THE USE OF AGRICULTURAL BASED BIOMASS ENERGY IN RURAL PUNJAB: HEALTH IMPLICATIONS AND CHALLENGES

Nabeela Farah * [1] , Izhar Ahmad Khan [2] , Ashfaq Ahmad Maan [3] , Babar Shahbaz [4]

[1] Ph.D. Scholar, [2] Associate Professor, [3] Professor, Department of Rural Sociology, [4] Associate Professor, Institute of Agricultural Extension and Rural Development, University of Agriculture, Faisalabad, Pakistan,

*Corresponding author email:
donia.nabeela@yahoo.com

ABSTRACT

Indoor air pollution due to burning of biomass fuel in developing countries is a well-established health hazard. In rural Punjab, biomass fuel is used as a primary source for cooking and heating. Biomass burning contains hundreds of compounds that have serious impact on women's health. The study conducted at Department of Rural Sociology, University of Agriculture, Faisalabad, Pakistan during the year 2019 to estimated the health effects of exposure to smoke from burning of agricultural waste, dung cakes and wood used in three districts of Punjab. Data included a survey of 480 women and interactions of fuel, stove and kitchen use were conducted to evaluate the health effects. These data were analyzed using ordinal and multivariate logistic regression models and presented in the form of mediation, moderation and interaction effects. The results show the odds of having more frequent headaches increased (OR =3.62, p=.001) when dung cake was used in conjunction with blocked kitchen. Similarly, the odds of having more frequent chest pain increased (OR =8.05, p=.026) when wood was used in a mid-brick stove. The interaction between dung cake and time spent in the kitchen was significant. It resulted in higher odds of having more frequent cardiac disease by a factor of 5, when dung cake was used for 7-9 hours in the kitchen. It was investigated that use of inferior biomass fuels is significantly positively associated with chest pain, coughing, asthma, breathing problems, headache and eye allergy. The study revealed that in rural areas, biomass fuels often burnt inefficiently in open fires, with high emission factors, leading to extremely high levels of indoor and local air pollution, many times higher than the limits specified by international standards of ambient air quality. Rural women can get rid of this issue with government attention, which was in reality observed not upto the mark.

KEYWORDS: biomass; fuel; cooking; smoke; women's health; Pakistan.

INTRODUCTION

Pakistan is predominately an agricultural country and has considerable natural resources (Asian Development Bank, 2014), but it has many gaps to meet its energy requirements (International Energy Agency, 2013). These energy challenges and shortfalls exist at both domestic and commercial level (Wakeela *et al.,* 2016). Households in many countries like Pakistan, India, Sri Lanka and Nepal use biomass as fuel (67%, 72%, 67% and 88% respectively) for daily cooking. "Biomass" refers to as "naturally occurring flammable material" includes grasses, crop residues, dung and wood (Goldemberg, 2000). Agricultural residues are major source of resources for energy at household level (Scott *et al.,* 2014). Dung is possibly the least desirable form of biomass fuel that indicates extreme fuel poverty (Goldemberg, 2000). Fuelwood is an efficient form in this group and is considered as the most desirable form which is relatively easier to use than other fuels in the group.

In 11 lesser-developed countries including Pakistan, biomass fuel exposure is responsible for 1.2 million excess deaths per year. Punjab is the largest province, approximately having 55.6% of total country's population approximately 68% population of Punjab lives in rural areas (Government of Punjab, 2013). Poverty is a root cause for rural people of Punjab using biomass for household needs. Reliance on biomass fuels and coal which are the sources to meet their energy demand is a significant problem to public health (Ezzati and Kammen, 2002). In Punjab, women do not have access for equal economic or life opportunities (Gull and Pulla, 2014). Household cooking practices are done by women, and they cook food 3-4 times a day. In Punjab, women typically collect agricultural residue and dung for daily use. Culturally women's education is a lower priority and many women remain ignorant about ill-effects of traditional fuel use, domestic smoke and kitchen environment (Dasgupta *et al.,* 2006). There is a strong link between gender, energy and poverty, and international efforts to improve women's energy rights are insufficient (Danielsen, 2012).

In rural areas, open fire fueled by biomass generates high levels of particulate matter as well as chlorinated organics, oxygenated organics and hydrocarbons (Naeher *et al.,* 2007). Particulate matter is categorized according to size, with inhalable material <10 μm aerodynamic diameter referred to as PM_{10}. The World Health Organization sets 24-hour mean particulate matter levels for air quality as 50 μg/m^3 for PM_{10} and 25 μg/m^3 for $PM_{2.5}$ (WHO, 2006). However, the levels exceed this recommend standard in many developing countries, where PM_{10} often exceeds 2000 μg/m^3 (Zhang and Morawska, 2002). A one rural village in Punjab where high indoor level of PM was studied during cooking, smoking and cleaning, the level of PM was found to be 4000 to 8555 μg/m^3 (Colbeck, 2010). WHO reports that on average 4.3 million people die annually due to poor indoor air resulting from the improper use of biomass fuels (WHO, 2018). There is a strong link between type of fuel use, health and disease (Akhtar *et al.,* 2007). The rate of female death in lower- middle income countries due to biomass burning occupied the 5th and 6th highest cause of death (Mathers *et al.,* 2006). Pakistan is among those developing countries enlisted as worst affected (WHO, 2018). In Punjab, women suffer from cough, asthma, shortness of breath and chest tightness conditions that appear to be getting worse over time (Jamali *et al.,* 2017).

The objective of this study is to investigate the impact of biomass fuel emissions on women's health with following goals:

- To determine the socio-economic characteristics of respondents.
- To examine the types of biomass fuel, stove and kitchen being used in the sampled households.
- To explore about the ill-effects of biomass emission on women's health.
- To identify the hazards effects in form of burning efficiency, incomplete consumption, time consumption in kitchen, ventilation and stove quality on women's health.

Theoretical Frame Work

Energy Ladder Model or Fuel Stacking Model: A common concept in household energy is "Energy ladder" which explains that poor people of rural areas rely more on a significantly different set of energy sources than that of rich. These people traditionally use agricultural waste, wood, dung in for cooking. Income is the most prominent factor in this model. Poverty is not only linked with the choice of fuel but also with health outcomes. Health outcome is the future cost that households pay after the selection of cheap fuels. In Punjab, the lack of reliable income pushes the poor households to think about the immediate cost of fuel rather than the longer-term lifecycle cost. Socioeconomic characteristics of households like attitude and attribute towards fuel are the main factors influencing the choice of fuel. "Fuel Stacking" explains that rural people use modern fuel as income increases but they also continue using traditional fuels for some activities, thus 'mixing' various energy sources. The fuel stacking model also explains that not only income but socio-environmental, socio-cultural and socio-economic factors count too.

Women and Gender Equity in Development Theory

Deadly Kitchens, Stoves and Fuel: Cooking, Air Pollution, and Disease: Fuel choice has adverse health impacts on women. Smith *et al.,* (2004) described in South Asia environmental risks due to poor kitchen ventilation are almost as large as those from poor water and sanitation. An important pathway that was studied during this study might be called the "unhealthy mother effect." It explained that a sick mother due to poor indoor air, combined perhaps with other impacts of kitchen, stove and solid fuel use such as long hours in gathering fuel, has difficulty taking good care of her children and other family members and therefore increasing risk of disease.

MATERIALS AND METHODS

This study was conducted at Department of Rural Sociology, University of Agirulcutre, Faisalabad during the year 2019. It employed a cross-sectional survey research design and empirically investigated biomass fuel emissions and their implications for women's health in rural Punjab. Punjab is the most populous province of Pakistan, (Census of Pakistan, 2017). There are 36 districts in Punjab. In present research three districts (Okara, Hafizabad, Multan) from Punjab were studied with multistage sampling technique. In the first stage three districts were selected randomly. In the next stage two tehsils from each district were selected randomly. Then four villages from each techsil were selected randomly and finally 20 women from each village were selected purposively. An interview schedule was developed for data collection. Most questions of the interview schedule were close ended. Quantitative data were analyzed through various statistical techniques such as, univariate, bi-variate and multi-variate techniques with SPSS. The univariate analysis (frequency, percentage) was applied to understand the data set one variable, one at a time. The bivariate analysis was applied to find out

the relationship between two sets of values (X and Y). In the present study, Chi-square, ANOVA and ordinal logistic regression model were used for bivariate data analysis. Multivariate analysis is based on the statistical principle of multivariate statistics, which involves observations and analysis of more than one statistical outcome variable at one time. In present study mediation, moderation and interaction models were used for multivariate regression analysis.

RESULTS AND DISCUSSION

Mediation with Regression Analysis:
The results (Table 1) from the test of a mediation process that is framed in terms of intermediate variables between an independent variable and a dependent variable. There are three variables: *X, M,* and *Y,* where *X* is the independent variable (IV, income), *Y* is the dependent variable (DV, health outcome), and *M* is the (hypothesized) mediator variable (fuel use) that is supposed to transmit the causal effect of *X* to *Y.* Income is associated with outcome variable with three categories for, where category 1 represents never, category 2 represents rarely, and category 3 (the omitted category) represents frequent occurrence of the health condition and for income the omitted category is high income. Regression analysis was used to investigate the hypothesis that fuel type mediates the relationship between income and health. There are three pathways in the model. The path "*A*" describes the relationship between income and fuel use, and path "*B*" explains the relationship between fuel use and health outcome, with age as a control variable. The main path "*C*" presents the relationship between income and health outcome. There is strong evidence that income plays a major role for a good health status and also the choice of fuel depends on level of income. Similarly, the choice of fuel has a strong relationship with health status.

Table1. Mediation Effect

Mediating effect	B	Std. Error	Sig	OR
Breathing problems (Never)	.715	.1880	.000	2.04
Breathing problems (Rarely)	2.201	.2142	.000	9.03
Income (Low)	.843	.2669	.002	2.32
Income (Average)	.456	.2023	.024	1.57
Agricultural waste	2.268	.6019	.000	9.66
Age (41 and above)	1.226	.2365	.000	3.40
Age (21 to 40)	.250	.2085	.231	1.28

Null =The income related breathing problem is not attributed to use of agricultural waste
Alternative = The income related breathing problem is attributed to use of agricultural waste
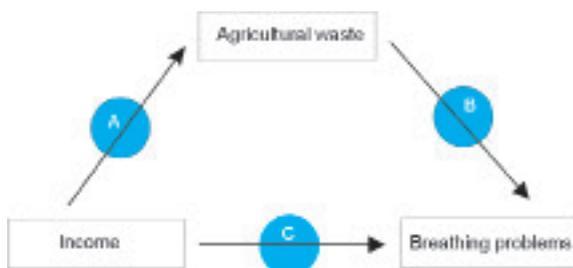B = Coefficient, OR = Odd ratio

Fig. 1. Relationship between income, agricultural waste and breathing problems

A hypothesis was generated that the relationship between income and health outcome is mediated by agriculture waste use (Fig. 1). The results in Table 1 show that the odds of more frequent breathing problems are higher in the low and average income groups compared to the high income group. The odds of more frequent breathing problems in the low income group are more than double (2.32) that of the high income group. The odds are about 1.5 times as high in the average income group (1.57) compared to the high income group. Similarly, the agricultural waste is associated with increased odds (9.66) of more frequent breathing problems, with a P-value (.000). The association between income and fuel use, generalized in the theory of "Energy ladder", explains that people uses better fuel as their income increases, and that the choice of biomass fuel depends on their low income. There is also an assumption that people with high income face less health risks compared to people with low income. Fuel use in this model accounts for significant variation between income and health outcome and also explains that the fuel use presents a partial mediating role (This analysis involves keeping age as control variable).

Prolonged exposure to wood smoke is associated with increased respiratory problems such as coughing and breathing difficulties (Fig. 2). Incomplete combustion of cooking fuel increases the rate of these problems. In Table 2, a second hypothesis was generated to explain the relationship between fuel use (dung) and coughing, which is mediated by incomplete combustion.

Incomplete combustion has two categories, 1 represents insufficient amount of air and 2 category represents insufficient time to burn (the omitted category). Results of this model show a significant association between wood use and coughing that is mediated by insufficient amount of air. Wood use is associated with increased odds (2.82) of more frequent coughing than that of non-use of wood.

Fig. 2. Relationship between wood use, incomplete combustion and coughing

Table 2.   Mediation Effect

Mediating effect	B	Std. Error	Sig	OR
Coughing (Never)	1.299	.2260	.000	3.66
Coughing (Rarely)	2.848	.2562	.000	17.25
Insufficient amount of air	.710	.1828	.000	2.03
Wood use	1.039	.2149	.000	2.82
Income (Low)	1.076	.2655	.000	2.93
Income (Average)	.604	.2043	.003	1.83
Age (41 and above)	1.166	.2403	.000	3.21
Age (20 to 40)	.400	.2091	.056	1.49

Null=Incomplete combustion does not explain the effect of wood on coughing
Alternative=Incomplete combustion explains the effect of wood on coughing

 Likewise, insufficient amount of air more than doubles the odds (2.48) of more frequent coughing compared to insufficient time to burn, holding all other variables constant. Incomplete combustion caused by insufficient amount of air accounts for some of the association between wood use and coughing. In other words, in this model insufficient amount of air can be considered as a partial mediating factor, keeping age and income as control variables. This matches with the findings of Rehana *et al.,* (2005) who found a significant association between wood use, coughing and breathing problems. They found wood users had higher odds of reporting cough, difficulty in breathing and ever having asthma. They further investigated the symptoms of respiratory infections, which were significantly more common with incomplete combustion of wood use.

Interaction in Multiple Regression Model

Table 3 analyzed the hypothesis, that was generated to explain the effect of interaction (dung cake dung use angitthi) on asthma. It is assumed that interaction variable has significant relationship with asthma keeping other as control variables. The results of this model showed a significant association between the interaction variable and asthma. The odds of having more frequent asthma increases by nearly two-fold (OR =1.93) with the use of dung. The findings show that dung cake and angitthi use interact to predict asthma. The odds ratio (4.42) indicates asthma increases by nearly a factor of 5 when dung cake is used in combination with angitthi compared to dung cake and no angitthi use. Angitthi was only marginally significant with odds ratio (1.51) in explaining its relationship with asthma.
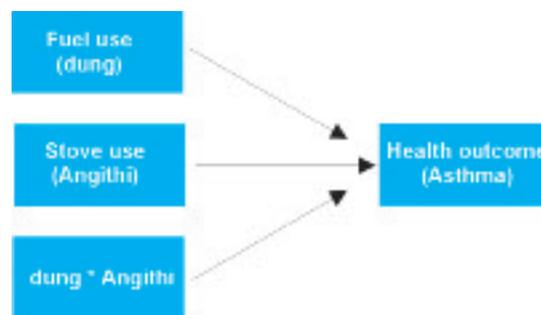

Fig. 3. Relationship between dung use, angithi and asthma

Table:3 Interaction

Interaction	B	Std. Error	Sig	OR
Asthma (Never)	.418	.1901	.028	1.52
Asthma (Rarely)	1.533	.2022	.000	4.63
Dung cake	.662	.3590	.050	1.93
Angitthi	.415	.2362	.079	1.51
Dung cake*angitthi	1.488	.7547	.049	4.42
Age (41 and above)	.964	.2341	.000	2.62
Age (20 to 40)	.482	.2021	.017	1.62
Income (Low)	.608	.2647	.022	1.83
Income (Average)	.536	.1986	.007	1.70

Null= Asthma is not caused by dung smoke with use of angitthi.
Alternative=Asthma is caused by dung smoke with use of angitthi.

Findings of this model highlight that angitthi (stove use) was dependent on dung use in explaining frequent asthma, keeping age and income as control variables. Kumar (2007) similarly explained that disease rates are determined by household characteristics such as fuel use, stove use, kitchen use, etc. He further examined the characteristics of age, income, sex and occupation and found the prevalence of asthma among the user of uncleaned fuel like dung was 1.5 times higher compared to the people who used cleaner fuels. He further explained that for each additional hour of using stove with uncleaned fuel (dung), the odds of reporting asthma increased by nearly 4%. It is therefore concluded that fuel use has significant effect on asthma, and the interaction of the fuel and stove type with asthma increase their significance level to reject the null hypothesis.

Moderation in Multiple Regression Model
In Table 4 moderator hypothesis is supported if the moderation effect is significant. It was assumed that moderation effect has significant relationship with

cardiac disease keeping other as control variables. In Table 4 dung cake is an independent variable, the moderator variable is time spent in kitchen and the dependent variable is cardiac disease. The moderator variable has two categories, where category 1 represents time (4-6 hours spent in kitchen) and category 2, the omitted category, represents 7-9 hours in the kitchen. The present findings show that dung use is significantly related to cardiac disease and time spent in kitchen significantly moderated that relationship. The results further indicate that the effect of dung use on cardiac disease is different depending on the length time that women spend in kitchen (Fig. 4).
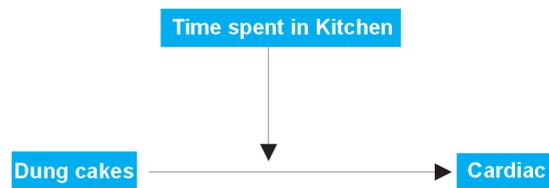

Fig. 4. Relationship between dung use, time spent in kitchen and cardiac

Table 4. Moderation

Moderation effect	B	Std. Error	Sig	OR
Cardiac disease (Never)	.938	.3325	.005	2.55
Cardiac disease (Rarely)	1.729	.3386	.000	5.63
Dung cake	1.461	.5514	.008	4.31
Time spent in kitchen (4-6 hours)	1.589	.3067	.000	4.89
Dung cake*time spent in kitchen	1.619	.7362	.028	5.04
Age (41 and above)	-.871	.2699	.000	0.41
Age (20 to 40)	.164	.2144	.443	1.17
Income (Low)	-.593	.2802	.034	0.55
Income (Average)	-1.002	.2078	.000	0.36

Null=Time spent in kitchen is not related to relationship between dung smoke and cardiac.
Alternative= Time spent in kitchen is related to relationship between dung smoke and cardiac disease

The odds ratio (4.31) indicates that dung use increases the odds of being in a higher cardiac disease category, or having more frequent cardiac disease, by a factor of 4, while the odds cardiac disease is about 5 times greater for women who spend 7-9 hours in the kitchen. The interaction between dung cake and time spent in kitchen is significant, suggesting that the odds of having more frequent cardiac disease by a factor of 5, when dung cake is used and women spent 7-9 hours in the kitchen. The results of this model indicate that relationship between fuel use (dung cake) and cardiac disease is moderated by time spent in kitchen controlling for age and income.

CONCLUSION
The study concludes that in rural areas of Punjab, biomass fuels are often burnt inefficiently in open fires, with high emission factors, leading to extremely high levels of indoor and local air pollution, many times higher than the limits specified by international

standards of ambient air quality. Further, analysis of the present study shows an association between types of biomass fuel, stove type, kitchen type and health. The hypotheses of the present study were designed to investigate such interactions. The interactions of fuel with stove and kitchen use revealed breathing problems, coughing and chest pain which have highly significant association with all three types of biomass fuel.

The findings of this study provides a strong case for public health policy and programs to reduce exposure to smoke from biomass fuel. Public information campaigns about health risks of exposure are needed. In areas where shifting to cleaner fuels is not feasible due to financial reasons, improving the way biomass is supplied and used for cooking is, therefore, an important way of reducing its harmful effects. Improved cook-stove design that significantly reduce fuel consumption could also reduce the burden of disease. Another approach to improve the efficiency of fuel is

adding chimneys to stoves. In this way stoves can reduce indoor air pollution. A rural information and training programme should be developed immediately. Coordinated, consistent and focused cooperation of all stakeholders at the grassroots, policy-making and implementation levels is crucial. Action-oriented programs should also include a treatment strategy at public health centers to help suffering women.

REFERENCES

ADB. 2014. Energy access assessment in Punjab Pakistan. Economic and center context in Punjab. Published by Asian Development Bank. Pp 3-8.

Akhtar, T., Z. Ullah, M. K. Hassan and R. Nazli. 2007. Chronic Bronchitis in Women Using Solid Biomass Fuel in Rural Peshawar, Pakistan. Published Online, J. Chest. 132;1472-1475.

Census of Pakistan. 2017. Block wise provisional summary results of 6th population and housing census. Retrieved from: http://www.pbscensus. gov.pk.

Colbeck, I. Z. A. Nasir and Z. Ali. 2010. Characteristics of indoor levels of particulate pollution in urban and rural environments in Pakistan. Int. J. Env. Health. 20(1):40-51; doi: 10.1111/j.1600-0668.2009.00624.x.

Danielsen, K. 2012 Gender Equality, Women's Rights and Access to Energy Services: An inspiration paper in the run-up to Rio+20', Danish Published by Ministry of Foreign Affairs, Denmark. p 8-10.

Dasgupta, S., M. Huq, M. Khaliquzzaman, K. Pandey and D. Wheeler. 2006. Indoor air quality for poor families: New evidences from Bangladesh. Int. J. Env. Health. 16(6):426-444.

Ezzati, M and D. 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. 110 (11):1057-1068.

Goldemberg, J. 2000. World Energy Assessment: Energy and the Challenge of Sustainability. An introduction to energy (Chapter 1), United Nations Publications, Washington D.C. p. 31-37.

GoP. 2013. Bureau of Statistics, Government of Punjab. Lahore, Pakistan. p 281-309.

Gull, T. and V. Pulla. 2014. Patriarchy, Gender Violence and Poverty amongst Pakistani Women: A Social Work Inquiry Maliha, Int. J. Social Work and Human Services Practice, Horizon Research Publishing. 2(2):56-63.

International Energy Agency. 2013. World Energy Outlook. http://www. world energ youtlook.org/resources/energydevelopment/ energyaccessdatabase/

Jamali, T. Z. Fatmi A. Shahid, A. Khoso M. M. Kadir and N. Sathiakumar. 2017. Evaluation of short-term health effects among rural women and reduction in household air pollution due to improved cooking stoves: quasi experimental study. J. Air Qual. Atmos. Health. 10(7):809-819.

Kumar, N. M. 2007. Health effects of chronic exposure to smoke from biomass fuel burning in rural areas in India. Chapter 3. p 36-57.

Mathers, C.D., A.D. Lopez and C.J.L. Murray. 2006. The burden of disease and mortality by condition: data, methods and results for 2001.The global burden of disease and risk factor. Oxford University Press, Washington D.C. p. 45-234.

Naeher, L. P., M. Brauer, M. Lipsett, J. T. Zelikoff, C. D. Simpson, J. Q. Koenig and K. R. Smith. 2007. Wood smoke health effects: A review. J. Inhalation Toxicology. 19(1):67–106.

Rehana, A. S. L. B. Kiyoung., B. Gold and Z. A. Bhutta. 2005. Eye and respiratory symptoms among women exposed to wood smoke emitted from indoor cooking: a study from southern Pakistan, Energgy for Sustainable Environment. 9(3):58-66.

Scott, N., B. C. Felby and B. J. Thorsen. 2014. Agricultural residue production and potentials for energy and materials services, Progress in Energy and Combustion Science. 40:59-73.

Smith, K. R., S. Mehta and M. Maeusezahl-Feuz. 2004. Indoor smoke from solid fuels, Assessing the environmental burden of disease at national and local levels, Environmental Burden of Disease Series, No. 4. p 30-31.

Wakeela, M., B. Chena and S. Jahangir. 2016. Overview of energy portfolio in Pakistan, Energy Procedia. 88:71-75.

World Health Organization. 2006. Statistical information system. Global health observatory data. Available: http://www.who.int/whosis. (Assessed on June 2018).

World Health Organization. 2018. Household air pollution and health. http://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health. (Assessed on July 2018).

Zhang, J. J and L. Morawska. 2002. Combustion sources of particles: 2 emission factors and measurement methods, Chemosphere. 49:1059-1074.

CONTRIBUTION OF AUTHORS

S. No.	Author name	Contribution	Signature
1.	Nabeela Farah	Principal author, conducted the research and prepared write-up	
2.	Izhar Ahmad Khan	Supervised the research	
3.	Ashfaq Ahmad Maan	Member supervisory committee	
4.	Babar Shahbaz	Member supervisory committee	