Original Article

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

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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. Spirometery of participants was conducted. The indoor particulate matter (PM_{10}, $PM_{2.5}$ and PM_{1}) 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 ($PM_{2.5}$), 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 Mexico[3] 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 PM_{10}, $PM_{2.5}$ and $PM_{1.0}$ PM_{10}, (particles <10µm) can penetrate the defense mechanisms of the upper and middle regions of the respiratory tract, while $PM_{2.5}$ (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/m^3 for $PM_{2.5}$ and 50µg/m^3 for PM_{10} (particles <10µm).[5] However, there is no similar standard reference value for $PM_{2.5}$ 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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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 $PM_{1.0}$ in $\mu g/m^3$) were carried out using the GRIMM Portable Laser Aerosol (GRIMM Aerosol Technik GmbH & Co., KG,

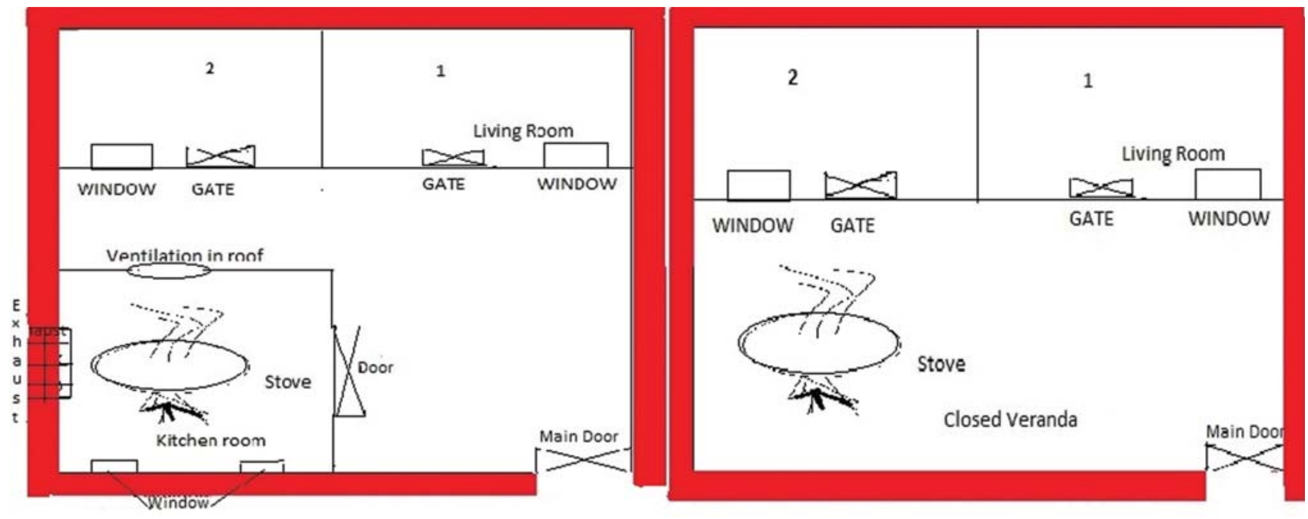

Figure 1. Cooking process done in separate kitchen (Group A) and in closed *verandah* (Group B).

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.[3] The recorded values were isobutylene equivalent concentration in parts per billion (ppb).

4. Measurements of pulmonary function. 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 (FEF) 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.[7]

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, (mean=3.0mg/m^3), respectively. While these were 6.6mg/m^3 and 28.5mg/m^3, (mean=11.1mg/m^3), respectively among the households in Group B. The

Table 1. Demographic profile of females of Group A and Group B

	Group A n (%)	Group B n (%)
Total no. of houses	46 (50.0)	46 (50.0)
No. of females	97 (55.7)	77 (44.3)
Mean age (years)	33.7	35.0
Education		
≥10th Class	41 (42.3)	16 (20.8)*
≤10th Class	56 (57.7)	61 (79.2)
No. of adult smokers in houses	47 (13.4)	48 (19.5)
Pack year of smoking	16	48.7**
Respiratory symptoms		
Breathlessness *or* Cough	5 (5.2)	20 (26.0)*
Breathlessness *and* Cough	3 (3.1)	10 (13.0)**
Ventilation in roof of kitchen	12 (26.1)	3 (6.5)*
Kitchen with exhaust	3 (6.5)	0
Fuel for cooking		
Biomass fuel	37 (80.4)	46 (100)*
LPG	9 (19.6)	0

*=p<0.01; **=p<0.05

Definitions of abbreviations: LPG=Liquified petroleum gas

$PM_{2.5}$ 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.[8] Means of parameter are shown in table 2. In Group A, among 70 females who performed acceptable spirometry, 41 (58.7%) were reported to have obstruction and remaining 29 (41.4%) were normal, while in Group B, out of 54 females, 33 (61.1%) have obstruction and 21 (38.9%) were normal. 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.

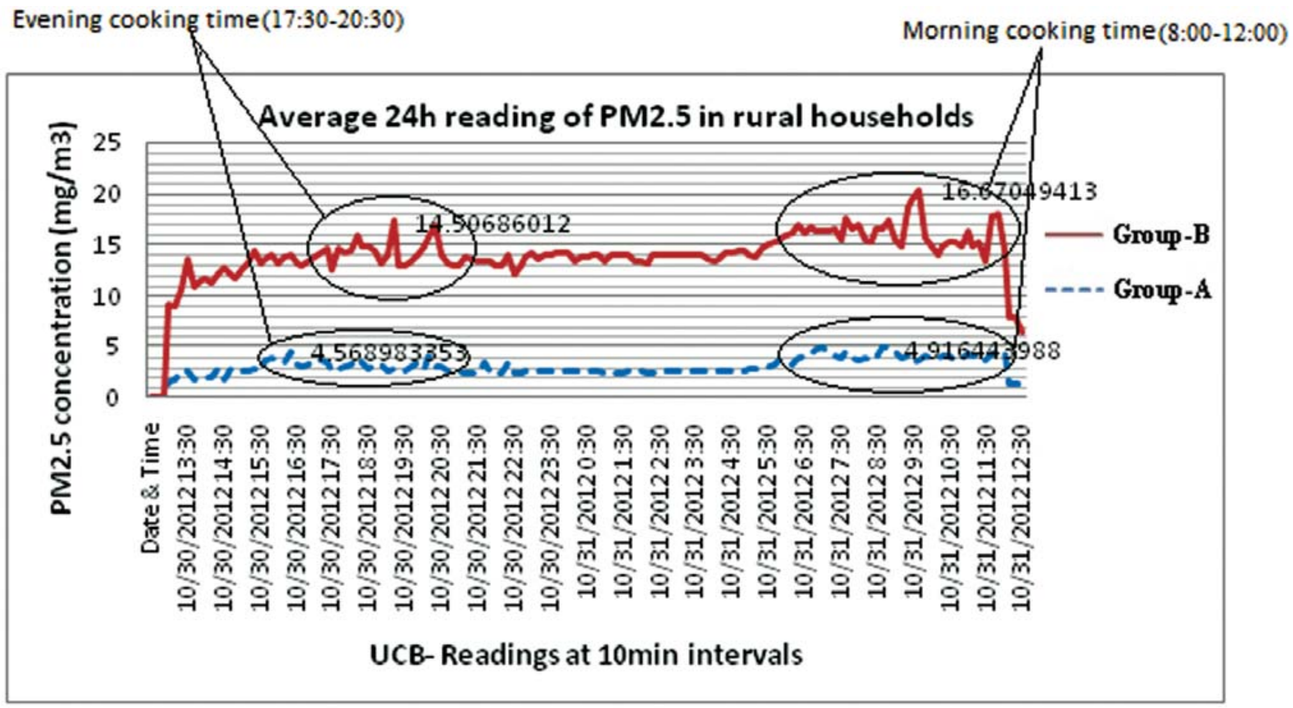

Figure 2. Average 24-hour $PM_{2.5}$ concentration in households of separate room (Group A) and closed *verandah* (Group B).

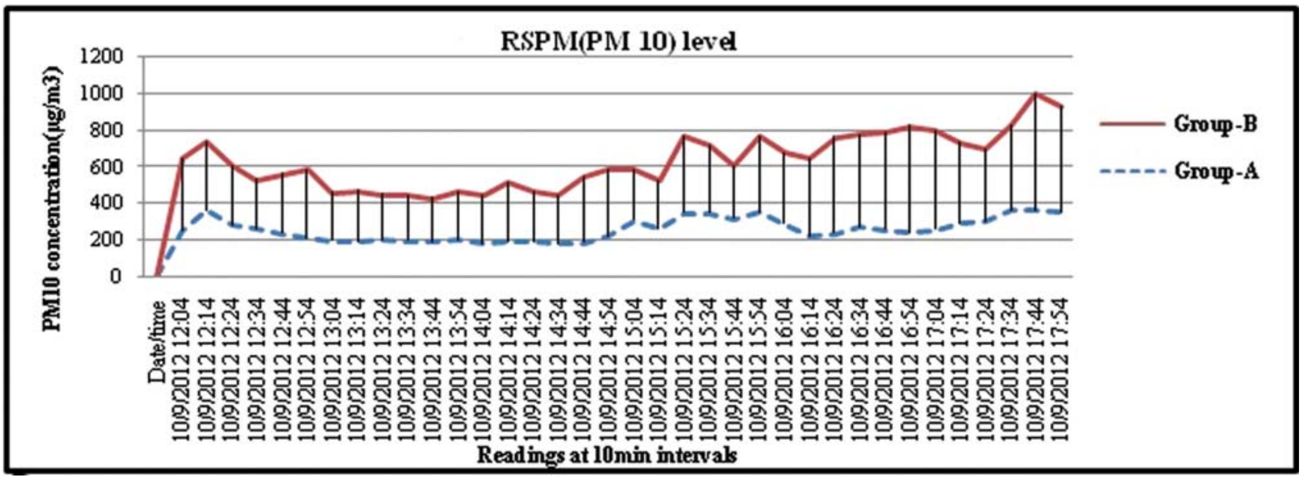

Figure 3. Average 6-hour PM_{10} concentration in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: RSPM=Respirable suspended particulate matter

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

Spirometry Parameters	Group A (Separate Kitchen) (mean±SD)	Group B (*Verandah* Kitchen) (mean±SD)
FVC (% predicted)	78.3±17.1	77.8±17.7
FEV_1(% predicted)	77.7±17.7	77.0±17.3
FEV_1/FVC (Ratio)	81.2±7.1	79.9±11.4

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}, $PM_{2.5}$ 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.[9]

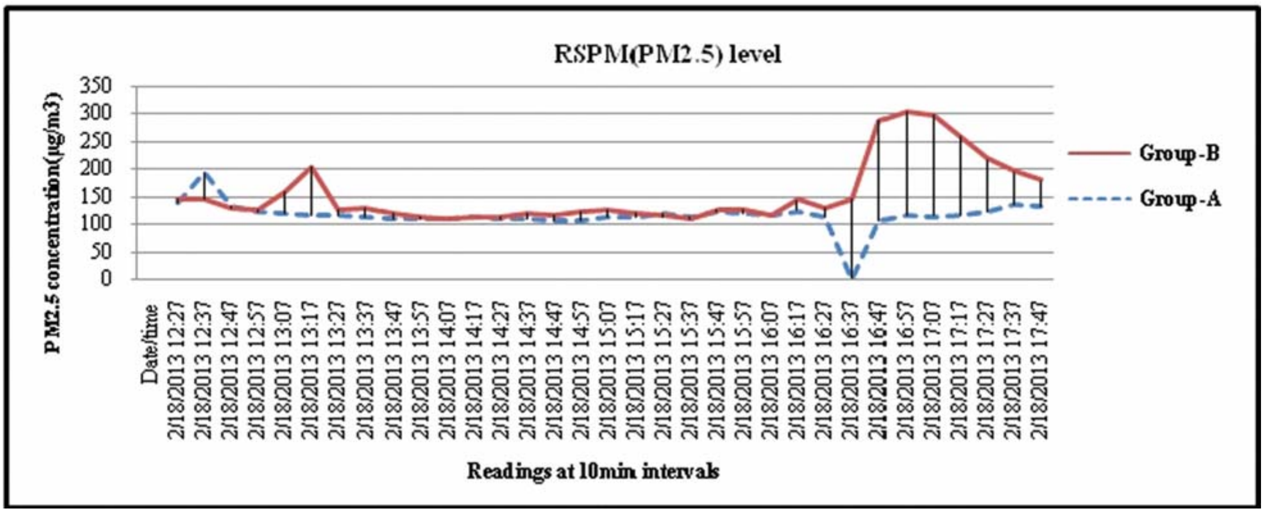

Figure 4. Average 6-hour $PM_{2.5}$ concentration in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: RSPM=Respirable suspended particulate matter

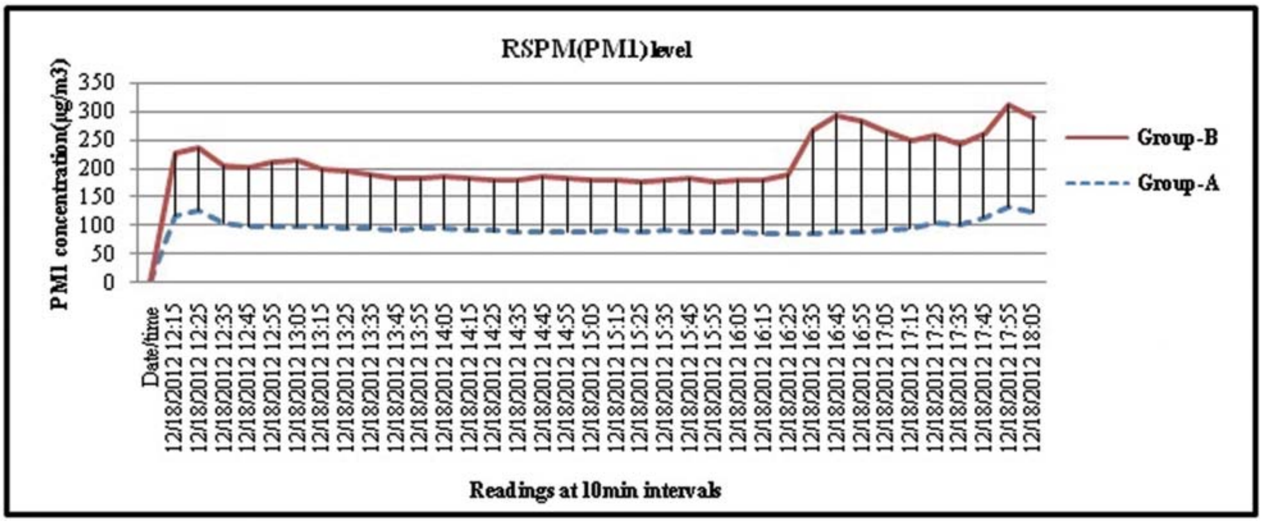

Figure 5. Average 6-hour PM_1 concentration in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: RSPM=Respirable suspended particulate matter

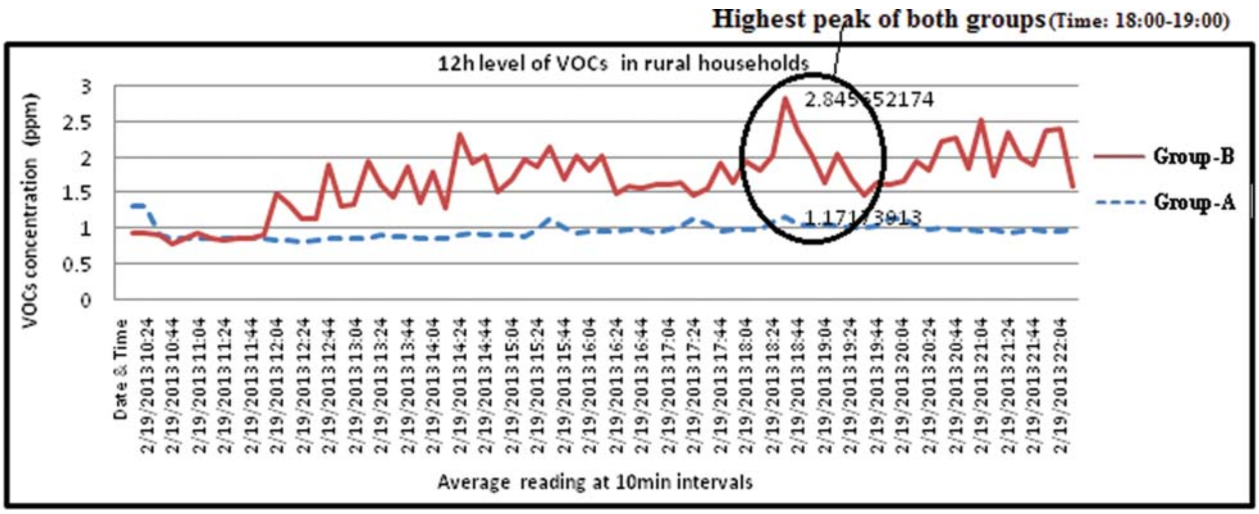

Figure 6. Comparison of average 12-hour VOCs readings at 10 minutes intervals in both the Groups (A and B) by using GRIMM.
Definitions of abbreviations: VOCs=Volatile organic compounds; ppm=Parts per million

Inflammation of the airways and alveoli, resulting from the exposure to these pollutants, may be another mechanism increasing the severity of respiratory infections.[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.[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 $PM_{2.5}$ by UCB-PATS over 24-hour period for kitchens of Group B households were significantly higher than kitchens of Group A households. The PM_{10}, $PM_{2.5}$ and PM_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 $PM_{2.5}$ was much higher than the 24-hour standard average of 35µg/m^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 two times more 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.[12] In the study population of the elderly men and women (age $\geq$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).[13] In previous studies from India[14-19], 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[20], that found a strong association with chronic bronchitis in biomass-using women when compared with LPG-using women. Shrestha *et al*[21] in their study from Nepal, showed that the average PM_{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 *et al*[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[23], biomass smoke exposure was associated with chronic bronchitis and reduced lung functions in women engaged in fish smoking. A study of Desalu *et al*[24] 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.[25] In a study in Guatemala[26], 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 *et al*[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, $PM_{2.5}$ levels may actually reach 10-50 times higher values than the standard WHO recommended level of 25µg/m^3, if biomass fuels is used for daily household needs.[28, 29]

The small sample size was a limitation of the present study. A higher level of $PM_{2.5}$ 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 (PM_1, $PM_{2.5}$, PM_{10}) 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

1. World Health Organization (WHO). Burden of disease from indoor air pollution for 2012. WHO Report 2014. *Available at URL:* http://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf. Accessed on: March 20, 2015.
2. Kumar R, Nagar JK, Gaur SN. Indoor air pollutants and respiratory morbidity: a review. *Indian J Allergy Asthma Immunol* 2005;19:l–9.
3. Romieu I, Riojas-Rodriguez H, Marron-Mares AT, Schilmann A, Perez-Padilla R, Masera O. Improved biomass stove intervention in rural Mexico: impact on the respiratory health of women. *Int J Respir Crit Care Med* 2009;180:649–56.
4. Pope CA 3rd, Dockery DW. Health effects of fine particulate air pollution: lines that connect. *J Air Waste Manag Assoc* 2006;56:709–42.
5. National ambient air quality standards for particulate matter. *Available at URL:* http://www.gpo.gov/fdsys/pkg/FR 2006 10 17/ pdf/06 8477.pdf#page=1. Accessed on: March 25, 2015.
6. Chikara H, Iwamoto S, Yoshimura T. Indoor air pollution of volatile organic compounds: indoor/outdoor concentrations, sources and exposures. *Nihon Eiseigaku Zasshi* 2009;64:683–8.
7. American Thoracic Society. Lung function testing: selection of reference values and interpretative strategies. *Am Rev Respir Dis* 1991;144:1202–18.
8. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, *et al.* Interpretative strategies for lung function tests. *Eur Respir J* 2005;26:948–68.
9. Smith KR. The national burden of disease in India from indoor air pollution. *Proc Natl Acad Sci* (USA) 2000;97:13286–93.
10. Ezzati M, Kammen D. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. *Lancet* 2001;358:619–24.
11. Desai MA, Mehta S, Smith KR. Indoor smoke from solid fuels: assessing the environmental burden of disease at national and local levels. In: *Environmental Burden of Disease (Series No. 4)*. WHO protection of the human environment. Geneva: WHO;2004.
12. Sehgal M, Rizwan SA, Krishnan A. Disease burden due to biomass cooking-fuel-related household air pollution among women in India. **Global Health Action,** [S.l.], v. 7, nov. 2014. *Available at URL*: http://www.globalhealthaction.net/index.php/gha/article/view/25326. Accessed on: August 14, 2015.
13. Mishra V. Effect of indoor air pollution from biomass combustion on prevalence of asthma in the elderly. *Environ Health Perspect* 2003;111:71–8.
14. Kumar R, Nagar JK, Raj N, Kumar P, Kushwah AS, Meena M, *et al.* Impact of domestic air pollution from cooking fuel on respiratory allergies in children in India. *Asian Pac J Allergy Immunol* 2008;26:213–22.
15. Kumar R, Nagar JK, Raj N, Kumar P, Kushwah AS, Meena M, *et al.* Indoor air pollution and respiratory function of children in Ashok Vihar, Delhi: an exposure response study. *Asia Pacific J Public Health* 2008;20:36–48.
16. Kumar R, Nagar JK, Kumar H, Khushwah AS, Meena M, Kumar P, *et al.* Association of indoor and outdoor air pollutant level with respiratory problems among children in an industrial area of Delhi. *Arch Environ Occup Health* 2007;62:75–80.
17. Kumar R, Goel N, Gupta N, Singh K, Nagar S, Mittal J. Indoor air pollution and respiratory illness in children from rural India: a pilot study. *Indian J Chest Dis Allied Sci* 2014;56:79–83.
18. Kumar R, Nagar JK, Goel N, Kumar P, Kushwah AS, Gaur SN. Indoor air pollution and asthma in children at Delhi, India. *Pneumonol Alergol Pol* 2015;83:275–82.
19. Gaur SN, Gupta K, Rajpal S, Singh AB, Rohatgi A. Prevalence of bronchial asthma and allergic rhinitis among urban and rural adult population of Delhi. *Indian J Allergy Asthma Immunol* 2006;20:90–7.
20. Akhtar T, Ullah Z, Khan MH, Nazli R. Chronic bronchitis in women using solid biomass fuel in rural Peshawar, Pakistan. *Chest* 2007;132:1472–5.
21. Shrestha IL, Shrestha SL. Indoor air pollution from biomass fuels and respiratory health of the exposed population in Nepalese households. *Int J Occup Environ Health* 2005;11:150–60.
22. Kurmi OP, Devereux GS, Smith WC, Semple S, Steiner MF, Simkhada P, *et al*. Reduced lung function due to biomass smoke exposure in young adults in rural Nepal. *Eur Respir J* 2013;41:25–30.
23. Etete Peters, Victor AU. The relationship between lung function and indoor air pollution among rural women in the Niger Delta region of Nigeria. *Lung India* 2014;31:110–15.
24. Desalu OO, Adekoya AO, Ampitan BA. Increased risk of respiratory symptoms and chronic bronchitis in women using biomass fuels in Nigeria. *J Bras Pneumol* 2010;36:441–6.
25. Regalado J, Perez-Padilla R, Sansores R, Ramirez JIP, Brauer M, Paré P, *et al*. The effect of biomass burning on respiratory symptoms and lung function in rural Mexican women. *J Am Respir Crit Care Med* 2006:174:901–5.
26. Smith-Sivertsen T, Diaz E, Pope D, Lie RT, Díaz A, McCracken J, *et al*. Effect of reducing indoor air pollution on women's respiratory symptoms and lung function: the Respire Randomized Trial, Guatemala. *J Am Epidemiol* 2009;170:211–20.
27. Larsson ML, Loit HM, Meren M, Põlluste J, Magnusson A, Larsson K, *et al*. Passive smoking and respiratory symptoms in the FinEsS Study. *Eur Respir J* 2003;21:672–6.
28. World Health Organization. "Guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide". Geneva: World Health Organization Press; 2006.
29. David P, Simone B, Seth M, Wilhelmina Q. Indoor air quality of an important wood stove in Ghana and an ethanol stove in Ethiopia. *Ener Sustain Develop* 2009;13:71–6.