. The estimated relative risks are then used to find the attributable fractions and then EBD attributable to ambient air pollution regarding PM_{10}. In addition, lower and upper confidence limits have been computed with 95% confidence interval.

PM_{10} and temperature are included as 3 day moving averages in the models to capture the short
term effect of PM_{10} except for models with Lung cancer counts as the dependent variable where monthly data are utilized for modeling.

The model can be expressed as

$$\eta = \beta^t X$$

where,

η = Log {E(Y)}, Y is the dependent variable on health effects, E means expected value

β = Vector of regression coefficients

X = Vector of explanatory variables including the confounding variable such that

$\beta^t X = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots + \beta_k X_k$

The types of explanatory variables are air pollution variable expressed in PM_{10}, weather variable expressed in average temperature and seasonal variable expressed in terms of $\text{Sin}(2\pi tk/365)$ and $\text{Cos}(2\pi tk/365)$ where t is time variable and k = 1, 2, 3, 4.

The estimated values from exposure-response modeling are presented for

- Parameter coefficients and the corresponding standard error
- Percent increase in health effect per 10 $\mu g/m^3$ increase in PM_{10} level
- Relative risks for average population exposure to PM_{10} above the threshold limits
- Attributable fractions due to PM_{10} exposure

Two exposure response models have been developed for each of the following health end points depending upon the value of the baseline or threshold PM_{10} concentration below which it is assumed there will be no serious health effects to people. Two threshold PM_{10} concentrations, 20 $\mu g/m^3$ and 10 $\mu g/m^3$ have been used for exposure assessment even though recent studies have indicated that there is actually no threshold value for PM_{10} as such and there can be health effects at any low PM_{10} value.

- All cause mortality
- Respiratory mortality
- Respiratory hospital admissions
- COPD hospital admissions
- Lung Cancer hospital admissions

Four diseases have been included in the present data analysis under respiratory category for both morbidity as well as mortality data namely COPD, Asthma, Bronchitis and Pneumonia. It is to be noted that the total inpatient cases reported in Nepal for these four diseases accounted for 64.4% of the total respiratory hospital admissions for the year 2003 / 2004 according to DoHS, 2060 / 61 BS.

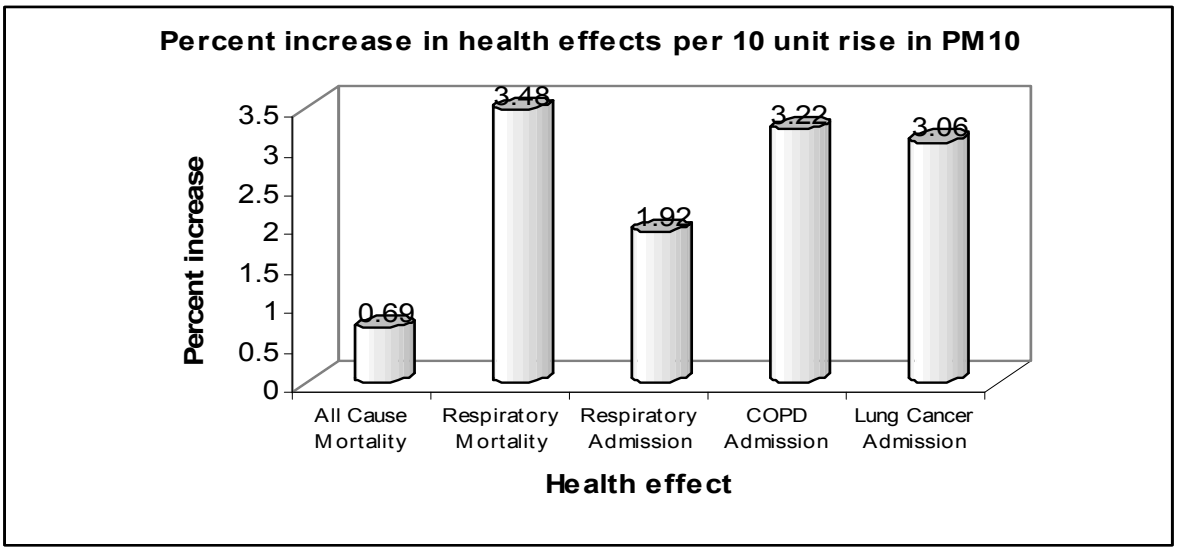
5.3.1.1 Percent increase in selected health effects per 10 μg/m^3 increase in PM_{10}

Table 19 shows the percent increase (central value) in selected health effects per 10 μg/m^3 increase in PM_{10}. The figures estimated by the models are 0.69 %, 3.48 %, 1.92 %, 3.22 % and 3.06 % for all cause mortality, respiratory mortality, respiratory hospital admissions, COPD hospital admission and Lung cancer hospital admissions respectively. Lower and upper limits have been computed from the local data on exposure and response for respiratory and COPD hospital admissions, For all cause mortality, the standard error estimated by meta analysis of studies conducted at different parts of the world and reported in WHO EBD series 5, 2004 has been used under the consideration that the estimated value of the standard error of PM_{10} coefficient is fairly stable in studies conducted elsewhere

Table 19 Estimates of percent increase in health effects from exposure-response models

Health effect	Percent increase per 10 μg/m^3 increase in PM_{10}		
	Central	Lower	Upper
All Cause Mortality	0.69	0.49	0.89
Respiratory Mortality	3.48	-	-
Respiratory Admission	1.92	0.37	3.49
COPD Admission	3.22	1.20	5.28
Lung Cancer Admission	3.06	-	-

Figure 13



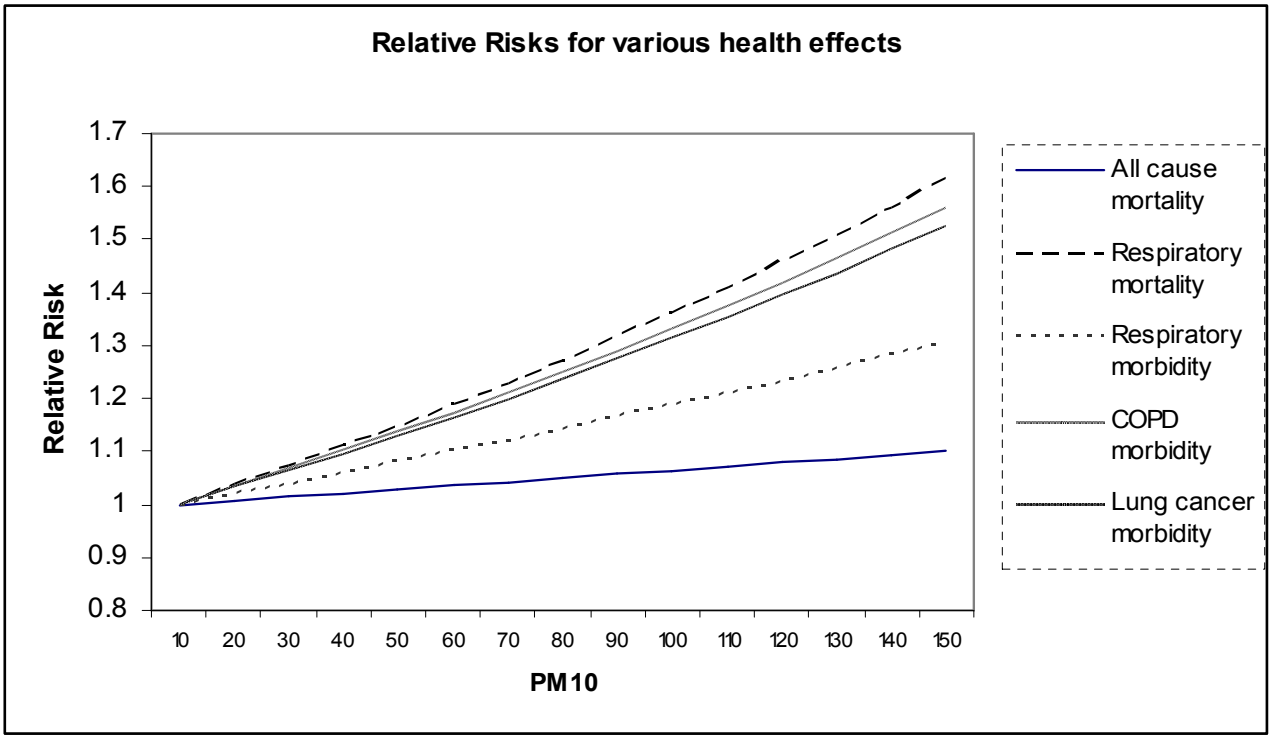
5.3.1.2 Relative Risks of health effects due to exposures to ambient PM_{10}

Table 20 shows the increase in relative risks of the health effects due to increase in exposure to average PM_{10} in ambient air. Figure shows linear trend in the increase of the relative risks due to fitting the generalized linear model with linear terms in air pollution.

Table 20 Change in Relative Risks of health effects due to change in PM_{10}

PM10	All cause mortality	Respiratory mortality	Respiratory morbidity	COPD morbidity	Lung cancer morbidity
10	1.0000	1.0000	1.0000	1.0000	1.0000
20	1.0069	1.0348	1.0192	1.0322	1.0306
30	1.0139	1.0708	1.0387	1.0654	1.0621
40	1.0209	1.1080	1.0587	1.0998	1.0945
50	1.0280	1.1466	1.079	1.1352	1.1280
60	1.0351	1.1865	1.0996	1.1717	1.1624
70	1.0423	1.2278	1.1207	1.2095	1.1980
80	1.0495	1.2705	1.1422	1.2484	1.2345
90	1.0567	1.3147	1.1642	1.2887	1.2723
100	1.0641	1.3604	1.1865	1.3302	1.3111
110	1.0714	1.4078	1.2092	1.3730	1.3512
120	1.0789	1.4567	1.2324	1.4172	1.3925
130	1.0863	1.5074	1.2561	1.4629	1.4350
140	1.0938	1.5560	1.2802	1.5100	1.4789
150	1.1014	1.6141	1.3047	1.5586	1.5241

Figure 14



5.3.1.3 Exposure-response model for all cause mortality

The Poisson model with all cause mortality count as the dependent variable and PM_{10} concentration, temperature and periodic variable as the explanatory variables show that PM_{10} exposure is positively correlated with death counts. The model estimates an increment of 0.69% in premature deaths associated with 10 $\mu g/m^3$ increase in PM_{10} concentration. However, the coefficient for PM_{10} is found to be statistically insignificant at 95% confidence level ($t<1.96$). The attributable fractions of mortality due to PM_{10} exposure are found to be about 7.2% and 7.9% for baseline PM_{10} concentrations taken as 20 $\mu g/m^3$ and 10 $\mu g/m^3$ with annual average PM_{10} equal to 129 $\mu g/m^3$ for Kathmandu Valley in 2004.

Temperature is found to be negatively associated with the mortality where as sine and cosine curves are associated more with 3 monthly period oscillation than higher period oscillations such as annual periodic variation.

Table 21 Estimated coefficients for all cause mortality (Model 1)

Variable type	Parameter	Estimated value	Standard Error	t value
	Intercept	1.22672	0.93656	1.31
Air pollution	PM10	0.00069	0.00104	0.66
Weather	Temperature	-0.03052	0.08972	-0.34
	Temperature^2	0.00102	0.00215	0.47
Seasonal / cyclic	Sin ($2\pi t/365$)	-0.03835	0.19753	-0.19
	Cos ($2\pi t/365$)	-0.05972	0.07133	-0.84
	Sin ($4\pi t/365$)	-0.00007	0.04304	-0.00
	Cos ($4\pi t/365$)	-0.01086	0.09602	-0.11
	Sin ($6\pi t/365$)	0.05208	0.05691	0.91
	Cos ($6\pi t/365$)	-0.01426	0.04228	-0.34
	Sin ($8\pi t/365$)	0.06968	0.04305	1.62
	Cos ($8\pi t/365$)	-0.09426	0.04350	2.17

Table 22 RR and AF for all cause mortality

Model	Percent Increase for 10 $\mu g/m^3$ increase in PM_{10}	Baseline PM_{10} concentration	RR for average exposure above threshold limit	AF
1(a)	0.692386	20	1.07811	0.072451
1(b)	0.692386	10	1.08557	0.078829

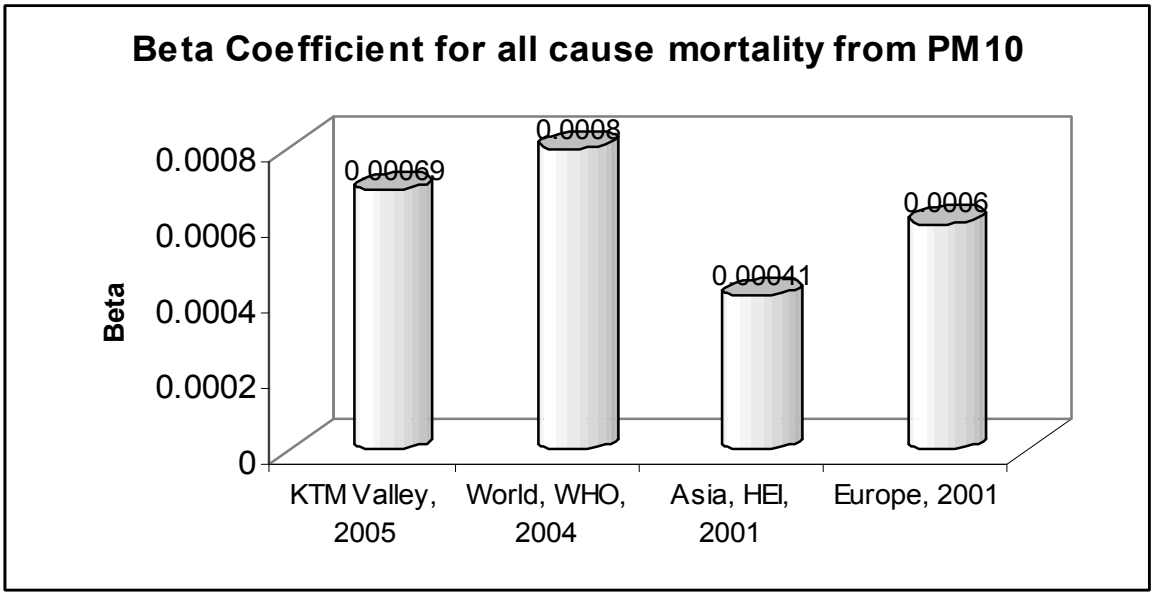
β Coefficients derived from meta-analysis of different studies worldwide

Table 23 shows β coefficients derived from meta-analysis of different studies worldwide. The central β coefficient varied from 0.00041 to 0.00080.

Table 23 Coefficients derived from main studies of the world for all cause mortality (all age group)

Outcome	Coefficient			Source
	Central	Lower	Upper	
All cause mortality	0.0008	0.0006	0.001	Meta analysis, EBD Series 5, WHO
All cause mortality	0.00041	0.00025	0.00056	Meta analysis, Health Effects of Outdoor Air Pollution in Developing Countries: A literature review, HEI, 2004
All cause mortality	0.0006	0.0004	0.0008	Meta analysis, 29 European cities, 2001

Figure 15



A comparative look on the coefficients estimated in the present study with the studies conducted at other parts of the world show that the value estimated in the present study lies in between the values estimated elsewhere with minimum and maximum being 0.00041 and 0.0008 respectively.

5.3.1.4 Exposure-response model for respiratory mortality

The exposure response model with respiratory mortality as the dependent variable shows that PM_{10} exposure is positively correlated with respiratory death counts with 3.48 % increase in premature respiratory deaths associated with 10 $\mu g/m^3$ increase in PM_{10} concentration. However, the coefficient for PM_{10} is found to be statistically insignificant at 95% confidence level ($t<1.96$). The attributable fractions of respiratory mortality due to PM_{10} exposure are found to be about 31.8 % and 34.1 % for baseline PM_{10} concentrations taken as 20 $\mu g/m^3$ and 10 $\mu g/m^3$ with annual average PM_{10} equal to 132 $\mu g/m^3$ for Kathmandu Valley for 2003 / 2004. High standard error is observed for PM_{10} coefficient due to which lower and upper limits have not been computed in this case as well.

Temperature is negatively associated with respiratory mortality with higher degree of associations for six monthly and four monthly periodic variations than tri-monthly and annual oscillations.

Table 24 Estimated coefficients for respiratory mortality (Model 2)

Variable type	Parameter	Estimated value	Standard Error	t value
	Intercept	-4.3373	2.07497	-2.09
Air pollution	PM10	0.00342	0.00302	1.13
Weather	Temperature	0.32109	0.19968	1.61
	Temperature^2	-0.00707	0.00488	-1.45
Seasonal / cyclic	Sin (2πt/365)	-0.44118	0.45572	-0.97
	Cos (2πt/365)	-0.22054	0.19075	-1.16
	Sin (4πt/365)	0.09695	0.10135	0.96
	Cos (4πt/365)	-0.52030	0.20702	-2.51
	Sin (6πt/365)	0.22203	0.12676	1.75
	Cos (6πt/365)	-0.29807	0.09932	-3.00
	Sin (8πt/365)	-0.00701	0.09890	-0.07
	Cos (8πt/365)	0.09680	0.09726	0.99

Table 25 RR and AF for respiratory mortality

Model	Percent Increase	Baseline PM_{10} concentration	RR for average exposure above threshold limit	AF
2(a)	3.479154	20	1.466737	0.318214
2(b)	3.479154	10	1.517767	0.341137

5.3.1.5 Exposure-response model for respiratory morbidity

The exposure response model with respiratory hospitalization as the dependent variable shows that PM_{10} exposure is positively correlated with respiratory hospitalization counts with 1.9% increase in premature respiratory admissions associated with 10 μg/m^3 increase in PM_{10} concentration. The coefficient for PM_{10} is found to be statistically significant at 95% confidence level (t>1.96).The attributable fractions of respiratory admission due to PM_{10} exposure are found to be about 19.1 % and 20.7 % for baseline PM_{10} concentrations taken as 20 μg/m^3 and 10 μg/m^3 with annual average PM_{10} equal to 132 μg/m^3 for Kathmandu Valley for 2003 / 2004. The lower and upper limits (95% confidence interval for AF) are found to be 0.0407 and 0.3189 for baseline PM_{10} concentration 20 μg/m^3 and 0.0443 and 0.3418 for baseline PM_{10} concentration 10 μg/m^3

While PM_{10} is positively associated with respiratory hospital admission, temperature is found to be negatively associated with higher degree of associations for six monthly and four monthly seasonal variations than other periodic variations.

Table 26 Estimated coefficients for respiratory morbidity

Variable type	Parameter	Estimated value	Standard Error	t value
	Intercept	2.45624	0.53548	4.59
Air pollution	PM10	0.00190	0.00078	2.42
Weather	Temperature	-0.06070	0.05230	-1.16
	Temperature^2	0.00140	0.00129	1.09
Seasonal / cyclic	Sin (2πt/365)	-0.04548	0.12034	-0.38
	Cos (2πt/365)	-0.02758	0.04894	-0.56
	Sin (4πt/365)	0.06129	0.02700	2.27
	Cos (4πt/365)	0.01268	0.05546	0.23
	Sin (6πt/365)	0.00916	0.03431	0.27
	Cos (6πt/365)	-0.10842	0.02670	-4.06
	Sin (8πt/365)	-0.00796	0.02663	-0.30
	Cos (8πt/365)	0.00544	0.02674	0.20

Table 27 RR and AF for respiratory morbidity

Model	Percent Increase	Baseline PM_{10} Concentration	RR for average exposure above threshold limit	AF (Central)	AF (Lower)	AF (Upper)
3(a)	1.918165	20	1.237137	0.191682	0.040722	0.318886
3(b)	1.918165	10	1.260868	0.206895	0.044276	0.341844

5.3.1.6 Exposure-response model for COPD morbidity

While PM_{10} is found to be positively associated with COPD hospital admissions, daily average temperature is found to be negatively associated. The estimated percent increase in COPD hospital admission is 3.22 per 10 μg/m^3 increase in ambient PM_{10} concentration. The coefficient for PM_{10} is found to be statistically significant at 95% confidence level (t>1.96).The central, lower and upper limits of the attributable fraction for exposure above the threshold limits are computes as 0.2988, 0.1248 and 0.4383 for 20 μg/m^3 threshold PM_{10} level and 0.3207, 0.1352 and 0.4665 for 10 μg/m^3 threshold PM_{10} level respectively. The annual daily average PM_{10} being 132 μg/m^3 for 2003 / 2004.

COPD hospital admissions have been found to be affected more by seasonality with six monthly and four monthly periodic oscillations.

Table 28 Estimated coefficients for COPD morbidity

Variable type	Parameter	Estimated value	Standard Error	t value
	Intercept	2.22876	0.66513	3.35
Air pollution	PM10	0.00317	0.00101	3.12
Weather	Temperature	-0.09588	0.06539	-1.47
	Temperature^2	0.00184	0.00163	1.12
Seasonal / cyclic	Sin (2πt/365)	0.06522	0.15614	0.42
	Cos (2πt/365)	0.03549	0.06503	0.54
	Sin (4πt/365)	0.09259	0.03567	2.59
	Cos (4πt/365)	-0.07016	0.07053	-0.99
	Sin (6πt/365)	-0.02353	0.04481	-0.52
	Cos (6πt/365)	-0.08877	0.03573	-2.48
	Sin (8πt/365)	0.00116	0.03524	0.03
	Cos (8πt/365)	-0.06946	0.03562	-1.95

Table 29 RR and AF for COPD morbidity

Model	Percent Increase	Baseline PM_{10} Concentration	RR above threshold limit	Attributable Fraction	Lower AF	Upper AF
4(a)	3.22078	20	1.426238	0.298855	0.124819	0.438282
4(b)	3.22078	10	1.472174	0.320732	0.135176	0.466476

5.3.1.7 Exposure-response model for Lung Cancer morbidity

PM_{10} is found to be positively associated with lung cancer hospitalization with 3.06% rise in the hospitalization per 10 μg/m^3 increase in PM_{10} level. However, the coefficient for PM_{10} is found to statistically insignificant at 95% confidence level (t<1.96).The estimated relative risks and attributable fractions are found to be 1.4009 and 0.2862 for 20 μg/m^3 threshold PM_{10} level and 1.4437 and 0.3073 for 10 μg/m^3 threshold PM_{10} level respectively. The annual daily average PM_{10} being 132 μg/m^3 for 2003 / 2004. Temperature is found to be negatively associated with lung cancer admissions.

Table 30 Estimated coefficients for Lung Cancer morbidity

Variable type	Parameter	Estimated value	Standard Error	t value
	Intercept	3.2520	1.33303	2.44
Air pollution	PM10	0.00301	0.00296	1.02
Weather	Temperature	-0.28319	0.20973	-1.35
	Temperature^2	0.01022	0.00791	1.29
Seasonal	Sin ($2\pi t/12$)	-0.54573	0.70054	-0.78

Table 31 RR and AF for Lung cancer morbidity

Model	Percent increase	Baseline PM_{10} Concentration	RR above threshold limit	Attributable Fraction
5(a)	3.055758	20	1.400907	0.286177
5(b)	3.055758	10	1.443716	0.307343

5.3.2 Computation of EBD due to ambient air pollution

EBD attributable to ambient air pollution exposure with respect to PM_{10} has been calculated for 20 $\mu g/m^3$ and 10 $\mu g/m^3$ baseline PM_{10} level. Upper and lower limits of the attributable burden are computed from 95% confidence interval for β coefficient.

5.3.2.1 EBD for all cause mortality

The total premature deaths attributable to short term exposure to ambient air pollution regarding PM_{10} in Kathmandu Valley for 2004 is found to be 1179 and 1282 for baseline PM_{10} concentration taken as 20 $\mu g/m^3$ and 10 $\mu g/m^3$ respectively.

Table 32 EBD attributable to Ambient Air Pollution regarding PM_{10} for all cause mortality

Model	Baseline PM_{10} Concentration	AF	Total Burden	Attributable Burden
1(a)	20	0.072451	16966	1229
1(b)	10	0.078829	16966	1337

Total deaths or burden has been estimated by taking population of Kathmandu valley for 2004 as 18,40,111 and CDR as 9.22 per 1000 population.

In above EBD computation it was not practically suitable to compute the lower and upper limits for total premature deaths since the computed standard error for the PM coefficient were unexpectedly high and could be due to several reasons. However, the lower and upper limits may be obtained using the standard error computed elsewhere. In the present analysis, standard error has been extrapolated from "Recommended health outcomes and risk functions to calculate EBD, EBD series, No.5, WHO, 2004" which is equal to 0.000102

Table 33 EBD with 95% Confidence Interval attributable to Ambient Air Pollution regarding PM_{10} for all cause mortality

Model	Baseline PM_{10} Concentration	AF	Total Burden	Attributable Burden	Lower	Upper
1(a)	20	0.072451	16966	1229	883	1568
1(b)	10	0.078829	16966	1337	961	1705

5.3.2.2 EBD for respiratory mortality

The total premature respiratory deaths attributable to short term exposure to ambient air pollution regarding PM_{10} in Kathmandu Valley for 2003 / 2004 (fiscal year 2060/61) is found to be 75 and 81 for baseline PM_{10} concentration taken as 20 $\mu g/m^3$ and 10 $\mu g/m^3$ respectively.

Computation of lower and upper limits of the attributable burden of respiratory mortality has been avoided since the standard error of the PM_{10} is found to be unexpectedly high.

Table 34 EBD attributable to Ambient Air Pollution regarding PM_{10} for respiratory mortality

Model	Baseline PM_{10} Concentration	AF	Total Burden	Attributable Burden
2(a)	20	0.318214	236	75
2(b)	10	0.341137	236	81

5.3.2.3 EBD for respiratory morbidity

The total premature respiratory hospital admissions attributable to short term exposure to ambient air pollution regarding PM_{10} in Kathmandu Valley for 2003 / 2004 (fiscal year 2060/61) is found to be 520 and 562 for baseline PM_{10} concentration taken as 20 $\mu g/m^3$ and 10 $\mu g/m^3$ respectively. The corresponding lower and upper limits are 293 and 729 for baseline PM_{10} concentration taken as 20 $\mu g/m^3$ and 318 and 786 for baseline PM_{10} concentration taken as 10 $\mu g/m^3$.

Table 35 EBD attributable to Ambient Air Pollution regarding PM_{10} for respiratory morbidity

Model	Total Burden	Attributable	Lower	Upper

		Burden		
3(a)	3188	611	130	1017
3(b)	3188	660	141	1090

5.3.2.4 EBD for COPD morbidity

Total COPD hospital admissions attributable to short term exposure to ambient air pollution regarding PM_{10} in Kathmandu Valley for 2003 / 2004 (fiscal year 2060/61) is found to be 553 which is about 29.23 % of the total COPD hospital admissions for baseline PM_{10} concentration as 20 $\mu g/m^3$ and 593 (31.39% of total COPD admissions) for 10 $\mu g/m^3$. The 95% confidence interval are 405 and 686 for baseline PM_{10} concentration as 20 $\mu g/m^3$ and 436 and 733 for baseline PM_{10} concentration as 10 $\mu g/m^3$.

Table 36 EBD attributable to Ambient Air Pollution regarding PM_{10} for COPD morbidity

Model	Burden Type	Total Burden	Attributable Burden	Lower	Upper
4(a)	Admission	1890	565	236	828
4(a)	OPD Visits	14058	4201	1755	6161
4(a)	Total	15948	4766	1991	6990
4(b)	Admission	1890	606	255	882
4(b)	OPD Visits	14058	4509	1900	6558
4(b)	Total	15948	5115	2156	7439

5.3.2.5 EBD for Lung Cancer morbidity

Total Lung Cancer hospital admissions attributable to ambient air pollution exposure regarding PM_{10} in Kathmandu Valley for 2003 / 2004 (fiscal year 2060/61) is found to be 35 which is about 28.6 % of the total Lung cancer hospital admissions for baseline PM_{10} concentration as 20 $\mu g/m^3$ and 37 (30.7%) of total Lung cancer admissions) for baseline PM_{10} concentration as 10 $\mu g/m^3$.

Table 37 EBD attributable to Ambient Air Pollution regarding PM_{10} for Lung Cancer morbidity

Model	Total Burden	Attributable Burden
5(a)	122	35
5(b)	122	37

5.4 EBD due to bacterial contamination of water supplies

The assessment of EBD due to bacterial contamination of water supplies is presented in two sections. The first section contains computation of EBD due to bacterial contamination of water supplies for diarrhea, gastro-enteritis and enteric fever morbidity. The second section contains computation of EBD for diarrhea / cholera mortality.

5.4.1 EBD for Water Borne Disease Morbidity

In the present study, bacterial contamination in water is assessed by total coliform content of water supplies across Kathamndu Valley for water borne disease morbidity assessment. However, for exposure-response modeling, only bacterial contamination in tap water could be used since time series data on bacterial contamination of other supply sources such as well, tube well, spout etc. was unavailable for modeling. Nevertheless, it is to be noted that according to population census 2001, 82.7% of the total households in the valley use tap water as their source of drinking water. Altogether, 442 tap water values on total coliform content obtained from NWSC for the year 2003 / 2004 (2060 BS) is used for building exposure response models. Also, total coliform content data for water supplies from other sources like well, deep well and spout water are utilized for EBD calculations even though not used during exposure-response modeling. 228 such data were used of which 90 was from spout water, 86 from well water and 52 from deep well water. The data is taken from monitoring of ground water quality in Kathamndu Valley, ENPHO, 1999. Similarly, data on health effects such as hospital admissions on dysentery, cholera, diarrhea and gastro-enteritis and enteric fever was obtained from various leading hospitals in Kathmandu Valley on monthly and daily basis for the year 2003 / 2004.

The relationship between response and exposure was modeled using monthly data on the selected health effects and exposure to bacterial contamination of tap water supply through the application of Poisson Model. Exposure data on total coliform contents was categorized to 4 distinct categories with respect the level of total coliform contamination. Grade scores was used for numerical representation of grade of water sample with respect to total coliform content for statistical modeling. Exposure-response models have been developed for the following health effects related to morbidity.

- Diarrhea morbidity including cholera, dysentery and gastro-enteritis
- Gastro-enteritis morbidity
- Enteric fever morbidity

Computation of the impact fraction attributable to bacterial contamination of water supplies within Kathmandu Valley is based upon categorization of the population with respect to bacterial contamination by sources. Altogether, 5 exposure scenarios were created namely tap water with home treatment, tap water with no home treatment, Well water, tube well water / deep well water and spout / other source generated water. It is interesting to note that according to a recent survey by CBS, about 70% of the Kathmandu inhabitants treat tap water by boiling, filtering etc. for the purpose of drinking. Home treated tap water is assumed of having no risk for water borne diseases in EBD calculations.

Total burden is represented in terms of total hospital admissions, hospital OPD visits and the sum of the two.

Table 38 Grading and attributing scores to water quality

Grade	Total Coliform (MPN / 100 ml)	Grade label	Attributed Score for modeling
A	0	No risk	1
B	1-10	Low risk	2
C	11-100	Intermediate risk	3
D	101-1000	High risk	4

Monthly data on average exposure and total selected hospital admissions is shown below.

Table 39 Monthly data on average tap water grade score regarding total coliform content and hospital admissions for various water borne diseases

Month	Average monthly score	Gastro-intestinal	Enteric fever	Diarrheoal
1	2.38	268	101	279
2	3.32	329	116	347
3	3.02	372	126	390
4	2.89	429	167	436
5	2.45	350	131	373
6	2.77	249	99	258
7	2.79	87	96	89
8	2.34	47	46	51
9	2.14	41	24	43
10	2.22	54	26	62
11	1.75	88	27	95
12	1.96	197	48	209

Table 40 Average grade score of water quality regarding total coliform content by source

Source	Sample Size	Average Score
Spout	90	3.82
Well	86	3.84
Deep well	52	2.25

Source: Monitoring of ground water quality in the Kathmandy Valley, Nepal, ENPHO, 1999

Figure 16

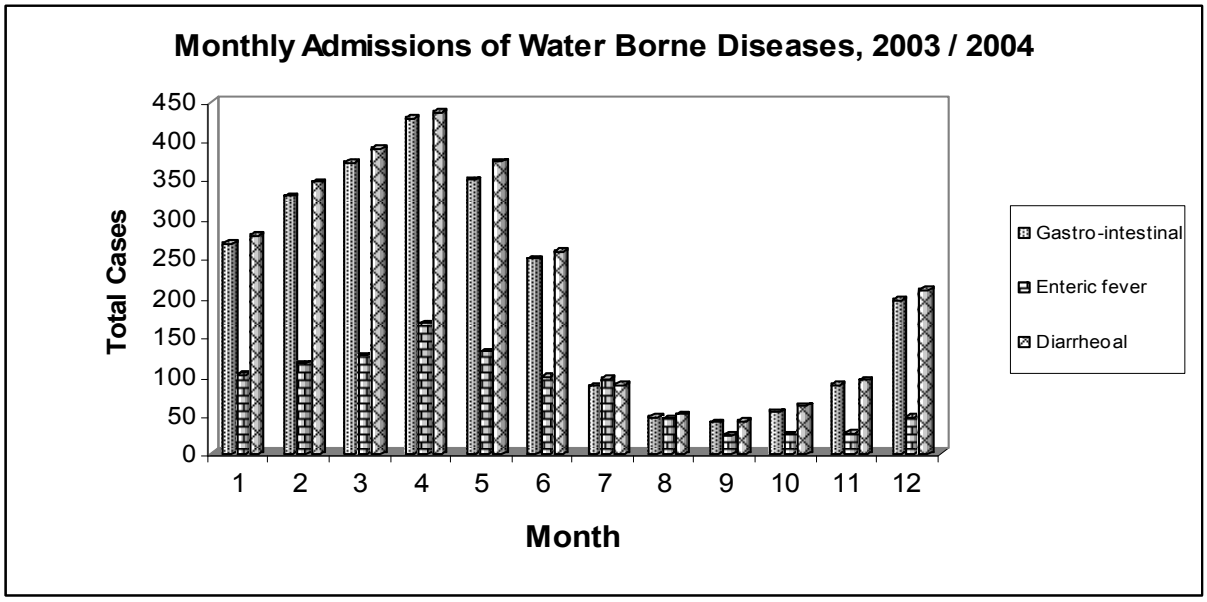
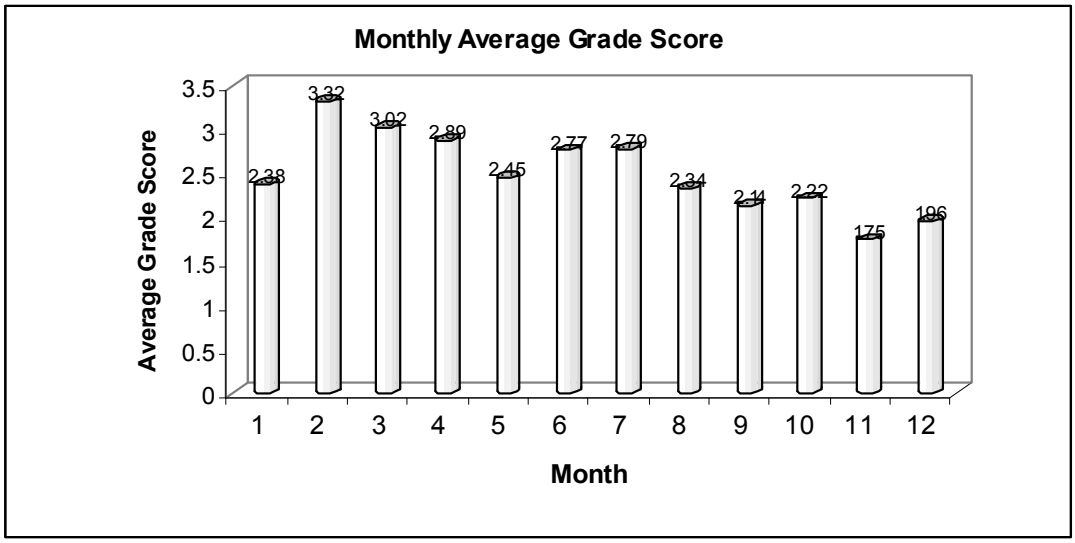


Figure 17



5.4.1.1 Exposure-response modeling and EBD for diarrheoal disease morbidity

The Poison model with diarrheoal admission counts as the response variable and grade score of the total coliform as the explanatory variable shows that the variables are positively correlated with one another with 4.6823 relative risk associated with average tap water exposure to total coliform count (2.71 average grade score) as compared to zero coliform exposure. The coefficient for coliform grade score is found to be statistically significant at 95% confidence level (t>1.96).Relative risk is assumed to be associated linearly with the grade score of total coliform content with 2.4665 times increase in the relative risk of

diarrheioal morbidity as the score increases by unity. The corresponding attributable fraction associated with the average grade exposure to tap water is found to be 0.7864.

With 2632 total hospitalization cases (2003/2004) for diarrheoal diseases in the selected hospitals, the EBD attributable to bacterial contamination of water supplies is found to be 1876 with lower and upper limits (95% confidence interval) found to be 1742 and 1995 respectively. The central, lower and upper estimated impact fractions are 0.7127, 0.6618 and 0.7578 which means that approximately 71.3 % of the diarrheoal morbidity can be attributed to bacterial contamination of water supplies with lower and upper limits 66.2% and 75.8% respectively.

The total burden of diarrheoal morbidity including hospital admissions and outpatients attributable to the bacterial contamination of water supplies in Kathmandu valley for the fiscal year 2060 / 61 (2003/2004) is estimated as 27,120 with 95% confidence interval as 25,164 – 28,837.

Table 41 Estimated coefficients for Diarrheoal Disease morbidity

Model	Parameter	Estimated value	Lower	Upper	Standard Error
1	Intercept	3.0504271	-	-	0.120792
	Coliform	0.9028059	0.815641995	0.989969805	0.044471

Table 42 RR and AF for diarrhea morbidity

Model	Score of Total Coliform	RR above zero total coli form	Attributable Fraction
1	2	2.466514	0.594569
	3	6.083692	0.835626
	4	15.005513	0.933358
	Average tap water Score	4.682340	0.786432

Figure 18

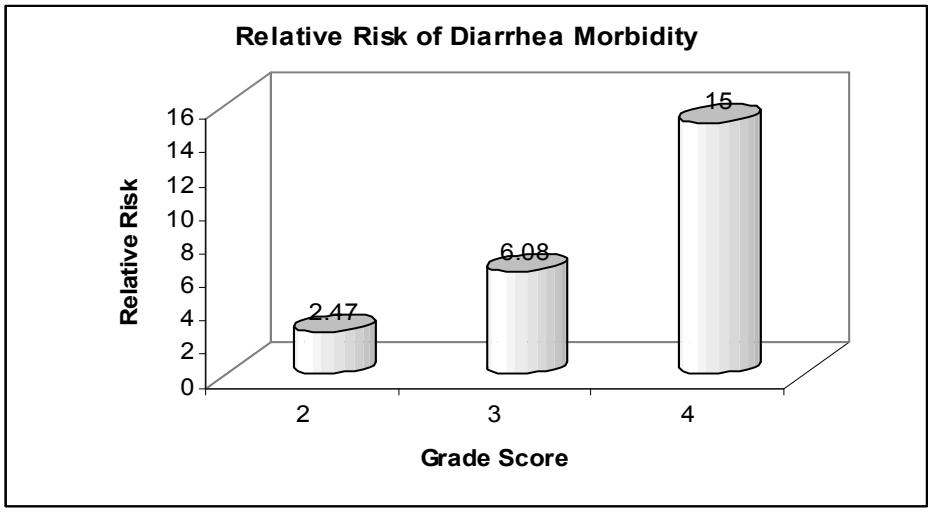


Table 43 Proportion exposed and Relative Risk by source of water supply

Source / type	Proportion Exposed	Average Score	RR Central	RR Lower	RR Upper
Tap, treated	0.5790	1.00	1.0000	1.0000	1.0000
Tap, untreated	0.2482	2.71	4.6823	4.0340	5.4349
Well	0.0761	3.84	12.9873	10.1393	16.6351
Tube well / Deep well	0.0499	2.25	3.0910	2.7720	3.4469
Spout / others	0.0468	3.82	12.7549	9.9753	16.3090

Table44 Attributable burden for Diarrhea morbidity due to bacterial contamination of water supplies in Kathmandu Valley

Model	Type of Burden	Total Burden	Attributable Burden	Lower	Upper
1	Hospital admission	2632	1876	1742	1995
1	Hospital OPD visits	35421	25244	23442	26842
1	Total	38053	27120	25184	28837

5.4.1.2 Exposure-response modeling and EBD for Gastro-enteritis morbidity

The Poison model with gastro-enteritis admission counts as the response variable and grade score of the total coliform as the explanatory variable shows that the variables are positively correlated with one another with 4.8476 relative risk associated with average population exposure to tap water coliform (2.71 average grade score) as compared to zero coliform exposure. The coefficient for coliform grade score is found to be statistically significant at 95% confidence level ($t>1.96$). Relative risk is assumed to be associated linearly with the grade score of total coliform content with 2.5171 times increase in the relative risk of Gastro-enteritis morbidity as the score increases by unity. The corresponding attributable fraction associated with the relative risk is found to be 0.7937.

With 2511 total hospitalization cases (2003/2004) for gastro-enteritis in the selected hospitals, the EBD attributable to bacterial contamination of water supplies is found to be 1817 with lower and upper limits (95% confidence interval) found to be 1690 and 1930 respectively. The central, lower and upper estimated impact fractions are 0.7237, 0.6729 and 0.7685 which means that 72.4 % of the gastro-enteritis morbidity can be attributed to bacterial contamination of water supplies with lower and upper limits 67.3% and 76.8% respectively.

Table 45 Estimated Coefficients for gastro-enteritis morbidity

Model	Parameter	Estimated value	Lower	Upper	Standard Error
2	Intercept	2.9489337	-	-	0.123977
	Coliform	0.9230962	0.833757577	1.012434823	0.045581

Table 46 RR and AF for gastro-enteritis morbidity

Model	Score of Total Coliform	RR above zero total coli form	Attributable Fraction
2	2	2.517071695	0.602713
	3	6.335649917	0.842163
	4	15.94728507	0.937293
	Average Score	4.847652	0.793715

Figure 19

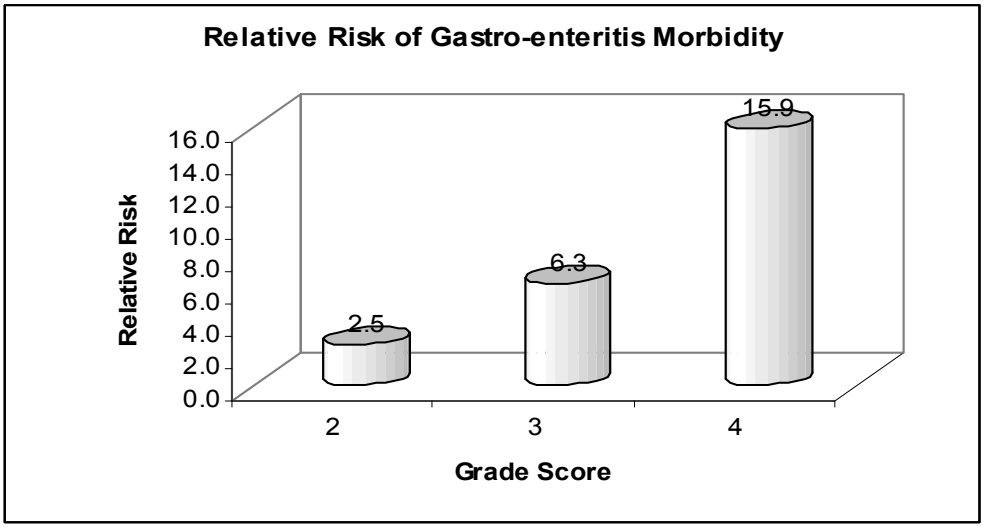


Table 47 Proportion exposed and relative risk by source of water supply

Source / type	Proportion Exposed	Average Score	RR Central	RR Lower	RR Upper
Tap, treated	0.5790	1.00	1.0000	1.0000	1.0000
Tap, untreated	0.2482	2.71	4.8477	4.1609	5.6478
Well	0.0761	3.84	13.7576	10.6746	17.7310
Tube well / Deep well	0.0499	2.25	3.1704	2.8354	3.5450
Spout / others	0.0468	3.82	13.5060	10.4981	17.3756

Table 48 Attributable burden for gastro-enteritis due to bacterial contamination of water supplies in Kathmandu Valley

Model	Total Burden	Attributable Burden	Lower	Upper
2	2511	1817	1690	1930

5.4.1.3 Exposure-response modeling and EBD for enteric fever morbidity

Similarly, the Poison model with enteric fever admission counts as the response variable and grade score of the total coliform as the explanatory variable shows that the variables are also positively correlated with one another with 5.14888 relative risk associated with average

population exposure to tap water coliform (2.71 average grade score) as compared to zero coliform exposure. The coefficient for coliform grade score is found to be statistically significant at 95% confidence level (t>1.96). Relative risk of enteric fever morbidity increases by 2.6074 as the score increases by unity. The corresponding attributable fraction associated with the relative risk is found to be 0.8058

With 1007 total hospitalization cases (2003/2004) for enteric fever in the selected hospitals, the EBD attributable to bacterial contamination of water supplies is found to be 747 with lower and upper limits (95% confidence interval) found to be 667 and 812 respectively. The central, lower and upper estimated impact fractions are 0.7421, 0.6626 and 0.8067 which means that 74.2 % of the enteric fever hospitalizations can be attributed to bacterial contamination of water supplies with lower and upper limits 66.3% and 80.7% respectively.

The total burden of enteric fever morbidity including hospital admissions and outpatients attributable to the bacterial contamination of water supplies in Kathmandu valley for the fiscal year 2060 / 61 (2003/2004) is estimated as 4,889 with 95% confidence interval as 4,365 – 5,314.

Table 49 Estimated coefficients for enteric fever morbidity

Model	Parameter	Estimated value	Lower	Upper	Standard Error
3	Intercept	1.9404899	-	-	0.196661
	Coliform	0.9583424	0.816968502	1.099716298	0.07213

Table 50 RR and AF for enteric fever morbidity

Model	Score of Total Coliform	RR above zero total coli form	Attributable Fraction
3	2	2.607371	0.616472
	3	6.798383	0.852906
	4	17.72591	0.943585
	Average Score	5.148809	0.80578

Figure 20

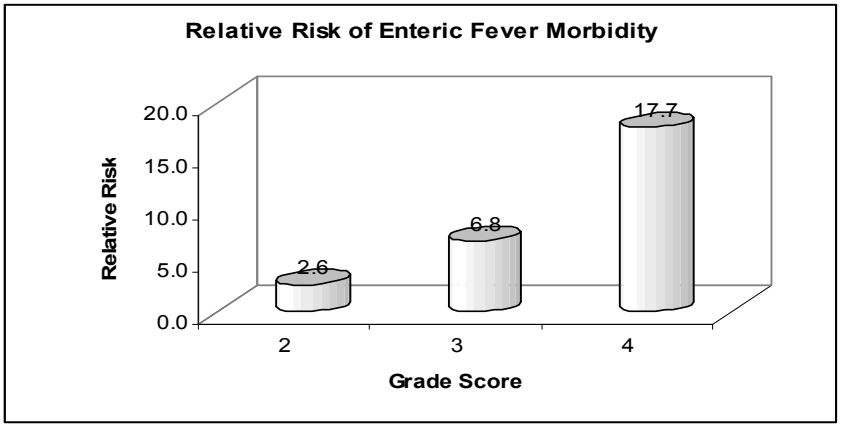


Table 51 Proportion exposed and relative risk by source of water supply

Source / type	Proportion Exposed	Average Score	RR Central	RR Lower	RR Upper
Tap, treated	0.5790	1.00	1.0000	1.0000	1.0000
Tap, untreated	0.2482	2.71	5.1488	4.0431	6.5569
Well	0.0761	3.84	15.2060	10.1776	22.7188
Tube well / Deep well	0.0499	2.25	3.3132	2.7766	3.9537
Spout / others	0.0468	3.82	14.9174	10.0127	22.2246

Table 52 Attributable burden for enteric fever due to bacterial contamination of water supplies in Kathmandu Valley

Model	Burden Type	Total Burden	Attributable Burden	Lower	Upper
3	Hospital admission	1007	747	667	812
3	Hospital OPD visits	5581	4142	3698	4502
3	Total	6588	4889	4365	5314

5.4.2 EBD due to bacterial contamination of water supplies for water borne disease mortality

In this section, the computation of EBD due to bacterial contamination of water supplies is accomplished with the help of exposure as well as health effect data obtained from population census, 2001 in which a 10 % sample of households was selected separately for collecting information on various variables including disease specific mortality since 12 months prior to the survey, household characteristics such as source of water supplies and sanitation situation beside other variables not included in the census itself. Exposure scenarios with respect to water supplies and sanitation situation were categorized according to the nature of water supplies of the sampled households such as tap water, tube well water, river water etc. and the nature of household sanitation situation such as availability or non availability of toilet facilities. Relative risks of the exposed group of scenarios were computed as compared to relatively unexposed group of population such as deep well water users having toilet facility. Consequently, the exposure-response modeling with computation of relative risks and impact fraction is scenario based approach.

EBD is computed for Diarrheoal and Enteric fever deaths. Further, EBD is calculated for children with age less than 5 years in the case of Diarrheoal deaths since large proportion of deaths due to diarrhea occur in Nepal especially in children. The impact fraction developed from data obtained from Nepal has been used here for the computation of EBD for Kathmandu valley since development of exposure-response model from data obtained from Kathmandu valley could not be used as the values were very low.

EBD has been computed separately for the following:

- EBD for Diarrheoal deaths due to unsafe water supply

- EBD for Diarrheoal deaths due to unsafe water supply for age less than 5
- EBD for Enteric Fever deaths due to unsafe water supply

- EBD for Diarrheoal deaths due to unsafe water supply and sanitation
- EBD for Enteric Fever deaths due to unsafe water supply and sanitation

Not reported cases are excluded from analysis if present.

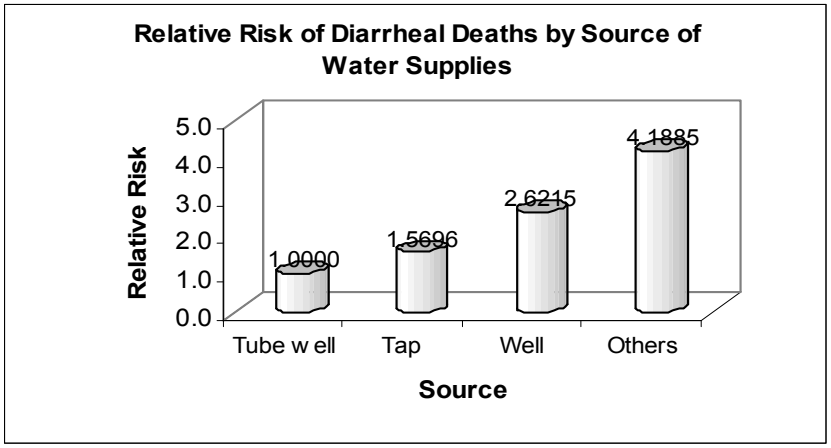
5.4.2.1 Exposure-response modeling and EBD for diarrheoal deaths due to unsafe water supply

Water supply source is divided in to different exposure scenarios namely tube well, tap, well and spout / river / stream / others. The level of bacterial contamination in these exposure scenarios has been found distinctly different from one another from water bacteriological analyses done so far in Nepal. As expected, the relative risks of diarrheoal deaths is also found to be different with respect to the difference in the source of water supplies as compared to tube well water source which is considered as having the least risk in terms of bacterial contamination. The highest relative risk is found for spout and other source users (4.19) followed by well (2.62) and tap (1.57). The computed impact fraction is found to be 0.4192 which means that around 42% of the total diarrheoal deaths can be attributed to unsafe drinking water supplies.

Table 53 Proportion exposed and relative risk by water supply source for Diarrheoal deaths

Water Supply Source	Total Diarrheoal Deaths	Exposed Population	Proportion of Exposed Population	Relative Risk
Tap	306	1394491	0.8346	1.5696
Well	89	242848	0.0768	2.6215
Tube well	100	715310	0.0504	1.0000
Spout/River/Stream/Others	141	240799	0.0382	4.1885
Total	636	2593447	1.0000	

Figure 21



The total number of diarrheoal deaths for all age group in Kathmandu valley from the leading hospital records for 2060 is only 3. Therefore, the number of diarrheoal deaths that can be attributed to unsafe water supply is only 1.

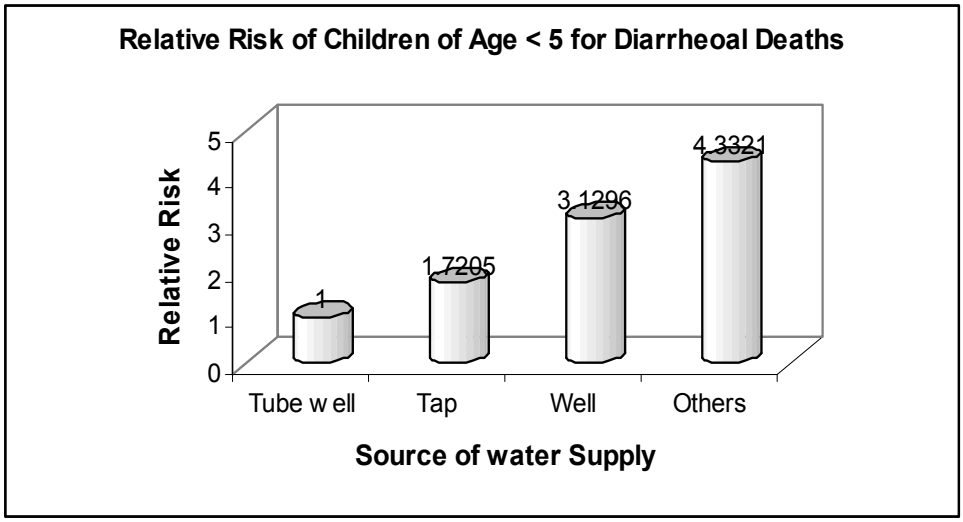
5.4.2.2 Exposure-response model and EBD for Diarrheoal deaths due to unsafe water supply (Age < 5)

Here, EBD is calculated for children of age less than 5. As compared to the whole age group, the relative risks are higher for all exposed scenarios with highest relative risk found for spout and other source users (4.33) followed by well (3.13) and tap (1.72) with impact fraction equal to 0.4715 which is again higher than found for the whole age group (0.4192). This indicates children are more vulnerable to the unsafe water supply than the adults.

Table 54 Proportion exposed and relative risk by water supply source for Diarrheoal deaths

Water Supply Source	Proportion of Population	Total Diarrheoal Deaths	Relative Risk
Tap	0.8346	161	1.7205
Well	0.0768	51	3.1296
Tube well	0.0504	48	1.0000
Spout/River/Stream/Others	0.0382	70	4.3321
Total	1.0000	330	

Figure 22



The under 5 year diahhreoal mortality for Nepal in 2060/61 is 194. Therefore, the total number of diarrheoal deaths attributed to unsafe water supply and sanitation is 91 for Nepal as a whole. However, the total number of reported under 5 diarrheoal deaths in Kathmandu

valley in the fiscal year 2060/61 is only 1. As a result, there is no point in estimating the number of deaths attributed to unsafe water.

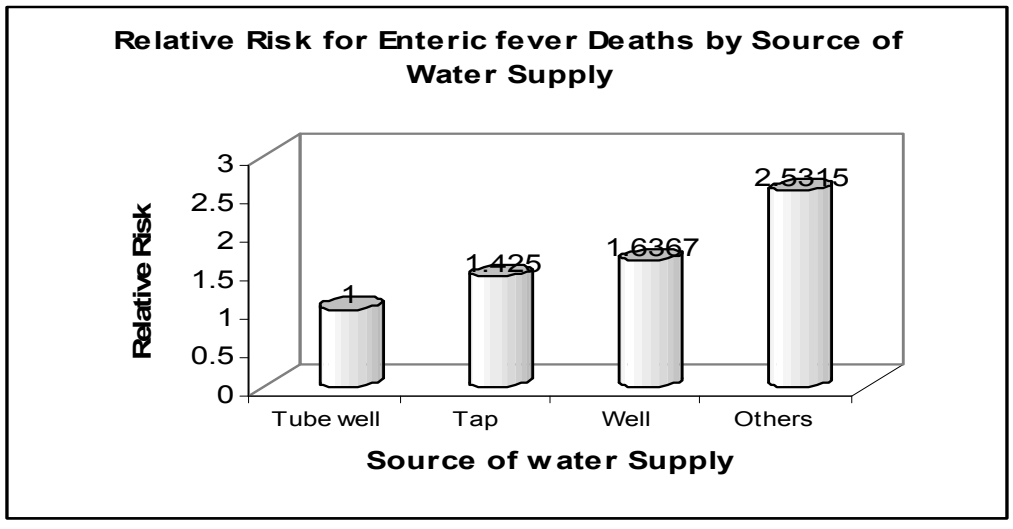
5.4.2.3 EBD for Enteric Fever deaths due to unsafe water supply

Relative risks computed for different exposure scenarios regarding Enteric fever deaths show that the values range between 1.42 to 2.53 with lowest found for tap water users and highest found for spout / river and other users as compared to tube well users. The risks are relatively lower than found for Diarrheoal deaths. The value of impact fraction is found to be 0.3161 which is again smaller than the corresponding value for Diarrheoal deaths (0.4192) which imply that the attributable fraction of Enteric fever deaths due to unsafe source of drinking water is less than found for diarrheoal deaths.

Table 55 Proportion exposed and relative risk by water supply source for Enteric fever deaths

Water Supply Source	Total Enteric fever Deaths	Total Population	Proportion of Population	Relative Risk
Tap	75	1394491	0.8346	1.4250
Well	15	242848	0.0768	1.6367
Tube well	27	715310	0.0504	1.0000
Spout/River/Spring/Others	23	240799	0.0382	2.5315
	140	2593447	1	

Figure 23



The total number of Enteric fever deaths in 2060 for Kathmandu valley from hospital records is 4. If we estimate the total deaths using the inpatient incidence rate for Nepal in 2060/61 (1.5092 per 1000,000 population), the value turns out to be 3 which is less than 4. Thus, taking total Enteric fever deaths as 4 for the year 2060, the number of deaths attributable to unsafe drinking water is only 1.

5.4.2.4 EBD for Diarrheoal deaths due to unsafe water supply and sanitation

EBD studies conducted by WHO have considered environmental risk factors for Diarrheoal diseases taken as unsafe water supply, sanitation and hygiene. Exposure scenarios were categorized taking account of the risk factors water supply, sanitation and hygiene together. In the present EBD calculation, if we consider unsafe water and sanitation as the risk factor adding sanitation situation to unsafe water supply, the following picture emerges. Exposure scenarios were divided in to 6 distinct categories as

Scenario 1	corresponds to	Tube Well with Toilet Facility
Scenario 2	corresponds to	Tube Well without Toilet Facility
Scenario 3	corresponds to	Tap water with Toilet Facility
Scenario 4	corresponds to	Tap water without Toilet Facility
Scenario 5	corresponds to	Well/Spout/River/Spring/others with Toilet Facility
Scenario 6	corresponds to	Well/Spout/River/Spring/others without Toilet Facility

Relative risks are computed for scenarios from 2 to 6 compared to scenario 1 assuming that the scenario has the least exposure in terms of unsafe water and sanitation. Scenario 6 posed the highest threat with RR = 15.53 followed by scenario 4 with RR = 9.71, scenario 5 with RR = 5.26, scenario 2 with RR = 5.13 and scenario 3 with RR = 3.03. The estimated impact fraction is found to be 0.8457 which means that 84.6% of the diarrheoal deaths can be attributed to unsafe water and sanitation.

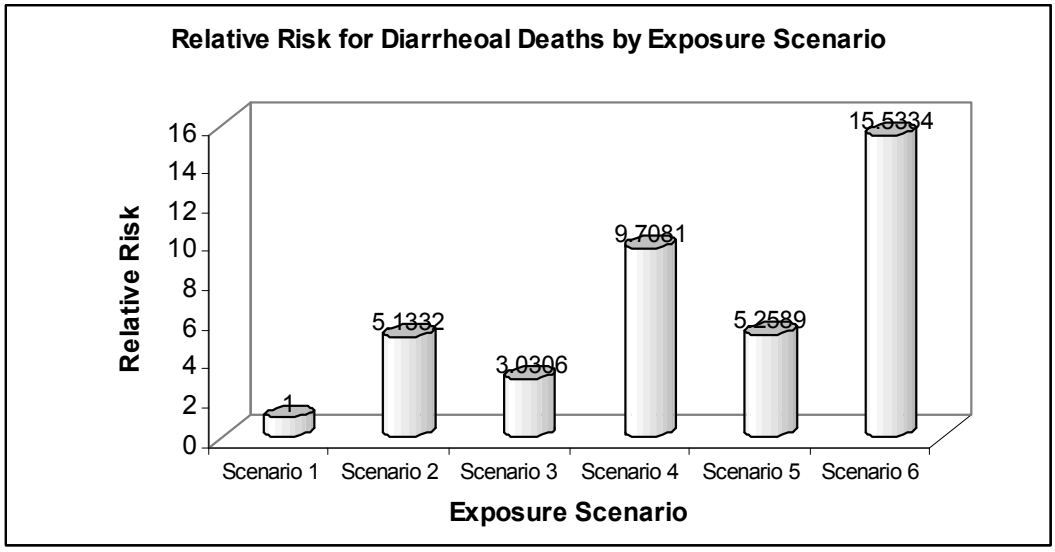
Table 56 Total Reported Diarrheoal Deaths by type of water supply source and sanitation facility

	Flush	ordinary	Toilet	No toilet	Not rep	Total
tap	22	70	92	211	3	306
well	0	9	9	79	1	89
tube well	3	6	9	91	0	100
spout	1	15	16	86	2	104
river	0	3	3	32	1	36
others	0	0	0	1	0	1
not reported	0	0	0	1	1	2
	26	103	129	501	8	638

Table 57 Exposure Scenarios and corresponding Relative risks for Diarrheoal deaths

Exposure Scenario	Scenario No.	Proportion exposed	Total Diarrheoal Deaths	Relative Risk
Tube Well with Toilet Facility	1	0.0170	10	1.0000
Tube Well without Toilet Facility	2	0.0334	91	5.1332
Tap water with Toilet Facility	3	0.4864	96	3.0306
Tap water without Toilet Facility	4	0.3482	226	9.7081
Others with Toilet Facility	5	0.0339	31	5.2589
Others without Toilet Facility	6	0.0811	210	15.5334
Total		1.0000	664	

Figure 24



The total number of diarrheoal deaths for all age group in Kathmandu valley from the leading hospital records for 2060 is only 3. Therefore, the number of diarrheoal deaths that can be attributed to unsafe water supply and sanitation is again 3.

5.4.2.5 EBD for Enteric Fever deaths due to unsafe water supply and sanitation

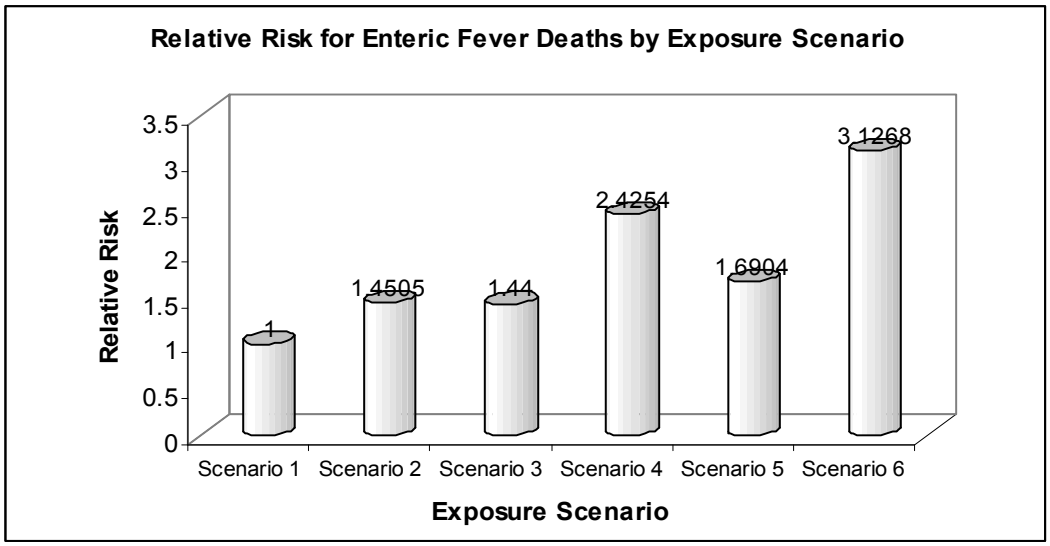
EBD for Enteric fever due to unsafe water and sanitation is also computed by dividing exposure scenario to 6 categories identical to above. Relative risks are computed for scenarios from 2 to 6 compared to scenario 1 assuming that the scenario has the least exposure in terms of unsafe water and sanitation. Scenario 6 posed the highest threat with RR

= 3.13 followed by scenario 4 with RR = 2.42, scenario 5 with RR = 1.69, scenario 2 with RR = 1.45 and scenario 3 with RR = 1.44. The estimated impact fraction is found to be 0.4795 which means that 47.95% of the Enteric fever deaths can be attributed to unsafe water and sanitation. This impact fraction is substantially lower than the impact fraction estimated for diarrheoal deaths which is 0.8459.

Table 58 Proportion exposed and relative risk by water supply source for Enteric fever mortality

Exposure Scenario	Proportion exposed	Total enteric fever Deaths	Relative Risk
Tube Well with Toilet Facility	0.0170	7	1
Tube Well without Toilet Facility	0.0334	20	1.4505
Tap water with Toilet Facility	0.4864	34	1.44
Tap water without Toilet Facility	0.3482	41	2.4254
Others with Toilet Facility	0.0339	7	1.6904
Others without Toilet Facility	0.0811	31	3.1268
Total	1.0000	140	

Figure 25



Taking the total number of Enteric fever deaths for 2060 as equal to 4, the number of deaths attributable to unsafe water supply and sanitation is 2.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Data compiled from various secondary sources on environmental health data based upon health effects and exposure were useful and productive in developing exposure-response models which statistically link the responses on health effects to environmental exposures. The computation and assessment of Environmental Burden of Disease greatly depends upon the formulation of these models. In the present EBD study, the models have shown positive associations between exposures and health effects with respect to mortalities as well as morbidities. The central question in an EBD assessment is what fraction of the health effects under investigation can be attributed to the given environmental risk factors. The answer to this particular question reveals the amount of disease burden in a population that can be attributed to the given risk factors. The two risk factors under consideration are ambient air pollution and bacterial contamination of water supplies in Kathmandu valley. The health effects under consideration for the risk factor, ambient air pollution are all cause mortality, respiratory mortality, respiratory morbidity, COPD morbidity and Lung cancer morbidity. Similarly, the health effects for the risk factor, bacterial contamination of water supplies are Diarrhea mortality, Enteric fever mortality, Diarrhea morbidity, Gastro-enteritis morbidity and Enteric fever morbidity.

The concluding remarks on general findings, exposure-response modeling, EBD assessment and recommendations are presented in separate sections below.

6.1.1 Conclusion on general findings

The findings are based upon data collected for the year 2003 and 2004.

- COPD hospital admissions were relatively high during winter months (November – March) and low during other months. Similar pattern of high and low values were also detected across the months for ambient PM_{10} levels indicative of strong relationship between COPD admissions and ambient PM_{10} levels in Kathmandu Valley.

- Reported hospital admission cases on Pneumonia did not show significantly similar pattern with ambient PM_{10} levels as in the case of COPD admissions. Admissions were found to be high in the month of October, relatively low in the months of April, July and August all falling warm months and moderately high in the rest of the months. The pattern is an indication of some other factors influencing Pneumonia hospitalization other than particulate pollution such as seasonal changes.

- If we include COPD, Asthma, Bronchitis and Pneumonia in the same category as respiratory, then comparing the pattern of monthly admission variations with PM_{10} levels, it was found that there exists a moderate resemblance between the two.

- Diarrheoal disease hospitalizations inclusive of Cholera, Dysentery and Gastro-enteritis were found to be high in warm and rainy season (Chaitra – Aswin) and relatively much low in cold

months (Kartik – Falgun). The pattern of monthly admission variation is closely associated with the level of bacterial tap water contamination in Kathmandu Valley suggesting a strong association between diarhheoal disease hospital admission and bacterial contamination of tap water supplies in the valley. Frequency table of tap water quality in Kathamndu Valley shows high percentage of D grade water quality in warm and rainy season (Jestha – Kartik), moderately high in Chaitra and Baiskak and relatively low in the rest of the months.

- Similar pattern of Enteric fever hospitalization pattern was also seen across the months with lowest hospitalization figure in Poush (24) and highest in Shrawan (167). This also suggests that Enteric fever hospitalization could be closely linked with bacterial contamination in tap water supply within the valley.

- Considering age and gender specific information on hospitalization data, it was found that:

    - Among COPD admissions, an overwhelming 87.3% were aged 50 or above.

    - Among pneumonia inpatients, almost half were aged below 50.

    - Among diarrheoal inpatients, 20% were aged below 20.

    - Among enteric fever inpatients, almost 90% were below 50.

    - The gender difference among hospital inpatients were not significantly different for both air pollution related health effects as ell as water borne disease related health effects

    - Only two hospitals provided information on place of residence of the hospital inpatients. The record showed that more than 80% of the hospital inpatients were valley residents. This implies that the health effect assessments made in the study with respect to exposure to ambient air pollution in Kathmandu Valley can be said to be representative of the valley resident inpatients.

Above figures suggest that hospital admissions were evenly distributed regarding gender difference, COPD admissions are mostly aged persons, pneumonia patients are evenly distributed above and below 50 years of age, high percentage of diarrheoal patients are adults and only small percent of enteric fever patients are old aged.

6.1.2 Conclusion on health effects and EBD due to ambient air pollution

Positive associations were detected for a range of health effects and ambient air pollution assessed by ambient PM_{10} concentrations as a result of exposure-response modeling. For short term health effects based upon mortalities as well as morbidities, there was a certain amount of rise in health effects for 10 $\mu g/m^3$ rise in PM_{10} level in the ambient air. About 0.7% increase in all cause mortality was observed, about 2% was observed for respiratory admissions and 3 to 3.5% was observed for respiratory mortality, COPD admissions and Lung cancer admissions. The coefficients for PM_{10} are found to be statistically significant for respiratory morbidity and COPD morbidity and insignificant for others at 95% confidence level

Considering 10 μg/m^3 as the threshold PM_{10} limit below which adverse health effects do not occur, 7.88% of all cause mortality, 34.11% of respiratory mortality, 20.69% of respiratory morbidity, 32.07% of COPD morbidity and 30.73% of Lung cancer morbidity can be attributed to ambient air pollution regarding PM_{10}.

Information on total burden prevailing in the study population (Kathmandu Valley) is lacking. As a result, crude death rate is assumed to be same as that of Nepal as a whole. Assuming this, the total number of deaths in Kathmandu Valley that can be attributed to short term exposure to PM_{10} is estimated to be 1337 for the year 2004 with 95% confidence interval of 961 and 1705.

The population disease specific mortality rates and morbidity rates are also unavailable. Therefore, there was no choice but to utilize the total burden of diseases that was available from the 5 leading hospitals from where data was compiled. This will most probably underestimate the disease burdens that can be attributed to the risk factor. However, using the available information, among 236 respiratory deaths 81 cases, among 3188 respiratory hospital admissions 660 (95% CI is 141 – 1090) cases, among 15948 COPD hospital admissions and OPD visits 5115 cases (95% CI is 2156 – 7439) and among 122 Lung cancer hospital admissions 73 cases can be attributed to ambient air pollution regarding PM_{10}.

It is important to note that only several main diseases were considered in the category of respiratory. They are COPD, Bronchitis, Asthma and Pneumonia. However, these four diseases accounted for 64.4 % of the total respiratory admissions for the year 2060 / 2061 according to DoHS annual report.

6.1.3 Conclusion on health effects and EBD due to bacterial contamination of water supplies

The development of exposure-response models for the assessment of EBD on morbidities due to bacterial contamination is based upon the tap water data on total coliform contents. However, data on total coliform contents from other sources of water supplies was also used for EBD calculations. Exposure based models were used for the calculation of EBD on morbidities on various health outcomes such as Diarrhea, Gastro-enteritis and Enteric fever where as scenario based models were used for calculation of EBD on disease specific mortalities such as Diarrhea and Enteric fever.

The exposure-response models showed positive associations between health effects and exposure to bacterial contamination of water supplies with 4.68, 4.85 and 5.15 relative risks associated with average grade score of tap water exposure to total coliform for diahhreoal disease hospitalization, Gastro-enteritis hospitalizations and Enteric fever hospitalizations respectively. The corresponding impact fractions are estimated to be 0.7127, 0.7236 and 0.7421 which means that more than 70% of the disease morbidities can be attributed to bacterial contamination of water supplies assessed by total coliform content in Kathamndu Valley. Data on E. Coli could not be used because sufficient data was not available for the indicator. The coefficients for coliform grade score are found to be statistically significant at 95% confidence level ($t>1.96$) for all the morbidities considered for modeling. The estimated disease burdens are found to be 27120 cases including hospital admissions and OPD visits out of 38053 cases in the year 2060 /61 for Diarrhea morbidity. The corresponding values for gastro-enteritis and Enteric fever morbidity are found to be 1817 hospitalization cases out of

2511 and 4889 hospitalization and OPD visits out of 6588 cases for the same year of reference.

The assessment of EBD on disease specific mortalities was done by using the data available from 10% sample survey in 2001 census in which data on household characteristics such as access of water supplies and sanitation and deaths due to diarrhea / cholera was taken. Estimated results show that 84.6% of the total diarrheoal deaths can be attributed to unsafe water supply and sanitation. Similarly, 47.95% of the total enteric fever deaths can be attributed to unsafe water supply and sanitation.

6.2 Recommendations

The conduction of the present EBD study lacked information on several aspects. In this view, several recommendations are made for the conduction such researches in the future.

- First of all, more conclusive results on issues of national importance such as environmental burden of diseases require not just one but several studies that link between health effects and environmental exposures so that stable and efficient coefficients are obtained. It is therefore, recommended to conduct such studies in the future as well.
- Information on total disease burdens through estimates of population prevalence rates are lacking in the present study. It is therefore, highly recommended to conduct studies that will find the population burden of diseases prevalent in the population under study.
- The present study could not consider DALY as the unified health indicator of the population health condition due to unavailability of necessary data especially for the computation of YLD. Studies that address this issue are also recommended.
- The present study has used PM_{10} as the parameter of air pollution exposure. It is also desirable to use $PM_{2.5}$ as the air pollution parameter for EBD studies. Daily air quality monitoring should also include this parameter in daily basis through out the year which is lacking currently. Also, time series and cross-sectional data base on E Coli. are lacking. This parameter is also essential in water quality testing for bacteriological contamination. Inclusion E. Coli. along with total coliform content is needed during water quality monitoring in large scale so that the values can represent actual population exposure to bacteriological contamination in drinking water.

The extent of health effects from exposure to ambient particulate air pollution and water pollution are found to be substantial in Kathmandu Valley. The results therefore obviously raise health concerns to all valley inhabitants from these risk factors. The attributable disease burdens are found to be high for all the health effects taken into consideration in the present EBD study. Even though efforts have been made in the direction of reducing the particulate level and bacteriological contamination of water supplies in Kathmandu Valley, the valley's urban air and drinking water are still polluted. Therefore, this is a matter of serious concern to all of us and further steps will be required to reduce these contaminations in the valley.

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