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POLLUTION EXPOSURE FROM COOKING & MORBIDITY: AN ANALYSIS BASED ON IHDS DATA

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ABSTRACT

Indoor air pollution (IAP) is a potential public health risk. The World Health Organisation (WHO) reports that globally 4.3 million die due to air pollution from household sources. This paper attempts to investigate the impact of indoor air pollution, arising out of use of polluting fuels for cooking, on the health of the population. The paper uses India Human Development Survey-II (IHDS-II) data, 2012. Data analysis using cross-tabulation method is applied to investigate the choice and collection time of fuel, location and ventilation of kitchen across households and morbidity profile across ages and sexes. A Personal Index for Cooking Exposure (PICK) has been constructed. Logit regression is run to find the impact of indoor smoke on the IAP induced morbidity controlling for other confounders like income (per capita), education and sexes. The PICK has a positive coefficient on the incidence of morbidity implying less exposure due to the use of cleaner fuel leads to less morbidity. Education of the individual also has a significant effect on the reduction of morbidity. Switching to a cleaner fuel (LPG) is a potential solution for IAP induced morbidity of the individuals. Educational attainment also can put an end to this menace through raising awareness.

KEYWORDS: *Indoor Air Pollution, Morbidity, Cooking Exposure, Clean Fuel*

INTRODUCTION

With the rapid increase in vehicular and other pollution sources in urban areas of developing countries, outdoor sources have remained the center of most air pollution research worldwide. The Global Burden of Disease, when first estimated, only considered the outdoor air pollution (Smith & Mehta, 2000). In reality exposure to indoor air pollution (IAP) poses substantial health risks. Exposure refers to the concentration of pollution in the immediate breathing environment during a specified period of time (Bruce et al., 2000). This can be measured either directly by the personal monitoring or indirectly by combining information on pollution concentration in any specific microenvironment[2] and the time an individual is spending in that particular microenvironment. The indoor exposure, worldwide, sometimes dominates the outdoor exposure for some particular pollutants because people, globally, spend most of their time indoor. Annually 2800,000 premature deaths occur worldwide due to exposure to IAP (WHO, 1997) where the figure is 200,000 for outdoor exposure. In India Smith (1994) estimated 850,000-3300, 000 IAP related and 50,000-300,000 OAP related premature

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[2] A microenvironment is defined in terms of the characteristics of the physical space and the nature of activity undertaken in that space.

deaths annually. Indoor smoke is the 10th major risk factor causing deaths worldwide. Developing countries mostly suffer from the problem of indoor pollution. Here it is the 5th most important factor explaining DALY. Among environmental risks, indoor smoke from solid fuels is the second most important factor next to unsafe water, sanitation and hygiene.

Majority of total IAP exposure seems to fall under two categories: the combustion of solid fuel for cooking and heating and Environmental Tobacco Smoke (ETS). This paper focuses only on solid fuel use. According to WHO factsheet, significant reduction in the exposure to air pollution can be achieved through lowering the concentrations of the pollutants emitted at the time of burning fossil or biomass fuels. A major source of the use of this biomass fuel arises out of the domestic cooking and heating. More than half of the world's population rely on the biomass fuels to meet their most basic energy needs and 95% of them are from the lower income countries (Smith et al., 2004). Cooking and heating with such solid fuels on open fires or stoves without proper ventilation leads to indoor air pollution. In poorly ventilated dwellings the levels of small particles coming out of indoor smoke can exceed that from outdoor air manifold (WHO, 2005). The most damaging substances contained in the biomass fuel include particles, carbon monoxide, nitrous oxides, sulphur oxides, formaldehyde, and polycyclic organic matters including carcinogens. Particles with diameters below 10 microns (PM_{10}), and particularly those less than 2.5 microns in diameter ($PM_{2.5}$) can penetrate deeply into the lung and have the greatest potential for damaging health (Bruce et al, op. cit.). The majority of the households in the developing countries use biomass fuels in the open fireplace or in inefficiently functioning stoves leading to incomplete combustion. These result in emissions, which coupled with poor ventilation, produce a very high level of indoor air pollution.

The WHO (2012) reports that indoor air pollution cause death because of heart disease and stroke, ALRI, COPD and lung cancer. Smith (2000, 2006), Bruce et al. (2002), Ezzati and Kammen (2002), Pant (2008), Smith et al. (2004), etc. have found strong evidence regarding the link between indoor smoke exposure and prevalence of ALRI, COPD, bronchitis and lung cancer. A study by Misra (1999), Misra et al. (2002), Lin et al. (2008), Gupta and Mathur (1997), Perez-Padilla et al., (1996, 2001), etc. found consistence evidence of an association between use of biomass cooking fuel and prevalence of tuberculosis. Song et al. (2011), Penard-Morand et al. (2010) associated skin infection to exposure to particles with a diameter less than 10 μm. Studies (Pokhrel, 2005) also have estimated the cooking fuel and the risk of cataract. Morgenstern et al. (2008) find an association between the exposure to particulate matter, $PM_{2.5}$ (one of the major indoor air pollutants with a size smaller than 2.5 μm) and the incidence of bronchitis in children. Evidence of association between $PM_{2.5}$ exposure and incidence of asthma are also found in Janssen et al. (2003), McCormack et al. (2009), Guneser et al. (1994), Azizi et al. (1995), etc. The link between cardiovascular disease and exposure to fine particles has been established in Brook et al. (2004), Miller (2007), McCracken et al. (2007), Fullerton, Bruce and Gordon (2008).

This paper attempts to investigate the impact of indoor air pollution, arising out of use of polluting fuels for cooking, on the health of the population, in general, and for females and children below five years of age, in particular. The analysis has been done for the year 2012. It also tries to find out the associated factors that affect the incidence of IAP induced diseases. Finally, some policy suggestions are made on the basis of the findings of the analysis carried out.

METHODOLOGY

The paper uses the India Human Development Survey (IHDS) II Data. The survey was conducted in the year 2011-12. It is a nationally representative multitopic survey including 42,152 households in 1,503 villages and 971 urban neighborhoods across India. The topics covered the areas of health, education, employment, economic status, marriage, fertility, gender relations, and social capital.

Quality of indoor air gets affected by the type of fuel used by the household, the medium of cooking, the location of the kitchen within the house, the ventilation system in the kitchen and adjacent rooms, the height of the ventilation from the hearth, etc. In IHDS data information is available on the type of fuel used for cooking, the type of chulah (stove) the household is using, vent in the cooking area, source of fuel, kitchen type, etc. The data also provide information on the type of morbidity an individual was suffering from at the time of the survey. Information on demographic characteristics of the individual is also available. In absence of the actual pollutant concentration in the air in-house the type of fuel used in the cooking has been used as the proxy of the indoor air pollution. On the basis of the type of fuel, the location of the kitchen, the age-sex based vulnerability weights in terms of time used by the individuals, a Personal Index for Cooking Exposure (PICK) has been constructed and its relation with morbidity of the individuals is examined. Few diseases have been selected from the list of reported ailments provided by IHDS. Respiratory infections like cough and cough with shortness of breath, tuberculosis, cataract, asthma, cardiovascular diseases like heart diseases and hypertension are considered to be the diseases and symptoms caused by IAP. The inclusion of these diseases has a background in literature in the area as mentioned in the preceding paragraph. The fuel used for cooking has been broadly divided into two categories-clean and dirty. The paper has used kerosene and LPG as the clean fuel and firewood, dung cake, crop residue and coal/charcoal as the dirty fuel. This classification has been made on the basis of the potential of the fuels to pollute. IHDS does not provide any direct information on the income of household or individuals, instead, information on per capita monthly household expenditure is available. It is taken as the surrogate for income. The sampled individuals have been arranged over different expenditure classes where the latter has been divided into three broad categories, viz., low (with MPCE less than Rs.4000.00), medium (with MPCE in the range Rs.4000.00 - Rs.8000.00) and high (with MPCE greater than Rs.8000.00). These classes have been constructed on the basis of the World Bank’s poverty line income. It is $1.90 per person per day, in 2011 PPP dollars for low and middle-income countries like India, which is coming out to be Rs. 4010 per person per month. So, income less than Rs.4000 are taken as low MPCE class. The individuals have been divided into five categories on the basis of education level attained. A number of completed years of education is taken as the education level. Those who have completed zero years of schooling (no schooling), completed up to 4th class, 5th class to 10th class, 11th class to 12th class and higher than that are categorised as not literate, below primary, above primary and up to secondary, above secondary and up to higher secondary, above higher secondary respectively. Age is also divided into five groups. The groups are infant and children below 5 years, children and teenagers in the age group 5-15 years, mothers who may carry children (15-49 years), mothers whose children are elder but those who engaged in cooking activities (49-60 years) and aged (over 60 years). Information is available on the total time taken for fuel collection per round trip from home to the place where fuel is available. This is reported in minutes.

Data analysis has been carried out using the information on the total time taken for fuel collection to construct an idea about the opportunity cost of the job. Data analysis also has been done through cross-tabulation technique between IAP induced diseases and sex, age group, MPCE, education, and type of fuel used for cooking in the household the individual belongs to. The IAP exposure is expressed in terms of the PICK. Finally, logit regressions have been run to analyze the health impact of IAP exposure in presence of different confounding variables that include household specific factors like individual-specific factors like MPCE, age, sex, education, and PICK. Any incidence of the disease is likely to affect the children and the aged most, as they are more vulnerable. So, in the logit regression, a non-linear function of age (squared age) is also been introduced. A total of 1, 68, 961 individuals have been studied as information on these individuals are available for all the variables included/constructed in the analysis. Almost an equal number of males and female individuals are present in the sample.

Variable Description

The variable included in the study is as follows:

IAP_disease: This is the response variable. The effect of indoor pollution will be studied on this variable. This represents the health outcome that arises out of IAP. This considers the incidence of diseases mentioned before. The variable is assigned a value 1 if any one of the included diseases occurs. Otherwise, 0 is given. Thus, the variable is binary in nature.

PICK: This is Personal Index for Cooking Exposure. The methodology for index construction is described in the next section.

age: This is the age of the individual and taken as reported in data.

Age Group: The age of the individuals is divided into five categories. Categories are defined earlier.

Sex: This is used from the data directly. 1 is used for female and 0 for male.

Edu Group: This is the education group. Five groups have been defined. The definitions have been mentioned earlier.

MPCE: This is monthly per capita expenditure and taken from the data in its original form.

Separate weight structures are used for different arrangements for cooking place and for fuel types used in cooking. IHDS data provide three varieties of cooking place, namely outdoor cooking, separate cooking and cooking in the living area. Fuels, as given in the data, are of six types. Firewood/twigs, dung cake, crop residue, and coal/charcoal are considered as dirty fuel and kerosene and LPG are treated as a clean fuel.

Methodology for Index Construction

Ideally speaking, in absence of pollution concentration level of different pollutant emitted from the cooking smoke, individual index of cooking pollution exposure should be sensitive to (i) time spent by the exposed person in a specific cooking environment and (ii) the age and sex of the person concerned. While item (i) tries to assess the intensity of exposure, item (ii) measures the relative vulnerability of the concerned individual. Denoting exposure weight of the j^{th} cooking arrangement by c_j, time spent by the i^{th} member of the household in the j^{th} cooking arrangement by t_{ij} and age-sex vulnerability weights of the i^{th} member by w_i, the final exposure index for the i^{th} individual may be developed at two stages.

Stage I: The intensity of exposure for individual i: $P_i = c_j * t_{ij}$

Stage II: The vulnerability weighted exposure of individual i, termed as Personal Index for Cooking Exposure, $PICK_i = w_i * P_i$.

We need three sets of weights to construct *PICK*, the personal exposure index, viz., w_i, which has been derived from Kathuria & Khan (2007), c_j and t_{ij}. c_j has been generated from the estimates extended by Suksena and Dayal (1997) and Ostro (1994). No data is available on t_{ij}. Instead w_i captures both time-use and the age-sex based vulnerability weights as it has been derived by Kathuria & Khan (op. cit.). The procedure of how this captures both will be described in the next paragraph. Table 1 presents the weighting scheme followed in PICK construction. In the absence of t_{ij} data the PICK would be derived by the following formula:

$PICK_i = c_j * w_i$; where w_i captures both t_{ij} and w_i itself.

In Suksena & Dayal (op cit) intensity of exposure in cooking as well as non-cooking activities were given for different types of fuel in rural, urban and slum areas. We have considered urban values to correspond the best possible kitchen (separate kitchen and outdoor cooking as cooking outdoor creates least pollution with no ventilation problem) and slum values with the worst possible kitchen (cooking inside the living room). Among the fuel options used in our survey, only LPG and kerosene are the 'clean' fuel and the rest are categorized as 'dirty' fuel. In the absence of any time-use survey data, Kathuria & Khan (op cit) proposed 5 hours exposure for adult male and adult female, 6 hours for old female, 8 hours for children and 9 hours for old male. Considering the exposure rate of adult male and female as the norm we have calculated the vulnerability weights for each age-sex based group as shown in Table 1. For example, old males have a vulnerability weight $(9/5)=1.8$, for old female it is $(6/5)=1.2$ and for children the weight is $(8/5)=1.6$. Since the weights have been calculated on the basis exposure rate of adult male and female (same for both) their weights have been given the value 1. In the cooking microenvironment, the dirtiest combination is dirty fuel and living room kitchen. Here the exposure should be much higher than simply being proportional to the time spent in this microenvironment. It is taken to be equal to one and a half times higher than the simple proportion (weight=1.5). Cooking with dirty fuel is itself very harmful, so even it is done in a separate kitchen the exposure would be higher than being proportional to the time spent in this microenvironment, though it would be much less than that in living room kitchen. Clean fuel improves the situation manifold. Cooking with clean fuel, even in the living room, is much less risky than cooking with dirty fuel in a separate kitchen. The exposure is less than proportional to the time spent and living room cooking with clean fuel has weight equal to 0.5. Separate kitchen clean fuel combination is the cleanest one and has been given the lowest weight in the cooking microenvironment (weight=0.4). It is the same for the outdoor kitchen as well. In fact, clean fuel poses much less risk irrespective of any other parameter; and that is why the weights for cooking in clean fuel do not differ much across the kitchen type. Rather time spent in different microenvironments plays a vital role in exposure assessment. This is one explanation why several studies have surrogated type of fuel for exposure to IAP. But one more important dimension like time use pattern could be missed out if only fuel is taken as the proxy for exposure.

Table 1: Exposure Weights

Cooking Arrangement Based Relative Intensity Weights				
Kitchen Type	Indoor Time			
	Cooking			
	Clean Fuel		Dirty Fuel	
Outdoor	0.4		1.1	
Separate	0.4		1.1	
Living room	0.5		1.5	
Age-Sex-Time use Based Relative Vulnerability Weights				
AdultMale	**AdultFemale**	**Old Male**	**Old Female**	**Children**
1.0	1.0	1.8	1.2	1.6

Source: Constructed by extracting information from different sources.

DATA ANALYSIS AND RESULT

Fuel Collection Time

Table 2: Fuel Collection Frequency and Time

	Adult Women (%)	Median Fuel Collection Time Per Trip (Woman)	Adult Men (%)	Median Fuel Collection Time Per Trip (Man)	Girls Under 15 Years of Age (%)	Median Fuel Collection Time Per Trip (girl)	Boys Under 15 Years of age (%)	Median Fuel Collection Time Per Trip (boy)
Daily	21.65	2 hours	10.79	2 hours	18.73	2 hours	19.27	2 hours
Weekly	52.73		49.29		44.32		41.71	
Monthly	13.94		22.71		21.38		20.11	

Source: Author's calculation

This work attempts to study the frequency at which people go for fuel collection and the total time spent for this purpose per trip. This is shown in table 2. It shows that weekly trip has the highest frequency for all the groups followed by a daily one. Adult women are a more frequent traveler than any other group studied. The average time spent on per trip is at least 120 minutes i.e., two hours. As the distribution of the total time spent on the trip is skewed in all cases, the median has been taken as the appropriate average. As most of the population travel weekly and it takes 2 hours per trip, it can be said that they spend monthly 8 hours for this purpose. It is interesting to note that 21.7% of adult women and around 19% of girls and boys under the age of 15 spend 2 hours daily for fuel collection. For the children under age 15, this time can be used for the purpose of education. For adult women, the time can be utilized in some other production activities. The timely and adequate supply of fuel at the demand end may reduce this unproductive utilization of time. Education and income generating activities during this time have a long-term impact on the standard of living.

Fuel Use and other Cooking Environments

Table 3 shows that 63.37% of the total surveyed individuals use firewood and 47.42% use LPG for cooking. Around 60% of the population use clean fuels. The table shows reveal that there exists a combination of fuel used by the individuals.

Table 3: Use of Different Fuels for Cooking by Individuals (%)

Type of Fuel	% of Population Using Mainly for Cooking
Firewood/twigs	63.37
Crop residue	20.86
Coal/Charcoal	3.45
Dung cake	41.64
Kerosene	12.63
LPG	47.42

Source: Author's calculation

The type of fuel used in cooking is the primary responsible factor for IAP. However, the extent of exposure depends upon the type of stove, location of the kitchen and the ventilation. The kitchen and chulha type are shown in table 4. Table 5 shows the window or ventilation in the cooking area across different kitchen and fuel type. Nearly 42% of the surveyed individuals use traditional chulha without chimney that makes them vulnerable to the smoke emitted. Only 6.62% use improved chulha with chimney. 58.54% of individuals cook in separate kitchens. 22.2% of those who do not have a separate kitchen cook inside the living room. This has a high pollution potential. Table 5 reveals that 50.42% of kitchens without ventilations are inside the living room. Cooking inside the living room creates pollution that affects not only the cook but also others who are present in that room. Higher pollution is created if the living room does not have any window/vent. The situation worsens when the fuel used for cooking is dirty in nature. 65.5% of the kitchens without vent use dirty fuels. The best possible combination is cooking in a separate kitchen with vent and with clean fuel whereas cooking with dirty fuel in the living room without vent compose the worst situation.

Table 4: Cooking Arrangements (%)

Chulah Type	%	Separate Kitchen	%		
Open Fire (three stone)	16.03	Yes	58.54	**No Separate kitchen (%)**	
Traditional chulha without chimney	41.96	No	41.46	Cooking outdoor	19.25
Improved chulha with chimney	6.62			Inside living room	22.21
Other/ not biomass	35.39				

Source: Author's calculation

Table 5: Ventilation of Cooking are Across Kitchen and Fuel Type

Window or Vent in Cooking Area	Separate Kitchen (%)	Cooking Inside the Living Room (%)	Total (%)
No	49.58	50.42	100
Yes	82.87	17.13	100
	Dirty Fuel (%)	**Clean Fuel (%)**	**Total (%)**
No	65.49	34.51	100
Yes	30.65	69.35	100

Source: Author's calculation

IAP Induced Morbidity

The data reveal that 16.7% of the total individuals studied in this analysis suffer from different kinds of disease which are likely to generate from indoor pollution. It is observed in table 6 that the morbidity related to indoor pollution is highest among the aged (over 60 years) and children. The differences are statistically significant. The females are more affected as they reach the age of 15 and more. As females are more involved in cooking activities, mainly in the age cohorts 15-49, 49-60 and above 60, they suffer most. This is interesting because those who cook in the household generally fall in this age bracket. So, the vulnerability of women for this particular section is higher than males as they are more exposed to the indoor pollutants coming out of the cooking smoke. Children, as carried by the mother and/or be with mother, suffer high. The older is more morbid either due to their vulnerability related to age or due to the fact that they spend most of their time indoor. Females are, in general, more affected. So, the problem is serious for females, especially for this particular age group. 55.24% of the affected people are females.

Table 6: Incidence of IAP Induced Morbidity Across Age Groups and Sexes

IAP Induced Morbidity	Age Group									
	0-5 (%)		5-15 (%)		15-49 (%)		49-60 (%)		Above 60 (%)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Yes	28.45	25.63	14.86	14.18	7.96	13.47	20.66	26.81	32.22	35.51
Total	27.99		14.58		11.00		23.85		33.18	
Male: 14.96%; Female: 18.36%. Among affected: Male:44.76%; Female:55.24%										

Source: Author's calculation

As the females who cook are likely to be more exposed, the fuel type must be an important factor explaining the incidence of IAP borne diseases. Table 7 reveals that the use of clean fuel is higher among those who suffer this ailment. This goes against the claim that fuel type is an important determinant of this illness. Use of fuel depends, among many other factors, upon the affordability and availability and awareness of the user. Here the affordability is measured by MPCE and awareness by education. Table 8 reports the pattern of IAP related morbidity across different MPCE class and education group.

Table 7: Incidence of IAP Induced Morbidity across Fuel Use

IAP Induced Morbidity	Dirty Fuel (%)	Clean Fuel (%)	Total (%)
Yes	45.24	54.76	100
No	46.94	53.06	100

Source: Author's calculation

Table 8: Incidence of IAP Induced Morbidity Across Income and Education

MPCE Class	IAP Induced Diseases (%)
	Yes (row %)
Low	17.30
Middle	16.31
High	16.44
Education Group Wise (row %)	
Not literate	22.93
Below Primary	16.99
Upto Secondary	13.44
Upto Higher Secondary	10.62
Above higher secondary	11.45

Source: Author's calculation

It is observed from the above table that the burden of the disease is mostly borne by low-income class followed by middle-income class. 17.96% of those who earn the least suffer from this ailment. The highest disease burden falls on the illiterate section of the population and it gradually decreases as the education level increases. It directs to the hypothesis that the effect of the indoor air pollution is inversely related to income and education. Regression analysis is done considering these confounders.

Exploratory Data Analysis

Since for linear regression to yield good estimates, we need all variables to conform normal distribution hence, depending on the descriptive measures we check whether the data are reasonably symmetric and, if so, whether the tails are sufficiently thin or not.

The regression is intended to be run taking IAP_disease (binary) as the response variable with *MPCE*, age, *PICK* and *edugroup* as the explanatory variables. Table 9 summarises the linear pairwise correlation among the variables with 5% level of significance. The association of the response variable with almost all the explanatory variables is statistically stronger except MPCE. The sign of association of IAP_disease with ***edugroup and PICK*** conforms our expectation that with the increase in education, awareness rises, households switch from dirty to cleaner fuels and hence suffer less. The exposure to has an expected correlation with IAP related morbidity. More exposure leads to more morbidity and hence the sign is positive. *age* shows a positive association which is not true, in general. As age increases, after a threshold level, resistance and immunity increase and hence probability to fall ill falls. A non-linear structure of MPCE and age are expected to conform the hypothesis.

Table 9: Pair-Wise Correlation

	IAP Induced Morbidity	mpci	age	Edugroup	PICK
IAP induced morbidity	1.0000				
mpce	0.0038	1.0000			
age	0.1080*	0.0954*	1.0000		
edugroup	-0.1159*	0.2184*	0.0179*	1.0000	
PICK	0.0382*	-0.2102*	-0.2631*	-0.2988*	1.0000*

Source: Author's calculation

The variables included in the study are examined in terms of their descriptive statistics This is shown in table 10. If the mean is larger than median then the distributions are positively skewed the opposite would be the case for median exceeding the mean value. The analysis of the Inter Quartile Range (IQR) helps to decide whether the tails of the distribution are thinner or fatter than a regular normal distribution. On the basis of IQR, we estimate a pseudo standard deviation. If this is smaller than the standard deviation then the tails are heavier than normal. Thus, an idea about the required transformation of the data can be formed by comparing mean-based vis-à-vis order-based statistics of the data when one is trying to model an average behavior (Mukherjee, White & Wuyts 1998).

Table 10: Descriptive Statistics

Descriptive Statistics	IAP_Disease	MPCE	age	PICK
Mean	0.17	26509.31	29.69	1.22
Median	0.00	15095	26.00	1.1
Standard Deviation	0.37	47933.88	20.35	0.60
IQR	0.00	21091.68	31.00	1.12
Pseudo SD	0.00	15623.47	22.96	0.83
Skewness	1.78	22.17	0.50	0.30
Kurtosis (Normalized)	1.20	1223.69	-0.45	-0.74
Sample size	168,961	168,961	168,961	168,961
Observations with 0 value	140,803			
Observations with 1 value	28,158			

Source: Author's calculation

In the data set, we have one attribute represented by a dummy variable: IAP_disease along with three quantitative variables: *MPCE*, *age*, and *PICK*. MPCE has a mean value much higher than the median value indicating the presence of positive skewness. Here the value of IQR is very high and pseudo standard deviation is smaller than the standard deviation indicating fat right tail. To reduce the fatness of the tail and get back the mean-centricity of the distribution the higher values of the observations need to be moderated by applying some non-linear transformation technique. Generally, for unimodal positively skewed data set with fat right tail (i.e., outliers at the higher end) logarithmic transformation works well. A log transformation of *MPCE* is taken (*lnMPCE*) here. The box-plot graph is shown for both MPCE and *lnMPCE* in Figure 1 and 2 respectively. This shows the change in distribution after transformation. The outliers in the higher end are managed to a considerable extent after transformation. *The* same exercise has been done for age and PICK. As for both of these variables, mean and median are not far different and the SD and pseudo SD are close with very low skewness and kurtosis measure, no transformation has been tried for them. Box plots of their original form have been shown in figure 3 and 4.

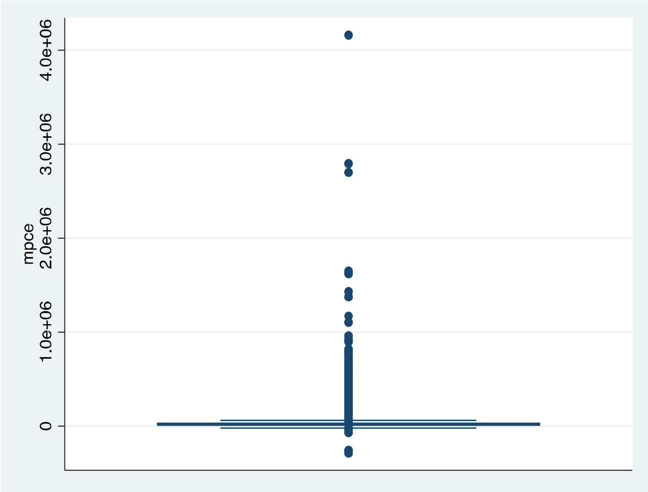

Figure 1: Box Plot of *MPCE*

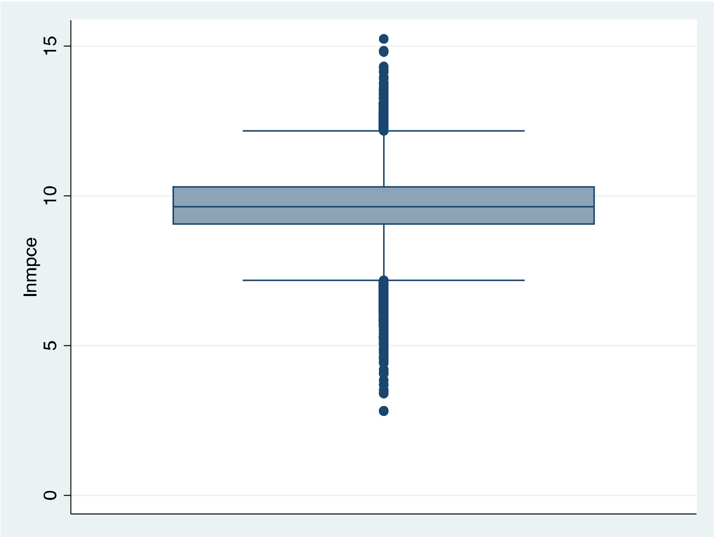

Figure 2: Box-Plot of *Ln MPCE*

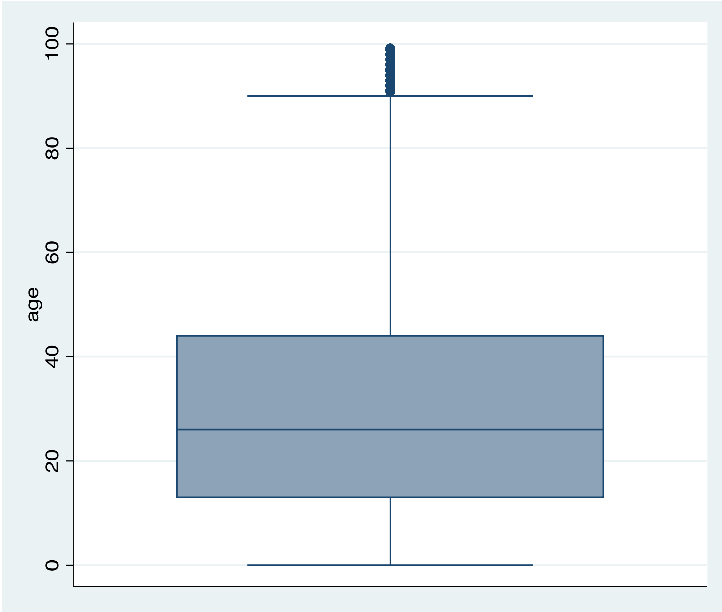

Figure 3: Box-Plot of *Age*

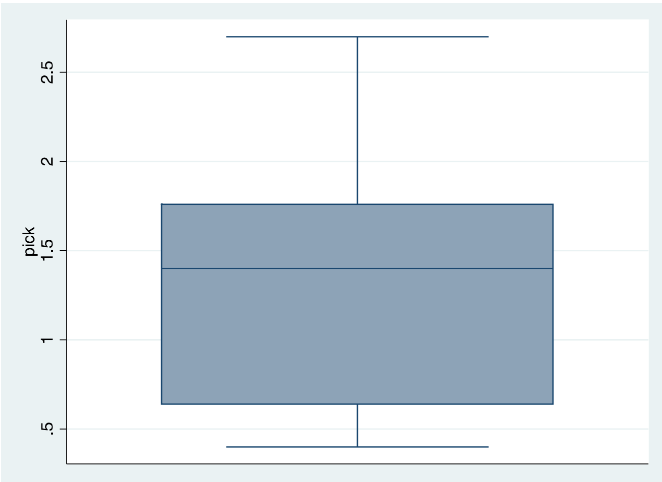

Figure 4: Box-Plot of *PICK*

Regression Analysis and Observations

Five sets of regressions are run with dependent variable IAP_disease. The results are reported in table- 11. From this table, a few observations are in order. The value of LR $\chi^2(k)$ is significant at less than 1% level for all cases making all regressions statistically acceptable. Regressions 1 uses lnMPCE, age and PICK as the independent variables. Since IAP_disease is a dummy variable LOGIT regression is run.

In regression 1 (reported in the table as R_1), all the regressors are coming out to be significant with expected signs. This confirms two of our hypotheses. In the first place this extends the support that the pattern of IAP exposure (PICK) has a significant impact on individual morbidity, the incidence of morbidity increases as the exposure increases, this morbidity depends upon the awareness of the individual captured in terms of education. Coefficients of *edugroup* are reported with reference to the base category. The 'not literate' group has been used as a base for *edugroup*. The regression result is reported in table 11. Sex has been included with the reference category 'male'. This will give the morbidity impact on females. However, some discomfort creeps in as the sign of ***lnMPCE*** and ***age*** is positive and significant. This may be due to the presence of some degree of non-linearity in the actual relationship. That means the effect of improvement in income will be reflected in lower morbidity provided the improvement is substantive, i.e., there may exist some threshold levels of MPCE after which they would be causally effective to lower morbidity. The same thing applies to the ***age*** as well.

To verify this possibility, ***(lnMPCE)***^{2} and ***(age)*** are added as two other regressors. The results are reported under Regression 2. For MPCE the variable has a significant influence on the incidence of morbidity both at level and square with opposite but expected signs. As MPCE increases morbidity decreases up to a certain level but after a threshold level of income, the effect gets reversed. At a moderate level of income, improvement in expenditure leads to better health status. However, at a very high level of income due to change in lifestyle and change in health-perception the reported morbidity may increase with further enhancement of income. Similarly, more age of the individual in the initial level leads to a reduction in the morbidity as resistance increases and vulnerability goes down with age. But, after a threshold reported morbidity goes up with the onset of age-related complications. With the introduction of additional regressors to account for these nonlinearities expected significant signs have been obtained for both the MPCE and age variables. This is shown in regression 2 (R_2). Here also the sign of education is negative and significant confirming the strategic need of spreading awareness to combat IAP.

Next, we have carried out regression exercises for males only (R_3), females only (R_4) and children only (R_5). For R_3, the *MPCE* and *age* show the same effect as R_1 and R_2. But it is interesting to note that the exposure index (PICK) is not significant in explaining the morbidity. Regression 4 (R_4) reports the results when only females are taken into account. There are two notable differences from R_3 that deserve attention. Exposure is coming significant here indicating the claim that females are worse victims of IAP. MPCE in the level is not a significant factor for females as the household income does not always ensure better health for the females. Rather, it involves an intra-household power relationship that impacts a decision on the adoption of pollution mitigating measures. Women, in many cases, do not possess much voice and holding in the household that helps them to secure the position required for gaining importance. So, they are more exposed, more vulnerable and more affected. R_5 reports the impact of the explanatory variables on child IAP related morbidity. Here the study fails to conclude that exposure leads to higher morbidity for this age group, but literature and related theories claim differently. The possible explanation lies in the definition of IAP related diseases. The diseases considered here include cataract, high blood pressure, heart disease, apart from the respiratory distress. These are not common in case of children and hence this work fails to find the hypothesized relation. Whether the children are carried by the mothers at the time of cooking or there are some other arrangements for them is also important to study. This is beyond the scope of the present study.

Indoor air pollution is the best estimated when the indoor air quality is measured with an appropriate device. This would provide an accurate amount of the harmful pollutants in different micro-environments inside the house. In the absence of such a measure, the study is limited and uses only surrogate measures for the pollution. As the indoor smoke contains not only pollutants from cooking hearth but also those come out from lighting and smoking inside the house, it may be misleading to consider only cooking smoke responsible for the diseases occurred. The study can be extended incorporating that aspect. A living condition such as house structure, latrine type, drainage type, and drinking water may be included in the analysis as these are also potential factors that may affect the health. So controlling for these factors may improve the result. More refinement is possible also by exploring the relationship for different quantiles of income and education as the intra-household factors like decision taking, taste, and preferences, customs may vary with these variables as well as with various demographic factors.

Table 11: Regression Results

Regressors & Diagnostics Values	Dependent Variable: IAP Induced Morbidity					
		R_1	R_2	R_3	R_4	R_5
				Male only	Female only	Children only
lnMPCE		0.083***	-0.276***	-0.364***	-0.147	0.086
sqlnMPCE			0.017***	0.019***	0.010**	-0.007
age		0.014***	-0.032***	-0.059***	-0.012***	0.111**
sqage			0.001***	0.001***	0.0003***	-0.055***
edugroup; Reference category:Not literate	Below Primary	-0.238***	-0.200***	-0.219***	-0.136***	--
	Upto Secondary	-0.567***	-0.377***	-0.352***	-0.330***	--
	Upto Higher Secondary	-0.783***	-0.565***	-0.438***	-0.605***	--
	More than higher secondary	-0.733***	-0.542***	-0.381***	-0.636***	--
PICK		0.252***	0.0719***	0.018	0.029*	0.042
Sex (reference:Male)		0.166***	0.195***	--	--	--
Constant		-2.912***	0.317	0.599	-1.041**	-1.022
LR χ^2(k)		4822.66***	6441.09***	3874.80***	2745.23***	111.48***

Source: Author's calculation

CONCLUSIONS

The analysis has been successful to establish the primary hypothesis i.e. it confirms a relation between morbidity and IAP exposure at the individual level. Some other factors also have been located that have significant impacts on this morbidity. Factors identified were household income, education and obviously the pollution exposure. Exposure, in turn, depends on fuel type, ventilation in the kitchen, occupation type, age and sex of the victims and the ambient pollution concentration. Now, except the age and sex of the individual, all other factors are equally important as an effective policy target. Fuels used in the household and kitchen type are household decisions altogether whereas education is related to public policy. Income is not a very effective policy target as it relates to much broader aspects like overall growth and development of the nation as a whole. So, the design of an effective intervention strategy is a complex issue in this context.

At the first hand, it is very difficult to improve the household factors. It involves household taste and preferences, culture and belief and some age-old habits. If the change of fuel type is targeted through a proper subsidization scheme the effect may not be as satisfactory as expected. Complete fuel switching generally does not occur even when households move up in the income ladder. Multiple fuel choice has been identified by many studies as the revealed household decision that rejects the energy-ladder hypothesis. Because the household maintains a portfolio of energy sources fuel stacking has become a common practice as opposed to the concept of fuel switching. Studies are there that mention even when households have sufficient income to purchase clean fuels they stick to traditional fuels which are collected free or available at fewer prices. So, subsidization may not work well as a strategic policy measure, though somewhere it ended up with excellent success (Schlag and Zuzarte, 2008).

Moreover, even if it is possible to change the fuel at the household, the efficiency of the fuel depends upon the type of cooking hearth the household is using. For that, Improved Cookstove (ICS) Program has been considered as an important policy strategy suggested by many literature. The RESPIRE study in Guatemala is an excellent example of the success of such intervention. In India also Improved Stove Program has been attempted but success was limited because of various social and physical factors that hindered the use of these stoves altogether. The performance of these stoves depends strongly on the maintenance of the stoves. Performances vary across actual conditions of use. Moreover, there are some traditional and cultural practices within the household regarding the use of fire, cooking habits, etc. that restricts the use of such stoves. So behavioral factors become all important in the context of such interventions.

The problem of IAP can be handled from the point of bringing effective change in the living condition such as change in the in-house ventilation system through installation of exhaust fans, making an arrangement for building partitions in homes to separate cooking and sleeping areas, improvement in the subsidiary living condition parameters like drainage, latrine and house structure that have a secondary effect on IAP related morbidity through altering the congested structure of the urban houses, especially slums. But part of this is again a matter of household choice and part comes under public domain. In fact, changing the living condition needs an improved and broad long-run planning from the grass root level and also related to the socio-political environment of the nation. In fact, it has been shown in Dutta (2008) that the exposure burden of female, elderly and infants in slums of Kolkata has gone down significantly between 1991 and 2001 due to the successful implementation of National Slum Development Program (NSDP). But it is impossible to change the living environment overnight. Any such policy to mitigate the IAP problem takes a considerable time to be implemented. So, this cannot be an attractive policy variable at all.

The behavioral pattern of the household members is all important in the context of effective policy design. It is after all the household decision (either a sole choice of the household head herself or a decision was taken jointly within the household) that matters for any policy suggestion to be realized at the household level. So, alteration of the behavioral pattern on the part of the household should be the first priority of any strategic intervention program. Any behavioral change depends upon the awareness of the individuals, especially of the victims and of the main decision taker in the household. This awareness can be improved through proper educational training right from the primary level of schooling. As we have obtained in our analysis that educational attainment has been always important under all circumstances, a mere literacy may not be sufficient for the realization of required improvement in the health. Education up to primary level or even more is necessary to conceptualize the hazardous effects of indoor air pollution on the morbidity level of the household. A targeted training program on health and hygiene at the school level may work well in this context. Since the educational policy is a state subject and does not depend much on the household decision it should be the first priority to be pinned on. A planned and well-designed educational policy, with special attention to health and hygiene, may hold the problem at its root and an overall change in the fuel use pattern, living condition and the behavior of the victims could be brought forward as an immediate outcome.

Since IAP depends on many correlated factors it cannot be treated as an isolated objective. No single policy instrument exists for proper mitigation of the problem, rather a comprehensive policy package needs to be designed to combat the menace in all respect. Any policy that improves the overall living condition of the individual and has some income generating implications may not target the reduction of IAP directly, but when income and other conditions improve representative household moved up in the energy ladder and go for a cleaner fuel choice. Awareness about adverse health outcomes of pollution exposure goes up and the affordability of safer sources of fuel increases. The combined effect leads to a reduction in the exposure burden of the most vulnerable group, women, children and also the elderly and unemployed. But all these programs need a long period of time to be implemented. This is an eventual policy instrument to be effective in the long run.

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