Original Article

Indoor Air Pollution and Respiratory Illness in Children from Rural India: A Pilot Study

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Abstract

Objective. Indoor air pollution measured in terms of particulate matter <2.5µm in diameter ($PM_{2.5}$), is an important cause of respiratory illness in children. Therefore, $PM_{2.5}$ levels in rural households and its correlation with respiratory illness-related symptoms in children were studied.

Methods. A questionnaire-based survey of children for respiratory illness-related symptoms was conducted in 37 households of a village (Khanpurjupti, Delhi-NCR, India) from September 2011 to October 2011. Assessment of 24-hour $PM_{2.5}$ level was done using University of California-Berkeley Particle and Temperature Sensor (UCB-PATS).

Results. Thirty-seven households in a rural area were studied. These were divided into 20 respiratory households, i.e. those with children with respiratory illness-related symptoms and 17 control households. The 24-hour $PM_{2.5}$ was measured in all the houses. The average minimum and maximum $PM_{2.5}$ levels were 7.24mg/m^3 and 22.70mg/m^3, respectively (mean=10.47mg/m^3) among the 20 respiratory households. The average minimum and maximum $PM_{2.5}$ levels were 1.10mg/m^3 and 18.17mg/m^3, respectively (mean=4.99mg/m^3) in the 17 control households. The $PM_{2.5}$ levels were significantly greater ($p<0.05$) in houses where children had respiratory symptoms compared to the control households. Further, biomass fuel use and number of family members were significantly associated with respiratory illness in children.

Conclusion. Increased $PM_{2.5}$ levels, biomass fuel use and number of family members were found to be associated with increased occurrence of respiratory illness in children. **[Indian J Chest Dis Allied Sci 2014;56:79-83]**

Key words: Air pollution, Biomass, Particulate matter ($PM_{2.5}$), Respiratory tract diseases, Tobacco smoke pollution.

Introduction

Indoor air pollution is an important cause of potential health risks to exposed populations, especially in developing countries. An important source of indoor air pollution in these countries is combustion of solid fuels, including biomass (wood, dung and crop residues) and exposure to environmental tobacco smoke (ETS). About 50% of the world's population relies on biomass fuel as the primary source of domestic energy, out of which developing countries contribute to 99% of the world's biomass fuel use.[1,2] Biomass fuel is used as the main source of domestic energy for cooking, heating and lighting.[3,4]

The particulates are indirectly formed when gases from burning fuels react with sunlight and water vapour, and also during smoking by members of household. In one of the earliest studies, Samet *et al*[5,6] examined indoor pollutant sources and related effects on the respiratory health of exposed subjects. The positive association between exposure to particulate matter (PM), air pollution and its adverse impacts on respiratory health has also been investigated.[7,8] In recent years, particles less than 2.5µm ($PM_{2.5}$) in aerodynamic diameter has been most strongly associated with adverse respiratory impacts. These are also referred to as "fine" particles and, are an important indicator of indoor air pollution. The small size and structural complexity causes these fine particles to lodge deeply into the lungs, and hence, results in respiratory illness.

There is consistent evidence that indoor air pollution increases morbidity and mortality from respiratory tract symptoms in childhood.[9] The respiratory illnesses reported are croup, bronchitis/bronchiolitis, asthma and pneumonia.[9] The permissible 24-hour mean particulate matter level as per the World Health Organization (WHO) guidelines for air quality is 25µg/m^3 for $PM_{2.5}$ and 50µg/m^3 for PM_{10} (particles less than 10µm).[10] However, there is no standard reference value for $PM_{2.5}$ levels for indoor air pollution. On extensive review of the literature, we found sparse data correlating indoor $PM_{2.5}$ levels with respiratory symptoms in children in India.

The present study was undertaken with the aim to assess the $PM_{2.5}$ levels in rural households using

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biomass fuel and exposure to ETS. The effect of indoor air pollution on health of children residing in the rural households in India was investigated.

Material and Methods

The study was conducted at Village Khanpurjupti, Loni, Ghaziabad, a rural area of NCR, Delhi, India. Farming and cattle herding are the prime occupations of people in this village. The study was conducted in total 37 households of this village during September 2011 to October 2011. The study was approved by the Institutional Ethics Review Committee.

A questionnaire-based survey of children was carried out for respiratory illness-related symptoms. The questionnaire designed for the Indian conditions was used.[11] The symptoms enquired were shortness of breath, wheezing, cough and phlegm production. Households were assessed for smoking history of adults, their occupation and socio-economic status. The details of the house construction, kitchen type, window, ventilation, roof-type, use of biomass fuel in the home for cooking, heating and lighting were also noted for each household. After assessment of respiratory symptoms in children, 20 houses were classified as respiratory households, and the other 17 houses with children having no respiratory illness-related symptoms were labelled as control households.

Fine particulate matter or respirable dust ≤2.5µm ($PM_{2.5}$) 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.

Statistical Analysis

All data analysis was performed using Statistical Package for the Social Sciences (SPSS) (version 14.0) for windows. Poisson regression model was used to explain the effect of the number of family members, $PM_{2.5}$ levels, number of smokers in a family, fuel type (biomass fuel [cow dung, coal and wood]) and others [kerosene, LPG]), kitchen type, ventilation (part of main house, separate room, *verandah*) on the number of children with respiratory illness. The model variables were established via backward selection which involves entering the above seven variables initially and then excluding the non-significant variables one by one. The Wald Chi-square statistics was used to assess the parameter significance. The statistical significance was considered at $p<0.05$.

Results

A total of 293 individuals were examined from the 37 households included in the study. Out of these, 20 households had at least one child with one of the four respiratory illness-related symptoms (cough, phlegm, shortness of breath and wheeze) and these were labelled as respiratory households. The rest of 17 households with no child having respiratory illness-related symptoms were labelled as control households. A total of 181 (61.8%, 90 children, 91 adults) subjects belonged to 20 respiratory households and 112 subjects (38.2%, 47 children, 65 adults) belonged to the 17 control households. The average age of children was 9.6 years and 7.9 years in respiratory and control households, respectively. The demographic details of these households are presented in the table. In all 30 children (33.3%), 20 (22.2%) male and 10 (11.1%) female children belonging to 20 households had a history of respiratory illness-related symptoms.

Table 1. Demographic profile of children in respiratory and control households

	Respiratory Households n (%)	Control Households n (%)
Total no. of houses	20 (54.0)	17 (45.9)
Total no. family members	181 (61.8)	112 (38.2)
Adults	91 (50.3)	65(58)
Children	90 (49.7)	47 (42)
Male children	52 (57.8)	22 (46.8)
Female children	38 (42.2)	25 (53.2)
Children average age	9.6	7.9
No. of adult smokers in houses	24 (26.4)	11 (16.9)
Packs/year of smoking	0.52	0.18
No. of households with smokers	13 (65)	7 (41.2)
Respiratory symptoms in children		
Cough	60 (66.7)	15 (31.9)
Phlegm	8 (8.9)	0
Shortness of breath	26 (28.9)	1 (2.13)
Wheezing	26 (28.9)	0
Respiratory positive children		
Male	20 (22.2)	0
Female	10 (11.1)	0
Total	30 (33.3)	0
Kitchen Type		
Part of main house	1(5)	0
Separate room	11(55)	12 (70.6)
Verandah	8 (40)	5 (29.4)
Ventilation in roof of kitchen		
No	14 (70)	14 (82.3)
Yes	6 (30)	3 (17.6)
Kitchen with exhaust	0	2 (11.8)
Fuel for cooking*		
LPG and kerosene	5 (25)	1 (5.9)
Cow dung cakes, wood and coal	18 (90)	16 (94.1)

*Some households used both kerosene and liquefied petroleum gas (LPG)

Indoor Air Pollution Measurements

The $PM_{2.5}$ was measured in 37 households (20 respiratory, 17 control). The average minimum and maximum $PM_{2.5}$ were 7.24mg/m^3 and 22.70mg/m^3, (mean=10.47mg/m^3) respectively among the 20 respiratory households. The average minimum and maximum $PM_{2.5}$ were 1.10mg/m^3 and 18.17mg/m^3, (mean=4.99mg/m^3) respectively among the 17 control households. The $PM_{2.5}$ value in the households with children having respiratory symptoms was significantly higher than control houses (10.46 *versus* 4.99 mg/m^3; $p<0.05$).

The cooking times in village's households were 6AM to 10AM in morning and 5PM to 8PM in evening. The $PM_{2.5}$ measured at a duration of 10 minutes logging intervals was higher in the respiratory houses than the control houses as shown in the figure.

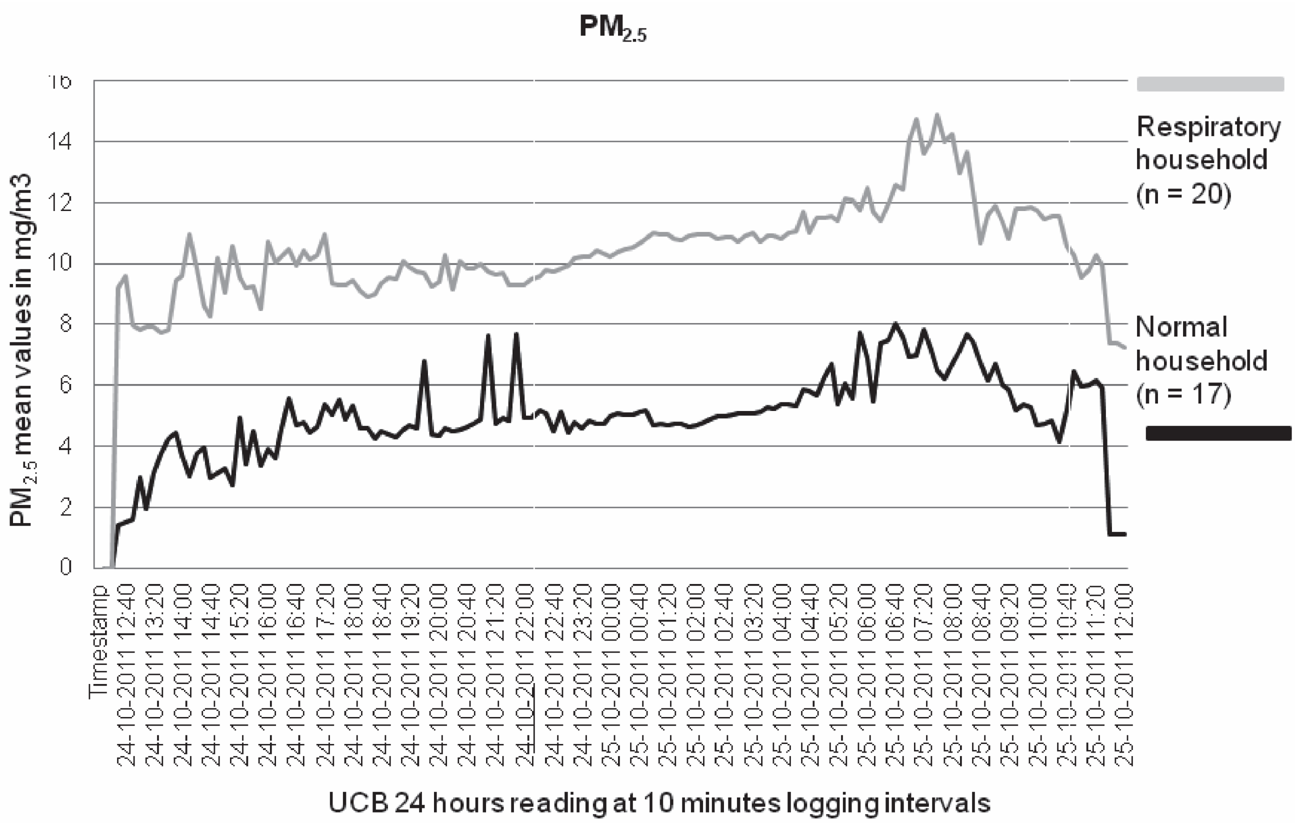

Figure. Continuous $PM_{2.5}$ average concentration in the cooking area of respiratory households (n=20) and control households (n=17) for a duration of 24 hours with sampling at 10 minutes intervals using University of California-Berkeley-Particle and Temperature Sensor (UCB-PATS).

Poisson regression model was applied with the number of affected children in a family as the response variable and number of family members, $PM_{2.5}$, number of smokers in a family, fuel type (Biomass fuel [cow dung, coal and wood] and others [kerosene, LPG]), kitchen type, ventilation (part of main house, separate room, *verandah*) as the independent variables. According to Wald Chi-square statistics, the predictors, number of family members, $PM_{2.5}$ and biomass fuel (cow dung, coal and wood) were found to have significant effect on the occurrence of respiratory illness among children. The variables, kitchen type, number of smokers and ventilation had no significant effects within the Poisson model and, therefore were excluded. Also, we failed to reject the hypothesis that Poisson model fits well to the data as p-value was greater than 0.05.

Discussion

Various gases and particles released during combustion contaminate the indoor environment. These mixtures of gases and particles have been found to weaken the host defences against respiratory infections and therefore, may lead to an increased predisposition to respiratory infections.[12] Inflammation of the airways and alveoli, resulting from exposure to these pollutants, may be another mechanism increasing the severity of respiratory infections.[13]

Combustion of solid fuel has been linked to various respiratory symptoms in the form of coughing, wheezing, etc. Studies to further elucidate this association have reported odd's ratio ranging from 1.9 to 2.7.[14]

In the present study, biomass was the main source of fuel for cooking in both respiratory households and control households. Further, there was inadequate ventilation in both types of households. The measured concentrations of $PM_{2.5}$ for kitchens of respiratory households were significantly higher than kitchens of control households. However, in both the households, the concentrations of $PM_{2.5}$ was much higher than the 24 hours standard average of 35µg/m^3 according to National Ambient Air Quality Standards (NAAQS)-2009. On statistical analysis, biomass fuel was found to be a significant contributor to the occurrence of respiratory illness in children.

In a study on adults in Italy conducted by Simoni *et al*,[15] significant association of acute respiratory illnesses/bronchitic/asthmatic symptoms with $PM_{2.5}$ exposures was found. The authors concluded that indoor pollution was associated with acute respiratory symptoms and lung function impairment. Kumar *et al*[16] conducted a study on 441 children, in the age group (7-15 years) residing in houses where biomass was used as a cooking fuel and reported that 38.3% children had a history of cough, 15% had phlegm production, and 20.9% had shortness of breath. The mean suspended particulate matter (SPM) levels were significantly higher in these houses. In another study by Kumar *et al*,[11] the indoor SPM levels were significantly higher in homes with children having symptoms of respiratory illness compared to homes without such children. The findings of the present study corroborate the evidence of biomass fuel leading to increased $PM_{2.5}$ levels and its association with respiratory illness.

We also found that the number of family members was a significant factor for increased respiratory illness in children. In a study by Awasthi *et al*,[17] use of cow dung as cooking fuel (OR 2.7, 95% CI 1.4 to 5.3) and crowding (OR 1.2, 95% CI 1.1 to 1.4) were associated with one or more of these respiratory symptoms in children. Studies on a larger population are required to further elucidate the role of crowding in contributing to indoor air pollution.

Studies[9,18,19] have shown that environmental tobacco smoke (ETS) leads to various ailments in children, such as cough, asthma, wheeze, bronchitis, pneumonia and deficits in childhood growth. Also, maternal exposure to ETS predisposes to low birth weight and peri-natal mortality.[18] There has been enough evidence that ETS contributes to indoor air pollution.[9] In a study by Strachn and Cook *et al*,[19] there was a significantly increased risk of early chest illness in children associated with the presence of smoking habit in any household member. However, in the present study, we did not find significant correlation between ETS exposure and occurrence of respiratory illness in children. This could be attributed to the small sample size.

To the best of our knowledge, this study is unique in presenting a detailed analysis of the association of respiratory illness-related symptoms and levels of $PM_{2.5}$ in India. The targets of standards of air quality have been laid down by WHO, so as to minimise the detrimental effects of air pollution. The purpose of these standards has been to achieve a gradual improvement, and hence, decrease in air pollution. Further, as these standards have been devised to achieve the best possible health protection from air pollution, these can be the benchmarks for both indoor and outdoor air pollution. However, 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.[20,21]

The small sample size was a limitation of the present study. Still we found raised $PM_{2.5}$ levels in households with children with respiratory illness-related symptoms. The present study contributes to the increasing literature and evidence for the adverse health effects of exposure to biomass fuel and ETS in children in rural areas of developing nations.

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