Consequence of indoor air pollution in rural area of Nepal: a simplified measurement approach

Chhabi Lal Ranabhat1,2, Chun-Bae Kim1,2 *, Chang-Soo Kim2, Nilambar Jha3, K. C. Deepak2 and Fredric A. Connel4

1 Department of Preventive Medicine, Wonju College of Medicine Yonsei University, Wonju, Gangwon, South Korea
2 Institute for Poverty Alleviation and International Development, Yonsei University, Wonju, Gangwon, South Korea
3 BP Koirala Institute of Health Science, School of Public Health and Community Medicine, Dharan, Nepal
4 Department of Health Services, School of Public Health, University of Washington, Seattle, WA, USA

INTRODUCTION

Indoor air pollution (IAP) can be traced to prehistoric times when humans first moved to temperate climates and it became necessary to construct shelters and use fire inside them for cooking, warmth, and light. Fire led to exposure to high levels of pollution, as evidenced by the soot found in prehistoric caves (1). Approximately half of the world’s population and up to 90% of rural households in the developing countries still rely on unprocessed biomass fuels in the form of wood, dung, and crop residues (2). People in developing countries are commonly exposed to high levels of pollution for 3–7 h daily over many years (3). During winter in cold and mountainous areas, exposure may occur over a substantial portion of each 24-h period (4). Because of their customary involvement in cooking, especially women’s exposure is much higher than men’s (5). Young children are often carried on their mothers’ backs while cooking in progress and therefore spend many hours breathing smoke (1).

Many of the substances in biomass smoke can damage human health. The most important (substances) are particles, carbon monoxide, nitrous oxides, sulfur oxides (mainly produced by unprocessed fuel are carbon monoxide, sulfur oxides, particles, and volatile organic, which are responsible for producing different disease and illness in human beings (8)).

The pollutants from biomass increase the risk of acute respiratory infections (ARIs) in childhood, chronic obstructive pulmonary disease (COPD) and lung cancer in adult (9, 10). It is the most important cause of death for children under five in developing countries. Evidence also exists of associations between low birth weight (LBW), increased infant and perinatal mortality, pulmonary tuberculosis, nasopharyngeal and laryngeal cancer, and especially with the exposure of coal, with lung cancer to the non-smoker too (1, 11). Biomass users illustrated high suppression in the total number of T-helper (CD4+) cells and B (CD19+) cells, while appreciable rise was documented in the number of CD8+ T-cytotoxic cells and CD16+CD56+ natural killer (NK) cells and consistent finding among biomass users was rise in regulatory T (Treg) cells (12). It proved that IAP is not only arising the health problems but also responsible to worsen the other disease and illness by reducing the immunity.

Nepal is the country of village where >80% live in villages and 75% population are using the unprocessed biomass like firewood, animal dung, and some paper residue leaves of trees as a source of heat, especially women are exposed to high levels of pollution and health problems related to IAP. The treatment cost and episodes of acute respiratory infection was >2 folders higher in severe IAP than mild IAP. Simplified measurement approach could be helpful to measure IAP in rural area. Some effective intervention is suggested to reduce the severe level of IAP considering women and children.

Keywords: indoor air pollution, biomass, acute respiratory infection, health problems, cooking fuel
Table 1 | Average magnitude of pollutants within household.

| S No | Category                                  | PM$_{2.5-10}$ (mg m$^{-3}$) | CO (PPM) |
|------|-------------------------------------------|-----------------------------|----------|
| 1    | Smoking per episode within room           | 14 (20)                     | 65.5     |
| 2    | Biomass                                   | 263                         | 62.6 (21) |
| 3    | Clean fuel                                | 133                         | Few      |
| 4    | Non-ventilation                           | 0.45                        | 11       |
| 5    | Ventilation                               | 0.10                        | 1.6–4.4  |
| 6    | Pollutant coverage (kitchen)              | 652                         | 5.1–5.8  |
| 7    | Pollutant coverage (outside the kitchen)  | 297                         | Few      |
| 8    | Open fire space/traditional mud stove     | 0.45                        | 4.4      |
| 9    | Improve cooking stove                     | 0.10                        | 0.7      |

Table 2 | Degree of air pollution from Table 1.

| Mild/no IAP | Average IAP | Severe IAP |
|-------------|-------------|------------|
| Separate kitchen | Separate kitchen | No separate kitchen |
| At least 1 window or ventilation | No window/ventilation | No window/ventilation |
| Improve cooking stove | Improve cooking stove | Traditional mud stove |
| No Smoke within family | No smoke within family | Smoking person in family |
| Alternative using biomass | Always using biomass | Always using biomass |

kitchen fuel (13). The housing structure is very vulnerable for IAP because 70% households have wooden and mud bonded house with poor ventilation (14). Here, the majority of populations live in countryside and they used unprocessed biomass as a cooking fuel. As a result, the situation of ARI and skin diseases has been first and second in morbidity rank each year. In addition, the COPDs, eye problems, and other cough related diseases are frequently recurrent disease. So, there could be some association with the housing condition and IAP (15).

To study the magnitude of harmful gas like carbon dioxide, carbon monoxide, nitrogen oxide, benzene butadiene, formaldehyde, etc., there is necessary to measure the pollutants by some sophisticated equipment at the level of >10 p.m. Such approach can precise the level of IAP produced from different sources, but they are quite unpractical in a rural context for the household and the researchers. There is still lacking to measure the indoor air pollutants by simple methods and arising health problems due to the long exposure in rural areas and developing countries. The simplified IAP measurement questionnaire was prepared based on Warwick H. study (16) related to type of stoves, type of fuel, used in kitchen, smoking situation in family members, and some behavioral pattern of cooking member than any devices. The main objective of this research is to explore the health consequence related to IAP and its major effects as well as the relation of some factors in community level without sophisticated measurement of the pollutants and clinical diagnosis of the health problems.

Table 3 | Assessment of health status.

| S No | Conditions | Response |
|------|------------|----------|
| 1    | Do you have health problems since you are involving long time in your kitchen? | Yes |
| 2    | How many times did you suffer since 1 year? | . . . . . . . . |
| 3    | If yes, what kinds of health problems do you have? (multiple response) | Difficulty in breathing |
|      |            | Dry cough |
|      |            | Productive cough |
|      |            | Tearing of eyes |
|      |            | Itching of skin |
|      |            | Headache |
|      |            | Vertigo |
|      |            | Others . . . . . . . . . . . |
| 4    | Are those problems recurrent? | Yes |
| 5    | Do your kids (<5 years) suffering from ARI since 1 year? | Yes |
| 6    | How many times did he/she attack since last year? | . . . . . . . . |
| 7    | Where did you treat? | Home remedy |
|      |            | Hospitals and health centers |
| 8    | How much did you pay (in Nrs) for the treatment in last year for ARI to your children? | . . . . . . . . |
familiarity with study areas, local language, and culture and they were provided intensive training to get the adequate information and minimizing the errors.

**HEALTH PROBLEMS AND GRADING OF IAP**

Health problems arises due to IAP was asked to the respondents and they were taken as layman reporting as their symptoms rather than and lab/clinical diagnosis. The degree of IAP was plotted based on the Warwick article (16) and focus group discussion in that community. Likewise, it is very difficult to measure the pollutants without any equipment in rural areas. Based on the study by Chowdhury et al. (18) and Dasagupta et al. in Bangladesh (19), the severity of IAP has been measured in three category measuring carbon monoxide (CO) and particulate matter2.5–10 (Table 1).

From the above table, the magnitude of IAP was categorized into no/mild, average, and severe (Table 2). It is the simplified measurement based on above articles where the application of equipment to measure is impossible.

Furthermore, the category of the IAP was merged into two categories such as mild/no IAP to IAP (No) and average and severe IAP to IAP (Yes) due small or number of cell value during classification.

**ASSESSMENT OF HEALTH STATUS**
The health problems were asked to the respondents as like Table 3.

**ETHICAL CONSENTS**
Verbal consent was taken from each participant who involved in the study and also the written permission was taken from authority of BP Koirala Institute of Health Science Dharan Nepal.

**DATA ENTRY AND ANALYSIS**
Data were entered into Microsoft Excel and exported to SPSS 20.0. Logistic regression and odds ratio were applied to show the association in different variables. Some variables were merged who had small value during the statistical analysis. Education category, type of houses, and stove used during cooking had merged into

Table 4 | Descriptive findings from study (N = 157).

| Characteristics               | Variables    | Category     | Grading IAP – No. (%) | p Value |
|-------------------------------|--------------|--------------|-----------------------|---------|
|                               |              |              | No/mild IAP (%) | Average IAP (%) | Severe IAP (%) |         |
| Demographic variables         | Education    | Illiterate   | 3 (23.1) | 8 (61.5) | 2 (15.4) | <0.001 |
|                               |              | Primary      | 7 (14.6) | 33 (68.8) | 8 (16.7) |         |
|                               |              | Secondary    | 7 (15.2) | 23 (50) | 16 (34.8) |         |
|                               |              | Higher education | 2 (4.0) | 18 (36.0) | 30 (60.0) |         |
| Geographical location         | Rural        | 6 (4.8) | 70 (55.6) | 50 (39.7) |         | <0.001 |
|                               | Semi urban   | 13 (41.9) | 12 (38.7) | 6 (19.4) |         |         |
| Caste                         | DAG          | 1 (71) | 8 (57.1) | 5 (35.7) |         | 0.82    |
|                               | Non-DAG      | 18 (12.6) | 74 (51.7) | 51 (35.7) |         |         |
| Per capita income per month   | Up to 100$  | 13 (10.1) | 64 (49.6) | 52 (40.3) |         | 0.05    |
|                               | 100–200$     | 5 (19.2) | 17 (65.4) | 4 (15.4) |         |         |
|                               | >200$        | 1 (50.0) | 1 (50.0) | 0 (0.0) |         |         |
| Having own cultivating land   | No           | 11 (13.3) | 58 (59.8) | 28 (28.9) |         | 0.04    |
|                               | Yes          | 8 (13.3) | 24 (40.0) | 28 (46.7) |         |         |
| Housing category              | Dwelling and risk | 12 (40) | 16 (53.3) | 2 (6.7) | <0.001  |
|                               | Semi dwelling | 2 (14.3) | 8 (57.1) | 4 (28.6) |         |         |
|                               | Concrete/safe | 5 (4.4) | 58 (51.3) | 50 (44.2) |         |         |
| Factors related to IAP        | Smoking behavior | No | 18 (19.4) | 73 (78.5) | 2 (2.2) | <0.001  |
|                               |              | Yes | 1 (1.6) | 9 (14.1) | 54 (64.4) |         |
|                               | Separate kitchen | No | 4 (11.4) | 15 (42.9) | 16 (45.7) | 0.35    |
|                               |              | Yes | 15 (12.3) | 67 (54.9) | 40 (32.8) |         |
|                               | Cooking fuel | Biomass | 9 (6.9) | 68 (51.9) | 54 (41.2) | <0.001  |
|                               |              | No biomass | 10 (38.5) | 14 (53.8) | 2 (7.7) |         |
|                               | Ventilation in kitchen | No | 5 (3.8) | 71 (54.6) | 54 (41.5) | <0.001  |
|                               |              | Yes | 14 (51.9) | 11 (40.7) | 2 (7.4) |         |
|                               | Stove used during cooking | Traditional mud | 2 (1.8) | 58 (52.3) | 51 (45.9) | <0.001  |
|                               |              | Improved cooking | 4 (20.0) | 14 (70.0) | 2 (10.0) |         |
|                               |              | Electric/gas | 13 (50.0) | 10 (38.5) | 3 (11.5) |         |
|                               | Health problems | Yes | 1 (0.9) | 75 (54.7) | 62 (44.4) | <0.001  |
|                               |              | No | 9 (45.0) | 9 (45.0) | 1 (10.0) |         |
Table 5 | Comparison of risk by odds ratio associated health problems on logistic regression.

| Characteristic            | Categories       | Health problems ~No. (%) | OR (95% CI) | Adjusted OR (95% CI) |
|---------------------------|------------------|--------------------------|-------------|----------------------|
|                           | Semi urban       | 18 (58.1)                | 1           | 1                    |
|                           | Rural            | 22 (17.5)                | 6.5 (2.8–15.2)** | 2.2 (0.3–14.4) |
| Geographical distribution | Rural            | 22 (17.5)                | 6.5 (2.8–15.2)** | 2.2 (0.3–14.4) |
|                           | Semi urban       | 18 (58.1)                | 1           | 1                    |
|                           | Rural            | 22 (17.5)                | 6.5 (2.8–15.2)** | 2.2 (0.3–14.4) |
|                           | Semi dwelling    | 20 (45.5)                | 1           | 1                    |
| House type                | Semi dwelling    | 20 (45.5)                | 1           | 1                    |
|                           | Dwelling and risk| 20 (17.7)                | 3.8 (1.8–8.3)** | 0.6 (0.1–2.3) |
|                           | Semi dwelling    | 20 (45.5)                | 1           | 1                    |
|                           | Dwelling and risk| 20 (17.7)                | 3.8 (1.8–8.3)** | 0.6 (0.1–2.3) |
|                           | Non-DAG          | 38 (26.6)                | 1           | 1                    |
| Caste                     | DAG              | 2 (14.3)                 | 2.1 (0.4–10.1) | 0.4 (0.08–2.7) |
|                           | Literate         | 34 (23.6)                | 1           | 1                    |
| Education                 | Illiterate       | 6 (42.2)                 | 0.3 (0.1–1.1) | 1.3 (0.2–8.6) |
|                           | Non-DAG          | 38 (26.6)                | 1           | 1                    |
| Smoking member in family  | Yes              | 9 (14.1)                 | 3.0 (1.3–6.9)** | 2.1 (0.7–5.8) |
|                           | No               | 31 (33.3)                | 1           | 1                    |
|                           | Yes              | 9 (14.1)                 | 3.0 (1.3–6.9)** | 2.1 (0.7–5.8) |
| Separate kitchen          | Yes              | 32 (26.2)                | 1           | 1                    |
|                           | No               | 8 (22.9)                 | 1.2 (0.4–2.9) | 0.6 (0.1–2.1) |
| Use of biomass            | No               | 17 (65.4)                | 1           | 1                    |
|                           | Yes              | 23 (176)                | 8.8 (3.5–22.3)** | 2.8 (0.4–16.3) |
| Ventilation in kitchen    | Yes              | 21 (16.2)                | 1           | 1                    |
|                           | No               | 19 (70.4)                | 8.0 (0.03–0.2)** | 0.2 (0.08–0.9)* |
| Type of stove             | Improve cooking  | 28 (60.9)                | 1           | 1                    |
|                           | Traditional mud  | 12 (10.8)                | 12.8 (5.5–29.7)** | 8.6 (3.0–24.7)** |

The adjusted variables were geographical distribution, house type, per capita income smoking, types of kitchen fuel, stove type, ventilation, and health problems by binary logistic regression. 1 is reference value.

*p < 0.05, **p < 0.001.

two categories from three categories during multivariate analysis. The problems associated with IAP were found by verbal reporting during research. Data quality was maintained by pre-test of questionnaire, training of the field researchers, data verification, and cleansing in both excel and SPSS formats.

RESULTS

The study area was rural area of Sunsari District in south part. Most (81.5%) household were under the poverty level (≤1$ income/day). Except the caste (demographical variable) and separate kitchen (IAP factor), all variables were statistically significant (Table 4).

Bivariate and multivariate analysis was performed to show the association between some variables with the health problems. Table 5 shows the odds ratio before and after adjustment where traditional mud stove (8.6; 3.0–24.7) and use of biomass (2.8; 0.4–16.3) in 95% CI were more risk than other variables.

In Table 6, there are indirect effects of the IAP. The treatment cost per household is three folder (301$ vs. 893$) higher in no/mild IAP than severe IAP. Similarly, average episode of the illness of child per year is almost double and average episode of illness adult is not high in severe IAP. Figure 1 shows the category of illness and it reveals 55.4% had tearing of eyes where as 6% reported vertigo since last year 2013.

DISCUSSION

This study was carried out to explore the multiple effects of IAP in rural Terai area of Nepal. Before this study, some studies were conducted in hill and mountain area. Our study was simply designed but represents the global rural area. In other words, it is the simplest approach to find out the different magnitude of IAP in rural setting. Even it is useful to reduce the burden of IAP intervention strategy in small scale from the community level like during the construction of home and pollution free kitchen. The general illness was assessed that represents the morbidity pattern in the community without clinical and laboratory investigation. It is the significant achievement of the study. Poverty related factors like per capita income, education, housing condition, etc., are consistently
associated with IAP. Use of traditional mud stove and unrefined biomass is the major risk factors for health problems associated with IAP (Table 5). Since, respiratory illnesses are the major causes of morbidity and mortality globally and in Nepal also (15, 22).

The poor health outcomes of respondents and their children were associated IAP in our findings (Table 3; Figure 1). Similar results were found with other related studies. A qualitative study conducted in rural area of Lalitpur district of Nepal showed ARI was one of the most prevalent and common where there was hazy and severe indoor air smoke (23). The prevalence of respiratory illnesses and symptoms were considerably higher in those living in mud and brick houses compared with concrete houses and prevalence was also higher in those living on hills and in rural areas compared with flatland and urban areas (24). It is similar findings to our study that there is statistically significant housing type and IAP. ARI increased from 0.03 to 0.56 per child when exposure level increased from 0.09 hour category to 4+ hours category, respectively, in poor communities (25). The prevalence of productive cough was 19.7% tearing of eyes is 55.4%, difficulty on breathing is 27.3%, asthma is 8.9%, skin problems 6.3%, vertigo 9.4%, and headache 12.8% within cooking member of family who are involving >5 years in kitchen; (25, 26) similar results with our study.

In global context, there is strong evidence of an association with use of solid kitchen fuels and acute lower respiratory infections (ALRIs) in children aged <5 years in comparative health risk assessed by WHO in developing countries (27). The occurrence of associated diseases, like acute upper and lower respiratory infections, COPD, asthma, perinatal mortality, pulmonary tuberculosis, LBW, eye irritation and cataract, etc., in Uttar Pradesh, India to the women who were responsible in cooking through household biomass (28). Solid fuel smoke like coal, firewood, steam of trees, etc., possess the majority of the toxins found in tobacco smoke and has also been associated with a variety of diseases, such as COPD in women, ARI in children, and lung cancer in women in Mexico (29).

Exposure to solid fuel smoke is consistently associated with COPD and chronic bronchitis in developing countries; especially Africa continents (30). Child ALRIs, LBW, stillbirth, preterm birth, stunting, and all-cause mortality in children and equally risk of COPD, tuberculosis, and even lungs cancer to their mothers were heavily associated with IAP in China (31). Continued exposure to smoke from traditional fuels has been shown to cause acute respiratory illnesses (ARI), COPDs, lung cancer, blindness, and TB in another study in China (32).

In Nepal’s hill areas, women’s total recorded work time was found to be between 150 and 180% of that of men, out of which 40% was spent on fuel collection alone (33). For the sites where deforestation was greatest, the time required to collect a standard load of fuel wood was 75% higher than where deforestation was low, which translated to a 45% increase in time spent for fuel wood collection (34). Additionally, spending hours for cooking in hazardous conditions in inefficient stoves result rise to eye infections and other respiratory problems. Similarly, women had to spend considerable amount of time in collecting kitchen fuel thereby reducing the time available for education and income generating activities (35). Our surplus findings show that the treatment cost is about three folder higher, average episodes being ill to children and adult, more than two times higher to spend time in kitchen in severe IAP than no/mild IAP. These associated findings show the indirect impact of IAP.

There are some limitations of this study, where one is the precision of IAP and another is confirmation of the disease or illness because there are no use of scientific equipment to measure the pollutant level and clinical diagnosis of disease/illness. Another, the severity of IAP was based on CO and PM though other pollutants were not taken into account. The level of precision was 0.07 due to errors in some samples. The condition of biomass (wet/dry), type of biomass, other human behaviors, etc., could not to include in the standard and need to verify by scientific equipment.

CONCLUSION
So in developing countries, most of the population is in rural area, they are suffering from IAP directly or indirectly especially women and children. There are some scientific standard of good housing (36), but they are not practical to improve in rural context. So,
practical standards could be helpful to reduce the magnitude of IAP and reform the housing standard in those rural areas. This approach will not be gold standard to measure the indoor pollutants but screening process to measure the nature and magnitude of the pollution level by specific biomasses that are hazardous. Some effective interventions are suggested to reduce the severe level of IAP in community.

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