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Indoor air pollution and women's health in India: an exploratory analysis

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Abstract Cooking and heating with solid fuels (wood, charcoal, crop waste, dung, coal etc) generates high levels health damaging pollutants in the home. This study is designed to test whether easy availability of cheap harmful fuels, income stratificatiom within society and awareness regarding negative health impact, causes tuberculosis and asthma, among adult married female respondents, along with profiles of their fuel selection. An empirical exercise, by applying binary logistic model and multivariate regression model, has been carried out using Third National Family Health Survey data conducted in India during 2005–2006. The results of binary logistic model indicate that with easy availability of biomass fuels, respondents are more prone to their usage. Therefore, availability/supply of least polluting cooking fuel may be ensured in reducing the level of IAP to eradicate IAP-related disease affecting most adversely the women. So easy availability and low cost of cleaner cooking fuel should get the priority in the policy criteria of the government.

Keywords Indoor air pollution impact on health · Incidence of disease · Biofuel · Women's health · India

1 Introduction

Indoor air pollution (IAP) is common among developing countries (Barnes 2014; Sood 2012). A major source of IAP in developing countries is the burning solid fuels on open fires or on traditional stoves without chimney. Solid fuels include coal and biomass fuel, e.g., wood, charcoal, dung or crop residue. In particular, poor households in rural areas of

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developing countries are more affected by indoor air pollution due to solid fuel use (SFU) (Cowling et al. 2014; Ruíz-Vera et al. 2014; Perez-Maldonado et al. 2014; Domínguez-Cortinas et al. 2013). The daily exposure level ranges from 3 to 7 h in poor rural households (Engel et al. 1998). In 2010, the share of disease burden from household solid fuels was highest in South Asia followed by central, eastern and western sub-Saharan Africa, and Southeast Asia and relatively low in Southern Latin America and Asia Pacific (Lim et al. 2012). IAP ranks fourth among global risk factors (WHO 2006). As a result of burning solid fuels for cooking, 3.5 million deaths were directly associated in 2010, accounting for almost 5.3 % of total burden of disease at the global level. IAP is also an important contributor to ambient particulate matter pollution. It accounted for 16 % of worldwide burden from ambient particulate matter pollution in 2010. In addition, another 500,000 deaths from outdoor air pollution were caused by cooking, with a large share of outdoor pollution in regions like Asia and Sub-Saharan Africa originating from household solid fuel use in 2010 (Lim et al. 2012). In India, about 67.3 % of the total population uses solid fuels for cooking, mainly consists of wood, crop residue and cow dung cake, whereas only 28.5 % uses liquefied petroleum gas (LPG) (Census of India 2011). Severe health effects from IAP include acute respiratory infection (ARI) in children and chronic obstructive pulmonary disorder (COPD), asthma and lung cancer in women, and adverse indoor air quality (IAQ) due to use of biomass fuel is considered as one of the main sources of these diseases (Smith 2000b). More than 1 million people die each year from COPD that develops due to exposure to such indoor air pollution (WHO 2011). Several studies established the association between IAP and deteriorating women health (Awasthi et al. 1996; Behera et al. 1991; Bruce et al. 2000; Mishra and Rutherford 1997; Pandey 1984; Ramakrishna et al. 1989; Smith et al. 1983, 2000; Smith 1993, 1996, 2000a, b). The observed phenomenon thereby stands that the IAP has a significant negative impact on human health, wherein women and children suffer the most.

In rural areas, biomass fuels like animal dung and agricultural residues are freely available without any additional cost to the user. So, there is less incentive in switching to cleaner and costlier fuels. The availability and ease of use are very important for the choice of fuel (Gupta and Köhlin 2006). The children from low-income households were suffering more in acute respiratory infections when compared to children from high-income (rich) households in Tanzania (Bukalasa 2011). The availability of biomass fuel in India is estimated at about 500 million tons per year covering residues from agriculture, processing industries and forestry (Biofuels Annual of India 2013). The first hypothesis of the study highlights easy availability of biomass fuel and their consequent increased usage. In developing countries, low-income members of a society in comparison with higher-income groups use low-cost fuels that result in IAP (Guoping and Pixin 2009). Therefore, the second hypothesis of the study is to assess whether lack of income is the contributing factor in consistent usage and adoption of cleaner and better fuels. Again, insouciant knowledge, in developing countries, regarding negative health impact for exposure to IAP leads to continuous usage of these fuels with increasing health-related issues among women. Education helps to understand the negative effects of biomass on health (Mekonnen and Köhlin 2008) and can contribute to the process of fuel switching (Heltberg 2004). The third hypothesis of this study thus analyzes whether lack of education or awareness is an important cause for IAP.

Thus, this study is designed to test whether (1) easy availability of cheap harmful fuels, (2) income stratification within the society and (3) awaremess regarding negative health impact, governs the fuel preferences. The study design considers two diseases, tuberculosis

(TB) and asthma among adult married female respondents, along with profiles of their fuel selection.

2 Experimental

2.1 Study design and data collection

The present study uses Third National Family Health Survey (NFHS-3) data conducted in India during 2005–2006 (IIPS 2007) under the stewardship of the Ministry of Health and Family Welfare, Government of India designating International Institute of Population Sciences (IIPS) as the nodal agency for the survey and was funded by Government of India along with foreign agencies. The survey was conducted among representative samples of married women in the age group of 15–49 years as well as men in the age group of 15–54 years from all states of India. However, this study considers women respondents from two states of India, West Bengal (WB) and Gujarat. West Bengal and Gujarat differ from each other in many aspects like socioeconomic and sociocultural status. Selection of the states with contrasting features like climate, vegetation, demography and population density from eastern and western part of the country is justified to test the hypotheses mentioned on objectives of the study.

The indicators identified from the NFHS-3 survey data as per the requirement of the study objective are as follows.

(A) Type of cooking fuel (CKFUEL): 1: traditional fuel such as wood, straw, agricultural residue and animal dung also termed as solid fuel; 2: intermediate fuel such as kerosene, coal and charcoal and 3: modern fuel such as electricity, LPG and natural gas
(B) Incidence of disease (DISEASE): 0: no disease (Asthma and TB) and 1: disease
(C) Wealth index (WI): 1: poor; 2: middle; 3: rich (as defined in NFHS 3)
(D) Type of place or residence (UR): 1: rural; 2: urban
(E) Educational attainment of the respondent (EDU): 0: no education, 1: incomplete primary, 2: complete primary, 3: incomplete secondary, 4: complete secondary, 5: higher.

2.2 Methods

Binary logistic distribution has been used to test the relation between incidence of disease and type of cooking fuel use. Algebraically, this can be written as

$$\log\left\{\frac{P}{1-P}\right\} = a - b(\text{CKFUEL})$$

where,

$$P = \text{Probability}\{\text{DISEASE} = 1\},\ b > 0 \tag{1}$$

In the next step, the study is to test the determinants of fuel use, experimenting the hypotheses that whether (1) easily available solid fuels in the absence of better type (2) or the income level (3) or lack of awareness about negative impact of IAP on women health or all the three factors determine the type of fuel use. In this context, a simple multiple

Table 1 Distribution of respondents by type of cooking fuel and by states for different contributing factors

Contributing factors	Percentage of respondents by states and by fuel type (%)							
	State—West Bengal				State—Gujarat			
	Type of cooking fuel				Type of cooking fuel			
	Modern fuel	Intermediate fuel	Traditional fuel	Total (No.)	Modern fuel	Intermediate fuel	Traditional fuel	Total (No.)
A. Type of residence								
Rural	2.8	6.3	90.9	46	20	4	76	57
Urban	50.1	40.9	9	54	73.6	10.7	15.7	43
B. Incidence of diseases (asthma and TB)								
No	28.44	25.12	46.44	96	43.14	6.80	50.06	98
Yes	22.69	19.75	57.56	4	38.81	8.96	52.24	2
C. Educational attainment								
No education	4.59	27.08	68.33	31	13.65	7.00	79.35	33
Incomplete primary	9.73	24.26	66.02	14	28.81	6.10	65.08	8
Complete primary	15.31	36.73	47.96	6	34.57	10.11	55.32	6
Incomplete secondary	36.89	27.35	35.76	36	57.31	7.67	35.02	40
Complete secondary	76.62	14.03	9.35	4	78.41	6.25	15.34	5
Higher	89.08	6.14	4.78	9	91.55	1.06	7.39	8
D. Wealth index								
Poor	0	5.78	94.22	33	0	0.94	99.06	18
Middle	0.99	34.39	64.62	16	2.85	4.44	92.71	18
Rich	54.90	34.44	10.65	51	66.42	9.18	24.40	64
E. Type of cooking fuel used								
	28.23	24.92	46.85	100	43.06	6.84	50.10	100

regression model would be fitted to the data for identifying the determining factors in the following form.

$$\text{CKFUEL} = \beta_1 + \beta_2(\text{UR}) + \beta_3(\text{EDU}) + \beta_4(\text{WI}) \quad (2)$$

Both the exercises [Eqs. (1), (2)] are to be done separately for two selected states.

For making the comparison of regression coefficients/slopes estimated for each of the explaining factors used in Eq. (2) from two independent samples from two states, a Z test is applied estimating the following statistic (Clifford et al. 1995). Z test is used to determine whether two population means are different when the variances are known and the sample size is large. The expression of Z statistic is given below.

$$Z = \frac{b_1 - b_2}{\sqrt{\text{SE}(b_1)^2 + \text{SE}(b_2)^2}},$$

where b_i stands for regression coefficient of any explanatory variable for a sample i, $i = 1$, 2, and $\text{SE}(b_i)$ is the standard error of b_i.

It is to be mentioned that total number of respondents included in the analysis is 6461 in place of 6794 for WB and 3537 in place of 3729 for Gujarat after dropping the non-responding respondents.

3 Results and discussion

3.1 Results

Table 1 shows the distribution of respondents by type of residence, by incidence of diseases, by wealth index and by educational attainment using three categories fuels in each state. Distribution of respondents by type of residence shows that in both the states (90.9 % in WB and 76 % in Gujarat), majority of the rural people use traditional fuel as expected and some percent of urban people still use this. However, in WB, only half of urban population uses modern fuels compared to Gujarat where more than two-third of urban women use modern fuel. Henceforth, incidence of disease among female respondents is very low in Gujarat compared to significantly high (P value = 0.00) in WB. In both the

Table 2 Logistic relation between incidence of diseases and type of fuel used dependent variable—incidence of diseases (asthma and TB)

Estimated coefficient	State—West Bengal		State—Gujarat	
(1)	Type of cooking fuel (2)	Constant (3)	Type of cooking fuel (4)	Constant (5)
Regression coefficient—B	−0.247	−2.836	−0.071	−3.813
Standard error of B	0.82	0.151	0.129	0.271
Wald statistic	9.014	351.37	0.301	198.58
Degrees of freedom	1.00	1.00	1.00	1.00
Significance level	0.03	0.00	0.583	0.00
Exp(B)	0.781	0.059	0.932	0.22

states, use of better type fuel is directly influenced by higher level of education as expected. Distribution by WI indicates that in both states, there is no significant difference (P value = 0.08) in fuel usage among low-income groups. Now, it is observed that as a whole, proportion of Gujarat women using modern fuel (43.06 %) is significantly higher (P value = 0.00) compared to that in WB (28.23 %) using one-sample t test between proportions. In both the states, about half of the total women use traditional fuel. However, for the rest, the pattern significantly differs between states. In Gujarat, out of rest of the respondents, 6.84 % uses intermediate fuel which is significantly lower (P value = 0.00) compared to that in WB (24.92 %). This indicates that modern fuel in Gujarat is easily available compared to WB.

Table 2 represents the result of Eq. (1). The regression coefficients both for Gujarat (−0.247) and for WB (−0.071) show the negative association between incidence of disease and choice of cooking fuel. Multiple regression model given in Eq. (2) is used to find out the factors influencing the decision to choose the type of cooking fuel for use. Table 3 provides the results of the regression model for both the states—WB and Gujarat. It is observed from the results that in both the states values of $\left(\overline{R}\right)^2$ are significant (P value = 0.00); all the regression coefficients are also in the expected direction and significant (P value = 0.00). However, the value of Z statistic in Table 4 shows that two factors WI and EDU significantly (P value 0.00) contribute to the decision of choice of fuel type in both the states. For U/R, the required Z statistic is insignificant (P value = 0.42) as expected.

3.2 Discussion

The study implies that the negative association between usage of better fuel type and incidence of disease decreases significantly among female respondents in WB ($P = 0.03$), whereas in Gujarat this association is not significant ($P = 0.583$) in Table 2. In WB, almost 90 % respondent from rural area uses traditional fuel, among them almost 58 % faces the incidence of disease, whereas in Gujarat the percentage of respondents using

Table 3 Results of multiple regression model for West Bengal- and Gujarat-dependent variable: CKFUEL

Independent variable	Unstandardized coefficients		Standardized coefficients	T ratio	Significance level
	B	SE (B)	B		
(1)	(2)	(3)	(4)	(5)	(6)
State: West Bengal					
Place of residence	0.653	0.16	0.385	40.979	0.00
Wealth index	0.273	0.006	0.460	42.033	0.00
Respondent's education	0.62	0.004	0.120	14.708	0.00
Constant	−0.208	0.018		−11.714	0.00
Adjusted R square	0.731				
State: Gujarat					
Place of residence	0.525	0.023	0.270	22.352	0.00
Wealth index	0.416	0.011	0.528	38.541	0.00
Respondent's education	0.081	0.007	0.139	11.187	0.00
Constant	−0.549	0.36		−15.129	0.00
Adjusted R square	0.621				

Table 4 Comparison of regression coefficients between West Bengal and Gujarat

Independent variable	*Z* statistic	Significance level
Place of residence (U/R)	0.8	0.42
Wealth index (WI)	23.83	0.00
Respondent's education (EDU)	134.75	0.00

modern fuel (43.06 %) is comparatively (P value = 0.00) higher than WB (28.23 %); this indicates the fact that in Gujarat, solid fuels are not preferred. However, there exists a negative association between incidence of disease and choice of cooking fuel; hence, outlining factors influencing the choice of fuel type may help in reducing the level of IAP-related health complications. But in WB, significant negative association between usage of modern fuel type and incidence of disease indicates that with easy availability of traditional fuels, respondents are more prone to their usage. According to Outlook, Annual Energy (2014), most oil reserves in India are found in the wsetern part of India, particularly western offshore in Gujarat (13%) and Rajasthan (24%) in 2013. According to the International Energy Outlook (2011), Gujarat is the major source of India's crude oil supplier in India. This indicates that cleaner or modern fuels are easily available in Gujarat in comparison with WB. So women are less exposed to more polluting fuel in Gujarat. We can strengthen this view with the negative but insignificant relation between incidence of disease and type of fuel use results for Gujarat. It indicates the presence of factor(s) other than IAP in this context as a significant number of women here use better type fuel which generates less pollution. This proves our first hypothesis.

The results obtained from a multivariate linear regression model indicate that the availability of better fuel with more urbanization (U/R), increase in awareness about negative health impact of IAP with increase in education (EDU) and more accessibility to better (costly) fuel by wealthier households (WI) determine the choice of better type of fuel leading to reduce IAP, so incidence of disease. It is seen from Table 3 that as one moves from rural to urban, pattern of fuel use changes from traditional to modern and positive significant (P value = 0.00) relation between CKFUEL and U/R indicates the same. It may be because of abundance and affordability of modern fuel in urban area compared to rural area. Positive and significant relation between CKFUEL and EDU indicates that respondent with higher education is more aware about negative health impact of IAP. In the similar way, positive and significant relation between CKFUEL and WI indicates less use of solid fuel by the richer people as they can afford the cost of cleaner fuel. This proves our second and third hypotheses that wealth index and educational attainment significantly affect choice of cooking fuel. The result of Table 4 also strengthens our results, indicating that wealth index and education attainment significantly contribute to the decision of choice of fuel type in both the states.

4 Summary and conclusions

Availability/supply of least polluting cooking fuel may be ensured in reducing the level of IAP to eradicate IAP-related disease affecting most adversely the women. This study also shows that wealth index and educational attainment also play pivotal role in choice of cooking fuel. So, easy availability, low cost of cleaner cooking fuel and awareness

programmes explaining negative effect of IAP should get the priority in the policy criteria of the government.

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