Available online at www.sciencedirect.com

Public Health

journal homepage: www.elsevier.com/puhe

Original Research

Effects of cooking fuel sources on the respiratory health of children: evidence from the Annual Health Survey, Uttar Pradesh, India

Surendra Kumar Patel [a,*], *S. Patel* [a], *A. Kumar* [b]

[a] *International Institute for Population Sciences (IIPS), Mumbai, Maharashtra, India*
[b] *Jawaharlal Nehru University, New Delhi, India*

ARTICLE INFO

Article history:
Received 29 August 2018
Received in revised form
5 December 2018
Accepted 7 January 2019
Available online 26 February 2019

Keywords:
Cooking fuels
Dung cake
Lighting sources
Acute respiratory infections

ABSTRACT

Objectives: India is predominantly a rural country, where more than two-thirds of the population live in rural areas. The majority of the rural population use crop residue, firewood, and dung cake as cooking fuel sources. Combustion of these fuels emits life-threatening pollutants that contaminate the household environment, which can have serious health consequences, especially for young children. This study examines the use of cooking fuel sources and their association with acute respiratory infections (ARIs) in children aged 0–59 months.

Study design: This study used data from the second update of the Annual Health Survey (2012–13). The prevalence rate was measured in terms of the number of children per 1000 children suffering from ARIs. Bivariate analysis was used to analyze the use of different cooking fuels (in percentage) and the prevalence of ARIs in Uttar Pradesh.

Methods: District-level variations in the cooking fuels used were assessed by simple bivariate analysis for all districts of Uttar Pradesh. A logistic regression was used to examine the association of household environment and pollutants with ARIs.

Results: In total, 89 per 1000 children suffered from ARIs in Uttar Pradesh. Infants (0–11 months) were significantly more likely to suffer from ARIs than older children (12–59 months). Households using dung cake for cooking and kerosene and other oils for lighting were found to have significantly higher odds for ARIs (odds ratio [OR]: 1.21; 95% confidence interval [CI]: 1.17–1.25 and OR: 1.07; 95% CI: 1.05–1.10, respectively). A considerable interdistrict difference was observed in the cooking fuel used and the prevalence of ARIs among children aged 0–59 months.

Conclusions: The type of cooking fuel and lighting source used were found to be significant predictors of ARIs among children aged 0–59 months. These results highlight the need for targeted efforts for the provision of clean cooking fuels (liquid petroleum gas/biogas/electricity) and for the improvement in knowledge and awareness of ARIs and exposure to cooking and lighting pollution.

* *Corresponding author.*
E-mail addresses: surendrabhu20@gmail.com (S.K. Patel), sunitapatel56@gmail.com, sunitapatel56@iips.net (S. Patel), ajitcpsjnu@gmail.com (A. Kumar).

https://doi.org/10.1016/j.puhe.2019.01.003

Introduction

Access to energy is essential to meet the basic needs of cooking and lighting. Around 2.8 billion people (38% of the global population and almost 50% of the total population in developing countries) lack access to clean cooking fuels; thus, they rely on the use of solid biomass fuels, such as firewood, crop residue, and dung cake.[1] In India, the National Institution for Transforming India (NITI) Aayog estimates that around two-thirds of households use solid cooking fuels (e.g. firewood, crop residue, cow dung cake, and coal/lignite/charcoal). In Uttar Pradesh, an estimated 80% of households use solid cooking fuels.[2]

Children are the most vulnerable group within the household when it comes to respiratory illnesses arising from proximity to pollution from domestic cooking fuels.[3,4] Out of the total deaths in India, 85–88% are contributed to by acute respiratory infection (ARI) episodes categorized as acute upper respiratory infections and acute lower respiratory infections (ALRIs).[5,6] India's under five mortality rates declined from 125 to 49 per 1000 live births from 1990 to 2013, and the Millennium Development Goals report suggests that India is roughly on track because of a sharp decline in child mortality.[7]

The most significant health impact of indoor pollution is observed among the poorest and the most vulnerable sections of society.[8] Household pollution from unprocessed fuel causes respiratory problems, which is a major concern of public health in India.[8] Globally, around 4.3 million deaths per year are attributed to household air pollution. Indoor air pollution emitted from burning biomass fuels in homes with inadequate ventilation has deleterious effects on health.[9] A recent study conducted in Bangladesh demonstrates the increased risk for ALRIs as a result of exposure to indoor particulate matters ($PM_{2.5}$).[10,11] The conventional sources of indoor PM include combustion of biofuels (e.g. crop residue, firewood, and dung cake) used for cooking purposes.[12]

Several studies show that biomass fuels cause high pollution.[3,11] Exposure to indoor air pollution, especially PM from the combustion of biofuels has been found to be associated with respiratory illnesses.[13,14] Smoke/fume emitted by biomass fuels contains hundreds of chemical compounds, such as PMs, carbon monoxide, nitrogen dioxide, sulfur dioxide, polycyclic aromatic hydrocarbons, and other volatile organic compounds, that have a significant impact on health. These pollutants increase the respiratory problems in the form of a persistent cough among adults and ALRIs among children aged below 5 years as well as older children.[14,15] Several studies show that household environment is a significant predictor of ARI prevalence among children.[8,12,16,17]

In the present study, we tried to examine the association of cooking fuels and household environment with ARIs among children aged 0–59 months in Uttar Pradesh, India. A few studies have investigated the prevalence of ARIs among children.[18–20] However, very little has been explored with respect to the association between household environment and ARIs among children at the national level.[21] This study focused on Uttar Pradesh, where most of the population resides in rural areas and only a small population has access to liquid petroleum gas/piped natural gas (LPG/PNG) and biogas, indicating a need for studying the causes of ARIs. Children are at high risk from pollution in the household environment.[17] Therefore, we tried to examine the association between household pollution and ARIs in children aged 0–59 months in Uttar Pradesh, India.

Methods

For the present research article, data from the second update of the Annual Health Survey (AHS, 2012–13) have been used. The objective of the AHS is to monitor the performance and outcome of government interventions in the health sectors, including those under the National Rural Health Mission. In addition, the AHS also aims to tailor interventions through benchmarking and preparing a comprehensive district health profile on core vital and health parameters. The second update of AHS collected information from nine Empowered Action Group states, namely Bihar, Jharkhand, Uttar Pradesh, Uttarakhand, Madhya Pradesh, Chhattisgarh, Odisha, Rajasthan, and Assam. In Uttar Pradesh, the total surveyed population was 20.9 million, comprising 4.3 million households. Uttar Pradesh accounts for about 19% of India's total population. The AHS provides information on different socio-economic and demographic characteristics, such as marriage, disability and injuries, acute illness, chronic illness, fertility, abortion, birth intervals, antenatal care, and childhood diseases. The present study focused on information about ARIs in children aged below 5 years in Uttar Pradesh, India.

Variables used in the analysis

Outcome variable

The outcome variable used in the analysis was ARIs. The survey asked participants to select the 'types of illness reported during the last 15 days?' The responses were diarrhea, dysentery, acute respiratory illness, jaundice with fever, fever with chills/rigors (malaria), fever for short duration with rashes, other types of fever, reproductive tract infection, others, and no illness. The responses were coded in a binary form, with '0' representing 'No' (i.e. no ARI reported) and '1' standing for 'Yes' (i.e. ARI reported).

Predictor variables

The household environment and pollutant variables included the type of cooking fuels and lighting sources used in the house. Cooking fuels had five categories: LPG/PNG/electricity/biogas, firewood, crop residue, dung cake, and other sources (e.g. coal/lignite/charcoal, kerosene, and any other). Lighting sources had three categories: electricity/solar, kerosene/other oils, and any other. The place of cooking had four categories: in-house-kitchen, in-house-no-kitchen, out-house-kitchen, and out-house-no-kitchen. These predictors (cooking fuels, lighting sources, and place of cooking) were considered the primary predictors of ARI among children aged 0–59 months.

Socio-economic and demographic characteristics

Characteristics included were sex (male and female), place of residence (rural and urban), religion (Hindu, Muslim, and other), and age of child (<12 months, 12–23 months, 24–35

months, 36–47 months, and 48–59 months). Castes were categorized into two groups: scheduled castes/scheduled tribes (SC/ST) and other than scheduled castes/scheduled tribes (other than ST/SC). The wealth quintile was categorized into five groups: poorest, poor, middle, rich, and richest. Finally, region was classified as follows: eastern region, southern upper Ganga plain, northern upper Ganga plain, southern region, and central region.

Statistical analysis

The prevalence rate was estimated as number of children per 1000 children suffering from ARIs. Bivariate analysis was used to analyze the use of different cooking fuels (in percentage) and the prevalence of ARI in Uttar Pradesh. District-level variations in the cooking fuels used were assessed by simple bivariate analysis for all the districts of Uttar Pradesh. A logistic regression was fitted to examine the association of household environment and pollutant with ARI.

Using logistic regression analysis, the following three models were identified:

Model 1: including only cooking fuels;
Model 2: including household environment, pollutant (cooking fuel and lighting sources), and place of cooking; and
Model 3: adjusted for household environment, pollutant, and place of cooking and socio-economic and demographic characteristics.

The odds ratio (OR) was estimated at 95% confidence intervals (CIs). All the data were analyzed using STATA (StataCorp LLC, USA) (version 13), and Arc-GIS (ESRI, USA) has been used to show district-level variations in the use of dung cake and prevalence of ARI.

Results

AHS data indicate that around 18.8% of children were <12 months old, and 84.5% of children were from the rural areas. In total, 73.6% of children belonged to 'other than SC/ST' communities and 79.7% belonged to the Hindu religion. Household environment, pollutant (cooking fuels and lighting sources), and place of cooking in the household were taken into consideration. Data showed that 40.5% of households were using firewood, and 37.6% of households were using dung cake as cooking fuels. Also, 56.9% of households cooked food inside the house without a kitchen, whereas only 29.2% had a kitchen inside the house. Results indicate that 66.1% of households used kerosene and other oils as lighting sources in the house, whereas only 32.8% used electricity/solar energy as lighting sources (Table 1).

Fig. 1 shows the pattern of cooking fuels used in rural Uttar Pradesh. It was found that 44% of households were using firewood, 43% dung cake, and only 5% were using LPG/PNG/electricity/biogas as cooking fuels. In contrast, in the urban areas, 57% of the households were using LPG/PNG/electricity/biogas, whereas 22% and 16% were using firewood and dung cake, respectively, for cooking purposes (Fig. 2).

Table 1 – Profile characteristics of respondents.

Characteristics	Sample distribution[a]	
	%	n
Total	100	932,341
Sex of child		
Male	52.4	488,152
Female	47.6	444,189
Age group (in months)		
<12	18.8	175, 539
12–23	19.6	182,532
24–35	22.5	209,714
36–47	20.2	187,997
48–59	18.9	176,559
Caste categories		
Other than SC/ST	73.6	686,249
SC/ST	26.4	246,092
Religion		
Hindu	79.7	743,117
Muslim	19.9	185,510
Others[b]	0.4	3714
Wealth index		
Poorest	21.3	198,720
Poor	20.0	186,220
Middle	24.0	223,267
Rich	22.1	206,193
Richest	12.1	117,941
Cooking fuel sources		
LPG/PNG/electricity/biogas	13.4	125,231
Firewood	40.5	377,629
Crop residue	7.7	71,979
Dung cake	37.6	350,338
Others[c]	0.8	7164
Cooking place		
In house: kitchen	29.2	272,380
In house: No kitchen	56.9	530,628
Out house: kitchen	4.4	41,390
Out house: no kitchen	9.4	87,943
Lighting source		
Electricity and solar	32.8	305,881
Kerosene and other oils	66.1	616,147
Other sources[d]	1.1	10,313
Place of residence		
Rural	84.5	787,746
Urban	15.5	144,595
Regional categories		
Eastern region	37.2	346,763
Southern Upper Ganga plane	33.2	309,868
Northern Upper Ganga plane	16.1	150,111
Southern region	8.4	77,948
Central region	5.1	47,651

LPG, liquid petroleum gas; PNG, piped natural gas; SC/ST, scheduled castes/scheduled tribes.
[a] Percentage of sample based on weighted analysis and sample size (n) are un-weighted.
[b] Includes Christian, Sikh, Buddhist, Jain, and other religion group.
[c] Includes coal, lignite, charcoal, kerosene, and any other source.
[d] Includes other oils and any other sources for lighting sources.

The distribution of the source of cooking fuels used with the type of kitchen has been presented for rural areas in Fig. 3 and for urban areas in Fig. 4. In rural areas, those having an in-house kitchen mostly used firewood (41.3%) and dung cake (37.8%); only 15.0% of households used LPG/PNG/electricity/

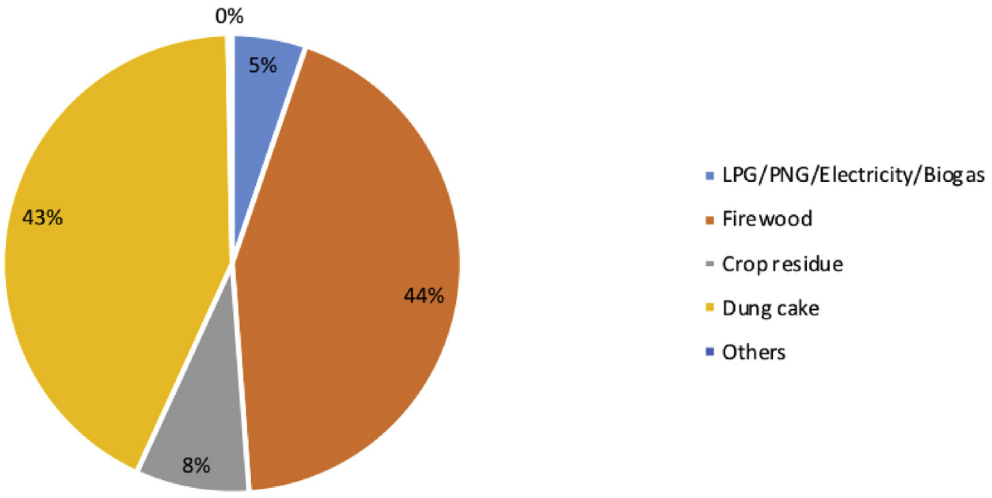

Fig. 1 – Cooking fuel sources used in rural areas in Uttar Pradesh, 2013. LPG, liquid petroleum gas; PNG, piped natural gas.

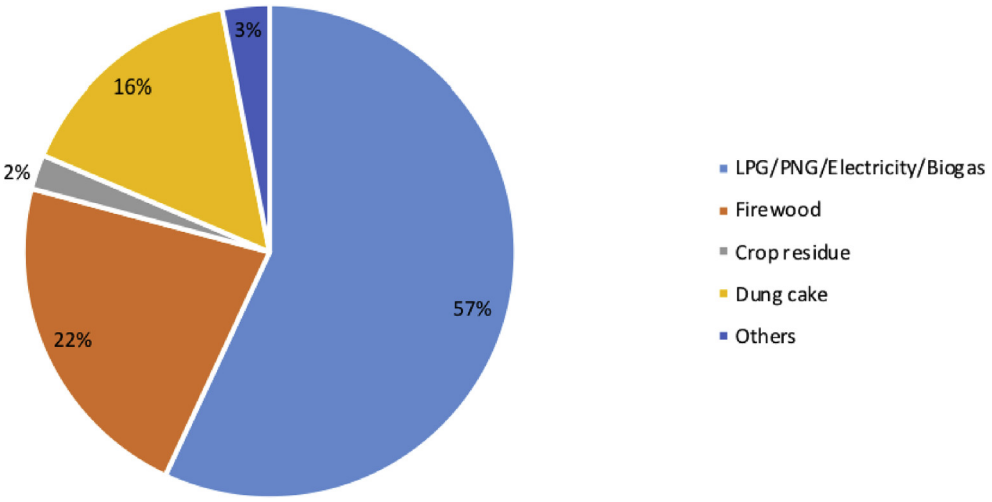

Fig. 2 – Cooking fuel sources used in urban areas in Uttar Pradesh, 2013. LPG, liquid petroleum gas; PNG, piped natural gas.

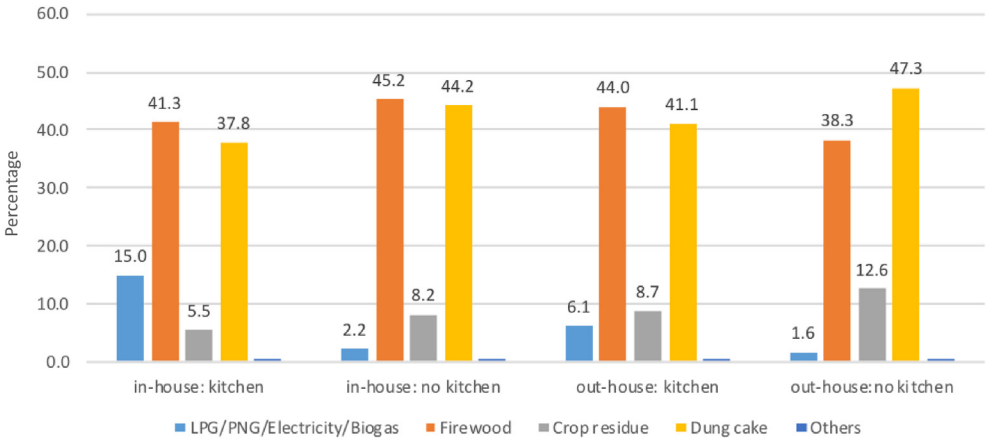

Fig. 3 – Cooking fuel sources used in kitchen in rural areas in Uttar Pradesh, 2013. LPG, liquid petroleum gas; PNG, piped natural gas.

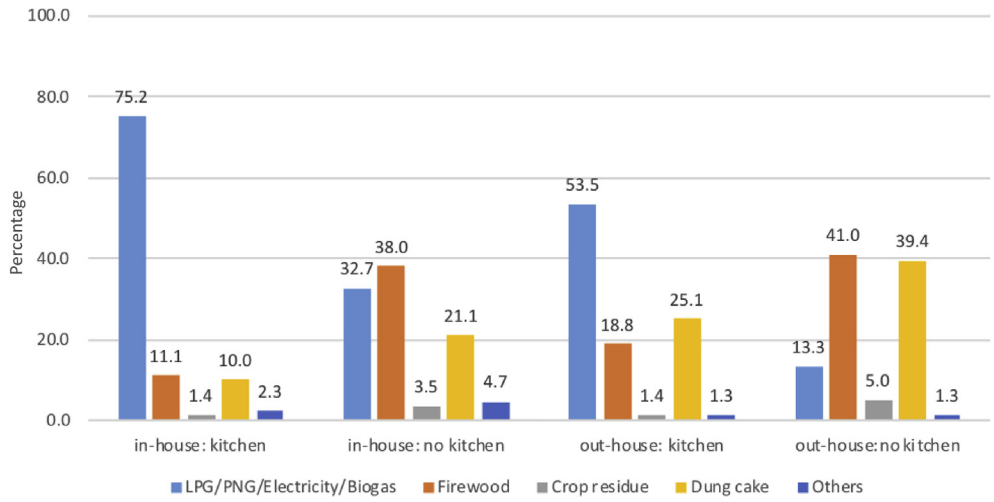

Fig. 4 – Cooking fuel sources used in kitchen in urban areas in Uttar Pradesh, 2013. LPG, liquid petroleum gas; PNG, piped natural gas.

biogas. A similar scenario was observed in the case of the in-house–no-kitchen, out-house-kitchen, and out-house-no-kitchen. In the urban areas, 75.2% of households having an in-house-kitchen were using LPG/PNG/electricity/biogas, and 11.1% and 10.0% were using firewood and dung cake, respectively. However, households having no kitchen inside the house were using firewood (38.0%) more than any other cooking fuel. Households having an out-house kitchen facility were also using firewood (41.0%) as well as dung cake (39.4%) for cooking (Fig. 4).

Fig. 5 shows the distribution of the use of dung cake as a cooking fuel in Uttar Pradesh. More than 45% of households in the southern and northern upper Ganga plain regions were using dung cake as the dominant cooking fuel (except Baghpat [5%] and Saharanpur [24%]). In the districts of the central region, dung cake was used as a cooking fuel in less than 15% of households (except Kanpur [59%] and Jalaun [48%]). Districts in the southern region also used less dung cake than in the upper Ganga plain regions. In the eastern region, the use of dung cake was very diverse, with less than 15% of households using it in the Sonbhadra and Maharajganj districts and more than 60% of households using it in Chandauli and Ghazipur. The distribution of the prevalence of ARI is similar to the use of dung cake in Uttar Pradesh. There was a higher prevalence of ARI in the districts of the southern upper Ganga plain region and the eastern region (Fig. 6). Fig. 6 shows that a high prevalence of ARI was found in Azamgarh (17.7%), followed by Srawasti (16.6%), and Ambedkar Nagar (15.5%). Districts in central and southern regions had less than 1% prevalence of ARI.

The prevalence of ARI among children aged 0–59 months was found to be about 90 per 1000 children (Table 2). A slightly higher prevalence of ARI was observed among male compared with female children. The prevalence of ARI was found to decrease with increasing age. For example, the prevalence of ARI was 112 per 1000 children aged <12 months compared with 77 per 1000 children aged 48–59 months. The prevalence of ARI was higher among the 'other than SC/ST' group compared with the 'SC/ST' group and among Muslims compared with Hindus. The ARI prevalence was higher among middle (93 per 1000) and poor households (90 per 1000) compared with the poorest (87 per 1000) and richest households (88 per 1000). In terms of the type of cooking fuel used, ARI prevalence was highest among households that used dung cake (107 per 1000 children). The corresponding figures were 98 per 1000 children for those who used crop residue and 72 per 1000 children for those who used firewood.

The source of lighting is also an important component of the household environment. The prevalence of ARI was highest among households that used kerosene and other oils (93 per 1000 children) compared with those who used electricity and solar energy sources (80 per 1000 children). A huge difference in the prevalence of ARI was found across the different regions of Uttar Pradesh, with prevalence being highest in the eastern region (119 per 1000) followed by the northern upper Ganga plain region (89 per 1000) and lowest in the southern region (only 14 per 1000 children).

Table 3 presents the OR of the predictors of ARI in Uttar Pradesh. Model 1 (unadjusted for socio-economic predictors) shows that crop residue, dung cake, and other cooking fuels had significantly higher odds than LPG/PNG/electricity/biogas. Households using dung cake were significantly more likely to suffer from ARIs (OR: 1.33; 95% CI: 1.29–1.36) compared with those using LPG/PNG/electricity/biogas. After adjustment with lightening source and cooking place, the crop residue became insignificant, and dung cake had slightly lower odds compared with the unadjusted result of cooking fuels. However, with socio-economic and demographic adjustment, the crop residue and firewood have significantly lower odds, and dung cake has higher odds compared with LPS/PNG/electricity/biogas. There was a linear association between age and the prevalence of ARI; children aged 48–59 months were 35% less likely to experience ARIs compared with those aged <12 months old. The ORs for children aged 48–59 months and 36–47 months were 0.64 and 0.72, respectively. Compared with Hindus, Muslims were significantly more likely (OR: 1.09; 95% CI: 1.06–1.11) to have an ARI. Children from urban areas

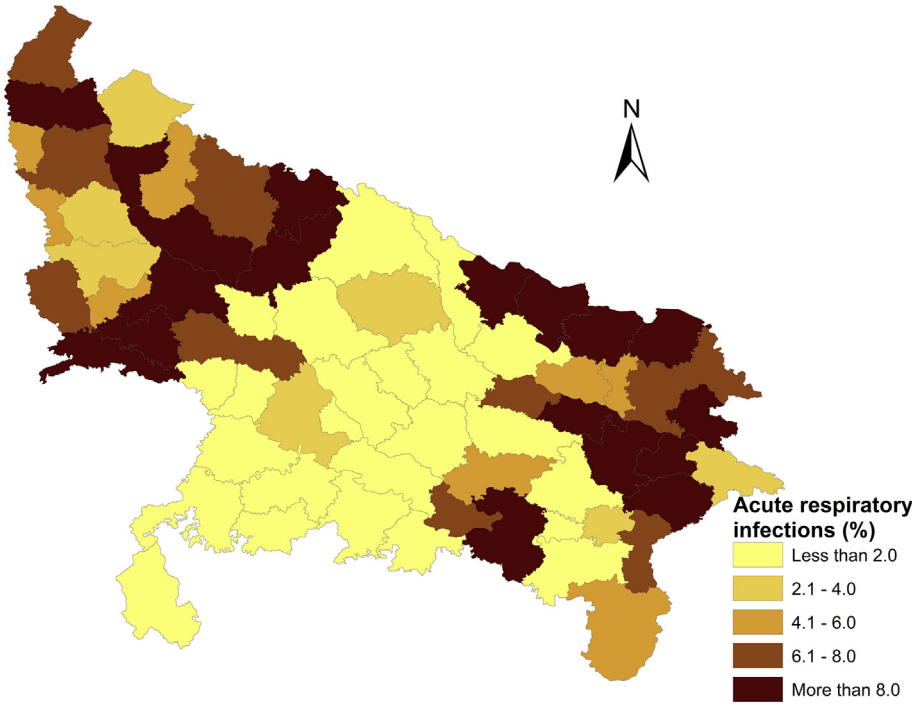

Fig. 5 – Percentage distribution of dung cake used for cooking in households, Uttar Pradesh, 2013.

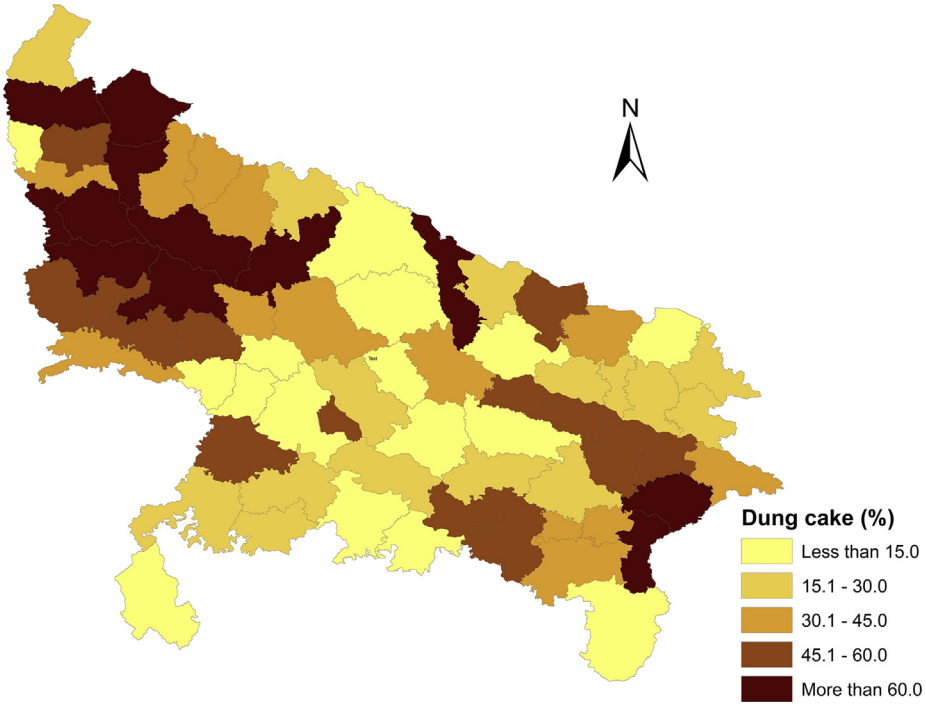

Fig. 6 – Prevalence of acute respiratory infections among ages 0–59 months, Uttar Pradesh, 2013.

were significantly more likely to have an ARI (OR: 1.28; 95% CI: 1.24–1.32) than those from rural areas. Compared with children from the eastern region, the odds of experiencing an ARI were significantly lower among children from the southern (OR: 0.11; 95% CI: 0.11, 0.12), central (OR: 0.20; 95% CI: 0.19, 0.22), and southern upper Ganga plain regions (OR: 0.55; 95% CI: 0.54, 0.56).

Discussion

The study found that approximately two-thirds of households in rural areas and about two-fifths of households in urban areas were using firewood and dung cake as cooking fuels. This finding is similar to the NITI Aayog report that shows a

Table 2 – Prevalence rate of acute respiratory infections (ARIs) among children aged 0–59 months in Uttar Pradesh, 2013.

Characteristics	Prevalence rate of ARI (per 1000)
Total	88.8
Sex of child	
Male	89.6
Female	88.0
Age (in months)	
<12	112.1
12–23	84.3
24–35	86.7
36–47	84.8
48–59	77.2
Caste categories	
Other than SC/ST	91.3
SC/ST	82.0
Religion	
Hindu	87.4
Muslim	94.5
Others[a]	78.2
Wealth index	
Poorest	87.2
Poor	90.0
Middle	93.4
Rich	84.4
Richest	88.4
Cooking fuel sources	
LPG/PNG/electricity/biogas	82.9
Firewood	71.8
Crop residue	98.4
Dung cake	107.1
Others[b]	95.2
Cooking place	
In house: kitchen	75.7
In house: No kitchen	91.8
Out house: kitchen	100.2
Out house: no kitchen	106.5
Lighting source	
Electricity and solar	79.8
Kerosene and other oils	93.3
Other sources[c]	80.1
Place of residence	
Rural	89.4
Urban	86.4
Regional categories	
Eastern region	119.3
Southern upper Ganga plane	72.3
Northern upper Ganga plane	89.4
Southern region	14.4
Central region	26.6

LPG, liquid petroleum gas; PNG, piped natural gas; SC/ST, scheduled castes/scheduled tribes.
[a] Includes Christian, Sikh, Buddhist, Jain, and other religion group.
[b] Includes coal, lignite, charcoal, kerosene, and any other source.
[c] Includes other oils and any other sources for lighting sources.

higher percentage of households were using dung cake as cooking fuel in Uttar Pradesh than in any other states.[2] Results presented here show that those who cooked in an in-house kitchen, an out-house kitchen, or in the absence of a kitchen were more likely to be using firewood and dung cake as cooking fuels in rural areas. The availability of clean fuel is a major challenge for poor rural households due to affordability factors.[22] A study by Dasgupta et al.[23] in Bangladesh suggested that ventilation and the structure of the kitchen were also important factors when considering ARI prevalence. However, no information on ventilation was collected in the AHS survey.

This study found that the use of crop residue, dung cake, and other fuels for cooking is a significant predictor of ARIs in children, and this is consistent with the findings of other studies.[8,16,17] The results show that place of cooking is also a predictor of ARI among children. Houses with no kitchen or having an out-house kitchen or no out-house kitchen reported a significantly higher ARI prevalence. In agreement with previous studies,[14,16] household pollution and availability of a kitchen facility are significantly associated with the prevalence of ARI. Cooking fuels in households that lack a kitchen emit more indoor pollutants, resulting in a more severe impact on the child's health.[21] Kerosene and other oils used for lighting were also found to be one of the predictors of ARI because of the emissions released by them, which directly impact on the health of the child.[8] The study finding shows ARI prevalence significantly decreases with increasing age of the child, which could be a result of older children having more developed immune systems and playing outside the home more often.

The findings of this study show that the type of kitchen facility in dwellings, together with the type of fuels used, may be better predictors of ARI prevalence. A recent study by Babatola et al.[24] dealt with the use of briquettes (production from sawdust) as an alternative source of household fuel. The results show that the use of crop residue and dung cake played a significant role in causing ARIs. This study included the lighting sources that have been associated with ARIs.

A strength of this study is that it considers comprehensive district-level data collected by the AHS to examine the association of household environment and pollutant with prevalence of ARI among children. The field staff for the survey were trained on the National Family Health Survey and the District Level Household Survey for collecting information on specific symptoms of ARI. However, there are several limitations; first, we could not measure the role of ventilation in exposure to pollutants because of the lack of information on this aspect in the survey. This is significant because wall and roof permeability are known to reduce pollution.[23] Second, tobacco smoking was not taken into consideration, even though it is a well-known risk factor contributing to ARIs.[25] Also, other factors, such as the availability of household members,[21] hand washing, and breastfeeding,[20] were not examined in this study. Nevertheless, another strong point of this study is that it includes information on lighting sources in the household environment, which is an important contributor to ARI in Uttar Pradesh.

In conclusion, the Empowered Action Group state of Uttar Pradesh has a large number of households that do not have access to clean fuels, such as LPG/NPG/electricity/biogas, for cooking or lighting purposes. These households are forced to use solid fuels, such as firewood, crop residue, dung cake, and other fuels, that are known to cause higher emissions than clean fuels. These emissions have long-term health consequences, such as a long-lasting cough, respiratory infections, and lung diseases for those who are directly exposed to the emissions. According to World Health Organization report on

Table 3 – Odds ratios (ORs) for acute respiratory infections (ARIs) with characteristics of children aged 0–59 months in Uttar Pradesh, 2013.

Characteristics	OR (95% CI)		
	Model 1[a]	Model 2[b]	Model 3[c]
Cooking fuels			
LPG/PNG/electricity/biogas			
Firewood	0.86***(0.83–0.88)	0.71***(0.69–0.73)	0.78***(0.75–0.80)
Crop residue	1.21***(1.17–1.25)	0.97 (0.93–1.01)	0.94***(0.90–0.98)
Dung cake	1.33***(1.29–1.36)	1.09***(1.06–1.12)	1.21***(1.17–1.25)
Others[d]	1.16***(1.06–1.28)	1.08 (0.98–1.18)	1.06 (0.96–1.16)
Lighting source in house			
Electricity and solar			
Kerosene and other oils		1.15***(1.13–1.17)	1.07***(1.05–1.10)
Others[e]		0.97 (0.90–1.05)	0.91**(0.84–0.99)
Cooking Place			
In house: kitchen			
In house: No kitchen		1.22***(1.19–1.24)	1.26***(1.23–1.29)
Out house: kitchen		1.35***(1.30–1.40)	1.19***(1.15–1.24)
Out house: no kitchen		1.40***(1.36–1.44)	1.40***(1.35–1.44)
Sex			
Male			
Female			0.97***(0.96–0.99)
Age group (months)			
<12			
12–23			0.72***(0.70–0.74)
24–35			0.75***(0.73–0.77)
36–47			0.72***(0.70–0.74)
48–59			0.64***(0.62–0.66)
Caste categories			
Other than SC/ST			
SC/ST			0.94***(0.92–0.96)
Religion			
Hindu			
Muslim			1.09***(1.06–1.11)
Others[f]			1.02 (0.89–1.16)
Wealth index			
Poorest			
Poor			1.01 (0.98–1.03)
Middle			1 (0.97–1.02)
Rich			0.96***(0.93–0.98)
Richest			1.03*(1.00–1.07)
Place of residence			
Rural			
Urban			1.28***(1.24–1.32)
Regional categories			
Eastern region			
Southern upper Ganga plane			0.55***(0.54–0.56)
Northern upper Ganga plane			0.66***(0.64–0.67)
Southern region			0.11***(0.11–0.12)
Central region			0.20***(0.19–0.22)
Constant	0.09***(0.09–0.09)	0.08***(0.08–0.08)	0.14***(0.14–0.15)

@ Reference Category
***P < 0.01, **P < 0.05, *P < 0.1.
CI, confidence interval; LPG, liquid petroleum gas; PNG, piped natural gas; SC/ST, scheduled castes/scheduled tribes.
[a] Model 1: including only cooking fuels.
[b] Model 2: including household environment, pollutant (cooking fuel and lighting sources) and place of cooking.
[c] Model 3: adjusted for household environment, pollutant, and place of cooking and socio-economic and demographic characteristics.
[d] Includes coal, lignite, charcoal, kerosene, and any other source.
[e] Includes other oils and any other sources for lighting sources.
[f] Includes Christian, Sikh, Buddhist, Jain, and other religion group.

public health and environment, smoke inhaled by women and children from unclean fuels is equivalent to burning 400 cigarettes in an hour. The Rajiv Gandhi Gramin LPG Vitaran Yojana (2009) and the Pradhan Mantri Ujjwala Yojana (PMUJ-2016) projects were started to provide LPG gas connections to the socially and economically disadvantaged or marginalized populations. The aim of these initiatives is to enhance the health of women and children by providing them with access

to clean cooking fuels, so they would not have to work in smoky kitchens and wander in unsafe areas to collect firewood.[22] These steps are significant in achieving the goal of access and use of clean fuels. This study helps to understand the prevalence rate of ARI and its determinants. The knowledge and information related to the risk for ARI should be spread across individual, household, as well as community levels, to reduce the prevalence of ARI in Uttar Pradesh.

Author statements

Ethical approval

The study used data sets that are available in the public domain; thus, there was no requirement to seek ethical consent.

Funding

This research work did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Competing interests

None.

Author contributions

Surendra Kumar Patel conceptualized the study and conducted literature review. Surendra Kumar Patel and Sunita Patel conceived and designed the experiments and conducted the statistical analysis. Surendra Kumar Patel performed the experiments, analyzed the data, and wrote the first draft of the manuscript. Sunita Patel, Surendra Kumar Patel contributed to writing of final paper. All authors contributed to and have approved the final manuscript.

REFERENCES

1. *IEA, energy access outlook: 2017 from poverty to prosperity*. 2017. Paris. Available from: https://webstore.iea.org/download/summary/274?fileName=English-Energy-Access-Outlook-2017-ES.pdf.
2. Aayog Niti. Distribution of Households by type of fuel used for cooking. In: *National Institution for Transforming India (NITI)*. Government of India; 2017. Available from: http://niti.gov.in/content/distribution-households-type-fuel-used-cooking.
3. Munroe RL, Gauvain M. Exposure to open-fire cooking and cognitive performance in children. *Int J Environ Health Res* 2012;**22**(2):156–64. Available from: https://www.ncbi.nlm.nih.gov/pubmed/?term=Exposure+to+open-fire+cooking+and+cognitive+performance+in+children.
4. Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. 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. *Lancet* 2012;**380**(9859):2224–60.
5. Krishnan SS, Amarchand R, Gupta V, Lafond KE, Sulaiankatchi RA, Saha S. Epidemiology of acute respiratory infections in children - preliminary results of a cohort in a rural north Indian community. *BMC Infect Dis* 2015;**15**:462. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4624162/.
6. Tambe MP, Shivaram C, Chandrashekhar Y. Acute respiratory infection in children: a survey in the rural community. *Indian J Med Sci* 1999;**53**(6):249–53. Available from: https://www.ncbi.nlm.nih.gov/pubmed/10776505.
7. MoSPI. *Millennium development goals India country report 2015*. 2015 [New Delhi].
8. Fullerton DG, Bruce N, Gordon SB. Indoor air pollution from biomass fuel smoke is a major health concern in the developing world. *Trans R Soc Trop Med Hyg* 2008;**102**(9):843–51.
9. WHO. *Summary of results: burden of disease from household air pollution for 2012*. 2014. Geneva, Switzerland. Available from: http://www.who.int/phe/health_topics/outdoorair/databases/FINAL_HAP_AAP_BoD_24March2014.pdf.
10. Gurley ES, Homaira N, Salje H, Ram PK, Haque R, Petri W, et al. Indoor exposure to particulate matter and the incidence of acute lower respiratory infections among children: a birth cohort study in urban Bangladesh. *Indoor Air* 2013;**23**(5):379–86. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3773273/.
11. Gurley ES, Salje H, Homaira N, Ram PK, Haque R, Petri W, et al. Indoor exposure to particulate matter and age at first acute lower respiratory infection in a low-income urban community in Bangladesh. *Am J Epidemiol* 2014;**179**(8):967–73. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3966716/.
12. Shibata T, Wilson JL, Watson LM, LeDuc A, Meng C, Ansariadi, et al. Childhood acute respiratory infections and household environment in an Eastern Indonesian urban setting. *Int J Environ Res Publ Health* 2014;**11**(12):12190–203. Available from: https://www.ncbi.nlm.nih.gov/pubmed/25429685.
13. Chen BH, Hong CJ, Pandey MR, Smith KR. *Indoor air pollution in developing countries*. Wid hlth statist. quart; 1990. p. 43. Available from: https://pdfs.semanticscholar.org/283e/f1d09b88b59fae2d126611ee8de41e89c6c0.pdf.
14. Ezzati M, Kammen D. Indoor air pollution from biomass combustion and acute respiratory infections in Kenya: an exposure-response study. *Lancet* 2001;**358**(9282):619–24. Available from: https://www.ncbi.nlm.nih.gov/pubmed/11530148.
15. 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**(9):1078–92. Available from: http://www.who.int/bulletin/archives/78(9)1078.pdf.
16. Buchner H, Rehfuess EA. Cooking and season as risk factors for acute lower respiratory infections in African children: a cross-sectional multi-country analysis. *PLoS One* 2015;**10**(6):e0128933.
17. Naz S, Page A, Agho KE. Household air pollution from use of cooking fuel and under-five mortality: the role of breastfeeding status and kitchen location in Pakistan. *PLoS One* 2017;**12**(3):e0173256. Available from: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0173256.
18. Kumar SG, Majumdar A, Kumar V, Naik BN, Selvaraj K, Balajee K. Prevalence of acute respiratory infection among under-five children in urban and rural areas of puducherry, India. *J Nat Sci Biol Med* 2015;**6**(1):3–6.
19. Prajapati B, Talsania N, Sonaliya KN. A study on prevalence of Acute Respiratory Tract Infections (ARI) in under five children in urban and rural communities of Ahmedabad District, Gujarat. *Nat J Commun Med* 2011;**2**(2):255–9.

Available from: https://pdfs.semanticscholar.org/53ed/11bf093bb92e01bf247dfa8f6d797b0fdc7c.pdf.
20. Selvaraj K, Chinnakali P, Majumdar A, Krishnan IS. Acute respiratory infections among under-5 children in India: a situational analysis. *J Nat Sci Biol Med* 2014;**5**(1):15–20.
21. Upadhyay AK, Singh A, Kumar K, Singh A. Impact of indoor air pollution from the use of solid fuels on the incidence of life threatening respiratory illnesses in children in India. *BMC Public Health* 2015;**15**:300. Available from: https://bmcpublichealth.biomedcentral.com/track/pdf/10.1186/s12889-015-1631-7.
22. Ahmad N, Sharma S, Singh AK. Pradhan Mantri Ujjwala Yojana (PMUY) step towards social inclusion in India. *International Journal of Trend in Research and Development* 2018;**5**(1). Available from: http://www.ijtrd.com/papers/IJTRD14650.pdf.
23. Dashupta S, Huq M, Khaliquzzaman M, Pandey K, Wheeler D. Indoor air quality for poor families: new evidence from Bangladesh. *Indoor Air* 2006;**16**(6):426–44. Available from: https://www.ncbi.nlm.nih.gov/pubmed/17100664.
24. Babatola JO, Lasisi KH, Ajibade FO. Production of Sawdust Briquettes as Alternative household fuel using water and cow dung as Binders. *Afr J Renew Altern Energy* 2017;**2**(3):51–8. Available from: https://www.ncbi.nlm.nih.gov/pubmed/22721493.
25. DiFranza JR, Masaquel A, Barrett AM, Colosia AD, Mahadevia PJ. Systematic literature review assessing tobacco smoke exposure as a risk factor for serious respiratory syncytial virus disease among infants and young children. *BMC Pediatr* 2012;**12**:81. Available from: https://www.ncbi.nlm.nih.gov/pubmed/22721493.