

Disease burden of fuelwood combustion pollutants in rural households of the Himalayas, India

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ABSTRACT

BACKGROUND: Household biomass combustion for cooking purposes produces pollutants. Exposure to these pollutants has various adverse health impacts and is a major contributor to global disease burden. However, a precise estimate of the burden attributable to biomass combustion at the local level is not available in different parts of the world, therefore restricting policymakers' ability to develop targeted actions against the health hazards. A study was conducted in the rural Himalayas to generate information about disease burden, with the purpose of aiding the development of strategies to improve public health.

METHODS: Exposure level, population exposed and other relevant data regarding fuel-wood use, were collected through questionnaire survey from 102 randomly selected households spread in 46 villages in a two phase cluster random sampling design study during 2008 – 09. The burden of disease for Acute Lower Respiratory Infection (ALRI), Chronic Obstructive Pulmonary Disease (COPD) and Lung Cancer were estimated as per fuel-based approach of WHO guidelines for rural hilly households, using fuel-wood for cooking.

RESULTS: Households, primarily dependent on fuel-wood for fuel, had disability adjusted life years (DALYs) lost and deaths that were much higher than the National status. The incidence of disease burden was 2 909 DALYs lost, with a share of 1 987 for ALRI in children "up to" 5 years age, 730 for COPD and 192 for Lung Cancer in adults more than 30 years old, respectively.

This result has implications for policy makers when deciding on an effective exposure reduction strategy and describes the risks connected between these health hazards and the health outcome of inhabitants exposed to them. The paper also discusses the intervention strategies for "addressing" the issues relevant to fuel-wood generated exposure.

Key words: Biomass, Exposure, Indoor air pollution, Pulmonary disease, Respiratory infection, Solid fuels

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INTRODUCTION

Energy sources generally used by households for cooking purposes can be categorised as traditional (such as dung, agricultural residues and fuel-wood, also termed as solid fuel), intermediate (such as charcoal and kerosene) or modern (such as LPG, biogas, ethanol gel, plant oils, dimethyl ether (DME) and electricity). Globally, large numbers of households are primarily dependent on traditional fuels for cooking and heating purposes

(1). Approximately 50% of total households worldwide, out of which 90% being rural households, use solid fuels for cooking or heating purposes (2). In developing countries, 2.5 billion rural households are primarily based on traditional sources for cooking purposes, and use solid fuels with a high preference for fuel-wood (3). The combustion of traditional fuel generates various harmful pollutants. Therefore, approximately 50% of the world population (close to 3 billion) is exposed to the harmful effects of these combustion products (4).

The composition of combustion products, i.e. pollutants, varies with the fuel used and the conditions of combustion (4). These pollutants are primarily responsible for indoor air pollution, mainly in poorly ventilated kitchens, and also influence the pollution level outside the kitchen (5). In particular, poor households in rural areas of developing countries are more affected by indoor air pollution due to solid fuel use (SFU). The daily exposure level ranges from 3 to 7 hours in poor rural households (6) and may exceed "up to" 24 hours for people living in mountainous regions during winter (7). Women and children are most exposed, due to their high permanence in fuel-wood burning environments. The indoor pollution exposures adversely affect the health of family members and the negative effects increase with high level of exposure (8).

For example, wood smoke, generated during cooking and heating with fuel-wood for various household purposes, is a complex mixture of numerous volatile and particulate substances constituted by different organic and inorganic compounds (9, 10). A significant number of these wood smoke constituents are known to be toxic or irritants for the respiratory system. These pollutants include airborne particulate matter PM (PM10), carbon monoxide (CO), nitrogen and sulphur oxides (NO₂, SO₂), aldehydes (e.g., formaldehyde), polycyclic aromatic hydrocarbons (e.g., benzo-pyrene), volatile organic compounds, chlorinated dioxins, and free radicals (9, 11).

Solid fuel use produces smoke containing human carcinogens and tiny particulate matter (PM) known to penetrate deep into the lungs (12, 13). The smoke and PM generated by solid fuel use is most firmly associated with acute lower respiratory infections (including pneumonia - ALRI) in young children, and chronic obstructive pulmonary disease (COPD) and lung cancer in women (and to a lesser degree in men) as well as with several other health outcomes such as adverse pregnancy and eye diseases (14, 15, 16, 17, 18). The estimated share of SFU-generated indoor air pollution for global disease burden is 2.7% (19). Estimates of Hong (20) and Bruce et al. (17) attribute 1.5 to 2 million annual deaths globally to indoor air pollution, most of them (1 million) occurring in children younger than 5 years due to acute respiratory infections (ARI), but rates are also higher in women due to chronic obstructive pulmonary disease (COPD) and lung cancer (21). The situation is no different in more recent

periods as the World Health Organization reports that more than 1.6 million deaths, and over 38.5 million disability-adjusted life-years can be attributable to indoor smoke from solid fuels affecting mainly children and women (4). India, with 80% of households depending on traditional fuels (22), has the largest burden of disease among developing countries and contributes alone to 28% of the deaths due to indoor air pollution generated by use of unprocessed fuels. About half a million women and children die every year from indoor air pollution in India (23).

Contrary to all, efficient mechanisms for 'addressing' the issue of diseases generated due to SFU have not evolved across the country due to lack of information about the disease burden at a regional and local level. The potential causes revolve around the unavailability of local and regional information about the volume and variety of solid fuel use and the proportion of the population exposed to indoor pollution generated from solid fuel combustion. The present study attempts to explore the regional estimates of forest dependent communities of the Himalayan Mountains of Uttarakhand, India, and outlines an estimation of the disease burden for ALRI, COPD and lung cancer at the local level caused by household exposure to indoor smoke from burning forest biomass. This article presents information about the evidence linking the exposure to wood smoke to the burden of disease attributable to the exposure. The prime aim of the study is to provide important information about the distribution of this burden across different subpopulations (e.g. infants, women) in mountains, thus helping define strategies to improve public health. In fact, disease burden estimates provide an indication of the health gains that could be achieved by implementing targeted actions against specific risk factors. The measures define the roles of policy makers and give them the right information to intervene properly when deciding the exposure reduction strategy and the reduction of connected risks, and also contribute to prioritize actions and direct them to the population groups at highest risk. The article also discusses prevention measures.

Symptoms of solid fuel use generated diseases

Acute Lower Respiratory Infection (ALRI) is one of the most dreadful diseases for India, and for the world, and predominately occurs in children due to high level of exposure to smoke. Symptoms of ALRI include shortness of breath,

weakness, high fever, coughing and fatigue, and vary with respect to the population exposed (24). ALRI contributes approximately one-twelfth of the total disease burden (25, 26). Lower respiratory tract infections were found to be the leading cause of deaths among all infectious diseases, and accounted for 3.9 million deaths worldwide and 6.9% of all deaths in 2002 (27).

Chronic obstructive pulmonary disease (COPD) refers to chronic bronchitis and emphysema, which lead to an inadequate supply of air to and from the lungs causing shortness of breath (Dyspnoea). Indoor air pollution is responsible for approximately 0.7 million out of the 2.7 million global deaths due to COPD (28). The occurrence of COPD in developing countries is high mainly because of smoking, but nonetheless non-smoking women also experience high rates of COPD (2). Cor pulmonale is also a serious heart problem occurring in women exposed to indoor air pollution in South Asia (12, 29). The symptoms of lung cancer include: a chronic cough, worsening breathlessness, weight loss, excessive fatigue, persistent pain in the chest. One of the most significant symptoms of lung cancer is coughing up blood or haemoptysis. Lung cancer in women is also serious problem associated with solid fuel uses (30, 31, 32).

The WHO included indoor air pollution among the 26 risk factors relevant to the global burden of disease thanks to the growing evidence from epidemiologic studies establishing a relationship between the use of biomass fuel in households and ill health (21, 19, 33). Indoor air pollution was globally ranked 10th among preventable risk factors causing burden of disease, and fourth in developing countries (19).

METHODS

The study region, a tribal area known as Jaunsar Bawar of the Dehradun district of Uttarakhand state in the lower Himalayas of India, is located between the latitudes of 30° 31' N and 31° 3' 30" N and the longitudes of 77° 45' E and 78° 7' 20" E. It is entirely composed of a succession of peculiarly rough and precipitous hills and mountains, and largely covered by forests. The altitude ranges from 405 to 3 071 metres with temperate climate in higher elevations and quite hot conditions in the lower river valleys along the Tonns and Yamuna rivers. The forest cover in the

region consists of conifers on the higher elevations and broad-leaved forests in the lower areas. The total of household count is 14 399 (total of population of 114 693), which are sparsely distributed in 357 scattered small nucleated villages (34). The households consist often live as small-holders. Their livelihoods depend on agriculture and forests (35). Communities in Jaunsar have two-storied wooden houses with indoor kitchens, in general. A few houses are made of mud-based or cemented bricks, with indoor or outdoor based kitchens, few of them having ventilated structures and chimneys.

Primary data were collected through exploratory survey from 102 randomly selected households spread in 46 villages across the study region. The sample size was based on the 10% margin of error through standard procedure (36) by considering the coefficient of variation of fuel-wood required. Villages were selected by a random cluster sampling procedure, keeping in view the homogeneous group of the sampling population of nearby villages, by following a two phase cluster random sampling design. In the first phase, villages were selected, followed by sampling units i.e. households. The selection of households was random irrespective of their status, though similar cooking "behavioural" characteristics of the households were selected, as observed during the pilot survey. The randomisation procedure for household selection was based on random number tables throughout the households of the villages. The required information on exposure to pollutants due to fuel-wood use as cooking energy, household characteristics, fuel-wood consumption pattern, cooking "behaviour" of the households and kitchen structure, were collected during 2008-09 through a questionnaire survey, as suggested by Lioy (37), from all randomly selected households of the region.

An estimation of disease burden due to exposure to SFU requires the estimates of Indian disease burden (published in WHO guide), relative risk (odds ratios), DALYs lost and death. The odds ratio approximates the relative risk (risk ratio) when the condition is "rare" (2). Relative risks were evaluated on evidence base. "Strong" indicates that results of the number of studies related to indoor air pollution in developing countries have a strong association with studies related to outdoor air pollution and smoking, while "moderate" indicates relatively lesser evidence from studies. Diseases like ALRI in children, COPD and lung cancer (from exposure

TABLE 1

| RELATIVE RISKS FOR STRONG AND MODERATE HEALTH OUTCOMES (2) | | | | |
|--|--|-------------------------------|---------------|-----------|
| Evidence | Health outcome | Gender and Age group in years | Relative risk | Interval |
| Strong | ALRI | Children < 5 | 2.3 | 1.9 - 2.7 |
| | COPD | Women ≥ 30 | 3.2 | 2.3 - 4.8 |
| | Lung cancer (from exposure to coal smoke) | Women ≥ 30 | 1.9 | 1.1 - 3.5 |
| Moderate - I | COPD | Men ≥ 30 | 1.8 | 1.0 - 3.2 |
| | Lung cancer (from exposure to coal smoke) | Men ≥ 30 | 1.5 | 1.0 - 2.5 |
| Moderate - II | Lung cancer (from exposure to biomass smoke) | Women ≥ 30 | 1.5 | 1.0 - 2.1 |

ALRI - Acute Lower Respiratory Infection; COPD - Chronic Obstructive Pulmonary Disease

to coal smoke) in adult women, have a “strong” association with SFU whereas COPD and lung cancer (from exposure to coal smoke) in men lies under “Moderate-I” category. Lung cancer (from exposure to biomass smoke) in women, asthma in children and adults, cataracts and tuberculosis in adults are in “Moderate-II” category due to low evidence (2). Data of relative risks for different age groups are reported in Table 1.

The disease burden was estimated as per fuel-based approach of WHO guidelines (2) outlined in the following procedure.

Step 1:

Attributable fraction (AF) was estimated for selected diseases occurring in males and females of different age group as follows.

The percentage of population exposed (exposure level) and unexposed was estimated, based

$$AF = \frac{(\% \text{ Population exposed} * \text{Relative Risk} + \% \text{ Population Unexposed} * 1) - 1}{(\% \text{ Population exposed} * \text{Relative Risk} + \% \text{ Population Unexposed} * 1)}$$

on a questionnaire survey of the rural households of Jaunsar.

Step 2:

Attributable burden was estimated by multiplying the attributable fraction by the corresponding disease burden in the region.

$$\text{Attributable burden} = \text{Attributable fraction} * \text{Disease level}$$

The disease level (DALYs lost or deaths) occurring due to exposure to SFU in the Jaunsar

population was based on national disease burden, multiplied by the proportion of Jaunsar’s population to the national population. The total Indian population for the year 2002 was 1018.5 (million) and for Jaunsar it was 114 593 individuals (38). The age and gender-wise Jaunsar population was estimated from national population proportions (Table 2).

The national disease level (DALYs lost or deaths) due to SFU (Table 3) was as per WHO (39), and was used to estimate the respective value of disease level for the population of Jaunsar by multiplying it to the age and gender-wise population proportion for respective diseases.

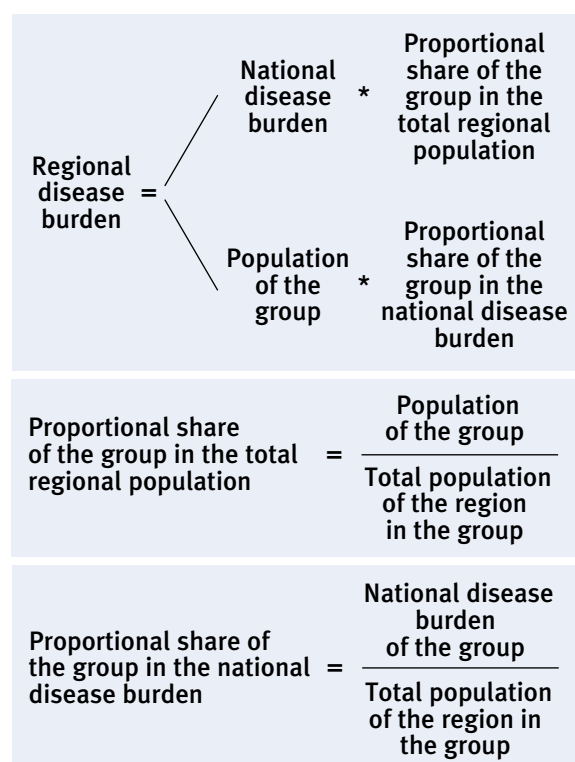


TABLE 2

| GENDER-WISE POPULATION DISTRIBUTION FOR INDIA AND JAUN SAR | | | | | | |
|--|--------------------------------|--------|---------|---------------------|----------|----------|
| Age (years) | India population (in Millions) | | | Jaunsar population* | | |
| | Male | Female | All | Male | Female | All |
| 0 - 4 | 59.0 | 56.0 | 115.2 | 6 702.7 | 6 235.2 | 12 937.9 |
| 5 - 14 | 114.6 | 107.5 | 222.1 | 13 019.1 | 11 969.4 | 24 988.5 |
| > 15 | 352.6 | 328.6 | 681.2 | 40 056.9 | 36 587.3 | 76 644.2 |
| > 30 | 203.8 | 194.6 | 398.4 | 23 152.6 | 21 667.3 | 44 819.9 |
| Totals | 526.3 | 492.2 | 1 018.5 | 59 790 | 54 803 | 11 4593 |

* - The age and gender-wise distribution of Jaunsar population is derived from national proportions of Census of India, 2001.

TABLE 3

| TABLE 3 INDIAN NATIONAL BURDEN OF DISEASE FOR SELECTED DISEASES IN 2000 (IN THOUSANDS) | | | | | | | | |
|--|------------|----------------------|--------|----------------------|------------|----------------------|--------|----------------------|
| (Per 1 000 persons) | | | | | | | | |
| Disease, Gender, Age group | Total | | | | SFU Share | | | |
| | DALYs lost | National Proportion* | Deaths | National Proportion* | DALYs lost | National Proportion* | Deaths | National Proportion* |
| ALRI, Children < 5 years | 17 674 | 0.15342 | 499 | 0.00433 | 9 065 | 0.07869 | 256 | 0.00222 |
| COPD, Women ≥ 30 years | 1 856 | 0.00954 | 104 | 0.00053 | 1 189 | 0.00611 | 66 | 0.00034 |
| COPD, Men ≥ 30 years | 1 890 | 0.00927 | 101 | 0.00050 | 743 | 0.00474 | 40 | 0.00020 |
| Lung cancer, Women ≥ 30 years | 209 | 0.00107 | 18 | 0.00009 | 6 | 0.00003 | 0 | 0.00000 |
| Lung cancer, Men ≥ 30 years | 763 | 0.00374 | 77 | 0.00038 | 11 | 0.00005 | 1 | 0.00000 |

ALRI - Acute Lower Respiratory Infection; COPD - Chronic Obstructive Pulmonary Disease

*National Proportion = National burden of disease in the gender for specified age group / Total population in the gender for specified age group

Step 3:

The sum of attributable burden results in the total Environmental burden of disease (EBD) from SFU, for total DALYs lost and Death, respectively.

RESULTS

The household survey results showed that 100% of the households of Jaunsar used biomass for cooking. Firewood was the most common fuel used by these households. The population distribution of Jaunsar was obtained with defined methodology by using national proportions for different age classes of both genders (Table 2). The disease burden in Jaunsar was estimated with a defined methodology by multiplying the national disease burden (Table 3) with the proportional share of respective popu-

lation under different age groups of both genders. For example, the population proportional share of children “up to” 5 years in Jaunsar was 0.0001123 (Total Population of children “up to” 5 years in Jaunsar divided by Total population of children “up to” 5 years in country) of the total Indian children population “up to” 5 years. Therefore, the burden of disease due to ALRI in Jaunsar for children “up to” 5 yrs of age would be 1 985, derived by multiplying 0.0001123 by the national burden of disease from ALRI for children “up to” 5 yrs of age (0.0001123*17 674 000). The distribution of disease burden (DALYs lost and deaths) for various diseases, such as ALRI in children and COPD and lung cancer in adults due to fuel-wood generated indoor air pollution, is reported in Table 4. In totality, disease burden in Jaunsar was 2 517 for DALYs lost and 90 for deaths.

TABLE 4

| DISEASE BURDEN (DALYS LOST AND DEATHS) IN JAUN SAR | | | | | | | | |
|--|------------|--------------------|--------------------------------|-------------|--------------------|---------|--------------------|---------|
| Gender | Age group | Jaunsar Population | National Population Proportion | Disease | DALYs lost | | Deaths | |
| | | | | | National (in '000) | Jaunsar | National (in '000) | Jaunsar |
| Boys | < 5 years | 6 702.7 | 0.0000582 | ALRI | 17 674 | 1 028 | 499 | 29 |
| Girls | < 5 years | 6 235.2 | 0.0000541 | | | 957 | | 27 |
| Men | > 30 years | 23 152.6 | 0.000114 | COPD | 1 890 | 215 | 101 | 11 |
| Women | > 30 years | 21 667.3 | 0.000111 | | 1 856 | 207 | 104 | 12 |
| Men | > 30 years | 23 152.6 | 0.000114 | Lung cancer | 763 | 87 | 77 | 9 |
| Women | > 30 years | 21 667.3 | 0.000111 | | 209 | 23 | 18 | 2 |
| Total | | | | | 22 392 | 2 517 | 799 | 90 |

ALRI - Acute Lower Respiratory Infection; COPD - Chronic Obstructive Pulmonary Disease
 DALYs lost in Jaunsar = National Population Proportion * National burden of diseases for DALYs lost

In Jaunsar, people were fully dependent upon solid fuel, mainly fuel-wood, and therefore exposure level was 100%. This was used to estimate the attributable fraction for ALRI, COPD and Lung cancer for females and males of different age groups as per methodology (Table 5). The attributable fraction was used to estimate the attributable burden (DALYs lost and Death) in Jaunsar, based on the disease burden of the region as per Table 4 and reported in Table 5. Attributable burden of disease is higher in children, probably due to the start of exposure at much younger ages, as also reported by Ezzati and Kammen (40).

The total environmental burden of disease (EBD) due to SFU in Jaunsar was 2506 DALYs lost and 89 deaths with a higher share of ALRI. This shows that, in Jaunsar, the share of the environmental burden of disease is approxi-

mately more than 95%. The Burden of disease per thousand was found to be highest in children i.e. 153 DALYs lost and 4 deaths due to exposure to indoor air pollution. Exposure level of pollutants from SFU is dependent on various factors such as cooking practices, stove types, climate, household structure, ventilation and therefore uncertainty may have entered the estimate. However, due to the 100% dependency of the population on fuel-wood, the estimates may not be sensitive for DALYs lost and death.

The highest contribution to disease burden is seen in acute lower respiratory infections in children and this is a serious concern due to the uncertainty in the future use of fuel-wood. The available complementary strategies, such as expanded case management for pneumonia and introduction of newer antigens such as those against haemophilus B and streptococcus pneu-

TABLE 5

| ATTRIBUTABLE FRACTION AND BURDENS (DALYS LOST AND DEATHS) OF DISEASE DUE TO SFUS IN JAUN SAR | | | | | |
|--|--------|------------|----------|------------|--------|
| Disease | Gender | Age group | Fraction | DALYs lost | Deaths |
| ALRI | Boys | < 5 years | 0.996 | 1 024 | 29 |
| | Girls | < 5 years | 0.996 | 953 | 27 |
| COPD | Men | > 30 years | 0.994 | 213 | 11 |
| | Women | > 30 years | 0.997 | 206 | 12 |
| Lung cancer | Men | > 30 years | 0.993 | 86 | 9 |
| | Women | > 30 years | 0.993 | 23 | 2 |
| Total | | | | 2 506 | 89 |

ALRI - Acute Lower Respiratory Infection; COPD - Chronic Obstructive Pulmonary Disease;
 DALYs - Disability adjusted life years

monia into child vaccination programs, may be suitably implemented in these areas to counter the acute respiratory infection (41).

DISCUSSION

Indoor air pollution is a major health hazard for the poor in developing countries worldwide. The present study analysed the burden of disease for selected diseases (ALRI, COPD and lung cancer) due to fuel-wood use in rural Jaunsar, India. This estimate facilitates the country level estimate and advocates for the exploration of evidence and a systematic review of these areas in terms of health perspectives. The analysis may assist decision-makers in setting priorities when selecting intervention areas, and may also lead to the economic evaluation of associated externalities against the health hazards due to fuel-wood use.

This study highlights that household energy supply and utilization planning should be taken into consideration, along with other aspects of cooking. The ideal way to prevent or reduce the health impacts due to fuel-wood use revolves around the reduction of the exposure, which is a complex issue due to the close link between fuel-wood use and cultural or economic aspects at individual and local levels. These aspects include the level of development that prevails in the region, available resources, technical capacity, the domestic needs of energy, the sustainability of the alternate sources of energy, and the protection of the environment (though at low level). Therefore, interventions should be deliberated and based on all these aspects to offer feasible solutions, as also advocated by Bruce et al. (17), Torres-Duque et al. (4). This will help to achieve a synergy with local resources, and offer widespread and sustainable improvements in household energy consumption.

In order to achieve a healthy household environment, attention should be focused on the interrelationship between poverty and dependency on unprocessed fuel. Household use of fuel-wood, with improved stoves for complete combustion and well-ventilated homes for proper dispensing of pollutants into the outside environment, may markedly mitigate exposure. The increased use of improved stoves through policy planning is cost effective also from a pub-

lic health perspective (42). The proper condition of fuel-wood and changes in local practices of cooking must be brought into the knowledge of the poor through educating them about the dreadful impact and consequences of fuel-wood generated air pollution (43).

Substantial improvements are expected with the adjustments in cooking "behaviour" and prevailing practices, even with fuel-wood use. These adjustments, such as simple changes in ventilation characteristics of housing (locations and placement of windows and doors, cooking locations, space configuration, construction materials) and ventilation practices (keeping doors and windows open after cooking) (as recommended by Dasgupta et al., (44)) can be quite simple; improving habits to avoid the unnecessarily closeness to the fire (21), and keeping children away from fires (4) are within the possibilities of poor households and may be cost effective too. It was estimated that 30% of the burden of disease due to household environment can be reduced just by improving the practice involving our daily. The proper choice of species i.e. better thermal efficiency with low emission and condition (properly dried and processed logs) of fuel-wood also helps to reduce the exposure of polluted smoke. These may also be associated with a reduction of the pollutant mix into atmosphere and may, therefore, help to achieve solutions to the environmental concerns.

In summary, transition to high-efficiency/low-emission fuels will have substantial health benefits. This transition should be adapted to the particular conditions of each region and country (1). Besides this, education and cultural modification should be necessary components of any intervention, including structural adjustments such as improvements in household ventilation and area distribution with the encouragement for the use of improved stoves (4). The study further recommends that exposure measurements should also be considered to evaluate the current status, and for establishing future prevention measures against health hazards. The in-depth evaluation of the impact of environmental factors on humans, including the "psychosocial" analysis in the local settings, will help to achieve a better quality of life for these people and a more holistic approach for "addressing" health hazards issues.

The present disease burden analysis is based on fuel-based approach, and used data from standardized questionnaires, a simple and relatively inexpensive method for collecting data instead of using some other available means. This may be a limitation and therefore should be complemented, when possible, with objective measurements. Important confounding fac-

tors, including dietary factors, passive smoking exposures, comorbidities, familial history of studied diseases, and overall active smoking, may also limit the significance of these findings. In addition, the consideration of study design, i.e. clustering approach according to resources, and poor infrastructural bases at the study site, may also be limiting factors of the study.

References

- (1) Smith KR, Mehta S, Maeusezahl-Feuz M. Indoor air pollution from household use of solid fuels: Comparative quantification of health risks. In: Global and regional burden of disease attributable to selected major risk factors (Ed.) Ezzati M, Rodgers AD, Lopez AD, Murray CJL. WHO, Geneva, 2004.
- (2) Desai MA, Mehta S, Smith KR. Indoor smoke from solid fuels: Assessing the environmental burden of disease at national and local levels. WHO Environmental Burden of Disease Series, No. 4, WHO, Geneva, 2004.
- (3) TERI. Securing energy sustainability: a development imperative. TERI, New Delhi, 2007.
- (4) Torres-Duque C, Maldonado D, Pe´rez-Padilla R, Ezzati M, Viegı G. Biomass Fuels and Respiratory Diseases: A Review of the Evidence. *Proc Am Thorac Soc* 2008;5:577-590.
- (5) Smith KR, Apte MG, Ma Y, Wongsekiartitar W, Kulkarni A. Air pollution and the energy ladder in Asian cities. *Energy the Internl. J* 1994;19(5):587-600.
- (6) Engel P, Hurtado E, Ruel M. Smoke exposure of women and young children in highland Guatemala: predictions and recall accuracy. *Human Organisation* 1988;54:408-417.
- (7) Norboo T, Yahya M, Bruce N, Heady A, Ball K. Domestic pollution and respiratory illness in a Himalayan village. *International Journal of Epidemiology* 1991;20(3):749-757.
- (8) Saksena S, Dayal V. Total exposure as a basis for the economic valuation of air pollution in India. *Energy Environ. Monitor* 1997;13:93-102.
- (9) Zelikoff JT, Chen LC, Cohen MD, Schlesinger RB. The toxicology of inhaled woodsmoke. *J Toxicol Environ Health* 2002;5:269-282.
- (10) Naeher LP, Brauer M, Lipsett M, Zelikoff JT, Simpson CD, Koenig JQ, Smith KR. Woodsmoke health effects: a review. *Inhal Toxicol* 2007;19:67-106.
- (11) Nolte CG, Schauer JJ, Cass GR, Simoneit BR. Highly polar organic compounds present in wood smoke and in the ambient atmosphere. *Environ Sci Technol* 2001;35:1912-1919.
- (12) Smith KR. *Biofuels, air pollution, and health: a global review*. Plenum, New York, 1987.

- (13) Purvis CR, McCrillis RC, Kariher PH. Fine particulate matter and organic speciation of fireplace emissions. *Environmental Science and Technology* 2000;34(9):1653-1658.
- (14) Armstrong JR, Campbell H. Indoor air pollution exposure and lower respiratory infections in young Gambian children. *International Journal of Epidemiology* 1991;20(2):424-429.
- (15) Behera D, Dash S, Yadav SP. Carboxyhaemoglobin in women exposed to different cooking fuels. *Thorax* 1991;46(5):344-346.
- (16) Awasthi S, Glick H, Fletcher R. Effect of cooking fuels on respiratory diseases in preschool children in Lucknow, India. *Am J Trop Med Hyg* 1996;55(1):48-51.
- (17) Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. *Bulletin of the World Health Organization* 2000;78(9):1067-1071.
- (18) Ezzati M, Lopez A. Mortality and morbidity due to smoking and oral tobacco use: global and regional estimates for 2000. In: *Comparative Quantification of Health Risks: The Global Burden of Disease due to Selected Risk Factors*, Ed. Ezzati M, Lopez AD, Rodgers A, Murray CJL. WHO, Geneva, 2004.
- (19) WHO. *The World Health Report 2002: reducing risks, promoting healthy life*. WHO, Geneva, 2002.
- (20) Hong C. *Global burden of disease from air pollution*. WHO, Geneva, Switzerland, 1995.
- (21) Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJ. Selected major risk factors and global and regional burden of disease. *Lancet* 2002;360:1347-1360.
- (22) IIPS. *National Family Health Survey (NFHS-2) - India, 1998-1999*. International Institute for Population Sciences, Mumbai, 2002.
- (23) Smith KR, Samet JM, Romieu I, Bruce N. Indoor air pollution in developing countries and acute respiratory infections in children. *Thorax* 2000;55: 518.
- (24) Bruce NG. *Household energy and public Health, An introduction*. Department of public health, WHO, Geneva, 2002.
- (25) Murray CJL, Lopez AD. The global burden of disease: a comprehensive Assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020. In: *Global burden of disease and injury series*. Harvard School of Public Health, Cambridge, 1996.
- (26) Smith KR. Indoor air pollution implicated in alarming health problems. In: *Indoor Air Pollution - Energy and Health for the poor*. Newsletter, World Bank, 2000.
- (27) WHO. *Changing history*. WHO, Geneva, 2004.
- (28) WHO. *World Health Report 2005*. WHO, Geneva, 2005.
- (29) Pandey MR, Basnyat B, Neupane RP. Chronic bronchitis and cor pulmonale in Nepal: a scientific epidemiologic study. Mrigenda Medical Trust, Kathmandu, Nepal, 1988.
- (30) Sobue T. Association of indoor air pollution and lifestyle with lung cancer in Osaka, Japan. *International Journal of Epidemiology* 1990; 19(Suppl 1):S62-S66.
- (31) Liu Q, Sasco AJ, Riboli E, Hu MX. Indoor air pollution and lung cancer in Guangzhou, People's Republic of China. *American Journal of Epidemiology* 1993;137(2):145-154.
- (32) Ko YC, Lee CH, Chen MJ, Huang CC, Chang WY, Lin HJ, Wang HZ, Chang PY. Risk factors for primary lung cancer among non-smoking women in Taiwan. *International Journal of Epidemiology* 1997; 26(1):24-31.
- (33) Lopez AD, Mathers CD, Ezzati M, Jamison DT, Murray CJL. *Global burden of disease and risk factors*. World Bank Publications, Washington, 2006.
- (34) Government of India. *Census of India. 2001. Housing profile: Uttaranchal*. Registrar General, India, New Delhi, 2001.
- (35) Pandey R. *Contribution of Forestry-Role in socio-economic of Jaunsaries and development of index*. Unpublished Ph.D. Thesis, FRI University, Dehradun, 2007.
- (36) Cochran WG. *Sampling techniques*. John Wiley & Sons Pvt. Ltd., New Delhi, 1977.
- (37) Liroy PJ. *Assessing total human exposure to contaminants: a multidisciplinary approach*. *Environmental Science and Technology* 1990;24(7):938-945.
- (38) US Bureau of the Census. *India 2001: Mid year population, by age and sex*. Washington, 2002.
- (39) WHO. *World Health Report 2001*. WHO, Geneva, 2001.
- (40) Ezzati M, Kammen DM. Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries. *Environmental Health Perspectives* 2001;109(5):481-488.
- (41) Victora CG, Kirkwood BR, Ashworth A, Black RE, Rogers S, Sazawal S, Campbell H, Gove S. Potential interventions for the prevention of childhood pneumonia in developing countries: improving nutrition. *Am J Clin Nutr* 1999;70(3):309-320.
- (42) Mehta S, Shahpar C. The health benefits of interventions to reduce indoor air pollution from solid fuel use: a cost-effectiveness analysis. *Energy for Sustainable Development* 2004;VIII(3):53-59.
- (43) Smith KR. Health impacts of household fuelwood use in developing countries. *Unasylva* 2006;224(57):41-44.
- (44) Dasgupta S, Huq M, Khaliqzaman M, Pandey K, Wheeler D. Indoor air quality for poor families: new evidence from Bangladesh. *Indoor Air* 2006;16:426-444.