

Research

Association between the use of biomass fuels on respiratory health of workers in food catering enterprises in Nairobi Kenya

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Abstract

Introduction: Indoor air pollution from biomass fuel use has been found to be responsible for more than 1.6 million annual deaths and 2.7% of the global burden of disease. This makes it the second biggest environmental contributor to ill health, behind unsafe water and sanitation.

Methods: The main objective of this study was to investigate if there was any association between use of bio-fuels in food catering enterprises and respiratory health of the workers. A cross-sectional design was employed, and data collected using Qualitative and quantitative techniques.

Results: The study found significantly higher prevalence of respiratory health outcomes among respondents in enterprises using biomass fuels compared to those using processed fuels. Biomass fuels are thus a major public health threat to workers in this sub-sector, and urgent intervention is required. **Conclusion:** The study recommends a switch from biomass fuels to processed fuels to protect the health of the workers.

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Introduction

Worldwide, approximately 50% of people, almost all in developing countries, rely on biomass fuels in the form of wood, dung and crop residues for domestic energy [1,2]. Biomass fuels are commonly burned in inefficient simple stoves and in poorly ventilated conditions. Due to the construction of such stoves acceptable principles of combustion is not complied to. According to [3] the three condition required for proper combustion are proper proportioning of fuel and oxygen (air), mixing of fuel and oxygen and ignition temperature of the fuel. In such situations, biomass fuel use generates substantial emissions of many health-damaging pollutants, including respirable particulates and carbon monoxide, and results in indoor air pollution exposures often far exceeding national standards and international guidelines [4]. Where biomass fuels are used, the average daily exposure concentration of children under the age of 5 to PM₁₀ (particulate matter smaller than 10 microns in diameter) is approximately 1500µg/m³ and that of adult women approximately 5000 µg/m³. This is many times higher than the latest United States Environmental Protection Agency (US: EPA) standard, which states that individuals should not to exceed PM₁₀ levels of 150 µg/m³ for a 24-hour period [5].

Several studies firmly associate biomass fuel use with acute lower respiratory tract infections, chronic obstructive pulmonary disease and lung cancer. Each of these three health outcomes is a major disease category in most societies. According to the World Health Organisation (WHO) [6], household biomass fuel use is likely to be a major cause of disease burden in communities where it is prevalent. Globally, WHO attributes 2.7% of all ill-health to indoor smoke from biomass fuels, nearly all in developing countries. Evidence is also emerging that exposure to indoor air pollution from biomass fuels may increase the risk of a number of other important conditions, including tuberculosis, low birth weight, and cataract [4, 7-9]. In developing countries, according to WHO [6], around 4.9% of deaths and 4.4% of Daily Adjusted Life Years (DALYs) are attributed to indoor air pollution from solid biomass fuels.

The above mentioned studies indicate that those who are mostly at risk are women, because they are responsible for food preparation and cooking, and infants/young children who are usually with their mothers near the cooking area. However, no study had previously been done to determine if other groups of people who spend a lot of time indoors during cooking using biomass fuels for instance workers in food catering enterprises are also vulnerable. This is the gap the study aimed to fill, focusing on respiratory health given that the pollutants are inhaled. Workers in food catering enterprises were particularly chosen since these enterprises are the largest biomass fuel energy consumer among all small and medium enterprises under the cottage and service sector category [10]. The general objective of this study was therefore to determine the association between use of biomass fuels in food catering enterprises and respiratory health outcomes exhibited by the workers. The specific objectives of the study were: To assess the determinants of exposure to indoor air pollution from biomass fuels; To determine the major fuel types used by food catering enterprises in Nairobi and factors determining their choice; To establish prevalence of respiratory health symptoms exhibited by the workers; and To investigate the influence of exposure factors on prevalence of respiratory health outcomes exhibited.

Methods

The study employed a cross-sectional design as most of the enterprises were built on illegal land and are constantly demolished.

Employment in the sector is also temporary, with workers constantly shifting from one form of activity to another. This is a general characteristic of the informal sector.

The study was carried out in the city of Nairobi between June 2008 and January 2009 According to the 1999 population and housing census, Nairobi's population was 2,807,154 with 1,397,963 males and 1,409,191 females. The number of males working for pay was estimated at 454,456 and females 209,514 [11]. Unemployment figures were 95,535 and 73,128 for males and females respectively. A large proportion of the unemployed engage in informal sector activities as a source of income. In 2004, Nairobi province accounted for 24.2% and the highest informal sector employment of 1,343,000 persons [11].

The study population comprised of both male and female workers (employees and employers) in food catering enterprises. Workers at these enterprises were the main respondents, while the food catering enterprises were taken as the sampling unit. A combination of cluster sampling and simple random sampling were used. To select the enterprises, a list of all the estates (clusters) in each of the eight divisions of Nairobi was made. One cluster was then picked at random from each Division. There were 250 enterprises in the eight clusters. Thirty per cent of the enterprises were randomly selected amounting 60 enterprises. Listing of the workers was done in the enterprises which had a total of 5 workers per enterprise hence a total of 400 workers. All the workers were targeted but only 368 were available for the interview. Hence 368 respondents were interviewed.

The study employed questionnaires for the workers, interview guides for the proprietors and observation checklists to observe if protective gear was used. Health outcomes were expressed in terms of respiratory symptoms such as cough, phlegm, breathlessness and wheezing as defined by the Medical Research Council (MRC) questionnaire for respiratory symptoms, chronic respiratory illnesses such as Chronic Obstructive Pulmonary Disease (COPD), asthma, and Acute Lower Respiratory Tract Infection (ALRI) which has been used in similar studies [12]. The MRC questionnaire was modified to suit local conditions.

Data were analysed using the SPSS software to generate descriptive statistics for independent and intermediate variables, while chi-square statistic was used to test the association between respiratory symptoms such as cough, phlegm, wheezing and breathlessness (dependent variables) and the independent variables or exposure factors. Confounding variables such as smoking, age and fuel used at home were treated as independent factors in separate analyses. Although broader environmental factors such as temperature, humidity, air velocity, ambient air quality and others might have contributed to the observed respiratory health symptoms, the principal focus of the study was on the effects of indoor exposure and type of biomass used across enterprises.

Results

Respondents' characteristics

The mean age of respondents was 28.6 years. A large proportion of the respondents (58.5%) were aged 21- 30 years of which 56% of the respondents were males and 44% females. Forty six (46%) had primary level of education, 39% had secondary education and 13% had tertiary education. Two thirds (67%) of the respondents earned 3000 Kenya Shillings (Kshs)(US\$35) or less per month, and were mostly casual employees. Over fifty percent of the respondents (59.5%) had worked in food catering enterprises for not more than

2 years, with 55% spending less than six hours a day in the cooking area.

Most respondents (62.4%) used kerosene for home cooking. Charcoal was the second and only biomass fuel used at home, accounting for 20.3% of the respondents. Liquid Petroleum Gas (LPG) was used by 8.6% of respondents. Some respondents (7.3%) used various fuels of varying quantities hence could not classify any as the main fuel type.

Enterprise characteristics

Most enterprises' structures were made of tin, which is generally the dominant construction material of informal enterprises, given their temporary nature. Concrete was mainly used by registered enterprises. A few enterprises were constructed with mud, and accounted for 5.5% of the respondents. Other enterprises were made of brick, while others used a mixture of materials such as wood and tin. Most of the kitchens were very small, measuring 3m² or less. Only 14.6% of respondents worked in enterprises that covered areas greater than 7m².

Two thirds of the enterprises had windows or chimneys as forms of ventilation. Enterprises that had windows as the main form of ventilation constituted 41.1% while those with chimneys accounted for 12.4%. Others had both chimneys and windows, accounting for 13.2%. Nearly one third of the respondents (33.2%) worked in enterprises that had neither windows nor chimneys, but other forms of ventilation. These ranged from large open spaces on the roof or wall to very tiny holes on the upper part of the walls that would hardly let out smoke from the kitchens. Some enterprises consisted of space with wire-mesh surrounding the entire wall of the kiosk especially in areas where customers were served, not in the kitchens.

Only 29% of the enterprises were registered by the Registrar of Companies of Kenya. The remaining 71% were not registered meaning that they were operating illegally. Nearly all the enterprises (95.5%) had 1 to 5 employees, thus falling in the micro-enterprises category. Small enterprises (with 6 to 20 employees) accounted for only 9%. Most enterprises (81%) reported using biomass fuels as the main form of fuel, whereas processed fuels accounted for only 19%.

Charcoal was the most utilised fuel type (58.9%), followed by fuelwood (18.6%) and electricity (14.1%). LPG came fourth, accounting for 4.9% of the businesses, followed by sawdust (3.5%). No enterprise reported using kerosene as a main fuel type. Charcoal was the most preferred biomass fuel. Even though many enterprises used fuelwood and sawdust, they were utilised as substitute fuels rather than main forms of fuel. Kerosene was also used as a substitute fuel. Despite the fact that charcoal was preferred to fuel wood, this should not be encouraged given that charcoal production contributes to emissions such as greenhouse gasses for example CO₂ as well as other air pollutants for example volatile organic compounds including benzene that is a known carcinogen [13]. Results from the enterprise proprietors indicate a shift to cleaner fuels such as liquid petroleum gas and electricity would not be affected due to cost implications.

Prevalence of respiratory health symptoms

Nearly half (49%) of the respondents reported having one form of respiratory symptom or another whilst 51% did not experience any of the listed symptoms. Other respondents had more than one symptom (16.5%), while a few (4%) reported experiencing all the symptoms under investigation.

Table 1 shows that the most experienced symptom was cough at 42% of the study population. Cough tends to be the first indication of irritation of the respiratory tract and that explains why it had the highest prevalence. The remaining symptoms were, however, reported by less than one fifth of respondents: breathlessness at 18%, wheezing at 15%, and lastly phlegm being the least experienced symptom at 14.5%.

Presence of these respiratory symptoms over a long period of time are considered indicative of respiratory health ailments especially in studies where it is impossible to ascertain the presence of respiratory diseases [8]. The study focused on respondents who had experienced these symptoms in the past one year. The study assessed all the symptoms in relation to exposure factors that could have influenced their presence.

Factors influencing respiratory health outcomes

Influence of age: A higher prevalence of most respiratory health symptoms is observed amongst those aged above 29 years (**Table 2**). The only exception was cough with equal proportions between those under and above 29 years. The difference in respiratory health outcomes between the two age categories were statistically significant: for phlegm ($\chi^2=18.78$; $df=1$; $p=0.004$) and all symptoms ($\chi^2=6.16$; $df=1$; $p=0.047$).

This finding can be explained by duration of exposure as those who were older had worked for longer periods in food catering enterprises, hence been exposed to the harmful pollutants for a longer period of time. Most of old people had worked in food catering enterprises for longer periods and had more stable business compared to the lower age-groups, of whom the majority were new entrants in the sector hence had not experienced long term exposure.

Fuel used at home: Uses of charcoal at home recorded the highest prevalence for most respiratory health symptoms (cough, 48%; phlegm, 17.3% and breathlessness, 26.7%) followed by Kerosene users. A significant association existed between the type of fuel used at home by the respondents and cough ($\chi^2=13.04$; $df=5$; $P=0.023$), with prevalence in charcoal users being nearly three times higher (48.1%) than that in LPG users (17.1%). Breathlessness was also found to be significantly higher in charcoal and kerosene users compared to those using other fuel types ($\chi^2=11.12$; $df=2$; $P=0.049$).

It was found that 78.7% of those using kerosene at home were using biomass fuels in the enterprises they worked in, hence leading to the exposure. Given that most respondents (82%) worked for nearly 12 hours a day for six days a week, they spent limited time at home. Hence most of their exposure occurred in the work environment.

Ventilation: The prevalence of respiratory health symptoms was higher for those with other forms of ventilation, followed by those with only windows. Those with chimney came in a distance third, and those with chimney and window had the least prevalence (**Table 3**).

Those using other forms of ventilation recorded the highest prevalence for nearly all respiratory health outcomes (with the exception of wheezing). The largest differences were observed between those with other forms of ventilation and those with chimney & window. For instance, the prevalence of cough was 60.9% in those with other forms of ventilation, and only 6.1% in those with chimney and window.

There was significant association between forms of ventilation and nearly all the health symptoms (**Table 3**), with enterprises having chimney and window recording significantly lower prevalence of symptoms compared to those that had other forms of ventilation.

Influence of fuels used in enterprises

Two analyses were done on respiratory health symptoms and fuel types. The first was based on all fuel types while the second involved the binary classification scheme, separating the study population into those using biomass fuels and those using processed fuels.

Table 4 shows that fuel wood and sawdust users reported the highest prevalence of most of the respiratory health symptoms, followed by charcoal users. LPG users came in third while electricity users had the least prevalence of symptoms, with none of them reporting experiencing wheezing.

Significant association was established between fuel types and most respiratory health outcomes as shown in **Table 5**, with respondents using charcoal, fuel wood and sawdust recording higher prevalence than those using electricity and LPG.

Although charcoal has poorer combustion efficiencies than other biomass fuels, the charcoal production process creates a fuel that burns with far less smoke than wood at the point of end-use, leading to lower emissions of PM₁₀. This is because charcoal has undergone some form of processing during which some of its PM content has been released, unlike raw wood. During the study, it was observed that enterprises using fuelwood and sawdust were visibly smoky, and respondents were coughing during the interviews. Enterprises using charcoal were however less smoky, and after the charcoal had caught fire, no smoke was visible. This would therefore explain why charcoal users had lower prevalence of respiratory symptoms compared to fuelwood and sawdust users, and why charcoal was not significantly associated with most symptoms.

Charcoal users reported higher prevalence of all the symptoms under investigation compared to electricity and LPG users. For instance, they recorded 75% prevalence of cough compared to only 19% recorded by electricity users. This is because charcoal is a biomass fuel, and biomass fuels have generally been associated with significant emissions of PM₁₀ in relation to processed fuels.

Influence of forms of fuels used

When classified on the basis of binary fuel types, biomass fuel users reported higher prevalence of all the symptoms compared to those using processed fuels (**Figure 1**). Prevalence of cough was nearly 5 times higher (49%) in biomass fuel users compared to processed fuel users (10%). For phlegm and breathlessness, the prevalence was up to three times higher in biomass fuel users compared to processed fuel users.

None of the processed fuel users reported experiencing wheezing or all the symptoms, yet biomass fuel users reported prevalence of 19% and 15% respectively. Prevalence of phlegm and breathlessness were up to three times higher in biomass fuel users compared to processed fuel users. The remaining symptoms were more than four times higher in biomass fuel users. None of the processed fuel users reported experiencing wheezing or all the symptoms, yet biomass fuel users reported prevalence of 19% and 15% respectively. The differences were found to be statistically significant for some symptoms (cough, $p=0.000$; phlegm, $p=0.011$; breathless, $p = 0.004$; wheezing, $p=0.000$).

Discussion

These findings are consistent with most studies that have related biomass fuel use to respiratory health outcomes, even though all the previous studies were done in households.

In a household study by [14] that used case-control design by reporting fuel type (wood vs. cleaner fuel) as a proxy for exposure, those who were exposed to smoke from biomass fuels reported higher prevalence of respiratory abnormalities as compared with users of cleaner fuels. For instance, prevalence of COPD and ALRI among unprocessed fuel users was three times higher compared to those using processed fuels. Similarly, much higher prevalences of all respiratory symptoms were found for the unprocessed fuel users. Studies in Kenya by [15, 16] in Mpala Ranch also revealed significantly higher prevalence of respiratory ailments among biomass fuel users. However, the high prevalence of symptoms among kerosene users found in this study is inconsistent with these studies, given that kerosene is a processed fuel. The inconsistency could therefore imply that the high prevalence observed did not arise from exposure at home, but from occupational environment.

Many studies show that biomass fuels are detrimental in kitchens that are poorly ventilated; therefore implying that ventilation is a crucial parameter in determining respiratory health outcomes. Ventilation is a major factor influencing the concentration of pollutants, hence a key factor in determining exposure and health outcomes. Poor ventilation therefore is associated with more symptoms.

A study by [17] found similar results, whereby there was a significant reduction in the risk of contracting ALRI between groups of people using charcoal relative to groups using fuel wood. Households using charcoal stoves had PM₁₀ concentrations of around 500 $\mu\text{g}/\text{m}^3$, while households using wood in an open fire had concentrations over 3000 $\mu\text{g}/\text{m}^3$. The risk of adult men contracting ALRI was 44% lower in households using charcoal rather than fuel wood, while reduction in risk for adult women was 65%.

The study indicates that despite the fuel type used, a key intervention measure would be to ensure adequate ventilation to protect health of the workers. Chimneys would especially be useful, as enterprises fitted with chimneys reported the least prevalence of respiratory health outcomes. This kind of intervention would yield other positive benefits such as becoming an income generating activity for people in the informal sector, as most of the chimneys were *jua kali* made (Swahili language directly translated as "hot sun" meaning that the enterprises are conducted in the open outdoor environment).

Security could have been a factor, but they need to be made aware of the danger they are exposing themselves to by cooking with biomass fuels in poorly ventilated conditions. Registration of the enterprises is also key, as this would enable them to make investments in ventilation knowing they'll be able to operate those facilities for a given period of time. Most of the unregistered enterprises had very small kitchen that could not fit in chimneys even if they had that option.

The results confirm what has been established by previous studies, that indoor air pollution from biomass fuels greatly compromises respiratory health of exposed populations. The study has thus demonstrated that workers in food catering enterprises who use biomass fuels are facing a great public health risk that needs attention. The results imply that switching from biomass fuels to

processed fuels would lead to significant reductions in the prevalence of respiratory health problems.

At the same time, the results indicate that some forms of biomass fuel are more harmful to health compared to others. In this instance, those using charcoal had significantly lower prevalence of respiratory health outcomes compared to those using fuelwood. Therefore a switch from fuelwood to charcoal would significantly reduce the health threat. Though in the long run, if the economic status of the study population is improved, it is recommended that there is a switch to liquid petroleum gas (LPG) and electricity as a cleaner source of energy supply for cooking purposes.

Conclusion

The study demonstrated that there is an association between use of biomass fuels in food catering enterprises and prevalence of respiratory disease symptoms among the workers. Biomass fuel use is therefore a major health threat, not just to women and children in households but also to workers in food catering enterprises. Improving access to cleaner and more efficient energy to these enterprises will lead to marked improvements in health and well being of the many workers engaged in the sub-sector. Aside from the fuel types, the study demonstrated that other factors including registration status of enterprises and ventilation are significant determinants of health symptoms. Therefore in addition to fuel switch, measures such as registering the enterprises and improving ventilation in them would lead to health benefits.

Based on the study findings the following measures to reduce the effects of indoor air pollution from biomass fuels on respiratory health of workers in food catering enterprises are proposed:

- Switch from biomass fuels to processed fuels, given the significant differences observed in health effects associated with the two forms of fuels. However, given that cost was found to be a major determinant of fuels choice, efforts aimed at reducing the cost of processed fuels should first be put in place. These include reduction in cost of appliances such as cookers and cylinders, fuel subsidies and sale of processed fuels in smaller quantities. This can be achieved through formulation of national level policies that would encourage supply and distribution of improved cleaner fuels.

- Switch from highly polluting biomass fuels such as fuelwood to less polluting ones such as charcoal, which was associated with lower prevalence of symptoms. This could be a more viable option, given that the cost implication involved is lower compared to switching that of switching to processed fuels. Reduction in charcoal costs can also be achieved through change of current policy that makes charcoal production and transportation illegal yet legalizes its sale. This intervention however needs to be balanced with potential environmental impacts that could result from greenhouse gas emissions associated with charcoal production and use.

Other general measures to include: education and awareness creation, ensuring improved ventilation through regular inspections, advise workers to reduce the number of hours spent indoors, registration of the enterprises and significant changes in Nairobi City Council Bylaws. A study by [18] revealed that elevated levels of air pollution during indoor activities can lead to increase in risk of respiratory health problems such as chronic bronchitis and obstructive pulmonary disease (assessed clinically and by spirometry). There is also a direct correlation between time of exposure and presented symptoms.

Competing interests

The authors declare that there is no competing interest (financial or non-financial). Funding for the project was received from the Kenyatta University in Nairobi, Kenya.

Authors' contributions

Margaret Keraka: She was responsible for initialising the research and acted as lead researcher of the project. She was also responsible for the formulation of the research problem and objectives. Carolyne Ochieng: She was responsible for the development of the measurement instruments, collection of the data, and literature survey. Jacobus Engelbrecht: He was responsible for the drafting of the manuscript and acted as advisor and collaborator during the project. Charles Hongoro: He was responsible for reviewing the quantitative analysis of the data and the peer review of the final article.

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Tables and figures

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Table 5: Association between fuel type and respiratory health outcomes

Figure 1: Distribution of respondents by symptoms and binary fuel types

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Table 1: Frequency distribution of responses by respiratory symptoms

| Respiratory Symptoms | Number of responses (%*) | | TOTAL |
|----------------------|--------------------------|-------------|--------------|
| | Yes | No | |
| Cough | 155 (42.0%) | 215 (58.0%) | 370 (100.0%) |
| Phlegm | 54 (14.5%) | 316 (85.5%) | 370 (100.0%) |
| Breathlessness | 67 (18.0%) | 303 (82.0%) | 370 (100.0%) |
| Wheezing | 56 (15.0%) | 314 (85.0%) | 370 (100.0%) |
| All symptoms | 15 (4.0%) | 355 (96.0%) | 370 (100.0%) |

* Multiple responses allowed

Table 2: Cross tabulation of respondents by respiratory symptoms and age

| Respiratory symptoms | Number of respondents with symptoms (%) | | TOTAL |
|----------------------|---|----------------|-------------|
| | 29 years and below | Above 29 years | |
| Cough | 103 (42.0) | 52 (41.6) | 155 (42.0%) |
| Phlegm | 34 (13.9) | 20 (16.0) | 54 (14.5%) |
| Breathlessness | 43 (17.6) | 24 (19.2) | 67 (18.0%) |
| Wheezing | 33 (13.5) | 23 (18.4) | 56 (15.0%) |
| All symptoms | 6 (2.4) | 9 (7.2) | 15 (4.0%) |

* Multiple responses allowed

Table 3: Cross tabulation of respondents by symptoms and forms of ventilation

| Respiratory symptoms | Number of respondents with symptoms (%) | | | | P – Value* |
|----------------------|---|------------|------------------|------------|------------|
| | Chimney | Window | Chimney & Window | Other | |
| Cough | 6 (13.0%) | 71 (46.7%) | 3 (6.1%) | 75 (60.9%) | 0.000 |
| Phlegm | 2 (4%) | 26 (17.1%) | 2 (3.8%) | 24 (19.5%) | 0.005 |
| Breathlessness | 6 (13%) | 27 (17.8%) | 3 (6.1%) | 31 (25.2%) | 0.008 |
| Wheezing | 2 (4.0%) | 28 (18.4%) | 3 (5.7%) | 23 (18.7%) | 0.058 |
| All symptoms | 0 | 6 (3.9%) | 0 | 9 (7.5%) | 0.035 |

* χ^2 Test, $p < 0.05$

Table 4: The relationship between reported health symptoms and fuel types

| Respiratory symptoms | Number of respondents with symptoms (%) | | | | | TOTAL |
|----------------------|---|------------|-----------|-------------|-----------|-------------|
| | Charcoal | Fuelwood | Sawdust | Electricity | LPG | |
| Cough | 89 (40.8%) | 51 (73.9%) | 8 (61.5%) | 4 (7.7%) | 3 (16.7%) | 155 (42.0%) |
| Phlegm | 31 (14.2%) | 16 (23.2%) | 3 (23.1%) | 3 (5.8%) | 1 (5.6%) | 54 (14.5%) |
| Breathlessness | 43 (19.7%) | 16 (23.2%) | 3 (23.1%) | 4 (7.7%) | 1 (5.6%) | 67 (18.0%) |
| Wheezing | 40 (18.3%) | 13 (18.8%) | 3 (23.1%) | 0 | 0 | 56 (15.0%) |
| All symptoms | 9 (4.1%) | 5 (7.2%) | 1 (7.7%) | 0 | 0 | 15 (4.0%) |

Table 5: Association between fuel type and respiratory health outcomes.

| Symptoms | Fuel Types | χ^2 | df | P value* |
|----------------|-----------------------------|----------|----|----------|
| Cough | Charcoal versus electricity | 68.48 | 4 | 0.000 |
| Phlegm | Fuel wood versus LPG | 11.35 | 4 | 0.023 |
| Breathlessness | Fuel wood versus LPG | 10.06 | 4 | 0.039 |
| Wheezing | Sawdust vs electricity/LPG | 17.4 | 4 | 0.020 |
| All symptoms | Sawdust vs electricity/LPG | | 4 | 0.051 |

Notes: $p < 0.05$

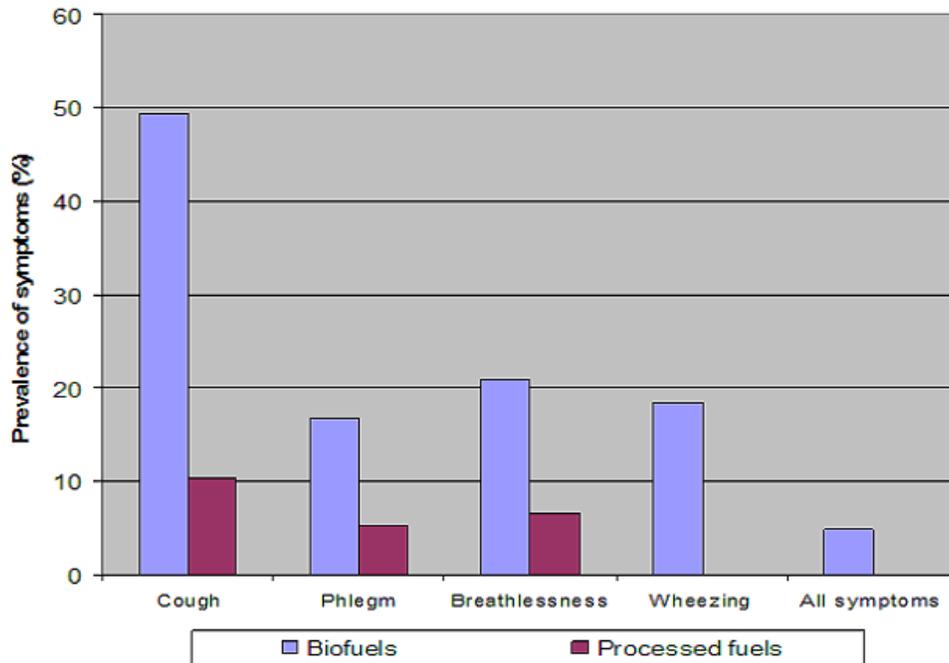


Figure 1: Distribution of respondents by symptoms and binary fuel types