Impact of Domestic Air Pollution from Cooking Fuel on Respiratory Allergies in Children in India

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SUMMARY This study undertaken in India was aimed at identifying the effects of the indoor air pollutants SO_2, NO_2 and total suspended particulate mater (SPM) generated from fuel used for cooking on respiratory allergy in children in Delhi. A total of 3,456 children were examined (59.2% male and 40.8% female). Among these, 31.2% of the children's families were using biomass fuels for cooking and 68.8% were using liquefied petroleum gas. Levels of indoor SO_2, NO_2 and SPM, measured using a Handy Air Sampler (Low Volume Sampler), were 4.60 ± 5.66 $\mu g/m^3$, 30.70 ± 23.95 $\mu g/m^3$ and 705 ± 441.6 $\mu g/m^3$, respectively. The mean level of indoor SO_2 was significantly higher ($p = 0.016$) for families using biomass fuels (coal, wood, cow dung cakes and kerosene) for cooking as compared to families using LP gas. The mean level of indoor NO_2 for families using biomass fuels for cooking was significantly higher in I.T.O. ($p = 0.003$) and Janakpuri ($p = 0.007$), while indoor SPM was significantly higher in Ashok Vihar ($p = 0.039$) and I.T.O. ($p = 0.001$), when compared to families using LP gas. Diagnoses of asthma, rhinitis and upper respiratory tract infection (URTI) were made in 7.7%, 26.1% and 22.1% of children, respectively. Respiratory allergies in children, which included asthma, rhinitis and URTI, could be associated with both types of fuels (liquefied petroleum gas [LPG] and biomass) used for cooking in the different study areas. This study suggests that biomass fuels increased the concentrations of indoor air pollutants that cause asthma, rhinitis and URTI in children. LP gas smoke was also associated with respiratory allergy.

Biomass and coal smoke contain a large number of indoor air pollutants and known health hazards. In many homes in developing countries, a major source of air pollutants is cooking smoke, caused by burning unprocessed biomass fuels such as wood, crop residues, and dung cakes for cooking and space heating.[1] According to some estimates, approximately half of the worlds population is reliant on biomass fuels (wood, agriculture residues, and charcoal) for cooking and heating as the primary source of domestic energy, and nearly 2 billion kilograms of biomass are burned every day in developing countries.[2,3] The use of wood and other forms of biomass as a cooking fuel is common in developing countries such as India. In rural areas of India, biomass is used as the primary household cooking fuel and almost 90% of the energy used is accounted for by biomass (wood, 56%; crop residues, 16%; dung, 21%).[4] Wood smoke contains hundreds of chemical compounds.[5] Some of the components present in wood smoke that are a health concern include particles, polycyclic aromatic hydrocarbons and car-

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bon monoxide.[6]

Smoke from biomass combustion produces a large number of health-damaging air pollutants such as respirable particulate matter, carbon monoxide (CO), nitrogen oxides, formaldehyde, benzene, polycyclic aromatic hydrocarbons and many other toxic organic compounds.[7] In developing countries where large proportions of households rely on biomass fuels for cooking and space heating, concentrations of these air pollutants tend to be highest indoors.[7] The fuels are typically burned in simple, inefficient, and mostly unvented household cook stoves, which, combined with poor ventilation, generate large volumes of smoke indoors. Moreover, cook stoves are typically used for several hours each day at times when people are present indoors, resulting in much higher exposure to air pollutants than from outdoor sources.[8]

Exposure of air pollutants levels are usually much higher among women who tend to do most of the cooking[9] and among young children who stay indoors and who are often carried on their mother's back or lap while cooking.[10] A recent baseline survey conducted in two districts of Zimbabwe showed that women and young children spend an average of 5 hours per day in the kitchen area, where air pollution levels from biomass fuel combustion for cooking are often very high. The measured levels of CO in the kitchen were in the range of 300-1,000 ppm.[11]

Several studies have examined the effects of coal stoves on indoor air pollutant levels.[12,13] Qing and colleagues measured indoor and outdoor inhalable particulate (IP), SO_2, and CO in children's homes and schools in four large cities in China.[12] The estimated concentrations for IP, SO_2, and CO were 247 $\mu g/m^3$, 185 $\mu g/m^3$, and 4.17 mg/m^3, respectively, for children living in households using gas stoves, but were 708 $\mu g/m^3$, 436 $\mu g/m^3$, and 6.55 mg/m^3, respectively, for children living in households using coal stoves. Luo[13] investigated 64 households to determine if any association exists between indoor air pollution and stove fuels in southeastern China. Indeed, there were significantly higher SO_2 levels in households using coal stoves than those using natural gas.

A number of studies have shown that biomass smoke is an important cause of indoor pollution[14,15] and is one of the predisposing factors in Acute Respiratory Infection (ARI), asthma[16] and rhinitis.[17] The highest exposure is most likely experienced by women, infants and young children. Exposure to pollution from wood burning stoves is associated with severe respiratory symptoms and mortality.[15] Indoor air pollution from the combustion of biomass or solid fuels has been implicated, with varying degrees of evidence, as a causal agent of Asthma.[18] Exposure to biomass smoke has been strongly associated with ARI in preschool age children.[19] However, a study of preschool age children has demonstrated a relationship between biomass smoke and ARI. Mishra studied the household use of biomass fuel for cooking and acute respiratory infections in preschool age children (< 5 years) in Zimbabwe, and found that children in households using wood, dung or straw for cooking were more than twice as likely suffer from ARI than children from households using liquefied petroleum gas (LPG)/natural gas or electricity.[20]

Studies in developed countries show an association between biomass fuel and indoor air pollution and respiratory allergy in children. However, these investigations are lacking in developing nations such as India, particularly those which attempt to uncover any relationship that might be present between cooking fuels and indoor air pollutants (*e.g.* SO_2, NO_2 and total suspended particulate mater [SPM]) and their effects on respiratory allergy in children. Hence, the present study aims to identify the effects of cooking fuels (such as LP gas and biomass) and indoor air pollutants on asthma, rhinitis and upper respiratory tract infection (URTI) allergies in children residing in Delhi, India.

MATERIALS AND METHOD

This study was conducted in Delhi, India throughout 2004-2006. The study areas were divided into nine locations, namely Ashok Vihar (residential area), I.T.O. (residential area), Janakpuri (residential area), Nizamuddin (residential area), Siri Fort (residential area), Shahdara (industrial area), Shahzada Bag (industrial area), Dallupura (Village) and Jagatpur (Village) based on the source of pollutants and information from the Central Pollution Control Board (CPCB), India's premier pollution monitoring authority. The CPCB has outdoor pollution monitoring stations in each area, with the exception of villages, which regulates daily pollutant levels. The 1 km areas surrounding the monitoring station were used in the study. Three colonies, one each representing the lower (residents earning a monthly income of less than 3,000 rupees and living in a house with a single room), middle (residents with a monthly income of 3,000-5,000 rupees and living in a house containing 2-3 rooms) and upper (residents earning a monthly income of 10,000 rupees and living in a house containing 4-5 rooms) socioeconomic segments were randomly selected for the survey. There was no class-wise distribution in the villages. One hundred houses which resided children aged 7-15 years and from each socioeconomic class were selected for surveys and health checkups. Indoor SO_2, NO_2 and SPM were monitored in 25% of the houses from each study area. Ethical clearance for the study was obtained from the Ethical Committee of the Vallabhbhai Patel Chest Institute, University of Delhi.

A questionnaire applicable for Indian conditions was prepared. It included demographic details including gender, diet, smoking habits in the family (including the children), indoor structure of the home, ventilation in the kitchen, types of fuels used for cooking, queries on indoor air pollution, and complaints of any major chronic chest symptoms (cough, phlegm, shortness of breath, wheezing, chest illness). The survey team contacted the resident welfare association of the colony for assistance in the study. Parental consent was also required.

Detailed examinations of children were conducted to gather information on various parameters that included height, weight, pulse rate, respiratory rate, nutritional status and body build. The pulmonary function for each child was assessed with an electronic portable spirometer and peak flow meter. Maximal expiratory flow volume (MEFV) curves were obtained as per American Thoracic Society (ATS) 1995 recommendations.[21] Three acceptable and a minimum of two reproducible curves were obtained from each subject. The selection of spirometry parameters was performed as recommended by the ATS. The highest values of FVC and FEV_1 were selected. Several subjects were unable to cooperate and complete the spirometry manoeuvres satisfactorily. In these circumstances, peak expiratory flow rates (PEFR) were obtained with a Wright's peak flow meter. The highest of the three recordings was recorded.

Indoor air measurement

Sampling systems and analytical procedures for indoor SO_2, NO_2 and SPM pollutants were adopted as described in earlier studies[22-25] and in accordance with the CPCB. Indoor SO_2, NO_2 and SPM levels were measured simultaneously using a Handy Air Sampler (Model No. APM 821, Envirotech Instruments Private Limited, New Delhi, India) with a flow rate of 1 liter per minute (l/m) over a 6 hour sampling period. The instrument was placed in the center or corner of the room, with the inlet approximately 1 m above ground level to correspond with the breathing height of the children. Indoor sulfur dioxide and nitrogen dioxide concentrations were measured using the methods of West and Gaeke[24] and Hochheiser,[25] respectively (both with modifications). Indoor SPM was collected on 25 mm Whatman glass microfibre filters. At the end of the sampling period, the filter paper was removed. The filter papers were then desiccated for 24 hours and re-weighted to determine the mass of the particles collected. The particle concentration was measured by the weight gain of the filter divided by the volume of air samples.

Statistical analysis

Statistical analyses were determined using SPSS statistical software. Groups were compared for all variables using the Student t-test to compare equality for means, and the chi square test to compare category value. The differences were considered to be statistically significant at the $p < 0.05$ (two tailed test) level. Results are presented as percentage and mean ± SD.

RESULTS

During the present study, the survey team visited a total of 7,466 houses from all of the study areas in Delhi, but children (7-15 years) were present in 4,421 houses, and the team was ultimately permitted to conduct the study in 2,828 houses. A total of 3,456 children were examined, of which 26.4% children were from lower, 27.5% from middle, and 26.0% from upper socioeconomic classes. Among these children, 59.2% were male and 40.8% were female, 20.1% were from urban villages and 34.8% were exposed to environmental tobacco smoke.

Only 46.3% children or their family members had any prior knowledge concerning indoor air pollution. The general profiles of the children are summarized in Table 1. Children with symptoms of respiratory allergy suffered from cough (42.8%), phlegm production (22.1%), shortness of breath (19.4%) and wheezing (14.2%). Asthma (7.7%), rhinitis (26.1%) and upper respiratory tract infection (UTRI) (22.1%) were diagnosed following medical histories and examinations of the children were completed. 7.8% of the children have a family history of respiratory disease (Table 2).

Overall, 2,377 (68.8%) of the children whose family members were predominantly from upper and middle classes were using liquefied petroleum gas (LPG) fuel for cooking. With respect to location, 77.1% of the children whose family members were using LP gas fuel for cooking were from Ashok Vihar, 71.0% from I.T.O., 73.8% from Janakpuri, 83.1% from Nizamuddin, 70.3% from Siri Fort, 74.1% from Shahdara, 66.8% from Shahzada Bag, 88.6% from Dallupura and 15.4% from Jagatpur. Of the overall total, 1,079 (31.2%) of the children whose family members were mainly from lower class were using biomass fuel (coal, wood, kerosene and cow dung) for cooking. Regarding location, 22.9% of the children whose family members were using biomass fuel for cooking were from Ashok Vihar, 29.0% from I.T.O., 26.3% from Janakpuri, 16.9% from Nizamuddin, 29.7% from Siri Fort, 25.9% from Shahdara, 33.2% from Shahzada Bag, 11.4% from Dallupura and 84.6% from Jagatpur (Table 3).

The mean level of indoor SO_2 was significantly higher in the houses of Ashok Vihar (p = 0.001), Janakpuri (p = 0.017) and Siri Fort (p = 0.050) where families were using biomass fuels for cooking compared to families using LP gas fuel for cooking (Table 4). The mean level of indoor NO_2 was significantly higher in the houses of I.T.O. (p = 0.003) and Janakpuri (p = 0.007) where families were using biomass fuels for cooking compared to families using LP gas fuel for cooking (table 4). The mean level of indoor SPM was significantly higher in the houses of Ashok Vihar (p = 0.039) and I.T.O. (p = 0.001) where families were using biomass fuels for cooking compared to families using LP gas fuel for cooking (table 4).

Significantly higher numbers of asthmatic children in I.T.O. (p = 0.016), Janakpuri (p = 0.038) and Nizamuddin (p = 0.004) were found in families

Table 1 General profile of children in the present study

Profile of children	Socioeconomic status of children				Total
	Lower	Middle	Upper	Villages	
Children studied	912	949	900	695	3556
Male	59.8%	56.0%	58.7%	63.6%	59.2%
Female	40.2%	44.0%	41.3%	36.4%	40.8%
Vegetarian	19.3%	57.0%	44.2%	53.7%	59.1%
Non-Vegetarian	80.3%	43.0%	55.8%	46.3%	40.9%
Students	88%	98.9%	99.4%	98.5%	96.0%
Go to school by bus	31.0%	36.3%	60.5%	18.4%	37.9%
Go to school on foot	69.0%	63.7%	39.5%	81.6%	62.1%
Smokers children	1.1%	0.1%	0	0	0.3%
Environmental tobacco smoke (ETS)	52.1%	26.6%	22.0%	39.7%	34.8%
≤ 4 person occupancy per room	37.7%	96.4%	98.4%	73.7%	76.9%
> 4 person occupancy per room	62.3%	3.65%	1.6%	26.3%	23.1%
Awareness of indoor air pollution	17.9%	62.6%	82.65	14.5%	46.3%

Table 2 Respiratory allergies diagnosed in children in the present study

Respiratory symptoms and diseases in children	Socioeconomic status of children				Total
	Lower	Middle	Upper	Villages	
History of cough	52.5%	45.8%	45.6%	22.3%	42.8%
History of phlegm production	29.3%	24.3%	24.4%	7.9%	22.1%
History of shortness of breath	26.9%	21.0%	18.6%	8.5%	19.4%
History of wheezing	20.1%	14.8%	14.2%	5.9%	14.2%
Asthma	9.4%	7.3%	9.4%	3.9%	7.7%
Rhinitis	27.1%	33.3%	28.6%	11.1%	26.1%
URTI	24.6%	27.6%	22.4%	10.9%	22.1%
Family history of respiratory disease	4.2%	9.4%	14.2%	2.2%	7.8%

Table 3 Types of fuels used for household cooking

Study areas	Type of fuels used for cooking	Class			Total (n = 2,761 + 695 [villages] = 3,456)
		Lower (n = 912)	Middle (n = 949)	Upper (n = 900)	
Ashok Vihar (n = 441)	LP gas	38	161	141	340 (77.1%)
	Biomass	101	0	0	101 (22.9%)
I.T.O. (n = 352)	LP gas	13	124	113	250 (71.0%)
	Biomass	98	4	0	102 (29.0%)
Janakpuri (n = 400)	LP gas	22	142	131	295 (73.8%)
	Biomass	102	3	0	105 (26.2%)
Nizamuddin (n = 350)	LP gas	65	114	112	291 (83.1%)
	Biomass	59	0	0	59 (16.9%)
Siri Fort (n = 387)	LP gas	20	133	119	272 (70.3%)
	Biomass	115	0	0	115 (29.7%)
Shahdara (n = 394)	LP gas	27	129	136	292 (74.1%)
	Biomass	102	0	0	102 (25.9%)
Shahzada Bagh (n = 437)	LP gas	7	138	147	292 (66.8%)
	Biomass	143	1	1	145 (33.2%)
Dallupura (n = 325)	LP gas				288 (88.6%)
	Biomass				37 (11.4%)
Jagatpur (n = 370)	LP gas				57 (15.4%)
	Biomass				313 (84.6%)
Total	LP gas	192	941	899	2,377 (68.8%)
	Biomass	720	8	1	1,079 (31.2%)

who generally used biomass fuels (coal, wood, kerosene and cow dung) for cooking compared to families using LP gas fuel for cooking (Table 5). Asthma in children was significantly (p = 0.016) greater in Shahzada Bag where families were using LP gas fuels for cooking compared to families using biomass fuels for cooking (Table 5). Rhinitis in the children was significantly more frequent in Nizamuddin (p = 0.027) and Dallupura (p = 0.009) where families were using biomass fuels for cooking compared to families using LP gas fuel for cooking (Table 5). Rhinitis in the children was also significantly higher in the Siri Fort (p = 0.004) and Shahzada Bag (p = 0.027) where families were using LP gas fuels for

Table 4 Indoor air pollutants (SPM, SO_2 & NO_2) and fuels used for cooking

Study areas	Fuels used for cooking	Mean ± SD of pollutants at different areas		
		So_2 (µg/m³)	**No_2** (µg/m³)	**SPM** (µg/m³)
Ashok Vihar (n = 126)	LP gas	0.57 ± 1.34	20.21 ± 14.05	920 ± 380
	Biomass	3.20 ± 2.91	15.82 ± 7.85	1,060 ± 300
	p value	**0.001**	0.029	**0.039**
I.T.O. (n = 93)	LP gas	5.60 ± 5.08	55.87 ± 24.36	490 ± 170
	Biomass	12.58 ± 19.09	94.81 ± 56.21	760 ± 200
	p value	0.089	**0.003**	**0.001**
Janakpuri (n = 105)	LP gas	3.23 ± 5.65	29.75 ± 10.68	870 ± 330
	Biomass	5.54 ± 3.31	55.40 ± 39.80	830 ± 390
	p value	**0.017**	**0.007**	0.682
Nizamuddin (n = 88)	LP gas	7.53 ± 4.13	27.76 ± 14.05	510 ± 270
	Biomass	7.50 ± 1.20	32.62 ± 12.95	580 ± 200
	p value	0.967	0.342	0.352
Siri Fort (n = 110)	LP gas	8.95 ± 1.89	28.32 ± 8.75	420 ± 220
	Biomass	10.34 ± 3.68	26.43 ± 8.67	410 ± 190
	p value	**0.050**	0.303	0.707
Shahdara (n = 103)	LP gas	2.55 ± 1.91	26.60 ± 14.29	1,010 ± 420
	Biomass	6.16 ± 8.64	32.18 ± 21.07	1,200 ± 530
	p value	0.064	0.252	0.137
Shahzada Bagh (n = 109)	LP gas	3.45 ± 1.94	44.35 ± 16.14	1,110 ± 470
	Biomass	4.50 ± 5.39	41.55 ± 20.27	1,120 ± 480
	p value	0.289	0.492	0.912
Dallupura (n = 91)	LP gas	3.00 ± 2.92	19.42 ± 11.11	370 ± 200
	Biomass	1.68 ± 1.73	17.09 ± 6.92	450 ± 180
	p value	0.024	0.298	0.121
Jagatpur (n = 87)	LP gas	3.52 ± 2.99	7.47 ± 9.02	280 ± 160
	Biomass	2.85 ± 2.65	11.19 ± 11.59	290 ± 150
	p value	0.498	0.153	0.890
Total (n = 912)	LP gas	4.24 ± 4.28	30.26 ± 18.60	710 ± 430
	Biomass	5.52 ± 8.12	31.80 ± 33.94	690 ± 460
	p value	**0.016**	0.492	0.637

cooking compared to families using biomass fuels for cooking (Table 5). Upper respiratory tract infection (URTI) in children was associated with both types of cooking fuels (Table 5).

DISCUSSION

There are four major air pollution sources in Delhi - industrial emissions, residential heating and cooking, vehicular traffic, and natural sources i.e. dust and wind. Suspended particulate matter, sulfur dioxide and nitrogen dioxide are the three major air pollutants in Delhi.[26] Airborne particulates are made up of a complex mixture of organic and inorganic substances of varying size. Only particles of less than 10 µm are likely to reach the lungs.[27] The particle mass in coal smoke is ≥ 90% respirable. Indoor coal combustion for cooking is the major source of indoor particulate matter. In addition, house dust may be detected by indoor particulate monitors.[26] The suspended particle concentration levels found in kitchens are very high. Combustion of fossil fuels for power generation (35%) and automobiles (45%) are the prime sources of outdoor, man-made NO_2. Indoor sources of NO_2 include cigarette smoke, gas and oil heaters and cookers which often result in

Table 5 Correlations between fuels used for cooking and respiratory allergy in children

Study areas	Fuels used for cooking	Respiratory allergy in children		
		Asthma	Rhinitis	URTI
Ashok Vihar (n = 126)	LP gas	28 (8.2%)	90 (26.5%)	71 (20.9%)
	Biomass	5 (5.0%)	32 (31.7%)	26 (25.7%)
	p value	*p* = 0.388	*p* = 0.183	*p* = 0.388
I.T.O. (n = 93)	LP gas	11 (4.4%)	49 (19.6%)	40 (16.0%)
	Biomass	12 (11.8%)	17 (16.7%)	17 (16.7%)
	p value	***p* = 0.016**	*p* = 0.316	*p* = 0.874
Janakpuri (n = 105)	LP gas	19 (6.4%)	105 (35.6%)	77 (26.1%)
	Biomass	14 (13.3%)	31 (29.5%)	30 (28.6%)
	p value	***p* = 0.038**	*p* = 0.157	*p* = 0.202
Nizamuddin (n = 88)	LP gas	18 (6.2%)	90 (30.9%)	51 (17.5%)
	Biomass	11 (18.6%)	26 (44.1%)	28 (47.5%)
	p value	***p* = 0.004**	***p* = 0.037**	***p* = 0.001**
Siri Fort (n = 110)	LP gas	17 (6.3%)	51 (18.8%)	38 (14.0%)
	Biomass	7 (6.1%)	9 (7.8%)	9 (7.8%)
	p value	*p* = 1.000	***p* = 0.004**	*p* = 0.124
Shahdara (n = 103)	LP gas	43 (14.7%)	134 (45.9%)	131 (44.9%)
	Biomass	13 (12.7%)	41 (40.2%)	39 (38.2%)
	p value	*p* = 0.742	*p* = 0.189	*p* = 0.296
Shahzada Bagh (n = 109)	LP gas	35 (12.0%)	109 (37.3%)	95 (32.5%)
	Biomass	7 (4.8%)	40 (27.6%)	36 (24.8%)
	p value	***p* = 0.016**	p **= 0.027**	*p* = 0.120
Dallupura (n = 91)	LP gas	13 (4.5%)	36 (12.5%)	38 (13.2%)
	Biomass	2 (5.4%)	11 (29.7%)	5 (13.5%)
	p value	*p* = 0.683	***p* = 0.009**	*p* = 1.000
Jagatpur (n = 87)	LP gas	3 (5.3%)	6 (10.5%)	8 (14.0%)
	Biomass	9 (2.9%)	24 (7.7%)	25 (8.0%)
	p value	*p* = 0.407	*p* = 0.307	*p* = 0.202
Total (n = 912)	LP gas	187 (7.9%)	670 (28.2%)	549 (23.1%)
	Biomass	80 (7.4%)	231 (21.4%)	215 (19.9%)
	p value	*p* = 0.680	***p* = 0.001**	***p* = 0.038**

high indoor concentrations.[27] The WHO and US Environmental Protection Agency recommends permissible limit or air quality standards of 125, 150 and 150 μg/m^3 for ambient SO_2, NO_2 and SPM, respectively, during a 24 hour period for the general population.[27]

The prevalence of asthma and rhinitis has increased worldwide over the past two or three decades, and the increase appears to greatest in children, teenagers and young adults.[28,29] The European Community Respiratory Health Survey (ECRHS)[30] in adults and International Study of Asthma and Allergy in Childhood (ISAAC)[31] studies in children have generated an extensive volume of data on the prevalence of asthma and allergic rhinitis worldwide. The prevalence of physician-diagnosed asthma and allergic rhinitis in children were 20.9% and 18.2% in United Kingdom,[31] 9.4% and 15.3% in Northern Africa,[32] 7.8% and 15.8% in Israel,[33] 20.7% and 10.5% in Oman,[34] 12.1% and 12.1% in Saudi Arabia,[35] and 11.69% and 11.03% in India,[36] respectively. The incidence of ARI is considerably higher in developing countries with 15-20% of children suffering from respiratory infection every year. A study[20] of indoor air pollution and acute respiratory illness conducted in Zimbabwe found that the prevalence of ARI in children was 16.67%. These studies are consistent with the present study in Delhi which showed that the respiratory diseases asthma, rhinitis and URTI were 7.7%, 26.1% and 20.1%, respectively.

Combustion of biomass fuels in poorly ventilated kitchens using poorly functioning stoves causes the accumulation of high concentrations of respirable particulates with gases including carbon monoxide, sulfur dioxide and nitrogen dioxide.[37] A study conducted by Ezzati and Kammen[19] in Kenya determined concentrations of indoor suspended particulate matter from biomass combustions that were 1,000-2,000 $\mu g/m^3$. The exposure level of particulates was very high arising from cooking using biomass fuels in developing countries. In Mozambique, the mean level of indoor PM_{10} during cooking by wood was 1,200 $\mu g/m^3$.[38] In rural Bolivia, the 6-hour mean levels of indoor PM_{10} while cooking using dung was 1,830 $\mu g/m^3$ in indoor kitchens and 250 $\mu g/m^3$ in outdoor kitchens.[37] Aggarwal *et al.*[39] measured the concentrations of indoor total suspended particulates (TSP), SO_2 and NO_2 from biomass combustion in India which were found to be 7.2 mg/m^3, 169 $\mu g/m^3$ and 318 $\mu g/m^3$, respectively. In the present study, the mean level of indoor SO_2, NO_2 and SPM was significantly higher where families used biomass fuels (coal, wood, cow dung cakes and kerosene) for cooking compared to families using LP gas for cooking.

Exposure to indoor air pollution from the combustion of biomass or solid fuels has been inferred, with varying degrees of evidence, as a causal agent of respiratory allergy.[18] Schei *et al.*[40] studied the association between childhood asthma and indoor wood smoke from cooking in Guatemala, Latin America and found the prevalence of all asthma symptoms were higher in children where wood was used for cooking. A study in India showed that the prevalence of asthma was almost two-fold higher among the elderly living in households using biomass fuels for cooking than among those living in households using cleaner fuels for this purpose.[16] An additional study in India reported that exposure to biomass fuel and LPG both affect pulmonary function (PEFR) in asthmatics.[41] A study in Netherlands found that gas cooking is significantly associated with nasal symptoms (22.1%) in young children.[42] In a German study, household wood or coal stove use was negatively associated with atopic sensitization and allergic rhinitis in childhood.[43] Exposure to pollution from wood burning stoves for indoor heating is associated with severe respiratory symptoms and infections.[44] Two other studies indicate that exposure to biomass smoke is also strongly associated with ARI in preschool children.[19,45] In our work, respiratory diseases in children such as asthma, rhinitis and upper respiratory tract infection were significantly associated with the use of both biomass (coal, wood cow dung cakes and kerosene) and LP gas as cooking fuels.

This study was conducted in an attempt to identify the impact of indoor air pollutants from fuel used for cooking on respiratory allergy in children of Delhi in India, particularly SO_2, NO_2 and SPM. The indoor levels of SO_2, NO_2 and SPM were significantly greater in houses where the cooking was made on coal, wood, kerosene and cow dung cake when compared to LP gas. Asthma, rhinitis and upper respiratory tract infection was diagnosed in children from these homes. Respiratory diseases including asthma, rhinitis and upper respiratory tract infection in the children could also be significantly associated with both types of cooking fuels. The findings from the present study indicate that biomass and LP gas cooking fuels increase the concentration of indoor air pollutants and may subsequently play a significant role in the development of respiratory allergy.

ACKNOWLEDGEMENT

The authors are thankful to Ministry of Environment and Forest, Government of India for financial assistance for the study.

REFERENCES

1. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull WHO 2000; 78: 1080-92.
2. Barnes DF, Openshaw K, Smith KR, Van der Plas R. What makes people cook with improved biomass stoves? A comparative International review of stove programs 1994. Washington DC: The World Bank.
3. Reddy AKN, Williams RH, Johansson TB. Energy after Rio: prospects and challenges. New York: United Nations Publications 1996.
4. TEDDY: Tata Energy Data Directory Yearbook 1998-1999. New Delhi: Tata Energy Research Institute.

5. Smith KR, Liu Y. Indoor air pollution in developing countries. In: Samet JM (ed.). Lung Biology in Health and Disease, Vol. 74: Epidemiology of Lung Cancer. New York: Marcel Dekker 1994; pp. 151-84.
6. Samet JM, Marbury MC, Spengler JD. Health effects and sources of indoor air pollution. Part I. Am Rev Respir Dis 1987; 136: 1486-508.
7. Bruce N, Perez-Padilla R, Albalak R. Indoor air pollution in developing countries: a major environmental and public health challenge. Bull World Health Organ 2000; 78: 1089-92.
8. Smith KR. Indoor air pollution in developing countries: recommendations for research. Indoor Air 2002; 12: 1-7.
9. Behera D, Dash S, Malik SK. Blood carboxyhaemoglobin levels following acute exposure to smoke of biomass fuel. India J Med Res 1988; 88: 522-42.
10. Albalak R. Cultural practices and exposure to particulate pollution from indoor biomass cooking: Effects on respiratory health and nutritional status among the aymara Indians of the Bolivian Highlands (Ph.D. Thesis). Ann Arobar, Michigan: University of Michigan. 1997.
11. Mika L. Addressing health and household energy problem in Zimbabwe. Paper presented at the 9th International Conference on indoor air quality and climate, Monterey, California. June 30-July 5, 2002.
12. Qing YH, *et al.* Effect of indoor air pollution on respiratory diseases in children. Proceeding (in Chinese) of China-Japan environment health conference. Zhengzhou, China, 1992; 53-5.
13. Luo DY. Investigation of air pollution in houses due to use of various fuels. Proceedings of the 5th international conference on indoor air quality and climate. Toronto, Canada 1990; 115-7.
14. Sharma S, Sethi GR, Rohatgi A, Chqudhary A, Shanker R, Bapna JS, Joshi V, Sapir DG. Indoor air quality and acute lower respiratory infection in Indian urban slums. Environ Health Perspect 1998; 106: 291-7.
15. Honicky RE, Osborne JS III, Akpom AC. Symptoms of respiratory illness in young children and the use of wood burning stoves for indoor heating. Paediatrics 1985: 75: 587-593.
16. Mishra V. Indoor air pollution from biomass combustion and prevalence of asthma in the elderly. Environ Health Perspect 2003: 111; 71-7.
17. Keles N, Ilicali OC, Deger K. Impact of air pollution on prevalence of rhinitis in Istanbul. Arch Environ Health 1999; 54: 48-51.
18. Ezzati M, Kammen DM. The health impacts of exposure to indoor air pollution from solid fuels in developing countries: knowledge, gaps and data needs. Environ Health Perspect 2002; 110: 1057-68.
19. Ezzati M, Kammen DM. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. Lancet 2001: 358; 619-24.
20. Mishra V. Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. Inter J Epidemiol 2003: 32; 847-53.
21. ATS recommendation. Standardization of spirometry. Am J Respir Crit Med 1995; 152: 1107-36.
22. Wedding JB, Mcfart AR, Cermak JE. Large particle collection characteristics of ambient aerosol samplers. Environ Sci & Tech 1977; 4: 387.
23. ISO (1983). Air quality-particle size fraction definitions for health-related sampling. Tech. Report ISO/TR, 7708; 1983 (E). International Standard Association, Geneva, Switzerland.
24. West PW, Gaeke GC. Fixation of sulfur dioxide as sulpitomercurate III and subsequent calorimetric determination. Anal Chem 1956; 28: 1816-9.
25. Jacabs MB, Hochheiser S. Continuous sampling and ultramicrodetermination of nitrogen dioxide in air. Anal Chem 1958; 30: 426-8.
26. Singh MP, Goyal P, Panwar TS, Aggarwal P, Nigam S. Predicted and observed concentrations of SO_2, SPM and NOx over Delhi. Atmospheric Environ 1990; 24A: 783-8.
27. Wardlaw AJ. The role of air pollution in asthma. Clin Exp Allergy 1993; 23: 81-96.
28. Burney PGJ, Chin S, Rona RJ. Has the prevalence of asthma increased in children? Evidence from the national study of health and growth 1973-86. Br Med J 1990; 300: 1306-10.
29. Parikh A, Scadding GK. Seasonal allergic rhinitis. Br Med J 1997; 314: 1392-5.
30. Burney P, Chinn S, Jarvis D, *et al.* Variations in the prevalence of respiratory symptoms, self reported asthma attacks, and use of asthma medication in the European Community Respiratory Health Survey (ECRHS). Eur Respir J 1996; 9: 687-95.
31. Pearce N, Weiland S, Keil U, *et al.* Self-reported prevalence of asthma symptoms in children in Australia, England, Germany and New Zealand: an international comparison using the ISAAC written and video questionnaires. Eur Respir J 1993; 6: 1455-61.
32. Georgy V, Fahim HI, Gaafary ME, Walters S. Prevalence and socioeconomic associations of asthma and allergic rhinitis in Northern Africa. Eur Respir J 2006; 28: 756-62.
33. Graif Y, Garty BZ, Livne I, Green MS, Sohat T. Prevalence and risk factors for allergic rhinitis and atopic eczema among schoolchildren in Israel: results from a national study. Ann Allergy Asthma Immunol 2004; 92: 245-9.
34. Al-Riyami BM, Al-Rawas OA, Al-Riyami AA, Jasim LG, Mohammed AJ. A relatively high prevalence and severity of asthma, allergic rhinitis and atopic eczema in schoolchildren in the Sultanate of Oman. Respirology 2003; 8: 69-76.
35. Hijazi N, Abalkhail B, Seaton A. Asthma and respiratory symptoms in urban and rural Saudi Arabia. Eur Respir J 1998; 12: 41-4.
36. Gour SN, Gupta K, Rajpal S, Singh AB, Rohtagi 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.
37. Albalak R, Keeler GJ, Frisancho AR, Haber M. Assessment of PM10 concentrations from domestic biomass fuel combustion in rural Bolivian highland villages. Environ Sci Technol 1999; 33: 2505-9.
38. Ellegard A. Cooking fuel smoke and respiratory symptoms among women of low income areas of Mapato. Environ Health Prospect 1996; 104: 980-5.
39. Aggarwal AL, *et al.* Assessment of exposure to benzo(a)pyrene in air for various population groups in Ahmedabad. Atmospheric Environ 1982; 16: 867-70.
40. Schei MA, Hessen JO, Smith KR, Bruce N, McCracken J, Lopez V. childhood asthma and indoor woodsmoke from

cooking in Gautemala. J Expo Anal Environ Epidemiol 2004; 14: S110-7.
41. Behera D, Chakrabarti T, Khanduja KL. Effect of exposure to domestic cooking fuels on bronchial asthma. Indian J Chest Dis Allied Sci 2001; 43: 27-31.
42. Willers SM, Brunekreef B, Oldenwening M, Smit HA, Kerkhof M, Vries HD, Gerritsen J, De Jongste JC. Gas cooking, kitchen ventilation, and asthma, allergic symptoms and sensitization in young children – the PIAMA study. Allergy 2006; 61:563-8.
43. Kilpelainen M, Koskenvuo M, Helenius H, Terho E. Wood stove heating, asthma and allergies. Respir Med 2001; 95: 911-6.
44. Honicky RE, Osborne JS III, Akpom AC. Symptoms of respiratory in young children and the use of wood burning stoves for indoor heating. Paediatrics 1985; 75: 587-93.
45. Pandey MR, Boleji J, Smith KR, Wafula E. Indoor air pollution in developing countries and acute respiratory infection in children. Lancet 1989; 25: 427-9.