ASSESSMENT OF BIOMASS FUEL USE AND ITS ASSOCIATION WITH ACUTE RESPIRATORY INFECTIONS AMONG UNDER FIVE CHILDREN IN ZAMBIA

BY

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements for the award of the degree of masters of public health - environmental health

THE UNIVERSITY OF ZAMBIA

LUSAKA

DECLARATION

I **Namwinga M Nachalwe** declare that this dissertation titled: "**Assessment of Biomass fuel use and its association with Acute Respiratory infections among under five children in Zambia**" is my original work and has not been submitted for a degree, diploma or other qualifications at this or another University. It has been prepared in accordance with the prescribed Guidelines for Post-graduate Studies Dissertations of the University of Zambia.

Researcher's Signature…………………………………Date………………………………..

CERTIFICATE OF COMPLETION

I ...., having supervised and read this dissertation is satisfied that this is the original work of the author whose name it is being presented. I confirm that the work has been completed satisfactorily and is hereby ready for presentation to the examiners.

Supervisor's Signature ______________________________ Date_____________________

Head of Department_________________________________ Date _____________________

APPROVAL

This Dissertation of Namwinga Nachalwe M has been approved as fulfilling the requirements or partial fulfilment of the requirements for the award of degree of Master in Public Health by the University of Zambia;

Examiner 1___________________________________Signature_____________Date_______

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Examiner 3 __________________________________Signature_____________Date_______

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Supervisor____________________________________Signature____________Date________

ABSTRACT

Around 3 billion people cook and heat food in their homes using biomass fuels like wood, crop wastes, charcoal, coal and dung. Up to 81% of Sub Sahara Africa (SSA) relies on biomass fuel for cooking. In Zambia, about 98% of rural households and 63% in urban areas use biomass fuel as their main source of cooking energy.

Research indicates that, extended exposure to high levels of biomass smoke can impair the clearing ability of the lungs and render them more susceptible to developing acute respiratory infection (ARI). ARI have been said to cause 15% of all deaths in children under the age of five and over half of these deaths occur in developing countries including Zambia. According to the 2013/14 Zambia demographic and health survey (ZDHS), ARI is the leading cause of childhood morbidity and mortality in Zambia.

This was a cross-sectional study. Children below the age of five from all the 10 provinces of Zambia were recruited. Secondary data from 2013/14 ZDHS was used for the study. Analytical statistical methods were performed using STATA software version 14. Descriptive statistics were used to provide overall characteristics. Variables such as age, sex, vaccination, mothers' education status are presented as proportions and frequencies. Bivariate analysis was done to establish association between dependent variable ARI and all the independent variables. Finally, multiple logistic regression model was performed to examine the association between our outcome of interest, ARI and biomass fuel which is our priori independent variable while controlling for other variables.

The prevalence of ARI was 30% (n=2,795). After controlling for confounders like type of housing unit walls, sex of the child, nutritional status, mothers age, smoking status, marital status and wealth quantile, it was found that children in households with biomass fuel had higher odds of ARI compared to those with electricity (OR, 1.53, 95%CI 1.04- 2.27).

At least 93 percent of children with ARI come from homes that rely on biomass fuel. There is therefore need to sensitize the mothers about the health problems associated biomass combustion and shift to cleaner fuels or promote stoves designed to reduce exposure to smoke.

Keywords: Biomass Fuel and Acute Respiratory Infections.

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ABBREVIATIONS

ARI	Acute Respiratory Infection
CSO	Central Statistical Office
EA	Enumeration Area
IMCI	Integrated Management of Childhood Illness
MOH	Ministry of Health
REA	Rural Electrification Authority
TDRC	Tropical Disease Research Centre
WHO	World Health Organization
UNICEF	United Nations International Childrens' Fund
UNZA	University of Zambia
USEPA	United States Environmental Protection Agency
ZDHS	Zambia Demographic and Health Survey
ZHHEUS	Zambia Household Health Expenditure and Utilization Survey

CHAPTER ONE: INTRODUCTION

1.1 Background

Around 3 billion people cook and heat food in their homes using biomass fuel like wood, crop wastes, charcoal, coal and dung. Up to 81% of Sub Sahara Africa relies on biomass fuel for cooking which is far more than any other region in the world (WHO, 2016; AFREA, 2011). In Zambia, about 98% of rural households and 63% in urban areas use solid fuel as their main source of cooking energy (CSO, 2015).

Biomass fuel is said to be among the least efficient and dirtiest of fuels due to incomplete combustion. As a result, it is categorized into the lowest group in the energy group ladder (IEA, 2015). The incomplete combustion of biomass fuel can result in emissions of smoke and high levels of health-damaging pollutants such as particulate matter (PM2.5 and PM10), Carbon monoxide (CO), Nitrogen dioxide (NO2), formaldehyde, benzene, 1,3 butadiene, polycyclic aromatic hydrocarbons such as benzo, and many other toxic organic compounds (USEPA, 2015).

Research indicates that, extended exposure to high levels of biomass smoke, which contains various irritants, cilia toxic fractions, and mucous coagulating agents, can impair the clearing ability of the lungs and render them more susceptible to developing stroke, ischemic heart disease, chronic obtrusive pulmonary disease (COPD), lung cancer, and acute respiratory infection (Torres-Duque et al, 2008)

Acute respiratory infection (ARI) refers to infectious diseases involving the respiratory tract and may interfere with normal breathing. ARI have been said to cause 15% of all deaths in children under the age of five and over half of these deaths occur in developing countries including Zambia (UNICEF, 2014). According to the 2013/14 Zambia demographic and health survey, ARI is the leading cause of childhood morbidity and mortality in Zambia (CSO, 2014).

The World Health Organisation (WHO), United Nations International Childrens' Fund (UNICEF) and other stakeholders introduced four types of interventions to control ARI around the world. These interventions include, immunization against certain pathogens, early diagnosis and treatment of the disease, improvement in nutrition and safer environments (WHO, 2008). Although there has been some form of reduction in ARI morbidity and mortality among under five children in low income countries, ARI still remain the leading infectious cause of death killing at least 2500 children a day globally including Zambia (Madhu et al, 2017; CSO, 2014).

Basically, ARI is caused by a variety of viruses and bacteria which include rhinoviruses, enteroviruses, and species such as influenza and mycoplasma only to mention a few(Lau et al, 2007). Mostly, respiratory viruses are said to infect the respirator tract but do not necessarily always produce clinical manifestation of ARI. Research has reported that for clinical manifestation to happen, a number of risk factors must be present; among them is sex of the child, parental smoking, crowding at home, respiratory infections among other siblings, low birth weight, non-exclusive breast feeding, incomplete immunizations, poor nutrition, formula feeding, young maternal age and low educational status of mothers and fathers and the use of biomass fuel (Mandal and Sahi, 2016).

It has been reported that over half of the deaths from ARI are as a result of particulate matter inhaled from combustion of household biomass fuel and one third of ARI deaths related to indoor air pollution occur in Africa (WHO, 2014).Research has indicated that there is an association between biomass fuel use and ARI. For instance, a study conducted in Cameroon and Gabon reported that under five children leaving in households using biomass fuel were more exposed to ARI compared to those using other kinds of cooking fuel (Jean-Daniel, 2016). Further, in Ethiopia, at least 50,320 of annual under five ARI deaths accounting 4.9% of national burden of disease were as a result of combustion of biomass fuel (WHO, 2014; WHO, 2007).

In Zambia, very little is known on the extent to which ARI can be attributed to the use of biomass fuel. An extensive search of literature showed no studies on biomass fuel use and its association to ARI. This study was aimed at assessing the use of biomass fuel and it association with reported ARI among under five children in Zambia.

1.2 Statement of the problem

Acute respiratory infections are a leading cause of childhood morbidity and mortality in Zambia (CSO, 2014). In every district of the country, ARI is the leading cause of hospital visit and death for under-five children which is followed by malaria and diarrhoea. According to the WHO Zambia statistical fact sheet, in 2014, 67% of the children visited health facilities as a result of ARI. WHO further reports that 16 % of under five deaths in 2013 were caused by ARI (WHO 2016, 2015).

Among the key interventions to reduce ARI in Zambia was the introduction of the Integrated Management of Childhood Illness (IMCI) in the early 90s which was developed by UNICEF and WHO to provide a holistic approach to child health. The three main components of this strategy are improving the case management skills of health care staff; improving overall health systems and improving family and community health practices. To complement facility based IMCI, the integrated community case management approach was initiated in 2010 were community health workers are trained to identify pneumonia and to treat affected children at the community level with amoxicillin. This approach was initiated to increase accessibility to care and reduce mortality resulting from pneumonia and malaria (CSO, 2014).

In addition to these interventions, children are vaccinated with pneumococcal, haemophilus influenza and other vaccines in order to reduce morbidity and mortality of under five children (GAVI, 2013). Despite this, ARIs remain a leading cause of childhood morbidity and mortality in Zambia (CSO, 2014). The figure 1 below shows trends on ARI in Zambia and indicates that these trends have been fluctuating, despite interventions and vaccinations, there has not been constant decrease in ARI.

ARI Trends

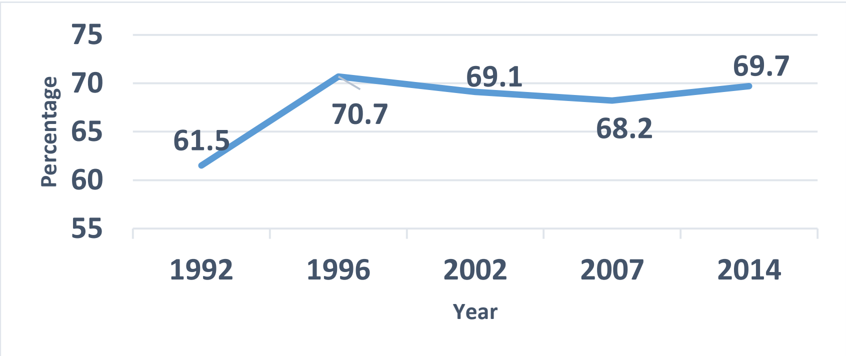

Figure 1 ARI trends in Zambia over the years

Source: UNICEF, state of the world children 2016

Zambia not only has high rates of ARI but also a high proportion (over 81 %) of households that use some form of biomass as their primary cooking fuel. This leads to high levels of cooking smoke exposures among women, young children, and the elderly who are usually in close range or around the fire during cooking activities. Studies from other countries have reported an association between the use of biomass fuel and ARI. However, there is barely anything known about the burden of ARI in under-fives associated with biomass fuel use in Zambia.

1.3 Justification of the Study

Biomass fuel generates dangerous toxins like carbon monoxide, nitrogen oxide and particulate matter. While we know the extent of biomass pollution, it is also important to know the effect for it on health in our setting. Biomass fuel has been shown to be associated with acute respiratory tract infections especially in children under the age of five. Acute respiratory infections are among the leading causes of morbidity and mortality in young children less than 5 years of age killing at least 2500 children a day globally (Madhu et al, 2017). The use of biomass fuel is common in this setting, about 98% of rural households and 63% in urban areas, however there is limited evidence to show what proportion of ARI are related to biomass fuel use. Therefore the findings of the study will help to know the proportion of ARI associated to biomass fuel use in our setting.

Zambia being a low-middle income country and 60 % of the population living below the poverty line, cheaper energy options are a common thing. A gap however exist in knowledge regarding the association between use of biofuel and ARI. Chronic exposure of children to pollutants lead to repeated episodes of ARI and can lead to death. There is need to document the extent of biomass fuel use in this setting and whether there is an association with acute infections among children.

1.4 Study Significance

An extensive search of the literature has shown that there are no studies that have documented the extent of biomass fuel use and its association with acute respiratory infections in this setting. Zambia being a lower middle income country with more than half its population living in rural setting and below the poverty line, the vast majority of the population use alternative sources of energy other than electricity. It is therefore important to document the extent of the use of biomass fuels and its relationship with respiratory infections in children. Potentially this would be useful information for policy makers and the information could be beneficial for designing interventions to reduce biomass fuel use and exposure of children to biomass fuel pollutants which in the long run could reduce morbidity and mortality in the young children.

The study will add to the existing knowledge on biomass fuel use and its association with ARI among under-fives and it might save as a basis for further research in Zambia.

1.5 Objectives of the Study

1 .5.1 Research Questions

Is there an association between biomass fuel use and acute respiratory infection outcomes among under five children in Zambia?

1.5.2 General Objective

To assess the association between biomass fuel use and acute respiratory infection outcomes among under five children in Zambia using the ZDHS 2013-2014.

1.5.3 Specific Objectives of the Study

i. To describe the socio-demographic characteristics of respondents affected by ARIs in Zambia between 2013 and 2014.

ii. To determine the proportion of under five children with the ARIs in Zambia between 2013 to 2014.

iii. To establish association between ARI, biomass fuel and other social-economic and demographic characteristics among under 5 children in Zambia in 2013-2014.

1.6 Conceptual Framework

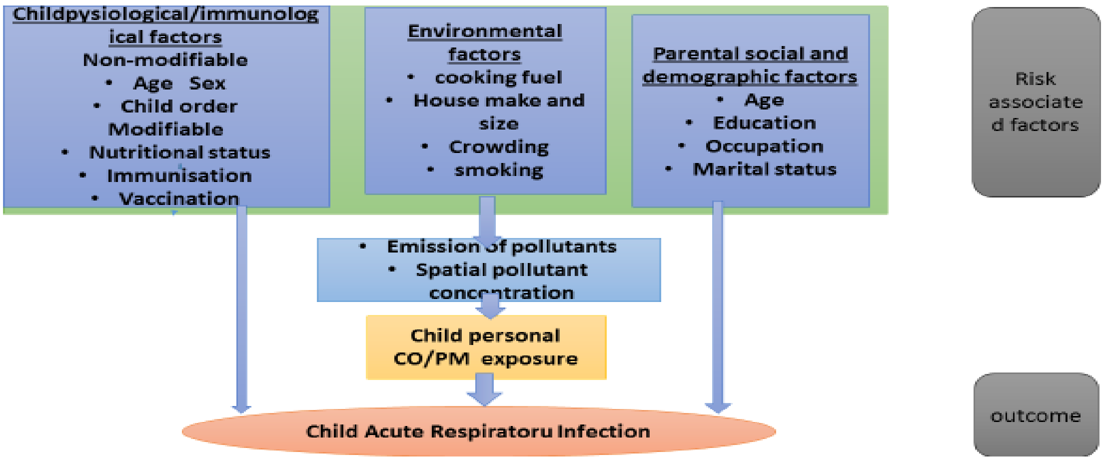

Figure 2: Conceptual framework

Source: Adopted from Briggs, 2003

To understand the factors that influence ARI, this study adopted a conceptual framework from Multiple Exposures Multiple Effects (MEME) model from the WHO as shown in figure 2. However, the model has some minor modifications. The model explains that risks are mainly dependent on the ability of children or their mothers to resist infection. Genetic factors and general state of health, social and environmental conditions may be important in this respect. Inadequate diet, poor housing and overcrowding may all work to reduce resistance or increase the risks. Because children spend most of their time at home, indoor exposures to air pollution are also extremely important. The main indoor exposures are biomass fuels especially in poorly ventilated fires or stoves, and environmental tobacco smoke. Poor housing and poverty are also a major risk factor (Briggs, 2003).

1.7 Outline of the Report

This report is outline in the following way. The first chapter has an introduction which starts with the background of the study and ends with the conceptual framework of the study. The second chapter consists of the literature reviewed from different search engines. Chapter three highlights the methods used in the study which is followed by chapter four giving us the results. Chapter five then follows with the discussion of the study lastly a conclusion and recommendations are drawn from the findings of the study in chapter six.

CHAPTER TWO: LITERATURE REVIEW

As a preliminary step for this study, a variety of literature from different search engines was reviewed. The main key terms used for the search is biomass fuel, indoor air pollution, ARI and risk factors of ARI among under-fives.

2.1 Brief Overview of Biomass Fuels

Generally energy used among humans consists of electricity, gas fuels (natural and methane gas), liquid fuels (kerosene, ethanol and methanol, and liquefied petroleum gas), and biomass fuels. Biomass fuels are defined as any type of fuel that produce energy from solid materials such as coal, lignite, charcoal, wood, straw, shrubs, grass, agricultural crop and animal dung (IEA, 2015). In developing countries, most people have restricted access to cleaner forms of energy such as electricity, gas, biogas, and kerosene. Biomass fuels thus become the primary choice as the source of energy in the households because they are readily available and affordable to most people. According to the 2015 Zambia Household Health Expenditure and Utilization Survey (ZHHEUS) report, only 16% of the Zambian population uses electricity while the remaining 83.3 % relies on biomass fuel and a very small percentage on liquid fuel.

As much as biomass fuels are available and affordable, they are considered to be of lower quality as compared to other energy fuels like electricity, solar and gas. This is because some biomass fuels, like firewood tends to have a higher moisture content and requires the use of uncontrolled combustion techniques as compared to high quality fuels (Ibid).

Studies indicate that wet fuels and uncontrolled combustion techniques are both associated with higher particle emission(Johansson et al., 2003). The incomplete combustion of this lower quality biomass, including straw and crop residue, can create high exposure to respirable particles and other health hazard gases such as carbon monoxide, formaldehyde, nitrogen oxides, and polyaromatic hydrocarbons (Jagger and Shively, 2014).

The use of biomass fuel by household creates exposure to pollutants, however, the level of exposure depends on many factors including proximity to the source of the pollutants, the time exposed to the pollutants, and the intensity of the pollutants. Women and children are more exposed to biomass fuel pollutants because they spend most of the time in the domestic arena, specifically, in the kitchen cooking(Po et al., 2011). Children usually tag along or are carried on their mothers' back as the mother performs these activities. The cultural practice of women spending more time in the kitchen and caring for children while cooking introduces both to greater risk of health problems associated with biomass fuels (Perez-Padilla et al., 2010).

Studies have reported that smoke from combustion of biomass fuels use as one of the top 10 risks for worldwide burden of disease, accounting for 2.7% of the global burden of disease and 2 million pre-mature deaths annually from chronic obstructive pulmonary disease lung cancer and ARI mainly occurring in developing countries (WHO, 2009). In addition, biomass fuel use has been associated with low birth-weight and perinatal mortality (Pope et al., 2010).

2.2 Acute Respiratory Infections

An acute respiratory infection refers to any number of infectious diseases involving the respiratory tract. Infections are usually classified as upper respiratory tract infection and lower respiratory tract infection (Simoes et al., 2006). The upper respiratory tract consists of the airways from the nostril to the vocal cords in the larynx including the paranasal sinuses and the middle ear. The most common types of acute upper respiratory infections are the common cold, sinusitis , tonsillitis, pharyngitis, laryngitis and otitis media (Eccles et al., 2007)

On the other hand, the lower respiratory tract covers the continuation of the airways from the trachea and bronchi to the bronchioles and the alveoli. Acute infections of the lower respiratory tract include pneumonia, acute bronchitis and bronchiolitis, influenza and whooping cough (Simoes et al., 2006).

Studies on aetiology of ARI indicate that about 50% of the infections are of viral aetiology while among the rest, majority are attributed to bacterial causes. Transmission of ARI is via respiratory droplets or by virus-contaminated hands. Upper respiratory tract (nose, throat, sinuses) mucosa inflammation causes increased secretions rhinorrhea and results in sneezing, and coughing facilitating the spread (Ibid). ARI are the most common causes of illness globally causing 15% of all deaths in children under the age of five. About 50% of these deaths occur in Sub-Saharan Africa including Zambia (UNICEF, 2014).

According to the WHO Zambia statistical fact sheet, in 2014, 67% of the children visited hospital facilities as a result of ARI. WHO further goes on to report that 16 % of under five deaths in 2013 was caused ARI (WHO 2016, 2015).

2.3 Mechanism of Solid Fuel Exposure and the Risk of ARI

The use of biomass fuel makes it easy for the respiratory tract to come in contact with pollutants. In the respiratory tract, there is a lining called the respiratory epithelium covered with mucus which moistens and protects the air ways. The lining is covered in tiny hairs called the cilia which move back and forth to sweep mucus upwards toward the throat. Once pollutants come in contact with the respiratory epithelium, an inflammatory response is initiated to produce mucus. (Kaliner et al, 1986). Inflammation is the bodies attempt at self-protection and mucus is produced as a defence mechanism against irritants, toxins, particles, viruses and bacteria. The aim of the process really is to trap, fight and remove these foreign unwanted substances from the body and respiratory system (PEC, 2017).

If the respiratory tract is constantly exposed to biomass fuel pollutants, inflammation results in the swelling of the mucus membrane lining in the respiratory epithelium which results to increased mucus production and blockage due to swelling. This in turn decreases the movement of the mucus by the cilia leading to congestion and stagnant mucus in the respiratory epithelium. Congestion and stagnant mucus in the respiratory tract favours the growth and multiplication of large numbers of bacteria which constitute an infection (Ibid).

Basically, stagnant mucus in the respiratory tract creates the risk of developing ARI. This is because it provides a suitable environment for bacteria to multiply and cause infections in the respiratory system. If there is little or no contact to pollutants, including those from biomass, there is moderate mucus production, no inflammation and swelling and blockage does not occur. This ensures regular coordinated beating of the cilia which sweeps mucus up and out of the airway carrying anything unwanted and harmful pathogens and particles in turn, there is no suitable environment for bacteria to multiply (ibid).

Children are more prone to infections because there respiratory tract have not yet fully developed the necessary protective immunities thus pollutants easily interfere with their airways. In addition, children have a differential ability to detoxify, and excrete environmental agents thereby making them prone to more harm (Smith et al, 2000). Further, children engage in more physical activity than adults which leads to a higher intake of air relative to body size (Salvi, 2007).

2.4 Evidence of Association between Solid Fuel Use and ARI among Under Fives

2.4.1 Global perspective

A study by Ashwani and Kalosona in India based on 52,868 children less than the age of five indicated that children living in households using biomass fuels have a significantly higher risk of ARI than those living in households using cleaner fuels (OR: 1.54; 95% CI: 1.38-1.72; p = .010). This significance was found after statistically controlling for other factors like tobacco smoking and age of mothers (Ashwani and Kalosona, 2016).

Bautista et al carried out a study in 2009 to evaluate relationship between exposure to indoor charcoal smoke and risks of acute respiratory infection in a cohort of children from the Dominican Republic. While accounting for other factors, findings of this study demonstrated that incidences of ARIs in children from charcoal-using households were 1.58 higher than those in children from households using gas (Bautista et al., 2009).

A randomised controlled trial of 265 interventions and 253 control children was conducted by Smith et al in Guatemala. The study reported that a reduction to wood smoke exposure did not significantly reduce physicians diagnosed pneumonia cases (Smith et al., 2011). Pneumonia is one of the acute respiratory infections and the findings of this study implies that there is no association between biomass fuel and ARI.

2.4.2 African perspective

A community based cross-sectional study in a highly populated area of Addis Ababa, Ethiopia conducted in 2012 among 422 households reported that the odds ratios of acute respiratory infection were 2.97 (95% CI: 1.38-3.87) and 1.96 (95% CI: 0.78-4.89) in households using biomass fuel and kerosene, respectively, relative to cleaner fuels after controlling for other confounding variables (Sanbata et al., 2014).

A study from Uganda suggests an ARI prevalence of about 34% for children below the age of five. The study found significant interactions between quantity and quality of biomass used and ARI episodes. The researchers suggest that lower quality biomass fuel is associated with a higher likelihood of ARI episodes, particularly in children (Jagger and Shively, 2014).

In South Africa a study by Barnes et al reports that children living in households reliant on polluting fuel like biomass fuels were 2-4 times more likely to suffer from an ALRI compared to children living in homes reliant on electricity, resulting in as many as 1400 under-five deaths annually (Barnes et al., 2009).

In Zimbabwe, it was found that that exposure to cooking smoke from biomass combustion is significantly associated with ARI prevalence in young children, independent of child's age, nutritional status, maternal education, household living standard, and other factors (OR = 2.20; 95% CI: 1.16, 4.19) (Mishra, 2003) .

Almost all of the literature reviewed shows that there is an association between biomass fuel and ARI among under-fives in Africa. However, a study conducted in Tanzania suggested no association between ARI and biomass fuel use and other cleaner fuels after controlling for other confounders (Kilabuko and Nakai, 2007).

2.5 Other Risk Factors of Acute Respiratory Infection

2.5.1 Global perspective

A longitudinal cohort study conducted for a one year period, comprising a cumulative sample of 400 children from 3 urban areas of Gulbarga city in India. The study reported that high rates of ARI were observed among 41.36% of children living in households with firewood fuel usage, 53.85% of children with grade IV and 66.67% of children with grade V malnutrition (Ramani et al., 2016).

A hospital based case control study was done to determine risk factors associated with respiratory tract infection in children in Central India. A significant association was found between ARI and lack of breastfeeding, nutritional status, immunization status, delayed weaning, prenatal feeding, living in overcrowded conditions, mothers' literacy status, low birth weight and prematurity. Among the environmental variables, inadequate ventilation, improper housing condition, and exposure to indoor air pollution from fuel used for cooking were found as significant risk factors for ARI in under-fives (Taksande and Yeole, 2015).

A case control study conducted by Acharya, Mishra & Gupta at Nepalgunj Medical College Teaching Hospital in Nepal reported that families using wood as a cooking material were associated with higher risk of ALRI .Family history of smoking was associated with six times increased risk of ARI . With the use of kerosene lamps risk of ARI was increased by 1.44 times (Acharya et al, 2017).

2.5.2 African perspective

A multilevel analysis of lifestyle variations in symptoms of acute respiratory infection among young children under five was conducted in Nigeria with a total of 28,596 under-fives. This study indicated that the odds of having ARI symptoms were increased by a number of lifestyle factors such as in-house biomass cooking (OR = 2.30; $p < 0.01$), no hand-washing and being an orphan or vulnerable child (Adesanya and Chiao, 2016).

Results of a cross-sectional study in Hadiya Zone Anilemo Woreda Ethiopia in 2015 found that carrying a child on the back while cooking, patterns of time- activity, which place children near sources of pollution such as cooking stoves, the absence of window in kitchen or limited ventilation rates were strongly associated to acute respiratory infections among the under five years children (Ramato, 2015).

2.5.3 Zambian perspective

In a case-control study with 220 hospitalized under-five children at Arthur Davison children's hospital in Ndola, factors found to be associated with ARI were: mothers and siblings with a history of ARI, not having a separate room for cooking, use of public transport, and households comprising of more than 3 people, however, ARI were negatively associated with low socio-economic status (Banda et al, 2016).

However, studies conducted in Cameroon and Gabon report contradicting results when reporting risk factors associated to ARI. It was seen that Children in the age bracket 0-5 months in rural areas of Cameroon are twice as likely to suffer from ARI as compared to children of 24-35 months, this however contradicts with findings from Tanzania and Gabon which report that children less than 6 months old are less likely to suffer from ARI as compared to those who are 11 months and older (Jean-Daniel, 2016).

In conclusion, from the above literature, studies have shown a strong associations between biomass fuel and prevalence of ARI in children under-five year. Apart from family size, educational level and house characteristics others factors like sex of the child, cigarette smoking habits, fuel type influence the prevalence of ARI in children under-five. However, the association between biomass and ARI has not been researched in Zambia. It is therefore important to undertake such a research as the findings may help to put in place mitigation strategy that can employ multiple interventions such as improvements in fuels and cooking technologies.

CHAPTER THREE: METHODOLOGY

3.1 Study Design

This was a cross-sectional study, implying that it was conducted at one point in time to determine both exposure and outcome of variables of interest. The study used secondary data with a specific interest in the under-five childrens' dataset which was extracted from the most recent demographic health survey, 2013-2014 ZDHS database. The 2013-2014 ZDHS survey collected data from all the ten provinces in Zambia (CSO, 2016).

3.2 Study Site

This was a national study which was conducted in Zambia with a population of about 15, 200,000 (ibid). The country is divided into 10 provinces and 74 districts. Of the 10 provinces, two are predominantly urban, namely Lusaka and Copperbelt. The remaining provinces, Central, Eastern, Muchinga, Northern, Luapula, North Western, Western, and Southern are predominantly rural. In Zambia, about 98% of rural households and 63% in urban areas use solid fuel as their main source of cooking energy (CSO, 2015).

3.3 Study Population

The population of this study was all under five children born to women aged 15-49 living in households comprised in a countrywide sample representing all the 10 provinces in the ZDHS 2013/2014 survey dataset.

3.4 The ZDHS Sampling Technique and Sample Size Determination

The 2013-14 ZDHS was implemented by the Central Statistical Office in partnership with the Ministry of Health and the University of Zambia Teaching Hospital (UTH) Virology Laboratory.

The survey used a two-stage stratified cluster sample design, with EAs (or clusters) selected during the first stage and households selected during the second stage. A list of enumeration areas (EAs) for the 2010 Population and Housing Census provided the sampling frame for the survey. The frame comprises 25,631 EAs and 2,815,897 households. In the first stage, 722 EAs (305 in urban areas and 417 in rural areas) were selected with probability proportional to size. In the second stage, a complete list of households served as the sampling frame in the selection of households for enumeration. An average of 25 households was selected in each EA.

During the second stage of selection a representative sample of 18,052 households was selected of which 16,258 were occupied at the time of the fieldwork. Of the occupied households, 15,920 were successfully interviewed, yielding a household response rate of 98 percent. In the interviewed households, a total of 17,064 women age 15-49 were identified as eligible for individual interviews, and 96 percent of these women were successfully interviewed. All provinces of Zambia are represented in the sample. Information of under five children was collected from the mothers. Characteristics such as sex, age and birth order were collected. Other information collected include immunization, nutritional status, and child illnesses like fever, diarrhoea, malaria and ARI.

Information collected in the 2013/2014 ZDHS data set was selected for this study because it is the most recent collected

3.5 Sample Size Calculation

The sample size required for this study was calculated using the prevalence rate sample size formula given below.

$n=Z^2p\ (1-p)\ /e^2$

Z= the standard normal deviation. This is set at 1.96 to correspond to 95% confidence level.

P= is the proportion used in the estimation formula (in our case p-value used is 0.4 (3.7% rounded off to 4%), based on the 2013/2014 ZDHS, the proportion of under five children who had ARI was estimated to be 3.7 percent in Zambia (CSO, 2014).

e = is the measure of precision, thus the margin of error. In this study, the margin of error is set at 0.05.

$n= 1.96^2 \times (0.4 \times (1-0.4))/ 0.05^2$

n= 369.

However, the data set sample was used since the data set provides an even bigger sample for better and more accurate findings. Therefore, the total sample size of our study was 2,795 under five children.

The population for this study was all children aged 0-5 year's old living in the sample households based on the 2013/2014 ZDHS data set.

3.5.1 Inclusion criteria.

All under five children born from women aged 15-49

3.5.2 Exclusion criteria

All under five children who did not have information on the outcome of ARI.

3.6 Study Variables

For analysis, the following variables were used,

3.6.1 Dependant variable

One of the questions on health required each woman to indicate whether her child had recently experienced fever or cough accompanied by short, rapid breathing and difficulty breathing as a result of a chest-related problem , particularly within the two weeks prior to the interview. The ZDHS categorized children who suffered from cough, accompanied with short and rapid breathing, coupled with a problem in the chest, at any time during the two week period preceding the survey, as having ARI. This reported occurrence of ARI was the response variable in our study.

3.6.2 Independent variables

Households were asked to identify the type of fuel they used for cooking. The choices provided were: electricity/gas, charcoal, firewood, coal, grass and so on. The priori variable in this study is the type of cooking fuel particularly solid fuels like fire wood, charcoal, animal dung and grass.

Because the effects of cooking smoke from biomass fuels relative to cleaner fuels on ARI are likely to be confounded with the effects of other demographic, economic and lifestyle factors. It was necessary to statistically control, or adjust, for such factors. Therefore, other variables included in this study were: sex of the child, vaccination status, nutritional status, age in months, birth, order, type of housing unit materials, mothers smoking status, urban-rural residence, mother’s education, mothers employment status and wealth quantile. Please refer to table 1 on the next page for more details.

Table 1: Study variables

Variable	Responses	Scale of Measurements
Dependant Variable		
ARI	Yes No	Binary
Independent Variables		
Biomass fuel(priori)	Wood/charcoal Electricity/gas	Binary
Sex of the child	Female Male.	Binary
Flooring material	Earth, sand, Dung Wood/planks Palm/bamboo/leeds Parquet or polished wood Vinyl or asphalt strip Ceramic/terrazzo tiles Concrete cement , Carpet	Nominal
Roof material	Grass thatched Asbestos Iron sheets Other	Norminal
Age in months	0-5 6-11 12-23 24-35 36-47 48-59	Categorical.
Child fully immunised	Yes No	Binary
Nutritional status	Good poor	Binary
Breast feeding status	Not breastfed Exclusively breastfed	Binary
Birth order	1 Other	Binary
Mothers age	15-19 20-24 25-29 30-34 35-39 40-44 45-49	Categorical.
Residence	Rural Urban	Binary
Mothers smoking status	Smokes, Does not smoke	Binary
Mothers Level of education	No education Secondary Primary >Secondary	Ordinal
Wealth quantile	Low	Ordinal

	Middle High	
Province	Lusaka Copper belt Southern Central Northern Western North-western Eastern Luapula Muchinga	Nominal

3.7 Data Collection Methods

Three questionnaires where used in the 2013-14 ZDHS: the Household Questionnaire, the Woman's Questionnaire, and the Man's Questionnaire. The three instruments were based on the questionnaires developed by the Demographic and Health Surveys Program and adapted to Zambia's specific data needs. This study is mainly interested in the womens' questionnaires which collected information on background characteristics like age, sex, education. Other information collected was family planning, fertility preferences, breastfeeding, infant feeding practices, child immunization and illnesses, child mortality and diseases like malaria.

3.8 Data Management

3.8.1 Quality control

In order to ensure quality, the Central Statistics Office (CSO) and Ministry of Health recruited and trained 306 participants for over a five-week period in May and June 2013 by resource personnel from the Centre for Disease Control (CDC), CSO, MoH Tropical Disease Research Centre (TDRC), University Teaching Hospital Virology, and University of Zambia (UNZA), Population Studies. Field staff were trained to serve as supervisors, field editors, and interviewers. All questionnaires for the 2013-14 ZDHS were returned to the CSO headquarters for processing, editing, coding, data entry, and editing of errors. All data were entered twice for 100 percent verification. Inconsistencies were resolved by tallying the data with the paper questionnaire entries and secondary editing of the data.

3.8.2 Data extraction plan

Data for this study was extracted from the 2013-2014 ZDHS database from CSO. The database has four datasets, for the household, women, men and children. This study extracted the variables from children's dataset which constitute all under five children born from women aged 15-49. Background characteristics such as sex of the child, age in months, mothers smoking status, residence, rural, urban and province were obtained and statistical methods were employed.

To extract the variables of interest, a data extraction tool was created, please refer to appendix 1. This was done by firstly listing down all the variables of interest which included information on biomass fuel sex of the child, age in months, mothers smoking status, residence, rural, urban and several others. After the variables of interest were listed, we further went on and checked for the specific questions asked and the available responses in the mothers' questionnaire in order to obtain information on the variables. The data extraction tool was used to further check and collect information on the variables of interest in the childrens' dataset.

3.8.3 Data entry, cleaning and storage

The data set was cleaned to ensure that all incomplete and inconsistent entries on ARI are accounted for and excluded from the analysis and data will be saved.

3.9 Data Analysis

Descriptive and analytical statistical methods were performed using STATA software version 14(Stata Corporation, College Station, TX, USA).

3.9.1 Descriptive Statistics

Univariate analysis

Descriptive statistics was used to provide overall characteristics and summarize the data. Variables such as age, sex, vaccination, nutritional status, mothers' education status are presented as proportions and frequencies. Proportions and frequencies are reported even for continuous variables such as age because they are categorised in the data set.

3.9.2 Analytical Statistics

Bivariate analysis

Chi-square test was done to establish association between dependent variable ARI and independent variables such as biomass fuel, age, sex, vaccination and mothers' education status and P-value was set at 0.05.

Multiple logistic regression analysis

Since the outcome variable ARI is dichotomous, multiple logistic regression model was performed to examine the type and strength of association between our outcome of interest, ARI and biomass fuel which is our priori independent variable. Other independent variables such as economic status, mothers education, nutritional status, vaccination status, household building material were treated as confounders therefore they were controlled for or adjusted during analysis. P-Value was set at 0.05. This analysis helped to answer the third specific objective in the study.

3.10 Ethical Consideration

The research study used secondary data therefore, there was no contact with the study population. This simply means the study no risk to the study population. The ZDHS, offered consent forms to the study participants before conducting interviews and after collecting information, ZDHS de-identifies the data collected from participants ensuring privacy of study participants especially in regard to sensitive information.

Despite minimal to no risks, ethical clearance and approval was obtained from the University of Zambia Biomedical research ethics committee. **Reference. No.026-06-17**.

3.11 Limitations and Strengths of the Study

Participants in the study were mainly questioned about the symptoms of ARI, no clinical or laboratory confirmation was done, this may in turn cause overestimation or underestimating of ARI among the under five children in Zambia. In addition, exposure to biomass fuel was only observed by the type of fuel used therefore there was inadequacy in exposure measurements.

The use of secondary data comes with limitations to variables, this study will be limited to variables in the ZDHS 2013/14 thus, some variables such as household ventilation that are important and confounding were not measured because the study was limited to ZDHS 2013/14 variables this may have caused overestimation or underestimating of ARI among the under five children in Zambia. Lastly but not the list, results reported in this study are primarily based on 2013/14 since the secondary data being used was collected in 2013/14.

Our estimated effect is also downwardly biased to the extent that ARI is more likely to be underreported for children from households that use unclean fuels. On the other hand, our estimated effect may be upwardly biased to the extent households that use unclean fuels are more likely to report some other disease condition with similar symptoms as ARI.

Despite the limitations mentioned above, this research was quite cheap to conduct as we used secondary data. The secondary data also provided a very large sample size there we were able to have acquire accurate findings to a certain degree.

CHAPTER FOUR: RESULTS

This chapter highlights the findings of the study to assess biomass fuel use and its association with acute respiratory infection among under five children in Zambia. The sample size for this study was 2, 795 under five children.

4.1 Social-economic and demographic characteristics

Table 2: Household characteristics

Variables	n=2795		Percentage %
Region			
Urban	1,080		38.6
Rural	1,715		61.4
Roof material			
Thatched roof	1,393		49.8
Asbestos	241		8.62
Iron sheets	1,107		39.6
Other(no roof/ wood planks/ palm / bamboo	54		1.93
Floor material			
Natural floor	1,812		64.9
Ceramic/ polished wood/cement	971		34.8
Carpet/wood planks and others	11		0.4
Wall material			
Rudimentary Wall	844		30.2
Bricks/blocks/cement	1,856		66.4
no walls/ply wood/plunks	94		3.36
Cooking fuel			
Electricity	184		6.6
Biomass	2,611		93.4
Living standard Poor	1,264		45.22
Middle	669		23.94
rich	862		30.84

Table 2 on the previous page presents the household characteristics of 2,795 under five children who met the inclusion criterial of the study. More than half (61.4 %) of under five children were from rural areas while the rest (38.6) were from urban areas. In terms of the buildings, housing units were predominantly thatched and covered with Iron sheets, 49.8% and 39.6% respectively. About two thirds (64.9 %) had natural floors and brick/cement walls (66.4%). The study also shows that at least 9 in 10 (93.4%) children come from homes that use biomass fuel as their main source of cooking fuel while only 6.6% used electricity. About 45.2% of the children belonged to households in the poor wealth quantile.

Table 3: Childs characteristics

Sex of child			
Male	1,409		50.4
Female	1,386		49.6
Age in months			
0-5	213		7.6
06-11	340		12
12-23	677		24
24-35	585		20.9
36-47	511		18.3
48-59	469		16.8
Birth order			
First born	2,183		78.1
Other	612		21.9
Child exclusively breastfed			
Yes	2,103		98.7
No	28		1.3
Nutritional status			
Good	342		12.24
Poor	2,453		87.76
Fully vaccinated			
No	18		1.15
Yes	1,544		98.85
ARI			
No	1,956		69.98
Yes	839		30.02

Table 3 presents characteristics of the children in the study. Slightly above half (50.4%) of the sampled children were male. About one quarter (20.9%) were aged between 24-35 months while only 7.6% were aged below 6 months. About 78% were first born while 22 % were not. The study also shows that 9 in every 10 children were exclusively breastfed and fully immunised. More than three quarters (87.8%) were reported to have poor nutritional status.

Table 4: Mothers' characteristics

Mothers age			
15-19	249		8.91
20-24	669		23.94
25-29	717		25.65
30-34	568		20.32
35-39	388		13.88
40-44	166		5.94
45-49	38		1.36
Mothers highest education			
Never been to school	304		10.89
primary	1,501		53.76
secondary	878		31.45
Tertiary	109		3.9
Mothers smoking status			
No	2,785		99.64
Yes	10		0.36
Marital status			
Single	286		10.23
Married	2,316		82.86
widowed	44		1.57
divorced	149		5.33
Employment status			
unemployed	975		35.02
Employed	1,809		64.98

Table 4 presents the mothers characteristic of the under five children. A quarter (25.7%) of the mothers were aged between 25 and 29 while only 1.4% were aged above 45. In terms of smoking, we find that less than 1 % of the mothers smoked. Slightly above half (53.8%) of the women went as far as primary school and only four percent went as far as tertiary education. About two thirds (65 %) of the women were employed.

4.2 Biomass Fuel Use per Province

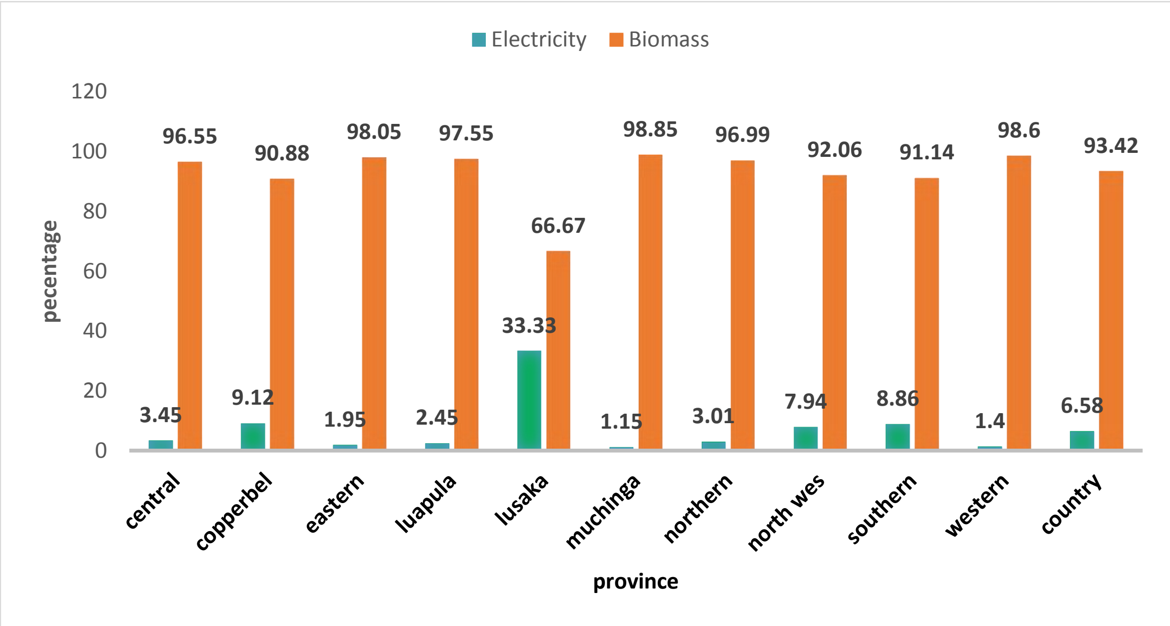

Figure 3: Graphical distribution of biomass fuel use by province

Figure 3 above shows that at least 93% of the Zambian population depend on biomass fuel. Almost 99% of the population in Western and Muchinga provinces rely on biomass fuel being the highest. However, results do not vary much among the provinces as they show that 9 in every 10 houses rely on biomass fuel except for Lusaka which reports the lowest percentage.

4.3 Proportion of ARI among Under five children

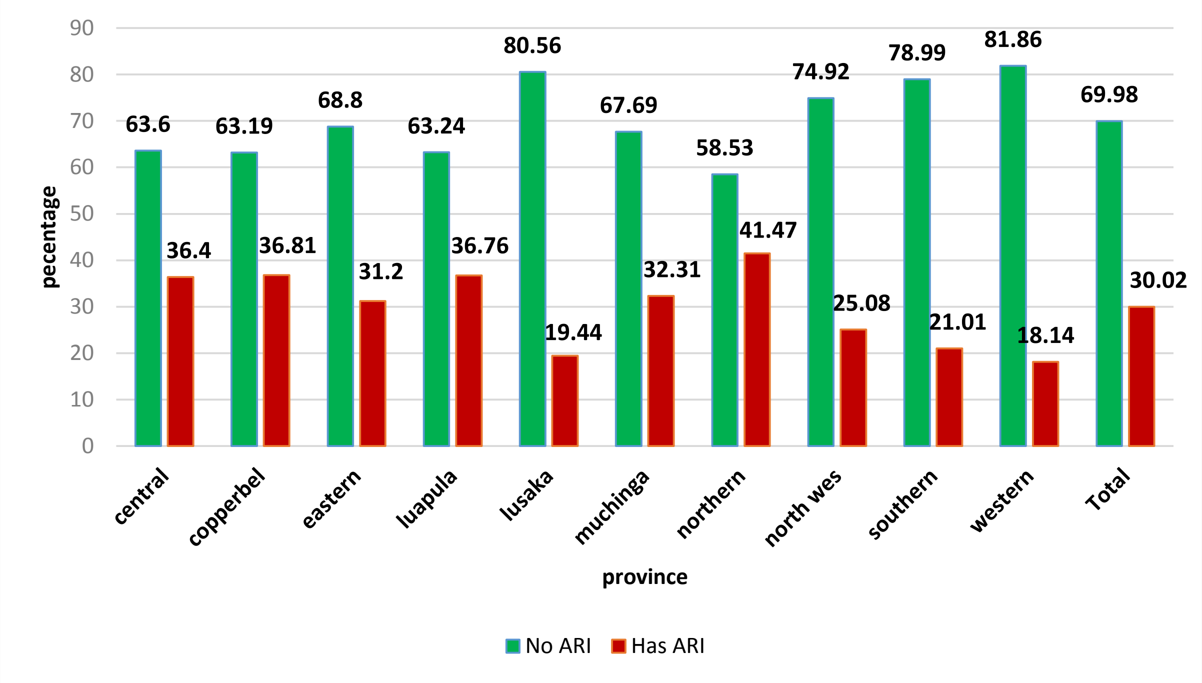

Figure 4: Graphical distribution of ARI by province

Figure 4 shows that the proportion of ARI in Zambia was reported at at least 30% ,Northern Province reported the highest percentage of ARI at 41% followed by Copperbelt and Lauapula province at 37%.Despite being one of the highest reliant on biomass fuel, Western province reported the lowest proportion of ARI followed by Lusaka which was the lowest user of biomass fuel.

Table 5: ARI among under five in Zambia (Household characteristics)

Variables	ARI YES	NO	P-value
	Counts (%)	Counts (%)	
Cooking fuel			
			0.018*
Electricity	41 (4.89)	143 (7.31)	
Biomass	798 (95.11)	1813 (92.69)	
Residential area			
			0.087
Urban	304 (36.23)	776 (39.67)	
Rural	535 (63.77)	1,180 (60.33)	
Roof material			
			0.065
Thatched roof	437(52.09)	956(48.88)	
Asbestos	56 (6.67)	188 (9.61)	
Iron sheets	330(39.33)	777(39.72)	
Other(no roof/ wood planks/ palm / bamboo	17(2.03)	37(1.89)	
Floor material			
			0.024*
Natural floor	556 (66.27)	1,256(64.25)	
Ceramic/ polished wood/cement	276 (32.90)	695 (35.55)	
Carpet/wood planks and others	7 (0.83)	4(0.20)	
Wall material			
			0.064
Rudimentary Wall	258 (30.75)	586 (29.97)	
Bricks/blocks/cement	563 (67.10)	1,293 (66.14)	
No walls/ply wood/plunks	18 (2.15)	76 (3.89)	
Wealth categories			
			0.048*
Poor	409(48.75)	855(43.71)	
Middle	186(22.17)	483(24.69)	
Rich	244(29.08)	618(31.60)	

p<0.05

Table 5 shows results of a test of association between the demographic and social-economic factors and ARI using household characteristics among under five children in Zambia. There was an association between ARI and the priori variable biomass fuel, (p=0.018). The other factors associated with ARI were type of floor (p=0.024), Childs age in months (p=<0.001), birth order (p=0.039) and wealth quantile (p=0.048).

Table 6: ARI among under five in Zambia (Childs characteristic)

Variables	ARI YES	NO	P-value
	Counts (%)	Counts (%)	
Sex of child			
			0.507
Male	431(51.37)	978(50.00)	
Female	408(48.63)	978(50.00)	
Age in months			
			<0.001*
0-5	74 (8.82)	139(7.11)	
06-11	132(15.73)	208(10.63)	
12-23	211(25.15)	466(23.82)	
24-35	156(18.59)	429 (21.93)	
36-47	143 (17.04)	368 (18.81)	
48-59	123 (14.66)	146(17.69)	
Birth order			
			0.039*
First born	676 (80.57)	1,507(77.04)	
Other	163 (19.43)	449 (22.96)	
Exclusively breastfed			
			0.053
Yes	4(0.60)	24(1.63)	
No	658(99.40)	1,445(98.37)	
Nutritional status			
			0.934
Good	102(12.16)	240(12.27)	
Poor	737(87.84)	1,716(87.73)	
Fully Vaccinated			
			0.745
Yes	2(0.47)	7(0.61)	
No	420(99.53)	1,133(99.39)	

p<0.05

Table 6 shows results of a test of association between the demographic and social-economic factors and ARI using the characteristics of the under five children in Zambia. There was an association between ARI and the sex of the child, (<0.001). The other factor associated with ARI was birth order (p=0.039).

Table 7: ARI among under five in Zambia (Mothers characteristics)

Variables	ARI YES	NO	P-value
	Counts (%)	Counts (%)	
Mothers age			
			0.141
15-19	93(11.08)	156(7.98)	
20-24	198(23.60)	471(24.08)	
25-29	207(24.67)	510(26.07)	
30-34	158(18.83)	410(20.96)	
35-39	122(14.54)	266(13.60)	
40-44	47(5.60)	119(6.08)	
45-49	14(1.67)	24(1.23)	
Mothers education			
			0.066
Never been to school	103(12.28)	201 (10.29)	
Primary	452(53.87)	1,049 (53.71)	
Secondary	262(31.23)	616 (31.54)	
Tertiary	22(2.62)	87 (4.45)	
Smoking status			
			0.489
No	837(99.76)	1,948(99.59)	
Yes	2(0.24)	8(0.41)	
Marital status			
			0.907
Single	85(10.13)	201(10.28)	
Married	699(83.31)	1,617(82.67)	
Widowed	14(1.67)	30(1.53)	
Divorced	41(4.89)	108(5.52)	
Employment status			
			0.847
unemployed	295(35.29)	680(34.91)	
Employed	541(64.71)	1,268(65.09)	

Table 7 shows results of a test of association between the demographic and social-economic factors and ARI using the characteristics of the mothers of under five children in Zambia. There was a significant association between ARI and any of the mothers' characteristics.

4.4 Multiple Logistic Regression

Table 8: Unadjusted and adjusted multiple logistic regression

Variables	Unadjusted OR (95%CI)	P-value	Adjusted OR (95%CI)	P-value
Cooking fuel				
Electricity	1.0			
Biomass	1.54 (1.07-2.19)	0.019*	1.53(1.04-2.27)	0.033*
Residential area				
Urban	1.0			
Rural	1.16(0.98 -1.37)	0.087	1.030.82-1.30)	0.793
Roof material				
Thatched roof	1.0			
Asbestos	0.65(0.47- 0.89)	0.008*		
Iron sheets	0.92(0.78- 1.10)	0.401		
Other(no roof/ wood planks/ palm / bamboo	1.00(0.55- 1.80)	0.986		
Floor material				
Natural floor	1.0			
Finished floor(Ceramic/ polished wood/cement	0.70(0.76- 1.06)	0.215	1.10(0.81-1.48)	0.554
Carpet/wood planks and others	3.95(1.15- 3.56)	0.029*	5.30(1.05 -2.46)	0.011*
Wall material				
Rudimentary Wall	1.0			
Bricks/blocks/cement	0.99(0.83- 1.18)	0.902	1.08 (0.89-1.33)	0.421
Other no walls/ply wood/plunks	0.54(0.32-0.92)	0.023*	0.56(0.33-0.96)	0.036*
Sex of child				
Male	1.0			
Female	0.95(0.81-1.11	0.507	0.97(0.82-1.14)	0.715
Age in months				
0-5	1.0			
06-11	1.19(0.83-1.70)	0.334		
12-23	0.85(.61-1.177	0.330		
24-35	0.68(.487-.956	0.026*		
36-47	0.73(0.518-1.027	0.071		
48-59	0.67(0.47-.946)	0.023*		
Birth order				
First born	1.0			
Other	0.81(0.66-0.99)	0.039*		
Exclusive breastfed				

Yes	1.0			
No	0.37(0.13 =1.06)	0.064		
Nutritional status				
Good	1.0			
Poor	1.01(0.79-1.29)	0.93	1.02 (0.77-1.27)	0.99
Fully Vaccinated				
Yes	1.0			
No	0.77(0.16 -3.72)	0.75		
Mothers age				
15-19	1.0			
20-24	0.70(0.52- 0 .96)	0.025*	0.69 (0.50-0.95)	0.024*
25-29	0.68(0.50-0.92)	0.013*	0.66(0.47-0.92)	0.014*
30-34	0.65(0.47-0.87)	0.007*	0.62 (0.44-0.88)	0.008*
35-39	0.77(0.55-1.07)	0.124	0.75 (0.52-1.08)	0.117
40-44	0.66(0.43-1.01)	0.057*	0.62 (0.40-0.97)	0.037*
45-49	0.98(0.48-1.96)	0.952	0.93 (0.45-1.93)	0.854
Mothers education				
Never	1.0			
Primary	0.84(0.65-1.09)	0.19		
Secondary	0.83(0.63-1.10)	0.19		
Tertiary	0.49(.292-.83)	0.01*		
Smoking status				
No	1.0			
Yes	0.58(.12-2.7)5	0.49	0.57(0.12-2.75)	0.484
Marital status				
Single	1.0			
Married	1.02(.78-1.33)	0.87	1.12 (.83-1.52)	0.433
Widowed	1.10(.56-2.19)	0.78	1.25 (.61-2.54)	0.545
Divorced	0.90(.58-1.39)	0.63	0.98 (.45-1.93)	0.942
Employment status				
unemployed	1.0			
Employed	0.98(0.83-1.17)	0.85	1.01 (0.84-1.20)	0.938
Standard of living				
Poor	1.00			
Middle	0.81(0.66-0.99)	0.039*	0.78(0.61-0.96)	0.021*
Rich	0.83(0.68-1.00)	0.047*	0.80(0.56-1.06)	0.106

p<0.05

Table 8 shows results before adjusting for confounders and after adjusting for confounders. Before adjusting for confounders, the results show that children in household using biomass fuel had higher odds of ARI compared to those in houses using electricity (OR= 1.54; 95% CI1.07 to2.19; p-value,0.019) which was statistically significant.

Children leaving in houses with asbestos roofs and iron sheets were less likely to have ARI compared to those that lived in grass thatched roof (OR= 0.65; 95%CI 0.47 to 0.89; p-value, 0.008) and (OR= 0.92; 95% CI 0.78 to 1.10; p-value,0.401) respectively. The comparison between thatched roofs and iron sheets was not statistically significant. Children leaving in houses with proper finished floors (Ceramic/ polished wood/cement) had lower odds of ARI compared to those leaving in homes with natural floor (earth and sand), (OR=0.70; 95% CI 0.76 to 1.06). However, children in homes with other type of floors (carpet/wood planks) were 3 times more likely to have ARI compared to those leaving in natural floors (OR= 3.95; 95%CI 1.15- 3.56) which was significant. When compared to children leaving houses with Rudimentary types of walls, those who lived in Bricks/blocks/cement walls and other (ply wood/plunks) walls were less likely to have ARI (OR=0.99; 95% CI 0.83 to1.18) and (OR=0.54; 95% CI 0.32 to 0.92) respectively.

The findings show that children in the age group of 12 to 59 months had lower odds of having ARI compared to children aged 5 months and below. However children aged between 6 and 11 months were more likely to have ARI compare to children aged 5months and below (OR=1.19; 95% CI 0.83 to 1.70). The findings also show that non first born were 0.8times less likely to have ARI compared to first born (OR=0.81; 95%CI 0.66 to 0.99). Children whose mothers were 20 years and above were less likely to have ARI compare to those whose mothers were 19 years of age and below.

An increase of the mothers educational reduced the odds of ARI among under 5 children. Children whose mothers had gone as far as tertiary education were 0.49 times less likely to have ARI compared to those whose mothers had never been to school. Finally, coming from a middle incomed and rich family reduced the odds of ARI among children as compared to belonging to a poor (OR= 0.81; 95%CI 0 .66 to 0.99) and (OR=0.83; 95% CI 0.68 to 1.00) respectively.

In this study, we have seen that ARI is associated with a number of social, economic and demographic factors. However our main priori variable was biomass fuel thus in order to assess the contribution of the priori variable to ARI, it was important at this stage to treat all other variables as confounders. These confounders were controlled for by conducting a multiple logistic regression analysis.

After biomass fuel is adjusted for area of residence, type of housing unit floor, type of housing unit walls, sex of the child, nutritional status, mothers age, smoking status, marital status, employment status and wealth quantile, it was seen that children in households with biomass fuel had an increased risk of ARI compared to those with electricity (OR, 1.53, 95%CI 1.04-2.27) which was statistically significant.

We further went on and did a final model adjusting only for statistically significant variables in the multiple logistic regression. Results still showed that using biomass fuel increased the odds of ARI among under five children as compared to electricity.

CHAPTER FIVE: DISCUSSION OF FINDINGS

5.1 Acute Respiratory Infection and Biomass Fuel Use

The study shows that 93 % of children under the age of five live in households that depend on biomass for cooking. From the results, we can see that the proportion of ARI among under five children in Zambia was estimated at 30.02 % implying that three in every ten children suffered from ARI. Acute respiratory infection was defined as presence of cough with trouble in breathing or breathing faster than usual with short, fast breaths for the two weeks prior to the interview. The results also show that 95 % of the children who suffered from ARI came from households that depended on biomass fuel for cooking purposes.

Exposure to smoke from biomass fuels was found to be a predictor for ARI among under five children. This was after controlling for confounders i.e, floor, type of wall, residential area, sex of the child, nutritional status and other factors (OR = 1.53; 95% CI 1.04 to 2.27; p= 0.033).

Our finding are consistent with a study by Ashwani and Kalosona in India who's was based on a sample of 52,000 children less than the age. Their study demonstrated that children living in households using biomass fuels had a significantly higher risk of ARI than those living in households using cleaner fuels (OR: 1.54; 95% CI: 1.38-1.72; p = .010). the association remained statistically significant even after controlling for age, sex, birth order, education, religion of household head, urban/rural resident (Ashwani and Kalosona, 2016).

Similar, a study in Addis Ababa, Ethiopia conducted in 2012 among 422 households reported that the odds ratios of acute respiratory infection were 2.97 (95% CI: 1.38-3.87) in households using biomass fuel, relative to cleaner fuels after controlling for other confounding variables such as sex of the household head, child handling behaviour and so on, (Sanbata et al., 2014).

Likewise, in Zimbabwe, it was found that exposure to cooking smoke from biomass combustion is significantly associated with ARI, independent of other factors (OR = 2.20; 95% CI: 1.16, 4.19) (Mishra, 2003) . Our findings were similar with findings in Dominican Republic, South Africa and Uganda after controlling for confounding factors, child's age, nutritional status, maternal education, household living standard, and other factors (Bautista et al., 2009), (Smith et al., 2011), (Barnes et al., 2009), (Jagger and Shively, 2014).

Studies indicate that biomass fuels and uncontrolled combustion techniques is associated with higher particle emission (Johansson et al., 2003). The incomplete combustion of biomass fuel can result in emissions of smoke and high levels of health-damaging pollutants such as particulate matter (PM2.5 and PM10), Carbon monoxide (CO), Nitrogen dioxide (NO2), formaldehyde, benzene, 1,3 butadiene, polycyclic aromatic hydrocarbons such as benzo, and many other toxic organic compounds (USEPA, 2015).

Research indicates that, extended exposure to high levels of biomass smoke, which contains various irritants, cilia toxic fractions, and mucous coagulating agents, can impair the clearing ability of the lungs and render them more susceptible to acute respiratory infection and other diseases (Torres-Duque et al, 2008).

Other evidence indicates that exposure to polycyclic aromatic hydrocarbons (PAH) especially benzo [a] pyrene (B[a]P), which is found in large quantities in biomass smoke can cause immune suppression and can increase the risk of infection (Jagger and Shively, 2014).

Moreover, acute and long term exposures to oxides of nitrogen, commonly found in biomass smoke, can increase bronchial reactivity and susceptibility to bacterial and viral infection (Torres-Duque et al, 2008). It is, therefore, possible that extended exposure to high levels of cooking smoke can impair the pulmonary defence mechanism, compromise lung function, and render children more susceptible to ARI.

Children are more prone to infections because there respiratory tract have not yet fully developed the necessary protective immunities thus pollutants easily interfere with their airways. In addition, children have a differential ability to detoxify, and excrete environmental agents thereby making them prone to more harm (Smith et al, 2000). Further, children engage in more physical activity than adults which leads to a higher intake of air relative to body size (Salvi, 2007).

Contrary to our findings, a randomised controlled trial of 265 interventions and 253 control children conducted by Smith et al in Guatemala reported that a reduction in exposure to wood smoke did not significantly reduce physicians diagnosed ARI cases (Smith et al., 2011) . These findings may have been attributed insufficient exposure reduction or less power to less exposure. The study recommended that stove or fuel interventions producing lower average exposures than chimney stoves might be needed to reduce ARI in populations heavily exposed to biomass fuel smoke (ibid).

5.2 Acute Respiratory Infection and the Effects of Other Factors

Some housing conditions are quite poor in Zambia both in rural and urban areas. Poor housing conditions may lead to ARI in under five children. This study established a relationship between the type of floor in housing units and ARI.

After adjustment, living in homes with other types of floor and other types of walls had an effect on ARI among under five children. A study conducted in Cameroon reported that children from households without floor material are nearly 3 times more likely to have suffered from ARI than those from households with modern floor materials (parquet, polished wood, vinyl, asphalt). Due to crawling, little children may be in regular contact with floor material like dust particles (Jean-Daniel, 2016). In a hospital based case control study was done to determine risk factors associated with respiratory tract infection in children in Central India. improper housing condition was found as significant risk factors for ARI in under-fives (Taksande and Yeole, 2015).

In regards to the mothers' age, adjusted results reported that children whose mothers were 20 years of age and above had lower risks of ARI compared to those whose mothers were 19 years and below. This may be as a result that older mothers are identified as a protective factor. It is expected that older parents may have more experience in managing various diseases and events especially if they have other children.

Compared to children who came poor families, those who belonged to middle incomed families and rich families were less likely to suffer from ARI (OR= 0.78; 95% CI 0.61 to O.96) and (OR=0.80; 0.56 to 1.06) respectively. These findings are similar to a study in Zimbabwe which found that children from households with higher standards of living were considerably less likely to have had ARI than those from low standard of living households. This can be explained by the fact that higher income provide better capacity to parents to provide houses with good conditions and cleaner fuels like electricity (Mishra, 2003).

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, the proportion of biomass fuel use in Zambia is very high. Despite an interplay of various factors that that contribute to ARI, the proportion of under five children suffering from ARI in houses that depend on biomass fuel is very high. Continued efforts at improving the fuel choice, housing conditions and stoves is much needed. Country specific results from this study can be used for policy making at country level since the study relied on large national representative sample.

After controlling for all other confounders, under five children from households using biomass fuel were found to be at risk of ARI. Apart from biomass fuel, other factors that were associated with ARI were the type of housing unit floor and wall, mothers' age and wealth quantile.

6.2 Recommendations

Based on the evidence derived from the study and the conclusion drawn, the following recommendations have been made.

The findings from this study have important policy and program implications, including the need for public information campaigns designed to inform people about the risks of exposure to cooking smoke.

The Ministry of Energy (MoE) and Ministry of Health (MoH) must work together in providing environmental awareness and health education to women/mothers about the health problems associated with ARI and biomass combustion.

Education through various types of media and communication network by the ministry of energy can play an important role by conveying and promoting the use and value of cleaner fuels like LPG and electricity, education may be as important in reducing the impact of dirty combustion.

The Rural Electrification Authority (REA) and the Ministry of Energy must scale up the provision of electricity, in rural areas as this will provide a cleaner cooking fuel and reduce the use of biomass fuel. Where shifts to cleaner fuels are not feasible, programs to promote improved cook stoves designed to reduce exposure to smoke by means of improved combustion and improved venting can be adopted.

Our research needs to be followed by carefully designed epidemiological studies, with direct measurement of smoke exposure and clinical measures of ARI.

REFERENCES

Acharya, N., Mishra, P. & Gupta, V. 2017. Indoor Air Pollution as a Risk Factor of Acute Lower Respiratory Tract Infection in Children. *Journal of Nepalgunj Medical College,* 13**,** 5-7.

Adesanya, O. A. & Chiao, C. 2016. A multilevel analysis of lifestyle variations in symptoms of acute respiratory infection among young children under five in Nigeria. *BMC public health,* 16**,** 880.

Ashwani, K. & Kalosona, P. 2016. Effect of Indoor Air Pollution on Acute Respiratory Infection samong Children in India. *Social and Natural Sciences Journal,* 10.

Africa Renewable Access Program, 2011. Wood based biomass energy development for SSA.

Banda, B., Mazaba, M. L., Mulenga, D. & Siziya, S. 2016. Risk factors associated with acute respiratory infections among under-five children admitted to Arthur's Children Hospital, Ndola, Zambia. Asian Pac. *J Health Sci,* 3**,** 153-159.

Barnes, B., Mathee, A., Thomas, E. & Bruce, N. 2009. Household energy, indoor air pollution and child respiratory health in South Africa. *Journal of Energy in Southern Africa,* 20**,** 4-13.

Bautista, L. E., Correa, A., Baumgartner, J., Breysse, P. & Matanoski, G. M. 2009. Indoor charcoal smoke and acute respiratory infections in young children in the Dominican Republic. *American journal of epidemiology,* 169**,** 572-580.

Briggs, D. 2003. *Making a difference: Indicators to improve children's environmental health,* World Health Organization Geneva.

Eccles, M. P., Grimshaw, J. M., Johnston, M., Steen, N., Pitts, N. B., Thomas, R., Glidewell, E., Maclennan, G., Bonetti, D. & Walker, A. 2007. Applying psychological theories to evidence-based clinical practice: Identifying factors predictive of managing upper respiratory tract infections without antibiotics. *Implementation Science,* 2**,** 26.

Global Alliance for Vaccination Immunization 2013. Zambia country fact sheet. *GAVI, the vaccine alliance.*

International Energy Agency 2015. Energy for cooking in developing countries. Available at; https://www.iea.org>publications.

Jagger, P. & Shively, G. 2014. Land use change, fuel use and respiratory health in Uganda. *Energy policy,* 67**,** 713-726.

Jean-Daniel, L. P. 2016. Effects of Biomass Fuel on Child Acute Respiratory Infections in Rural Areas of Cameroon and Gabon. *Universal Journal of Public Health,* 4**,** 121-132.

Johansson, L., Tullin, C., Leckner, B. & Sjövall, P. 2003. Particle emissions from biomass combustion in small combustors. *Biomass and bioenergy,* 25**,** 435-446.

Kaliner, M., Shelhamer, J. H., Borson, B., Nadel, J., Patow, C. & Marom, Z. 1986. Human Respiratory Mucus 1–3. *American Review of Respiratory Disease,* 134**,** 612-621.

Kilabuko, J. H. & Nakai, S. 2007. Effects of cooking fuels on acute respiratory infections in children in Tanzania. *International journal of environmental research and public health,* 4**,** 283-288.

Kodgule, R. & Salvi, S. 2012. Exposure to biomass smoke as a cause for airway disease in women and children. *Current opinion in allergy and clinical immunology,* 12**,** 82-90.

Lau, S. K., Yip, C. C., Tsoi, H.-W., Lee, R. A., So, L.-Y., Lau, Y.-L., Chan, K.-H., Woo, P. C. & Yuen, K.-Y. 2007. Clinical features and complete genome characterization of a distinct human rhinovirus (HRV) genetic cluster, probably representing a previously undetected HRV species, HRV-C, associated with acute respiratory illness in children. *Journal of clinical microbiology,* 45**,** 3655-3664.

Madhu, G., Sb, S. S. & Manasa, G. 2017. Association between low hemoglobin level, vitamin D deficiency and acute lower respiratory tract infections in children aged 6 months to 5 years. *Current Pediatric Research*, 21.

Mandal, A. & Sahi, P. K. 2016. Correspondence: risk factors of acute respiratory infection in under-fives in a rural hospital of Central India. *J Pediatr Neonat Individual Med,* 5**,** e050207.

Mishra, V. 2003. Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. *International Journal of Epidemiology,* 32**,** 847-853.

Patient Education Centre 2017. Sinuses, Inflammation and Infection. Harvard media network. *Harvard health publications.*

Perez-Padilla, R., Schilmann, A. & Riojas-Rodriguez, H. 2010. Respiratory health effects of indoor air pollution [Review article]. *The International Journal of Tuberculosis and Lung Disease,* 14**,** 1079-1086.

Po, J. Y., Fitzgerald, J. M. & Carlsten, C. 2011. Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. *Thorax,* 66**,** 232-239.

Pope, D. P., Mishra, V., Thompson, L., Siddiqui, A. R., Rehfuess, E. A., Weber, M. & Bruce, N. G. 2010. Risk of low birth weight and stillbirth associated with indoor air pollution from solid fuel use in developing countries. *Epidemiologic reviews***,** mxq005.

Ramani, V. K., Pattankar, J. & Puttahonnappa, S. K. 2016. Acute Respiratory Infections among Under-Five Age Group Children at Urban Slums of Gulbarga City: A Longitudinal Study. *Journal of Clinical and Diagnostic Research: JCDR,* 10**,** LC08.

Ramato, T. 2015. Household Biomass Fuel Use and Acute Respiratory Infections among Younger Children: An Exposure Assessment in Anilemo Woreda, Southern Ethiopia. Addis Ababa University.

Salvi, S. 2007. Health effects of ambient air pollution in children. *Paediatric Respiratory Reviews,* 8, 275-280.

Sanbata, H., Asfaw, A. & Kumie, A. 2014. Association of biomass fuel use with acute respiratory infections among under-five children in a slum urban of Addis Ababa, Ethiopia. *BMC public health,* 14, 1122.

Simoes, E. A., Cherian, T., Chow, J., Shahid-Salles, S. A., Laxminarayan, R. & John, T. J. 2006. Acute respiratory infections in children.

Smith, K. R., Mccracken, J. P., Weber, M. W., Hubbard, A., Jenny, A., Thompson, L. M., Balmes, J., Diaz, A., Arana, B. & Bruce, N. 2011. Effect of reduction in household air pollution on childhood pneumonia in Guatemala (RESPIRE): a randomised controlled trial. *The Lancet,* 378, 1717-1726.

Smith, K. R., Samet, J. M., Romieu, I. & Bruce, N. 2000. Indoor air pollution in developing countries and acute lower respiratory infections in children. *Thorax,* 55, 518-532.

Taksande, A. M. & Yeole, M. 2015. Risk factors of Acute Respiratory Infection (ARI) in under-fives in a rural hospital of Central India. *Journal of Pediatric and Neonatal Individualized Medicine (JPNIM),* 5, e050105.

Torres-Duque, C., Maldonado, D., Pérez-Padilla, R., Ezzati, M. & Viegi, G. 2008. Biomass fuels and respiratory diseases: a review of the evidence. *Proceedings of the American Thoracic Society,* 5, 577-590.

UNICEF 2017. Monitoring the situation of children and women. Available at: https://data.unicef.org.

UNICEF 2016. State of the world children: child info and DHS. Available at: https://www.unicef.org>files.

UNICEF 2014. A promise renewed progress report 2014.Committing to Child Survival: A Promise Renewed -Unicef files.unicef.org/publications/files/APR_2014_web_15Sept14.pdf.

WHO 2008. Department of child and adolescent health and development. WHO and UNICEF; 2008. Integrated management of childhood illnesses Available at: http://whqlibdoc.who.int/publications/2008/9789241597289_eng.pdf.

WHO 2012. Burden of disease from Household Air Pollution for 2012. Available at: www.who.int>outdoorair>databases.

WHO 2014. Zambia statistical fact sheet. Available at: www.who.int>country>zmb.

World Health Organisation Zambia 2015 Annual Report. Available at: www.afro.who.int

World Health Organisation Zambia 2016 Annual Report. Available at: www.afro.who.int

World Health Organisation 2016. Household air pollution and health Media Centre. Available at: www.who.int>mediacentre>factsheets.

CSO 2014. Zambia Demographic and Heath Survey 2013/2014, Lusaka, Zambia.

CSO 2015. Zambia Household Health Expenditure and Utilization Survey 2015, Lusaka, Zambia.

APPENDICES

Appendix 1: Data Extraction Tool

Variable	Question from ZDHS questionnaire	Response expected	Number of respondents.
Respondents Background.			
ARI	Has (NAME) had an illness with a cough at any time in the last 2 weeks?	Yes No	
	When (NAME) had an illness with a cough, did he/she breathe faster than usual with short, rapid breaths or have difficulty breathing?	Yes No	
Biomass fuel(priori)	What type of fuel does your household mainly use?	Electricity, Solar Liquid propane gas (LPG) Natural gas Biogas Kerosene Charcoal Wood Straw/Shrubs/Grass Animal dug No food cooked.	
Sex of the child		Male Female	
Flooring material	Main material of the floor	Earth, sand, Dung Wood/planks Palm/bamboo/Leeds Parquet or polished wood Vinyl or asphalt strip Ceramic/terrazzo tiles Concrete cement , Carpet	
Roof material	What type of roof does the house have?	Grass thatched Asbestos Iron sheets Other	

Age in months	0-5 6-11 12-23 24-35 36-47 48-59	Categorical.	
Child fully immunised	Did (name) ever receive any vaccination to prevent him or her from getting any diseases including vaccinations received in a national immunization day campaign.	Yes No	
Mothers age	How old were you on your last birthday.		
Residence	Categorized in dataset.	Rural Urban	
Mothers smoking status	Do you smoke	Yes No	
Mothers Level of education	What is your highest level of education?	No education Secondary Primary >Secondary	
Wealth quantile	Categorised in dataset.	Poorest Poor Middle Rich Richest	
Province	Categorized in dataset	Lusaka Copper belt Southern Central Northern Western North-western Eastern Luapula Muchinga	

Appendix 2 : Final multiple logistic regression model

Variables	OR (95%CI)	P-value
Cooking fuel		
Electricity		
Biomass	1.54(1.04- 2.28)	0.029
Wall material		
Rudimentary Wall		0.320
Bricks/blocks/cement	1.11(0.91-1.35)	0.320
no walls/ply wood/plunks	0.55(0.32- 0.94)	0.028
Floor material		
Natural floor		
Ceramic/ polished wood/cement	1.11 (0.86- 1.49)	0.352
Carpet/wood planks and others	5.32(1.56- 19.84)	0.008
Mothers age		
15-19		
20-24	0.72(0.53-0.98)	0.035
25-29	0.71(0.52-.96)	0.026
30-34	0.67(0.49-.93)	0.015
35-39	0.81(0.58-1.13)	0.210
40-44	0.67(0.44-1.02)	0.061
45-49	1.03(0.50-2.09)	0.944
Standard of living		
Poor		
Middle	0.76(0.61-0.97)	0.021
Rich	0.76(0.54-1.09)	0.106