ISSN 1804-4158

EFFECT OF INDOOR AIR POLLUTION ON ACUTE RESPIRATORY INFECTION AMONG CHILDREN IN INDIA

Kumar Ashwani[I], Paul Kalosona[II]
1 - International Institute for Population Sciences, Mumbai, India 2 - Tata Institute of Social Sciences, Mumbai, India

ABSTRACT

Indoor Air Pollution (IAP) has become a major concern in India in recent years because women and young children are highly exposed to smoke of various types of unclean fuels used for cooking and heating in the household result into risk of respiratory disorders among them. The paper aims to seek association between prevalence of acute respiratory infection (ARI) among children less than five years of age and use of cooking fuels in households of India. The analysis is based on 52,868 Children less than five years of age included in India's third National Family Health Survey conducted in 2005-2006. Effects of exposure to cooking smoke, determined by the type of fuel used for cooking such as biomass and solid fuels versus cleaner fuels, on the reported prevalence of ARI were estimated using multivariate logistic regression. Since the effects of cooking smoke are likely to be confounded with effects of tobacco smoking, age, and other such factors, the analysis was carried out after statistically controlling for such factors. The results indicate that Children under five years of age living in households using biomass and solid fuels have a significantly higher risk of ARI than those living in households using cleaner fuels (OR: 1.54; 95% CI: 1.38-1.72; p = .010). The findings have important program and policy implications for countries such as India, where large proportions of the population still rely on polluting biomass fuels for cooking and heating. Decreasing household biomass and solid fuel use and increasing use of improved stove technology may decrease the health effects of indoor air pollution. More epidemiological research with better measures of smoke exposure and clinical measures of ARI is needed to validate the findings.

UDC & KEYWORDS

■ UDC: 614.2, 614.7 ■ FUEL ■ INDOOR ■ ARI ■ UNDER FIVE CHILDREN ■ INDIA

INTRODUCTION

One-half of the world's households and up to 95 per cent of people in poor countries burn wood, dung-cake, peat and other biomass fuels, as well as coal, for energy. Cooking and heating with solid fuels, such as dung-cake, wood, agricultural residues, grass, straw, charcoal and coal, is a major source of indoor air pollution. The indoor smoke comprises a variety of health- damaging pollutants, such as particles (complex mixtures of chemicals in solid form and droplets), carbon monoxide, nitrogen oxides, sulphur oxides, formaldehyde, and carcinogens such as benzo[a]pyrene and benzene. Small particles with a diameter of 10 µm or less (PM10) are able to penetrate deep into the lungs. The smallest particles, with a diameter of 2.5 µm or less (PM2.5), appear to have the greatest health-damaging potential. (Smith, Feuz & Mehta, 2004; WHO, 2006; ENHIS, 2009).

Combustion of solid fuels in incompetent stoves under poor ventilation conditions can result in large exposure burdens, particularly for women and young children, who spend most of their time in the home (Mehta, 2006). According to the report on the "Cause of Death 2001 - 03", respiratory infections with 22% constitute the second leading cause of death among children 0-4 years in India. (RGI, 2003) In India, more than 4 lakh deaths every year are due to pneumonia accounting for 13%-16% of all deaths in the paediatric hospital admissions. (Jain et al. 2001; Vashishtha, 2010) Million deaths study based on the register general of India mortality statistics had reported 3.7 lakh deaths due to pneumonia among children under age five at the rate of 13.5/1000 live births. A higher proportion of deaths due to pneumonia was reported from central India (Cause of neonatal and child mortality in India, 2010).

Worldwide, around 3.5 million deaths per year occur due to household air pollution from rudimentary biomass and coal stoves (Lim et al., 2013) - this recent assessment is considerably higher than previous estimates; (Global health risk, 2009), around 50 per cent are in children aged less than five years. Exposure to indoor air pollution almost doubles the risk for childhood pneumonia. Over half of deaths among children less than 5 years old from acute lower respiratory infections (ALRI), are due to particulate matter inhaled from indoor air pollution from combustion of household solid fuels (WHO, 2006).

There is some evidence for associations between biomass smoke and chronic respiratory disease, asthma, cataracts, lung cancer, and tuberculosis. On the basis of the few studies available, there is evidence to suggest a link between indoor air pollution and adverse pregnancy outcomes, in particular, low birth weight. Tentative evidence exists for associations with ischaemic heart disease and cancers of the nose and throat (WHO, 2007). There is consistent evidence that exposure to indoor air pollution increases the risk of pneumonia among children under age five years, and of chronic respiratory disease and lung cancer (in relation to coal use) among adults aged over 30 years (WHO, 2005). While the precise mechanism of how exposure causes disease is still unclear, it is known that small particles and several of the other pollutants contained in indoor smoke cause inflammation of the air- ways and lungs and impair the immune response. Carbon monoxide also results in systemic effects by reducing the oxygen-carrying capacity of the blood. Other components of indoor air pollution can cause healthy cells to mutate into cancerous ones (Bruce, Perez-Padilla & Albalak, 2000).

Risk factors and determinants of ARI

Exposure is a function of both the pollutant concentration in an environment, and the person-time spent in the environment. (Mishra, 2003; Smith and Mehta, 2003) Since most people spend the majority of their time in homes, schools and workplaces, human exposure to air pollution is largely a function of pollutant levels in indoor settings (which can arise from outdoor sources and vice-versa). In many

[I] ashwaniips17@gmail.com
[II] kalosonapaul@gmail.com

populations, exposures to major pollutants from indoor sources can be higher than exposures to pollutants from outdoor sources (Smith and Mehta, 2003).

Several small-scale community-based studies have reported poor socioeconomic factors; low level of literacy, suboptimal breastfeeding, malnutrition, unsatisfactory level of immunization coverage, cooking fuel used other than liquefied petroleum gas as risk factors contributing to increasing burden of ARI among children.(Acharya et al., 2003; Savitha et al., 2007; Broor et al., 2001).

In developing countries, children who are exclusively breastfed for 6 months had 30%-42% lower incidence of ARI compared to children who did not receive for the same duration of breastfeeding. (Ladomenou et al., 2010) Quantitative systematic review of studies from developed countries estimated hand washing reduces the incidence of respiratory infections by 24% (ranging from 6% to 44%). (Wiley Online Library, 2013) The evidence from developing countries is lacking on this issue. Exposure to indoor air pollution has 2.3 (1.9-2.7) times increased the risk of respiratory infections (especially lower respiratory tract infections) (Ladomenou et al., 2010).

The full scale of this environmental health problem is clear when the high pollutant concentrations from Solid Fuel Use (SFU) are combined with a large amount of time people spend indoors. In particular, few activities involve as much person-time as cooking. Women responsible for preparing meals, and the young children they care for, are most heavily exposed to indoor air pollution from SFU. As women are primarily responsible for cooking, and children often spend time with their mothers, women and young children are disproportionately at higher risk of the indoor air pollution caused by the use of solid fuels and traditional stoves. Older children and men may also spend significant time indoors, although their activity patterns are less generalizable. Access to clean fuels is lowest among poor households in rural areas of developing countries, and poor households in urban or peri-urban areas of developing countries may also have inadequate access to clean fuels (Desai, Mehta & Smith, 2004; Smith , Mehta & Feuz, 2004).

Significant of the study

The bulk of air pollution research has focused on urban outdoor (ambient) air pollution. Within the rapid increase in vehicular and other pollution sources in urban areas of developing countries, and burgeoning numbers of epidemiological studies in developed countries showing effects at what used to be considered low levels , outdoor sources have remained the centre of most air pollution research worldwide (Smith, 2000). The use of unprocessed solid fuels in the households is an indicator of the potential for excessive air pollution exposures. In this way, access to clean fuels is parallel to the often-cited statistic on access to clean water as an indicator of diseases risk (Smith, 2000).

The Millennium Development Goals (MDGs 8) with the overall objective of encouraging healthy and prosperous development around the world with Target (No. 7) calls for environmental sustainability. Within this context, WHO has identified the “proportion of the population using solid fuels for cooking” as an indicator for assessing progress towards the integration of the principles of sustainable development into country policies and programmes. So, India, where over 70 per cent of the country population are at the risk of exposure due to unclean fuels use for cooking and heating in their households and toll lakhs of life and millions of years of disease burden per year, need to address the issue related to indoor air pollution and their impact on human health and national economy. Along this, it is still relevant in terms of reducing child mortality (MDGs Goal-4) and improving maternal health (MDG Goal-5) owing to the known effects on health of indoor air pollution (UNDP, 2005).

Data sources and Methodology

The household characteristics data from all the three series of National Family Health Survey {NFHS-I (1992-93), NFHS-II (1998-99) and NFHS-III (2005-06)} conducted by the International Institute for Population Sciences, Mumbai under the stewardship of the Ministry of Health and Family Welfare (MoHFW), Government of India has been used to examine the level and trend of various types fuels used in India. NFHS-3 collected demographic, socioeconomic, and health information from a nationally representative probability sample of 109,041 households. All states of India are represented in the sample, covering more than 99% of the country’s population. The sample is a multistage cluster sample with an overall response rate of 98%. The analysis here is based on 52,868 children aged 0-4 years old living in the sample households.

Response variable:

The survey asked several questions relating to the current health status of household members. In NFHS-3, the prevalence of ARI were estimated by asking mothers whether their children under age five years had been ill with a cough accompanied by short, rapid breathing which was chest related in the two weeks preceding the survey. These symptoms are compatible with ARI. The survey were conducted using an interviewer-administered questionnaire in the native language of the respondent using a local, commonly understood term for ARI like having cough, short rapid breathing, chest pain etc. 18 languages were used in the survey. No effort were made to clinically test for the disease.

In India, where clinical data on ARI are mostly unavailable or very weak, this reported prevalence of ARI from a representative national sample provides a unique opportunity to examine the factors associated with ARI prevalence among the children under age five years. The study has been reported of prevalence of ARI is the response variable.

Predictor variables: Exposure to cooking smoke have ascertained indirectly by type of fuel used for cooking or heating. The survey used a 10-item classification of cooking fuel: electricity, liquid petroleum gas (LPG), biogas, wood, crop residues, animal dung cakes, coal/coke/lignite, charcoal, kerosene, and a residual category of other fuels. The question was “What type of fuel does your household mainly use for cooking?” followed by the above list of fuels. We used information from this question to group households into two categories representing the extent of exposure to cooking smoke - high-exposure group (households using fuels: wood, crop residues, dung cakes, or coal/coke/lignite/charcoal - unclean fuels), low-exposure group (households using fuels: liquid petroleum gas, biogas, kerosene or electricity - clean fuel). This two-category classification of fuels is the principal predictor variable.

The survey also collected information on women’s smoking as children spend most of their time with mother for care and feeding. For eligible women in the sampled households, NFHS 3 asked “Does she smokes - cigarettes/bidis, pipe/cigar, paan masala, ghutka, chewing tobacco, uses snuff, smoke other or nothing?” We used information from this question to group women into two categories representing the children’s exposure to smoke - high exposure group (smoking anything) and low exposure group (smoking nothing). This two-category classification of fuels is the second most principal predictor variable.

Because the effects of exposure to cooking smoke as well as women's smoke on the prevalence of ARI are likely to be confounded with the effects of other risk factors, it is necessary to statistically control, or adjust, for such factors. Control variables included in this study were age, sex, birth order, education, religion of household head, caste/tribe of household head, house type, availability of window (ventilation) in the house, living standard of the household, urban/rural residence, and geographic region. For definition of variables, see Table 1.

Analysis: Because our response variable "prevalence of ARI" is dichotomous, we use logistic regression to estimate the effects of cooking smoke (from unclean fuel use relative to cleaner fuel use) and women's smoke (anything and nothing) on ARI prevalence with the other 11 demographic and socioeconomic variables mentioned above as controls. Results have presented in the form of odds ratios (ORs) with 95% confidence intervals (95% CI). The estimation of confidence intervals takes into account design effects due to clustering at the level of the primary sampling unit. The logistic regression models have estimated using the SPSS-20 and Arc GIS 10.1 statistical software package.

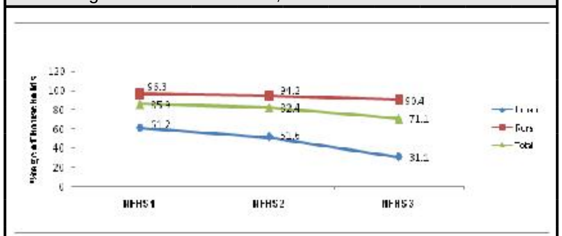
We tested for the possibility of multi-collinearity between the predictor variables, before carrying out the multivariate models. In the correlation matrix of predictor variables, all pairwise Pearson correlation coefficients are < 0.5, suggesting that multi-collinearity is not a problem. In the survey, certain states and certain categories of households were over-sampled. In all our analysis, weights are used to restore the representativeness of the sample (IIPS & ORC Macro, 2007).

Results and Discussion

Status of Household Fuel Use in India:

Figure 1 shows the trends and rural-urban differential in using unclean biomass fuel for cooking in Indian households from 1992-2006. The uses of unclean biomass fuel fallen down from the first survey to third survey of National Family Health Survey in India. The 1991 National Census included for the first time a question about the primary household fuel used and reflected that about 95 per cent of the rural population were relied primarily on biomass fuels (dung, crop residues, and wood). Following the same, National Family Health Survey (NFHS) in all her three series of survey asked about the primary household fuel used and the result reflected marginal improvement over NFHS I in NFHS III ; still overall 71 per cent and about 90 per cent of the rural households were relied primarily on unclean fuels in 2005-06.(Figure 1).

Figure 1: Trend and rural-urban differential in using unclean fuels for cooking in Indian households, 1992 – 2006

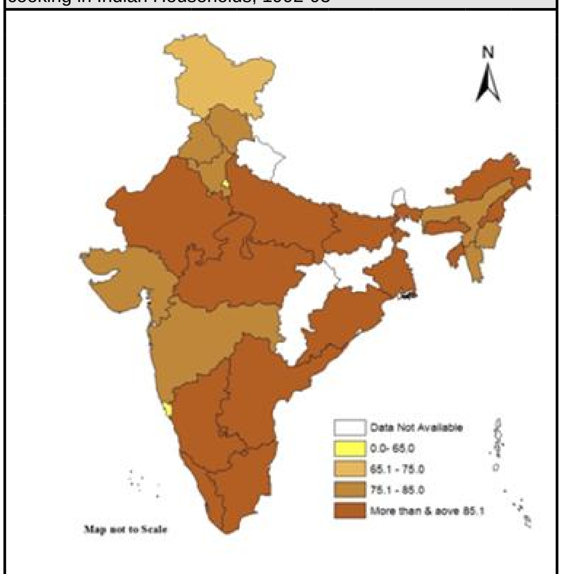


Sources: NFHS-I (1992-93) NFHS-II (1997-98), and NFHS-III (2005-06)

According to state-wise distribution, the north east regions like Nagaland, Tripura, Arunachal Pradesh and Eastern India State of Odisha having with high utilised of unclean fuel in 1992-93. Whereas, Bihar remained at the top in used of unclean biomass fuel in last two rounds of NFHS e.g. in 1997- 98 and 2005-06. Interestingly, the demographically low performing states such as Bihar, Jharkhand. Rajasthan all of which come under EAG (Empowered Action Group) states reported very high levels of uses of unclean biomass fuel of the recent round of NFHS. In the NFHS-III, Goa and Mizoram and Delhi were showing the lower parentage of households using unclean fuels for cooking or heating. On the contrary, the poorer states such as all EAG States (Bihar, Jharkhand, Odisha, Madhya Pradesh and Rajasthan) reported very high levels of unclean biomass used. In the earlier rounds, Nagaland Tripura and Arunachal Pradesh reported relatively high levels of using of fuel, however, in the recent round, used of fuels in these states were comparatively low (Figure 2-4). On the other hand, Western and southern region states were reported low levels of uses of unclean biomass fuel in the earlier rounds of NFHS but indicated decreasing trend in the recent survey. The high reporting of unclean biomass fuel could be attributed to factors like literacy, freedom, media exposure, wealth class (MPCE), and to some extent social caste or custom (Subramanian et al., 2009).

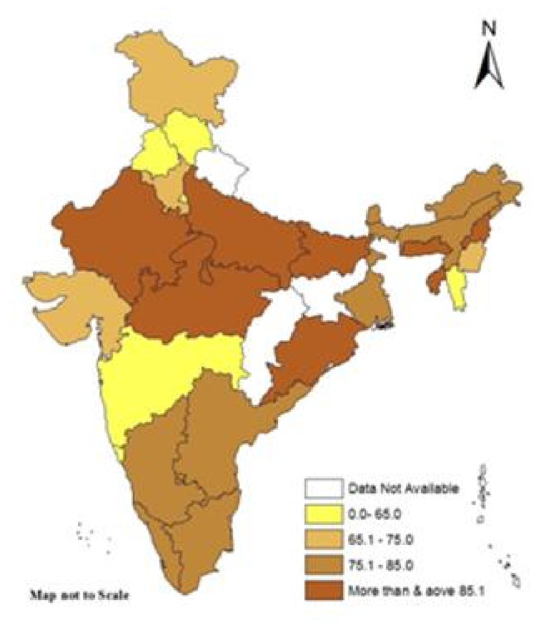
Recently published Indian Census (2011) do not reflect major improvement; around 67.5 per cent of all households in India and 90 per cent of households in the country's poorer, rural areas used traditional solid fuels, such as crop residue, cow-dung, firewood, coal and other unclean fuels to meet their cooking energy needs (RGI, 2011). The report of the committee on slum statistics, headed by Pranob Sen, projected India's slum population to rise up to 93.06 million by 2011, and about 90 per cent of India's slum population depends upon unclean fuels to achieve their basic needs. Lack of improved biomass cook stoves (ICs) with chimneys, separate kitchen, and lack of ventilation exposed millions of Indian life at risk of Indoor air pollution and their harmful health hazards.

Figure 2: State wise distribution of biomass (unclean) fuel for cooking in Indian Households, 1992-93



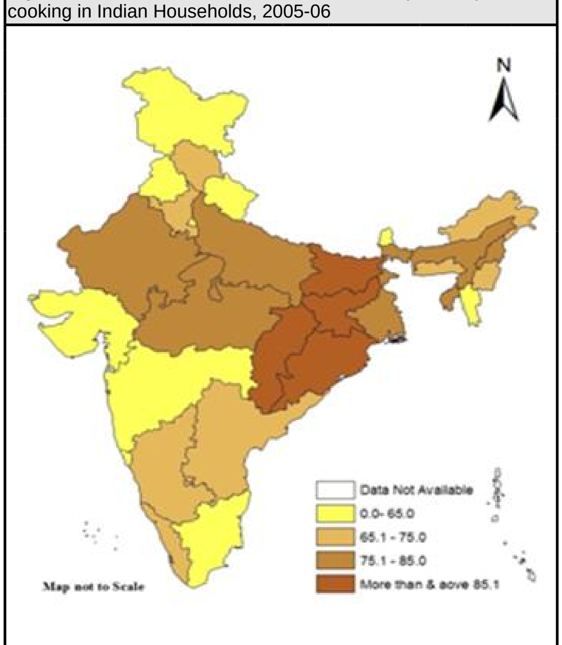
Source: National Family Health Survey-I (1992-93)

Figure 3: State wise distribution of biomass (unclean) fuel for cooking in Indian Households, 1997-98



Source: National Family Health Survey-II (1997-98)

Figure 4: State wise distribution of biomass (unclean) fuel for cooking in Indian Households, 2005-06



Source: National Family Health Survey-III (2005-06)

Profile of the Children under age five:

According to the NFHS-3, about 12% of India's population is <5 years old (IIPS and ORC Macro 2007). Table 1 shows the distribution of children under age five by selected background characteristics. Around 80 per cent of the children (both male and female) live in households using unclean fuels (wood, dung cakes, coal or crop residues) and remaining 20% live in households using cleaner fuels (liquid petroleum gas, kerosene, biogas, or electricity). Eighty one per cent of infants and 79% of children aged 1-4 years were exposed to unclean fuel. Around eighty per cent of Hindu and 81.5% of Muslim children live in households using unclean fuels. About eighty three per cent children of illiterate/primary/secondary completed mothers and 19% children of higher (10th +) educated mothers live in households using unclean fuels. Ninety nine per cent children belong to low standard and kachha houses and about 50% children of high standard of living and pucca houses were exposed to harmful effect of unclean fuels.

Table 1: Variable definitions and distribution of children less than 5 years of age exposed to Unclean Biomass Fuel by selected characteristics, India, 2005-2006

Background characteristics	**Count**	**Distribution (%)**
Sex of child		
Male	19912	78.9
Female	18495	80.2
Children u-5		
Infants	7216	81
1 - 4yr	31190	79.2
Religion		
Hindu	29997	79.8
Muslim	6813	81.5
Others#	1596	68.2
Education level		
Illiterate/primary/secondary	37937	82.7
High school+	468	19.2
Standard of living##		
Low	15457	99.1
Medium	14801	89.3
High	7469	48.9
House type*		
Kachha	7676	99.2
Semi pucca	21295	95.7
Pucca	9219	51
Caste/category		
ST/SC/OBC**	28943	84.7
Others	8149	64.8
Type of place of residence		
Urban	4939	39.2
Rural	33467	93.8
Birth order		
Jan-16	26078	74.6
4 or higher	12329	92.5
House has any window		
No	17701	95.1
Yes	20690	69.7
Major states		
EAG states@ & Assam	24098	89
Other states@@	14309	67.4
Total	38407	79.5

Sikh, Buddhist, Christian, Jain, Jewish, Zorastrian; ## Standard of living index is calculated by adding the scores assigned to the durable goods in the household as following: 4 for a car or tractor; 3 each for a moped/scooter /motorcycle, telephone, refrigerator, or color television; 2 each for a bicycle, electric fan, radio/transistor; and 1 each for a mattress, pressure cooker, chair, cot/bed, table, or clock/watch. Index scores range from 0–5 for low SLI, 6–15 for medium SLI, to 16–42 for high SLI.; * Pucca houses are made from high-quality materials (bricks, tiles, cement, and concrete) throughout, including roof, walls, and floor; kachha houses are made from mud, thatch, or other low-quality materials. Semi-pucca houses are made from a combination.; ** ST-Schedule Tribe, SC-Schedule Caste, OBC-Other Backward Caste; @ Rajasthan, Madhya Pradesh, Uttar Pradesh, Bihar, Orrisa, Uttaranchal, Jharkhand and Chhattisgarh.; @@ Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, West Bengal, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Kerala, Tamil Nadu and Goa.

Source: Figures have calculated for NFHS 3rd (2005-06) round only

About 82% - 88% children of ST/SC/OBC category and 68% children of others category live in households using unclean use. Ninety four of all children living in rural settings and only 39% children of urban households were exposed to unclean fuels. Ninety five children were living in houses having not a single window for ventilation. Eighty-nine per cent children of EAG states 1 and 67% children of other states live in households using unclean.

Prevalence of ARI among children under age five in India:

ARI is the second leading cause of death among children under age five worldwide, after diarrhoeal diseases. According to NFHS-3, overall 6% children under five years of age suffer from ARI. Table 2 shows that the prevalence of ARI is much higher among children living in households using unclean fuels (6.2%) than are those living in households using cleaner fuels (4.1%). Children living with women who smoke (7.3%) (cigarettes/bidis, pipe/cigar, paan masala, ghutka, chewing tobacco, uses snuff, smoke other) are also much more likely to suffer from ARI than those who have never smoked (5.6%).

Male children are more likely to suffer from ARI than female children. The prevalence of ARI among Infants (7.2%) is much higher than the children aged 1-4 years (5.4%). Children belong to Muslim community (8.6%) have also a very high chance to suffer from ARI than those who belong to Hindu (5.2%) and other communities (4.4%). Children living with higher educated women (3.4%) are very less likely to suffer from ARI than are those with less or no education (6%).

The prevalence of ARI is considerably lower among the children living in Pucca houses and among children living in households with a high standard of living. The prevalence is also somewhat lower among children belong to ST/SC/OBC than those with other caste. The prevalence of ARI is higher among children living in rural areas (6%) than those living in urban areas (5.1%). Children of EAG states and Assam (6.1%) are also more likely to suffer from ARI compare to those of other states (5.4%) of India.

Effects of cooking smoke on ARI: Table 3 shows the estimated effects of type of cooking smoke, women's smoke, and selected demographic and socioeconomic variables on the prevalence of ARI among the children (< 5 years old) in alternative models. Model 1 in Table 3 shows that unadjusted odds of suffering from ARI are much higher among the children living in households using unclean fuels for cooking than among those living in households using cleaner fuels for cooking (OR = 1.54; 95% CI, 1.38–1.72).

Controlling for exposure to women's smoking (in Model 3) reduces the effect of biomass fuel use on ARI prevalence marginally (OR = 1.51; 95% CI, 1.35–1.68). The effect of unclean fuel use remains virtually unchanged when the two demographic variables—age and sex—are additionally controlled in Model 4. Even when the 11 socioeconomic and demographic control variables are included in Model 5, the children living in households cooking with unclean fuels still has a statistically significant effect (OR = 1.30; 95% CI, 1.05–1.40) on the prevalence of ARI compared with those living in households that use cleaner fuels.

Effects of women smoking on ARI: The unadjusted odds of suffering from ARI are considerably higher among the children living or exposed to those women who indulge in smoking of any type (OR = 1.31; 95% CI, 1.18–1.47) than do those who have never smoked. (Model 2, Table 3). This effect is reduced somewhat when the effect of cooking smoke is controlled (OR = 1.26; 95% CI, 1.12–1.41) and marginally changed when children's age and sex are

Table 2: Reported prevalence of Acute Respiratory Infection (ARI) among the children less than 5 years of age by selected characteristics, India, 2005-2006

Background characteristics	**Count**	**Distribution (%)**
Type of fules		
Clean fules	406	4.1
Unclean fuels	2377	6.2
Women smoking^		
Yes	386	7.3
Nothing	2671	5.6
Sex of child		
Male	1647	6
Female	1411	5.6
Children u-5		
Infants	746	7.2
1 - 4yr	2312	5.4
Religion		
Hindu	2164	5.2
Mushlim	783	8.6
Others	111	4.4
Education level		
Illiterate\primary\secondary	2963	5.9
High school+	95	3.4
Standard of living		
Low	993	6.4
Medium	1023	6.2
High	732	4.8
House type		
Kachha	471	6.1
Semi pucca	1467	6.6
Pucca	830	4.6
Caste/category		
ST/SC/OBC	1969	5.3
Others	918	6.7
Type of place of residence		
Urban	691	5.1
Rural	2367	6
Birth order		
Jan-16	2248	5.7
4 or higher	810	5.9
House has any window		
No	1071	5.8
Yes	1711	5.8
Major states		
EAG states & Assam	1820	6.1
Other states	1237	5.4
Total	3058	5.8

^ smoking at least one: cigarettes/bidis, pipe/cigar, paan masala, ghutka, chewing tobacco, uses snuff, smoke other

Source: Figures have calculated for NFHS 3rd (2005-06) round only

additionally controlled in Model 4. In the full model (Model 5), when the effects of cooking fuel type and the 11 other variables are controlled, the odds of suffering from ARI are remain 1.25 (95% CI, 1.11–1.42) times higher among the children who are exposed to mother's smoking.

Effects of the control variables on ARI: The discussion of the adjusted effects of the control variables focuses on the full model (Model 5) in Table 3. With other variables controlled, age has a positive effect on the prevalence of ARI and male child have a higher prevalence of ARI than do girl child. Effects of both age and sex are statistically significant. Infants have a considerably higher risk of having ARI than do children aged 1-4 years. (Model. 4 & Model 5,

Table 3.) Children under age five living with middle/primary and illiterate mothers have significantly higher prevalence of ARI (OR = 1.39; 95% CI, 1.09-1.78) than do those with higher educated. Children of Muslim community also have a significantly very higher prevalence of ARI (OR = 1.47; 95% CI, 1.32-1.63) than do those with Hindu community. As expected, children living in Kachha houses have a significantly higher prevalence of ARI (OR = 1.34; 95% CI, 1.19-1.50) than do those living in Pucca houses. Kachha houses in India is characterized with very poor ventilation and higher use of solid unclean fuels indoor cause very high chance of exposure to smoke that result into higher risk to prevalence of ARI among children as well as other household members.

However, contrary to the expectation, children belong to ST/SC/OBC and living in houses having no window have a significantly lower risk of ARI than do those belong to other or general category and living in houses having windows. Standard of living has a negative effect on prevalence of ARI among children and children of low standard houses have significantly higher prevalence of ARI than do those of high standard houses. Place of residence also has a negative effect on the prevalence of ARI among children, but the effect is not significant statistically. With other variables controlled, the prevalence of ARI among the children does not vary significantly by birth order and houses with window. By socioeconomic and demographic region, children in the EAG states and Assam have significantly higher prevalence of ARI than do those in other states/UTs.

CONCLUSION

Taking into account the models that have been applied for estimation, findings would suggest that indoor air pollution from unclean fuel combustion is a public health problem in major parts of India. Results from this study suggest that exposure to unclean cooking smoke is strongly associated with the prevalence of ARI among children under age five, independent of exposure to mother's smoking, sex, age, education, living standard, and other factors. Mother's smoking also has substantial effects on prevalence of ARI among children. The result also reflects that switch to cleaner fuels for cooking in India can reduce the prevalence of ARI among children under age five by 42% (range between 30% - 54%). A larger effect of mother's smoking reflects the greater vulnerability of children because of their compromised respiratory system from mother's smoke.

The finding that the effect of cooking smoke is greater for infants than children aged 1-4 years consistent with expectation; because infants are more exposed to cooking smoke as spend more time with mother for breastfeeding and care and cooking is considered to be primary duty of women in India. The finding that male children are more vulnerable at the risk of ARI than their counterparts; may be due to the fact that male child is biologically inferior to the female child. Very high prevalence of ARI among Muslim children may be due to their higher proportion live in urban slum characterised by poor and faulty arrangement of housing, crowd situation, lack of ventilation, safe water and other basic amenities. As expected, children living in the socioeconomic and demographically poor region e.g. in EAG states and Assam are at substantially higher risk of ARI than other states of India.

This indicator should be interpreted with caution, owing to the inherent problems associated with the methodology and data used. The indicator does not take into account factors such as stove type, breastfeeding practices, hand-washing and behaviour, which are likely to affect exposures and

Table 3: Unadjusted and adjusted effects (OR, 95% CI) of type of cooking fuels, women's smoking, and other factors on ARI among the children (< 5 years old), India 2005-06

Background characteristics	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Type of fuels					
Unclean fuels	1.54***(1.38-1.72)		1.51***(1.35-1.68)	1.50***(1.35-1.67)	1.30***(1.05-1.40)
Clean fuels@					
Women smoking					
Yes		1.31***(1.18-1.47)	1.26***(1.12-1.41)	1.27***(1.13-1.42)	1.25***(1.11-1.42)
Nothing@					
Sex of child					
Male				1.08**(1.00-1.16)	1.10**(1.02-1.19)
Female@					
Children u-5					
Infants				1.36***(1.24-1.48)	1.37***(1.25-1.51)
1 - 4yr@					
Religion					
Hindu@					
Muslim					1.47***(1.32-1.63)
Others					0.94(0.81-1.09)
Education level					
Illiterate/ Primary/ Secondary					1.39***(1.09-1.78)
High school+@					
Standard of living					
Low					1.12*(0.99-1.26)
Medium					1.10(0.94-1.28)
High@					
House type					
Kachha					1.34***(1.19-1.50)
Semi pucca					1.26***(1.07-1.48)
Pucca@					
Caste/category					
ST/SC/OBC					0.74***(0.67-0.81)
Others@					
Place of residence					
Urban					1.05(0.93-1.18)
Rural@					
Birth order					
1 – 3rd					1.15***(1.05-1.27)
4th or higher@					
House has any window					
No					0.82***(0.74-0.90)
Yes@					
Major states					
EAG states					1.15***(1.05-1.26)
Other states@					

*= P< 0.1, **= P<0.05, ***= P<0.01
@Reference category

Source: Figures have calculated for NFHS 3rd (2005-06) round only health outcomes. Our estimated effect is also downwardly biased to the extent that ARI is more likely to be underreported for children from households that use unclean fuels. On the other hand, our estimated effect may be upwardly biased to the extent households that use unclean fuels are more likely to report some other disease condition with similar symptoms as ARI.

The findings from this study have important policy and program implications, including the need for public information campaigns designed to inform people about the risks of exposure to cooking smoke and, where shifts to cleaner fuels are not feasible, programs to promote improved cook stoves designed to reduce exposure to smoke by means of improved combustion and improved venting. For such programs to be effective, local needs and community participation should be given high priority. There is, however, no magic solution for reducing unclean fuel smoke exposures. Efforts to reduce indoor air pollution from Solid Fuel Use centre on the four general categories of interventions listed below (Smith, 1987; Smith, 1989; Barnes et al., 1993; Ezzati & Kammen, 2001; WHO, 2002).

- Behavioural modifications to reduce exposure (e.g. encouraging mothers to keep their young babies away from the fire);
- Household changes to improve ventilation (e.g. increasing the number of window openings in the kitchen, providing gaps between the roof and walls, or moving the stove out of the living area);
- Improvements to cooking stoves (e.g. ventilation by flues, hoods or chimneys, or increases in combustion efficiency - nearly all pollutants damaging to health are products of incomplete combustion);
- Interventions to enable people to use higher-quality, lower-emission liquid or gaseous fuels (e.g. petroleum-based kerosene and liquid petroleum gas, or biomass-based alcohol and biogas).

Programmes and policies can be designed to encourage urban slum and peri-urban households that use unclean fuels to move up the “energy ladder” to cleaner fuels (such as biogas or liquid petroleum gas), and do so at lower income levels. This approach requires that the availability and affordability of cleaner fuels be enhanced. On the other hand, the poorest rural populations with nearly no cash income, but access to wood and/or agricultural wastes, are unlikely to acquire improved cooking stoves–without large subsidies, which are often unsustainable in the long term. It seems to be large populations between these extremes, however, that can be effectively targeted by efforts to disseminate improved stoves.

In particular, education through various types of media and communication network can play an important role by conveying the value of cleaner kitchens and air to households. In this, hygiene education may be as important in reducing the impact of dirty combustion and lack of ventilation as it is in reducing the impact of dirty water and lack of sanitation.

REFERENCES

Acharya, D., Prasanna, K. S., Nair, S., & Rao, R. S. (2003). Acute respiratory infections in children: A community based longitudinal study in south India. Indian J Public Health, 47:7–13. [PubMed].

Barnes, D. F., Openshaw, K., Smith, K. R., & Van der Plas, R. (1993). The design and diffusion of improved cookstoves. World Bank Research Observer, 8(2):119–141.

Broor, S., Pandey, R. M., Ghosh, M., Maitreyi, R. S., Lodha, R., & Singhal, T. (2001). Risk factors for severe acute lower respiratory tract infection under-five children. Indian Pediatr, 38:1361–9. [PubMed].

Bruce, N., Perez-Padilla, R., & Albalak, R. (2000). Indoor air pollution in developing countries: a major environmental and public health challenge for the new millennium.ʃ Bulletin of the World Health Organization 78 (9): 1078 ± 1092.

Desai, M. A., Mehta, S., & Smith, K. (2004). Indoor smoke from solid fuels Assessing the environmental burden of disease at national and local levels. Environmental Burden of Disease Series, (4), 675-740.

ENHIS (2009). Proportion of children living homes using solid fuels. European Environmental and Health Information System. Fact sheet 3.6, December 2009, Code: rpg3_hous_ex3 Available from: http://www.euro.who.int/__data/assets/pdf_file/0006/97008/3.6.-Homes-with-solid-fuels-EDITED_layouted_V3.pdf?ua=1 accessed on 16 July 2014.

Ezzati, M., & Kammen, D. M. (2001). Quantifying the effects of exposure to indoor air pollution from biomass combustion on acute respiratory infections in developing countries. Environmental Health Perspectives, 109(5):481–488.

Global health risks (2009). Mortality and burden of disease attributable to selected major risks. World Health Organization, Geneva. http://unstats.un.org/unsd/mi/pdf/mdg%20book.pdf

IIPS and ORC Macro (2007). National Family Health Survey (NFHS-3), 2005-06: India. Mumbai: International Institute for Population Sciences.

Jain, N., Lodha, R., & Kabra, S. K. (2001). Upper respiratory tract infections. Indian J Pediatr, 68:1135–8. [PubMed].

Ladomenou, F., Moschandreas, J., Kafatos, A., Tselentis, Y., & Galanakis, E. (2010). Protective effect of exclusive breastfeeding against infections during infancy: A prospective study. Arch Dis Child, 95:1004–8. [PubMed].

Lim, S. S., Vos, T., Flaxman, A. D., Danaei, G., Shibuya, K., Adair-Rohani, H., & Aryee, M. (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The lancet, 380(9859), 2224-2260.

Mehta, S. (2006). Modelling household solid fuel use towards reporting of the Millennium Development Goal indicator. Energy for Sustainable Development, 10(3): 36–45 Available from: http://www.who.int/indoorair/mdg/esdmodellingsolidfueluse.pdf, accessed 17 July 2014.

Million Death Study Collaborators (2010). Causes of neonatal and child mortality in India: a nationally representative mortality survey. The Lancet, 376 (9755), 1853-1860. Available from: (http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(10)61461-4/abstract) accessed 18 July 2014.

Mishra, V. (2003) Effect of Indoor air pollution from Biomass Combution on prevalence of Asthma in the Elderly, Environ Health perspective, 111: 71-77.

RGI (2003). Report on Cause of Death in India 2001-03, Census Commissioner of India, Ministry of Home Affairs (MoHA), Government of India. Available from: http://www.cghr.org/wordpress/wp-content/uploads/Causes_of_death_2001-03.pdf accessed 20 July 2014.

RGI (2011). Provisional Population Total. Census Commissioner of India, Ministry of Home Affairs (MoHA), Government of India.

Savitha, M. R., Nandeeshwara, S. B., Kumar, M. J., Ul-Haque, F., & Raju, C. K. (2007). Modifiable risk factors for acute lower respiratory tract infections. Indian J Pediatr, 74:477–82. [PubMed].

Smith, K. R. (1987). Biofuels, air pollution, and health: a global review. New York, Plenum.

Smith, K. R. (1989). The dialectics of improved stoves. Economic and Political Weekly, 24(10):517–522.

Smith, K. R., Mehta, S., Feuz, M. (2004). Indoor air pollution from household use of solid fuels. In: Ezzati M et al., eds. Comparative

Smith, K. R., & Mehta, S. (2003). The burden of disease from indoor air pollution in Developing countries: comparison of estimates, Int. J. Hyg. Environ. Health, 206: 279-289.

Smith, K. R. (2000). National burden of Disease in India from Indoor air pollution, Proceedings of the National Academy of Sciences of the United States of America, 97:13286-13293.

Subramanian, S. V., Subramanyam, M. A., Selvaraj, S., & Kawachi, I. (2009). Are self-reports of health and morbidities in developing countries misleading? Evidence from India. Social science & medicine, 68(2), 260-265.

UNDP (2005). The Millennium Development Goals Report 2005. United Nations.

Vashishtha, V. M. (2010). Current status of tuberculosis and acute respiratory infections in India: Much more needs to be done! Indian Pediatr, 47:88–9. [PubMed].

Wiley Online Library (2013). Handwashing and risk of respiratory infections: A quantitative systematic review-Rabie-2006-Tropical Medicine and International Health. Available from: http://online library.wiley.com/doi/10.1111/j.1365-3156.2006.01568.x/pdf, accessed 11March 2014.

World Health Organization (2006). Fuel for life: household energy and health, WHO, Geneva. Available from http://www.who.int/indoorair/publications/fuelforlife.pdf.html

World Health Organization (2002). World Health Report: Reducing Risks, Promoting Healthy Life. Geneva, WHO.

World Health Organization (2005). Indoor air pollution and health. WHO, Geneva, (Fact Sheet No 292) Available from: http://www.who.int/mediacentre/factsheets/fs292/en/index.html, accessed 17 July 2014).

World Health Organization (2007). Indoor air pollution: national burden of disease estimates. WHO, Geneva. Available from http://www.who.int/indoorair/publications/indoor_air_national_burden_estimate_revised.pdf, accessed 17 July 2014).