Pollutant Levels at Cooking Place and Their Association with Respiratory Symptoms in Women in a Rural Area of Delhi-NCR

Raj Kumar, Kamal Singh, Sumit Nagar, Manoj Kumar, Uday Kumar Mehto, Ganpat Rai and Nitesh Gupta

Department of Respiratory Allergy and Applied Immunology, Vallabhbhai Patel Chest Institute, University of Delhi, Delhi, India

Abstract

Background. Household air pollution resulting from biomass and coal stoves is implicated in more than one-third cases of annual deaths from chronic lung diseases worldwide and nearly 3% of lung cancer deaths. This burden is borne largely by poor women in the developing countries. We carried out a study to evaluate its association with respiratory symptoms in women in a rural area.

Methods. The study was carried out using a standard questionnaire, in 92 households including 174 women. The data on respiratory symptoms in women, kitchen type and location in households, type of fuel used for cooking, permanent ventilation in kitchen, presence of exhaust, history of tobacco smoking and indoor pollution level were obtained. Spirometry of participants was conducted. The indoor particulate matter (PM10, PM2.5 and PM1) and volatile organic compounds (VOCs) were measured in each home.

Results. The households were divided into two groups according to the location of the kitchen. In 46 households (Group A) women had a separate room as kitchen for cooking with good ventilation and exhaust conditions; and in the remaining 46 households (Group B) cooking was done in the living area. Seventy (76.1%) households used biomass fuel for cooking and heating (37; 80.4%, in Group A versus 46; 100% in Group B). The proportion of women with respiratory symptoms for one year or more was significantly high in Group B compared to Group A (13.0% versus 3.1% p=0.01). The households which did not have a separate kitchen (Group B) had higher particulate matter and VOCs concentration.

Conclusions. This study contributes to the growing evidence of adverse impact of indoor air pollution from biomass combustion on health of females. Results of the study demonstrated significantly high particulate matter (PM1), in households not using a separate room for cooking with biomass fuel. [Indian J Chest Dis Allied Sci 2015;57:225-231]

Key words: Biomass fuels, Volatile organic compounds, Tobacco smoke, Indoor air pollution.

Introduction

As per World Health Organization (WHO) report of 2012, globally 4.3 million deaths were attributable to indoor air pollution (IAP).1 Approximately three billion people used solid fuels (i.e., wood, charcoal, coal, dung, crop wastes) on open fires or traditional stoves for cooking and heating their homes.1 Exposure to indoor air pollution, especially to particulate matter from the combustion of biofuels has been implicated as a causal agent for respiratory diseases in the developing countries.2 Much of the cooking is carried out in indoor environment with poor ventilation and lack of exhaust, primarily affecting women and children. Smoke results from incomplete combustion of solid fuel in a closed environment.1 Randomised control trials in rural Mexico3 have concluded that cleaner fuels were significantly associated with a reduction of respiratory symptoms among women. Household air pollution is prevalent mainly in rural areas while ambient air pollution is predominantly an urban problem. In poorly ventilated dwellings, smoke in and around the household may exceed acceptable levels for fine particles by even 100-folds.

The respirable suspended particulate matter (RSPM) is of major significance as it may significantly affect the health of individuals.4 The Environmental Protection Agency (2006) regulates particulate matter (PM) as PM10, PM2.5 and PM1.0. PM10 (particles <10µm) can penetrate the defense mechanisms of the upper and middle regions of the respiratory tract, while PM2.5 (particles <2.5µm) is transported into the lower pulmonary system. The 24-hour mean PM level as per WHO guidelines for air quality is 25µg/m3 for PM2.5 and 50µg/m3 for PM10 (particles <10µm).5 However, there is no similar standard reference value for PM2.5 levels in indoor air. The volatile organic compounds (VOCs) include a variety of chemicals, some of which may have short- and long-term adverse health effects.6

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Correspondence and reprint requests: Dr Raj Kumar, Professor and Head, Department of Respiratory Allergy and Applied Immunology, Vallabhbhai Patel Chest Institute, University of Delhi, Delhi-110 007, India; E-mail: rajkumarvpci@gmail.com
In India, especially in the rural areas, the cooking fuel commonly used is of biomass origin and it may be often done in a separate kitchen room or in household living area without a separate kitchen, i.e. in a closed space. Therefore, the objective of the study was to compare respiratory symptoms in females in relation to cooking at two different locations (separate room and closed space), and their association with concentration of the PM (PM$_{10}$, PM$_{2.5}$ and PM$_{1}$) and VOCs, in a rural area of the Delhi-National Capital Region (NCR).

Materials and Methods

Study period and location

The study was conducted in Khanpurjupti village, located close to Delhi in NCR. The population is mainly of middle socio-economic status and relies on biomass fuel for daily cooking and heating. The present study was conducted between June 2011 and December 2013. The Institutional Ethics Committee approved the study.

A questionnaire-based survey of females was carried out for respiratory illness-related symptoms. A questionnaire designed for the Indian conditions was used. The symptoms enquired were shortness of breath, wheezing, cough and phlegm production; spirometry performed simultaneously. Subjects were asked for smoking history, occupation and socio-economic status. The details of the house construction, kitchen type, presence of windows, ventilation, roof-type and use of biomass fuel in the home for cooking, heating and lighting were obtained for each household. After the assessment of respiratory symptoms, 174 females were included in the study. The households were divided into two groups (Group A consisted of households with separate kitchen [n=46] and Group B households with kitchen in a closed space [n=46]) (Figure 1). There were 97 women involved in the cooking activity in Group A and 77 women in Group B. The females with an age of more than 18 years and cooking for more than three years were selected for the study. The average age of the participants was 34.4±14.3 years.

The cooking fuel source was identified for each of the household. Age, gender, height, weight, education, occupation, and IAP exposure were recorded for each subject. All the 92 households used biomass fuel, except that in Group A, where 9 households also used liquid petroleum gas along with biomass fuel. The assessment of the indoor air pollutants level (PM$_{10}$, PM$_{2.5}$, PM$_{1}$ and VOCs) was done in the individual household.

Measurement of indoor environmental exposures

1. Measurement of PM$_{2.5}$. Fine particulate matter less than 2.5µm (PM$_{2.5}$) in size was measured in each of the household using a small portable data logging device (a modified commercial smoke detector; University of California-Berkeley Particle and Temperature Sensor [UCB-PATS] equipped with a photo-electric detector). These monitors measured and logged the PM$_{2.5}$ concentration for every minute of the sampling period. The UCB-PATS was placed on the wall of the kitchen at 100cm from the combustion zone of the stove or open fire, 125cm above the floor (this height relates to the approximate edge of the active cooking area). The instrument was kept for 24 hours in these houses and continuous recording of PM$_{2.5}$ levels was done. The PM$_{2.5}$ was measured as an average daily exposure expressed as photomass in mg/m$^3$. Data were downloaded from each device using UCB monitor manager (2.5) software. The chamber of the photo-electric detector was cleaned with isopropyl alcohol after every five uses.

2. Measurement of PM$_{10}$, PM$_{2.5}$ and PM$_{1}$. Dust particles (PM$_{10}$ [Coarse], PM$_{2.5}$ and PM$_{1}$ in µg/m$^3$) were carried out using the GRIMM Portable Laser Aerosol (GRIMM Aerosol Technik GmbH & Co., KG, Figure 1. Cooking process done in separate kitchen (Group A) and in closed verandah (Group B).
Germany) spectrometer and dust monitor model 1.108/1.109 measuring instrument. It displays simultaneously all the three PM values (PM$_{10}$, PM$_{2.5}$, and PM$_{1}$) in real-time. The PM masses are gathered in a size range from 0.25 to 32 µm in $>$30 size classes and displayed as PM values by using PTFE-filter paper of the size 47mm. The sampling period this monitor measured and logged the RSPM concentration for every 10 minutes. The instrument was kept for six hours in these households and continuous reading of PM$_{10}$, PM$_{2.5}$ and PM$_{1}$ levels was done.

3. Monitoring of VOC.

The VOCs level was monitored for 12 hours at a 10-minute interval by using a portable VOC monitor with PID (Photo ionisation detection) (Phocheck Tiger, version 1.0.0.58, Ion Science Ltd, Cambridge shire, UK). The detector is equipped with 10.6-eV UV lamp and measure in parts per million (ppm). Isobutylene is used to calibrate PID as it is relatively moderate among the VOCs generally observed in the general environment. Furthermore, at the low concentration used for the calibration, it is easy to handle because it is a non-toxic and non-flammable. The recorded values were isobutylene equivalent concentration in parts per billion (ppb).


Pulmonary function tests including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV$_1$), FEV$_1$/FVC (expressed as a percentage), and forced expiratory flow over the middle half of the FVC (FEF$_{25-75}$) were conducted in all females using a CPFS/D USB spirometer (MGC Diagnostics, USA). Spirometry was conducted based on the American Thoracic Society (ATS) guidelines. The airway obstruction was diagnosed when fixed FEV$_1$/FVC% ratio was observed to be $<$70% of the predicted.

Statistical Analysis

Data was analysed by using the Statistical Package for Social Sciences (SPSS) version 16.0. Independent $t$-test was used to compare means of both the groups A and B. A two-tailed $p$-value $<$0.05 was considered as statistically significant.

Results

The demographic profile and other features of the study population are described in Table 1.

Indoor air pollution measurement

1. 24-hour PM$_{2.5}$ concentration.

This was measured in 92 households (46 belong to Group A and the remaining to Group B). The average minimum and maximum PM$_{2.5}$ in Group A households were 1.3mg/m$^3$ and 13.8mg/m$^3$, respectively. While these were 6.6mg/m$^3$ and 28.5mg/m$^3$, respectively among the households in Group B. The PM$_{2.5}$ values in the households with females having respiratory symptoms was significantly higher than control houses (11.1 versus 6.6 mg/m$^3$, p=0.007) (Figure 2).

2. Six-hours PM$_{10}$, PM$_{2.5}$, PM$_{1}$ concentration.

Differences between group A and B households were observed in concentration of particulate matter during cooking are: PM$_{10}$ (288.5µg/m$^3$ versus 368.3µg/m$^3$; $p=0.182$), PM$_{2.5}$ (123.9µg/m$^3$ versus 159.0µg/m$^3$; $p=0.22$) and PM$_{1}$ (96.9µg/m$^3$ versus 115.7µg/m$^3$; $p=0.396$). The differences were not statistically significant (Figures 3-5).

3. 12-hour VOCs concentration.

The maximum peak of VOC in Group B was higher than in Group A (2.8ppm versus 1.2ppm), though not statistically significant. The average concentrations of VOCs of households of Group B were higher than Group A households but not statistically significant (1.7ppm versus 0.9ppm; $p=0.28$) at evening cooking time (18:30) (Figure 6).

4. Pulmonary function test.

Among all the households (n=92) in both the groups, only 124 women were able to perform acceptable spirometry as per ATS guidelines. The number of females with airway obstruction was higher in Group B than Group A (58.7 versus 61.1%; $p=0.07$), though not statistically significant.
Figure 3. Average 6-hour PM$_{10}$ concentration in both the Groups (A and B) by using GRIMM.

Definitions of abbreviations: GRIMM=Gas, Radon, and Indoor Microbial Monitor for Homes, PM=Particulate Matter, RSPM=Respirable suspended particulate matter.

Table 2. Spirometry profile of females of Group A and Group B.

<table>
<thead>
<tr>
<th>Parameters (mean±SD)</th>
<th>Group A (Separate Kitchen)</th>
<th>Group B (Verandah Kitchen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC (% predicted)</td>
<td>78.3±17.1</td>
<td>77.8±17.7</td>
</tr>
<tr>
<td>FEV$_1$ (% predicted)</td>
<td>77.7±17.7</td>
<td>77.0±17.3</td>
</tr>
<tr>
<td>FEV$_1$/FVC (Ratio)</td>
<td>81.2±7.1</td>
<td>79.9±11.4</td>
</tr>
</tbody>
</table>

Definitions of abbreviations: SD=Standard deviation; FVC=Forced vital capacity; FEV$_1$=Forced expiratory volume in 1 Second.

5. Factors associated with higher environmental exposures in verandah households. The study identified using biomass fuel as a main fuel for cooking and heating, absence of ventilation in roof (p=0.01), high pack-years of smoking (p=0.04) and low level of education (p=0.003) in Group B, to be positively associated with increased 24-hour PM$_{2.5}$, 6-hour PM$_{10}$, PM$_{1.5}$ and PM$_{1.0}$ and 12-hour VOCs concentrations.

Discussion

A combination of various gases and particulate matter is released during combustion, which contaminate the indoor environment. These mixtures of gases and particles are responsible for weak host defenses against respiratory infections which would further lead to an increased predisposition to respiratory infections.
Figure 4. Average 6-hour PM$_{2.5}$ concentration in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: RSPM=Respirable suspended particulate matter

Figure 5. Average 6-hour PM$_1$ concentration in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: RSPM=Respirable suspended particulate matter

Figure 6. Comparison of average 12-hour VOCs readings at 10 minutes intervals in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: VOCs=Volatile organic compounds; ppm=Parts per million
Inflammation of the airways and alveoli, resulting from the exposure to these pollutants, may be another mechanism increasing the severity of respiratory infections.\textsuperscript{10} Combustion of solid fuel has been linked to various respiratory symptoms in the form of coughing, wheezing, etc. Studies have reported this association in terms of odd’s ratio ranging from 1.9 to 2.7.\textsuperscript{11}

In the present study, biomass was the main source of fuel for cooking in both the groups. Further, there was inadequate ventilation in both types of households. The measured concentrations of PM\textsubscript{1.2} by UCB-PATS over 24-hour period for kitchens of Group B households were significantly higher than kitchens of Group A households. The PM\textsubscript{10}, PM\textsubscript{2.5} and PM\textsubscript{1} concentration measured by GRIMM over 6-hour period were higher in Group A, though the results failed to reach statistical significance. The study highlights the importance of continuous monitoring of particulate matter concentration over longer duration (24 hours) in comparison to shorter duration (6 hours). However, in both the households, the concentration of PM\textsubscript{1.2} was much higher than the 24-hour standard average of 35\mu g/m\textsuperscript{3} according to National Ambient Air Quality Standards (NAAQS)-2009. Biomass fuel was found to be a significant contributor to the occurrence of respiratory illness in females.

The current study documents high prevalence of respiratory illness among females of Group B (closed verandah) who engage in biomass fuel burning in households without having exhaust and poor ventilation. The levels of particulate matter and VOCs were higher in Group B than Group A where cooking is done in separate room with exhaust and good ventilation. In a study estimating disease burden due to biomass cooking fuel-related household air pollution among women in India, it was concluded that chronic bronchitis was nearly twice as common among women exposed to biomass cooking fuel (Odds ratio [OR]=2.37, 95% Confidence interval [95%CI]: 1.59, 3.54). Overall, biomass fuel contributed to about 2.4 (95%CI: 1.4, 3.2) out of the 5.6 million cases in the country.\textsuperscript{15} In the study population of the elderly men and women (age \textbf{\textgreater}60 years) higher prevalence of asthma in households using biomass fuels than those using cleaner fuels (OR=1.59; 95%CI: 1.30-1.94) was observed; the effect of cooking smoke on asthma was greater among women (OR=1.83; 95%CI: 1.32-2.53).\textsuperscript{15} In previous studies from India,\textsuperscript{16,19} a positive association between biomass fuels causing increased concentrations of indoor air pollutants leading to increased prevalence of asthma, rhinitis and upper respiratory tract infection in children.

The results of the present study were comparable to studies from other Asian countries. In 2007, a study was conducted in Pakistan,\textsuperscript{30} that found a strong association with chronic bronchitis in biomass-using women when compared with LPG-using women. Shrestha \textit{et al}\textsuperscript{22} in their study from Nepal, showed that the average PM\textsubscript{10} level in kitchens using biomass fuel was three times higher than other cleaner fuels-using kitchen, and 94% of the respondents were disadvantaged women. In 2013, Kurmi \textit{et al}\textsuperscript{22} in Nepal shown different indices in lung functions in population (both males and females) were significantly lower, due to high biomass smoke exposure, and increase the double risk of airflow obstruction.

Similar observations were made in the studies from countries outside Asia. In a study among Nigerian women,\textsuperscript{31} biomass smoke exposure was associated with chronic bronchitis and reduced lung functions in women engaged in fish smoking. A study of Desalu \textit{et al}\textsuperscript{32} to evaluate the effects of biomass smoke on lung function among women in South-West Nigeria demonstrated a reduction in lung function among women who predominantly used biomass fuels for cooking. Among rural Mexican women who use solid fuels for cooking, have increased respiratory symptoms, including chronic cough and phlegm and a decrease in lung function.\textsuperscript{23} In a study in Guatemala,\textsuperscript{23} Central America household wood smoke exposure from cooking was a risk factor for chronic obstructive lung disease among women.

The female population is a special category that needs attention because exposure to tobacco smoke can also seriously affect fertility and may lead to complications in pregnancy and childbirth. Larsson \textit{et al}\textsuperscript{27} demonstrated that the incidence of respiratory symptoms and deficits in ventilating pulmonary function correlate positively with exposure to passive smoking at homes. However, in the present study, we did not find significant difference between environmental tobacco smoke exposure in the two groups.

To the best of our knowledge, this study is among the few in presenting a detailed analysis of the association of respiratory illness-related symptoms and levels of particulate matter and VOCs in females in India. The targets of standards of air quality have been laid down by WHO with a purpose to achieve a gradual improvement, and hence, decrease in air pollution. An important fact that deserves mention is that, PM\textsubscript{2.5} levels may actually reach 10-50 times higher values than the standard WHO recommended level of 25\mu g/m\textsuperscript{3}, if biomass fuels is used for daily household needs.\textsuperscript{28,29}

The small sample size was a limitation of the present study. A higher level of PM\textsubscript{2.5} in households using biomass fuel was reported where females were suffering from respiratory illness-related symptoms. Therefore, it is an attractive proposal in terms of the benefits that could be derived from reducing or eliminating use of biomass fuel. Also, the importance should be given to adequate ventilation; for poorly ventilated houses, a window above the cooking stove and cross ventilation though doors should be done.
Conclusions

Our study shows that indoor air concentration associated with biomass smoke were four-fold greater in households of closed verandah kitchen (Group B) than separate kitchen (Group A). The plausible explanation is poorly ventilated condition in the Group B households where females are mainly suffered from respiratory diseases. Exposure to particulates (PM1, PM2.5, PM10) and volatile organic compounds are the main respiratory disease causing agents in indoors. The use of liquefied petroleum gas as a fuel, separate kitchen with adequate ventilation, prevention from environmental tobacco smoke exposure along with health education to the rural population are the measures that will prevent the rise in respiratory illnesses in females from the rural background in India.

References


