Final Report

Situation Analysis of Indoor Air Pollution and Development of Guidelines for Indoor Air Quality Assessment and House Building for Health

Submitted To:

Nepal Health Research Council

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Kathmandu

Nepal

July 2004

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Acknowledgement

This report on "Situation Analysis of Indoor Air Pollution and Development of Guidelines for Indoor Air Quality Assessment and House Building for Health" has been prepared by incorporating all aspects relevant to the study as far as possible.

The study itself is part of ongoing NHRC programs in environmental issues and is conducted in collaboration and support from World Health Organization (WHO) / Nepal.

Indoor Air Pollution from biomass smoke is taken at low key in Nepal in spite of the consistent evidence that this constitutes a matter of serious public health concern particularly to rural women and children living under poverty.

The study is broad based and encompasses some seemingly intractable matters such as indoor air pollution exposure assessment, health response identification and their relationship development etc. In spite of these limitations, this report has come up; thus sincere thanks, deep appreciation and gratitude is expressed to all who directly or indirectly; in one way or other have contributed during the course of the study and in bringing up this document, chief among them are as follows:

Sincere thanks go to DR. Anil Kumar Mishra, Member Secretary, NHRC for his continuous support and encouragement provided to us during the study period and also to Mr. Chandra Shekhar Yadav, Chief of Environmental Health Unit, NHRC for facilitating the development of the document and at times giving valuable suggestions. Special thanks are due to WHO for providing support to this project and also to Mr. Shamsul Huda, WHO Environmental Health Advisor for his valuable comments and suggestions during the course of interaction programs.

The provision of field measuring equipments and laboratory facilities by Nepal Environmental and Scientific Studies (NESS) is gratefully acknowledged and special thanks to Dr. Toran Sharma for the support and encouragement given to this study.

Special thanks also go to Mr. Takao Ishida, Sappora, Japan for facilitating support to this study.

Sincere thanks are also due to the project team members particularly to Mr. sanil babu Khatri, Mr. Salil Devkota, Dr. Sunil Kumar Joshi and Mr. Srijan lal shrestha for their respective part of contributions.

A note on the inclusion of additional study members

Keeping in view of the nature of activities required for achieving the objectives of the study, it was thought essential to include an Occupational Health Specialist and a Bio-Statistician in the study team, who were not there initially. In fact, participation by the two specialists has enhanced the study output considerably both in terms of field health checks turn-out / health impact assessment because of the presence of Dr. Sunil Kumar Joshi in the field party; and increased quality of data input and data management due to the presence of Mr. Srijan Lal Shrestha, whose contribution to this project work is regarded as a part of his ongoing Ph. D research.

Dr. Iswori Lal Shrestha
Project Team Leader
July 2004

Abbreviation

ALRI	Acute Lower Respiratory Infection
ARI	Acute Respiratory Infection
BMRC	British medical research Council
CB	Chronic Bronchitis
CO	Carbon Mono Oxide
COPD	Chronic Obstructive Pulmonary Disease
CPM	Count Per Minute
CRA	Comparative Risk Assessment
DALYs	Daily Adjusted Life Years
DANIDA	Danish International Development Agency
ENT	Ear Nose Throat
FEV	Forced Expiration Volume
FVC	Forced Vital Count
GS	Gas Chromatography
HCHO	Formaldehyde
HHs	Households
HVS	High Volume Air Sampler
IAP	Indoor Air Pollution
LD	Laser Dust
LPG	Liquid petroleum Gas
LVS	Low Volume Air Sampler
mg / m^3	Milligram per Cubic Meter
NESS	Nepal Environmental and Scientific Services
ng / m^3	Nano gram per Cubic Meter
NHRC	Nepal Health Research Council
NO_2	Nitrogen Dioxide
PAHs	Poly Aromatic Hydrocarbons
PEM	Personal Exposure Monitor
PEFR	Peak Expiratory Flow Rate
PM_{10}	Particulate Matter of size less than 10 Micron
$PM_{2.5}$	Particulate Matter of size less than 2.5 Micron
SO_2	Sulfur Dioxide
TOR	Terms of Reference
TSP	Total Suspended Particles
URI	Upper Respiratory Infection
$\mu g / m^3$	Microgram per Cubic Meter
VDC	Village development Committee
VOCs	Volatile Organic Compounds
WHO	World Health Organization

Executive Summary

Background

Indoor air pollution in developing world from bio-mass smoke is considered to be a significant source of public health hazard, particularly to the poor and vulnerable women and children. About 50 % of the world's population is estimated to use solid bio-fuels like animal dung, crop residues, wood and coal for cooking daily meals and heating homes and exposure from bio-mass smoke is estimated to cause a global death toll of 2.5 million every year equivalent to 4 to 5 % of total global deaths. In fact, the emerging data from recent studies indicate that risk-wise, it ranks only below malnutrition and poor quality of water/sanitation.

In Nepal, epidemiological studies as such is lacking at the moment. However, census 2001 report shows that 80 % of households depend upon solid bio-fuels for domestic uses. The total death from pneumonia alone is reported to be 4429 during the last 12 months preceding 2001 census (4.14 % of the total deaths). Similarly, the total deaths from asthma / bronchitis are reported to be 7170 (6.71%). According to Nepal Demography and Health survey, 2001, the prevalence of ARI for children below 5 years old is found to be 23 %. The below 5 years population is 12.1 % of the total population.

Study Components / Activities

This study is basically a field-oriented epidemiological study program linked with direct measurement and observational works, and is meant to provide the required baseline data to the policy / decision makers on the state of kitchen smoke pollution and the possible serious health outcomes to the exposed population, which could be substantial in terms of DALYs (Disability Adjusted Life Years) and other losses, and that there is a range of intervention methods available that could be implemented selectively and cost-effectively with local participatory approach.

<u>The main components of the study are</u>:

1. Baseline data survey on household characteristics, domestic energy uses, kitchen ventilation, types of stoves used for cooking, user behaviors etc.

2. Indoor air pollution (smoke/PM_{10}, CO, other gaseous emissions) monitoring particularly during cooking hours at kitchens using solid bio-fuels (dung, crop residues, wood) or cleaner fuels (SKO, LPG, Bio-Gas).

3. Exposure assessment of respondents (women and children below 5 yrs old) who are exposed to bio-mass smoke during cooking time and calculation of daily integrated exposure indices.

4. Health response assessment which includes medical examination of respondents; data acquisition on health effects through questionnaires / interviews; computation of Comparative Risk Assessment (CRA), disease prevalence etc.

5. Recommended measures to reduce bio-mass smoke / exposure through appropriate interventions, ventilation improvements, awareness raising etc.

Activities carried out included the following:

- Area and Household Coverage / Respondent Size: The hill area is limited to Kathmandu valley districts and terai area is limited to Chitwan and Nawalparasi districts. The surveyed and studied household size is altogether 98, 58 from hills and 40 from terai inclusive of both rural and urban areas.

- The respondent size, mainly women who cook, is 168 in number, who went through medical examination and questionnaire interviews.

- Smoke / PM10 as well as CO were measured in each kitchen during cooking time. Other gaseous emissions (SO_2, NO_2, HCHO) were measured in kitchens during cooking time on campaign basis only. Measurements of PM_{10}, gaseous concentrations were carried out in indoor and outdoor ambient air as and when necessary.

- On the basis of data / information obtained from above, indoor and outdoor air pollutions were estimated; smoke / PM_{10} exposures experienced by the respondents under various environmental settings were calculated; and the health outcomes assessed using various statistical tools. The basis for comparative risk assessment with respect to various diseases / symptoms is the binary fuel uses in the studied kitchens, namely, solid bio-fuel users and the users of cleaner fuels like gas and kerosene.

Key Findings

Smoke / PM_{10} Pollution

- The smoke pollution is found to be the highest in kitchens having traditional clay stoves and using solid bio-fuels (dung, crop residue and wood) while cooking where the mean PM_{10} concentration level is found to be 2418 $\mu g/m^3$ (average of 62 readings).

- Under similar ventilation and other household conditions, the mean smoke / PM_{10} concentration level in kitchens using cleaner fuels (kerosene, LPG, biogas) is found to be 792 $\mu g/m^3$ (26 readings) which is about 3 times low.

- Under above conditions, the daily integrated PM_{10} exposure index level is estimated to be 15.58 mg-hr/m^3 for those exposed to solid bio-fuel smoke and 10.15 mg-hr/m^3 for those exposed to cleaner fuels.

- While comparing smoke / PM_{10} pollution by eco-regions for solid bio-fuel users, the hill kitchens seem to be more polluted (Mean PM_{10}, 2545 $\mu g/m^3$) as compared to kitchens from plains (Mean PM_{10}, 2186 $\mu g/m^3$). Similarly, area-wise also, rural kitchens are more polluted (Mean PM_{10}, 2427 $\mu g/m^3$) compared to urban kitchens (2124 $\mu g/m^3$). The observed differences in kitchen pollution can be attributed to differences in ventilation conditions. But for those using cleaner fuels, the pollution levels do not seem to vary much region-wise or area-wise.

- As has been observed in other countries, solid bio-fuels are the main sources of indoor air pollution for both hills and plains and also rural and urban homes of Nepal.

Health Responses

- The health responses recorded for all the respondents (168) exposed to various levels of air pollution in indoor kitchen during cooking time seem to corroborate fully with the state of exposure conditions to which each group of individuals is subjected. This means that those who are exposed to solid bio-fuels smoke show higher prevalence of respiratory abnormalities as compared to clean fuel users. For instance, prevalence of COPD and LRI among unprocessed fuel users was found to be 16.8% compared to only 7% for those using processed fuels (table 31).

- Similarly, much higher prevalence in all respiratory symptoms (2.5 to 4 times) has been found for unprocessed fuel users. For instance, 24.8% of the respondents using unprocessed fuels reported having breathlessness and wheezing and 14.4% reported having all respiratory symptoms. The corresponding figures for processed fuels were 7% and 4.7% respectively.

- Relative risk estimates in terms of Odds Ratios have also been computed in order to compare health outcomes (respiratory diseases and symptoms) associated with unprocessed fuel users as compared to processed fuel users. Statistically significant Odds Ratio (3.85) with 95% confidence interval, 1.11 – 13.84 was detected for Chronic respiratory Diseases (COPD and Asthma jointly).

- Similarly, statistically significant Odds Ratios with 95% confidence level were found for respiratory symptoms, namely Cough (3.71), Phlegm (3.08), Breathlessness (3.71) and Wheezing (5.39). The 95% confidence intervals were 1.46 – 9.46, 1.02 – 9.32, 1.36 – 10.13, and 1.57 – 18.55 respectively.

- Considering smoking as a potential confounder, Odds ratios have been computed separately for Non-smokers and Smokers. The values show that Non-smokers have relatively higher odds ratio than smokers (5.21 for non-smokers and 1.52 for smokers) regarding COPD/Asthma taken jointly. Similarly, higher odds ratios were computed for non-smokers regarding all respiratory symptoms when compared to smokers.

- Similarly, considering age as another confounder, Odds ratios have been computed separately for two different age groups. The values show that for individuals aged below 40, the odds ratio is higher as compared to those aged 40 or above (3.04 for aged below 40 and 2.19 for aged 40 or above) regarding COPD/Asthma jointly. However, mixed results were obtained regarding different respiratory symptoms.

Conclusion

Indoor Air Pollution in Nepalese houses is real. The principal pollutant, smoke particulate originates from freshly combusted biomass. The ensuing smoke exposure conditions are unacceptable by any human standards and therefore, severe health effect attributable to indoor kitchen air seems indisputable.

A wide range of interventions are available to reduce IAP, for instance, Changes in Energy Technology, such as, switching from bio-mass fuels to cleaner fuels like SKO / Cooking gas, Improving the design and construction of locally made traditional stoves by the use of chimney, fume hoods etc., and Changes in the living environment such as, improving the state of kitchen ventilation and raising awareness among the local people about the seriousness of the kitchen air pollution and building up participatory approach in the efforts made to reduce indoor air pollution.

Recommendations

- Concrete evidence through more researches is to be established between IAP and its impact on health inclusive of diseases other than respiratory illnesses.
- Quantification of public health burden from IAP, particularly from biomass smoke.
- Identification of most smoke pollution affected areas / population size and prioritization of intervention measures required for implementation in those places.
- Identification of policy changes at local / national levels needed for successful / sustainable implementation of desired intervention measures.

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1. Introduction

This report "on Situation Analysis of Indoor Air Pollution and Development of Guidelines for Air Quality Monitoring and House Building for Health" has been prepared as per the contract agreement and TOR provided by Nepal Health Research Council (NHRC) to the Team Leader of this Project.

This project work is a part of the ongoing NHRC programs on Environmental and Health issues. The main objective of this study is to assist Government planners and policy makers in the formulation of national policy and programs of intervention so as to reduce the indoor air pollution (kitchen), particularly from the use of unprocessed solid bio-fuels in the rural homes of Nepal.

Since the study involves direct quantitative measurement of air pollution such as PM_{10}, CO, and other gaseous emissions along with on the spot health checks of the exposed house members, the results and the findings of the study is expected to provide the required baseline data on the state of indoor air pollution and possible serious health outcomes to the exposed population, mainly the poor and vulnerable women and children of rural Nepal.

The study results also may provide added impetus of importance to the decision makers to the fact that the overall public health impact from the indoor air pollution could be substantial, in terms of DALYs (Disability Adjusted Life Years) and other losses, and that there is a range of intervention methods available which could be implemented selectively and cost-effectively with local participatory approach, such as, provision of alternate energy sources for cooking, improvement in the traditional stoves, improvement in housing design, attitude / userś behaviors changes in the public etc.

2. 0 Indoor Air Pollution in Developing Countries

2. 1 Review of Literature

2.1.1 General

A brief review of studies carried out in recent years indicates that the state of air pollution in rural / urban households of developing countries is considered to be one of the worst in the world posing a significant public health hazard risk to a large number of country populations, particularly to the poor and vulnerable women / young children. This is particularly so, when bio-mass fuels like wood, animal dung, crop residues and coal are burnt in traditional un-vented stoves for cooking daily meals and heating homes in cold climates.

It is known that the heat efficiency of three stone type fires, similar to Ageno Chulos kept in rural hill households of Nepal is only 10 to 15 % (Ref. 2) which means that most heat is wasted in the form of un-burnt smoke. The bio-mass smoke is reported to contain a large number of harmful pollutants at varying concentration levels, chief among them are: particulate matter of ≤10 µm (PM_{10}) aerodynamic size, carbon monoxide (CO), Sulfur Dioxide (SO_2), Oxides of Nitrogen (NOx), Formaldehyde (HCHO) and Poly Cyclic Aromatic Hydrocarbons (PAHs). The concentration levels, for example, of PM_{10} may exceed the internationally accepted values by factors of 10, 20 and more depending on the types of fuel / cooking stoves used, state of ventilation etc. A typical 24-hr.mean value of PM_{10} from the use of bio-fuels in different settings is reported to lie in the range from 300 to 3000+ $\mu g/m^3$ (Annex 3, Table A). Thus in terms of exposure and associated health risk, those who stay in front of the fire for even a short period of time say an hour per meal for years and years together, the housewives and women of rural and urban poor families become potential targets for serious health outcomes in the long run. Studies carried out elsewhere also mentions that there is consistent evidence that smoke exposure increases the risk of common and serious diseases for children and adults such as Acute Lower Respiratory Illness (ALRI) in childhood (pneumonia); Chronic Bronchitis (CB); and Chronic Obstructive Pulmonary diseases (COPD); etc.

When we come to the global data, about 50% of the world population, bulk of which lives in the developing world, is estimated to use solid bio-fuels for daily essential foods or heating homes and indoor smoke exposure is estimated to cause a global death toll of 2.5 million people every year equivalent to 4 to 5% of the total global deaths (Ref. 1). The fraction of global energy attributable to solid bio-fuel use has fallen down from 50% in 1900 to 13% now, but this trend is reported to have leveled off and there is evidence that such fuel use is increasing among poorer nations (Ref. 2).

In India, studies carried out in early 1990 estimate that 95% of the national population relies on the use of wood, dung, coal and crop residues for cooking daily meals and calculates that countrywide, 480 million people were at health risk from indoor air pollution and ARI alone accounts for 11% of national burden of diseases. (Ref 20)

In Nepal, epidemiological studies as such is lacking at the moment. However, 2001 census report shows that 80% of the households use animal dung and wood as solid fuels for cooking purposes. The total death from pneumonia alone is reported to be 4429 during the last 12 months preceding 2001 census (4.15 % of the total deaths). Similarly, the total death from Asthma / Bronchitis is reported to be 7170 (6.71 %). According to Nepal Demographic and Health Survey, 2001, the prevalence of ARI for children below 5 years, is found to be 23 % (Ref. 5). The below 5 years population is 12.1 % of the total national population.

2.1.2 Solid Bio-mass Smoke/Gaseous Emissions and its Health Effects

In most air pollution studies, bio-mass smoke is measured as respirable particles of size 10≤ micron. In outdoor ambient condition, such PM_{10} may constitute more of wind blown fugitive dusts of larger particle sizes which are considered much less hazardous to health compared to smaller size smoke particles originating from combustion sources. Thus, particle composition and size distribution within PM_{10} may play major roles in exposure estimation and health impact assessment.

But, as discussed in earlier pages, the kitchen air in rural homes during cooking time is most often filled with thick smoke emitted by freshly combusted wood or crop residues and the limited studies available carried out elsewhere suggest that such PM_{10} is associated largely with various types of toxic organic compounds, although, exact data as such could not be obtained from published literatures.

However, recently, some 24 hr PM_{10} samples collected from six permanent ambient air quality monitoring stations operating now located at different areas of Kathmandu Valley have been analyzed for PAHs (18 organic compounds) by the use of GC Mass Spectrometry. Results indicate that at some stations, in the winter month (November, 2003), PAH (Benzo(a)pyrene) value lies at around 5 ng/m^3 and the total PAHs value at 40 to 60 ng/m^3 range [1]. It is to be noted that PAH (Benzo(a)pyrene is listed as having carcinogenic health endpoint and the recommended guideline value is 1 to 10 ng/m^3, the health endpoint being lung cancer in exposed humans, (Ref. 23). The guideline value for total PAHs is not available.

Judging from the above ambient outdoor data, PAHs values associated with PM_{10} in the working kitchen air where solid bio-fuels are burnt for cooking daily meals, is expected to be considerably at the higher side because of their strong tendency to remain adsorbed in smoke particles posing a high risk status to the exposed kitchen inmates.

Now, when we talk about the high risk syndrome, it may be worthwhile to be aware of the areas of the uncertainties before the pollutants actually hit the victims in terms of health outcomes or the endpoints.

Monitoring results on pollutant concentrations and on the spot examining the health status of the exposed subjects may not be adequate in defining the health outcomes, they can, at best only indicate the risk of potential health effects.

The health effect in fact is defined by the dose to human lungs from the exposure and, subsequently the dose delivered to different target organs or the biological systems within the body, along with the toxicity of the pollutant or its metabolites. There is again the uncertainty factor of individual

[1] From ESPS/MOPE unpublished data

susceptibility because different people exposed similarly may receive different doses of the same pollutant and thus may produce dissimilar health effects.

Again in the case of the cooking inmates of the rural households, some pollutants for instance, CO causes mainly acute health effects and here, a brief high level exposure becomes more important than cumulative ones. Whereas, health effects from PM_{10} for instance, are considered to cause from cumulative exposure due to brief high level peaks plus continuous low level exposure on long term basis.

2.1.3 Some Data / Information from Past Studies

A brief review of literature indicates that although pollutant emissions are dominated by out-door sources resulting in to numerous epidemiological studies related to ambient air pollutant concentrations and corresponding health outcomes, similar studies on indoor air pollution and its effects on health of the exposed people are few and far between. In fact, there seems to be a complete lack of consistent results in indoor air quality monitoring as well as health response studies.

The problem is aggravated because of inconsistencies in the measurement methods used, differing averaging time adopted as well as due to spatial and temporal variations of pollutant concentrations usually encountered inside the household during cooking time using solid bio-fuels.

Table-A, Annex 3 summarizes results of indoor particle concentrations including CO values during cooking time obtained for a number of developing countries using solid bio-fuels for cooking purposes, from 1978 to 1999. Although between studies, the measurement condition (e.g. of averaging time, number of determinations (n); locations, time of measurement) etc. differ widely, the particulate matter concentrations of indoor air recorded in most cases, ranges from 300 to 10000 $\mu g/m^3$. In Nepal, (1986), the reported PM_{10} concentration, average of 17 determinations, is 4400 $\mu g/m^3$ (Ref 4).

Similarly, summary of exposure-response results on Chronic Bronchitis / COPD etc. from bio-mass smoke exposure for several developing counties including Nepal is attached (Annex 3, Table-B, Table-C and Table-D).

All above study results leads to the fact that exposure to traditional bio-mass smoke in indoor conditions is a significant health hazard risk to a large number of rural population of developing world. However, as said before, they also suffer from methodological limitations as described elsewhere in this report (e.g. lack of systematic measurement of pollution /exposure levels etc.).

In spite of all limitations, one common approach of all studies has been to characterize the local problems and quantify the health effects of indoor air pollution.

2.2 Some Key Elements that Need to be Addressed

Studies conducted by professionals elsewhere reveal that broadly, the following key elements are to be addressed comprehensively so that IAP and associated problems can be dealt with properly.

2.2.1 Equipments/Devices for Measuring Concentration Levels of Air Pollutants

Currently, various types of equipment/devices are used for air quality monitoring. The choice of equipment depends upon study type, its objectives that are to be realized and other specifics related to a particular study such as, the environmental settings in which the monitoring is carried out (indoor, outdoor, ambient, non-ambient), averaging time (in minutes, hours, days) etc. so that the results could be compared with international standards

Some commonly used equipment; tools, devices, and methodology involved are as follows:

Personal Exposure Monitoring (PEM), a direct method

This is a direct measurement method of personal exposure of an individual whereby the subject of the study carries with him/her a set of PEM through the study period usually 12 or 24 hr. The PEM could be a filter paper-based mass measurement of a particle size fraction either PM_{10} or $PM_{2.5}$ integrated over the exposure period at air flow rate of 2 to 4 liters per min. In this way, the total exposure of an individual while passing through various micro-environments can be determined directly (time-activity pattern).

Indirect Method

The indirect approach involves acquisition of data/information through questionnaire survey and interviews with individuals / sections of population (daily time-activity basis) with known time spent in each micro-environment and the known pollutant concentration levels in those micro-environments. The total daily exposure of an individual can then be estimated as the product of pollutant concentration in question and the time spent in each micro-environment during the course of the day.

Available literature indicates that for exposure calculation, most researchers relied on types of fuel or stove used, state of ventilation etc. as the indicators of pollution and not by directly measuring the pollutant concentrations in indoor air.

Measurement Tools (Active samplers)

Samplers used for the direct measurement of indoor / outdoor air pollution include standard equipment like: High Volume air Sampler (HVS) and Low Volume air Sampler (LVS) for measuring air particulates of various sizes (TSP, PM_{10}, and $PM_{2.5}$ etc.). These samplers draw specified amounts of air e.g. 500 liters/min. by HVS and 30 liters /min by LVS during operation.

The design of PM_{10} sampling head for example of HVS containing an impactor is such that at the stated flow rate, particles larger than the aerodynamic size of 10 µm are pre-separated and only particle size of $\leq_{10}$ µm are let in and deposited in a special glass fiber filter paper, which is then quantitatively weighed in a sensitive balance. Knowing the total volume of air drawn through the sampler, PM_{10} concentration in $\mu g/m^3$ of is calculated.

Passive/Diffusive Samplers

These are easier and cheaper to use and can be kept in ambient / non-ambient environments in out-door and indoor conditions at places of choices for days/weeks/months as required. At the end of the study period, the exposed cartridges are removed and brought to the laboratory for air pollutant concentration assessment by chemical / instrumental methods.
The diffusive samplers could be used for selective individual gaseous pollutants like: SO_2, NOx, Benzene, Toluene etc.

Manual Gas Analyzers with detector tubes

These analyzers are used for spot measurements of gaseous pollutant concentrations in air. Standard disposable detector tubes are available for hundreds of gaseous pollutants including SO_2, NOx, CO, formaldehyde etc. In such analyses, specific volumes of air are drawn usually by hand pumps at specified rates of intake, and time needed for exposures vary from 3 to 15 min. The pollutant concentration of interest usually in ppm is immediately displayed in the tube by color changes in ppm.

Equipment Using Physical Parameters (light scattering and remote sensing)

Laser Dust Monitor is one such equipment and is used to determine relative dust concentration (PM_{10}) in ambient and indoor air. The principle behind this is light scattering (the incident light is laser beam) by PM_{10} particles contained in the air chamber.

It has two step operations for zero and sensitive adjustments meant to minimize the personal errors. Both adjustments are carried out by capping the sampling inlet, setting a built-in reference light scattering board at the prescribed position, and adjusting the trimmer potentiometer to the board's value. The air sampling inlet is then uncapped and the monitor is run for the required time, usually 10 minutes, automatically set for the purpose. During the exposure, the scattered light is continuously channeled in to a digital converter and at the end of 10 minutes total counts corresponding to the PM_{10} content is displayed in the counter.

Such monitor is applicable for measuring spatial and temporal PM_{10} variations in air in a particular environmental setting with ease and accuracy. But the monitor has to be standardized in each environment setting, which is carried out by running the monitor as well as HVS simultaneously side by side at the specified height, specified distance from the fire and exactly for the same exposure time (e.g. 10 min.). Once it is standardized, air pollution assessment could be carried out rapidly in similar settings.

All devices/equipment described above are meant for specific purposes under specific environments. However, none of the above seems to satisfy sufficiently the indoor air quality assessment requirements as demanded, say by this study. In fact, researchers in other countries too feel the need of a cost-effective, reliable and easier to use under field conditions types of equipment/devices which can deliver results of needed accuracy so that exposure estimation could be performed with more confidence.

2.2.2 Exposure Assessment

The next logical step is the exposure calculation relative to a particular pollutant experienced by an individual representing a section of population or sub population. Here, the population exposure is defined as the simple combination of the concentration of the pollutants in air being inhaled, the duration of time over which it is inhaled, and the number of people exposed.

The validity of exposure quantification process seems to be still a matter of debate because of the uncertainty associated with concentration levels measured in each micro-environment at the breathing zone of the subject involved. It can at best be a matter of approximation.

Moreover, attempts to quantify exposure in a valid way are more problematic because of a probable association with confounding factors and the most study methodology do not address the problem directly but through surrogates. Thus, the development of practical and valid methods for measuring exposure levels seems to be still awaited.

2.2.3 Health Outcomes from Exposure

Epidemiological studies in developing countries have linked exposure to indoor air pollution from different fuel uses with at least four major categories of diseases. They are:

- Acute Respiratory Infection (ARI), most commonly in children, for instance, Pneumonia
- Chronic Obstructive Pulmonary Disease (COPD), Chronic Bronchitis (CB) and Asthma
- Lung Cancer
- Child Birth Problem

Although there seems to be growing evidence that at least, first two of the above categories of disease are due to the bio-mass smoke exposure, very little systematic work with quantitative expressions has been carried out in Nepal in this respect.

3.0 About the Present Study

In view of what has been said above, this study seems to have been conceived and launched in a right way and in the right time, because basically it is a field-oriented epidemiological study program linked with direct measurement and observational works. There are of course, some severe limitations which may be inherent in this kind of study which is so broad-based and highly demanding (c/o TOR), but unusual, if it demands specific scientific and technical output at grass-root level at the same time.
Anyway, the message has been noted and limitations have been circumvented as far as possible which is evident from the methodology adopted.

4.0 Study Objectives

The main objectives of the study are as follows:

- Assessment of Indoor Air Quality situation in Hills and Terai Households of Nepal where particularly solid bio-fuels (wood, crop residues, dung) are used for cooking daily meals
- Assessment of pollutant exposure conditions (ventilation, stove types etc) at kitchen and other places.
- Assessment of health effects situation to the inmates of the studied households from smoke exposure, particularly, women and children below 5 years of age.
- Development of guidelines / suggestions to minimize indoor smoke levels, thereby minimizing exposure risks

5.0 Scope of the Study

The study scope includes the following activities:

- Development of study design e.g. area coverage, sampling schemes, fixing number of households required to be visited in hills and terai regions, selection of pollutants for measurement etc.
- Development of survey questionnaires for recording household characteristics such as: ventilation, types of fuels and cooking stoves used etc.; individual responses from inmates of households regarding their occupation, time spent in different microenvironments; health effects such as ARI, CB, COPD and Asthma: development of Indoor Air Quality Monitoring Data Sheet for recording pollutant concentrations; Health Effect Examination and Assessment Form to be filled by a Medical Officer.
- Selection of equipment/devices for quantitative measurement of indoor air pollution/parameters of pollution.

6.0 Approach Methodology

As discussed in the previous sections, this study is basically regarded as epidemiological one and focuses mainly on:

- Monitoring/measuring of PM_{10} and CO concentration levels at kitchens of each household during cooking time. Other gaseous pollutants are to be measured on campaign basis.
- Assessing exposure experienced by cooking inmates of the surveyed households and children of below 5 years based on survey results, like: indoor/outdoor air pollution levels, time spent at kitchen, and other places of activities (indoor and outdoor).
- Assessing health effects, if any, by direct interviews and on the spot health checks etc. During health checks, emphasis is made on commonly experienced diseases from bio-mass smoke exposures e.g. ARI, CB, COPD.
- Taking recourse to fuel-based approach, meaning exposure to indoor air pollution from solid bio-fuel smoke as a binary variable, i.e. those using un-processed bio-fuels (wood, crop residues, dung) or those using processed fossil fuels: kerosene, LPG or Bio-gas for comparative exposure estimates.
- Applying relative risk assessment approach by the use of standard statistical means from binary variable results.

Since epidemiological studies as such i.e. focusing on above stated points, may not be widely applied to cover population exposure (because of being resource intensive) as demanded by TOR provided for this project with limited resource, the survey works has been limited to a few areas typical of rural hills and terai regions of Nepal.

7.0 Methodology Adopted

The main components of the study and the methodology adopted to carry out tasks under each component are as follows:

7.1 Tasks Completed Prior to the Field Visits

7.1.1 Development of Survey Questionnaires (Annex-1)

Three different types of questionnaire have been prepared for the field survey. They are described below:

FORM I HOUSEHOLD

The form includes household characteristics including general information, Kitchen ventilation, Fuel Type, Stove Type, Fuel Consumption etc.

FORM II INDIVIDUAL

The form is divided in to four groups.

FORM III POLLUTANT MONITORING

The form includes data sheet for measurements on various pollutant concentration levels.
(Note: 1. Information on Group B, C, and D is filled by medical Doctor. 2. Sample copies of questionnaire are given in Annex-1)

Table 1 Grouping Individual Questionnaire

Group	Contents
Group A	Includes general information such as Marital Status, Literacy, Occupation, Time-Activity Pattern, Smoking Habit etc.
Group B	Systematic Examination Sheet which includes chest, ENT examinations, Peak Flow Meter Reading etc.
Group C	Respiratory Symptom Questionnaire (British Medical Research Council Questionnaire) which includes questions on Cough, Phlegm, Wheezing and Breathlessness.
Group D	Optional Attachment Sheet for ARI (Acute Respiratory Infection) Identification.

7.1.2 Selection of Equipment, Pollution Parameters, and Measurement Methods Used

Measurement of PM_{10} by Laser Dust Monitor LD-1 and High Volume Air Sampler HVS

PM_{10} is an important constituent in bio-mass smoke effecting health. Some standard equipment available for PM_{10} measurement has already been described in section 2.2.1 including LD-1 and HVS.

The nature of the present study requires that smoke in kitchen during cooking time be measured in the short time available with reasonable precision and convenience under field conditions and this was why LD-1 was chosen for smoke monitoring in the field, which is also much cheaper. HVS was needed to standardize LD-1 from time to time so that its output value i.e. counts per minute (CPM) could be converted in to mass concentration levels, $\mu g/m^3$ of air. Equipment Specification:

Laser Dust Monitor

Model: LD-1
Measuring Sensitivity: 1 count per minute (CPM) = 0.01 mg/m^3
Suction Flow Rate = 3.4 liter per minute
Accuracy = ‹ ± 10% by standard calibration latex particles
Manufacturer: Sibata CO, Japan.

High Volume Air Sampler

Model: HVS 500-5
Suction Flow Rate: 500 liter per minute
Manufacturer: Sibata. Japan

Measurement of gaseous emissions (CO, HCHO, SO_2 and NOx)

Again the study requires that gaseous emissions be measured quickly in the kitchen air and other places using low-cost, easy to use devices to get indicative values and that precise quantitative result of these gasses may not be warranted at this stage. So, the appropriate device for this, namely, GASTEC Sampling Pump using factory calibrated Disposable Gas Detectors was used.

Specification: GV-100; Type: Piston Operated; Manufacturer: GASTEC Corp., Japan.

Measurement of Respiratory Functions by Peak Flow Meter (Vitalograph)

Model: M 1253 Catalogue No.: 43.000

Range: Low (0 – 280) Manufacturer: Ennis, Ireland

Operating Procedure

The washed and dried mouth piece was inserted in to the Peak Flow Meter and the pointer was set at zero marked scale followed by holding it without squeezing with chin up position. The lips of the respondent was sealed around the mouth piece, air was breathed in as deeply as possible then out as hard and as fast as the respondent could. The maximum value at which the pointer stopped was recorded and the same process was repeated three times. The highest of the three readings was recorded the peak respiratory flow in liter per minute.

7.1.3 Preliminary Information on Households (HHs) of Study Area

The study area covers both rural and urban hills as well as rural and urban terai. But as stated in earlier section, since the study is directed toward achieving specific objectives and most database is generated from field works, it becomes imperative that area / cluster of households (by fuel type) be identified prior to the actual field visits. Moreover, indoor air pollution is to be measured in the kitchen during cooking time and the questionnaire survey requires interviews and health checks of HH inmates, for this reason too, a full co-operation / willingness from the stakeholder side is essential. Therefore, assistance was sought from potential related organizations / local people who can assist in identifying the types of HHs needed for sample selection. Whenever required or possible, preliminary field visits by team members were organized to identify HHs in advance keeping in mind the cross-sectional representation of the area HHs. For this, preliminary HHs identification data entry form was used (Annex 2).

Prior to each field visit, all team members were consulted and acquainted with field schedule and the nature of field works so that the study could be accomplished in a coordinated way and in time. All field equipment and devices were tested and the methods of measurement, locations of measurement etc were briefed.

7.2 Sampling Design, Area Coverage and Household Sample Size

7.2.1 Sampling Design

Multistage (Two Stage) Random Sampling has been adopted for field survey. Kathmandu Valley Districts and other districts have been selected prior to the survey purposively. From Kathmandu valley districts and the other selected districts in the Terai region, VDCs were selected randomly during the first stage of selection (except for one VDC in Nawalparasi District which has been taken in a nearby and peripheral VDC from adjoining Chiwan district for reasons of convenience). The two municipalities from Chitwan have been included and 2 municipalities from Kathmandu valley districts were selected randomly. From each of the selected VDCs and the municipalities the households were chosen randomly at the second stage of selection from the pre-identified clusters of households during the field visits with randomization restriction by coverage of household fuel types as illustrated below.

The household coverage by fuel types (Excluding Not Stated Households) according to 2001 census is as follows

Wood	Cow Dung	Bio Gas	Kerosene	LPG	Others
66.17 %	10.06 %	1.67 %	13.65 %	7.74 %	0.7 %

The percentage of households using unprocessed Solid Bio-fuels (wood, cow dung, Crop Residues etc.) is 76.93 % and those using processed fuels (Kerosene, Bio Gas and LPG) are 23.07 %. In the present study, the household coverage has been approximately in the same pattern for the two distinct fuel user groups of households, namely unprocessed fuels and processed fuels.

7.2.2 Area Coverage and Sample Size

For the present study, the determination of area coverage as well as the total number of households to be visited during the field survey is basically dependent upon optimization of the available resources and budgetary constraints. Moreover, the determination of sample size statistically needs an idea about the variation of the main variables under the study (e. g. in this case, the range of spatial and temporal variations of pollutant concentrations in the kitchen air during cooking hours) which are usually taken from previous studies. Such information was lacking in advance.

It is believed that so far such kind of multi-pronged studies has not been conducted in Nepal before and also believed that to achieve the basic objectives of the study, the need of calculation of the sample size in statistical sense without prior information may not be required. Therefore, the present study has focused to utilize the available resources to the maximum and has tried to maintain the sample size as large as possible. Thus, it was decided to fix the total number of households to be surveyed around 100. The final number of household coverage is 98.

- **HILLS COVERAGE**

The Hills coverage has been limited to Kathmandu valley districts. From Rural Area within Kathmandu valley, altogether, 6 VDCs have been selected randomly. The distribution of number of selected households from each of the selected VDCs is shown in table 2. The total rural hills household coverage is 49.

Similarly for Urban Hills Area, altogether 9 HHs have been surveyed, 4 from Kathmandu Municipality and 5 from Lalitpur Municipality.

Table 2 Surveyed Household Distribution in Rural Hills

District	VDC	Number of Households
Kathmandu	Matsyagaon	8
	Sheshnarayan	8
	Seuchatar	9
Bhaktapur	Katunje, Sudal	18
Lalitpur	Sainbhu	6
	Total Households Covered	49

- **TERAI COVERAGE**

Altogether 40 households have been included for survey from rural and urban areas of the Terai region. Two districts have been included from this region namely Chitwan and Nawalparasi. Altogether, 4 VDCS and 2 Municipalities have been selected. The VDCs covered are Mangalpur, Phulbari, Sibanagar, Patihani and Gaidakot. The two municipalities from Chitwan district covered are Bharatpur NP and Ratnanagar NP. The distribution of the surveyed households for Terai is given in Table 3 below:

Table 3 Surveyed Household Distribution in Terai

District	VDC / Municipality	Number of Households
Chitwan	Mangalpur VDC	7
	Phulbari VDC	8
	Sibanagar VDC	3
	Patihani VDC	5
Nawalparasi	Gaidakot VDC	7
Chitwan	Bharatpur NP	5
Chitwan	Ratnanagar NP	5
	Total Households Covered	40

Respondent Sample Size

From each of the selected households, the respondents chosen are those who cook in Kitchen and the mothers of children whose age is below 5. The individuals who do not cook even once a week have been excluded from interview. Therefore, the total number of respondents in the present study turned out to be 168. From the total 98 households included in the survey, 23 households reported of having children below 5 years of age from which 25 children were examined.

7.3 Field Survey and Investigations

Activities carried out under field survey and investigation comprised the following elements

7.3.1. Determination of Conversion Factors

The relationship between CPM (Count Per Minute) displayed by LD-1 after the end of a measurement and Smoke concentration (PM_{10}) levels in mg / m^3 is given below.

$$K = \frac{\text{Mass Concentration in mg/m}^3}{\text{Dust Count per Minute}}$$

where K is the conversion factor. According to the equipment manufacturer, the above linear relationship is valid for similar environment settings only, meaning that it has to be calibrated for a particular setting. Thus, to determine different values of K factors valid for all field observations, expected to be encountered during the survey (for instance, PM_{10} concentration levels may vary from 0.05 mg/m^3 to 5 mg/m^3, table 4), the laser Dust Monitor and the High Volume Sampler had to be run simultaneously at different places having dissimilar environmental settings.

During the field monitoring work, the actual number of such simultaneous readings were 21 covering CPM range from 1 to 300^+. The corresponding PM_{10} concentration ranged from 0.06 to 5^+ mg/m^3 (table 4). The categorized CPM ranges and the corresponding mean K factors and concentration values in mg/m^3 are tabulated below (table 5 with a diagrammatic presentation).

From table 5, it is clear that any CPM value obtained from routine LD-1 monitoring results lying between 1 to 300^+ can be converted in to corresponding concentration values (mg or µg/m^3) by multiplying CPM value with the K factor specified for the CPM range. For instance, if the CPM value obtained for a particular household kitchen is say 70 (Third category from 51 to 100 count per minute), then the mass concentration value is 1225 µg/m^3 since 70 X 0.0175 = 1.225 mg/m^3 where K = 0.0175 is the conversion factor for the range. Accordingly, all CPM values (Air Quality monitoring results) obtained from LD-1 has been converted in to corresponding PM_{10} values in µg/m^3.

Table 4 Simultaneous Readings by LD-1 and High Volume Sampler

SN	LD-1 Reading Count Per Minute	HV Reading mg/m^3	SN	LD-1 Reading Count Per Minute	HV Reading mg/m^3
01	3.70	.42	12	80.60	1.18
02	5.80	.32	13	93.30	1.30
03	6.50	.38	14	123.70	1.70
04	7.90	.32	15	172.90	4.16
05	13.40	.54	16	202.30	4.24
06	14.40	.06	17	219.90	3.54
07	15.60	.06	18	288.80	4.72
08	16.20	.78	19	407.70	3.76
09	30.20	1.12	20	446.80	5.12
10	40.10	.44	21	881.60	6.00
11	52.00	1.24			

Table 5 Conversion Table with Mean K Factors (from CPM to Mass Concentration)

LD-1 Reading Range	Number of Readings	Mean HV	Mean K Factor
1-25	8	0.36	0.045514
26-50	2	0.78	0.024029
51-100	3	1.24	0.017473
101-200	2	2.93	0.018901
201-300	3	4.17	0.017800
Above 300	3	4.96	0.009192

Above Figure shows that mean K factor is highest at the lowest range of dust count per minute. It drops in the next higher range for dust count per minute and remains fairly constant between 51 to 300 dust counts CPM. It is lowest for the highest range of dust count as categorized in this particular study. This suggests that the conversion factor tends to reduce as the dust level rises at different environmental settings.

7.3.2 Air Pollutant Monitoring Schedules, Methodologies and Result Validation Procedure

Measurement of Smoke (PM_{10}) and Quality Control Steps

As discussed in previous section, LD-1 was used on a routine basis for the measurement of PM_{10} in indoor as well as outdoor settings. It was standardized for different environmental settings during the course of the survey. The standardization was accomplished basically in terms of smoke concentration ranges which depended upon emission sources by fuel types and stove types. In a number of environmental settings both Laser Dust Monitor and High Volume Sampler were kept side by side and run simultaneously for equal length of time and different K factors were determined. Then the concentration levels for all measurements were determined using the mean K Factors for a number of categorized ranges of CPM. Therefore, the determination of the conversion factors in a correct way as far as possible is crucial for assessing air pollution (smoke concentration levels) in this study. Measurement specifics are summarized in the following table. (Table 6)

Table 6 Measurement Specifics

Equipment	Location type	Microenvironment	Frequency	Remarks
LD-1	Indoor	Kitchen when fuel is burning	All houses surveyed	Routine Basis
LD-1	Indoor	Other room when Fuel is not burning	1 / 2 readings per VDC / Municipality	Campaign Basis
LD-1 & HVS	Indoor	Kitchen when fuel is burning	1 reading per VDC/ Municipality	Routine Basis
LD-1 & HVS	Outdoor	Ambient	1 / 2 readings per VDC / Municipality	Routine Basis

Note: Averaging time for all measurements is 10 minutes.

Some steps taken for Quality Control

For quality control and result validation, regarding the operation of LD-1 and HVS, procedures recommended by the respective manufacturers were strictly followed according to the manuals provided. During the handling and weighing HVS filter papers, the following steps were taken during the field survey as well as in the laboratory.

⇒ HVS filter papers were conditioned by keeping inside the desiccators for 48 hours, weighed accurately and kept inside air tight container marked with specifics like identity no., date etc. before taking to the field.

⇒ After measurements, filter papers with smoke contents were conditioned similarly before being weighed.

⇒ For blank correction if any, a blank filter paper accompanied each field trip and returned unexposed and weighed to see if there is any change in weight during the field visit. However, no change has been observed requiring correction.

⇒ HVS filter papers were conditioned as said before for 48 hours, weighed accurately and kept inside air tight container marked with specifics like identity no., date etc. before taking to the field.

Gaseous Emission Monitoring Schedule

It is reported that almost all classical air pollutants namely CO, SO_2, NO_X have been found in Solid bio-mass smoke but the concentration levels have not been reported except for CO in some cases. During non cooking time, when solid bio-fuels are not being burnt, indoor air pollution except arising from common domestic activities is almost non-existent**.** This is expected to be true in the majority of rural households of Nepal.

In this study, therefore, only CO was monitored along with PM_{10} on routine basis. HCHO, SO_2 and NO_X were measured on campaign basis only. Equipment and measurement methodology used in gaseous emission have already been described in earlier sections.

Some measurement specifics for gaseous emission are given in table 7.

Table 7 Measurement Specifics for Gaseous Emission

Equipment	Location type	Microenvironment	Frequency	Remark
GASTEC with CO detector tubes	Indoor	Kitchen when fuel is burning	All houses surveyed	Routine Basis
GASTEC with CO detector tubes	Indoor	Other Room when Fuel is burning	Average of 1 reading per VDC / Municipality	Campaign Basis
GASTEC with CO detector tubes	Indoor	Other room when Fuel is not burning	A few readings	Campaign Basis
GASTEC with respective gas detector tubes (SO_2, NO_X and HCHO)	Indoor	Kitchen when fuel is burning	As needed	Campaign Basis
GASTEC with respective gas detector tubes (SO_2, NO_X and HCHO)	Indoor	Kitchen / other room when fuel is not burning	As needed	Campaign Basis
GASTEC with respective gas detector tubes (SO_2, NO_X and HCHO)	Outdoor	Ambient / Commercial	As needed	Campaign Basis

7.3.3 Data Acquisition of Household Characteristics and Personal Information / Habits of Respondents (Photos: Cover Page, 1, 2, 7 & 12)

This portion of task was generally attended by a team member and a helper designated for the purpose, who duly interviewed the household head / respondents. Data on state of ventilation in the kitchen was taken by actual measurement of open window area, kitchen volume and door area. Accounting all these measurements, the ventilation situation was later coded in to poor, moderate and improved for meaningful interpretation and data analysis. Section 12 shows the ventilation situation and types of households surveyed during the study period. Similarly data on fuel / stove types used during monitoring were also recorded. The exposure estimates, data on education, occupation, personal habit with regard to smoking, time activity pattern were also noted.

7.3.4 Data Acquisition on Health Effects, Medical Examination of Respondents

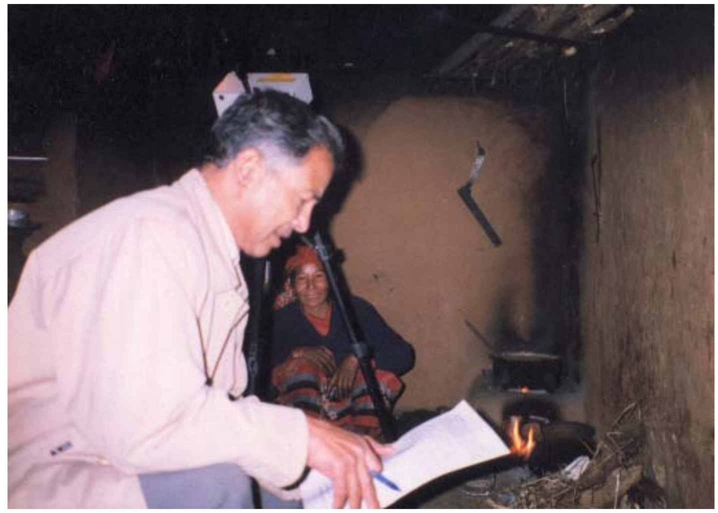
This portion of task was attended the Medical Doctor who is also a team member, examined the respondents for health outcomes particularly related to indoor air pollution. The health check up focused primarily on:

⇒ Examination of ENT and chest followed by measurement by Peak Flow Meter (Spiro meter)

⇒ Acquiring data on respiratory symptoms such as cough, phlegm, wheezing, breathlessness and other `health complaints.

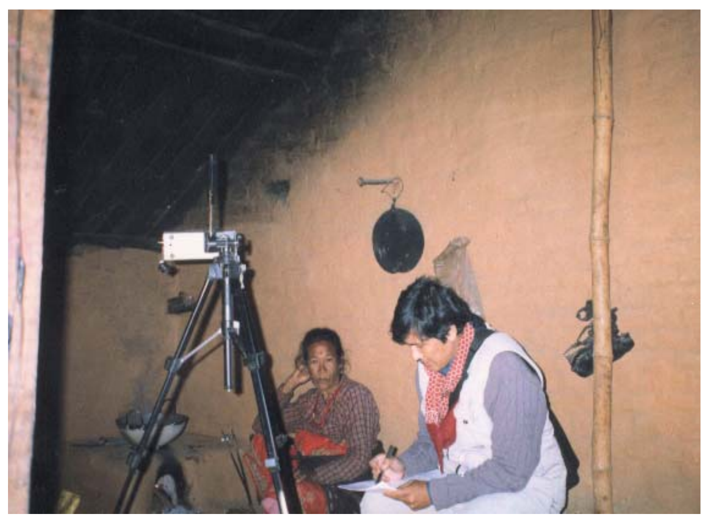
⇒ Particular attention was also given on ARI identification to children below 5 years of age

Photo 1



A respondent cooking in traditional stove using wood, and answering to questions; Sudal VDC, Bhaktapur

Photo 2



A respondent answering questions; Sudal VDC, Bhaktapur

8.0 Presentation of Results

After the completion of the field survey and investigation, all data / information obtained were compiled, classified and processed by the statistician, a member of the study team.

Since the main theme of the study has been the effect of solid bio-mass fuel on health, the general approach taken in most study proceedings was fuel-based rather than pollutant-based.

In order to put all the study outputs in to proper perspectives, the field results were grouped in to three major data packages. They are:

1. Pollution Monitoring and Related Data
2. Exposure and Related Data
3. Health Effects and Related Data

8.1 Pollution Monitoring and Related Data

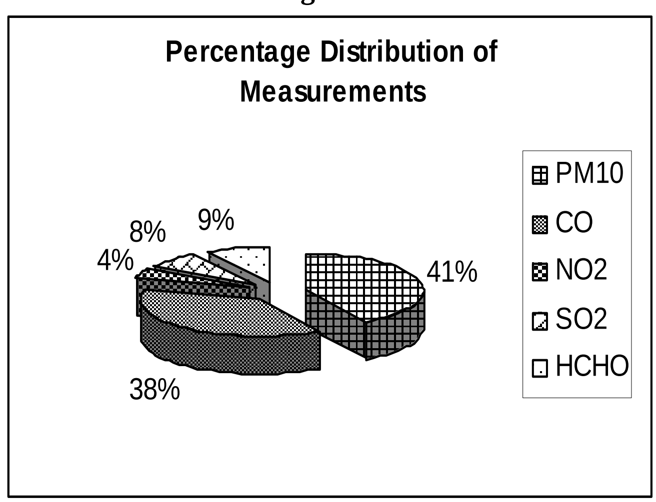
8.1.1 Overall Scenario of Types of Monitoring, Measurement Frequency and Measurement Audits

This section addresses the different types of monitoring techniques undertaken for assessing pollutant concentration levels in various environmental settings and their measurement frequencies. Firstly, the overall frequency of measurement carried out for each pollutant during the field visits is summarized in Table 8.

Table 8
Frequency of Measurements

S.N.	Name of the Pollutant	Frequency
1	PM_{10}	114
2	CO	105
3	NO_2	12
4	SO_2	21
5	HCHO	24
Total		276

Fig 1



The tables (9 to 13) that follow show the measurement frequency breakdowns for each pollutant namely PM_{10}, CO, NO_X, SO_2 and HCHO together with environmental settings in which each was measured.

Although data given the tables are self explanatory, the size of measurement frequency and exposure location which vary from one pollutant to another and from one environmental setting to another may require some elaboration. They are as follows:

- The frequency of measurement (number of determinations) for PM_{10} and CO inside kitchen when fuel was burning is 98 each, which means that both pollutants were measured invariably for each of the households surveyed. However, one Kitchen PM_{10} and two Kitchen CO values were found invalid because of some error and therefore not taken in to account for data processing. (Table 9 and 10)

- Indoor PM_{10} determination in rural households during non-cooking time was limited to only a few readings (5) because the values observed were only slightly different from one another although they were measured for different VDC households. (Table 9)

- Similarly, Outdoor PM_{10} determination was limited to 11 for reason mentioned above. (Table 9)

- For other gaseous pollutants, the measurement frequencies were relatively much smaller since they were also conducted on campaign basis as were done for PM_{10} and CO during non cooking time and outdoor environments.

- Measurement for Formaldehyde (volatile organic compound; usually emitted by freshly burnt bio-mass fuel) were conducted at 24 locations out of which 22 were from solid bio-fuel burning kitchens and 2 from ambient conditions for control measures. (Table 13)

- SO_2 measurements were conducted mostly in smoky kitchens (N=16) in conjunction with PM_{10} measurements because it is known that even low SO_2 values in combination with high level of smoke can act synergistically and show enhanced negative health impact to exposed house inmates. (Table 12)

- Most of the NO_X determinations were conducted in fossil fuel (Kerosene and LPG) burning kitchens (N=8) and 4 more determinations in other environmental settings. (Table 11)

Table 9 Frequency for PM_{10} Measurements

Environment	Setting	Valid Measurements	Invalid Measurements	Total Measurements
Indoor	Kitchen When fuel is burning	97	1	98
Indoor	When fuel is not burning	5	0	5
Outdoor	Ambient	11	0	11
Total		113	1	114

Table 10 Frequency for CO Measurements

Environment	Setting	Valid Measurements	Invalid Measurements	Total Measurements
Indoor	Kitchen When fuel is burning	96	2	98
Indoor	When fuel is not burning	2	0	2
Outdoor	Ambient	5	0	5
Total		103	2	105

Table 11 Frequency for NO_2 Measurements

Environment	Setting	Valid Measurements	Invalid Measurements	Total Measurements
Indoor	Kitchen When fuel is burning	8	0	8
Indoor	When fuel is not burning	1	0	1
Outdoor	Ambient	3	0	3
Total		12	0	12

Table 12 Frequency for SO_2 Measurements

Environment	Setting	Valid Measurements	Invalid Measurements	Total Measurements
Indoor	Kitchen When fuel is burning	16	0	16
Indoor	When fuel is not burning	1	0	1
Outdoor	Ambient	4	0	4
Total		21	0	21

Table 13 Frequency for HCHO Measurements

Environment	Setting	Valid Measurements	Invalid Measurements	Total Measurements
Indoor	Kitchen When fuel is burning	22	0	22
Indoor	When fuel is not burning	0	0	0
Outdoor	Ambient	2	0	2
Outdoor	Non Ambient	0	0	0
Total		24	0	24

8.1.2 Smoke / PM_{10} Monitoring Results

8.1.2.1 Smoke / PM_{10} Mass Concentration by Fuel and Stove Types

Table 14 shows very high concentration levels observed for kitchens using solid bio-fuels, namely, dung, crop residues and wood. The mean concentrations were as high as 2838, 2686 and 2298 µg / m^3 for Dung, Crop Residues and Wood respectively. The stove type used for these fuels is Traditional Ageno Chulo (Photos: 1, 3, 4, 5, & 14). The mean concentration levels for kitchens using cleaner fuels namely, Kerosene, Bio-gas and LPG were 880, 667 and 754 µg / m^3 respectively which are much lower than those measured for solid bio-fuels.

The maximum values reported for solid bio-fuel using kitchens were in the very high range of 5000 to 8000 µg / m^3 though some low values have also been observed (500 to 700 µg/m^3). The range of divergence between minimum and maximum values for each of the fuel types indicate that there may be other potential factors apart from fuel types that determine the smoke concentration levels inside kitchen in our households such as ventilation, kitchen space, chimney etc. The total variability of PM_{10} level for all fuel types in terms of coefficient of variation is 77%.

Among the surveyed households, wood using number was found to be maximum (44). Dung and Bio-gas using households was minimum (3 each).

The Energy Ladder

The term energy ladder usually denotes that as we move up the ladder, the types of fuel used typically increase in cleanliness, convenience, efficiency, free energy content per unit mass and cost. (Ref: Smith et al, 1994, Air Pollution and Energy Ladder in Asian cities, Energy, 19(5), 587-600). In the table, the fuel types used (survey results) were arranged in the energy ladder sequence, and it is remarkable to observe that PM_{10} emissions levels too decreased as we move up the ladder to cleaner fuels from dung to biogas (Photo 6). The author is of the opinion that the above data may probably be the first of its kind reported under the field conditions in Nepal. The data obtained is represented in diagram also (Fig.-2).

Photo 3

Kitchen PM_{10} Monitoring by LD-1, HVS and CO by Gas Analyzer; Katunje VDC, Bhaktapur

Photo 4

A housewife cooking with rice husk in a traditional Ageno Chulo; Machhagaon VDC, Kirtipur

8.1.2.2 Binary Fuel Based Monitoring Results at Kitchen for PM_{10} During Cooking Time

For comparison purpose, Fuel types studied, have been grouped in to binary fuels, i.e. unprocessed fuels (dung, crop residue, wood) and processed one i.e. Kerosene, LPG, Biogas. The mean concentration of PM_{10} for unprocessed Solid Bio-fuel is found to be 2418 $\mu g/m^3$ (62 readings) which is approximately three fold higher than observed for processed fuel (792 $\mu g/m^3$ from 26 readings). With substantial and majority of households in Nepal depending upon unprocessed fuels, these high figures are of major concern to all of us (Table 15).

Table 14 Individual Fuel Based Monitoring Results at Kitchen for PM_{10} During Cooking Time

Fuel Type During Monitoring	Mean Level ($\mu g / m^3$)	Minimum Level ($\mu g / m^3$)	Maximum Level ($\mu g / m^3$)	Number of Readings		Stove Type
				N	%	
Dung	2838.82	505.21	5089.09	3	3.4	Traditional Ageno Chulo
Crop Residue	2686.12	725.69	4970.66	15	17.0	Traditional Ageno Chulo
Wood	2298.01	541.62	8077.67	44	50.0	Traditional Ageno Chulo
Kerosene	880.00	514.31	1698.40	10	11.4	Kerosene Stove
Bio Gas	666.82	555.27	755.54	3	3.4	Gas Stove
LPG	754.22	355.01	1194.26	13	14.8	Gas Stove
Total				88	100.0	

1 invalid case

8.1.2.3 Comparative Binary Fuel Based Monitoring Results by Regions/Areas at Kitchen for PM_{10} During Cooking Time

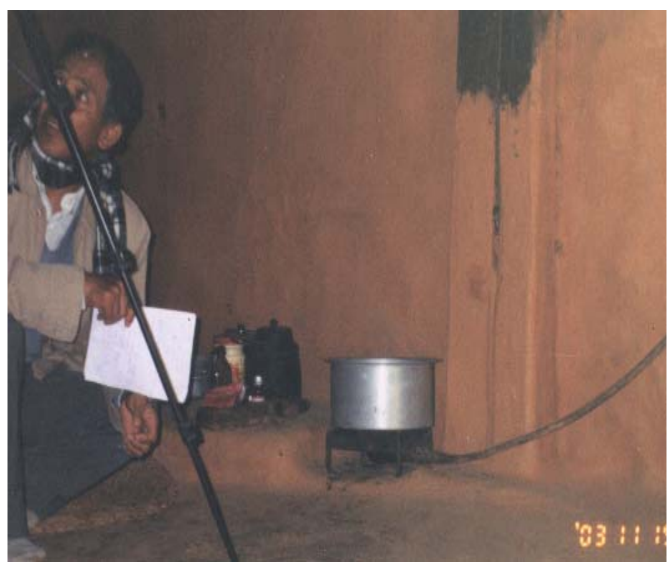
Comparison by Region

For hills (Kathmandu valley elevation: 1372m-2732m) and terai regions (chitwan, elevation: 244m-1945m and Nawalparasi, elevation: 91m–1936m), the mean smoke concentration at kitchens using unprocessed fuels has been found to be nearly 3 times higher than kitchens using processed fuels (Table 16). However, for hill region, such smoke concentration both for unprocessed and processed fuel users, are found to be relatively at high side (e.g. 2545 $\mu g/m^3$ for unprocessed and 856 $\mu g/m^3$ for processed) compared to terai region. These differences in smoke levels may be attributed largely to differences in housing characteristics, user behaviors, living conditions etc between hill dwellers and terai dwellers. For example, Terai kitchens are more open with many eaves spaces (because of typical roofing materials used.) whereas the hills kitchens are not that open because of being colder and roofing materials are also different.

Photo 5

Cooking Mealin traditional stove with Solid Bio-fuel Burning; A VDC, Lalitpur

Photo 6



Cooking with Biogas; Sheshnarayan VDC, Kathmandu

Comparison by Area

The mean PM_{10} concentration at kitchens is found to be higher in Rural areas of Nepal than in urban areas for households using unprocessed solid bio-fuels because of difference in ventilation situation. However, the concentration is lower in rural areas than urban areas for households using processed fuels. Comparing values for unprocessed with processed fuels, the mean concentrations for PM_{10} are again approximately three times higher by eco-development region-wise as well as rural-urban area wise. The ratios of mean PM_{10} concentrations are 2.97, 2.96, 3.23 and 2.60 for Hills, Terai, Rural and Urban areas (Table 16).

Fig 2

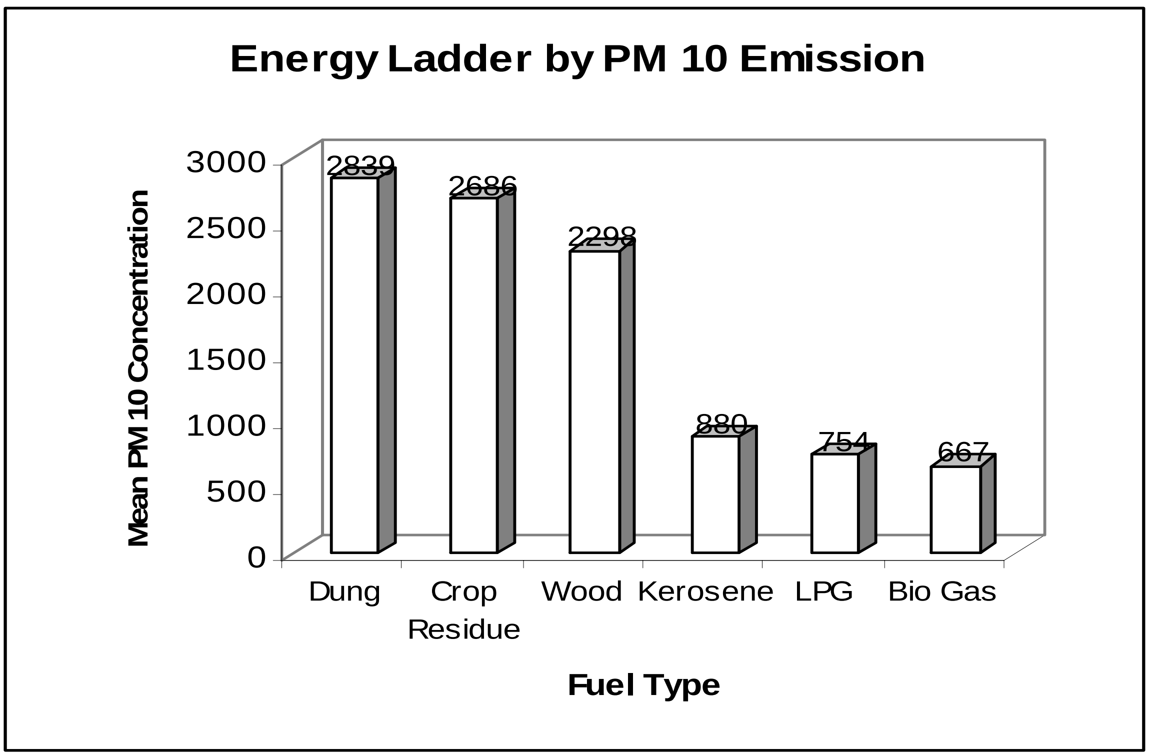


Table 15 Binary Fuel Based Monitoring Results at Kitchen for PM_{10} during Cooking Time

Binary Fuels During Monitoring	Mean Level (µg / m³)	Minimum Level (µg / m³)	Maximum Level (µg / m³)	Measurements N	Measurements %	Stove Type
Unprocessed Solid Bio-fuel (Dung / Crop Residue / Wood)	2418.07	505.21	8077.67	62	70.5	Traditional Ageno Chulo
Processed Fuels (Kerosene / Bio-Gas / LPG)	792.51	355.01	1698.40	26	29.5	Kerosene / Gas Stove
Total				88	100.0	

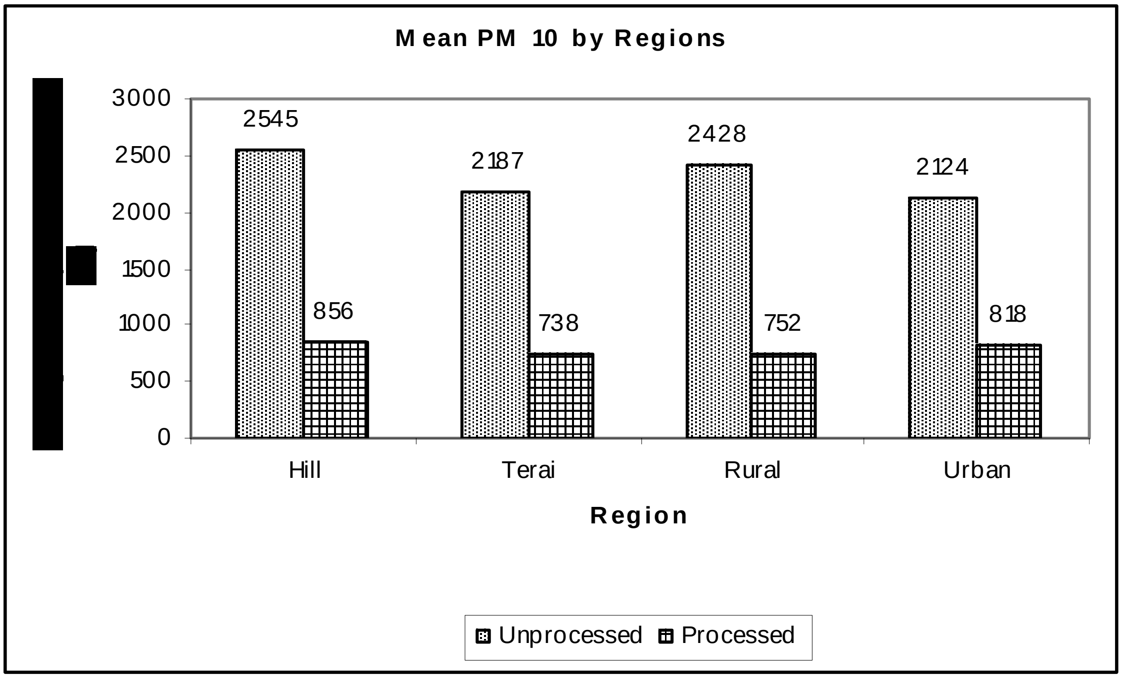
1 invalid case

Table 16 Binary Fuel Based Monitoring Results at Kitchen for PM_{10} during Cooking Time by Regions/Areas

Region / Area	Ratio (unprocessed /processed	Unprocessed Solid Bio-Fuels (µg/m³)				Processed Fuels (µg/m³)			
		Mean	**Min**	**Max**	**N**	**Mean**	**Min**	**Max**	**N**
Hill	2.97	2545.39	505.21	5089.09	40	856.33	523.41	1194.26	12
Terai	2.96	2186.58	541.62	8077.67	22	737.81	355.01	1698.40	14
Rural	3.23	2427.87	505.21	8077.67	60	751.86	514.31	1194.26	10
Urban	2.60	2124.16	980.25	3268.08	2	817.92	355.01	1698.40	16

1 invalid case

Fig 3

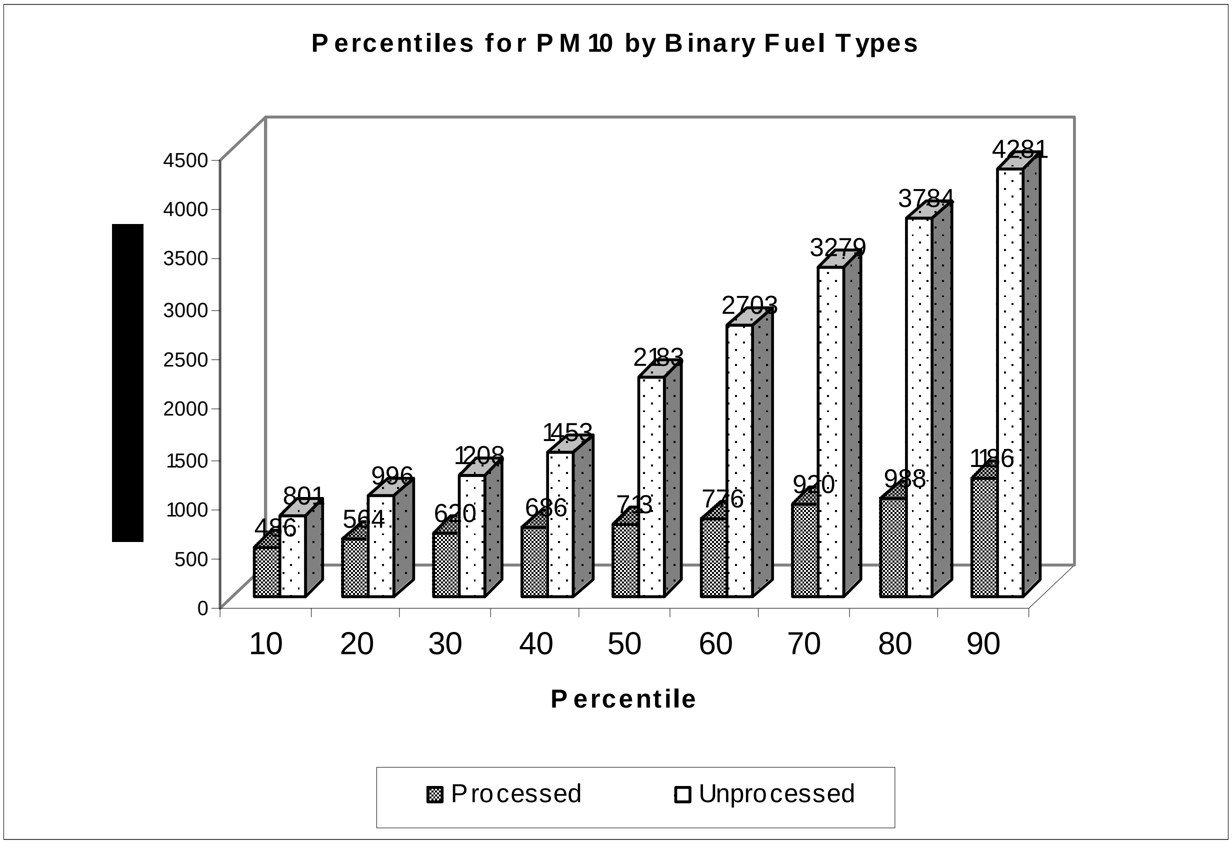


<u>Percentile Values of PM_{10} by Binary Fuel Types</u>

The percentile[2] values of PM_{10} by Binary fuel types are presented below (Fig. 4) graphically in order to visualize the differences between the observed PM_{10} values for unprocessed fuels and processed fuels. The figure shows that the percentile values for unprocessed fuels are much higher than for the processed fuels. For instance, 10% of the number of cases for processed fuels and unprocessed fuels has PM_{10} levels below 486µg/m^3 and 801µg/m^3respectively. Considering percentiles of PM_{10}, the gap between unprocessed fuels and processed fuels widen as we move on to higher percentiles. The figure also shows that 90% of the observations for processed fuels and unprocessed fuels lie below 1186 µg/m^3 (90% percentile value for PM_{10} concentration) and 4281 µg/m^3 respectively. This value for unprocessed fuel is 3.6 times higher than the same value for processed fuel and this demonstrates that kitchen air is far more polluted when solid bio fuels are in operation compared to cleaner fuels.

[2] For each specified percentile, displays the value below which that percentage of the cases fall. For example the 50th percentile is the value below which 50% of the cases fall.

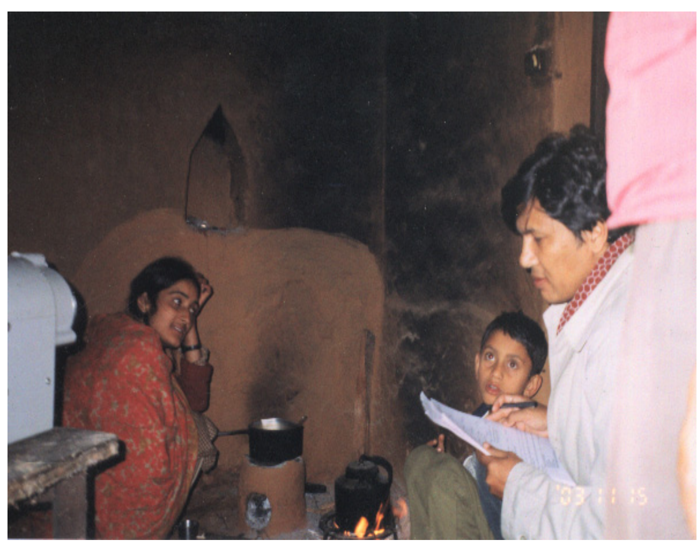
Fig 4



8.1.2.4 Smoke / PM_{10} Monitoring Results by Stove types (Bhuse chulo/Traditional chulo fitted with hood and chimney)

The PM_{10} mean concentration is presented separately here because of the uniqueness regarding fuel type, Stove type and Ventilation. The mean concentration for PM_{10} observed for 5 households using saw-dust with Bhuse Chulo (Photo 7) as stove type is found to be 1728 $\mu g/m^3$ (Table 17). Similarly, the mean concentration observed for 4 households using wood with hood and

Photo 7



A respondent cooking in traditional stove, Bhuse chulo seen nearby is not being used and answering to questions; Seshnarayan VDC, Kathmandu chimney is found to be only 960 µg/m^3 (Table 17).

It is to be noted that the later figure is approximately same as the overall mean concentration observed for processed fuels. This emphasizes the need of appropriate ventilation condition in the kitchen as it reduces PM_{10} mass concentration substantially. For the former, the type of stove used needs to be elaborated because under similar condition of fuel use and the ventilation, the smoke pollution seemed to have been reduced substantially.

Table 17 PM_{10} Monitoring Results for Bhuse Chulo and Wood Burning with Chimney

Fuel Type During Monitoring	Mean Level (µg / m^3)	Minimum Level (µg / m^3)	Maximum Level (µg / m^3)	N	Stove Type
Saw Dust	1728.46	591.68	2508.23	5	Bhuse Chulo
Wood	785.12	455.14	960.35	4	Traditional Ageno Chulo with hood and chimney
Total				9	

<u>Typical Bhuse Chulo (construction and geometrics)</u> (Photo 7)

This single piece portable stove is made of clay materials with one opening at the top to contain a cooking pot and another smaller one at the base for introducing wood sticks for burning the main fuel: saw-dust or rice-husk etc. It is typically cylindrical, slightly broader at the base (the outer diameter is approximately 12 in) and dia. at the top is about 8 in. having 3 small protruding where the cooking pot rests to allow free passage of air while the fuel burns.

The stove is readied by packing saw dust / or rice husk. But before the saw dust is packed a stout hollow cylinder (a kind of mold) say of about 4 in. dia. of appropriate material is kept centrally inside the hollow stove, the fuel dust is poured around the gap and packed and then the hollow piece is removed so that the packed dust stands inside without collapse with a central opening of the size of mold. The stove is now ready for burning and cooking daily meals. Normally, the packed dust fuel lasts for 4 to 5 meals for a family of 5 before recharging.

Traditional Clay Stoves fitted with chimneys

The households surveyed using these stoves were from terai region. Stoves were similar to traditional Ageno Chulos, but fitted with hoods and chimneys and they seemed to reduce smoke pollution considerably.

Some improved stoves (traditional clay stoves constructed with some changes in geometrics with vents) were also studied in some Kathmandu VDC HHs (Photo 8). But assessment of monitoring results (PM_{10}, CO and other gasses) indicated that the fuel burning efficiencies of the studied stoves did not seem to have improved at all and that pollutants values of the kitchen air obtained were similar to those obtained for traditional Ageno Chulos with fuel wood burning. Thus, the results obtained were combined and assessed together with traditional stoves.

Photo 8

A respondent cooking with wood in a stove fitted with clay vent pipe; Seuchtar VDC, Kathmandu

Outwardly, the kitchens using improved stoves looked cleaner compared to those using traditional ones. The apparent non performance of the stoves studied in 5 HHs may be related to other factors such as lack of maintenance of those stoves/chimneys or the ventilation conditions inside kitchens. As a result, further studies are warranted covering many such stove using kitchens so that the exact problem, if any, could be identified.

8.1.2.5 Comparative Binary Fuel Based Monitoring Results by Ventilation Situation at Kitchen for PM_{10} During Cooking Time

The assessment of ventilation situation in the kitchen has been done by measuring various kitchen dimensions such as kitchen space, open window area and door area and existence of chimney or

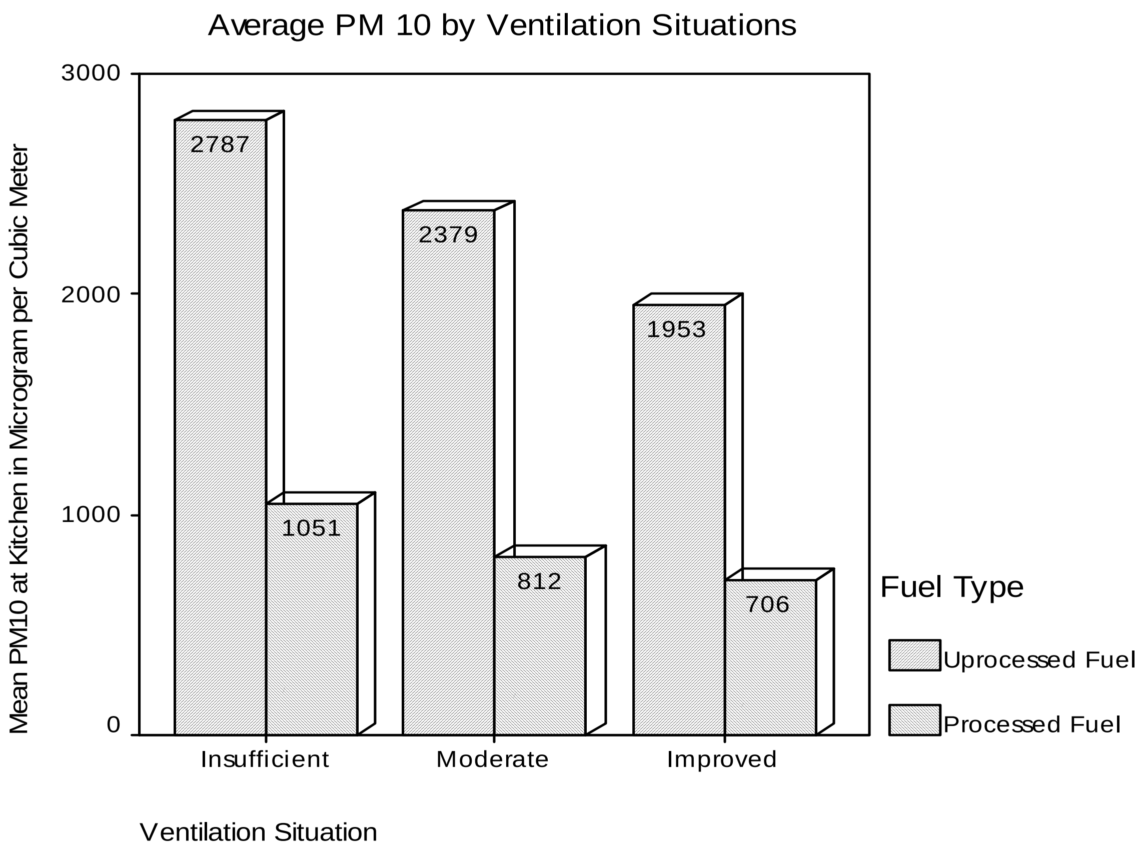
vent pipes. The presentation of PM_{10} concentration data for household using chimney has been done in the preceding section. In this section, the ventilation situation is recoded in to ordinal scale (Poor, Moderate and Improved) for convenience in data presentation and interpretation. This has been scaled taking account of Kitchen space (area and height), open window area and door area. The resulting Smoke mass concentrations are presented according to ventilation situations.
As we would expect, the table 18 shows that the concentrations decreased as the ventilation situation improved for both unprocessed as well as processed fuels. This is an ample evidence of the effect of ventilation condition in to observed differences in mass concentrations.

It is to be noted however that even in improved ventilation situation, the size of pollution reduction is not to the desired extent as in the case of traditional stove fitted with hood and chimney (Table 17) which means that there is still considerable room to improve the ventilation situation by means of some simple structural changes in the kitchen design (c/o guidelines for building houses for health).

Table 18 Comparison of PM_{10} by Binary Fuel Types and Ventilation Situations

Ventilation	Unprocessed Solid Bio-Fuels			Processed Fuels		
	Mean ($\mu g / m^3$)	**N**	**%**	**Mean ($\mu g / m^3$)**	**N**	**%**
Poor	2786.84	16	30.2	1051.09	5	20.8
Moderate	2379.09	30	56.6	812.16	7	29.2
Improved	1952.61	7	13.2	705.64	12	50.0
Total		53	100.0		24	100.0

Fig 5



8.1.3 Carbon Monoxide (CO) Monitoring Results

8.1.3.1 Carbon Monoxide (CO) Concentration by Fuel and Stove Types

As shown in table 19, the mean CO concentration is recorded as relatively high among unprocessed solid bio-fuels. (Dung – 17.2 mg / m^3, Crop Residue – 17.8 mg / m^3 and Wood – 14.8 mg / m^3) and low among unprocessed fuels (Kerosene – 3.7 mg / m^3, Bio-gas – 2.1 mg / m^3 and LPG – 1.4 mg / m^3). Therefore, relatively high exposure of CO is expected for individuals who spend a bulk of time cooking in kitchen with unprocessed fuels as their means of cooking daily meals, (particularly women and children who accompany during cooking). The overall Coefficient of Variation is 92.5%.

Data given in the table19 and the diagram (Fig 6) show that CO values found do not exactly fall in to the same sequence as required by energy ladder (c/o crop residue value is higher than dung value; biogas value is also higher than LPG value)

Table 19 Individual Fuel Based Monitoring Results at Kitchen for CO during Cooking Time

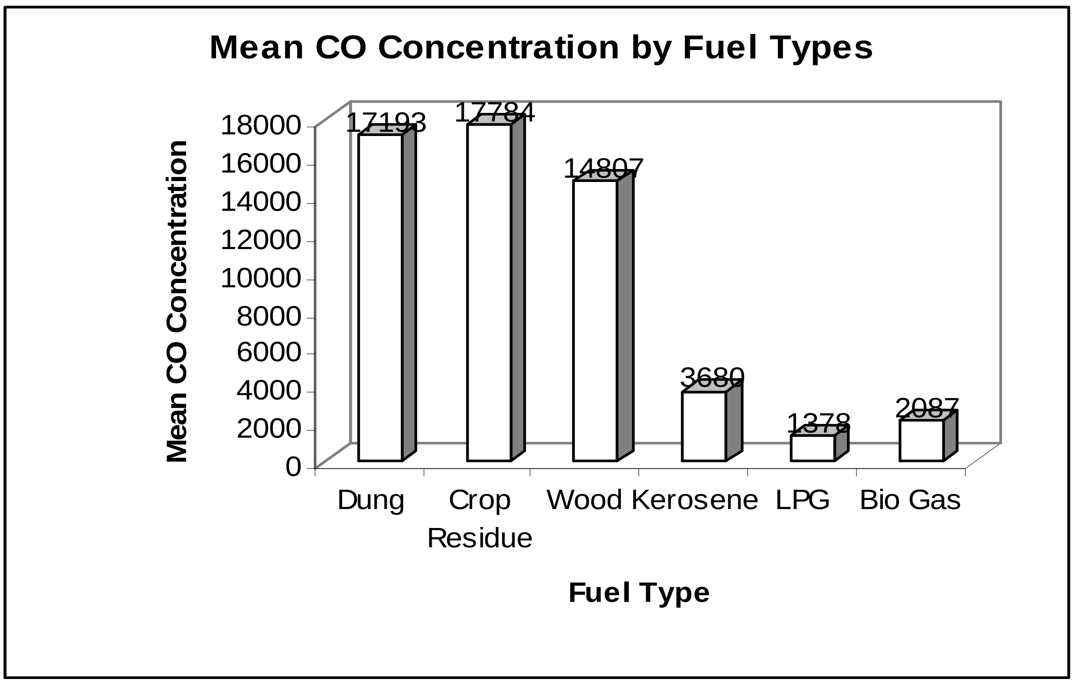
Fuel Type During Monitoring	Mean Level (µg / m^3)	Minimum Level (µg / m^3)	Maximum Level (µg / m^3)	Measurements		Stove Type
				N	**%**	
Dung	17193.33	280.00	28500.00	3	3.4	Traditional Ageno Chulo
Crop Residue	17784.00	3420.00	37620.00	15	17.2	Traditional Ageno Chulo
Wood	14806.74	570.00	34200.00	43	49.4	Traditional Ageno Chulo
Kerosene	3680.00	280.00	13680.00	10	11.5	Kerosene Stove
Bio Gas	2086.67	280.00	5700.00	3	3.4	Gas Stove
LPG	1378.46	280.00	5700.00	13	14.9	Gas Stove
Total				87	100.0	

2 invalid cases

For this, it is important that following points be noted:

- The method used for measuring gaseous emission including CO was not as precise as used for PM_{10}.
- The averaging time is only 2 -5 minutes
- The indicator concentration levels obtained for CO were not as alarmingly high as those of PM_{10}.
- The highest mean level obtained for crop residue was 17784 µg/m^3 and the maximum was 37620 µg/m^3 which is much below The WHO recommended guideline value of 100,000µg/m^3 (averaging time 15 minutes, see Annex-4)

Fig 6



8.1.3.2 Binary Fuel Based Monitoring Results at Kitchen for CO During Cooking Time

The mean CO concentration for unprocessed fuels at kitchen when fuel is burning is found to be 15.66 mg/m^3 which is 6.67 times higher than the mean concentration measured for processed fuels (Table 20).

8.1.3.3 Comparative Binary Fuel Based Monitoring Results at Kitchen for CO During Cooking Time by Regions

For unprocessed fuel, mean CO concentration is higher in Terai than in Hills and also higher in Rural area than in urban area. However, for processed fuel, the concentration is higher in Hills than in Terai and higher in urban area than in rural area. Consequently, comparing concentrations by binary fuel types, the mean CO concentrations do not follow the same pattern by the type of region. Also, the concentrations are 5 to 10 fold higher (Table 21 and Fig 7) for unprocessed fuels as compared to processed fuels when we examine by eco-development regions and area types.

Table 20 Binary Fuel Based Monitoring Results at Kitchen for CO during Cooking Time

Binary Fuels During Monitoring	Mean Level (µg / m^3)	Minimum Level (µg / m^3)	Maximum Level (µg / m^3)	Measurements		Stove Type
				N	%	
Unprocessed Solid Bio-fuel (Dung / Crop Residue / Wood)	15656.23	280.00	37620.00	61	70.1	Traditional Ageno Chulo
Processed Fuels (Kerosene / Bio-Gas / LPG)	2345.38	280.00	13680.00	26	29.9	Kerosene / Gas Stove
Total				87	100.0%	

2 invalid cases

Fig 7

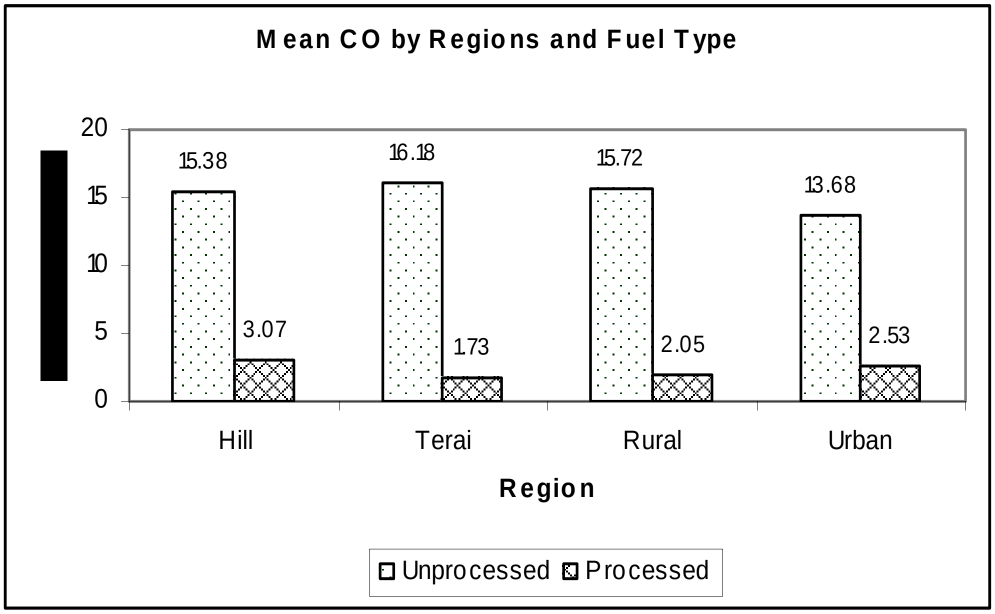


Table 21 Binary Fuel Based Monitoring Results at Kitchen for CO during Cooking Time by Regions/Areas

Region	Ratio	Unprocessed Fuels				Processed Fuels			
		Mean	**Min**	**Max**	**N**	**Mean**	**Min**	**Max**	**N**
Hill	5.0	15382.75	280.0	37620.00	40	3066.67	280.00	5700.00	12
Terai	9.4	16177.14	3420.0	34200.00	21	1727.14	280.00	13680.00	14
Rural	7.7	15723.22	280.0	37620.00	59	2050.00	280.00	5700.00	10
Urban	5.4	13680.00	4560.0	22800.00	2	2530.00	280.00	13680.00	16

2 invalid cases

8.1.3.4 CO Concentration for Bhuse Chulo / Wood Burning with Chimney

For Sawdust with Bhuse Chulo as the stove type, the mean CO concentration is found to be 14.14 mg/m^3 which is marginally lower than the mean value obtained for unprocessed fuel but substantially higher than the mean value obtained for processed fuel (Table 22).

On the other hand, for Wood with Chimney, the mean CO concentration is found to be only 3.42 mg/m^3 which again demonstrates that chimney plays an important role in reducing pollution concentrations at kitchen when fuel is burning.

Table 22 CO Monitoring Results for Bhuse Chulo and Wood Burning with Chimney

Fuel Type During Monitoring	Mean Level ($\mu g / m^3$)	Minimum Level ($\mu g / m^3$)	Maximum Level ($\mu g / m^3$)	N	Stove Type
Saw Dust	14136.00	2280.00	34200.00	5	Bhuse Chulo
Wood	1567.50	570.00	3420.00	4	Traditional Ageno Chulo fitted with hood & chimney.
Total				9	

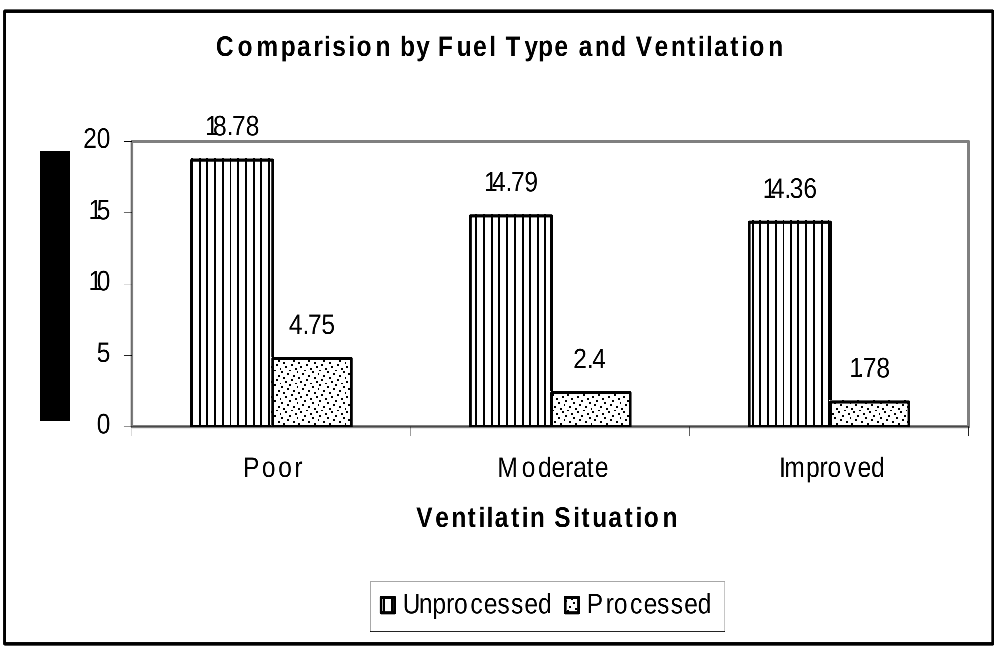
8.1.3.5 Comparative Binary Fuel Based Monitoring Results by Ventilation Situation at Kitchen for CO During Cooking Time

As observed for Smoke mass concentration, improvement in ventilation situation in kitchen is accompanied by decrease in CO concentration as well. This is demonstrated by marginal decrease in mean CO concentrations for both binary fuel types as the ventilation situation improves from one stage to another (Table 23 and fig 8).

Table 23 Comparison of CO by Binary Fuel Types and Ventilation Situations

Ventilation	Unprocessed Solid Bio-Fuels			Processed Fuels		
	Mean	N	%	Mean	N	%
Poor	19522.5	16	30.8	4852.00	5	20.8
Moderate	14563.33	30	57.7	1788.57	7	29.2
Improved	14250.00	6	11.5	1708.33	12	50.0
Total		52	100.0		24	100.0

Fig 8



8.1.4 Gaseous Emission Monitoring Results, NO_2, SO_2, HCHO

A total number of 46 measurements were recorded for assessing Gaseous Emission Concentration Levels namely Sulfur Dioxide, Nitrogen Dioxide and HCHO (Photo 3, cover page). Since these measurements have been done mostly by campaign basis, measurements have not been taken from all the houses surveyed.

8.1.4.1 Gaseous Emission Concentrations by Fuel Types

As shown in table 24, a total of 8 measurements have been carried out for NO_2 inside kitchen during cooking time and results indicate that Indoor NO_2 concentrations are at minimum levels even during cooking time for processed fuel users (c/o WHO 1999a guideline value for NO_2 is 200 $\mu g/m^3$, averaging time 1 hr., Annex-4))

A total of 16 measurements were taken for SO_2. Mean Kitchen SO_2 concentration level is found relatively high only for Dung (652 $\mu g/m^3$). Moreover, the mean concentrations are approximately at the same level for rest of the measured fuel types inside kitchen during cooking time (260 – 300 $\mu g/m^3$) (c/o WHO 1999a guideline value for SO_2 is 500 $\mu g/m^3$ with averaging time of 10 mins., Annex-4).

A total of 22 measurements were taken for HCHO (Photo 3). Mean Kitchen HCHO concentration is found the highest for Wood (355 $\mu g/m^3$) and lowest for LPG and Kerosene (53 $\mu g/m^3$). For all unprocessed fuels, the mean HCHO concentrations are found to be much higher than found for processed fuels (c/o WHO 2002 health effect guideline value for HCHO is 100 $\mu g/m^3$, the averaging time being 30 mins.). Comparing the observed results with WHO recommended values, it looks that formaldehyde concentration levels in kitchens using solid bio-fuels may pose health problems to the exposed population and warrants further studies.

Data given in the table indicate that NO_2 and SO_2 levels found in the kitchen using various fuels do not seem to pose health threats to the exposed people. Thus, further elaboration on comparative estimates for the unprocessed and processed fuels were not carried out.

But for Formaldehyde, values observed particularly for unprocessed fuels exceeded the WHO guideline value by about 3 fold.

Table 24 Gaseous Emission Monitoring Results by Fuel Types

Fuel Type During Monitoring	Mean NO_2 Level (µg / m^3)	Number of Readings		Mean SO_2 Level (µg / m^3)	Number of Readings		Mean HCHO Level (µg / m^3)	Number of Readings	
		N	%		N	%		N	%
Dung	—	0	0.0	652.50	1	6.3	213.00	1	4.5
Crop Residue	—	0	0.0	293.37	4	25.0	182.57	7	31.8
Wood	—	0	0.0	260.86	7	43.8	355.00	12	54.5
Kerosene	188.00	1	12.5	260.67	3	18.8	53.25	1	4.5
Bio Gas	188.00	2	25.0	—	0	0.0	—	0	0.0
LPG	188.00	5	62.5	261.00	1	6.3	53.25	1	4.5
Total		8	100.0		16	100.0		22	100.0

Note: WHO guideline values for NO_2 and SO_2 are 200 µg/m^3 (1 hour averaging time) and 500 µg/m^3 (10 minute averaging time) respectively.

8.1.5 Indoor Ambient and Outdoor Pollutants Concentration Levels

Table 25 shows pollutants concentration levels in indoor ambient condition. Altogether 9 measurements were taken: 5 for PM_{10}, 2 for CO, 1 each for SO_2 and NOx, to get an idea about their pollution levels when fuels are not being burnt. The data obtained indicate that the concentration levels obtained were similar to those obtained for outdoor ambient, which means that the sources of indoor air pollution are mainly the fuels used for cooking meals.

Altogether 25 measurements have been taken to measure outdoor concentration levels for various pollutants (Table 26(a) and 26(b)) (Photos: 9 & 10).

Relatively high outdoor concentration level for PM_{10} is found in Sainbhu VDC (1149 µg/m^3) as compared to other VDC / Municipalities included in the survey. Otherwise, the concentration levels ranged between 320 to 780 µg/m^3 for other VDC / Municipalities except for Mangalpur VDC (Chitwan) where the ambient PM_{10} was only 60 µg/m^3.

Ambient CO concentration was not detected in 3 measurements with minimum detection level 285µg/m^3. However, in 2 measurements, the CO levels were 3420 and 1140 µg/m^3 recorded in Bharatpur NP and Ratnanagar NP respectively, and these high values may be attributed to vehicular emission.

Ambient SO_2 was not detected in Bharatpur NP, measured 261 µg/m^3 in Gaidakot VDC and 522 µg/m^3 in Mangalpur VDC. One non-ambient reading showed 522 µg/m^3 in Bharatpur NP.

Lastly, in two readings taken from Bharatpur NP and Ratnannagar NP, the concentrations were not detected for Ambient HCHO. The minimum detection level for HCHO is 53 µg/m^3.

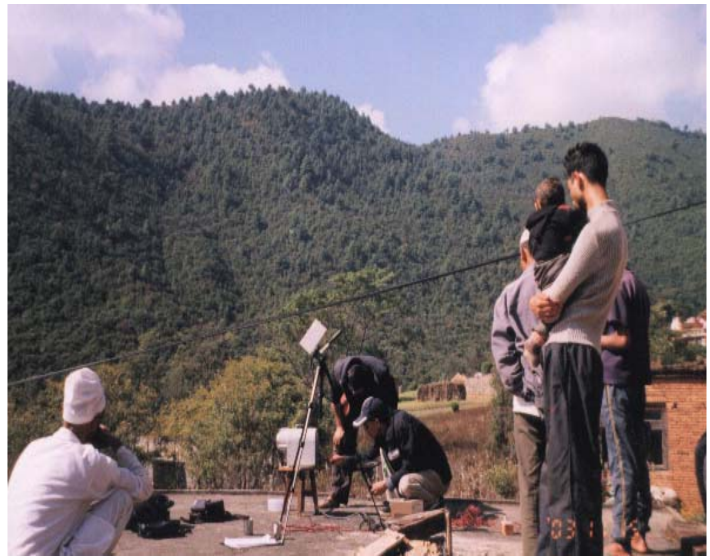
Table 25 Indoor Concentration Levels When Fuel Is Not Burning

VDC/Municipality	PM_{10}		CO		NO_2		SO_2	
	Mean (µg/m^3)	**N**	**Mean (µg/m^3)**	**N**	**Mean (µg/m^3)**	**N**	**Mean (µg/m^3)**	**N**
MatsyaGaon	420.60	1	285	1	__	0	__	0
Bharatpur NP	343.63	2	285	1	<90	1	<260	1
Seshnarayan	420.00	1	___	0	___	0	___	0
Mangalpur	60	1	___	0	___	0	___	0
Total		5		2		1		1

Table 26(a) Outdoor Pollutant Concentration Levels

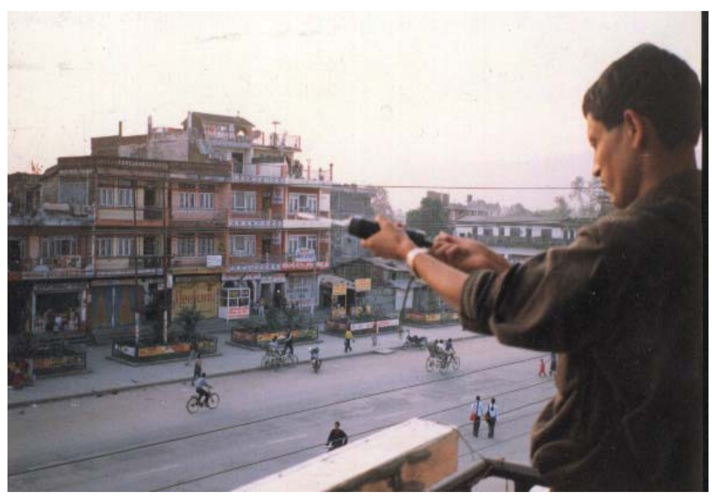
VDC/NP	PM_{10} µg/m^3	CO µg/m^3
	Outdoor	Outdoor
Bharatpur NP	320.00 780.00	1850.00
Gaidakot VDC	380.00	ND
Kathmandu NP	626.4	---
Katunje VDC	534.0	ND
Mangalpur VDC	60.00	---
Matsya gaon VDC	440.00	ND
Ratnanagar NP	537.10	1140.00
Sainbhu VDC	1149.00	---
Seshnarayan VDC	420.00	---
Seuchatar VDC	634.00	---
Total Observations	11	5

Photo 9



Ambient PM_{10} Monitoring, with LD-1 and HVS; Sheshnarayan VDC, Kathmandu

Photo 10



Gaseous monitoring in Ambient air using Gas analyzer; Bharatpur NP, Chitwan

Table 26(b) Outdoor Pollutant Concentration Levels

VDC	SO_2	NO_2	HCHO
	Outdoor	Outdoor	Outdoor
Bharatpur NP	ND	ND	ND (‹53 µg/m3)
Gaidakot	261.00		
Mangalpur	522.00	ND	
Ratnanagar NP	522.00	188.00	ND
Total Observations	4	3	2

8.2 Exposure Assessment and Related Data

Exposure as has been mentioned in earlier pages is determined by the concentration of the pollutants in air and length of time spent by the subject in that air. 24 – hr personal exposure refers to true integrated pollutant concentrations experienced by the subject in question while passing from one micro-environment to another, characterized by the presence of pollutant concentrations at various levels, during the course of an individual's daily activities.

In the present study, results on exposure have been confined to the target population comprising those who cook daily meals and carry out other domestic activities. During the survey, 168 respondents, mostly women, were interrogated about their exposure conditions inside households including kitchen, and outdoors including work and other places.

It is apparent from the survey results on daily activity pattern that majority of women spend bulk of their time in household activities such as cooking meals, rearing livestock, crop cultivation and other agriculture related activities; gathering fodders, fuel wood, crop residues etc. A few of them were students below 20 years of age who apart from going to school also attend to domestic activities including cooking.

Respondents who work mostly in non ambient conditions like shop keepers along streets, business houses, factory workers, laborers whose frequency was very low were excluded from exposure data analysis

The micro-environments in which the studied respondents spend their daily time were broadly classified in to three categories namely indoor kitchen during cooking time where the pollutant concentrations varied largely due to the fuel type used; ambient indoor during non cooking time where the pollutant concentrations were expected to remain within a narrow range at least in the rural areas and ambient outdoor where respondents carry out their day time activities. The ambient outdoor concentrations may not vary much because during the monitoring period there were no other air pollution sources in the nearby area which could alter the pollutant concentrations substantially.

Thus, the exposure assessment i.e. calculation of daily total PM_{10} exposure experienced by the respondents is based upon the following two averages.

- Mean PM_{10} concentration levels found in each of the three micro-environments: Mean kitchen PM_{10} during cooking time for different fuel types at different locations ; PM_{10} levels in ambient indoor and ambient outdoor
- Daily mean time spent in hours in each micro-environment.

Using the above data, exposure indices corresponding to various exposure conditions were calculated for comparative assessment.

8.2.1 Daily Integrated Exposures by Primary Fuel Types

Table 27 gives an overall picture of exposure for all respondents included for exposure analysis and also the comparative estimates of health risk factors under various environmental conditions. When we examine the data displayed in the table, the following points should be noted carefully.

1. All numerical data given are necessary elements for the calculation of exposure index and so were put in one single table. Column 1 of the table describing the fuel type (Primary Fuel Type which means the fuel type most often used for cooking meals as compared to others if any) are relevant only with PM_{10} concentrations as given in column 3 and not with PM_{10} levels given in column 5 and 7.
2. Columns 2, 4 and 6 show the average daily time spent by the respondents in different micro-environments which totals to 24 hours.
3. “N” represents the number of respondents from which the time averages are obtained for columns 2, 4 and 6
4. “N” represents the number of measurements from which average PM_{10} concentrations are obtained for columns 3, 5 and 7.
5. The PM_{10} concentrations as shown in columns 3, 5 and 7 are average concentrations obtained in the field survey representing average indoor kitchen concentrations during cooking time, average indoor concentration during non cooking time and average ambient outdoor concentration respectively.
6. The calculated figures given in column 8 represent the daily integrated exposure indices for the respondents under various exposure conditions.
7. The general mathematical expression for calculation of the daily integrated exposure index is given below:

   $$E_{ij} = \Sigma\, C_{ijk}\, t_{ik}$$

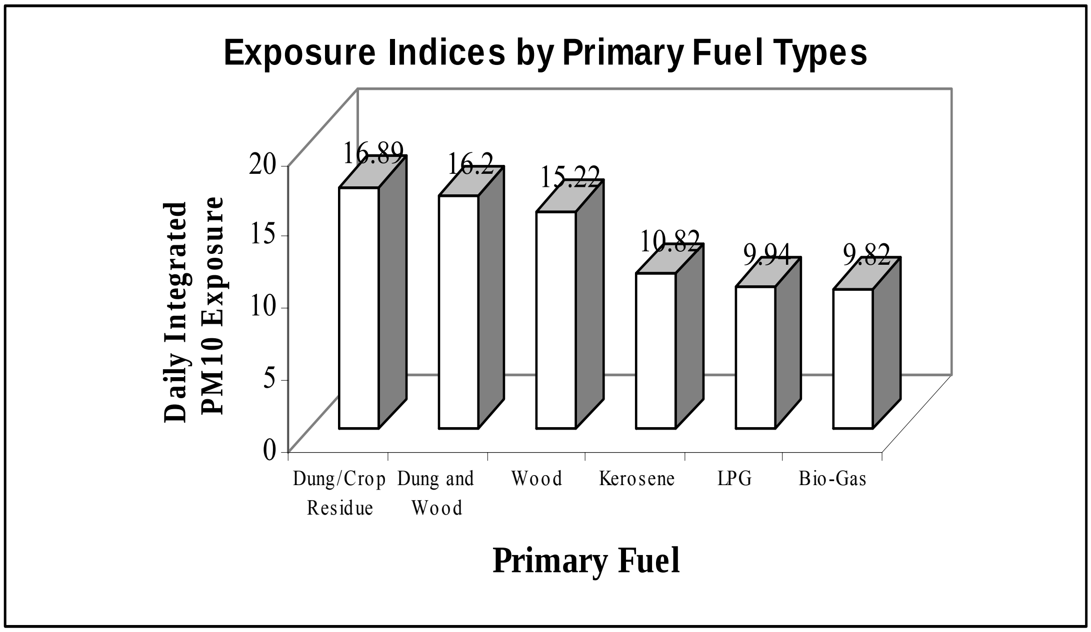
   E_{ij} is the exposure of i^{th} individual to j^{th} type of pollutant.

   C_{ijk} is the concentration of j^{th} type of pollutant measured in k^{th} type of micro-environment of i^{th} individual

   t_{ik} is the length of time spent by i^{th} individual in the k^{th} micro-environment. (Ref. 8, Page No. 172 & Ref. 24)
8. The fuel types (mixed) given in column 1 were reported by respondents as primary fuel and the corresponding mean PM_{10} were obtained in column 3 are averages from the individual fuel based monitoring results.

The exposure indices measuring the daily integrated exposures were approximately the same (ranged from 15.22 mg – hr / m^3 to 16.89 mg – hr / m^3) for solid bio-fuel users. Similarly, for cleaner fuel users (Kerosene, LPG and Bio-gas), the indices were around 10 mg – hr / m^3 (ranged from 9.82 mg – hr / m^3 to 10.82 mg – hr / m^3). Notably, exposures to solid bio-fuel users are found to be substantially higher when compared to cleaner fuel users (about 1.5 times higher). As a result, the health risk for the unprocessed fuel users is evidently at the higher level than for the processed fuel users.

Fig 9



8.2.2 Daily Integrated Exposures by Binary Fuel Types and Regions

In the following table 28, the survey results have been processed and classified in to binary fuel types (based upon primary fuel), unprocessed and processed. The data within unprocessed fuel users is further classified by eco-development regions (hills and terai) and area wise (urban and rural). The data is similarly classified for processed fuel users.

In fact, all processed data obtained from PM_{10} air quality, fuel types, time spent in different micro-environments and exposure indices have been compressed in to a single data sheet classified with regard to eco-development regions and area types. The purpose of this exercise is to see at a glance the PM_{10} exposure conditions experienced by the respondents while being in different micro-environments during the course of their daily activities. It also depicts the comparative estimates of health risk factors for each category of respondents.

According to the observed data given in the table 28, respondents (N=24) living in terai and using processed fuel (out of 153 total respondents) was relatively at low risk to health from PM_{10} exposure with exposure index being 8.34 mg – hr / m^3. Where as, respondents (N=74) accounting

Table 27 Daily Integrated Exposure by Primary Fuel Types

Primary Fuel (1)	Microenvironment						Daily Integrated Exposure ($mg - hr / m^3$) (8)
	Indoor Kitchen at Cooking Time		Indoor at Non Cooking Time		Outdoor		
	Time Spent in 24hr (hr) (2)	PM_{10} Level ($\mu g/m^3$) (3)	Time Spent in 24hr (hr) (4)	PM_{10} Level ($\mu g/m^3$) (5)	Time Spent in 24hr (hr) (6)	PM_{10} Level ($\mu g/m^3$) (7)	
Dung and Crop Residue	3.14 (N=35)	2762 (N=18)	13.66 (N=35)	321 (N=5)	7.17 (N=35)	535 (N=11)	16.89
Dung and Wood	3.06 (N=9)	2568 (N=47)	13.67 (N=9)	321 (N=5)	7.39 (N=9)	535 (N=6)	16.20
Wood	2.99 (N=71)	2298 (N=44)	13.51 (N=71)	321 (N=5)	7.51 (N=71)	535 (N=5)	15.22
Kerosene	2.83 (N=6)	880 (N=10)	14.00 (N=6)	321 (N=5)	7.17 (N=6)	535 (N=7)	10.82
LPG	2.37 (N=27)	754 (N=13)	15.96 (N=27)	321 (N=5)	5.67 (N=27)	535 (N=4)	9.94
Bio-Gas	2.87 (N=4)	667 (N=3)	15.87 (N=4)	321 (N=5)	5.25 (N=4)	535 (N=11)	9.82

48.3% of the total living in Hills using unprocessed fuel, was apparently at high PM_{10} risk to health with exposure index being 18.02 mg – hr / m^3 (comparison by binary fuel type).

Among the unprocessed fuel users, respondents from hills have higher exposure index (18.02) than the respondents from terai (13.32). However, the exposure indices for rural and urban dwellers using unprocessed fuels showed little difference (15.53 mg – hr / m^3 for rural dwellers and 14.27 mg – hr / m^3 for urban dwellers).

In spite of using processed fuel (Kerosene, LPG, or Bio-gas) for cooking, people living in hills apparently are at higher risk (12.34 mg – hr / m^3) compared to the people living in terai (8.34 mg – hr / m^3). This may be attributed probably due to difference in housing structure, state of ventilation and user behavior.

For those using processed fuels, the exposure index values showed practically no difference whether one is from rural or urban areas (10.08 mg – hr / m^3 for rural residents and 10.37 mg – hr / m^3 for urban residents).

Fig 10

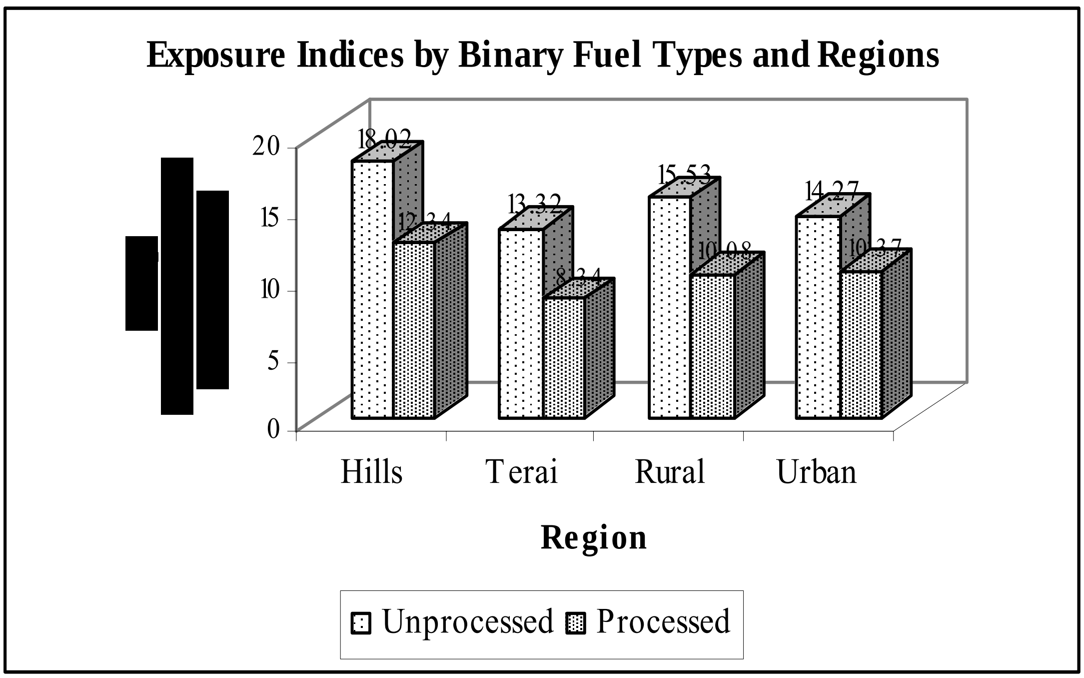


Table 28 Daily Integrated Exposure by Binary Fuel Types and Regions

Primary Fuel	Microenvironment						Daily Integrated Exposure (mg – hr / m³)
	Indoor Kitchen at Cooking Time		Indoor at Non Cooking Time		Outdoor		
	Time in 24hr (1)	PM_{10} Level (μg/m³) (2)	Time in 24hr (3)	PM_{10} Level (μg/m³) (4)	Time in 24hr (5)	PM_{10} Level (μg/m³) (6)	
Unprocessed	3.0 (N=116)	2418 (N=62)	13.6 (N=116)	321 (N=5)	7.4 (N=116)	535 (N=11)	15.58
Hills	2.9 (N=74)	2545 (N=40)	13.4 (N=74)	430 (N=2)	7.7 (N=74)	634 (N=6)	18.02
Terai	3.2 (N=42)	2187 (N=22)	13.9 (N=42)	249 (N=3)	6.9 (N=42)	415 (N=5)	13.32
Rural	3.1 (N=112)	2428 (N=60)	13.6 (N=112)	307 (N=3)	7.4 (N=112)	517 (N=7)	15.53
Urban	2.3 (N=4)	2124 (N=2)	13.3 (N=4)	344 (N=2)	8.5 (N=4)	566 (N=4)	14.27
Processed	2.5 (N=37)	793 (N=26)	15.6 (N=37)	321 (N=5)	5.9 (N=37)	535 (N=11)	10.15
Hills	2.2 (N=13)	856 (N=12)	16.8 (N=13)	430 (N=2)	5.1 (N=13)	634 (N=6)	12.34
Terai	2.7 (N=24)	738 (N=14)	15.0 (N=24)	249 (N=3)	6.3 (N=24)	415 (N=5)	08.34
Rural	2.7 (N=18)	752 (N=11)	14.1 (N=18)	307 (N=3)	7.2 (N=18)	517 (N=7)	10.08
Urban	2.3 (N=19)	818 (N=16)	17.1 (N=19)	344 (N=2)	4.6 (N=19)	566 (N=4)	10.37

At this point, it may be interesting to elaborate on the magnitude of 24-hr. exposure index values obtained (Range: 8.34 to 18.02 mg-hr./m^3).

The main purpose of the exposure indices presented above is to make comparative assessment of daily integrated exposures between categories (e. g. Hills and Terai). Otherwise, it is to be noted that these indices may not represent the true exposure values under the prevailing field conditions because of the following reasons:

- The mean time spent by the respondents in the kitchen during cooking hours was about 3 hours daily. Thus, even with 10 minutes averaging time used for PM_{10} measurement, the exposure index load component from kitchen exposure may reflect true exposure conditions.

- Where as, the total time spent by the respondents in indoor non-cooking time plus outdoor was about 21 hours and the PM_{10} concentrations obtained with 10 minutes averaging time may not reflect true field exposure conditions and consequently, the load component calculated for those two micro-environments may not match the field conditions (resulting in to over estimation of 24-hr exposure index values).

Now, for the estimation of ambient PM_{10} in the Kathmandu Valley air, ESPS (DANIDA) / MOPE has been running 6 permanent Air Quality Monitoring Stations located at various places to represent Core, Sub-Core, Residential and Remote areas. These stations have been automatically recording 24-hr PM_{10} concentration levels for more than a year now and the results being disseminated through various communication media.

For our purpose, monthly mean PM_{10} values from 6 stations have been collected for 4 months: November and December of 2003 and January and February of 2004 (this was field monitoring duration of this study) and from the monthly data of 6 stations given in Annex 5, 24 hr PM_{10} Valley average for that 4 months duration has been calculated. This Valley mean is considered to realistically represent the indoor / outdoor ambient air quality condition (PM_{10}) of the study area of Kathmandu Valley. The calculated daily exposure index with the valley PM_{10} and other related data is shown below (table 29).

The corresponding daily exposure indices calculated from survey results with 10 min. averaging time were 18.02 mg-hr / m^3 and 12.34 mg-hr / m^3 (Table 28), which shows that the magnitude of the exposure indices have been considerably reduced. But the ratio of ratio of unprocessed to Processed changed only slightly (from 1.46 to 2.0).

Table 29 Daily Exposure Indices (Hills)

Primary Fuel	Kitchen, Cooking Time: Time spent In hr.	Kitchen, Cooking Time: PM_{10} (µg/m^3) 10 min. averaging time	Indoor, Non-cooking time & outdoor ambient: Time spent in hr.	Indoor, Non-cooking time & outdoor ambient: PM_{10} (µg/m^3) 24 hr averaging time	Daily Exposure Indices Mg-hr / m^3
Unprocessed Hills	2.9 N=74	2545 N=40	21.1 N=74	161 N=715	10.78
Processed Hills	2.1 N=13	856 N=12	21.8 N=13	161 N=715	5.39

8.3 Results on Health Effects (Photos: 11, 12, 13)

Studies in the past have shown association between Indoor Air Pollution and many diseases related to respiratory disorders and infections such as Chronic Obstructive Pulmonary Disease (COPD), Asthma, Lung Cancer, Cataract, Acute Lower Respiratory Infections (ALRI), Low Birth Weight in newly born babies etc. particularly to women and children who are exposed to Solid Bio-fuels. In this context, all the respondents were screened through the following health check ups to identify respiratory problems and diseases, in particular to examine the extent of health effects due to indoor air pollution.

- General Health Check Up including chest examination and BP measurement.
- ENT Examination
- Peak Flow Meter Examination
- Responses through British MRC questionnaire on respiratory symptoms such as occurrences of Cough, Phlegm, Wheezing, Breathlessness and past illness.

In addition, the mothers of the children below 5 years of age were questioned for the identification of Acute Respiratory Infection (ARI) in children. Data arising from responses and medical examination were scrutinized and classified into the following major health outcomes / diseases:

- Eye, Ear and Nose Problems including Cataract
- Upper Respiratory Infection (URI)
- Lower Respiratory Infection (LRI)
- Prevalence of Cough, Phlegm, Wheezing and Breathlessness
- Chronic Respiratory Diseases such as COPD and Asthma
- Acute Respiratory Infection (ARI) in Children below 5 years of age
- Other problems / Diseases

Upper Respiratory Infections (URI) included all Respiratory Infections that effect Ear, Nose and Throat such as, Sinusitis, Influenza, Rhinitis, Tonsillitis, Pharyngitis, Otitis Media etc.

Photo 11

Conducting Medical Examination to a respondent; Syuechatar VDC, Kathmandu

Similarly Lower Respiratory Infections included all infections on Trachea, Bronchial Tubes and Lung itself such as Broncholitis, Pneumonia etc.

Prevalence of COPD, Asthma and Respiratory infections were judged through clinical examination, responses on respiratory symptoms on cough, phlegm, wheezing, breathlessness and Peak Flow Meter readings.

Acute Respiratory Infection (ARI), mainly lower respiratory infection in children below 5 years of age was judged through clinical examination of children and responses given by their mothers. The data generated though examinations and responses were processed and categorized to compute the following statistics

- The overall symptoms / diseases Prevalence Rates.
- Prevalence Rates categorized by Eco-regions, Area types and Binary Fuel types.
- Odds Ratios for exposed group (with a risk factor using unprocessed solid bio-fuels) as compared to unexposed group (without risk factor using processed fuels).
- Odds Ratios considering two potential confounding variables namely smoking habit and age.

8.3.1 Prevalence of Respiratory Diseases / Problems

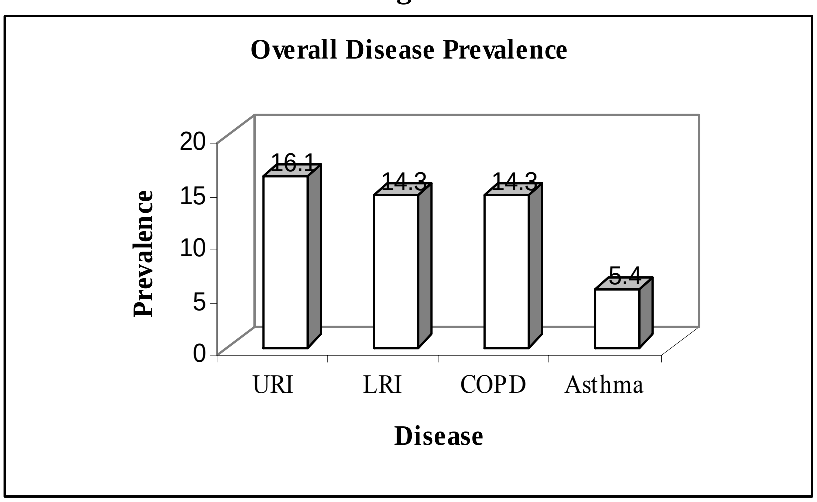
8.3.1.1 Overall Prevalence

The following table 30 shows the prevalence of different respiratory diseases among the respondents (168) most of whom were women (94%). Except for Asthma and Eye/Ear problems, the prevalence of all respiratory diseases is found to be substantial. The highest prevalence is found to be 18.5 % for COPD or Asthma jointly where as 16.1% and 14.3% were suffering from URI and LRI respectively. Also 17.3% of the respondents had nose problems.

Table 30 Overall Frequency Distribution of Diseases / Problems

S.N.	Disease / Problem	Yes		No		Total
		Frequency	%	Frequency	%	
1	Eye Problem (Including Cataract)	8	4.8	160	95.2	168
2	Nose Problem	29	17.3	139	82.7	168
3	Ear Problem	8	4.8	160	95.2	168
4	URI	27	16.1	141	83.9	168
5	LRI	24	14.3	144	85.7	168
6	Chronic Respiratory Diseases (COPD/Asthma)	31	18.5	137	81.5	168
6(a)	COPD	24	14.3	144	85.7	168
6(b)	Asthma	9	5.4	159	94.6	168

Fig 11



8.3.1.2 Prevalence by Eco-regions and Area Types

Eco-Regions

In general, respondents from Hills showed higher prevalence of respiratory diseases as well as respiratory problems as compared to respondents from Terai. For instance, the prevalence of COPD / Asthma jointly is found to be more than twice in Hills than in Terai and that of LRI is 14.7% in Hills as compared to 13.7 in Terai (Table 31).

Table 31 Frequency Distribution of Individuals with Diseases / Problems by Eco-Regions

S.N.	Disease / Symptom	Hills		Terai		Total
		Frequency	%	Frequency	%	
1	Eye Problem (Including Cataract)	5	5.3	3	4.1	8
2	Nose Problem	14	14.7	15	20.5	29
3	Ear Problem	7	7.4	1	1.4	8
4	URI	16	16.8	11	15.1	27
5	LRI	14	14.7	10	13.7	24
6	Chronic Respiratory Disease (COPD / Asthma)	23	24.2	8	11.0	31
6(a)	COPD	19	20.0	5	6.8	24
6(b)	Asthma	6	6.3	3	4.1	9

Area Types

Except for Nose problem and URI, the prevalence of other diseases and infections including LRI, COPD / Asthma are found to be much higher in rural areas as compared to urban areas of Nepal. One of the principal factors responsible for this higher prevalence in rural areas could be more abundant use of Unprocessed Solid Bio-Fuels in the rural areas (Table 32)

Fig 12

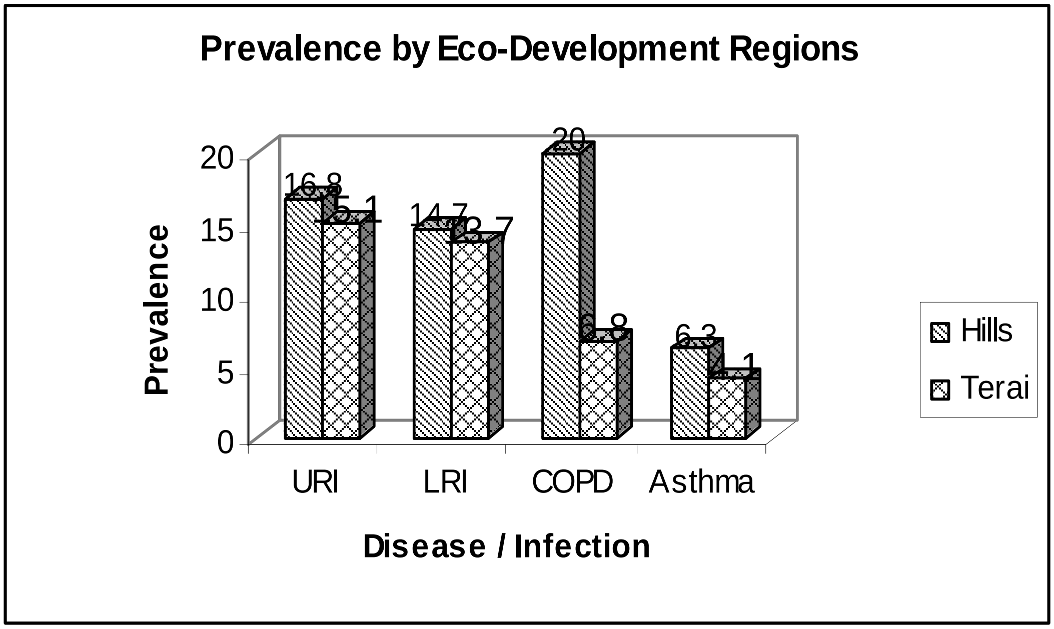


Table 32 Frequency Distribution of Individuals with Diseases / Problems by Area Types

S.N.	Disease / Symptom	Rural		Urban		Total
		Frequency	%	Frequency	%	
1	Eye Problem (Including Cataract)	8	5.7	0	0.0	8
2	Nose Problem	24	17.1	5	17.9	29
3	Ear Problem	7	5.0	1	3.6	8
4	URI	21	15.0	6	21.4	27
5	LRI	22	15.7	2	7.1	24
6	Chronic Respiratory Disease (COPD / Asthma)	29	20.7	2	7.1	31
6(a)	COPD	23	16.4	1	3.6	24
6(b)	Asthma	8	5.7	1	3.6	9

8.3.1.3 Prevalence by Binary Fuel Types

If we examine the diseases as well as respiratory problems prevalence by Binary fuel types (regarding primary fuel types and not the fuel types used at the time of monitoring where primary means the fuel type most often used), we find that for more serious problems like LRI, COPD or Asthma, much higher prevalence were detected for those individuals who depend upon unprocessed fuels than those who depend upon processed fuels. For instance, the prevalence of COPD and LRI is found to be 16.8% for those using unprocessed fuels as compared to 7% for those using processed fuels respectively. However, for others like URI, the prevalence is found to be higher for processed fuels rather than unprocessed fuels (Table 33)

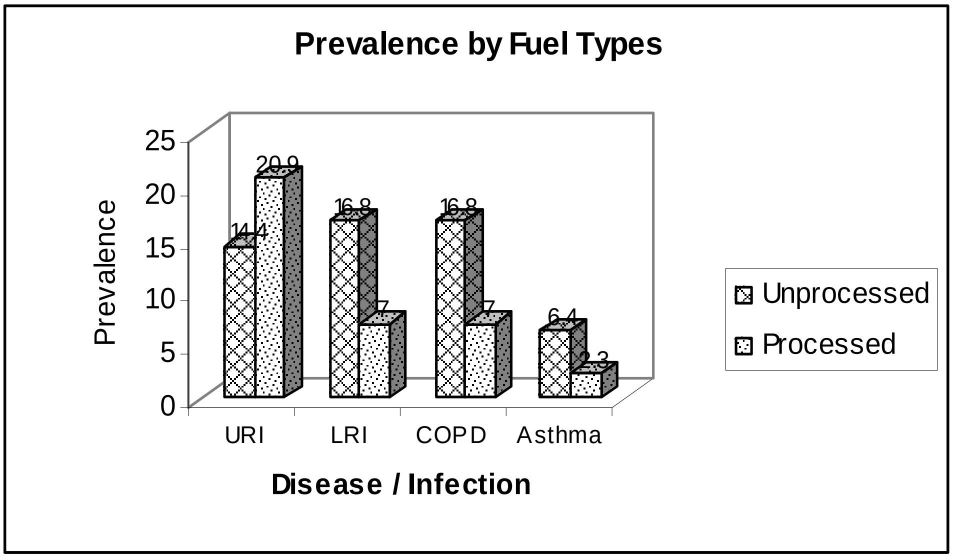
Photo 12

Asking Questions before Conducting Medical Examination to a respondent; Sudal VDC, Bhaktapur

Table 33 Frequency Distribution of Individuals with Diseases / Problems by Binary Fuel Types

S.N.	Disease / Symptom	Unprocessed Solid Bio-fuels		Processed Fuel		Total
		Frequency	%	Frequency	%	
1	Eye Problem (Including Cataract)	8	6.4	0	0.0	8
2	Nose Problem	20	16.0	9	20.9	29
3	Ear Problem	7	5.6	1	2.3	8
4	URI	18	14.4	9	20.9	27
5	LRI	21	16.8	3	7.0	24
6	Chronic Respiratory Disease (COPD / Asthma)	28	22.4	3	7.0	31
6(a)	COPD	21	16.8	3	7.0	24
6(b)	Asthma	8	6.4	1	2.3	9

Fig 13



8.3.2 Prevalence of Respiratory Symptoms

Respondents were asked about different reparatory symptoms according to British Medical Research Council (MRC) questionnaire. The main reason for using this questionnaire was to detect COPD and Asthma among the respondents. Presence of wheezing and Breathlessness indicates the presence of Asthma while presence of all respiratory symptoms including Cough, Phlegm, Wheezing and Breathlessness is an indication of COPD.
The definitions of respiratory symptoms according to MRC questionnaire is shown in table 34.

Table 34 Respiratory Symptoms Definitions

Symptom	Meaning
Cough	Usual occurrence of cough first thing in the winter mornings
Phlegm	Usual occurrence of phlegm from chest first thing in the winter mornings
Cough and Phlegm	Experience of Cough and Phlegm lasting for three weeks or more during past three years
Breathlessness	Troubled by shortness of breath when hurrying on level ground or walking up a slight hill
Wheezing	Attacks of wheezing or whistling in chest at any time in the past one year

8.3.2.1 Overall Prevalence

The frequency distribution of respiratory symptoms experienced by the respondents is shown in table. The table 35 shows substantial proportion of respondents with occurrence of all the respiratory symptoms. Among various symptoms, prevalence of Cough is found to be highest (31.5%). A substantial proportion (20.2%) of the respondents had both wheezing and breathlessness problems which is an indication of possible Asthma in them. Moreover, 11.9% of the respondents complained of having all the respiratory symptoms and 35.7% experienced at least one respiratory symptom.

8.3.2.2 Prevalence by Binary Fuel Types

The frequency distribution of prevalence of all respiratory symptoms categorized by binary fuel types is shown in table 36. The table shows much higher prevalence in all respiratory symptoms for unprocessed fuel users as compared to processed fuel users. The prevalence of respiratory symptoms is approximately 2.5 to 4 times higher for unprocessed solid bio-fuel with highest 4.1 times for Wheezing and the lowest 2.58 times for Phlegm.

Table 35 Frequency Distribution of Respiratory Symptoms

Symptom	Yes		No		Total
	Frequency	%	Frequency	%	Count
Cough	53	31.5	115	68.5	168
Phlegm	34	20.2	134	79.8	168
Cough and Phlegm	26	15.5	142	84.5	168
Breathlessness	46	27.4	122	72.6	168
Wheezing	39	23.2	129	76.8	168
At least One Respiratory Symptom	60	35.7	108	64.3	168
Breathlessness and Wheezing	34	20.2	134	79.8	168
All Respiratory Symptoms	20	11.9	148	88.1	168

Total unprocessed fuel users = 125 and total processed fuel users = 43

Fig 14

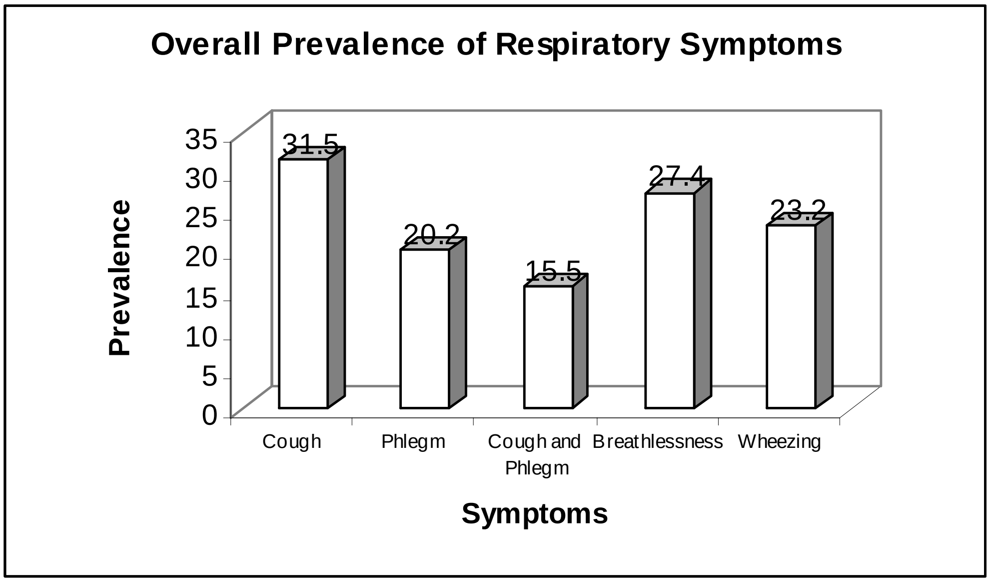


Table 36 Frequency Distribution of Individuals with Respiratory Symptoms by Binary Fuel Types

Symptom	Ratio	Unprocessed Solid Bio-fuels		Processed Fuels		Total
		Frequency	%	Frequency	%	
Cough	2.68	47	37.6	6	14.0	53
Phlegm	2.58	30	24.0	4	9.3	34
Cough and Phlegm	2.63	23	18.4	3	7.0	26
Breathlessness	2.83	41	32.8	5	11.6	46
Wheezing	4.11	36	28.8	3	7.0	39
At least One Respiratory Symptom	3.08	54	43.2	6	14.0	60
Breathlessness and Wheezing	3.54	31	24.8	3	7.0	34
All Respiratory Symptoms	3.06	18	14.4	2	4.7	20

8.3.3 Odds Ratios

Odds Ratios have been computed for various respiratory diseases, infections and symptoms for comparing risks associated with exposed group of individuals with respect to relatively unexposed group of individuals. In the present context, group of individuals having the risk factor is taken as unprocessed solid bio-fuel users and the group without risk factor or relatively much lower risk is taken as processed fuel users.

Photo 13

Conducting Medical Examination to a small boy; Gaindakot VDC, Terai

In order to find whether the computed sample Odds ratios are statistically significant or not, 95% confidence intervals for Odds Ratios have been set up. If the intervals include value 1, then the computed Odds Ratios are considered as insignificant at 95% confidence interval. If otherwise, the values are considered as statistically significant.

In addition, P values have also been mentioned to see whether binary fuel types (regarding primary fuel) are statistically significant in modeling health effects (diseases / symptoms) by Binary Logistic Regression. The normal practice is if $p < 0.05$, then the explanatory variable (binary fuel type) are said to be statistically significant at 5% level of significance.

As for the present analysis, Odds Ratios have been computed for cases with LRI, COPD, Asthma and various respiratory symptoms.

Moreover, Odds Ratios have been computed considering principal confounding factors, namely smoking and age.

8.3.3.1 Odds Ratios for Respiratory Diseases / Infection

As shown in table 37, the odds ratios for LRI, COPD and Asthma are 2.69, 2.69 and 2.87 respectively. If COPD and Asthma are to be considered jointly, the unadjusted odds ratio would be 3.85.

The computed Odds Ratio for LRI is found to be statistically insignificant ($p>0.05$) where as Odds Ratio for COPD / Asthma taken jointly is found to be statistically significant ($p<0.05$) with 95% confidence interval from 1.11 to 13.38.

Considering smoking habit as the confounding variable, the Odds Ratios for LRI and COPD/Asthma are found to be 2.75 and 5.21 for non smokers respectively. Similarly, the Odds Ratio for COPD/Asthma is found to be 1.52 for smokers (current or previous).

The above figures imply the following:

- Odds Ratio is highest for COPD/Asthma (3.17) suggesting that the risk of getting COPD or Asthma is 3 fold higher for unprocessed solid bio-fuel users as compared to processed fuel users.

- The Odds Ratios for COPD/Asthma are found to be 5.21 for non smokers and 1.52 for smokers. This shows that Odds Ratio is much higher for non smokers than smokers.

- Similar scenario emerges when we find Odds Ratios for COPD comparing non smokers and smokers as in case of COPD/Asthma.

Considering age as the confounding variable, the Odds Ratios for LRI and COPD/Asthma are found to be 6.48 and 3.04 for individuals below 40 years of age respectively and 0.68 and 2.19 for individuals aged 40 or above respectively. The figures show that the Odds Ratios are higher for younger exposed population than the exposed older ones.

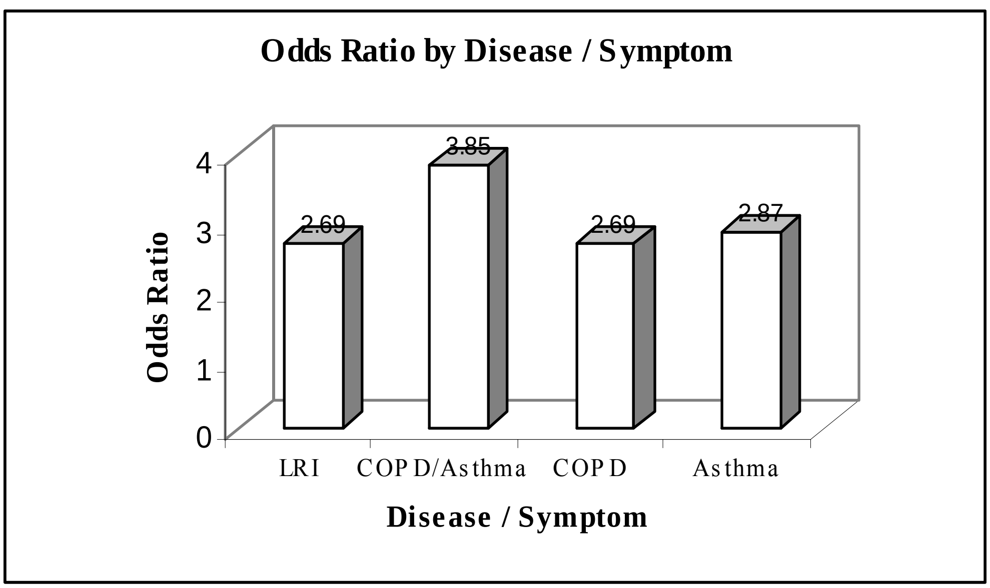
However, it is to be noted that the Odds ratios computed separately for non smokers, smokers, aged below 40 and aged 40 or above are not found to be statistically significant at 95% confidence interval.

Table 37 Odds Ratios for Respiratory Diseases / Infection

S.N	Disease	Odds Ratio	Odds Ratio			
			Smoking Status		Age Group	
			Non Smoker	Smoker	Up to 40	Above 40
1	LRI	2.69 (0.76 – 9.52)	2.75	--	6.48	0.68
2	Chronic Respiratory Disease (COPD / Asthma)	3.85* (1.11 – 13.38)	5.21	1.52	3.04	2.19
3	COPD	2.69 (0.76 – 9.52)	2.20	1.36	0.93	2.00
4	Asthma	2.87 0.35 – 23.63	--	--	1.95	-

* means statistically significant at 95% confidence interval and confidence intervals are stated within the brackets.

Fig 15



8.3.3.2 Odds Ratios for Respiratory Symptoms

As shown in table 38, Odds Ratios ranged between 3 and 5.4 for respiratory symptoms, the highest found to be 5.39 for wheezing and lowest, 3.00 for Cough and Phlegm. The computed Odds ratios are found to be statistically significant for Cough ($p<0.01$), Phlegm ($p< 0.05$), Breathlessness ($p<0.05$) and Wheezing ($p<0.01$); with 95% confidence intervals, 1.46 – 9.46, 1.02 – 9.32, 1.36 – 10.13 and 1.57 – 18.55 respectively. In addition, the Odds Ratios were significant for occurrence of at least one respiratory symptom ($p<0.01$) and breathlessness and wheezing ($p<0.05$). However, the insignificant Odds Ratios were found for Cough and Phlegm and occurrence of all respiratory symptoms.

The table also shows Odds ratios for non smokers, smokers, aged below 40 and aged 40 or above separately. In all the cases the Odds ratios are found to be much higher for non smokers than smokers. This means that non smokers are more vulnerable to unprocessed solid bio-fuel exposure than the smokers which could be because smokers may have more tendencies to develop respiratory symptoms with or without kitchen smoke exposures as compared to non smokers. When adjusted for age group, the odds ratios showed mixed results. It increased for individuals up to age 40 for some of the respiratory symptoms but decreased for rest of the respiratory symptoms. Similar mixed results were obtained for individuals of age 40 or above.

Fig 16

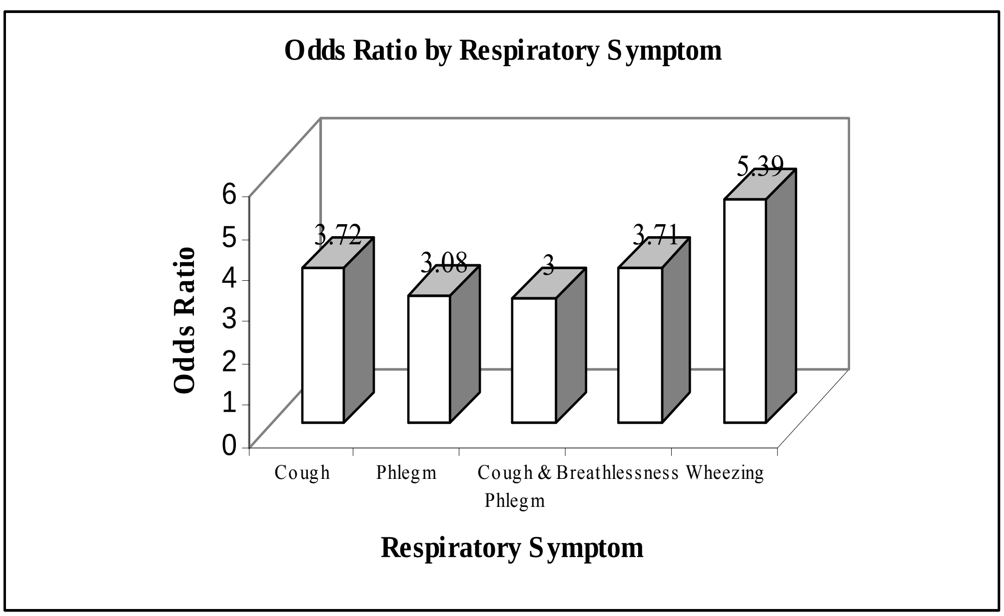


Table 38 Odds Ratios for Respiratory Symptoms

S.N	Disease	Odds Ratio	Odds Ratio			
			Smoking Status		Age Group	
			Non Smoker	Smoker	Up to 40	Above 40
1	Cough	3.71* (1.46 – 9.46)	3.52* (1.13 – 10.94)	2.35	2.25	3.14
2	Phlegm	3.08* (1.02 – 9.32)	3.35	1.36	2.37	1.65
3	Cough and Phlegm	3.00 (0.85 – 10.57)	4.67	0.96	1.46	3.16
4	Breathlessness	3.71* (1.36 – 10.13)	4.32* (1.21 – 15.38)	1.70	2.44	2.62
5	Wheezing	5.39* (1.57 – 18.55)	10.74* (1.38 – 83.34)	1.36	6.97	2.00
6	At least One Respiratory Symptom	4.69* (1.85 – 11.91)	4.80* (1.56 – 14.79)	2.62	5.37	4.10
7	Breathlessness and Wheezing	4.40* (1.27 – 15.22)	8.74* (1.12 – 68.33)	1.22	5.54	1.65
	All Respiratory Symptoms	3.44 (0.77 – 15.47)	—	0.85	2.30	2.26

* means statistically significant at 95% confidence interval and confidence intervals are stated within the brackets.

8.3.4 Acute Respiratory Infection (ARI) in Children below Age 5

Acute Respiratory Infection (ARI) in children has been associated to indoor air pollution in many studies particularly to those children who are below 5 years of age and stay in kitchen along with mothers during cooking time with unprocessed fuel burning. The general tendency of mothers in rural areas of developing nations like Nepal has been found to accompany their young ones along with them in kitchen while cooking meals. The fact is also supported by the current study (25 out of 29 children stay with their mothers in kitchen during cooking time in rural area). This could be one of the major reasons of high prevalence of ARI in children.

From all the surveyed households, only in 26 households, children of age below 5 were found. Therefore, all the results presented in this section are based upon data generated from these 26 households with 29 children of age below 5. Clinical examinations were conducted along with responses provided by mothers for all these children.
Questions asked to mothers were

- Whether the child had any illness with cough or cold at any time in the past 2 weeks
- If yes, what were the symptoms?
- From where did the child get the treatment?
- How many times had the child suffered from ARI during the last year?

The existence of ARI on a child was determined by general medical check up as well as by the responses given by the mothers. The presence of cough and breathing problem with fever has been strongly correlated with the presence of ARI in children. Odds ratios are not computed here because of lack of sufficient sample size of the children below 5 years of age.

8.3.4.1 Prevalence of illness with Cough or Cold in the Past 2 Weeks

Among 29 children examined, 20 (69%) of the children had illness with cough or cold during the past 2 weeks prior to survey. The prevalence of symptoms of these children is given in table. The values in the table demonstrates that more than 90% of the children suffering from illness had fever, cough and blocked or running nose and more than 50% had all the above mentioned symptoms including difficulty in breathing or breathing fast. About 21% had eating problem and 5% had chest in drawing (Table 39).

8.3.4.2 Prevalence of Acute Respiratory Infection (ARI)

With general clinical examination of the child and assessing the responses given by the mothers, the prevalence of ARI was computed. Among 29 children, 11 children had ARI which accounts to 37.9% of the total.

Table 39 Frequency Distribution of Symptoms during Illness

Symptom	Positive Response		Negative Response		Total
	Count	%	Count	%	Count
Existence of coughing	19	95.0	1	5.0	20
Existence of blocked or running nose	18	90.0	2	10.0	20
Existence of fever	19	95.0	1	5.0	20
Baby is breathing fast	14	70.0	6	30.0	20
Baby is breathing in difficulty	11	55.0	9	45.0	20
Baby has chest in drawing	1	5.0	19	95.0	20
baby has problem during eating or drinking	4	21.1	15	78.9	19

The prevalence of ARI by binary fuel types is given in table. The table shows that for unprocessed fuel users 10 out of 22 (45.5%) had ARI and for processed fuel users 1 out of 7 (14.3%) had ARI. The prevalence is 3.2 times higher for unprocessed fuel users though the frequency distribution for processed fuel users has been low (Table 40).

Table 40 Prevalence of ARI by Binary Fuel Types

Binary fuel Type	With ARI		Without ARI		Total
	Count	%	Count	%	
Unprocessed Fuel	10	45.5	12	54.5	22
Processed Fuel	1	14.3	6	85.7	3
Total	11		18		29

8.3.4.3 Frequency of Occurrence of ARI During the Past One Year

The number of occurrence of ARI in Children below 5 years in the past one year has been recorded through the responses provided by the mothers though they are subjective in nature. On the average children suffered from ARI 4.1 times in the past one year prior to survey which is a high figure. For unprocessed Solid Bio-fuel users the average is 4.2 and for processed fuel users, the average is 3.7. This implies that the average number of times children below 5 years had ARI is higher for unprocessed fuel than for processed fuel (Table 41).

Considering the fact that occurrence of ARI or any other respiratory disorder, particularly for those who use unprocessed fuels, is also likely to depend upon how often the child stays inside kitchen at the time of cooking, the following cross tabulation is constructed for average number of times children suffered from ARI during the past one year.

Table 41 Average Number of Times Children Below 5 Years Suffered from ARI in the Past One Year by Fuel Types and Duration of Stay in Kitchen

Binary fuel Type	Unprocessed Fuel		Processed Fuel		Total
	Mean	N	Mean	N	
Sometimes	3.90	10	4.33	3	13
Often	4.78	9	4.00	3	12
Total	11	19	9	6	25

4 Non response cases

If we look at the table, we find that the average increases only for unprocessed fuel users from 3.9 to 4.78 comparing children who stayed only sometimes inside kitchen with those who stayed regularly inside kitchen. However, the average does not show the same kind of increment for processed fuel users but surprisingly decreases.

8.3.5 Other Diseases

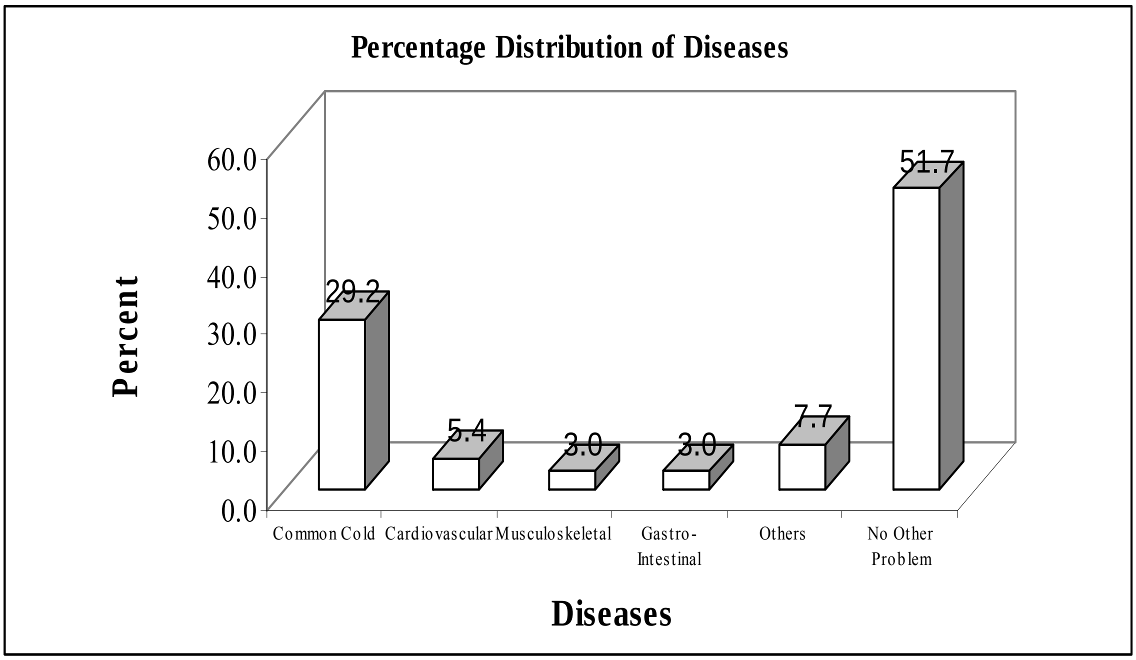
Respondents were also asked if they suffered from diseases other than respiratory. The table below shows the frequency distribution of diseases other than respiratory except Common Cold. The frequency distribution of Common cold, though a respiratory infection is presented here since it has not been linked to indoor air pollution.

Table 42 shows that 29.2% of the respondent had common cold (which may well be due to seasonal effect since the time of survey was winter), 5.4% had Cardio-Vascular disease, 3.0% had Musculo-skeletal problem and 3.0% had Gastro-Intestinal disorders.

Table 42 Existence of Other Diseases

Disease / Problem	Frequency	Percent
Common Cold	49	29.2
Cardiovascular Disease	9	5.4
Musculoskeletal Problem	5	3.0
Gastro-Intestinal Problem	5	3.0
Others	13	7.7
No Other Problem	87	51.8
Total	168	100.0

Fig 17



9.0 Key Findings

Key findings of the study are regarded as follows:

Smoke / PM_{10} Pollution

- Regarding smoke / PM_{10} pollution, the worst scenario is represented by the kitchen air with traditional clay stoves using solid bio-fuels (dung, crop residue and wood) where the mean PM_{10} concentration level is found to be 2418 μg/m^3 (average of 62 readings).

- Under similar ventilation and other household conditions, the mean smoke / PM_{10} concentration level in kitchens using cleaner fuels (kerosene, LPG, biogas) is found to be 792 μg/m^3 (26 readings) which is about 3 times low.

- Under above conditions, the daily integrated PM_{10} exposure index level is estimated to be 15.58 mg-hr/m^3 for those exposed to solid bio-fuel smoke and 10.15 mg-hr/m^3 for those exposed to cleaner fuels.

- Comparing smoke/PM_{10} pollution by eco-regions for solid bio-fuel users, the hill kitchens seem to be more polluted (Mean PM_{10}, 2545 μg/m^3) as compared to kitchens from plains (Mean PM_{10}, 2186 μg/m^3). Similarly, area-wise also, rural kitchens are more polluted (Mean PM_{10}, 2427 μg/m^3) compared to urban kitchens (2124 μg/m^3.). The observed differences in kitchen pollution can be attributed to differences in ventilation conditions. But for those using cleaner fuels, the pollution levels do not seem to vary much region-wise or area-wise.

- As has been observed in other countries, solid bio-fuels are the main sources of indoor air pollution for both hills and plains and also rural and urban homes of Nepal.

Health Responses

- The health responses recorded for all the respondents (168) exposed to various levels of air pollution in indoor kitchen during cooking time seem to corroborate fully with the state of exposure conditions to which each group of individuals is subjected. This means that those who are exposed to solid bio-fuels smoke reported of having higher prevalence of respiratory abnormalities as compared to clean fuel users. For instance, prevalence of COPD and LRI among unprocessed fuel users was found to be 16.8% compared to only 7% for those using processed fuels (table 31).

- Similarly, much higher prevalence in all respiratory symptoms (2.5 to 4 times) has been found for unprocessed fuel users. For instance, 24.8% of the respondents using unprocessed fuels reported having breathlessness and wheezing and 14.4% reported having all respiratory symptoms. The corresponding figures for processed fuels were 7% and 4.7% respectively.

- Relative risk estimates in terms of Odds Ratios have also been computed in order to compare health outcomes (respiratory diseases and symptoms) associated with unprocessed fuel users as compared to processed fuel users. Statistically significant Odds Ratio (3.85) with 95% confidence interval, 1.11 – 13.84 was detected for Chronic respiratory Diseases (COPD and Asthma jointly).

- Similarly, statistically significant Odds Ratios with 95% confidence level were found for respiratory symptoms, namely Cough (3.71), Phlegm (3.08), Breathlessness (3.71) and Wheezing (5.39). The 95% confidence intervals were 1.46 – 9.46, 1.02 – 9.32, 1.36 – 10.13, 1.57 – 18.55 respectively.

- Considering smoking as a potential confounder, Odds ratios have been computed separately for Non-smokers and Smokers. The values show that Non-smokers have relatively higher odds ratio than smokers (5.21 for non-smokers and 1.52 for smokers) regarding COPD/Asthma taken jointly. Similarly, higher odds ratios were computed for non-smokers regarding all respiratory symptoms when compared to smokers.

- Similarly, considering age as another confounder, Odds ratios have been computed separately for two different age groups. The values show that for individuals aged below 40, the odds ratio is higher as compared to those aged 40 or above (3.04 for aged below 40 and 2.19 for aged 40 or above) regarding COPD/Asthma jointly. However, mixed results were obtained regarding different respiratory symptoms. In some respiratory symptoms, individuals aged below 40 had higher odds ratios and for other respiratory symptoms, individuals aged 40 or above had higher odds ratios.

- The prevalence of ARI among children aged below 5 is found to be 37.9% (11 out of 29 examined). Comparing ARI by binary fuel types, children with unprocessed fuel in kitchen had higher prevalence (58.8%, 10 out of 17)) as compared to children with processed fuel in kitchen (33.3%, 1 out of 3).

10.0 Indoor Air Pollution, Measures of Intervention, and Policy considerations

From what has been mentioned so far, it becomes clear that Indoor Air Pollution in Nepalese houses is real. The principal pollutant, smoke particulate originates from freshly combusted biomass. The ensuing smoke exposure conditions are unacceptable by any human standards and therefore, severe health effects attributable to indoor kitchen air seems indisputable.

Measures of Intervention

A wide range of interventions are available to reduce IAP and some of them are being carried out in Nepal too, such as:

- Changes in Energy Technology

➢ Switching from biomass fuels to cleaner fuels such as, fossil fuels: SKO, LPG; or Biogas; use of solar energy in the form of solar heaters etc.

During the field survey, a few biogas using kitchens were visited (Mixed Fuel Using Household). The users seem to be satisfied with the biogas plant performances which substantially reduced the smoke levels as is indicated by the monitoring results but apparently there are not many biogas operating houses in the area visited although local people seem to be quite interested to have one in their kitchens.

During the field visits, it was also observed that several houses which used to depend solely on biomass fuels for cooking meals only a few years ago, now used kerosene / LPG frequently depending upon availability. This shows that rural people too is prone to switch over to cleaner fuels provided they are available at their proximity.

➢ Improving the design and construction of locally made traditional stoves by the use of chimney, fume hoods and others.

One intervention measure which is being implemented in some bigger scale in Nepal seems to be in the construction of clay stoves fitted with vents, an improved version of traditional

Ageno Chulo. But a few kitchens using such stoves (photo 8) studied, indicated that there seemed to be no observable reduction in smoke pollution, probably because either these stoves are not being maintained in a proper way or they need some construction/design improvements.

Bhuse Chulo has been described in earlier pages. This is one such stove which seems to be environment-friendly (except for a short time during initial burning when it is smoky) because smoke level measured is considerably low during cooking time compared to the traditional one. But users are not many probably because cooking with this takes a longer time (lower heat efficiency) or saw dust/rice husk is not easily available.

- Changes in Living Environment

Improving ventilation through changes in windows, their sizes, providing more eves spaces.

Traditionally also biomass fuel users do seem to be aware of smoky kitchens during cooking time and in order to get some sort of relief from concentrated smoke, kitchen spaces are made larger in size whenever possible in rural houses (Photo 14), but in relation to ventilation, open window areas are too small. Such kitchen spaces are also used for storing daily required utilities. The study also indicated that the mean area of kitchen was around 13.6290 m^2 which is large enough for a rural home (c/o guidelines for ventilation, section 12). The study also demonstrated that the kitchen pollution decreased as the ventilation situation improved and that there is scope for reducing pollution with small changes in ventilation situation such as, keeping the already present windows open during cooking times (a case of reduced awareness).

- Raising awareness among locals, particularly women and building up participatory approach.

Awareness among women having babies to care seems to be still at low key regarding smoke exposure and health care. A case in point is that out of 29 babies examined, 20 showed respiratory symptoms of illness at varying degree (8.3.4.1, table: 38). Thus mothers should take care that babies are kept away from fire during cooking time as far as possible.

Local people from visited areas were found to be enthusiastically responding to our queries and assisting in pollution monitoring works. They were particularly glad to see a medical doctor at their doorsteps, a rare event in rural homes of Nepal and were found to be quite open in medical responses

The general indication is that there is a lot more things to be accomplished in terms of strengthening health care units and others.

Regarding improvements in housing and ventilation conditions, it is hard to see how it could be affected in practical terms because apart from environmental aspects, they are also related with local topography, climate, security, cultural as well as socio-economic aspects.

- Government Policy Considerations

It is expected that reducing indoor air pollution requires an inter-disciplinary approach and any intervention measure can best be implemented through participation by all concerned stakeholders from different sectors, such as, health, environment, development, local and international bodies.

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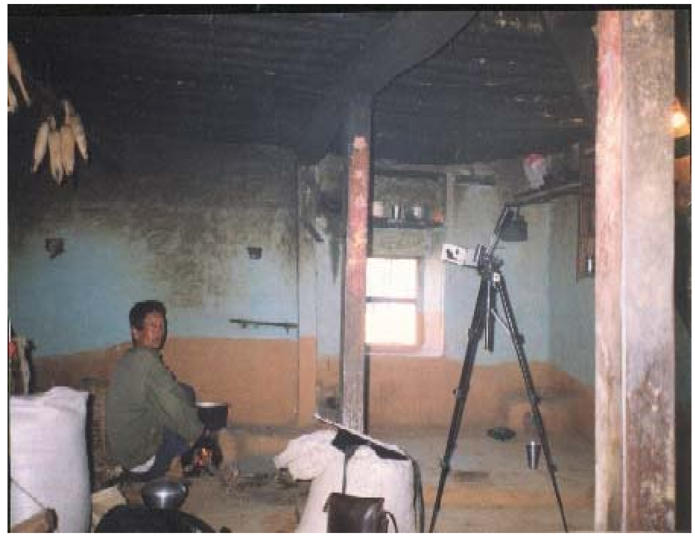
Photo 14



A typical rural kitchen with larger space; Sudal VDC, Bhaktapur

Photo 15

Wood burning in traditional Ageno Chulo; Seshnararayan VDC, Kathmandu

Thus, changes made in Government strategy/policy should be such that they are favorable to the successful implementation of the intervention measures and that the intervention measures are needs-oriented and sustainable.

11.0 Conclusion and Recommendations

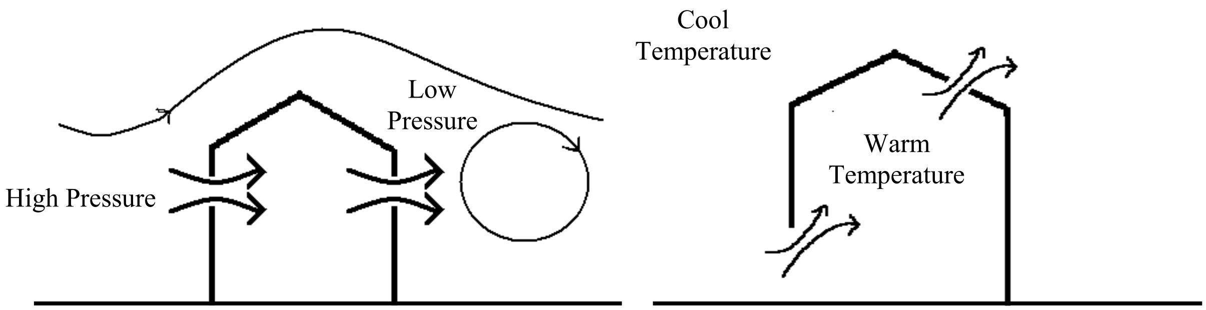
With limited resources made available, this study has determined indoor biomass smoke/PM_{10} concentration levels, particularly, in kitchens using solid bio-fuels as accurately as possible; made comparative health risk assessment (CRA) of the exposed population, particularly women and children aged below 5 (binary fuel users); and also made health response calculations (prevalence of diseases etc.) with respect to certain common/serious IAP related diseases. However, it should be borne in mind that to put the whole matter of exposure/response relationship in proper perspectives, further works should be carried out e.g. by increasing the sample size of households and respondents in different environmental settings inclusive of seasonal differences since the present study has shown high variability in pollutant concentrations at kitchens during fuel burning time; by carrying out more detailed studies on children below 5 years old about the diseases attributable to biomass smoke exposure.

Apart from what has been indicated above, further works on following specific areas are recommended:

- More concrete evidence is to be established between IAP and its impact on health inclusive of diseases other than respiratory illnesses.
- Quantification of public health burden from IAP, particularly from biomass smoke.
- Identification of most affected areas/population size and prioritization of intervention measures required for implementation in those places.
- Identification of policy changes at local/national levels needed for successful/sustainable implementation of desired intervention measures.

12.0 Standard Guidelines for Building Houses for Health

All occupied spaces need ventilation, to maintain good quality and a comfortable temperature. Which of these constraints is the most important varies across the world, and with the time of year. The building ventilation could be provided through mechanical or natural means. In natural ventilation, air movements occur because of pressure differences created by natural effects as shown below in the sketch.

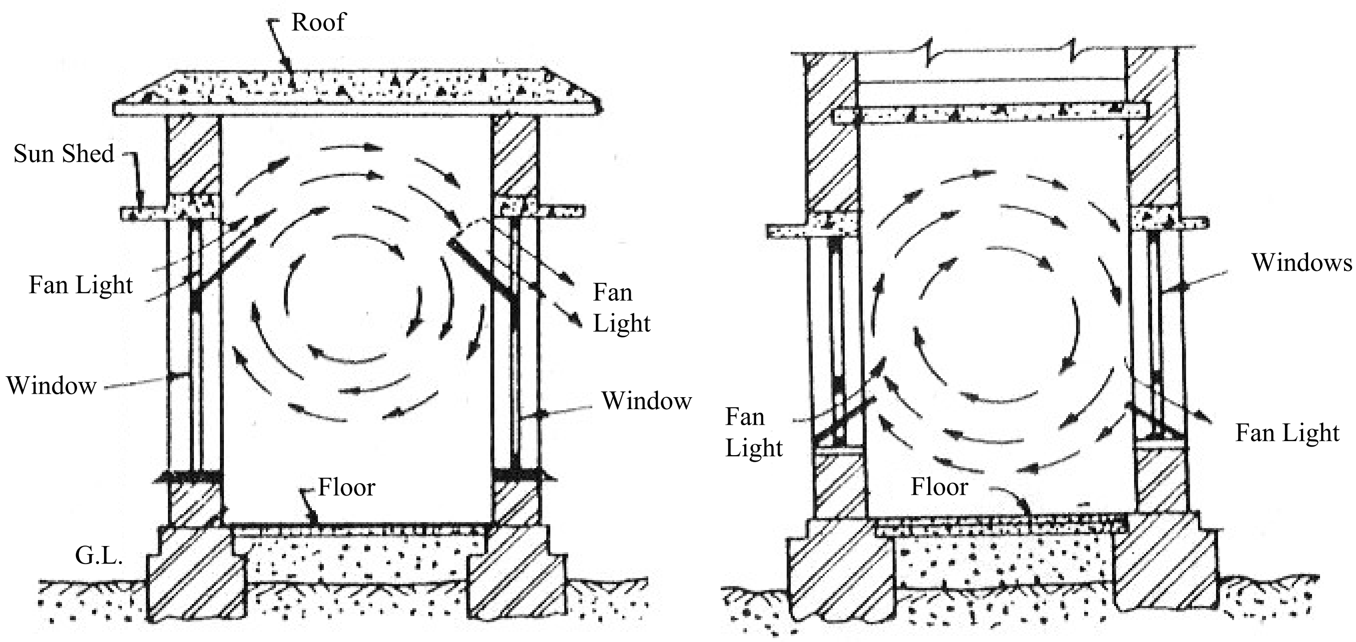


The air movement in natural ventilation occurs, either dynamic pressure differences due to the flow of the wind around a building or a static pressure differences due to the build-up of warm air within a building (the stake pressure). The design and arrangement of openings in houses for natural ventilation flow are not so easy. However with the introduction of new construction material and technology in Nepal, we can build houses that address the challenges for ventilation. This survey has clearly analyzed the relation between the indoor air pollution and ventilation pattern in houses especially in kitchen.

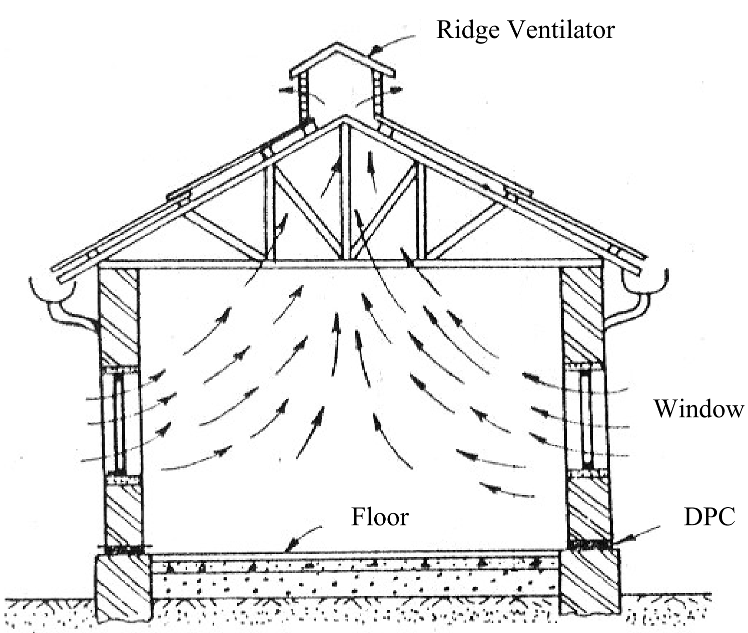
During this survey, the openings found in a kitchen and rooms of houses are below the minimum standard. Adequate natural ventilation is essential which could be provided by suitable openings in a room, at lower levels by admitting free atmospheric air, and also at upper levels for removing the warmer and lighter used up air. Doors and windows near the floor level admit fresh air, and ventilators near the ceiling; take out the vitiated air from a room.

In Nepal, the majority of windows in houses are generally provided at about 0.75 to 0.9 meter above the floor level, for admitting fresh outside air into the room. The size and the number of the windows provided, depends upon the size of the room, number of occupants, the purpose and use of room. On minimum side, a window area of 0.052 m^2 per person should generally be provided so as to ensure admission of at least 28 cubic meter (1000 cft) of air per hour with a velocity not greater than 9 m/min. Another recommendation is to provide about 1/10 to 1/15 th of the floor area in the living rooms for windows. Every room should preferably be provided with at least 2 windows, and at least one of them should face open space or verandah. Kitchens must be provided with more window areas.

Provision of deflectors (also called fan lights) of 30 cm height at the bottom or top of a window, opening inwards, permits the ventilation of the room, even when windows are closed as shown in figure below.



In case of sloppy roofs, ridge ventilators may be provided as shown in figure below. Such ventilators are useful in taking out used vitiated air from large halls.



The recommended dimensions for kitchen room

The dimension of kitchen with respect to different fuel use is as follows:

Table 43 Recommended values for area

S.N	Type of fuel used	Recommended ares (sq. meter)
1	Gas	3.5
2	Improved coal	4
3	Firewood	Larger than 5.5
4	Kitchen should have out facing or corridor facing window Kitchen having small area and poor ventilation must use of gas and set up mechanical exhaust equipment	

The horizontal dimension shouldn't be less than 1.8-meter width.

Recommended size of doorway:

Width of doorway = 0.7 m Minimum opening of doorway 1.4 m^2
Height of door way= 2.0 m

All internal doors have to be provided with air passage not less than 150 cm^2. The passage can be provided with bottom gap of 2 or 2.5 cm under the door.

Recommended height of kitchen room:

The height of kitchen room should not be less than 2.4 meter

The requirement of airflow in each room:

All habitable rooms shall be provided with minimum ventilation rates of 30 m^3/hr for continuous ventilation for every 12 m^2 of the floor area or part of such rooms. The ventilation shall be through windows, doors or other natural opening.
The minimum exhaust airflow for each room is as follows:

Kitchen: 120 m^3/hour
Bathroom: 60 m^3/hr
Toilet : 30 m^3/hr

Survey Findings:

- **Analysis of Indoor Air Pollution and Physical Characteristics of Kitchen Under Surveyed Households**

Table 44 Kitchen Area Statistics

Based on Eco Development Region.		Kitchen Area in sq. Meter	Kitchen Height in Meter	Door Area in sq Meter	Open Window Area
Hill	Mean	17.2978	2.1488	1.4772	.5258
	N	50	50	50	50
	Std. Deviation	9.3339	.3797	.7090	.5363
Terai	Mean	9.0430	2.2533	1.7813	.5885
	N	40	40	40	40
	Std. Deviation	5.2549	.4520	1.2610	.6521
Total	Mean	13.6290	2.1952	1.6123	.5536
	N	90	90	90	90
	Std. Deviation	8.7796	.4143	.9983	.5879

Table 45 Comparison of Physical Characteristics of Kitchen Based on Rural-Urban Setting

Based on Eco Development Region.		Kitchen Area in sq. Meter	Kitchen Height in Meter	Door Area in sq Meter	Open Window Area
Rural	Mean	14.3615	2.1096	1.4063	.4916
	N	71	71	71	71
	Std. Deviation	9.2335	.8431	.8431	.5250
Urban	Mean	10.8916	2.5153	2.3821	.7854
	N	19	19	19	19
	Std. Deviation	6.2880	.3470	1.1706	.7520
Total	Mean	13.6290	2.1952	1.6123	.5536
	N	90	90	90	90
	Std. Deviation	8.7796	.4143	.9983	.5879

Table 46 Comparison of Kitchen Based on Type of Construction

Based on Eco Development Region.		Kitchen Area in sq. Meter	Kitchen Height in Meter	Door Area in sq Meter	Open Window Area
Kacchi	Mean	15.6797	1.9868	1.3311	.3386
	N	37	37	37	37
	Std. Deviation	9.8286	.3461	.5925	.4307
Pakki	Mean	12.8042	2.0874	1.4621	.6900
	N	19	19	19	19
	Std. Deviation	8.6976	.2535	.5333	.6051
Mixed	Mean	17.4637	2.0888	1.3075	.5400
	N	8	8	8	8
	Std. Deviation	12.1642	.2592	.7174	.5900
Concrete	Mean	10.1335	2.6035	2.2162	.7642
	N	26	26	26	26
	Std. Deviation	3.9049	.3512	1.4664	.6882
Total	Mean	13.6290	2.1952	1.6123	.5536
	N	90	90	90	90
	Std. Deviation	8.7796	.4143	.9983	.5879

Analysis of Survey Findings

1. The construction pattern of houses, size of rooms including the kitchen was found different in surveyed region.

2. The construction of house, its structure and facilities were found interrelated with the topographic region, socioeconomic condition of dwellers, users behavior, prevailing cultural practices etc.

3. Different types of fuel were used in surveyed households. The majority of respondents were not familiar on the type of fuel and its likely effect on human health.

4. The openings in kitchen were found fixed without considering scientific and building norms.

5. The mean area of kitchen is found to be 13.6290 sq. meters, the area is found to be higher than the standard norms of 5.5 square meters. The area of kitchen in surveyed houses was found high because of several reasons. Majority of kitchen is found like a multipurpose room. The kitchen is situated in corner of storage room where crops, crop residue, kitchen utensils are stored. It was also observed in some houses that the cattle were housed in same room as kitchen. The combination of kitchen cum bedroom is also observed in majority of houses. The mean area of kitchen is found substantially higher because of above reasons.

6. The mean height of the kitchen is found to be 2.19 meter, which is 0.2 meter less than the recommended height of 2.4 meter.

7. The opening required for the kitchen door is found to be adequate as compared with prevailing standards. The mean door area of kitchen in this survey is 1.6 meter that is 0.2 meter higher than the prevailing recommended standards.

8. Because of security reason and lack of awareness, less number of windows and openings are observed in kitchen. The number of windows in houses needs to be improved. As per general rule of thumb, a window area of 0.052 m^2 per person should generally be provided. 2 windows per room are generally recommended. However, since the kitchen is used as multipurpose and the area is higher than the average recommended size, the more windows and openings are required.

Recommendations:

Good quality housing is a key element for healthy living. Poor housing can lead to many health problems, and is associated with infectious diseases (such as tuberculosis) and stress and depression. Specific aspects of housing quality based on the survey findings are recommended below.

1. The concept of kitchen as an independent unit of the house is not existence in majority of cases. The separate unit for kitchen with the standard dimension based on fuel use should be recommended in practice.
2. The awareness on effect of indoor air pollution and its effect on human health is found lacking among majority if people. So awareness-raising activity on effect of indoor air pollution in human health must be promoted through relevant institutions.

3. The awareness for the use of clean (environmentally friendly) fuel must be promoted and consider as the best alternative for reducing indoor air pollution in houses.

4. Adequate home ventilation is important. Where cooking is done indoor, it is essential that smoke and fumes be removed from house quickly and efficiently. Ventilation may be improved by constructing houses with sufficient number of windows particularly in cooking areas.

5. Houses can be constructed using bricks with holes drilled through them (air bricks), which allows fresh air to circulate within the house.

6. Ventilation in kitchen and other rooms could be improved by incorporating mechanical devices like exhaust fans.

13.0 References

1. The Health Effects of Indoor Air Pollution Exposure in Developing Countries, WHO Department for the protection of human health, 2002.
2. Paper by Schirnding et al on impact of household energy use on health of the poor
3. Population Census, 2001; National Report. HMG, CBS in collaboration with UNFPA, Nepal June 2002.
4. Table 4.2 and Table-4.3, WHO Guidelines for Air Quality, 2000 published by Cluster of Sustainable Development and Healthy Environment, Department of Protection of Human Environment, Occupational and Environmental Health Program.
5. Nepal Demographic and Health Survey, 2001, DHS, Ministry of Health, HMGN Report on the Situation of Women, Children and Households, Between Census Household Information, Monitoring and Evaluation System (BCHIMES), March-May 2000, NPCS CBS UNICEF, Nepal, Sept., 2001.
6. Chronic Bronchitis and Pulmonale in Nepal, a Scientific Epidemiologic Study, M.N. Pahdey, et al,

7. NHRC, a final report on Determination of Health Health Risk Effects of PM_{10} (Activity 1) and Determination of National Standards for Ambient and Indoor Air Quality, NESS, 2001.
8. Monitoring Ambient Air Quality for Health Impact Assessment, ISBN 92 890 1351 6, 1998.
9. Guidelines For Air Quality, WHO publication, Geneva, 2000.
10. Statistical Issues in the Study of Air Pollution Involving Airborne Particulate Matter, Lawrence H. Cox, NRCSE Technical Report Series, 2000.
11. Biostatistics, Perspective in Health Care and Research and Practice, B.L.Verma et al, CBS publication, Delhi, India.
12. Health Effects of Indoor Air Pollution Exposure in Developing Countries, WHO, Geneva, 2002.
13. Standard Guide for Statistical Evaluation of Indoor Air Quality Models, ASTM Designation: D 5157 – 91
14. Environment Sector Programme Support: Permanent Ambient Air Quality Monitoring System for Kathmandu Valley, ESPS/MOPE, HMGN, 2002.
15. A Methodology for Estimating Air Pollution Health Effects, Health and Environment Analysis for Decision-Making, WHO, Geneva.
16. Quantifying the Effects of Exposure to Indoor Air Pollution from Biomass Combustion on Acute Respiratory Infection in Developing Countries, Majid Ezzati et al, Environment Health Programme- Volume 109, No. 5, May 2001.
17. Exposure to Air Pollutants from Combustion of Cooking Fuels: a case Study of Rural Tamil Nadu, India. Jyoti Parikh et al, Mumbai, India.
18. Indoor Air Quality Guiddelines, WHO, 1999.
19. Methodology in the epidemiological research of respiratory diseases and environmental pollution, Simon Brquera, et al, Mexico, Rev. Saude Publica 2002. Epidemiology, WHO/ILO, Vol10, 1999.
20. National Burden of Disease in India from Indoor Air Pollution, Kirk R. Smith, 2000.
21. Energy and Health Transitions in Development: Fuel use, Stove Technology, and Morbidity in Jaracuaro, Mexico, Barbara D. Saatkamp et al., Energy and Resources Group, University of California, Berkley, U.S.A.
22. Indoor Environmental Quality Guidance and Reference Manual, James Martin, 2000.
23. Guidelines for Air Quality, published by WHO,Geneva, 2000, Table No. 3.3, Page 57
24. Exposure assessment to suspended particulate matter in the middle class population of Delhi, CSIR, New Delhi, Nandita Shukla

ANNEX 1

Questionnaire

Household Questionnaire for Survey and Measurement of Indoor Air Quality and its Health Effects

This Questionnaire is meant to get a measure of the state of air quality inside households, particularly at cooking places during cooking time and the health effects experienced by the inmates of the houses, if any. Your sincere assistance will be highly appreciated in filling this questionnaire. Please answer all questions as frankly and accurately as possible so that the results of this study can become beneficial to you also. All personal information and data obtained will be treated as confidential and used for the purpose of this study only.

A. Household Serial No. ________________ Household Identification No. ______________________

1. District ______________________ 2. Municipality/VDC ____

3. Ward number ________ 4. Cluster number ______ 5. Name of the village/tole ____________________________

6. Date of the interview _________________

7. Name of the HH: Last name _________________ first and middle ___________________________ Age _____

8. How many other family members live in the house? ________

9. Description of the house:

☐ Kachhi ☐ Pakki ☐ Reinforced Concrete Number of Storey ___________________

10. Total number of Rooms _______

<u>About Kitchen and Ventilation</u> ☐ Low ☐ Moderate ☐ Sufficient

11. Is the cooking place separate ☐ Yes ☐ No

12. Measurement of kitchen size (in meters):

Length (L) ________________Breadth (B) ____________________Height (H) ___________________________

13. Measurement of size of open windows (in meters):

1. (L) ____________(B) _____________ 2. (L) ____________ (B) ___________ 3. (L) _________(B) ________

14 Measurement of Door Size (in meters):

1. (L) ______________(B) ________________ 2. (L) ________________ (B) _______________

Kitchen door open to ☐ outside ☐ inside ☐ both inside and outside of the house.

15. Black soot/tar deposit in the ceiling/walls visibly thick ☐ yes ☐ No

16. <u>For mothers / housewives</u>: Do children up to the age of 5 years (if any) accompany you during cooking time?
☐ Always ☐ Most often ☐ Sometimes ☐ Never

17. Which cooking oils do you use most often? Raw oil or refined oil such as Soya bean oil, Mustard oil, Rape seed oil , others (name) : ____

18. How much cooking oil is required (liters) per month/week? ___________________

19. During cooking time, smoke in the kitchen is often

☐ Not noticeable ☐ Feebly smoky ☐ Visibly smoky ☐ Unbearably smoky

20. Description of Cooking Stove (s) (Chulo):

Types	NUM.	Remarks	Types	NUM.	Remarks
Outside the house at an open place (Ageno chulo)			LPG Gas Stove		
Traditional clay stove			Bio-Gas Stove (Gober Gas Stove)		
Improved Stove (Sulav Chulo)			Electric Heater		
Kerosene Stove			Others		

Note: In remarks column, write one or more than one, of the following against each type of stove as applicable, for instance: i-one; ii-no; iv-ground etc.

i. Number of holes available for placing cooking pots, as one, two, three etc

ii. The stove is fitted with vent pipes yes / no

iii. The chimney is fitted with Exhaust Fan yes / no

iv The stove is located at ground floor or top floor

v. Chimney orientation, general direction of smoke (plum) from the vent: towards or away from the house.

21. The existence of air circulation system in the house/rooms:

Air-conditioners, Coolers etc ☐ yes ☐ no

22. Existence of Indoor air pollution from near-by activities such as, Restaurant, Commercial, industrial etc.

☐ yes ☐ no

23. If Improved stove is used, from how many years back was it used? ___________________

24 Fuel Use Types ☐ **Fuel-wood** ☐ **Animal Dung, Straw etc** ☐ **Coal / Charcoal** ☐ **Bio-Gas**

☐ **Kerosene** ☐ **LPG** ☐ **Electricity**

S.N.	Type	Unit	Consumption figure (per day / week / month or as applicable)	Use: Cooking. Lighting, Heating etc	Duration of Use in Hrs, (per day / week / month or as applicable)	Primary Secondary Or Occasional Fuel	User: Male/ Female
1							
2							
3							

Questionnaire (Individual) for Survey and Measurement of Indoor Air Quality and its Health Effects

PART A (General)

1. Household Identification Number ___________

2. Name of the respondent: Last Name:-___________________.First Name ______________________________

Gender __________Age ________ 3. Date of the Interview _________________________________

4. Literacy (Aged 6 or Over)

☐ Not Applicable ☐ Cannot Read and Write ☐ can read only ☐ Read and Write

5. Education (Aged 6 or Over)

☐ No Schooling ☐ under SLC ☐ SLC ☐ Intermediate ☐ Graduate ☐ Master or above

6. Marital Status

☐ Single ☐ Married ☐ Divorced ☐ Separated ☐ Others

7. How long have you been living in this house? ____________ (years)

8. Give the time you usually spend at home / outdoors daily (in hours):

Description	Duration	Description	Duration
At the kitchen during cooking		Inside home when kitchen is not functioning, including sleeping at night	
At other rooms during cooking hours		Total time you spend outside home	

9. Occupation

☐ Agriculture ☐ Labor ☐ Factory Worker ☐ Business Office Staff

☐ Others (Specify) ____

10. Describe the general environment of your workplace ____

(Open Outdoor: clean / dusty / smelly / traffic area ; Indoor ; clean / dusty / smelly ; teaching / business / government building ; shop ; restaurant etc.)

11. If you have to pass through various places (micro-environments) while attending daily routine jobs, Describe the nature of the environment____

12. How long you have been in the present job? __________ (years)

13. Describe your previous jobs (accounting for 10 yrs of occupation) _____________________________________

14. About Smoking habit (if any) ☐ Smoker ☐ Previous Smoker ☐ Never Smoked

If Current Smoker

Age (smoking started) ________ Type of Smoking ☐ Cigarettes ☐ Bidis ☐ Hukka ☐ Others

Specify if others ______________________________ Type of cigarette ☐ plain ☐ filter

Number of Cigarettes / Bidis per day ______________ Duration of Hukka Smoking per day _______________

How would you inhale during smoking? ☐ Slightly ☐ Moderately ☐ Deeply

If Previous Smoker

Age at which Smoking started _______________ Type of cigarette ☐ plain ☐ filter

Number of years of Smoking______ Reason for stopping smoking ___________________ Years of smoking ______

PART B

SYSTEMIC EXAMINATION FOR THE DETECTION OF HEALTH EFFECTS LINKED TO INDOOR AIR POLLUTION

Household Identification Number________________ Name ____

1. GENERAL

Weight _______(Kg) Height ________(cm) Pulse _____ per min BP ______________

Temperature __________ Respiration Rate ____________ Pallor [ ] Icterus [ ] Cynosis [ ]

Lymph nodes enlarged [ ] Not Enlarged [ ] Appetite Normal [ ] Poor [ ]

2. CHEST

Inspiration [ ] Expiration [ ] Normal [ ] Abnormal [ ]

Specify ________________ Lung ____________________ Heart ________________ Auxiliary

Lymph Nodes __________________ Any Other ____

3. EYE

Conjunctiva [ ] Glistering Moist [ ] Dry and Wrinkled [ ] Bitot's Spot [ ]

Eyelid [ ] Visual Acquity RE [ ] LE [ ]

Light Reflex RE [ ] LE [ ] Color Blindness RE [ ] LE [ ]

4. ENT

- Ear → Pina [ ] Wax [ ]
- Nose → Normal [PNS / Polyp / Discharge]
- Throat → Tonsil Lt [ ] Rt [ ]

5. PEAK FLOW RATE

I [ ] II [ ] III [ ] Best One [ ]

6. IMPRESSION / COMMENT

____

____

____

PART C

Questions for detection of Respiratory Symptoms (for adults) When in doubt record as No.

1. Have you ever had periods of COUGH, PHLEGM, BREATHLESSNESS, AND WHEEZING in the past?

COUGH → Yes / No If Yes, When __________________ Duration / Frequency____________________

PHLEGM → Yes / No If Yes, When __________________ Duration / Frequency____________________

BREATHLESSNESS → Yes / No If Yes, When __________________ Duration / Frequency ____________________

WHEEZING → Yes / No If Yes, When __________________ Duration / Frequency____________________

2. COUGH

a. Do you usually cough first thing in the morning in winter? (Exclude clearing of throat) ☐ Yes ☐ No

b. Do you usually cough during the day or at night-in the winter? (Ignore an occasional cough) ☐ Yes ☐ No

c. If Yes to a or b, Do you cough like this on most days for as much as three months each year?) ☐ Yes ☐ No

3. PHLEGM

d. Do you usually bring up phlegm from your chest first thing in the morning in the winter? ☐ Yes ☐ No

e. Do you usually bring up any phlegm from your chest during the day-or at night in winter? ☐ Yes ☐ No

f. If yes to d or e, Do you bring up phlegm like this on most days for as much as three months each year? ☐ Yes ☐ No

4. PERIODS OF COUGH AND PHLEGM

g. In the past three years have you had a period of (increased) cough and phlegm lasting for three weeks or more? ☐ Yes ☐ No

h. If Yes to g, Have you had more than one such period? ☐ Yes ☐ No

5. BREATHLESSNESS

If subject is disabled from walking by any condition other than heart or lung disease, omit the questions in this section.

i. Are you troubled by shortness of breath when hurrying on level ground or walking up a slight hill? ☐ Yes ☐ No

j. If Yes to i, Do you get short of breath walking with other people of your own age on level ground? ☐ Yes ☐ No

k. If Yes to j, Do you have to stop for breath when walking at your own pace on level ground? ☐ Yes ☐ No

6. WHEEZING

l. Have you had attacks of wheezing or whistling in your chest at any time in the last 12 months? ☐ Yes ☐ No

m. Have you ever had attacks of shortness of breath with wheezing? ☐ Yes ☐ No

n. If Yes to m, Is/was your breathing absolutely normal between attacks? ☐ Yes ☐ No

o. Have you at any time in the last 12 months been woken at night by an attack of shortness of breath? ☐ Yes ☐ No

7. PAST ILLNESS

Have you ever had, or been told that you have had:

p.	An injury or operation affecting your chest	Yes / No	t.	Pneumonia	Yes / No
q.	Heart trouble	Yes / No	u.	Pleurisy	Yes / No
r.	Blood Pressure	Yes / No	v.	Pulmonary Tuberculosis	Yes / No
s.	Bronchitis	Yes / No	w.	Bronchial Asthma	Yes / No

PART D

(OPTIONAL ATTACHMENT)

Questions on Respiratory Symptoms for the diagnosis of Acute Respiratory Infections (ARI) in children up to 5 years of age (to be asked to the mother of the child)

1. Has (NAME) had an illness with cough and cold at any time in the last two weeks?

   ☐ Yes ☐ No

   Yes → go to others questions No → go to Q. N. 4 Don't Know → End

2. What signs and symptoms did you notice when the child was sick?
   - is coughing
   - has a blocked / running nose
   - has fever
   - is breathing fast`
   - has difficulty in breathing
   - has chest in drawing
   - has problem eating / drinking
   - others, specify ______________________________________

3. Did you seek advice or treatment for the sickness?
   - Nowhere and no treatment
   - Nowhere but home treatment
   - Sub-health post / health post
   - PHCC / hospital
   - Aurvedic center / hospital
   - Private clinic / nursing home
   - Medical shop / pharmacy
   - Others, specify ____

4. How many times had this child suffered from ARI during the last year? ____________________________

IMPRESSION

____

____

____

Indoor Air Quality Monitoring Program

District ________________ VDC / Municipality___________ Village ___________ Ward No. ______Household No.______ Temperature ________ Monitoring Date___________ Time_______Photo___

A) Particulate Matter (PM_{10}) : LD-1

Micro Environmental Setting	Exposure time, min	Total Count	Concentration(mg/m^3 / $\mu g/m^3$)
Kitchen (cooking time)			
Other room (cooking time)			
Indoor (non cooking time)			
Outdoor (ambient)			
Outdoor (non ambient)			

B) Gaseous Pollutants

Micro Environmental Setting	Pollutant	Draw Characteristics			Observed Concentration (ppm)	Actual concentration (mg/m^3/$\mu g/m^3$)
		No.	time	Volume per draw		
Kitchen (cooking time)	CO n= ______					
Other room (cooking time)						
Indoor (non cooking time)						
Outdoor (ambient)						
Outdoor (non ambient)						
Kitchen (cooking time)	NO_X n=___					
Other room (cooking time)						
Indoor (non cooking time)						
Outdoor (ambient)						
Outdoor (non ambient)						
Kitchen (cooking time)	SO_X n=___					
Other room (cooking time)						
Indoor (non cooking time)						
Outdoor (ambient)						
Outdoor (non ambient)						
Kitchen (cooking time)	HCHO n=___					
Other room (cooking time)						
Indoor (non cooking time)						
Outdoor (ambient)						
Outdoor (non ambient)						

A) Control measurement of PM_{10} (HVAS):

Dust Quantity	Time (Hrs. / Mins.)	Duration (Mins.)	Total air volume (m^3)	Concentration (mg/m^3 / $\mu g/m^3$)

ANNEX 2

Household Identification Form for Sample Survey (Permanent Residents Only)

Eco-Development Region:_________ Hills / Terai) Area Type:_________(Rural / Urban) Name of the VDC / Municipality _____________

Description	Description	Description
ID No. __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________
ID No. __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________
ID No. __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________	**ID No.** __________ **Name (HH)**_______________________ **Location** _________________________ _________________________________ **Fuel Type** ________________________

ANNEX 3

Table A Survey of studies on indoor air pollution levels in developing countries

Location	Reference	Sample duration/size fraction	Fuel Type	Cooking condition/ Comments	PM, mean ;range $\mu g/m^3$	CO in ppm
Lusaka, Maputo	Ellergard (1997)	Not clear/PM10	Mixed	Range of means	531 - 1032	
Maputo, Mozambique	Ellerghaed (1996)	Cooking time/PM`10	Wood, charcoal, coal		1200 540 940	
Zimbabwe	Martin (1991)	Cooking time/not clear	Wood	Children with ALRI With ARI	1998 546	
Zimbanwe	Collings et Al (1990)	Blood sample/HbCO	Wood			6.45%
Bangkok	Smith et al (1994)	12 - 24 hrs./PM10	Charcoal	Indoor, personal Monitoring	330 550	1.6 8.5
Beijing	Do, (1994)	Same as above	Coal (vented)	Same as above	550 1900	20
Beizing	Do (1994)	Estimated daily exposure, PM_{10} ($\mu g\text{-}h/m^3$)	Do	Do	23000 35000	
Garwal Himalaya	Sksena et al (1992)	Cooking time, kitchen TSP/ CO	Wood & Shrubs	Geometric Mean	4500	10
Do	Do	Estimated total Exposure	Do			
Himalayan village,India	Norboo et al (1991)		Wood & Yak dung	Summer Winter		14.9 26.2
Pune, India	Smith et al	12 - 24 hr./ PM_{10}	Wood	Area monitoring	2000	

	(1994)		Wood	Personal Monitoring	1100	10
Navajo children Arizona	Robin et al (1996)	15 hr. / PM10	Wood		3 - 186	
Rural Bolivia	Albalak et al (1999)	6 hr. / PM10	Cow Dung	Indoor/ outdoor, kitchen, Geometric mean	1830 280	
Do	Do	Estimated daily Exposure				
Rural, Guatemala	Mc Cracken & Smith	Expt. Conditions Standardized cooking Test / PM2.5	Wood	Open Fire Improved stove	27200 450	
Eastern Highland, PNG,Ocenia	Anderson (1978)	6 pm - 4 am / TSP	Wood		600 to 2000	
Hypothetical village kitchen, Developing countries	Zhang et al (1999)	1 hour	Charbriquette Charcoal Brush wood Dung Crop residue Fuelwood			562 528 511 464 241 150

Source:- WHO, Protection of the Human Environment, Geneva, 2002 . The Health Effects of Indoor Air Pollution Exposure in Developing Countries.

Table B Studies of Chronic Bronchitis or COPD and Exposure to biomass smoke

Study/location	Study design & Numberes	Measure of Exposure	Measure of Health outcome	Findings	Common confoundings
Padmabati and Pathak(1959) Delhi	127 case series of cor pulmonale	Cooking fuel from charts, partly only	Clinical diagnosis of cor Pulmonale	Most exposed to cow dung & rural origin	No control of Confoundings
Master (1974) Papua New Guinea, Highlands	94 adults selected randomly, clinically evaluated	All living in nearly Closed huts, biomass Burning	Clinical assessment	Smoky huts to keep warm, Most smokers, 78% had chronic lung disease mainly obstructive	No control of confoundings, equal distribution among genders Smoking, malnutriotion, Poor sanitation
Anderson (1979a and b) Highlands Papua New Guinea	Cross sectional study of 1284 adults,11 villages 1800m Altitude	Questionnaire	Spirometry	Air flow obstruction (FEV1/FVC<60% in 20% of men &10% of women, no risk estimated. Lung disease not associated with smoking. Disease attributed to wood smoke and acute chest infections.	Prevalence reported stratified by age, gender, & smoking habits; Most men & women were smokers of home grown tobacco (smoked without inhalation)
Anderson (1976) Karkar Island, Papua New Guinea	Cross-sectional study of 87% of residents, total 1026 from 3 villages	Do	Spirometry, Questionnaire	Prevalence of respiratory abnormalities similar in men and women, with air flow obstruction	Control for gender, age, smoking. Smoking resembles cigar smoking. Authors suggest repeat chest chest infection also a cause of COPD
Pandey, (1984a) rural hill region of Nepal	Cross sectional study of 2826 adults. 57% of those with CB had air flow obstructioon. 93% of cases with CB were confirmed in hospital, also some cases of emphysema & corpulmonale	Questionnaire, hours spent near fire.	Questionnaire, clinical evaluation, chest X-rays, Pulmonary function tests	Prevalence of CB 18.3%, similar in men and women. No analysis of association between exposure and emphysema or cor pulmonale or air flow obstruction reported.	Stratified analysis by age. Simiolar prevalence in four ethinic groups and in both sexes. No influenza epidemics detected during the study. Sputum analyzed for TB in patients with chronic cough.
Do (1984b)	Cross sectional study of	Questionnaire, type	Questionnaire	Prevalence of CB	Control for smnoking,

	1375 adults aged 20 plus. Included 1077 smokers, 223 non-smokers, 75 past smokers	of stove, hours spent near fire		increases with hours near the fireplace in smokers and non-smokers. Additive effect with tobacco	gender, and age
Do, (1985), rural area near Kathmandu, Nepal	Cross-sectional study of 150 women from a rural area, similasr numbers of smoker and non-smoker.	Questionnaire to assess the number of hours of cooking, seperated in 3 levels	Spirometry	Group with most exposure had a 16% lower FEV1 and FVC in smokers, and a 7% lower FEV1 and 4% lower FVC in non-smokeers. Differences in non-smokers were not statistically significant.	Stratified by smoking status. No control outdoor pollution
Malik (1985) Chandigarh, India	Cross-sectional syudy of 2180 women older than 20	Questionnaire, Type of fuel used	Symptoms by questionnaire, spirometry	CB in group exposed to cow dung and wood, 5%; in LPG, 1.6%; parafin oil, 1.3%; coal + parafin. 2.6 %; PEFR was lower in the group exposed to biomass (chula stove).	No control for confounding reported
Pandey et al (1988), Plains and hill region of Nepal	Cross-sectional study of adults: 652 from the plains, 641 from mountains,	Questionnaire, Type of fuel used.	Questionnaire	Prevalence of CB 13.1% in plains, 30.9% in mountains. Similar in men and women. Difference attributed to lesser ventilation and more exposure in mountains.	Control for gender, age and smoking.
Anderson et al (1988) Papua New Guinea	2026 Highland, 1734 coast, 15 year mortality follow up after surveys in 1970-71.	Questionnaire	Mortality, Spirometry.	Increased mortality in subjects short of breath, wheezers, and those with reduced lung function, but not in local tobacco smokers.	Control for age, height and smoking.
Norboo et al (1991a), Rural Ladakh in North India	Cross-sectional study of 208 women and 156 men aged 20 and over, carried out on summer and winter on same subjects. Alt. >3000 m	Type of stove and fuel, ambient and personal exhaled air CO level.	MRC (UK) Questionnaire for CB, Spirometry	Inverse relationship between personal CO and FEV1/FVC ratio ($p<0.05$ for women). Significant increase in exposure (assessed by room CO & personal exhaled CO)	Adjusted for age and height. Very few woman smoked, and smoking men excluded from analysis.

				between summer and winter. Fall in individual FEV1 between summer and winter associated with increase in personal CO (p<o.o1)	
Behara et al (1991), Rural India	Cross-sectional study of 3701 women, of whom only 93 were smokers.	Questionnaire, Type of fuel.	Symptoms by questionnaire, Spirometry	CB in 1.9% of sample, 2.9% of those using bio mass chula.Total symptoms more common in mixed fuels and bio mass than in gas. Reduction in FEV1 (3%) and FVC (2%) in bio-mass users compared to LPG. No RR reported.	No adjustment for confounding reported.
Dossing et al (1994), Saudi Arabia	Case (n=50) control (n=71) study. Cases were of COPD (FEV1<70% predicted, FEV1/FVC<0.70, non-reversible. Healthy controls	Questionnaire, Type of stove	Spirometry	Association in non-smoking women with indoor wood fire (OR=49; 95% Cl). COPD not associated with incense burning.	Passive smoking and occupational exposure to dust equally distributed among cases and controls. No other comments on control of confounding.
Menezes et al (1994) Urban Pelotas, Brazil	Cross-section study of 1053 adults aged over 40 years. CB in 12.7%	Questionnaire	Symptoms by questionnaire	Increased risk of CB with higher indoor pollution, OR=1.9 (1.2-3.0)	Multivariate analysis used. Low family income, no education, and smoking and respiratory illnesses in infancy also risk factors.
Qureshi (1994) Rural Kasmir, Pakistan)	Cross-sectional study of all residents over 15 years in 2 villages, 1 biomass using, the other using mainly kerosene, LPG and electricity. Alt. 1600 m.	Interview and observation of ventilation, smoking , fuel type and average time per day neat fireplace.	Symptoms of CB and Asthma by questionnaire, Spirometry.	7.7% with CB, 2 with Asthma. Higher prevalence in women and in bio-mass using village. CB in women positively associated with time spent near the fire (p<0.01, but asthma not associated (small numbers). Association between lung function and exposure not	CB associated with smoking, but very few women smoked. CB also associated with quality of housing and ventilation, but these factors not adjusted for.

				reported.	
Dennis et al (1996) Columbia	Hospital based case (n-104) Control (n=104) study. Cases had COPD, FEV1/FVC <70, FEV1<70% predicted. controls	Questionnaire, Type of stoves	Spirometry	Crude OR for wood smoke 3.4, adjusted 3.9. Also significant for 2.6 and ETS 2.0	Stratified analysis by age, hospital, smoking, use of alcohol, occupational exposures. Multivariate analysis with smoking , passive smoking, age hospital.
Perez Padilla et al (1996) , Mixico	Hospital based case (n=127) Control (n=375) study. Cases were CB or COPD (FEV1 <70% predicted). Controls (4 groups) had ILD, ENT, and TB as diagnoses, and visitors.	Questionnaire, type of stoves	Spirometry for COPD and questionnaire to define CB	Crude OR 3.9 for CB, 9.7 for CB + COPD. Adjusted OR similar to unadjusted.	Control of confounding by stratified analysis and logistic regression which included age, smoking, place of birth and residence, SE status, level of education.
Dutt et al (1996) Urban Slum, Pondicherry, India	Stratified random sample of 1117 women, drawn from 1560 subjects identified in a survey. Included 105 using biofuels, 105 kerosene, and (number) LPG	Questionnaire, type of fuel	Questionnaire, Spirometry.	Respiratory symptoms in 26% of those using biofuels, 13% for kerosene, and 8% for LPG. Lung function lower in biomass users as well. No RR reported	No adjustment for confounding reported.
Elegard (1996) Suburbs of Maputo, Mozambique	Cross-sectional study in 1188 women, 218 with monitoring of air pollution.	Questionnaire of fuel types, and measurement of particulates	Questionnaire of symptoms (cough, symptom index), PEF with Wright mini peak flow	PM in wood users 1200 µg/m3, charcoal 540, gas & electricity 200-300. After adjustment, wood use and time cooking significantly associated with cough symptom index. Kitchen ventilation and time in house (but not fuel type) associated with PEF. No association with wheeze.	Adjusting for a range of socio-economic and environment variables.
Regalado et al (1996) Highland (2500 m), Mexico.	Cross-sectional study of 871of women aged over 38. Alt. 2500 m)	Type of fuel used from questionnaire. Kitchen PM conc. while cooking	Symptoms by questionnaire, Spirometry.	Biomass stove associated with increase in phlegm and 4% reduction in FEV1/FVC. Mild effect in	76% of women cooked with gas but also with biomass, 10% only biomass. Control for age,

		measured with nephelometer		FEV1 in homes with higher PM10. At levels of PM10 above 2000 µg/m3, an increase in 1000 µg/mn3 was associated with a reduction of 2% in FEV1.	smoking, socio-economic status.
Albalak et al (1999), Rural Highland, Bolivia.	Cross-sectional study of all residents (total n = 241) from 2 villages, 1 cooking indoors and other outdoors. Alt. 4100 m.	Questionnaire to assess time activity patterns. Sampling for area PM10 measurements in 12 randomly selected homes in each village.	Questionnaire for symptoms of CB	Prevalence of CB was 22% and 13% in indoor and outdoor cooking villages respectively. OR = 2.5 (95% Cl) for indoor cooking. Estimate exposures for women (based on time activity and PM10 measurement) were about double in village cooking indoors.	Communities similar in SE status, climate, altitude, access to health care. Adjustment for age and sex in logistic regression.

Table C: Studies reporting interstitial and pneumoconiosis like lung changes in subjects exposed to biomass smoke.

Author	Setting	N	Description	Proposed pathogenesis	Findings
Master (1974)	Highlands in New Guinea	98	Chronic pulmonary disease	Wood smoke, poor sanitation, endemic infectious diseases, tobacco smoking	Obstructive and restrictive disease
Restrepo et al (1983)	Mountain areas of Colombia	22	Pneumoconiosis, features of bronchitis and lung fibrosis	Inhalation of wood smoke fly ash with silicates in cold areas using biomass with poor ventilation	Functional pattern Obstructive and restrictive. In biopsy, fibrosis and anthracosis with crystals under polarized light.
Grobbelar (1991)	Xhosas from Transkei, grind dry maize producing a fine dust.	25	Hut lung	Domestically acquired pneumoconiosis due to wood smoke, plus exposure to dust containing quartz	17 non-smokers, 7 previous TB 12 simple anthracosis, 6 macula formation, 7 fibrosis, or mixed dust pneumoconiosis. BAL with macrophages laden with particles. Cases with PMF and coalescent nodules.
Dhar (1991)	Gujjar community, Kashmir altitude, closed environment.	46	Gujjar lung	severe exposure to wood smoke	Anthracosis, 27/36 biopsies with fibrotic reaction, no particles by polarized light. PFT with obstruction and restriction. Cases with coalescent nodules.
Saiyed (1991)	3 villages Ladakh. India	449	Pneumoconiosis, including silicosis in 2%, 20%, 45%	Dust storms and smoke from domestic fuels	Cases of progressive massive fibrosis and egg-shelled calcification.
Norbo et al (1991b)	Villages in Ladakh N. Indian Himalayas	20 men and 20 women above 50 years	Silicosis	Dust storms, quartz demonstrated in dust and lung. Also exposed to biomass (See Norbo, 1991a)	Cases with progressive massive fibrosis. Silicosis in 8/20 men and 16/20 women.
Sandoval (1993)	Rural Mexico, women	22	Lung disease associated with wood smoke exposure	Wood smoke	Anthracosis with fibrotic reaction

Note: All patients had micro nodular or reticular opacities in chest X-rays and several had reduced lung volumes in addition to air flow obstruction and symptoms of airways disease.

Table D **Published studies from developing countries reporting on associations between exposure to polluting household fuels which include biofuels, and wheeze and / or asthma. Listed by year of publication.**

Study and location	Study design / number	measure of exposure	measure of wheeze or asthma	Findings	Comments
Guneser et al (1994) Adana, S. Turkey	Cross-sectional survey of 9-12 year olds (n=617)	Reported fuel and stove type used at home. Annual mean (out door) smoke level (1988) 26 µg/m3.	Reported symptoms including day and night cough. Spirometry: FVC, FEV1, PEFR, FEF25	Coal using group reported more day and night cough than kerosene, oil, electricity users ($p<0.05$). Lowest values of FVC, PEFR, FEF25 in wood stove group ($p<0.05$)	No adjustment for confounding reported.
Mohamed et al 91995) urban Nairobi, Kenya	Community matched case (n=77) control (77) study, with cases from a prevalence survey in 9-11 year old school children. Matched for age and gender.	Type of stove and fuel, visible indoor pollution observed at home visit.	Doctors diagnosis, history of wheeze or >10% FEV1 decline after exercise.	22% (17) of cases using wood and charcoal versus 10% (8) of controls. Use of other fuels similar. Main analysis based on subjective assessment of indoor air pollution not on fuel, with a crude OR 3 (2.0-6.4). Adjusted OR for pollution 2.5 (2.0 –6.4)	Adjusted for air pollution outside home, passive smoking, mud floors. Fuel types not associated with asthma.
Azizi et al (1995) Kuala Lumpur	Hospital based case (n=201) study of children 1 month to 5 years. Controls age matched non-respiratory admissions.	Type of fuel and stove useed at home reported by mothers at interview.	First hospitalized episode of acute asthma, with physician diagnosis. Excluded acute bronchiolitis, pneumonia, stridor, and other respiratory conditions.	Unadjusted OR for asthma with wood stove was 1.4 (0.6-3.6). Also NS in multivariate model. For mosquito coil smoke adjusted OR=1.73 (1.02-2.93).	Multivariate analysis used.
Noorhassim et al (1995) Rural Malaysia	Cross-sectional study of 1000 children aged 1 to 12 years	Questionnaire	How was asthma defined and cases ascertained?	No association. Is OR (95% CI) given?	
Gharaibeb (1996) Jordan	Cross-sectional survey of 7-13 years old (n=1905). 72% of sample urban, 28% rural.	Reported fuel and stove type used at home, divided in to exposed (wood or kerosene), and unexposed (electricity or modified kerosene stove which expels fumes outside).	Symptoms not reported. Spirometry: FVC, FEV1, PEFR, FEF25-75.	Values of FVC, EFV1, PEFR, FEF25 all lower in exposed children ($p<0.005$).	No adjustment for confounding, but children exposed to polluting fuels at home, and to smoking, were excluded.
Xu et al	Cross-sectional	Interview questionnaire on	Interview	Adjusted Ors for occupational	Adjustment for

(1996) Rural China	study of 28946 adults aged 15 years and over.	environmental exposures, including dust, fumes, outdoor and indoor air pollution. 93% of population used wood/hay for cooking, so occupational exposures used to study effect of biomass on asthma, but cooking exposures for effects of coal on asthma.	questionnaire using standard questions for asthma symptoms, and for recall of physician diagnosed asthma.	exposure to wood/hay smoke: wheezing 1.36 (1.14-1.61); asthma 1.27 (1.02-1.58); Coal for cooking: Wheezing 1.47 (1.09-1.98); asthma 1.51 (1.05-2.17).	gender, age, area. Education, smoking, and ambient air pollution.
Lopez-Bravo et al (1997), Santiago, Chile	Cohort study of 437 children followed from birth to 18 months. Neonates with birth weigh <2500 gms. excluded.	Type of fuel and stove used at home reported by mothers at interview. Defined groups as polluted (use of wood, kerosene, or coal for cooking or heating) and for non-polluted (use of gas)	cases seen in clinic and referred to hospital for physician diagnosis of ARI. Three groups defined: bronchitis, obstructive bronchitis syndrome (presumed to include wheeze or other evidence of asthma), pneumonia.	% children with >or =2 episodes of obstructive bronchitis syndrome: 47.3%for polluted homes, 34.2 for non-polluted homes (p<0.01). Difference for pneumonia (20.6% vs 15.7%) not significant.	97% homes used gas for cooking, but 81% used kerosene, wood, or coal for heating. No adjustment for confounding reported.
Melsom et al (2001), urban and rural Nepal.	Case control study of 121 children aged 11-17 years with asthma and 126 controls	Interview questionnaire on type of fuels used in home.	Standard ISAAC core questionnaire and video questionnaire	Adjusted OR for asthma associated with smoking by 2 or more family members 1.9 (1.0-3.9), for use of open fire/stove without flue 2.2 (1.0-4.5) compared to stove with flue or cleaner fuels.	stratification by sex, showed results for smoking and smoky fuels only significant for boys.
Schei et al (2002), rural Guatemala	Cross-sectional study of 4-6 year olds in 1058 homes	Interview questionnaire and observation on type of fire and fuel used: open fire (38.1%), chimney stove using wood (51.5%), gas/open fire combination (10.4%).	Standard ISAAC questionnaire to assess ever wheezed, wheezing in last 12 months, speech limiting symptoms, exercise-induced wheezing, asthma diagnosis	Overall prevalence of ever wheezing 7.3%, and 3.45 for for last 12 months. In logistic regression, adjusted OR for open fire was 1.81 (1.04-3.12) for ever wheezed, and 2.35 (1.08-5.13) for wheeze in the last 12 months.	Regression model included family history of wheeze (independently associated with all asthma symptoms in this study), sex, and interview.

ANNEX 4
Ambient Air Quality Standards

Table 1: WHO GuidelineValues for the "Classical" Air Pollutants (WHO 1999a)

Compound	Annual ambient air concentration {µg/m^3}	Health endpoint	Observed effect level {µg/m^3}	Uncertainty factor	Guideline Value {µg/m^3}	Averaging time
Carbon monoxide	500-700	Critical level of COHb <2.5%	n.a.	n.a.	100000 60000 30000 10000	15 minutes 30 minutes 1 hour 8 hour
Lead	0.01-2	Critical level of Pb in blood <100-150 {µg Pb/l	n.a.	n.a.	0.5	1 year
Nitrogen dioxide	10-150	Slight changes in lung function in asthmatics	365-565	0.5	200 40	1 hour 1year
Ozone	10-100	Respiratory function responses	n.a	n.a	120	8 hours
Sulphur dioxide	5-400	Changes in lung function in asthmatics	1000	2	500	10 minutes
		Exacerbations of respiratory symptoms	250	2	125	24 hours
		in sensitive individuals	100	2	50	1 year

Source: WHO, 2000

Note: n.a. – not applicable

ANNEX 5

Ambient PM_{10} (in $\mu g/m^3$) Data for Kathmandu Valley measured at 6 Stations during Nov. 2003 to Feb. 2004

Date	Thamel	Matsyagaon	Kirtipur	Bhaktapur	Patan Hospital	Putalisadak
2003/11/01	114	42	63	91	146	121
2003/11/02	157	66	86	112	181	172
2003/11/03	196	69	102	124	209	190
2003/11/04	183	58	84	124	186	189
2003/11/05	180	61	90	116	161	195
2003/11/06	198	71	96	131	174	191
2003/11/07	190	74	105	117	214	197
2003/11/08	174	64	85	114	152	186
2003/11/09	172	56	81	99	170	171
2003/11/10	--	--	--	--	--	--
2003/11/11	146	56	70	96	180	167
2003/11/12	165	50	78	91	178	174
2003/11/13	175	45	85	102	163	232
2003/11/14	186	45	66	103	163	192
2003/11/15	173	44	72	93	140	175
2003/11/16	145	65	63	77	179	166
2003/11/17	156	41	72	99	159	192
2003/11/18	143	46	68	105	168	189
2003/11/19	182	37	71	104	167	192
2003/11/20	210	40	73	112	170	220
2003/11/21	157	53	87	106	193	193
2003/11/22	157	56	79	108	153	176
2003/11/23	149	49	72	99	187	180
2003/11/24	185	44	66	108	187	200
2003/11/25	167	47	69	117	189	189
2003/11/26	132	50	71	91	193	191
2003/11/27	176	52	81	108	186	217
2003/11/28	157	48	75	103	149	192
2003/11/29	165	55	79	105	169	184

Date	Thamel	Matsyagaon	Kirtipur	Bhaktapur	Patan Hospital	Putalisadak
2003/11/30	192	56	80	121	199	209
2003/12/01	215	62	104	121	215	235
2003/12/02	218	62	96	114	224	248
2003/12/03	180	52	91	110	201	278
2003/12/04	151	48	67	98	182	200
2003/12/05	190	56	92	117	208	243
2003/12/06	225	70	114	134	202	276
2003/12/07	173	76	95	134	211	227
2003/12/08	179	68	85	124	194	245
2003/12/09	162	37	60	97	159	231
2003/12/10	159	32	63	96	181	251
2003/12/11	181	36	66	106	201	226
2003/12/12	186	36	70	104	211	265
2003/12/13	214	36	77	126	218	336
2003/12/14	232	32	80	128	206	--
2003/12/15	238	44	96	136	223	--
2003/12/16	287	82	121	155	304	474
2003/12/17	259	47	112	115	238	356
2003/12/18	217	42	84	124	231	338
2003/12/19	233	34	81	162	232	303
2003/12/20	198	41	92	149	238	285
2003/12/21	208	42	82	159	244	297
2003/12/22	217	36	74	132	217	278
2003/12/23	213	36	90	127	257	--
2003/12/24	210	39	84	135	224	--
2003/12/25	260	32	83	160	231	323
2003/12/26	215	49	96	140	251	322
2003/12/27	195	54	110	156	208	245
2003/12/28	118	26	56	75	101	239
2003/12/29	204	43	90	124	198	282
2003/12/30	236	54	92	157	193	360
2003/12/31	271	49	114	195	256	347

Date	Thamel	Matsyagaon	Kirtipur	Bhaktapur	Patan Hospital	Putalisadak
2004/01/01	263	44	90	183	236	340
2004/01/02	220	51	87	156	292	314
2004/01/03	224	42	102	169	234	260
2004/01/04	226	55	103	177	234	262
2004/01/05	195	57	105	164	264	280
2004/01/06	231	47	106	169	249	330
2004/01/07	241	45	97	200	242	326
2004/01/08	255	49	116	232	298	366
2004/01/09	248	50	107	205	299	349
2004/01/10	237	51	110	202	273	295
2004/01/11	256	60	125	172	271	316
2004/01/12	264	57	112	207	271	279
2004/01/13	212	56	104	206	260	277
2004/01/14	196	45	105	184	192	--
2004/01/15	183	51	101	151	198	182
2004/01/16	204	81	130	197	229	320
2004/01/17	223	65	113	184	226	287
2004/01/18	234	69	123	227	330	313
2004/01/19	216	63	133	214	265	285
2004/01/20	221	69	124	221	271	270
2004/01/21	180	67	119	195	199	244
2004/01/22	137	59	102	179	212	251
2004/01/23	170	65	140	219	204	195
2004/01/24	104	33	66	100	118	139
2004/01/25	190	34	77	153	217	343
2004/01/26	233	61	89	149	267	309
2004/01/27	177	57	81	143	229	254
2004/01/28	208	57	106	149	261	248
2004/01/29	215	81	126	175	220	294
2004/01/30	227	66	113	167	236	297
2004/01/31	256	71	168	247	300	317
2004/02/01	234	49	136	202	290	365

Date	Thamel	Matsyagaon	Kirtipur	Bhaktapur	Patan Hospital	Putalisadak
2004/02/02	151	45	93	160	187	186
2004/02/03	185	43	86	167	225	222
2004/02/04	162	64	81	127	210	173
2004/02/05	137	64	83	109	172	187
2004/02/06	168	62	90	151	221	227
2004/02/07	180	67	108	182	207	223
2004/02/08	219	73	115	206	251	255
2004/02/09	225	58	122	240	274	263
2004/02/10	219	62	112	203	251	308
2004/02/11	--	48	114	223	249	279
2004/02/12	--	46	92	168	187	192
2004/02/13	--	52	123	203	299	286
2004/02/14	--	66	114	171	265	217
2004/02/15	194	66	128	174	256	280
2004/02/16	256	64	110	210	261	311
2004/02/17	216	69	120	210	213	217
2004/02/18	265	81	146	295	333	288
2004/02/19	301	83	157	244	291	318
2004/02/20	195	69	114	188	273	239
2004/02/21	190	92	131	213	256	231
2004/02/22	175	70	115	172	192	232
2004/02/23	197	93	131	200	277	260
2004/02/24	204	110	135	190	214	238
2004/02/25	192	98	143	206	175	196
2004/02/26	186	93	129	213	--	220
2004/02/27	182	97	129	207	--	222
2004/02/28	188	77	118	180	--	245
2004/02/29	205	68	122	205	233	248