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Assessing the indoor air pollution level as per energy ladder and its effect on respiratory health

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ABSTRACT

In rural areas of developing countries, where about 40 % of all people live, the household stove accounts for more of all national fuel combustion occur under cooking pots. The present study was undertaken in Hisar district of Haryana state to assess the indoor air pollution level as per the energy ladder and its effect on respiratory health. The study was conducted in the rural villages of Hisar district and rural women who were using traditional chullah were selected as the sample of the study. Results revealed that most of the women were using chullah for cooking their own food and hara for animal feed with fuel placed on the lower rung of energy ladder i.e. crop waste and dung cakes, wood, kerosene, and LPG. Major health problems faced by women were 'headache' and 'irritation in eyes' while using the traditional chullah and hara. The majority of them were also having respiratory problems like 'phlegm' (mean score-2.7) 'shortness of breath' (mean score-2.6), 'cough' (mean score-2.5), and 'wheezing' (attacks) with mean score of 2.0, respectively. Mean PEFR values for the traditional chullah and hara exposed women were significantly lower as compared with MDV chullah and improved hara. Therefore, it is recommended that the use of cheap improved chullah and hara are the best alternative, which is the permanent solution of smoke and also consumes less fuel than traditional chullah and hara.

Introduction

In India over 70 % of the population live in rural areas and less than 1 % of rural households has accessed to electricity and biomass such as firewood, coal, charcoal, kerosene, and agricultural residues. For cooking purposes, the household sector relies heavily on traditional chullah and hara. Pitt *et al.* (2005) observed that the households at lower levels of income and development tend to be at the bottom of the energy ladder, using solid fuel that is cheap and locally available but not clean and nor efficient to use. Over three billion people worldwide are at these lower rungs, depending on biomass fuels-crop waste, dung, wood, leaves etc., and coal to meet their energy needs. A disproportionate number of these individuals reside in Asia and Africa: 95 % of the population in Afghanistan uses these fuels, 95 % in Chad, 87 % in Ghana, 82 % in India, 80 % in China, and so forth (Duflo *et al.,* 2008). According to International Energy Agency (2015) an estimated 2.7 billion people cook meals over brick, stone or clay stoves fuelled by wood, leaves, dung etc. The World Health Organization (2015) reported that the traditional use of solid biomass for cooking, including the release of harmful indoor air pollutants are the major causes of premature death. Mohapatra *et al.* (2018) around three billion people use solid fuels (biomass and coal) for cooking and heating, and this number is expected to grow until at least 2030. Many women and children are

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exposed to high levels of indoor air pollution chullah. There is a serious impact of air pollutants on human health as they are taken by blood and circulated in the body. These chullah and hara are thermally as well as environmentally inefficient and are prone to damage because these are made from mud and baked mud which is quite a good insulator but at the same, it needs to be very thick as mud can crack allowing heat to escape that way and hence creating drudgery and heat problems and indoor pollution. Recently, the concentration of indoor pollution in households that burn traditional fuels is at an alarming point. Burning such fuels produce a large amount of smoke and other air pollutants in the confined space of the home. Policies to reduce indoor air pollution focus on either inducing a healthier fuel choice or on making biomass use cleaner and safer, for example through improved stoves or better ventilation in the cooking areas. As incomes rise, we would expect that households would substitute for higher quality fuel choices. Keeping the above facts in mind a study was planned to assess the indoor air quality and health hazards faced by families who were using the chullah for cooking.

Material and Methods

The present study was undertaken in Hisar district of Haryana state to assess the indoor air pollution level as per the energy ladder and its effect on respiratory health. Two villages (Ludas and Gangwa) from Hisar district were selected randomly. From the selected villages, 50 women (from each village) making a total sample of 100 women were selected randomly to find out the health problems faced by them due to the use of traditional chullah. From the selected women, ten women who were physically fit and willing to cooperate and had not MDV chullah and hara in their households were selected purposively to impart the knowledge regarding construction and benefits of improved chullah and hara. A self-structured schedule was prepared to collect the data regarding problems faced by women during the use of traditional chullah with the different fuels. An observation sheet was prepared to observe the temperature, humidity, and air pollutants in the households. A thermometer, hygrometer, and air quality monitor were used to measure the indoor air emitted from biomass fuel used in quality parameters respectively. For the lung capacity of the women, peak flow meter was used. percentage, mean score, rank, and t-test were computed to assess the different parameters in the study.

Results and Discussion

Fuel switching behaviour of respondents for cooking as per energy ladder: It is evident from perusal of data presented in Figure 1 that in totality, all of the respondents were using crop waste and dung cakes for cooking, followed by 81.00 % respondents who were using wood for cooking purposes, 17.00 % respondents were using LPG gas and an equal number of respondents (3.00% each) were using kerosene and electricity for cooking in both the villages i.e. Gangwa and Ludas. Banerjee (2019) supported this and mentioned that 63% of the rural households were using firewood as the primary cooking fuel while another 23% were using crop residues/dung cakes as fuels for cooking. Only 11 % of rural households were using LPG as primary cooking fuel.

Health-related problems while using chullah and hara: The data presented in Table 1 show that respondents reported health problems when they were using the chullah and hara. The various health constraints' reported by the respondents were; 'headache' got the first rank with a mean score of 2.8, 'irritation in eyes' got the second rank with a mean score of 2.7, 'skin problem' and 'respiratory problem' got 3rd rank with mean score of 2.6, 'backache' and 'bronchial' got 4th rank with mean score of 2.5, 'low visibility, 'decreased working efficiency' and 'cough' got 5th and 6th rank with mean score of 2.4 and 2.2 respectively. Mohapatra *et al.* (2018) also found similar results and concluded that dry cough was the most common reported symptom (15.03%), followed by eye and nose irritation present in nearly 12 % each by the respondents. Headache, dry cough, and hypertension (HT) were found to be associated with the number of cooking years and were also found to be statistically significant ($P =$ 0.03, 0.02, and 0.0065, respectively).

Health-related problems in respondents by use of different fuels Respondents were found to face

everal problems while using wood, crop waste, and dung cakes in

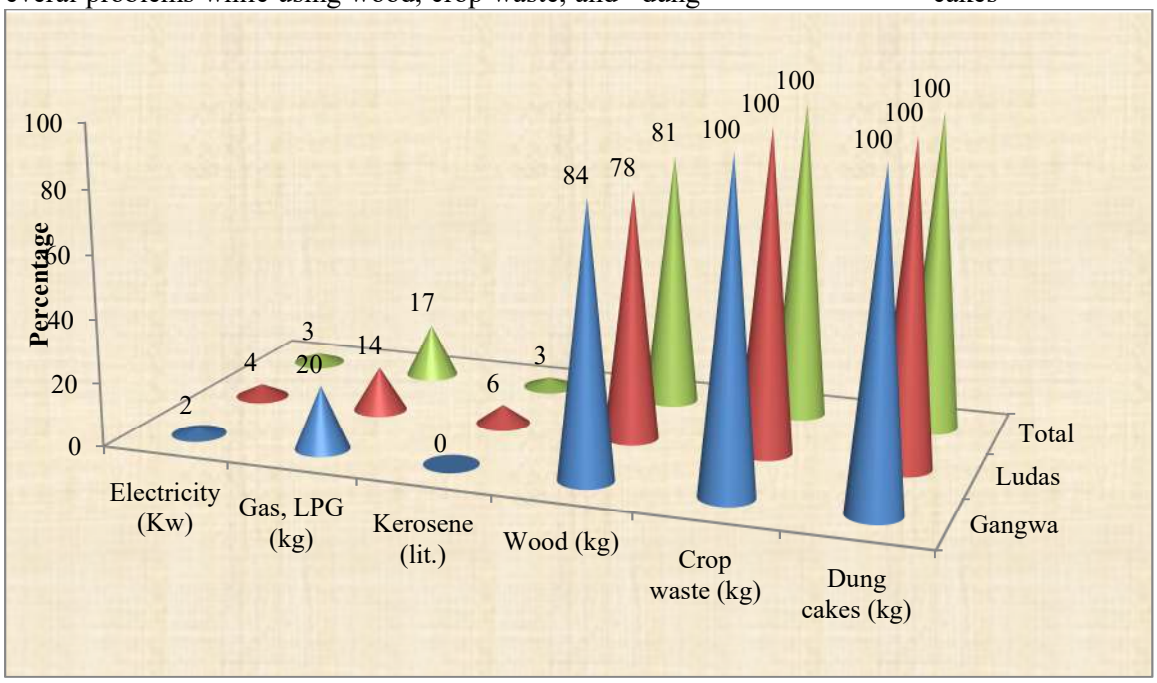

Figure 1: Fuel switching behaivour of respondents for cooking as per energy ladder

traditional chullah and hara. The various health constraints' reported by the respondents were; 'headache' and 'trouble breathing' got the first rank with mean score of 1.4, 'cough' and 'respiratory problem, got 2nd rank with mean score of 1.3, 'irritation in eyes' and 'low visibility' got the third rank with mean score of 1.2 respectively (Table 2). Jaiswal and Meshram (2019) found that most of the selected women in the households achieved a sort of comfort level with the smoke produced from the burning of biomass in chullah while cooking. In the studied populace, (96.7%) were awared about the effects of smoke produced by chullah on women's health like irritation to eyes (95.3%), cough (87.3%), and chest illness (23.8%).

Respiratory health status of respondents: The major respiratory health problems faced by them were cough, phlegm (sputum), shortness of breath and wheezing (attacks) which have been presented in Table 3. The respiratory health problems reported by the respondents were; 'phlegm' (sputum) got the first rank with mean score of 2.7, 'shortness of breath' got 2nd rank with mean score of 2.6, 'cough' got the third rank with mean score of 2.5 and 'wheezing' (attacks) got 4th rank with mean score of 2.0, respectively. According to Dass and Panda (2017), about 400 million people in India were exposed to respiratory, pulmonary, and vision problems allied with indoor air pollution from the use of biomass.

Frequency of respiratory diseases in respondents during the last year: The perusal of data given in Table 4 depicts the frequency of occurrence of respiratory diseases viz. 3 or more, 1 or 2, and not at all by the respondents during the last one year. Respiratory diseases faced by the majority of the respondents were in 'not severe' (2.6) followed by 'moderate' (1.5) and 'severe' (1.4) categories respectively. James *et al.* (2020) also concluded the self-reported health conditions among women were grouped as follows—ophthalmic conditions included diminished vision, cataract, irritation, and watering of eyes, while respiratory conditions included throat irritation, ear pain, asthma, nasal stuffiness/ running nose, cough with/ without phlegm by the exposure of biomass fuel used in chullah.

Environmental parameters in the household as per energy ladder with use of chullah: To measure the difference in environmental parameters while using different fuels as per energy ladder, only crop waste and dung cake were used as a fuel for chullah and it was observed that SPM was (456 $\mu g/m^3$) in the traditional chullah before cooking and

Table 1 : Health related problems while using chullah and hara (n=100)

SN	Health problems	Severe (3)	Moderate (2)	Not severe (1)	Mean score	Rank
1.	Cough	40	40	20	2.2	VI
2.	Backache	60	30	10	2.5	IV
3.	Headache	80	20	-	2.8	I
4.	Low visibility	50	40	10	2.4	V
5.	Irritation in eyes	70	30	-	2.7	II
6.	Decreased working efficiency	40	40	20	2.2	VI
7.	Respiratory problems	60	40	-	2.6	III
8.	Skin problem	60	40	-	2.6	III

Table 2: Health related problems in respondnets by using of different fuels (n=100)

SN	Health problems	Fuels		Mean score	Rank
		Wood (2)	Crop waste and dung cakes (1)		
1.	Cough	30	70	1.3	II
2.	Headache	40	60	1.4	I
3.	Low visibility	20	80	1.2	III
4.	Irritation in eyes	20	80	1.2	III
5.	Respiratory problems	30	70	1.3	II
6.	Trouble breathing	40	60	1.4	I

Table 3: Respiratory health status of respondents (n=10)

SN	Respiratory problem	Most days a week (4)	Several days a week (3)	Only with chest infections (2)	Not at all (1)	Mean score	Rank
1.	Cough	2	2	5	1	2.5	III
2.	Phlegm (sputum)	2	4	3	1	2.7	I
3.	Shortness of breath	2	4	2	2	2.6	II
4.	Wheezing (Attacks)	1	1	5	3	2.0	IV

*St. George respiratory health status

Table 4: Frequency of respiratory diseases in respondents during the last year (n=10)

SN	Types of diseases	3 or more (3)	1 or 2 (2)	None (1)	Mean score	Rank
1.	Severe	1	2	7	1.4	III
2.	Moderate	2	1	7	1.5	II
3.	Not severe	7	2	1	2.6	I

Table 5: Environmental parameters in household as per energy ladder with use of chullah (n=10)

Parameters	Permissible limit	Crop waste used for cooking				Dung cakes used for cooking			
		Traditional chullah		MDVchullah		Traditional chullah		Improved chullah	
		Before	After	Before	After	Before	After	Before	After
SPM(μg/m³)	500	456	670	456	490	498	980	498	596
Temp. (^{0}C)	25-30	34.5	37.3	34.5	36.4	34.4	38.1	34.4	36.7
R.H. (%)	40-60	50.6	47.2	50.6	48.1	50.1	46.2	50.1	48.5
CO_2(ppm)	400-600	524	782	524	672	694	825	694	745

Table 6: Environmental parameters in households as per energy ladder with use of hara(n=10)

Parameters	Permissible limit	Dung cakes used for cooking			
		Traditional hara		Improved hara	
		Before	After	Before	After
SPM(µg/m³)	500	657	710	657	545
Temp. (^{0}C)	25-30	35.1	38.4	35.1	36.9
R.H. (%)	40-60	52.0	48.4	52.0	49.3
CO_2(ppm)	400-600	668	914	668	823

Table 7: Comparative analysis of PEFR (Peak expiratory flow rate) in village Gangwa and Ludas (n=10)

SN	PEFR	Permissible Limit (L/min.)	Traditional chullah and hara	MDV Chullah and Improvedhara	Difference	t-value
Gangwa						
1.	Before	300-400	250±14.14	346±11.40	96.3**	18.83
2.	After		238±8.37	324±11.19	86.2**	12.50
Ludas						
1.	Before	300-400	262±19.23	360±15.81	98.3**	16.81
2.	After		220±18.71	332±13.04	112.5**	9.33

after cooking was 670 µg/m³ whereas, in the MDV chullah, it was observed that SPM before cooking (456 µg/m³) and after cooking (490 µg/m³) while using the crop waste. Whereas, in use of dung cakes, before cooking activity, it was 498 µg/m³ and after cooking 980 µg/m³ on traditional chullah whereas, in MDV chullah before cooking 498 µg/m³ and after cooking 596 µg/m³. The permissive value was 500 µg/m³. Data in table 5 show that the mean temperature near the cooking unit was 37.3^{o}C where cooking on traditional chullah whereas, mean temperature of the household where cooking was carried out on MDV chullah was 36.4^{o}C as use of crop waste for cooking. Whereas, the use of dung cakes for cooking, in traditional chullah the average mean temperature was 38.1^{o}C, and MDV chullah was 36.7^{o}C.

Average relative humidity was least in the household where cooking was carried out on MDV chullah i.e. 47.2% whereas 48.1% in the household environment where cooking was carried out on traditional chullah as crop waste used for cooking. The recommended level was 40 to 60 %. As dung cakes used for cooking, the average relative humidity on traditional chullah was 48.5 % whereas, 46.2 % on MDV chullah. Data in the table also show that the average CO_2 in the environment of traditional chullah before cooking was 524 ppm and after cooking was 782 ppm. Whereas, in MDV chullah it was 524 ppm before cooking and 672 ppm after cooking, respectively as used for crop waste. As dung cakes used for cooking, the average CO_2 on traditional chullah was 825 ppm whereas, 745 ppm in MDV chullah. Kasom (2019) & Baqir *et al.* (2019) reported that the majority of the rural people were using U-shaped traditional chulha. That is thermally inefficient and emitted emissions directly into the indoor areas of households and raised health and environmental issues.

Environmental parameters in the household as per energy ladder with use of dung cakes in hara: In the process of cooking in hara with dung cakes, it was observed that in the smoke of traditional hara and improved hara, the SPM present was with the difference of 710 and 545 µg/m³ respectively (Table 6) but the permissive value was 500 µg/m³. Suspended particulate matter of smoke released from both the hara was not in the permissible limit, but in improved hara it was on the lower side. After cooking, the average mean temperature of traditional hara was 38.4 ^{o}C and improved hara was 36.9^{o}C. Whereas the relative humidity of traditional hara was 48.4% and improved hara was 49.3%. Data in the table also show that the average CO_2 in the environment of

traditional hara after cooking was 914 ppm and in improved hara it was 823 ppm. Faizan and Thakur (2019) also stated that the use of solid fuels in household cooking contributes to indoor air pollution and is the cause of more than 4 million deaths around the world annually. High dependence on solid fuels (80.5%) and a higher risk of respiratory diseases were observed in rural areas as compared to urban areas.

Comparative analysis of PEFR (Peak expiratory flow rate)

Before the cooking activity: Data in Table 7 elucidate that the average PEFR of the respondents of Gangwa village before cooking on traditional chullah and hara was 250±14.14 (L/min), on MDV chullah and improved hara it was 346±11.40 (L/min) and in Ludas village respondents before cooking on traditional chullah and hara was 262±19.23 (L/min), on MDV chullah and improved hara was 360±15.81 (L/min). Results were also in consonance with Ibhazehiebo *et al.* (2006) who studied the ventilatory function peak expiratory flow rate (PEFR) of 350 rural women engaged in cooking. The mean PEFR value for the wood exposed women (289 ± 19.6 L/mm) was significantly lower ($P<0.05$) compared with control (non-wood smoke exposure) (364 ± 17.2 L/mm). The PEFR decreases with increase in years of exposure to wood smoke and the fall was neither accounted for by age nor height. The respiratory symptom was also markedly elevated in these women compared to control.

After cooking activity: Data in Table 7 shows that the average PEFR of the respondents after minutes of cooking on traditional chullah and hara was 238±8.37 (L/min), followed by MDV chullah and improved hara with PEFR of 324±11.19 (L/min) in Gangwa village and 220±18.71 and 332±13.04 (L/min.). The 't' test proved that mean PEFR values for the traditional chullah and hara exposed women were significantly lower compared with MDV chullah and improved hara exposure at 5% level of significance. Hence, it can be concluded that with the use of MDV chullah and improved hara which clearly shows that quantity of smoke generated decreased in MDV chullah and improved hara. Johnson *et al.* (2011) found that PEFR was significantly decreased (319.3 l/min) in biomass users as compared to users of clean fuel (371.7 l/min). Dudi *et al.* (2017) reported that Peak Expiratory Flow Rate (PEFR) in the biomass user group was 2.34 ± 0.38 while in LPG user group FVC is 2.51 ± 0.31 which is significantly lower as compared to LPG user group.

Conclusion

It was concluded that cent percent of respondents were using chullah for own food and hara for animal feed with fuel placed on the lower rung of the energy ladder i.e. crop waste and dung cakes. While using chullah and hara, respondents faced major health problems of 'headache (mean score-2.8)', 'irritation in eyes (mean score-2.7)', respiratory and skin problems (mean score-2.6 respectively). In respiratory problems, the majority of them were having like 'phlegm' (2.7) 'shortness of breath' (2.6), 'cough' (2.5), and 'wheezing' (attacks) with mean score of 2.0, respectively. By using of dung cakes SPM and CO_2 values were high in traditional hara in comparison to improved hara. There was a significant difference in PEFR value in traditional and MDV chullah and improved hara. SPM and CO_2 were found to be in permissible limits i.e. 500 µg/m³ and 400-600 ppm respectively with the use of improved hara and MDV chullah and hence, found to be reducing pollution burden to some extent. It is recommended that motivational programmes need to be conducted with help of anganwadi/volunteers/extension workers to promote improved cookstoves for a healthy indoor environment and to reduce respiratory problems of women.

Conflict of interest

The authors declare that they have no conflict of interest.

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