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A Comparative Analysis of Indoor Air Pollution due to Domestic Fuel Used in Rural and Urban Households: a case study

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Abstract

Although indoor air pollution from domestic fuel use in the households is estimated to be one of the main health risks worldwide but there is little knowledge of the actual exposure experienced by large populations. Available findings indicate that indoor air pollution from household cooking and space heating apparently causes considerable ill-health and the majority of households rely on solid biomass fuels (coal or biomass as wood, crop residues, and dung).

Present investigation was undertaken to asses the status of indoor air quality of rural and urban households. The study revealed that the use of gas and electricity was more prevalent in urban households while mostly the rural households were found dependent on traditional biomass fuels. The analysis revealed that educational level, occupational status is directly related with the choice of type of domestic fuel. The monitoring of indoor air pollutant revealed that the concentration of pollutants were very much higher during cooking hours as compared to non-cooking hours and the concentration of pollutant emissions from biomass fuel was also very much higher compared to the emissions from LPG. Due to rigorous exposure to these indoor toxic pollutants the rural women were found suffering from instant and short term problems, respiratory infections, adverse pregnancy outcomes, eye related problems and diseases, severe ulcers/cancers etc in higher percentages as compared to urban women who were mostly found using modern fuels for cooking except for the lower income strata.

Keywords: *Domestic fuel, air pollution, biomass fuel, chulha, ventilation particulate matter*

Introduction

Indoor air pollution from solid fuel used in the households of developing countries is estimated to be one of the main health risks worldwide but there is little knowledge of actual exposure experienced by large populations. On a national basis it is found that 80 to 90 per cent of exposure in the rural population results from indoor air pollution. For the urban population the contribution is somewhat lower, about 50 to 60 per cent (Mondal, et al, 2011). In India indoor air pollution studies has so far been neglected although the estimates reveals that 96 per cent particulate matter, 88 per cent of volatile organic, 88 per cent of volatile organic compounds and emissions, 82 per cent of sulphur dioxide, 38 per cent of nitrogen dioxide in the country come from the household sector (Parikh, 1999).

Nearly 75 per cent of Indian households use solid fuels (primarily firewood and cow dung), including up to 90 per cent of households in some rural areas. Nearly three fourth of the Indian households (including 3 out of 10 urban households and 8 out of 10 rural households) use open fires or *chulhas* without chimneys (NFHS-3, 2007). Marked socioeconomic differences (indicated by income level, women's education, awareness) exists in both rural and urban areas. Generally the poor are the main sufferers of indoor air pollution because they rely predominantly on biomass fuels using simple stoves or *chulhas* or open fires, often without chimneys, flues or appropriate ventilation devices. Findings asserts the rule of 1000 which states that a pollutant released indoors is one thousand times more likely to reach people's lung than a pollutant released outdoors (WHO, 1997).

Compared with other countries, India has among the largest burden of disease due to the use of dirty household fuels and 28% of all deaths due to indoor air pollution in developing countries occurs in India. An estimated 400,000 deaths from acute lower respiratory infections (ALRI) in children < 5 years of age and 34,000 deaths from chronic obstructive pulmonary disease (COPD) in women are attributed annually to indoor air pollution (Smith 2009; Smith et al. 2004). Several Indian studies have revealed systematic reviews of associations between exposure to solid fuel smoke and ALRI (Dherani et al. 2008), low birth weight (Pope et al. 2010), and COPD (Kurmi et al. 2010), available quantitative exposure information has not been integrated into studies of health outcomes in India. In addition, limited evaluations of improved biomass stoves have shown that exposures still exceed WHO AQG guidelines and that the feasibility of sustained use is uncertain. Large data sets on indoor air quality measurements in solid fuel using households in India [International Agency for Research on Cancer (IARC) 2010] have been used to examine temporal, spatial, and multipollutant exposure patterns and to identify household level determinants and indicators of exposure (Balakrishnan et al. 2004). Data from rural indoor settings provide unequivocal evidence of extreme exposures that often are 15 to 30 times higher than WHO AQG recommendations. Recognizing the significance of modern energy services for sustainable development the United Nations declared 2012 as "International Year of Sustainable Energy for All" in which the UN resolutions calls to "increase awareness of the importance of addressing energy issues, including access to modern energy for all, access to affordable energy, energy efficiency and the sustainability of energy sources and use" at local, national, regional and international levels (Yojna, April 2012). Under these circumstances the present investigation was carried out in order to establish a relationship between income, education and occupation level, awareness, type of fuel used and associated indoor air quality among the rural and urban households. Aligarh city (27°53'N latitudes and 78°4'E longitudes) and its adjoining rural areas located in the fertile Ganga- Yamuna *doab* (inter-riverine plain), in the western part of the state of Uttar Pradesh in North India was selected as the study area. Indepth investigations were conducted in the different income rural and urban households to assess the differential environmental and health outcomes due to indoor air pollution.

Data base and Methodology

The study is mainly based on primary sources of data which were collected through household surveys from rural and urban areas with the help of questionnaire interviews. Field work was conducted during the years 2010 and 2011. The following methods were adopted for the study (Jamal, 2012),

i. For the purpose of selecting the sample, five hundred households from each location (rural and urban) belonging to different income strata (50 households of each income category ranging from Rs. <2000, 2000-4000, 4001-6000, 6001-8000, 8001-10,000, 10,001-12,000, 12,001-14,000, 14,001-16,000, 16,001-18000, >18,000) were sampled. The total sample size consisted of 1000 households. From each household woman respondents actively engaged in household/cooking work were chosen. Information regarding the socio-economic characteristics, domestic fuels used for cooking and indoor air quality were collected.

ii. Indoor air pollutants were monitored in 5 per cent households of the total sample (1000) in different cooking places (in separate kitchen with ventilation, separate kitchen without ventilation, in multipurpose room, in *verandah* and in open air) using different domestic cooking fuels (traditional/biomass fuels, modern/ LPG) to diagnose the indoor air quality. For the purpose of monitoring of SPM (PM_{10}, $PM_{2.5}$), a handy sampler "Portable GRIMM Dust Monitor Series 1.109" and for monitoring gaseous pollutants (CO_2, CO, SO_2, NO, NO_2) "YES-206" and "YES-205" handy samplers were used.

iii. Data regarding the health conditions associated to indoor air pollution was collected through (i) personal interviews with the help of the questionnaire and (ii) from the records of the Out Patient Departments of Jawahar Lal Nehru Medical College Hospital, Malkhan Singh Government Hospital, Mohan Lal Gautam Women's Government Hospital and various private doctors clinics.

Results and Discussions

Socioeconomic profile of the sampled households

Women are regarded as household managers. An educated woman, who has broader outlook, will have better awareness about every thing. In this case she is aware of the ill effects of indoor air pollution and can sustain her family in a healthier way. Higher level of education opens the door for better employment opportunities for women, who also contribute to the family income. Higher income will help towards better access to nutrition, housing, basic services, use of clean fuels, health services etc. It can be said higher the level of education of the women, greater is the possibility of accepting modern values in changing socio-economic milieu (Sudha, 2000).

A perusal of table 1 shows that of the total sampled rural women respondents, 62 per cent were uneducated and 38 percent were educated (26 per cent were educated up to primary level, 25 per cent up to secondary, 19 percent up to high school, 15 per cent up to intermediate, 7 per cent up to graduation, 5 per cent up to post graduation and rest 2 per cent had professional education). The urban picture was somewhat different as of the total sampled urban women respondents, 36 per cent were uneducated and 64 percent were educated (22 per cent were educated up to intermediate, 20 per cent up to graduation, 14 percent up to high school, 13 per cent upto post graduation, 12 per cent up to secondary, 10 per cent up to primary, and rest 9 per cent had professional education).

Table 1: Educational status of the sampled rural and urban women respondents

Households (500-rural; 500-urban)	Educational status								
	Educated	Uneducated	Educational level						
			P	S	HS	IM	G	PG	Pro.
Rural	37.8	62.2	26.98	24.86	18.51	15.34	6.87	5.29	1.58
Urban	64.4	35.6	9.62	11.80	14.28	22.04	19.87	13.35	9.00

Source: Based on field survey, 2010-11

Regarding the occupational status of the earning members of the sampled households, table 2 shows that of the total sampled rural households, nearly 37 per cent were engaged in agriculture, 21 per cent in business activities like they had confectionary shops, grocery shops, embroidery and tailoring shops etc, 21 per cent were engaged in cattle rearing, 15 per cent were labourers and 5 per cent were earning from government and private jobs. While of the total sampled urban households, nearly 63 per cent were engaged in business, 25 per cent were earning from government and private jobs as advocates, doctors/engineers, teachers etc), 8 per cent were working as labourers and nearly 4 per cent were engaged agricultural and cattle rearing activities.

Table 2: Occupational status of the sampled rural and urban households

Households (500-rural; 500-urban)	Occupational status				
	Agriculture	Cattle rearing	Labourers	Business	Gov.jobs/Private jobs
Rural	36.6	21.00	15.00	21.2	5.00
Urban	2.4	1.8	7.6	63.00	25.2

Source: Based on field survey, 2010-11

The quality of housing is exhibited by the material used for its construction. If the whole house including walls and roofs are made of *pucca* material (brick, concrete, tiles, asbestos) then it is classified as *pucca* house while the houses made of *kutcha* material (mud, grass, thatches, bamboos, leaves etc.) are classified as *kutcha* house and those made by using both *kutcha* and *pucca* material comes under the category of semi - *pucca* housing. The built materials used in *kutcha*/semi-*pucca* houses absorbs the smoke and other pollutants emitted from cooking fuels for longer period increasing the exposure duration of the individuals living in the house thus posing severe health risks. A perusal of table 3 shows the distribution of sampled households according to the type of house. Of the total sampled rural households, most of the houses were semi-*pucca* (57 per cent), nearly one fourth were *kutcha* and few were *pucca* houses (18 per cent) while of the total sampled urban households, most of the houses were *pucca* (54 per cent) and semi-*pucca* and few were *kutchaa* houses (11 per cent).

Ventilation is one of the important processes in determining the quality of indoor air and is a complex process that results in supply/removal of air from inside a closed structure. When the processes of ventilation are faulty or improper, the indoor

Table 3: Housing condition of the sampled rural and urban households

Households (500-rural; 500-urban)	Housing type			Ventilation facility		Kitchen facility			
	Kutcha	*Pucca*	Semi-*pucca*	Proper	Improper	Separate kitchen	*verandah*	Multipur-pose oom	Open air
Rural	24.8	17.8	57.4	34.4	65.6	19.6	30.6	27.6	22.2
Urban	10.6	53.8	35.6	56.2	43.8	51.8	29.6	13.00	5.6

Source: Based on field survey, 2010-11

air quality falls and becomes unhealthy. Indoor air pollution has been identified as a major health risk which is highly associated with poor ventilation. Nearly 66 per cent of the sampled rural households and 44 per cent of the sampled urban households reported of improper ventilation facility in their houses.

Of the total sampled rural women respondents, about 31 per cent reported of cooking in *verandah* mostly having thatched roof, 28 per cent reported of cooking in multipurpose room, 22 per cent in open air and only 20 per cent were having separate kitchen facility while of the total sampled urban women respondents, nearly 52 per cent reported of having separate kitchen facility, 30 per cent were cooking in *verandah,* 13 per cent reported of cooking in multipurpose room and 6 per cent in open air.

The over all analysis revealed that the educational and occupational status and housing condition in urban area is much better than in the rural area. The conditions directly or indirectly affect the fuel choice and status of indoor air pollution affecting indoor air quality.

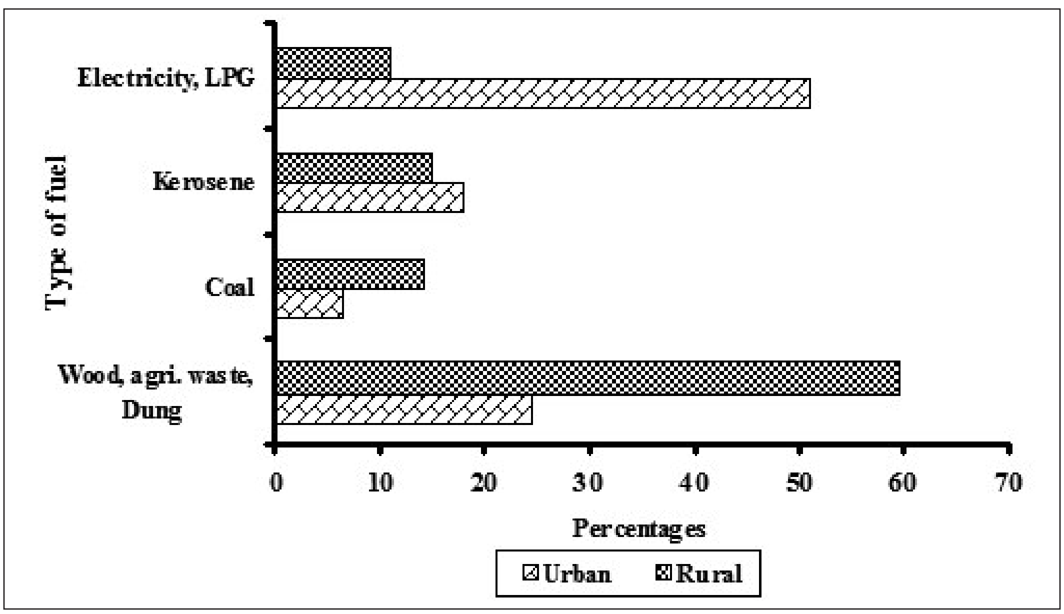

Fig. 1: Primary household fuel used in urban and rural areas

Primary household fuel used and its relation with income level in rural and urban households

The types of fuel used by both rural and urban households are wood, agricultural waste, dung, coal, kerosene, LPG, electricity. Fig. 1 reveals that 91 per cent rural households reported of using traditional fuels (wood, agricultural waste, dung, coal, kerosene) where as 41 per cent of urban households reported of using modern (LPG, electricity) fuels. The use of kerosene is more pronounced in urban areas because the urban population is more aware of subsidies on kerosene provided by government through BPL cards while the use of wood, agricultural residues and dung is more pronounced in rural areas because of availability. The traditional fuel emits many health damaging pollutants including particulate matter, carbon monoxide, oxides of nitrogen, sulphur dioxide, aldehydes, benzene, and polyaromatic compounds (Smith, 1987). The analysis revealed that the use of modern fuel is more prevalent in urban households as compared to the rural households.

Over the last 25 years, the trend in global bio fuel use has changed a little and in some parts of the World where poverty and prices of alternative fuels such as kerosene and bottled gas has increased, the use of biomass fuel has increased (WHO, 1997). A wide variation in use of type of cooking fuel and stoves is also spectacular in different income strata due to which level of exposure also varies which has been specified by the number of researchers using the energy ladder model (Baldwin, 1986; Hosier & Dowd, 1988; Smith, 1987; Leach, 1992). The energy ladder model has been derived from the empirical evidence so-called modern fuels are increasingly used as household income increases in urban areas but it is not the case with rural areas. However, the fuel choice by the households is influenced by the income, educational status, awareness and the occupation of the household members (Rao & Reddy 2007). Preferences for switching include convenience in obtaining, storing, and using the fuels (cleanliness, versatility and a large and easily controlled range of power output) (Leach, 1988) and lower fuel costs (Reddy & Reddy, 1994). Here in this household survey, 50 households of each income strata (ranging from less than Rs. 2000 to more than Rs.18000) from rural (500 households) and urban areas (500 households) were sampled to find out the traditional cooking fuel prevalence.

Fig. 2 reveals that in the urban households, use of traditional biomass fuel decreases with increase of income and in rural areas the same situation is observed but to a very modest extent and the use of biomass fuels prevails in higher income strata also, as most of households were practicing agriculture, cattle rearing, working as labourers and as businessman. Thus, the easy availability of agricultural residues, wood, dung remains one of the principal factors for choice of traditional biomass fuel and the other factors like education, occupation, awareness are the important determinants of type of fuel used. Survey reveals that the educational status leading to awareness, occupational status of the rural people are of low level as compared to urban areas and in addition their is easy availability of biomass fuels. The rural households having high and affordable income to use modern fuels also depends on traditional biomass fuel

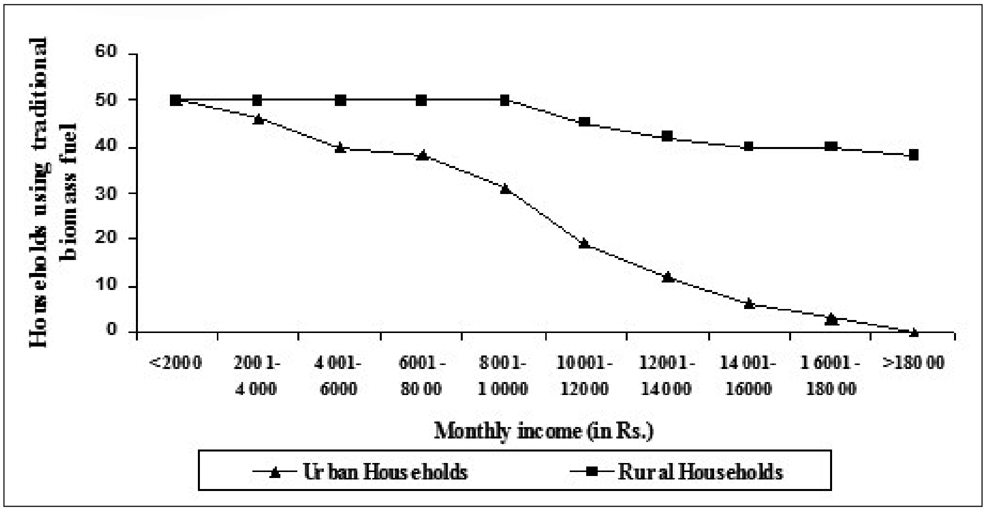

Fig. 2: Type of fuel used and its relation with income level

because lack of awareness, attitude of negligence for women and sometimes due to inaccessibility to modern fuels. All these factors lead to prevalence of biomass fuels in rural households while the educational and occupational status of urban households are much better and there is easy availability and accessibility to modern fuels leading to cleaner fuel choice.

Concentration of indoor air pollutants from different types of cooking fuel

Of the total sample, in about 5 per cent household's concentration of indoor air pollutants was monitored. An attempt was made to measure the suspended particulate matter and the gaseous pollutants emitted from different types of cooking fuel in different cooking locations. Among the pollutants released during combustion of domestic fuels the suspended particulate matter is the most important one, particularly the small particles of less than 10 microns (i.e PM_{10}, $PM_{2.5}$) poses greater threat to health as they are capable of penetrating deep into lungs. The other toxic pollutants include carbon monoxide, nitrous oxides, sulphur oxides, polycyclic organic matters including benzo [a] pyrene etc.

Table 4 illustrates the concentration of suspended particulate matter released from (i) using biomass and (ii) using LPG as cooking fuels. It exhibits that the emission of particulate matter (PM_{10}, $PM_{2..5}$) were found low in LPG compared to traditional fuels but in both cases the emissions are higher during cooking process rather than before cooking. Particulate concentrations were recorded higher in *chulha* placed in verandah, separate kitchen with ventilation and kitchen in the verandah because of outdoor environmental effects. All the average concentration, peak values were recorded higher during the cooking process.

Table 5 illustrates gaseous air pollutant near cooking places in working hours using traditional (biomass) and modern fuel (LPG). Of this the maximum value of CO (7.3 ppm), CO_2 (676 ppm), SO_2 (0.15 ppm), NO (0.16), NO_2 (0.06) were recorded

Table 4: Average daily concentration of SPM before and during cooking around cooking places

(i)Using biomass fuel for cooking

Concentation of SPM (µgm-3) before and after cooking around cooking place				
Time 30 minutes before cooking	Chulha in verandah		Chulha in open space	
	PM-10	PM-2.5	PM-10	PM-2.5
Average	162.98	78.27	248.97	187.85
Maximum	256.30	133.60	384.30	259.70
Minimum	79.90	41.20	123.30	112.30
2 hours during cooking				
Average	264.810	128.18	380.90	249.35
Maximum	523.50	265.20	685.30	451.50
Minimum	133.50	68.90	264.10	165.30

(ii) Using LPG for cooking

Concentation of SPM (µgm-3) before and after cooking around cooking place								
	Separate kitchen without ventilation		Separate kitchen with ventilation		Kitchen in verandah		Kitchen in multipurpose room	
Time 30 minutes before cooking	PM-10	PM-2.5	PM-10	PM-2.5	PM-10	PM-2.5	PM-10	PM-2.5
Average	93.70	45.95	83.63	53.82	113.32	74.43	80.80	41.08
Maximum	112.10	47.70	140.50	121.50	125.50	92.90	141.20	47.70
Minimum	79.50	44.10	33.40	20.40	102.70	54.80	54.80	33.5
2 hours during cooking								
Average	112.94	54.65	122.91	67.09	167.70	111.14	118.08	50.94
Maximum	248.10	124.70	411.20	146.20	378.80	276.40	235.60	81.00
Minimum	64.80	38.60	34.30	21.20	105.20	68.90	57.00	38.90

Source: Based on field survey, 2011

for biomass emission while CO (1.7 ppm), CO_2 (556 ppm), SO_2 (0.06 ppm), NO (0.07), NO_2 (0.04) were recorded for LPG emission. These maximum concentrations of gaseous pollutants were recorded during cooking hours while the minimum concentration were recorded either before or after cooking hours.

The above analysis revealed that the concentration of indoor air pollutants was very much higher in biomass emissions compared to LPG emissions and as most of the houses in rural areas are dependent on traditional biomass fuels and thus they suffer from shoddier indoor air quality.

Health impacts of indoor air pollution

Exposure to indoor air pollution plays an important role in poor health outcomes. Table 6 and fig.3 shows that the rural women were suffering from the various health problems more than the urban women. Of the total sampled rural women 82 per cent reported of instant problems, 75 per cent of

Table 5: Variation in concentration of gaseous pollutants during working hours

(i) Including cooking hours using biomass fuel for cooking

Time (working hour uration)	Concentration of gaseous pollutants (in ppm)				
	CO	CO2	SO2	NO	NO2
6:30-7:30	1.5	348	0.01	0.04	0.03
7:30-8:30	6.91	593	0.12	0.16	0.06
8:30-9:30	3.83	456	0.13	0.13	0.03
9:30-10:30	1.9	664	0.09	0.07	0.02
10:30-11:30	1.13	659	0.03	0.06	0.01
11:30-12:30	0.8	480	0.05	0.03	0
12:30-13:30	0.5	343	0.02	0.02	0
13:30-14:30	0.4	321	0.01	0.01	0.01
14:30-15:30	0.21	289	0.01	0.05	0.02
15:30-16:30	3.11	543	0	0.09	0.03
16:30-17:30	4.15	676	0.1	0.11	0.02
17:30-18:30	7.3	532	0.15	0.14	0.04
Average	2.65	492.00	0.06	0.08	0.02
Maximum	7.3	676	0.15	0.16	0.06
Minimum	0.21	289	0.00	0.01	0.00

(ii) Including cooking hours using LPG fuel for cooking

Time (working hour duration	Concentration of gaseous pollutants (in ppm)				
	CO	CO2	SO2	NO	NO2
6:30-7:30	0.7	234	0.01	0.02	0.01
7:30-8:30	1.7	487	0.00	0.05	0.02
8:30-9:30	1.4	450	0.04	0.04	0.03
9:30-10:30	0.8	386	0.06	0.06	0.01
10:30-11:30	0.8	376	0.03	0.03	0.04
11:30-12:30	1.3	459	0.03	0.01	0.01
12:30-13:30	1.1	354	0	0.02	0.00
13:30-14:30	0.4	345	0.01	0.01	0.00
14:30-15:30	0.2	298	0.01	0.03	0.00
15:30-16:30	0.3	273	0.01	0.03	0.01
16:30-17:30	0.3	378	0.02	0.05	0.02
17:30-18:30	1.1	512	0.03	0.07	0.04
18:30-19:30	1.7	556	0.05	0.05	0.03
19:30-20:30	0.6	432	0.04	0.03	0.01
Average	0.89	395.71	0.02	0.04	0.02
Maximum	1.7	556	0.06	0.07	0.04
Minimum	0.2	234	0.00	0.01	0.00

Source: Based on field survey, 2011

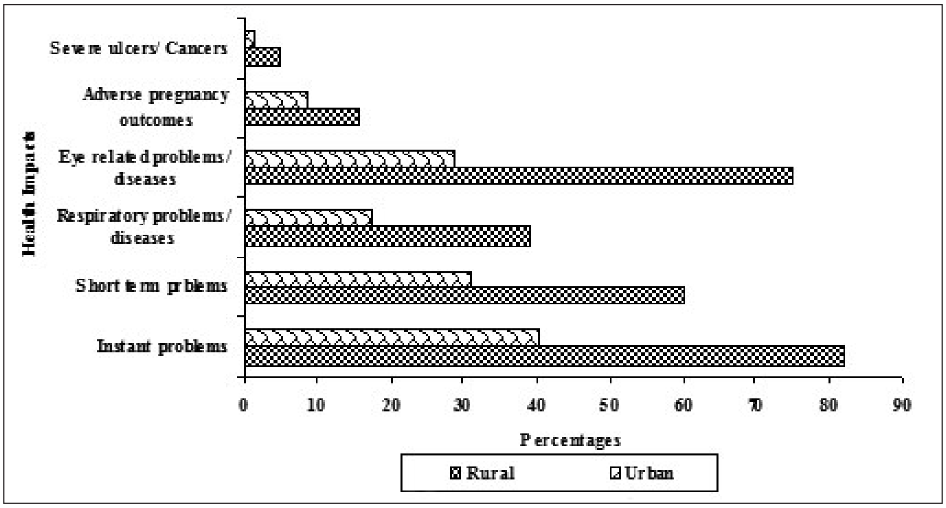

Fig. 3: Differential health outcomes associated to indoor air pollution in rural and urban women

Table 6: Differential health outcomes associated to indoor air pollution in rural and urban women

Health Impacts	Types	Rural	Urban
Instant problems	Cough, eye irritation and watering, skin burns etc.	82.00	40.40
Short term problems	Headache, Shoulder ache, backache, skin irritation, dizziness, wheezing, mood problems, others	60.2	31.20
Respiratory problems/ diseases	Acute lower respiratory infection Acute upper respiratory infection Asthma Tuberculosis	39.00	17.20
Eye related problems/ diseases	Watering of eyes, weak eye sight, cataract, others	74.8	28.80
Adverse pregnancy outcomes	Infant mortality, low birth weight, still birth, others	15.6	8.80
Severe ulcers/Cancers	Skin, nasal, larynx, pharynx, others	4.8	1.40

Source: Based on field survey, 2011

eye related problems and diseases, 60 per cent of short term problems, 39 per cent of respiratory problems/diseases, 16 per cent of adverse pregnancy outcomes and nearly 5 per cent of severe ulcers and cancers (5 per cent)). Of the total sampled urban women, 40 per cent reported of instant problems, 31 per cent of short term problems, 29 per cent of eye related problems and diseases, 17 per cent of respiratory problems/diseases, 9 per cent of adverse pregnancy outcomes, 1 per cent of severe ulcers and cancers (table 6).

Conclusion

From the entire study it has been found that most of the rural families were living in substandard dwellings (*kutcha* and semi-*pucca* housing without proper ventilation and separate kitchen facility) and were using traditional biomass fuels for cooking. The monitoring of indoor air pollutant revealed that the concentration of pollutants were very much higher during cooking hours as compared to non-cooking hours and the concentration of pollutant emissions from biomass fuel was also very much higher compared to the emissions from LPG. Due to rigorous exposure to these indoor toxic pollutants the rural women were found suffering from instant and short term problems, respiratory infections, adverse pregnancy outcomes, eye related problems and diseases, severe ulcers/cancers etc in higher percentages as compared to urban women who were mostly found using modern fuels for cooking except for the lower income strata.

If we view energy access from development perspective, adequate supply of energy at affordable price is indispensable for economic growth and social development as well as empowerment of weaker sections of society, particularly women in rural areas through proper educational and occupational opportunity will help out to combat with existing situation. Finally, it is strongly recommended that education, quality occupation, awareness about the ill health effects of indoor air pollution, increase in income leading to affordability and standard dwellings, availability, accessibility, government indoor air pollution oriented programmes through subsidies will lead to cleaner fuel choice in rural households while the increase in income and mass awareness can reduce indoor air pollution in low income urban households.

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