Impact of Wood Burning Mud Cook Stove on Indoor Air Quality Vis-À-Vis Human Health in Western Himalayan Region

Yashpal Thakur, R K Aggarwal*, S K Bhardwaj, Ajay Singh
Department of Environmental Science, Dr Y S Parmar University of Horticulture & Forestry, Nauni (Solan) India 173230

Abstract

The thermal efficiency of cookstoves was found to be 8% and power output 0.43 kW resulting in the emission of PM_{10} and VOCs which increased with increase in altitude from 31.91 µg/m^3 and 2.52 ppb at lower to 92.63 µg/m^3 and 8.71 ppb at higher altitude, respectively. It was found that 18% (26/142) of the respondents had cough, 11% (16/142) were having Grade 1 dyspnea (significant shortness of breath while walking up an incline or hurrying on the level), about 6% (8/142) complained of chest pain and 7% (10/142) had given the history of having recurrent fever. The females are more exposed to the exhalants of the cooking fuel. The reproductive health of the females indicates that about 77% (40/52), with significant p value of 0.000, of the females had irregular menstrual history and 8% (4/52) with p=0.157gave the history of having suffered from hypertension during their respective pregnancy.

Keywords: *Cookstove, efficiency, pollutants, female, reproductive health.*

I. INTRODUCTION

In rural areas of developing countries, three billion people depend on biomass to meet out their energy requirements for cooking (WEO, 2006).The World Health Organization (WHO, 2016) estimated that indoor air pollution due to biomass burning is responsible for four million premature deaths annually and more than half of them children are less than five years of age. According to UNEP (2006) the indoor air pollution causes about 36% of lower respiratory infections and 22% of chronic respiratory disease. Black carbon and methane emitted by inefficient stove combustion are potent climate change pollutants (WHO, 2016). The probability of a child exposed to indoor air pollution is two to three times more likely to catch pneumonia, which is one of the world's devastating killers of young children.People of developing countries especially from rural area are commonly exposed to high levels of household pollution for 3–7 h daily using biomass in their kitchen (Chhabi et al, 2015).In developing countries fuelwood is collected by the women and children on their head which is a time consuming can suffer serious long term physical damage and increases the drop out from schools. In general, rural domestic sector in India uses 1.2-2.1 kg of biomass/capita/day (Smith, 1987). Fuelwood, roots, agricultural residues and animal dung result high emissions of carbon monoxide, hydrocarbons and particulate matter (Smith et al., 2000). Smith (2000) reported that 24-hour PM_{10} concentration using solid fuel in India sometimes exceeds 2000µg/m^3. Dasgupta*et al.* (2004) find an average of 600µg/m^3 in Bangladesh.

The type of fuel to be used for cooking depends upon the income, as the income increases the people shift from dung and agro wastes to wood to charcoal to kerosene to LPG and to electricity which are cleaner and efficient (Majid et al, 2002). In poorly ventilated dwellings, indoor smoke can be 100 times higher than acceptable levels for fine particles (WHO, 2016). Evidence also showed that health education, improvements in household ventilation, improvements in stoves and changes of the fuels for cooking and heating can reduce IAP (Hu et al , 2009). The effect of indoor air pollutants on human health depends upon age, gender and socioeconomic conditions of families (Bruce et al., 2000).

Incomplete combustion of biomass fuel produces high levels ofindoor pollutants (e.g., PM, carbon monoxide, sulfur dioxide, etc.).As such, its use can result in devastating effects on human healthand diverse potential health risks (such as respiratory tract infections, chronic obstructive lung disease, tuberculosis, asthma, lungcancer, cardiovascular events (e.g., high blood pressure, stroke),cataract, and even exerts adverse effects on neonatal outcome(preterm delivery, low birth weight neonate, infant mortality, etc.) (Ki-Hyum, 2011). The most important (substances) are particles, carbon monoxide, nitrous oxides, sulfur oxides (principally from coal),

formaldehyde, and polycyclic organic matter. The VOCs have varied adverse effects, including eye and upper and lower respiratory irritation but can cause rhinitis, nasal congestion, rash, pruritus, headache, nausea, vomiting, dyspnea, and epistaxis (R.Perez, 2010).

Indoor air pollution depends on fuel type used, time spent cooking, structural characteristics of houses and household ventilationpractices (opening of windows and doors). All of these factors are important for households where there are diversity in cooking fuels, stove types, cooking locations and quality of ventilation. It has been found that most of the traditionally used biofuel stoveshave low thermal efficiency and emit large quantities of pollutants, exposing the users to high concentrations of toxic and carcinogenic emissions.Biomass fuel use and number of family members were significantly associated with respiratory illness in children(Kumar et al, 2014).New studies from Asia suggest that short term variations in PM and several gaseous pollutants are associated with short-term variations in mortality(Bert, 2010).IAP due to biomass fuel has diverse and major impacts on women's health in India (Sehgal et al, 2014).

Climate change is a critical challenge facing humanity due to emission of greenhouse gases from burning of various fossil fuels mainly responsible for global warming. Indoor air pollution is responsible for several health, environmental, and social issues that disproportionately and adversely affect women and children worldwide(Martin, 2011).Intergovernmental Panel on Climate Change in 2007 recognized open fire cooking as a source of carbon emission as domestic biomass burning is the largest source of black carbon (Streets, 2013).

Due to low thermal efficiency of traditional wood burning mud cookstoves, the consumption of fuelwood increases resulting in increased greenhouse gas emissions. These cookstoves are the source of black carbon which accounts for 18 % of greenhouse gas emissions globally.The average concentrations of black carbon in the range of 10-1000 $\mu g/m^3$ measured indoors in India may pose a serious threat to women and children subject to soot laden smoke from traditional stoves.

In Himachal Pradesh, people use wood, agro waste and forest waste, liquid petroleum gas, electricity and kerosene oil for cooking, room heating, water heating and lighting. The pattern of consumption of fuel for cooking in the state is firewood 72.2 % and 0.5 %, crop residue 1.2 % and 0.5 %, cow dung cake 0.1 % and 0.1 %, kerosene 3.6 % and 14.5 %, liquid petroleum gas 21.8 % and 76.6 %, electricity 0.2 % and 0.4 %, biogas 0.4 % and 0.3 % in rural and urban areas respectively (Census, 2001).People use wood burning traditional mud cookstove for cooking and heating. In the present study the effect of low thermal efficiency of traditional wood burning mud cookstovesresulting in the emission of pollutants emitted in the kitchen, on human health was assessed. Keeping in view of this a case study was carried out to examine the emission of air pollutants in the kitchen and assess its impacts on human health.

II. METHODOLOGY

The study area lies in hilly state between 31°13′20″ to 32°04′30″ North latitude and 76°37′20″ to 77°23′15″ East longitude (Fig 1). It falls in the mid-hills sub-humid zone and high hills temperate wet agro climatic zone of Himachal Pradesh with total population of 82,407 (Census 2011). The district has two categories, 1st Shivalik or outer Himalaya region, which varies from 651-1500 meter above mean sea level and 2nd mid mountain or Inner Himalaya region, varying from 1500-4500 meter above mean sea level. The district receives annual average rainfall of 1239.98 mm. Low hills of the district experience hot summer (up to 40^0C) and cold winter with frost and fog. Hilly area experiences mild summer and cold winter with low to high snowfall and mist in rainy season.

Under the present study the block was divided into three altitudinal zones (<1000 meter, 1000-1500 meter and 1500-2000 meter). In each zone cluster wise four villages were selected.In each village two households were selected on the basis of income i.e. above poverty line (APL) and below poverty line (BPL) randomly. The Ethical clearance was sought from the Advisory Board of the Department of Environmental Science, University of Horticulture and Forestry, Nauni, Solan. The President of the respective Village Advisory Board of respective villages was taken into confidence before the start of the study.

Water Boiling Test was used to determine the thermal efficiency of wood burning mud cookstove (Danshehu, 1992). The emission of pollutants (particulate matter and volatile organic compounds) was monitored during cooking period using Environmental Perimeter Air Station.CO_2 analyzer was used to monitor carbon dioxide emitted from burning of fuelwood. The data generated from present investigation were statistically analyzed using critical difference at 5% level. Pre tested questionnaire was used to analyze effect of indoor air pollution on human health and the data was analyzed by IBM SPSS Statistics software. Health advisory was given to the sick persons.

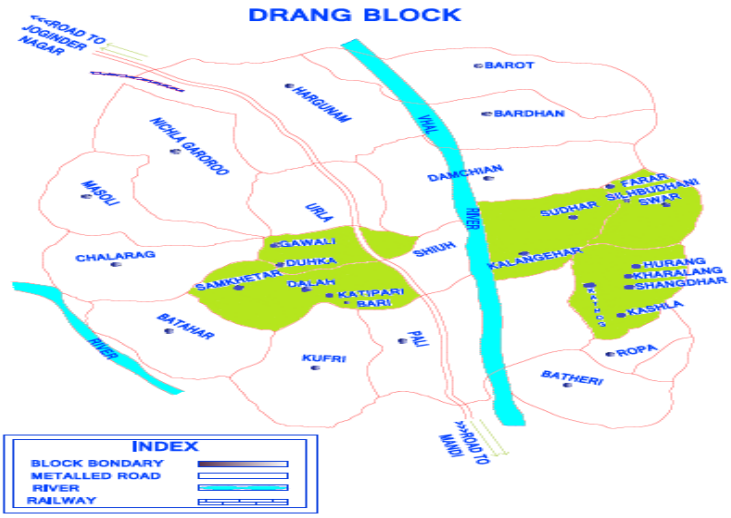

Fig.1. Map of Study Area

III. RESULTS AND DISCUSSION

A. Indoor Air Pollution from Wood Burning Mud Cookstove

The emission of particulate matter was found to be 92.63µg/m^{3}and is within permissible limits as per United States Environment Protection Agency. However the results are above permissible limits according to the World Health Organization. The maximum emission of volatile organic compound was 8.71 ppb and is within permissible limits as per United States Environment Protection Agency.The emission of carbon dioxide was 252 ppm and the values are in permissible limit as per United States Environment Protection Agency (Yashpal, 2016).The burning of solid biomass increases the temperature inside the kitchen, as required by the people for space heating during winters. The study indicated that the temperature increased by 7.9^{0}C during cooking period in the kitchen.

B. Effect of indoor air pollution on health (Based on questionnaire)

1) Age and Gender profile of the Respondents (N=142)

The information about the incidence of disease and ailment was collected for 142 persons and information on children in the age group of 0-15 years, was sought from either of the parents of the child. Out of the total respondents, 56 % (80/142) were males with median average age of 31 years and 44% (62/142) were females with median average age of 33 years. A larger proportion of 35 % (50/142) belonged to the age group of 16-30 years (Table 1).

Age group (years)	Male	Female
0-15	20	10
16-30	27	23
31-45	16	13
46-60	11	13
61-75	3	3
76-90	3	0
Total	80	62

Table 1. Age and Gender Profile of the Respondents (N=142)

*2) **Age and Gender Wise Incidence of Symptoms Related to Respiratory Disease and Other Chronic Ailments***

Although the results of the incidence of the symptoms related to respiratory and other included chronic ailments were not found to be statistically significant (chi square and p values) with respect to the age and gender wise distribution, it was observed that almost respondents of all the age groups had one or the other symptoms of respiratory diseases such as cough, shortness of breath, chest pain and recurrent fever (Table 2). It was found that 18% (26/142) of the respondents had cough, 11% (16/142) were having Grade 1 shortness of breath (mMRC scale - felt shortness of breath while walking up an incline or hurrying on the level), about 6% (8/142) complained of chest pain and 7% (10/142) had given the history of having recurrent fever. The results revealed that 15% (21/142) of the respondents were having generalized weakness. There were two diagnosed cases of migraine, one case each of gout, cancer and paralysis and Tuberculosis. A hospital-based case-control study (Karunasekara, 2001) of 300 subjects (age-matched) found that the presence of dust at home was a significant risk factor for asthma. A cross-sectional study conducted in a Colombo suburb reported that the use of fire wood for cooking was a significant risk factor for respiratory symptoms (Lankathikala, 2000). Results strongly suggest that use of biomass fuels for cooking substantially increases the risk of tuberculosis in India (Mishra, 1999). For every 20 $\mu g/m^3$ of PM_{10} rise in ambient air, daily mortality increases by 1% (Ezzati, 2002). An association between exposure to indoor air pollution and pregnancy outcome has been reported from some developing countries where women using biomass as cooking fuel are exposed to carbon monoxide, which may affect the foetus and could lead to spontaneous abortions, reduced birth weights, and could also increase the incidence of perinatal mortality (Saswata, Ghosh, 2005).

Symptoms	Gender	Age in years			Chi square value	P value
		0-30	31-60	> 60		
Cough	M	4	11	5	0.274	0.872
	F	1	4	1	-	-
Shortness of Breath	M	1	4	3	0.311	0.856
	F	1	5	2	-	-
Blood in sputum	M	0	0	0	-	-
	F	0	0	0	-	-
Chest pain	M	1	2	1	1.20	0.549
	F	0	3	1	-	-
Recurrent fever	M	2	1	2	1.67	0.435
	F	1	3	1	-	-
Generalized weakness	M	2	3	4	1.94	0.378
	F	4	6	2	-	-
Any other chronic ailment	M	2	1	1	0.750	0.687
	F	1	1	0	-	

Table 2. Age and Gender Wise Incidence of Symptoms Related to Respiratory Disease and Other Chronic Ailments

*3) **Age wise distribution of reproductive health parameters***

The results pertaining to the age wise distribution of reproductive health parameters are given in table 3.The study indicates that the females are more exposed to the exhalants of the cooking fuel. The reproductive health of the females indicates that about 77% (40/52) of the females, with significant p value of 0.000, had irregular menstrual history and 8% (4/52) gave the history of having suffered from hypertension during their respective pregnancy. A case, each of infertility and abortion was also reported.Mukherjee et al. (2015) have observed positive association between cumulative biomass smoke exposure and shortened menstrual cycle (OR = 5.1, 95 % CI 3.62–9.21), irregular cycle (OR = 1.8, 95 % CI 1.33–2.34), spontaneous abortions (OR =1.7, 95 % CI 1.10–4.10). Smoke emitted from burning biomass contains particulate matters that affects lung function and affects menstrual cycle and reproductive outcome of the women (WHO, 2009). The chances of spontaneous abortion are very high (14%) those exposed to smoke from biomass cookstove once in their life as compared to 7.5% using LPG. (Bhola et al)

Indicator	Age in years		Total	P value
	15-30	> 30		
Irregular menstrual flow	11	29	40	0.000
Infertility	0	1	1	-
Abortions	1	0	1	-
Hypertension during pregnancy	1	3	4	0.157

Table 3: Age Wise Distribution of Reproductive Health Parameters

Limitations of the study: The sample size of the study population was small and there was no baseline data revealing the knowledge of the respondents regarding indoor air pollutants.

IV. CONCLUSIONS

Based on the present investigation it can be concluded that the people are using fuelwood which has high calorific values but the thermal efficiency of wood burning mud cook stove decreased with increase in altitude and average thermal efficiency of wood burning mud cookstoves in selected households was 8.02% which is well below the minimum requirement of 20% of improved cookstove. Due to this, more consumption of fuelwood was observed at higher altitudes in comparison to lower altitudes. The daily average per capita fuelwood consumption was found to be 4.57 kg in the study area. Due to low thermal efficiency and poor combustion of fuelwood the emission of pollutants viz. particulate matter (PM_{10}) and volatile organic compounds increased significantly with the increase in altitude but, were in permissible limit. The average value of particulate matter and volatile organic compound was found to be 68.25 µg/ $m^3$and 5.68 ppb, respectively. The average increase in carbon dioxide was found to be 471 ppm. The study revealed that the women are most affected persons right from the collection of fuelwood, presence of poor conditions inside the kitchen and high fuelwood consumption resulting air pollutants such as CO_2 and VOCs. The study indicates that the females are more exposed to the exhalants of the cooking fuel. The reproductive health of the females indicates that about 77% (40/52) of the females had irregular menstrual history and 8% (4/52) gave the history of having suffered from hypertension during their respective pregnancy. A case, each of infertility and abortion was also reported. A future cross sectional study with larger population sample size of the area is needed to assess the knowledge, attitude and practice of the study population with regard to the indoor air pollution.

REFERENCES

[1] Bert Brunekreef (2010). Air Pollution and Human Health: From Local to Global Issues. Procedia Social and Behavioral Sciences 41 6661–6669.

[2] Bhola R. Gurjar, Luisa T. Molina, C.S. P. Ojha. Air Pollution: Health and Environmental Impacts, CRC press.

[3] Bruce, N., Perez-Padilla, R., Albalak, R., (2000). Indoor air pollution in developing countries: a major environmental and public health challenge. Bull. World Health Organ.78, 1078—1092.

[4] Census of India (2011). Houses, household amenities and assets, Government of India. http://www. devinfolive. info/censusinfodashboard/website/index.php/pages/kitchen_fuel used/Total/insidehouse/ind.

[5] Census of India (2001).. Summary of tables on houses, households, amenities and assets of H.P. directorate of census operations, Himachal Pradesh, Shimla. http://censusindia .gov. in/2011 census /hlo/ Houselisting_Housing_2011_Himachalpradesh.html

[6] Chhabi Lal Ranabhat, Chun-Bae Kim, Chang-Soo Kim, Nilambar Jha, K. C. Deepak, and Fredric A (2015). Connel Consequence of Indoor Air Pollution in Rural Area of Nepal: A Simplified Measurement Approach. Front Public Health.; 3: 5.

[7] Danshehu B G, Sambo A S and Musa M (1992). Comparative performance of sawdust and wood burning stoves. *Nigerian Journal of Renewable Energy*.3(1 and 2), pp.50-55.

[8] Dasgupta, S., M. Huq, M. Khaliquzzaman, K. Pandey, and D. Wheeler (2004). "Who Suffers from Indoor Air Pollution? Evidence from Bangladesh," World Bank Policy Research Working Paper 3428.

[9] Ezzati M, Kammen DM (2002) The health impacts of exposure to indoor air pollution from solid fuels in developing countries: Knowledge, gaps, and data needs. Environ Health Perspect 110: 1057- 1068.

[10] Hu, Guoping; Ran, Pixin (2009). Indoor air pollution as a lung health hazard: focus on populous countries, Current Opinion in Pulmonary Medicine: - Volume 15 - Issue 2 - p 158–164.

[11] Karunasekara KAW, Jayasinhe JA, Alwis LW (2001): Risk factors of childhood asthma: a Sri Lankan study. Journal of Tropical Pediatrics., 47 (3): 142-145. 10.1093/tropej/47.3.142.

[12] Ki-Hyun Kim, ShaminAraJahan, EhsanulKabir (2011). A review of diseases associated with household air pollution due to the use of biomass fuelsJournal of Hazardous Materials 192 425– 431

[13] Lankathilaka KN, Seneviratne SRDA, Fernando DN (2000): Indoor air quality and respiratory symptoms among children and women. Sri Lanka Association for the Advancement of Science - 56th Annual Session.Volume Part - 1 abstract. Colombo.

[14] Majid Ezzati and Daniel M. Kammen (2002). The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gaps, and Data Needs. Environmental Health Perspectives • vol 110, (11)

[15] Martin W J, Glass R I, Balbus J M and Collins F S (2011). A major environmental cause of death.*Science*.334, pp.180-181.

[16] Meena Sehgal,Suliankatchi Abdulkader Rizwan, and Anand Krishnan (2014). Disease burden due to biomass cooking-fuel-related household air pollution among women in India.Glob Health Action. 2014; 7: 10.3402/gha.v7.25326.
[17] Mishra, Vinod K. , Retherford, Robert D. , (1999). Biomass cooking fuels and prevalence of tuberculosis in India. International Journal of Infectious Diseases, Volume 3, Issue 3, 1999, Pages 119-129
[18] R. Perez-Padilla, A. Schilmann, H. Riojas-Rodriguez. (2010). Respiratory health effects of indoor air pollution. INT J TUBERC LUNG DIS 14(9):1079–1086
[19] Raj Kumar, NitinGoel, Nitesh Gupta, Kamal Singh, Sumit Nagar and Juhi Mittal (2014). Indoor Air Pollution and Respiratory Illness in Children from Rural India: A Pilot Study. Indoor Pollution and Respiratory Illness,;Vol.56, 79-83.
[20] Saswata, Ghosh. (2005) Adverse pregnancy outcome and indoor air pollution: Is there a linkage? Epidemiology: Volume 16 - Issue 5 - pp S22-S23).
[21] Sayali Mukherjee,Shabana Siddique, Sreeparna Chakraborty, Purba Bhattacharya, Madhuchanda Banerjee, Sanghita Roychoudhury, Twisha Lahiri, Manas Ranjan Ray (2015). Adverse reproductive health outcomes in pre-menopausal Indian women chronically exposed to biomass smoke. Journal of Public Health, Volume 23, Issue 6, pp 363–372
[22] Smith K, Uma R, Kishore V, Junfeng Z, Joshi V, Khalil M. (2000a). Greenhouse Implications of Household Stoves: An Analysis for India. Annu. Rev. Energy Environ. 25:741-63.
[23] Smith KR (1987) Biofuels, air pollution, and health.A global review. Plenum Press, New York, 1987. Smith, K. (2000). National burden of disease in India from indoor air pollution. Proc. Natl. Acad. Sci. 97 (24):13286-13293.
[24] Streets D G, Shindell D T, Lu Z and Faluvegi G (2013). Radiative forcing due to major aerosol emitting sectors in China and India. *Geophysical ReseachLetters*.40(16), pp.4409-4414.
[25] WHO (2016).Household air pollution and health.
[26] World Energy Outlook (2006) - FOCUS ON KEY TOPICS.
[27] World Health Organization (India) (2009).IMPACT OF Indoor Air Pollution From Biomass Fuel Burning On Reproductive Health And Neurobehavioral Symptoms Of Premenopausal Women In Rural India. Nature Environment and Wildlife Society (NEWS).