THE IMPACT OF INDOOR AIR POLLUTION ON THE RESPIRATORY HEALTH OF CHILDREN IN SOUTH AFRICA

By

Poopedi Mashita

Submitted in fulfilment/partial fulfilment of the requirements for the degree of Masters in Population Studies

College of Humanities
School of Built Environment and Development Studies
University of KwaZulu Natal
Howard College
Durban
South Africa

December 2014

COLLEGE OF HUMANITIES

DECLARATION - PLAGIARISM

I, …………………………………………..……………………., declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs or other information, unless specifically acknowledged as being sourced from other persons.

4. This thesis does not contain other persons' writing, unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then:

    a. Their words have been re-written but the general information attributed to them has been referenced

    b. Where their exact words have been used, then their writing has been placed in italics and inside quotation marks, and referenced.

5. This thesis does not contain text, graphics or tables copied and pasted from the Internet, unless specifically acknowledged, and the source being detailed in the thesis and in the References sections.

Signed

………………………………………………………………………………

ACKNOWLEDGEMENTS

First and foremost, I would like to thank God for everything. I would like to express my genuine gratitude to my supervisor, Dr Kerry Vermaak, for her guidance, endless support and wisdom throughout the research project. She is the best, I could not have asked for a better supervisor. I also want to extend my appreciation to academic staff in population studies, Prof Pranitha Maharaj, Ms Nompu Nzimande, Priya Konan and to all my classmates for the support and sleepless nights doing school work. And to my true special friend, Mr Pedzi Ndangura for his amazing support, advice since my first year in UKZN, Thank you.

Last but not least I would like to thank my family for their prayers, support and believing in me Thabo, Nthabi, Koena, Nare, Nkai and Leroy Mashita. A special thanks to my mom (Edith Mashita) whom I will forever be thankful for. Special gratitude and thanks to my late father (Piet Tantshie Mashita) and grandfather (Thlokwa la tsela Mashita) who passed on last year (2013) for the love as well as guidance they gave me and I will forever be indebted to them. May their soul rest in peace. Finally I will like to extend my gratitude to my brother Sammy Mashita for all his support and inspiration.

LIST OF ACRONYMS AND DEFINITIONS

Indoor Air Quality refers to the presence or absence of air pollutants in buildings.

Biomass fuel refers to

WHO- World Health Organisation

ALRI- Acute Lower Respiratory Infection

IAP- Indoor Air Pollution

BMF- Biomass Fuel

PM_{10}-Particles less than 10 microns in diameter

DALY-Disability adjusted Life Years

YLL-Years of lost life

ABSTRACT

This study investigates the impact of indoor air pollution on respiratory health of children in South Africa. Biomass in the form of wood, crop residuals, and animal dung is used in most low income households as main fuel for cooking and heating. The study used quantitative methodology using secondary survey data from GHS2010 conducted by Statistics South Africa. Bivariate, independent and nested logistic regression analyses were conducted to examine the impact of indoor air pollution on respiratory health of a sample of 0 to 17 year old South African children. Results showed that children living in households that used unclean energy sources were more likely to have asthma compared to those who stayed in households that use clean energy sources. Female children had higher risk of having asthma compared to children. Regression analyses also observed that younger children below the age of 5 years were generally more likely to have asthma compared to those aged 5 years and above. There were higher odds of having asthma for children living outside KwaZulu Natal compared to those living in the province. There was a positive relationship between odds of having asthma and level of socioeconomic status. Based on the findings of the study, use of unclean energy sources for household purposes increases the risk of having respiratory health problems for children.

CONTENTS

LIST OF TABLES AND FIGURES

CHAPTER 1. INTRODUCTION

1.1 Background to the Study

Households in South Africa use a variety of energy sources for cooking, heating, lighting and other household purposes (Balmer, 2007; Aitken, 2007). The main sources of household energy in rural areas include wood, paraffin, candles and LPG (Aitken, 2007). In a study conducted by Aitken (2007), 90 percent of the sample of rural households in Eastern Cape (EC) used paraffin for cooking while the corresponding figures for KwaZulu Natal (KZN) and North West (NW) were 33 and 71 percent. With respect to wood, the percentages of households that used the fuel source for cooking range from 77 to 98 percent across the three provinces of EC, KZN and NW. In the urban areas, electricity is the modal source of energy especially among the populations living in formal housing. Among the section of urban population living in informal settlements, there is high usage of paraffin for domestic purposes like cooking and heating.

There is a direct relationship between socioeconomic class and type of energy source used by households with cleaner energy being adopted as households moved up to higher socioeconomic status. Given the backdrop of rising unemployment and energy prices as reported in Bond and Ngwane (2010), an increasing number of households in South Africa have adopted biomass fuels for cooking and heating. This is highlighted in increasing electricity disconnections due to inability to pay that were experienced in townships like Soweto at a time when unemployment rate increased from 16 percent in 1994 to 32 percent in the 2000s (Bond and Ngwane, 2010). The same period witnessed a widening gap between the rich and the poor with the Gini coefficient rising from 0.6 in 1994 to 0.72 in 2006 (Bond and Ngwane, 2010). This implies that many households in South Africa are using unclean energy sources which expose children to indoor air pollution with negative consequences on respiratory health, general wellbeing and optimal growth. A systematic analysis of the impact of exposure to indoor air pollution and respiratory health of children thus makes for interesting academic inquiry with important positive implications on relevant socioeconomic policies.

Indoor air pollution (IAP) has been identified as a global health threat, especially for Third World countries (Ezzati and Kammen, 2002). According to Fullerton *et al.* (2008), an estimated 2.4 billion people were still relying on biomass fuel such as wood, animal dung, straw, and remains of crop processing as sources of energy for domestic purposes such as cooking, heating and lighting post-2000. This included countries like India and China where more than 70 percent of the people still depended on unclean fuels (Norman *et al.*, 2007). South Africa has also been faced with the Indoor Air Pollution (IAP) challenge as a significant proportion of the population was still reliant on unclean fuels for heating and cooking (Rollin *et al.*, 2004). The World Health Report of 2002 estimated acute respiratory infection as one of the leading causes of child mortality in the world, accounting for up to 20 per cent of fatalities among children under five (Duflo *et al.*, 2008). However, one should note that not only children under five are affected, even those above the age of five. According to Duflo *et al.* (2008), this makes solid fuels the second most significant environmental cause of disease after contaminated waterborne disease and malaria.

In order to survive cold climates, humans were required to build shelters and use fire indoors for cooking, heating and lighting. Consequently, indoor air pollution can be traced to ancient times when people first used fire within shelters for protection against the elements (Bruce *et al.,* 2002). Ironically, fire, which allowed humans to enjoy the benefits of living indoors, resulted in exposure to high levels of pollution with negative implications on respiratory health (Bruce *et al.*, 2002). Barnes *et al.* (2006) argue that IAP has gained attention generally due to its health impacts particularly respiratory complications. Moreover, respiratory disease has constantly been among the most widespread disease in developing countries (Smith *et al.*, 2000). However, until late in the 20th century, limited reference to the function of air pollution in the incidence of diseases was made in the medical community (Ezzati and Kammen, 2002). Due to increasing number of research projects in the 1980s, the public health importance of IAP appeared on the agenda of research and policy (Zhang and Smith, 2007; Ezzati and Kammen, 2002). This culminated in the official acknowledgement of the size and extent of the public health threat posed by use of unclean fuels in homes (WHO, 2002, Barnes *et al.,* 2006).

1.2 Problem Statement

Young children living in households which used solid fuels have a two to three times greater risk of developing acute lower respiratory infection compared with those living in household using cleaner fuels (Norman *et al.*. 2007). Biomass fuel is usually used as a source of energy for cooking and heating by women in developing countries including South Africa. Cooking is a central part of people's daily lives yet under particular conditions it poses a serious health challenge to wellbeing through use of unclean energy sources which emit pollutants (Clancy, 2002). IAP has become a main contributor to mortality and morbidity given its link to acute lower respiratory illness in children (Franklin, 2007). According to the World Health Organisation (WHO), an estimated 1.6 million people in developing countries die prematurely each year due to indoor air pollution.

Evidence from epidemiological studies indicates that the issue of IAP has been largely ignored by policy makers (Barnes *et al.*, 2002). Furthermore, the greatest health impacts from air pollution worldwide occur among the poorest and most vulnerable sections of the population (Fullerton *et al.*, 2008). Evidence from previous studies reveal that the majority of households using biomass fuels belong to the low income quartile, even after the introductions of electricity (Rollin *et al.*, 2004).

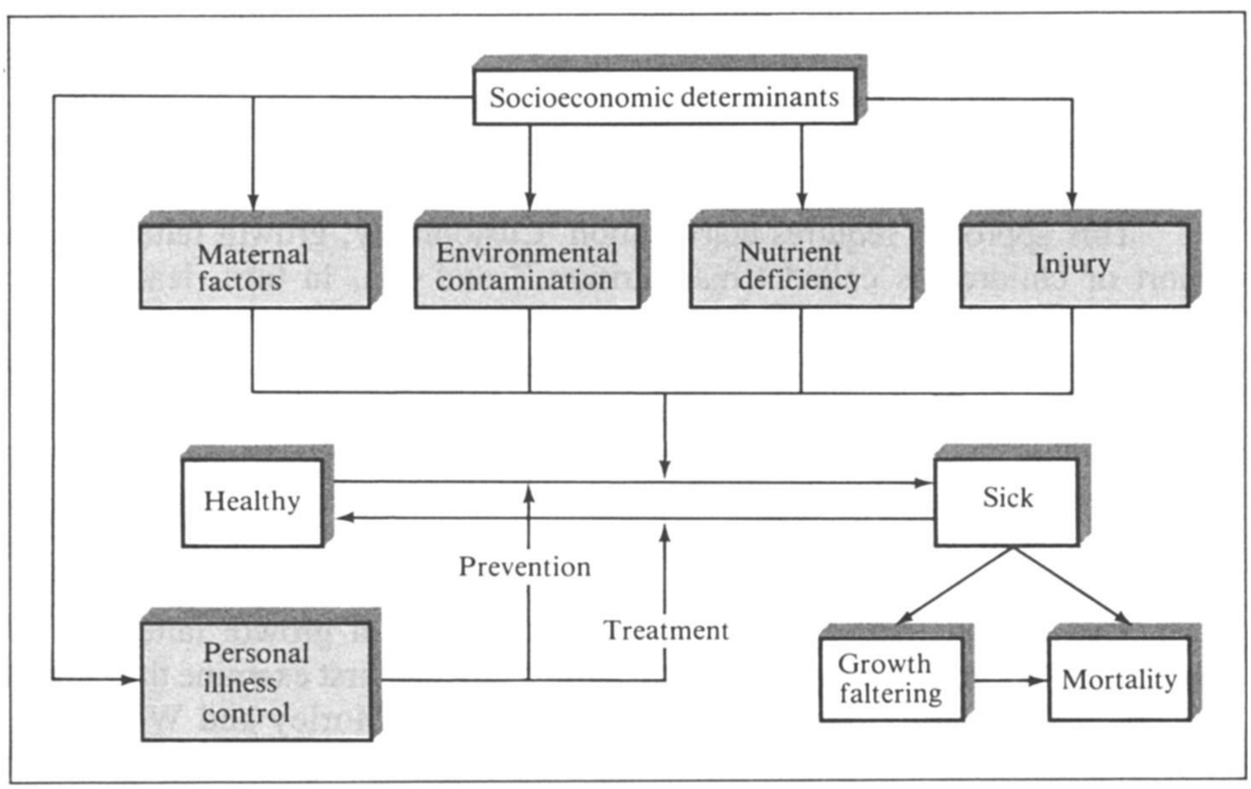
According to Norman *et al.*, (2007: 764), "the distribution of households by main energy source used for cooking or heating differs markedly by population group and province" in South Africa. Although many households in South Africa used electricity for lighting, only half used electricity for cooking and heating in 2001 (Norman *et al.,* 2007). Meanwhile, an estimated one-third of households in the country used solid fuels (wood, coal, dung) for cooking 95 percent of which were black African households (Norman *et al.*, 2007). According to Statistics South Africa (Stats SA) (2007), electricity as a source of energy for cooking in households increased by 8.9 per cent while that for heating increased by 9.3 per cent among African group between 1996 and 2007. The focus on African group is due to the fact that they were excluded from state benefits such as electricity during apartheid era and are on average the poorest population group in South Africa. However, the census data is derived from the question that focuses on the main source of fuel used for cooking and heating despite that in reality, multiple fuel sources are used to fulfil domestic energy needs in poor households (Barnes *et al.,* 2009).

Despite the significance of household energy sources and implications on the health of people, there has been few epidemiological studies that have investigated the subject. It is however, acknowledged that social science researchers are becoming more interested in IAP and its effect on human health (Duflo *et al.*, 2008). Existing literature on the implications of IAP on health is largely based on observational studies. This study aims to quantitatively investigate the implications of indoor air pollution on the respiratory health of children in South Africa.

1.3 Theoretical Framework

Mosley and Chen's (1984) framework will be used for this paper as it fits well with the topic. The structure of the framework provides a conceptual model for researchers investigating child survival and mortality. Mosley and Chen (1984) were concerned with the lack of an appropriate conceptual model for understanding child survival and mortality. The model by Mosley and Chen aimed bridging the gap between social sciences and medical research on child health and survival (Hill, 2003). The conceptual core of Mosley and Chen, borrowing on the idea of proximate determinants of fertility developed by Davies and Blake in 1956, asserts that background factors which are social, economic and cultural "operate through a limited set of proximate determinants that directly influence the risk of disease and the outcome of disease processes" (Hill, 2003:138). The Mosley and Chen model of proximate determinants on health dynamics is shown in table 1.1 below.

Figure 1.1 Operation of the proximate determinants on the health dynamics of a population



Source: Mosley and Chen, 1984

Referrals to this model will be made in the discussion under literature review. The framework defines five categories of total of 14 proximate determinants such as maternal factors, environmental contamination, nutrient deficiency, injury and personal illness control. Determinants in the first groups affect the rate at which children move from healthy to sick, whereas factors in the last group influence rate of recovery and prevention. Despite borrowing on the conceptual structure of Davies and Blake (1956), Mosley and Chen (1984:29) opined that child mortality analysis is more complex than fertility event because “a child’s death is the ultimate consequence of a cumulative series of biological insults rather than the outcome of single biological event”. Consequently, Mosley and Chen (1984) developed an index to measure health status of children using Gómez, Ramos-Galvin, Cravioto and Frenk’s (1955) classification framework called ‘weight-for-age index’. The index, as reported in Hill (2003) has the following five categories;

- Healthy – 90 percent or higher of standard weight-for-age,
- Grade I – 75-85 percent of standard,
- Grade II – 60-74 percent of standard,
- Grade III – less than 60 percent of standard,
- Dead.

The five categories range from 1 to 5 where an index of 1 represents being ‘dead’ and 5 represents ‘healthy’ state.

1.4 Objectives of the study

The main aim of this study is to establish the extent of the impact of indoor air pollution on the respiratory health of children in South Africa. The specific objectives of the study are as follows;

- To determine and describe the distribution of reported asthma diagnosis in children by selected variables which include age, sex, province of residence and socioeconomic status,
- To determine, using odds from regression analysis, the level of impact of unclean fuel has on children’s reported asthma diagnosis.

- To establish compelling evidence supporting the argument that welfare policies ought to seriously consider clean energy supply for the health of children and general population in the country.

1.5 Hypothesis of the study

The study hypothesis is that:

- The use of unclean sources of fuel as the main source of energy for cooking and heating is negatively associated with reported asthma diagnosis in children.

Null hypothesis

- There is no significant association between the use of unclean fuel as the main source of energy for cooking and heating with reported asthma diagnosis in children.

1.6 Significance of the study

This research is predicated on the importance of children's wellbeing as an indispensable component of child development, wellbeing of the society and the socioeconomic and political aspirations of the country going into the future. Furthermore, there is currently limited body of knowledge on the impact of indoor air pollution on children's respiratory health particularly in South Africa at a national level hence the justification for conducting this research. One of the South African government's efforts is to improve public health through service delivery programmes and access to clean energy sources especially electricity one of the important components of service delivery. This study aims to make a contribution to both the academic body of knowledge and evidence for social policy by analysing one of the recent national household survey data conducted by Statistics South Africa.

1.7 Organisation of the study

This dissertation contains five chapters. Chapter 1 introduces the research topic, highlighting the problem statement and the main objectives of the research. Chapter 2 will provide literature review, looking at international studies as well as local studies on this topic. Chapter 3 describes the methodology while chapter 4 discusses the findings of the study. Chapter 5 provides a discussion of the results, suggests policy recommendations and conclusion to the study.

2.1 Introduction

This chapter reviews existing literature on household energy sources, and previous findings on impacts of air pollution on health. The chapter contains six subsections excluding the introduction and conclusion, and begins by exploring fuel types, traditional cooking stoves and air pollution levels. This is followed by a review of gender roles and energy, epidemiological evidence on indoor air pollution and health, poverty and respiratory health, exposure, and risk factors associated with indoor air pollution. A conclusion comes at the end and summarises chapters.

2.2 Fuel types, traditional cooking stoves and air pollution levels

The type of fuels used typically increase in cleanliness, convenience, efficiency and cost as people move up what has been termed the "energy ladder" (Smith *et al.*, 2002). The energy ladder is seen as a theoretical and functionally useful framework for explaining the dynamics of fuel and stove adoption (Saatkamp *et al.*, 2000:7). It is a model that has been used to classify energy sources along a hierarchy according to the cost, ease of use, technological advancement and most critically the concentration of air pollution produced (Barnes *et al.,* 2009). However, due to generally low levels of income and lack of development in third world countries, many households tend to be at the bottom of the energy ladder (Duflo *et al.,* 2008). The bottom third of the ladder comprises solid biomass fuels such as cow dung, crop residues and wood (Barnes *et al.,* 2009).

The middle third of the energy ladder comprises sources of energy such as coal, paraffin while modern fuels such as liquid petroleum gas, natural gas and electricity occupy the top third of the ladder (Barnes *et al.,* 2009). Electricity is situated on the top of the ladder and considered to be the safest fuel in terms of indoor air quality but, the production of electricity carries negative impacts on the environment. People generally move up the ladder as socio-economic conditions improve (Bruce *et al.*, 2002: 10). It is expected that as income rises, households would substitute to higher quality fuel choices but, existing studies still show that the process has been quite slow in most developing countries (Duflo *et al.,* 2008).

Typically a poor household in urban area is more likely to spend 20 percent of its income on fuel, while a rural poor household will generally restrict fuel purchases to lighting uses such as candles (Reddy, 2000). It is possible to identify an energy element to poverty hence the term energy poverty was introduced. According to Clancy (2002:5) energy poverty has been defined "as the absence of sufficient choice in accessing adequate, affordable, reliable, high quality, safe and environmentally benign energy services to support economic and human development". This can be considered a true reflection of the South African energy access context especially among the poor households in urban areas and most of rural households with no access to electricity and are not able to afford connection to mains as well as the monthly cost of purchasing electricity. The predicament of the energy access among the poor households in South African has been exacerbated by rising unemployment amid jobless growth of the economy in the post-1994 period (Bond and Ngwane, 2010). For example, the unemployment rate in South Africa increased from 16 percent in 1994 to 32 percent in 2000 and this occurred amid increasing electricity disconnections particularly in townships like Soweto (Bond and Ngwane, 2010).

Barnes *et al.* (2009) noted that in 2006 over 73 per cent of South African households had access to electricity. However, it is not clear as to the composition of the remaining 27 per cent's sources of household energy. While it could generally be believed that the 27 percent is comprised of mainly rural households, the shanty and squatter settlements have mostly been excluded from official statistical records such that the distribution of energy sources may not be truly reflected in aforementioned figures. Rollin *et al.,* (2004) found that over half of South African households still depended mainly on solid fuels for cooking and heating despite the widespread electrification including in areas outside urban centres.

Use of multiple fuels has been emphasized by number of local studies that have investigated household energy patterns in South Africa largely because of inability to afford the price of electricity. For instance, a study conducted in the rural areas of North West province observed that roughly 44 per cent and 89 per cent of the households had never used electricity for cooking and heating respectively three years after being electrified (Barnes *et al.*, 2009). In a related study Rollin *et al.* (2004) observed that in un-electrified homes wood and paraffin were the main sources of energy used for cooking. In electrified homes only 26 per cent of the respondents reported using mainly electricity for cooking purposes while the remainder used either paraffin only or a combination of electricity, paraffin and other solid fuels (Rollin *et al.*, 2004). Furthermore, there was an average of 3.6 years elapsed since connection to electricity mains without using electricity for household purposes (Rollin *et al.*, 2004). With respect to cooking, only 17 per cent of households reported immediate use of electrical stoves while 44 per cent had never used an electrical stove for cooking (Rollin *et al.*, 2004).

In South Africa, reliance on coal for household purposes is relatively low at national level, it is highly localized in areas surrounding coal mines (Barnes *et al.*, 2009). Existing literature on household energy sources reveal that in most African countries poor people rely on wood for cooking and heating especially in rural areas (Barnes *et al.*, 2002; Rollin *et al.*, 2004). In addition large number of households mainly in South Asia use kerosene which has considerably high particulate emission which increases indoor air pollution (Smith, 1993). According to Barnes *et al.,* (2009) and Rollin *et al.* (2004), paraffin remains a major source of energy for cooking in informal settlements in South Africa. In a study conducted by Muller *et al.* (2003) in Cato Crest area of Durban in South Africa, it was observed that more than 70 percent of households in the low-income metropolitan area relied on kerosene and paraffin for cooking and heating and this was associated with high prevalence of problems of poor indoor air quality.

2.3 Gender roles and energy

Most studies link the term household energy with cooking and stoves, household features that are strongly associated with women. However, this does not imply that it is sufficient to consider women only when dealing with household energy issue because men also play a vital role in decision making on household energy (Clancy, 2002). Gender roles are socially determined and vary according to time and place, often influenced by social relations such as ethnicity, culture, race and class. In most households, decision making including on household energy maybe shared but, it is women and girls who are mostly involved in cooking and other household responsibilities requiring use of energy. Consequently, females are generally faced with greater risk of respiratory infections resulting from inhaling pollutants from the incomplete combustion of unclean fuels.

The health effects of indoor air pollution are often exacerbated by lack of ventilation in homes using biomass fuels and by the poor design of stoves that do not have proper chimneys to take smoke out of the living area (Fullerton *et al.*, 2008). According to Ezzati and Kammen (2002), the latest National Ambient Air Quality Standards of the U.S Environmental Protection Agency requires the daily average concentration of PM_{10} to be <150µg/m3. Moreover a typical hour mean average concentration of PM_{10} in homes using biofuel may range from 300 to 3000µg/m3 depending on the type of fuel, stove and housing (Schirnding *et al.,* 2000). Ezzati and Kammen (2002) found that the concentration of PM_{10} in households using biomass fuel ranged from 200 to 500 µg/m3 or more throughout the year. However, the concentration levels measures depend on where and when the monitoring takes place. Some of the measurements focus on the cooking time only, when indoor concentration can be expected to be highest (Smith, 1993). For example, a study conducted in Zimbabwe in 1990 showed that the typical pollution level of 1300 µg/m3 in respirable particles was reached at the cooking time of just 2 hours (Smith, 1993). In a related study, Ezzati and Kammen (Ezzati and Kammen, 2002) found that peaks in emission concentrations commonly occur due to factors such as cooking pot is placed or removed from the fire, food is stirred, fuel is added among others. However, the aforementioned literature does not address the impact on children's respiratory health of the emissions from burning biomass fuels for cooking and heating. This is rather to some extent reflected in reports such as that by WHO (2013) which showed percentages of population using solid fuels with commensurate number of deaths attributable to indoor air pollution for selected countries. This is shown in table 1.1 below.

Table 1. Percentages of households using solid fuels and number of under 5 deaths attributed to indoor air pollution for selected countries.

Country	**Population using solid fuels in 2012 (%)**	**Under 5 deaths attributable to IAP (2004)**
South Africa	13	1 191
India	63	167 926
China	45	9 065
Bangladesh	89	24 972
Botswana	37	450
Afghanistan	81	52 386

Source: WHO, 2013

Table 1.1 shows the percentage of population using solid fuels in 2012 and number of deaths among children less than 5 years of age attributable to indoor air pollution in 2004. The table shows that India had the highest number of IAP-related under 5 deaths compared to other highly populous countries like China and Bangladesh. This may be attributed to relatively high level of poverty and population growth especially in India compared to Bangladesh inasmuch as Bangladesh had the highest percentage of people who were using solid fuels.

2.4 Epidemiological evidence on the effect of indoor air pollution on health

Most people are aware that outdoor pollution has dangerous effect on health but few are aware of the dangers of IAP to wellbeing. The significance of exposure to air pollutants in indoor settings on children's health has been acknowledged during the last decade. The first published local systematic study of wood smoke ARI in young children was based on examination of 150 infants coming to a hospital in South Africa, observing that use of wood for household energy requirements had an adverse effect on infants' respiratory health (Smith, 1993). In a related study by Sanyal and Maduma (2000) it was found that there was a possible association between recurrence of respiratory symptoms among children and high levels of IAP in the low income communities of the Eastern Cape Province in South Africa. Sanyal and Maduma (2000) surveyed a total of 550 households with monitoring of gaseous pollutants such as carbon monoxide, sulphur dioxide conducted in 115 participating households. Pollutants were recorded continuously for six hours in the cooking and living areas in each household (Sanyal and Maduma, 2000). The findings from the study were consistent with World Health Organization's (2002) observation that children are more vulnerable to acute lower respiratory infections (ALRI) as a result of exposure to indoor air pollution compared to adults.

Specifically, in relation to asthma Khalequzzaman *et al.* (2007) studied a sample of children under the age of 5 years and observed increased risk of having asthma for children living in homes where unclean energy sources were used indoors while Mohammed *et al.* (1995) found increased risk of having asthma for school children who were exposed to wood smoke compared to their counterparts who were not.

However, one of the reasons for children's vulnerability might be attributed to the fact that while adults spent more time outdoors in various fields of employment and other socioeconomic activities, children are spend relatively more time indoors and around fire places during the winter season. Moreover, due to changing social organisation in the homes as a result of HIV/AIDS-related mortality and morbidity, young children are now assuming domestic responsibilities like cooking which were formerly done mainly by adults. Exposure to indoor air pollution is also underlain by weather conditions in the early hours of day and late afternoon irrespective of season, and some households may need to have their fire places on throughout the night to provide heat while all doors and windows are closed.

2.5 Poverty and respiratory health

Exposure to indoor air pollution has been associated with chronic obstructive pulmonary disease, lung cancer, low birth weight, and acute lower respiratory illness (Smith *et al.,* 2000). There are studies that observed that exposure to indoor air pollution doubles the risk of pneumonia thereby increasing the rate of death among children (Carlsten, 2011). Because of the detrimental effect of indoor air pollution and relatively high prevalence of children exposed, it is among the top four killers of South African children less than five years old (Barnes *et al.*, 2009). This is partly due to weak immune system that young children are more prone to ALRI through exposure to indoor air pollution exposure which restraints the body's defences against infection (Barnes *et al.*, 2009). In addition other studies have found that risk factors such as nutrition, crowding, family history of infection and exposure to environmental tobacco smoke may influence child susceptibility to ALRI (Barnes *et al.*, 2009). As a result of the growing prominence of the impact of indoor air pollution, the World Bank and other international development institutions in 2001 identified the reduction of IAP as critical objective for the coming decade (Smith *et al.*, 2000).

Numerous studies have highlighted an association of indoor air pollution with ALRI in previous years (Smith *et al.*, 2000; Wichmann and Voyi, 2008). Wichmann and Voyi (2008) explored the association between polluting fuels and child ALRI using data from the 1998 South African Demographic Health Survey. The study found that two-thirds of children lived in households using polluting fuels and 19 per cent suffered from acute lower respiratory infections (Wichmann and Voyi, 2008). The results were related with those observed in studies by Norman *et al.* (2007) and Barnes *et al.* (2009). Barnes *et al.* (2009) observed that children from households that used a combination of clean and unclean sources of energy were 27 per cent more likely to have ALRI compared to their counterparts from households that used clean energy source only. Other studies have quantitatively investigated the relationship between exposure to biomass smoke and ALRI in young children in developing countries where identified, for example, Rollin *et al.*, 2004). The study by Rollin *et al.* (2004) was a feasibility assessment on the suitability of a South African rural village due to be electrified as well as to estimate attendant reductions in indoor air pollution and impact on ALRI. The study followed a comparative quantitative assessment of indoor air pollution in non-electrified and electrified households, concluding that electrification significantly reduced levels of indoor respirable particulate matter (RSP) and young children's personal exposure (Rollin *et al.* (2004). In the study concurrent measurements were made of levels of respirable particulate matter and carbon monoxide, and standard quality control procedures were used throughout (Rollin *et al.*, 2004). The investigation found lower levels of pollutants in un-electrified homes when compared with other published data from homes using biomass fuels. This difference may be attributed to the fact that the study was done in summer and the other one in winter, in rural areas far from industrial activities and busy roads, and that people can change their behaviour when conscious of being monitored (Rollin *et al.*, 2004). . However, the study was conducted in summer in the rural villages of North West province when average length of time spent indoors is less compared to winter. Therefore, the findings were mainly focusing on cooking and have not taken into account exposure to indoor pollution resulting from heating. More people can be expected to be indoors during cold weather than in summer, therefore the result might have missed the peak times of exposure. The other issue in winter is that the fire wood may be wet such that the smoke emitted will be intense than during summer. Furthermore health impacts from the relatively brief elevated concentrations may differ from daily exposure (Duflo *et al.*, 2008).However, a similar study by Barnes *et al.* in 2006 was done in winter. The two studies used the same methodology and both showed a difference of PM_{10} measured in kitchens of over 200 per cent. Based on these and other studies, the World Health Organisation (WHO) estimated that 1000 people die annually from Indoor Air Pollution exposure in South Africa, and 450 children die of ALRI as a result of indoor air pollution (Barnes *et al.*, 2009). The levels of respirable particles measured in un-electrified dwellings in the study can be considered high enough to generate negative health effects in small children (Rollin *et al.*, 2004).

The prevalence of the respiratory infections is high in the developing world partly due to indoor air pollution and generally social economic status among many people. A study on the effects of cooking fuel on acute respiratory infection conducted in Tanzania showed that increasing household living standards reduced the occurrence of ARI and the reduction was higher for households with a medium living standard than with a high living standard (Bukalasa, 2011). This was similar to the study that was done in South Africa by Barnes *et al.* (2009) which showed that children living in households reliant on polluting 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-fives death annually. The study, being based on rural communities, also showed that connection to electricity mains was not enough to reduce the exposure to indoor air pollution because many households did not use electricity for cooking or heating because of inability to afford the price of electricity and electrical appliances (Bukalasa, 2011). The reasons for not using electricity that many studies did not consider include the nature of food being cooked, for example the animal trotters, tripe, bones, samp and beans, very solid foods that require prolonged heating. Hence when such foods are being considered in urban areas, urban dwellers consider firewood. Finally quantities of food being cooked should also be taken into consideration.

Published studies which quantitatively addressed the relationship between exposure to household biomass smoke and ALRI in young children in developing countries were identified by Smith and colleagues in their 2000 paper (Smith *et al.*, 2000). The studies were chosen for the reason that they address actual ALRI and children under five years old and involve indoor exposure to biomass fuel smoke. One of the studies found significant associations in Africa compared to other countries (Smith *et al.*, 2007). However, not all studies report the connection between exposure and mortality. For instance a case-control study reported by Johnson and Adele cited in Smith *et al.* (2007) in Nigeria found no significant association of ALRI morbidity with reported type of household fuel but, a strong relationship of fuel type with case fatality. In a detailed analysis of data from the Gambia, Armstrong and Campbell cited in Smith *et al.* (2007) found that the risk of pneumonia in association with smoke exposure was increasing in girls but not boys. This might be due to greater exposure and not from the biological differences between the sexes (Smith *et al.*, 2007).

2.6 Exposure

Health effects are determined not just by the pollution level, but more importantly by the time people spend breathing polluted air. Exposure refers to the concentration of pollution in the immediate breathing environment over a specified time interval (Bruce *et al.*, 2002). Use of biomass fuel leads to levels of indoor air pollution many times higher than international ambient air quality standards allow (Schirnding *et al.*, 2002). Evidence from most studies suggest that women and young children in developing countries are at greater risk because of their gender roles and household responsibilities which involve spending more time indoors resulting in high exposure to indoor air pollution (Carlsten *et al.*, 2011). However, Carlsten *et al.* (2011) did not consider female headed households. Besides, women are no longer solely responsible for domestic activities. Traditionally male migration increased the number of female-headed household and recently female migration and HIV/AIDS has also increased, hence male–headed and child-headed households emerged. Due to changing family structures more men are now responsible for domestic activities therefore should also be considered. Looking at changing family systems in South Africa, Merli and Palloni (2004) highlighted that an increasing number of children were living with grandparents and extended family members in the wake of HIV/AIDS pandemic in Africa using 1998 South Africa Demographic Health Survey. Despite being small in proportion, child-headed households have rose markedly during the period between 1995 and 2005 especially considering the absolute numbers of children being orphaned. This makes changing family compositions an important factor in understanding the dynamics of health and exposure to indoor air pollution.

Exposure to indoor air pollution from the burning of solid fuels has been implicated, with varying degrees of evidence, as a causal agent of several diseases in developing countries including acute respiratory infections like pneumonia (Ezzati and Kammen 2002). There are other risks of direct exposure to burning biomass fuel such as burns to the children, injuries to women from carrying woods (Schirnding *et al.*, 2005). The amount of exposure in terms of the number of people, exposure intensity and time spent exposed is far greater in the developing world compared to the developed world. Exposure to unclean air has other health effects besides respiratory complications. For example, a relatively small cohort study in rural Kenya found that the amount of pollution a child is exposed to directly correlate with the risk of developing pneumonia (Fullerton *et al.,* 2008).

2.7 Risk factors associated with IAP

2.7.1 Indoor air pollution and Pneumonia

Prevention remains a critical component of control strategy with annual deaths from pneumonia in children under 5 years old exceeding 2 million (Dherani *et al.*, 2008). According to Dherani *et al.,* (2008:390) indoor air pollution from household use of solid fuels was identified by

Kirkwood *et al.* (1995) as one of several modifiable risk factors requiring evaluation. Several reviews have examined the available evidence linking indoor air pollution to pneumonia during childhood (Dherani *et al.*, 2008).

Evidence from literature suggests that ARI is one of the leading causes of death in the world in terms of lost healthy life years, which is normally measured as disability adjusted life years (Smith *et al.*, 2000). According to Smith *et al.* (2000), three to five million deaths occur annually among under 5 children as a result of ARI of which 75 per cent result from pneumonia (Smith *et al.,* 2000). The first report in the biomedical literature to describe an association between indoor cooking smoke and childhood pneumonia in developing countries reported measurements of indoor pollution levels in the homes of infants diagnosed with bronchiolitis and bronchopneumonia at Lagos University Teaching Hospital (Smith *et al.,* 2000. Furthermore it has been argued that ARI is currently a major cause of ill health globally because its biggest impact is in young children (Smith *et al.*, 2000). Lack of awareness and poor ventilation in most households is one of the reasons for the prevalence of acute respiratory infections in the developing world including South Africa especially in rural areas and informal settlements (Bukalasa, 2011).

2.7.2 Genetics and Asthma

There are studies that maintain that genetics are an important underlying factor in people's susceptibility to respiratory infections (Franklin, 2007; Sanford and Pare, 2000). It is argued that one of the most common characteristics of complex genetic disorders such as asthma result from genetic heterogeneity. This implies that different combinations of gene variants contribute to the phenotype in different families (Sanford and Pare, 2000). Therefore, genes can also be a major contributing factor to the existence of asthma in children. A study done by Rona *et al.* (1997) found that parents who had asthma or wheezing were highly likely to have children who also suffered from asthma or wheezing regardless of ethnicity.

Fewer than ten studies from developing countries examining the association between biomass fuel smoke and asthma mainly in children have been published. However, outcome definitions have not been well standardized; exposure has not been measured and confounding variables were not appropriately dealt with in other studies (Schirnding *et al.,* 2005). This was evident in a study done in South Eastern Kentucky by Mehta and Shahparl in 2004 using burden of obstructive lung disease data on self-reported prevalence of asthma among 508 subjects which observed that increased odds of reporting current asthma were associated with cooking indoors with wood or coal (Mehta and Shahparl, 2004). With respect to developing countries, biomass and coal will continue to be used by a large number of households for the foreseeable future, thereby maintaining a high morbidity levels although there is uncertainty associated with the exact risk estimates (Schirnding *et al.,* 2005). Therefore, the health consequences of IAP exposure from biomass and other solid fuels in developing countries should not be ignored (Schirnding *et al.*, 2005). While evidence show that IAP is highly associated with ARI mortality, it is critical to understand the contributions related factors such as family size, crowding, malnutrition, poor sanitation, exposure to passive smoking and lack of immunization are environmental factors that promote the transmission of respiratory pathogens and increase the size of the infecting inoculums (Berman, 1991). In the Mosley and Chen framework proximate determinants such as maternal factors, environmental contamination, nutrients deficiency where highlighted.

2.7.3 Poverty and nutrition

The quarterly bulletin of 2009 published by South African Reserve Bank cited in UNICEF (2009) pointed out that a Gross Domestic Product (GDP) of 281 billion US dollars and per capita of 5 740 US dollars qualified South Africa as a middle-income nation. However, income inequality meant that 68 percent of the children were living in poverty in 2009 despite high per capita income (UNICEF, 2009). Furthermore while South Africa may be food secure as a country, large numbers of households within the country are food insecure. Unemployment and food inflation have increasingly worsened the level of impoverishment among many households every year (Altman *et al.*, 2009). According to UNICEF (2009), the 2005 national survey on food consumption revealed that 18.0 percent, 9.3 percent and 4.5 percent of children aged 1-9 years were stunted, underweight and wasted respectively. The affected children's bodies have their immune defence systems compromised, making them susceptible to infections including respiratory-related problems. It is thus interesting to examine the role of poverty as a compromising factor in children's experience of respiratory diseases as a result of exposure to indoor air pollution.

Evidence from literature suggests that malnutrition is strongly associated with increased risk of mortality from acute lower respiratory infections (Rice *et al.*, 2000). This is highlighted in Mosley and Chen's (1984) framework which postulates that determinants of health like nutrients deficiency increase the risk of illness among children. The association might be attributed to the fact that malnutrition generates several deleterious effects including alterations in the immune and non-immune host defences, and respiratory muscle weakness which make it difficult to fight infections (Berman, 1991). In a study conducted in Costa Rica, 83 malnourished and 54 normal-weight infants and children were followed weekly for 54 consecutive weeks to determine annual incidence of total ARI episode. The study found that the incidence of total ARI episodes was similar in the two groups of children but, malnourished children's respiratory infections were of significantly longer duration and the likelihood of pneumonia was 12 times higher than in normal weight children (Berman, 1991). However, it should be taken into consideration that hunger and mal-nutrition are not the same. Hunger describes the state of 'not eating enough food' while under-nutrition refers to the lack of sufficient micro-nutrients such as key vitamins, iron and zinc (Altman *et al.*, 2009).

The study by Berman (1991) also found that the frequency of hospitalization for respiratory infection was 15 per cent among the malnourished sample compared to just 4 per cent among normal weight sample. Malnutrition has been found to have negative effect on children at later stages of development (Berman, 1991). According to Mosley and Chen (1984:138) "both child mortality and child growth are affected by the same set of underlying nutritional and infectious conditions such that weight-for-age can be regarded as a measure of health status rather than just for nutritional status". Maternal diet and good nutrition during pregnancy affect birth weight and influence nutrient quality of breast milk, hence having a negative impact on the infants (Mosley and Chen, 1984).

In order to advance the public health application of knowledge about the interrelated burdens of childhood ALRI and poor nutrition in developing countries, Roth *et al.* (2008) critically reviewed existing data regarding the efficacy and effectiveness of specific nutritional interventions for reducing global childhood ALRI incidence, morbidity and ALRI mortality in South Asia. The review included Meta analyses and large scale randomized controlled trials of micronutrient supplementation, breastfeeding promotion, complementary food provision in which childhood ALRI outcome (such as incidence, morbidity or mortality) was measured (Roth *et al.*, 2008). The review found that routine oral daily or weekly zinc supplementation for at least three months significantly reduced the incidence of childhood ALRI (Roth *et al.*, 2008). Furthermore it is argued that lack of exclusive breastfeeding and Vitamin D has risk factor for ALRI mortality and incidence in developing countries. However vitamin A has not been constant in all the studies reviewed. Therefore promotion of such interventions can have a broad range of child health benefits (Roth *et al.*, 2008).

Mosley and Chen's framework highlighted the environmental contamination as one of the proximate determinants of child survival. According to Mosley and Chen (1984) environmental contamination refers to the transmission of infectious agents to children and mothers. Therefore lack of clean water and sanitation systems influence poor personal hygiene and can further enhance transmission (Roth *et al.*, 2008). Intensity of household crowding was also observed to increase the risk of acquired respiratory infections (Hill, 2003).

2.7.4 Environmental tobacco smoke

According to Chan-Yeung and Dimich-Ward (2003), tobacco smoke is a major component of IAP. Despite growing awareness of adverse health effects on non-smokers, exposure to environmental tobacco smoke is a major health issue worldwide. For example, direct evidence indicates that smoking in pregnancy harms the development of the foetus' respiratory system, increase the risk of Asthma and reduces the growth of lung function later in the life of the child (Chan-Yeung and Dimich-Ward, 2003). Children exposed to second hand smoke are more likely to suffer from pneumonia, bronchitis and other lung infections as well as ear infections (Chan-Yeung and Dimich-Ward, 2003). Children whose mothers smoke during pregnancy tend to be born with smaller air ways, which increases their chances of developing asthma. Studies shows that second hand smoke may intensify symptoms in children suffering from asthma, and may contribute to the development of asthma.

3. Conclusion

This chapter reviewed existing literature on the dynamics of energy sources, uses, gender and poverty in South Africa and other parts of the world. It showed that most rural households and those in urban informal housing and townships use biomass energy like wood and paraffin for cooking and heating. Domestic energy uses are closely linked to gender roles with women and children being more exposed to indoor air pollution compared to men. Poverty plays an important role in energy sources by determining type of energy a household adopts. The chapter reviewed literature showing negative health impacts of indoor air pollution on health.

3.1 Introduction

This chapter presents the methodological approach used to carry out the study in order to address the research questions and achieve the set objectives. The chapter recaps the research questions, describes the research design, the data set used including the advantages and disadvantages of the dataset. It also describes the study sample, the variables examined in the study, statistical methods employed and the limitations of the study. A conclusion is provided at the end to round of the chapter.

3.2 Research questions

The research aimed to establish the impact of indoor air pollution on the respiratory health of children in South Africa. The investigation was guided by the following key questions:

- Is there a significant association between independent variables such as age, sex, province and SES and reported asthma diagnosis in children?
- What is the relationship between the use of unclean fuel for cooking and heating and reported asthma diagnosis in children?
- Investigate relationship between unclean cooking fuel and reported asthma diagnosis when controlling other independent variables (IV)?

3.3 Research design

This research followed a quantitative design methodology using cross-sectional survey data to examine the effect of indoor air pollution on the respiratory health of children in South Africa. The particular type of quantitative design employed was explanatory given that the research aimed to go beyond merely describing relationship between indoor uses of unclean fuels and having asthma to also explaining the observed relationship. Unclean fuel refers to any animal or plant based material as well as coals deliberately burned by humans for the purpose of heating and cooking (Bruce et al, 2002).

Explanatory design for quantitative studies entails that the researcher follows clearly defined steps when investigating the chosen topic. The steps of the investigation, chronologically, comprise research design, sampling, measurement, analysis and conclusion. These steps were followed in this research. The research hypothesis was developed following a review of existing literature on respiratory health, asthma and household energy. Following a review of existing literature, this research hypothesised that indoor air pollution has a negative impact on the respiratory health of children. The research design for this study was predicated on the need to have analytical methods suitable for analysing national survey data and allowing for results to be generalised.

3.4 Data

3.4.1 General Household Survey 2010 (DHS2010)

The General Household Survey of 2010 (DHS2010) was a national household survey conducted by Stats SA. It covered six broad areas such as education, health, social development, and housing among others (Statistics South Africa, 2010). The survey was designed to measure multiple facets of the living conditions of South African households as well as the quality of service delivery. The sampling population of the survey consisted of all private households in all nine provinces. The survey was done in July 2010.

The selection of households to partake in the survey was carried out using two stage stratified design with probability-proportional-to-size sampling of the Primary Sampling Units (PSUs) within a strata at the first stage. The PSUs are the enumerator areas used by Statistics South Africa in the collection of the Census data and at the second stage systematic sampling of households within these PSUs was employed (Statistics South Africa: 2010). The sample was allocated to the provinces, after the allocation the sample was further stratified by geography and by population attributes using secondary stratification (Census 2001). Furthermore fieldworkers were trained in order for them to be competent and avoid unnecessary errors.

A face to face interviews was successfully done for total of 25 653 household. In addition 233 enumerators, 62 provincial and district coordinators participated in the survey across all nine provinces. An additional 27 quality assurors were responsible for monitoring and ensuring questionnaire quality (Statistics South Africa: 2010).

The unit of analysis used in this study was all individuals under the age of 18 years listed as household members on the household listing in the selected households.

3.4.2 Advantages and disadvantages of using secondary data

The main advantage is the availability of data, usually from a large sample size that has already been collected, either to meet other primary objectives or for administrative purposes (Sorensen, Sabroe and Olsen, 1996). As the data has already been collected, the researcher does not have to spend the time or other costs to obtain data, however as the secondary data were not designed specifically to meet the researcher's needs, the questions covered in the data collection tool may not cover the subject of the interest in sufficient detail (Sorensen, Sabroe and Olsen, 1996). Other potential challenges are that the data may be outdated, variation in definition terms and different units of measurement among others (Hox and Boeije, 2005).

3.5 Study sample

The study sample was made up of South African children below the age of 18 years living in the households. Statssa used a questionnaire to collect data and enumerators where trained to perform the task effectively. The following table presents the distribution and age distribution of the study sample by biographical variables.

Table 3.1 Distribution and age distribution of the study sample by biographical variables

Variable	N	Frequency	Percentage	Mean age	Std Error
Age (whole sample)	36 208	-	100	8.57	0.03
Age group	36 208				
0-4 years		10 269	28.36	2.04	0.01
5-9 years		9 554	26.39	6.95	0.01
10-14 years		9 998	27.61	12.07	0.01
15-17 years		6 387	17.64	16.02	0.01
Sex	36 208				
Male		18 211	50.30	8.55	0.04
Female		17 997	49.70	8.45	0.04
Population group	36 208				
African		30 897	85.33	8.55	0.03
Coloured		3 598	9.94	8.43	0.09
Indian/Asian		575	1.59	9.79	0.22
White		1 138	3.14	9.02	0.15

3.6 Variables

3.6.1 Dependant Variable

The dependent variable for this research was respiratory health. In order to measure respiratory health, asthma was used as the attribute to measure a child's respiratory health status. The DHS2010 used the following question to obtain data on whether one had asthma or not

- Has (the *person)* been informed by the medical practitioner that he/she suffers from any of the following chronic illness?

3.6.2 Main independent variable

The main independent variable was the unclean fuel (coal, wood and paraffin) and was determined by using questions such as

- What is the Main source of fuel for cooking and heating for this household?

3.6.1 Other explanatory variables

3.6.1.1 Age (whole sample)

Age can be defined as the duration of time expressed in days, weeks, months or years that a person has lived from birth. This research operationalised age as the number of completed years at a child's last birthday using the GHS2010 question '**what is** *(the person)***'s age in completed years?'**

3.6.1.2 Sex

Sex defines biological differences between males and females. It is a binary variable arbitrarily coded 1 for males and 2 for females in response to the question '**is** (*the person*) **male or female?**'

3.6.1.3 Population group

Defined based on physical characteristics distinct to a group of people, population group in South Africa is divided into four categories; African, Coloured, Indian/Asian and White. The GHS2010 asked '**what population group does (the person) belong to?'**

3.6.1.4 Province

South Africa has nine provinces which are Western Cape, Eastern Cape, Northern Cape, Free State, KwaZulu Natal, North West, Gauteng, Mpumalanga and Limpopo. The provinces differ in terms of demographics and economic levels.

3.6.1.5 Socio-economic status (SES)

SES is most frequently characterized as the hierarchical order of an individual or family in a particular society (Chen et al, 2002). It spreads across a range stratified by social and economic resources. Moreover SES has a profound influence on health. According to Chen et al (2002) individuals lower in SES experience higher rates of morbidity and mortality in almost every disease category than those higher in SES. For the purpose of the paper, SES was operationalised as a composite of household variables believed to define a household's investment capacity that reflects its social class in the context of GHS2010.

Household were classified into four categories of SES, low, medium, high. SES was computed using principal component analysis (PCA). The variables used to determine SES are described later in the chapter. Data analysis included controlling for SES because wealth differences among households affect child outcomes. However SES data are collected for variables that capture living standards, infrastructure and housing characteristics rather than Income and expenditure. More recently, studies have applied PCA to such data to derive a SES index (Vyas and Kumaranayake, 2006).

(a) Principal Component Analysis (PCA)

Vyas and Kumaranayake (2006) define PCA as a multivariate statistical technique used to reduce the number of variables in a data set into a smaller number of dimensions. It was first introduced by Pearson (1901) and developed separately by Hostelling in 1933 (Jollife, 2002). PCA works best when asset variables are correlated, but also when the distribution of variables differ across cases and regarded the best method to be used and relied on for past decades (Filmer and Pritchett, 2001). Computation of PCA involves generating new variables called principal components (PCs) whereby the first component accounts for the largest possible variance in the original variables (Ndagurwa, 2013). This is followed by generating the second PC, third, fourth until the last PC in a 'hierarchical' fashion on the precept that each succeeding component accounts for maximal residual variance and is orthogonal to the one preceding it (Ndagurwa, 2013; Jollife, 2002). In addition PCA creates uncorrelated indices or components, where each component is a linear weighted combination of the initial variables (Jollife, 2002).

There are three steps that can be distinguished in PCA. The first step entails running PCA on a table of explanatory variables. The second step involves selecting components on which ordinary least squares is run. The third step is about computing parameters for the selected components of the model (Ndagurwa, 2013).

Table 2.2 Factor scoring from principal component analysis for classification of households into categories of socioeconomic status.

Variable	FL	FS	Mean	SE	AI
Has piped water	0.834	0.419	1.328	0.470	0.891
Has good shelter	0.610	-0.105	1.209	0.407	-0.258
Has close water source	-0.800	-0.389	6.240	2.941	-0.132
Has municipal water	0.579	0.343	1.163	0.369	0.930
Has electricity mains	0.672	-0.201	1.142	0.349	-0.576
Has refuse collection	0.698	0.392	1.444	0.497	0.789
Has television	0.678	-0.217	1.206	0.404	-0.538
Has refrigerator	0.703	-0.215	1.243	0.429	-0.501

FL=Factor Loadings, FS=Factor Scores, SD=Standard Error, AI=Asset Index

The table above shows factor scoring from principal component analysis explored to compute SES index. The SES index was created using 8 variables on whether a household has a good (made of brick or concrete) shelter, piped water, is close to its water source, connected to electricity mains, refuse collection by municipality, television and refrigerator. Only variables with factor loadings above 0.5 were retained, and the factor scores operate to increase the SES index. Given that the variables are binary, the asset index entails that a one unit increase in each variable results in an increase in the asset index which is equal to factor scoring divided by standard deviation of the mean score for that variable.

The SES index indicates the difference in the asset index of a household that have a particular asset compared to that which does not have that asset. For example, a household with piped water has an asset index which is 0.891 times higher than a household without piped water. The column with means indicates the average score of the sample for the respective variable. The factor scores were used to construct an ordinal SES variable with 3 levels (low, medium and high) which was used in the multivariate regression analysis as a control variable in determining the impact of source of energy for cooking and heating on the odds of having asthma for children.

(a.i) Access to piped water

Piped water refers to water obtained from pipe inside the dwelling or in the yard. This excludes water from access point outside the yard. The GHS2010 collected data on access to piped water using the question **'In which way does this household obtain water for domestic use?**'. Access to water was classified into piped water and other for PCA. According to the classification of water 'other' included water from dams, boreholes, rain water tank. Evidence from previous research shows that there is a significant relationship between source of water and socioeconomic status (Dungumaro 2007; Klasen, 2000).

(a.ii) Distance to water source

Distance to water source was measured in metres and kilometres in the DHS2010. The survey collected data on distance to water source using the question '**How far is the water source from the dwelling or yard (200m is equal to the length of two football/soccer fields)?**'. For computation of PCA, the variable was entered as 'has close water source' where less than 200 metres was considered close while more than 200 metres was considered far.

(a.iii) Access to municipal water

Data on the variable access to municipal water for PCA was obtained from the DHS2010 question '**Is your main source of drinking water supplied by a municipality?**'. The question was binary in the DHS2010 and required no adjusting with yes or no being the responses.

(a.iv) Type of dwelling

GHS2010 collected information on the type of main dwelling of every household according to the materials used to construct the dwelling such as bricks and traditional materials, and name of dwelling, for example, flat, workers' hostel and informal dwelling. Classification of dwelling type for PCA was done according to materials used to construct the main dwelling of a household. Dwelling types made of bricks or concrete were regarded as good while those made of other materials were classified as bad. House or brick structure on a separate stand or yard, flat in block of flats, town or semi-detached house (simplex, duplex or triplex), and room or flat-let not in backyard but on a shared property were classified as good. Dwelling types that were considered bad are traditional dwelling or hut structure made of traditional material, informal dwelling or shack in backyard, informal dwelling or shack not in backyard, for example squatter settlements, caravan or tent, workers' hostel and private ship or boat. GHS2010 collected information on type of dwelling by asking '**Which of the following types describe the main dwelling unit that these households occupy?**' The variable was included in PCA because type of dwelling has been found to be an important predictor of socioeconomic status in South Africa (Ndagurwa, 2013; Michael, 2003).

(a.v) Source of household energy

GHS2010 collected data on source of energy for cooking, heating and lighting as three separate variables. Only source of energy for cooking was considered for PCA because cooking demands the most energy thus better reflects a household's socioeconomic status. (Sugrue, 2005 cited in Balmer, 2007). Household energy source was categorised into electricity and 'other' for PCA with the latter representing gas, paraffin, wood, and coal, animal dung, solar and other forms not specifically identified in GHS2010. The question as phrased in DHS2010) was '**What type of energy or fuel does this household mainly use for cooking?**' and the variable was depicted as 'has electricity' in PCA.

(a.vi) Refuse collection

Refuse collection refers to how rubbish from a household is mainly disposed of. The DHS2010 asked of each household, '**How is the refuse or rubbish from this household collected or removed?**'. In the PCA, refuse collection was divided into either by 'local authority' or 'other' and was entered into the computation as 'has refuse collection'. The 'other' referred to forms of refuse collection which are communal refuse dump, no rubbish disposal, and other forms.

(a.vii) Television and refrigerator

GHS2010 collected data on ownership of eight household goods two of which, namely television and refrigerator, were included in PCA. Data on ownership of household goods was using a single question '**Does the household own any of the following?**' hence the presentation of the two variables under one subheading. Ownership of television and ownership of refrigerator were retained because they returned high factor loadings when PCA was initially run for all household variables implying that the two household goods had significant predictive power on a household socioeconomic status.

3.7 Data analysis and statistical analysis

Data analysis was performed using STATA version 11. The analysis presented in this paper is based on information on 36208 children under the age of 18 years included in the GHS2010. The analysis of data was done using bivariate and regression techniques. Bivariate methods were used to describe the distribution of the sample for each independent variable while regression techniques were employed to determine and explain the probability of having asthma. Independent logistic regression models were conducted before nested models. This was to determine the associated probability of having asthma for each independent variable without controlling for other factors. Nested models were explored using multivariate binary logistic regression model. The reason for exploring nested models was to enable the study to determine the extent of the actual impact of indoor air pollution on the odds of having asthma for children when the effects of other important variables like age and sex were removed.

3.7.1 Logistic regression

Regression analysis, defined by Weisberg (2013) as the study of dependence that was conducted to determine the statistical significance of differences in health outcomes among children. Logistic regression is based on binary dependent variables, viz. child has an asthma diagnosis (1), and child has no asthma diagnosis (0). Logistic regression makes use of one or more predictor variables that may be either continuous or categorical.

According to Sykes (1993) cited in Ndagurwa (2013), regression analysis is a statistical tool used to investigate relationships, which may be causal, among variables. In many quantitative research projects, regression analysis is a central tool used to investigate and understand functional relationships among variables of interest (Weisberg, 2013). The aim of conducting regression is to determine statistical significance, and in some instances, explain the nature of relationships among the variables of interest (Ndagurwa, 2013; Sykes, 1993). The suitability of regression models is predicated on the measures of dependent variable. Regression methods were therefore chosen for this study due to their associated advantages one of which was that it enabled the study to establish if the relationship between indoor air pollution and asthma was legitimate or spurious.

The type of logistic regression model used in the analysis was predicated on the nature of the dependent variable which was binary where 1 represented not having asthma and 0 represented having asthma. The logistic model was explored in the form of log of odds which represented the probability of having asthma for children. The model, taking X to represent independent variables, can be represented as follows;

$$log\frac{\pi_i}{1-\pi_i} = logO_i = \alpha + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3) + \beta_4(X_4) \quad [3.1]$$

Where $1 - \pi_i$ represent the conditional probability of not having asthma; π_i is the conditional probability of having asthma; and O_i is the conditional odds of having asthma. In order for interpretation of logistic regression using odds, antilogs were applied to equation 3.1 to have the model as;

$$\frac{\pi}{1-\pi} = e^{\alpha+\beta} = e^{\alpha}\left(e^{\beta}\right)^{\mathrm{X}} \quad [3.2]$$

Where the two constants multiplied by each other raised to the power x implied that every additional explanatory variable added on to the model had a multiplicative effect on the odds of having asthma.

Three sets of nested models were explored. The first set of nested models were for cooking, the second set for heating and the third set combined energy sources for cooking and heating to have ‘household energy source’. For each set, four models were explored with the first model controlling for age and sex while population group, province and socioeconomic status variables were added in successive models. Within the models, the reference category for each variable was based on the existing coding in the data.

3.8 Limitations of the study

Relatively small sample sizes require differences in observed odds to be very big before they are judged to be significant.

3.9 Conclusion

The purpose of this chapter was to present the research design and methodological approach that were explored when carrying out the study. The advantages and disadvantages of using secondary data were discussed. The quantitative techniques employed in analysing data were described. The chapter also described the dataset used for the study. The main variables of the study were also discussed in detail. The specific method of analysis employed was logistic regression and was presented discussed in the chapter.

CHAPTER 4: RESULTS

4.1 Introduction

This research was designed to examine the impact of indoor pollution on respiratory health of children in South Africa. Respiratory health was measured in terms of known diagnosis of asthma while indoor pollution was measured from household source of energy for cooking and heating. This chapter presents results on the odds of having asthma on a number of explanatory variables which are source of household energy, age, age group, sex, population group, province and socioeconomic status (SES). The chapter is organised as follows:

The first section presents a description of the sample. The second section presents results from bivariate analysis and independent logistic regression. The third section presents results from nested logistic models which analysed the impact of source of energy for cooking on the odds of having asthma. The fourth section provides results from analysis of the impact of source of energy for heating on the odds of having asthma for children. The fifth section presents results from analysis which simultaneously analysed sources of energy for cooking and heating referred to as exposure to indoor pollution. The last section is a summary of the chapter.

4.2 Description of the sample

Table 4.1 below shows descriptive statistics on the distribution of the study sample by household energy source for cooking. The layout of the figures in the tables was so that all important dimensions were captured. For example, using the total row percentages, it can be seen in Table 4.1 that the majority of children lived in households that used electricity and wood for cooking, 67.7 and 26.5 percent respectively. It can also be observed in Table 4.1 that of the total number of children living in households using electricity, 28.2 percent were in the 0-4 year age group while 18 percent were aged 15-17 year age group. Tables 4.2 and 4.3 follow a similar format to table 4.1. Table 4.3 combines sources of energy for cooking and heating such that living in a household that used a combination of clean and unclean energy sources were considered exposed to indoor pollution together with living in households that used only unclean energy sources. Consequently, Table 4.3 captured under 'clean sources' column only children from households that used electricity for both cooking and heating.

Table 3.1 Frequency and percentage distributions of household energy source for cooking by selected variables for the study sample

Variable	Electricity	Paraffin	Wood	Coal	Animal dung	Other	Total
Age groups (years)							
00-04	6 600 (64.4:28.2)	611 (5.9:31.3)	2 625 (25.6:27.4)	245 (2.4:31.3)	63 (0.6:27.6)	104 (1.0:52.8)	**10 248 (100:28.4)**
05-09	6 112 (64.1:26.1)	498 (5.2:25.5)	2 601 (27.3:27.1)	209 (2.2:26.7)	69 (0.7:30.3)	48 (0.5:24.4)	**9 537 (100:26.4)**
10-14	6 468 (64.8:27.6)	539 (5.4:27.6)	2 682 (26.9:28.0)	210 (2.1:26.8)	58 (0.6:25.4)	27 (0.3:13.7)	**9 984 (100:27.6)**
15-17	4 220 (66.2:18.0)	302 (4.7:15.5)	1 679 (26.3:17.5)	120 (1.9:15.3)	38 (0.6:16.7)	18 (0.3:9.1)	**6 377 (100:17.6)**
Total	**23 400 (64.7:100.0)**	**1 950 (5.4:100.0)**	**9 587 (26.5:100,0)**	**784 (2.2:100.0)**	**228 (0.6:100.0)**	**197: 0.6:100.0)**	**36 146 (100:100)**
Sex							
Male	11 694 (64.4:50.0)	979 (5.4:50.2)	4 904 (27.0:51.2)	389 (2.1:49.6)	114 (0.6:50.0)	93 (0.5:47.2)	**18 173 (100:50.3)**
Female	11 706 (65.1:50.0)	971 (5.4:49.8)	4 683 (26.1:48.9)	395 (2.2:50.4)	114 (0.650.0)	104 (0.6:52.8)	**17 973 (100:49.7)**
Total	**23 400 (64.7:100.0)**	**1 950 (5.4:1000.0)**	**9 587 (26.5:100.0)**	**784 (2.2: 100.0)**	**228 (0.63:100.0)**	**197 (0.6:100.0)**	**36 146 (100:100)**
Population group							
African	18 333 (59.4:78.4)	1 905 (6.2:97.7)	9 470 (30.7:98.8)	779 (2.5: 99.4)	223 (0.7:97.8)	132 (0.4: 67.0)	**30 842 (100:85.3)**
Coloured	3 364 (93.6:14.4)	43 (1.2:2.2)	116 (3.2:1.2)	5 (0.1:0.6)	5 (0.1:2.2)	63 (1.8: 32.0)	**3 596 (100:10.0)**
Indian/Asian	572 (99.5:2.4)	2 (0.4:0.1)	1 (0.2:0.0)	0 (0.0:0.0)	0 (0.0:0.0)	0 (0.0:0.0)	**575 (100:1.6)**
White	1 131 (99.8:4.8)	0 (0.0:0.0)	0 (0.0:0.0)	0 (0.0:0.0)	0 (0.0:0.0)	2 (0.2:1.0)	**1 133 (100: 3.1)**
Total	**23 400 (64.7:100.0)**	**1 950 (5.4:100.0)**	**9 587 (26.5:100.0)**	**784 (2.2:100.0)**	**228 (0.6:100.0)**	**197 (0.6:100.0)**	**36 146 (100:100)**
Province							
KwaZulu Natal	3 767 (54.8:16.1)	281 (4.1:14.4)	2 630 (38.3:27.4)	77 (1.2:9.8)	102 (1.5:44.7)	16 (0.2:8.1)	**6 873 (100:19.0)**
Eastern Cape	2 054 (44.6:8.8)	808 (17.4:41.4)	1 700 (36.6:17.7)	0 (0.0:0.0)	77 (1.7:33.8)	2 (0.0:1.0)	**4 641(100:12.8)**
Northern Cape	1 850 (81.6:7.9)	76 (3.4:3.9)	341 (15.9:3.6)	0 (0.0:0.0)	0 (0.0:0.0)	1 (0.0:0.5)	**2 268 (100:6.3)**
Free State	2 535 (88.2:10.8)	159 (5.5:8.2)	102 (3.6:1.2)	70 (2.4:8.9)	8 (0.3:3.5)	0 (0.0:0.0)	**2 874 (100:7.9)**
Western Cape	2 999 (93.2:12.8)	67 (2.1:3.4)	38 (1.2:0.4)	1 (0.0:0.1)	5 (0.2:2.3)	108 (3.4:54.8)	**3 218 (100:8.0)**
Northwest	2.272 (72.7:9.7)	166 (5.3:8.5)	648 (20.7:6.8)	9 (0.3:1.2)	20 (0.6:8.8)	9 (0.3:4.6)	**3 124 (100:8.6)**
Gauteng	3 792 (90.3:16.2)	247 (5.9:12.7)	43 (1.0:0.5)	60 (1.4:7.7)	0 (0.0:0.0)	59 (1.4:30.0)	**4 201 (100:10.7)**
Mpumalanga	2 232 (57.6:9.5)	86 (2.2:4.4)	1 020 (26.3:10.6)	529 (13.6:67.5)	10 (0.3:4.4)	1 (0.0:0.5)	**3 878 (100:11.6)**
Limpopo	1 899 (37.5:8.1)	60 (1.2:3.1)	3 065 (60.5:32.0)	38 (0.8:4.9)	6 (0.1:2.6)	1 (0.0:0.5)	**5 069 (100:14.0)**
Total	**23 400 (64.7:100.0)**	**1 950 (5.4:100.0)**	**9 587 (26.5:100.0)**	**784 (2.2:100.0)**	**228 (0.6:100.0)**	**197 (0.55:100.0)**	**36 146 (100:100)**
SES							
Low	14 979 (88.2:66.6)	681 (4.0:36.8)	795 (4.7:8.8)	351 (2.1:46.9)	25 (0.2:11.5)	150 (0.9:81.1)	**16 981 (100:49.1)**
Medium	2 948 (51.7:13.1)	411 (7.2:22.2)	2 034 (35.7:22.5)	243 (4.3:32.5)	49 (0.9:22.5)	18 (0.3:9.7)	**5 703 (100:16.5)**
High	4 578 (38.5:20.3)	757 (6.4:40.9)	6 231 (52.5:68.8)	154 (1.3:20.6)	144 (1.2:66.1)	17 (0.1:9.9)	**11 881 (100:16.5)**
Total	**22 505 (65.1:100.0)**	**1 849 (5.5:100.0)**	**9 060 (26.2:100.0)**	**748 (2.2:100.0)**	**218 (0.6:100.0)**	**185 (0.5:100.0)**	**34 565 (100:100)**

Note: Percentages are in parenthesis in the form (row percentage: column percentage)

Table 4.2 Frequency and percentage distributions of household energy source for heating by selected variables for the study sample

Variable	Electricity	Paraffin	Wood	Coal	Animal dung	Other	Total
Age groups (years)							
00-04	3 617 (43.0:28.2)	925 (11.0:28.3)	3 302 (5.1:30.2)	425 (5.1:30.2)	66 (0.8:26.1)	68 (0.8:46.3)	**8 403 (100:28.1)**
05-09	3 330 (42.0:26.0)	891 (11.3:27.3)	3 208 (40.5:26.8)	376 (4.8:26.7)	83 (1.1:32.8)	35 (0.4:23.8)	**7 923 (100:26.5)**
10-14	3 570 (43.0:27.8)	878 (10.6:26.9)	3 382 (40.8:28.2)	377 (4.5:26.8)	63 (0,8:24.9)	27 (0.3:18.4)	**8 297 (100:27.8)**
15-17	2 313 (44.0:18.0)	574 (10.9:17.6)	2 089 (39.7:17.4)	228 (4.3:16.2)	41 (0.8: 16.2)	17 (0.3:11.6)	**5 262 (100:17.6)**
Total	**12 830 (43.0:100.0)**	**3 268 (10.9:100.0)**	**11 981 (40.1:100.0)**	**1 406 (4.7:100.0)**	**253 (0.9:100.0)**	**147 (0.5:100.0)**	**29 885 (100:100)**
Sex							
Male	6 345 (42.2:49.5)	1 679 (11.2:51.4)	6 107 (40.6:51.0)	720 (4.8:51.2)	128 (0.9:51.0)	66 (0.4:44.9)	**15 045 (100:50.3)**
Female	6 485 (43.7:50.6)	1 589 (10.7:48.6)	5 874 (39.6:49.0)	686 (4.6:48.8)	125 (0.8:49.4)	81 (0.6:55.1)	**14 840 (100:49.7)**
Total	**12 830 (42.9:100.0)**	**3 268 (10.9:100.0)**	**11 981 (40.1:100.0)**	**1 406 (4.7:100.0)**	**253 (0.9:100.0)**	**147 (0.5:100.0)**	**29 885 (100:100)**
Population group							
African	9 530 (36.9:74.3)	3 134 (12.2:95.9)	11 383 (44.1:95.0)	1 379 (5.3:98.1)	253 (1.0:100.0)	124 (0.5:84.4)	**25 803 (100:86.3)**
Coloured	1 870 (71.9:14.6)	133 (5.1:4.1)	559 (21.5:4.7)	19 (0.7:1.4)	0 (0.0:0.0)	20 (0.8:13.6)	**2 601 (100:8.7)**
Indian/Asian	453 (98.7:3.5)	0 (0.0:0.0)	3 (0.7:0.2)	3 (0.7:0.2)	0 (0.0:0.0)	0 (0.0:0.0)	**459 (100:1.5)**
White	977 (95.6:7.6)	1 (0.1:0.0)	36 (3.5:0.3)	5 (0.5:0.4)	0 (0.0:0.0)	3 (-.3:2.0)	**1 022 (100:3.4)**
Total	**12 830 (42.9:100.0)**	**3 268 (10.9:100.0)**	**11 981 (40.1:100.0)**	**1 406 (4.7:100.0)**	**253 (0.9:100.0)**	**147 (0.5:100.0)**	**29 885 (100:100)**
Province							
KwaZulu Natal	2 229 (40.6:17.4)	131 (2.4:4.0)	2 895 (52.7:24.2)	92 (1.7:6.5)	143 (2.6:56.5)	0 (0.0:0.0)	**5 490 (100:18.4)**
Eastern Cape	365 (8.6:2.8)	1 346 (31.5:41.2)	2 482 (58.2:20.7)	11 (0.3:0.8)	63 (1.5:24.9)	0 (0.0:0.0)	**4 267 (100:14.3)**
Northern Cape	890 (48.2:6.9)	169 (9.2:5.2)	776 (42.0:6.5)	8 (0.4:0.6)	0 (0.0:0.0)	3 (0.2:2.0)	**1 846 (100:6.2)**
Free State	981 (41.2:7.7)	880 (37.0:26.9)	293 (12.3:2.5)	212 (8.9:15.1)	9 (0.4:3.6)	5 (0.2:3.4)	**2 380 (100:8.0)**
Western Cape	1 486 (64.1:11.6)	520 (22.4:15.9)	278 (12.0:2.3)	3 (0.1:0.2)	1 (0.0:0.4)	29 (1.3:19.7)	**2 317 (100:7.8)**
Northwest	1 338 (59.7:10.4)	74 (3.3:2.3)	759 (33.9:6.3)	39 (1.7:2.8)	21 (0.9:8.3)	10 (0.5:5.8)	**2 241 (100:7.5)**
Gauteng	3 118 (84.5:24.3)	92 (2.5:2.8)	127 (3.4:1.1)	259 (7.0:18.4)	0 (0.0:0.0)	96 (2.6:65.3)	**3 692 (100:12.4)**
Mpumalanga	1 354 (42.3:10.6)	23 (0.7:0.7)	1 100 (34.4:9.2)	710 (22.2:50.5)	10 (0.3:4.0)	2 (0.1:1.4)	**3 199 (100:10.7)**
Limpopo	1 069 (24.0:8.3)	33 (0.7:1.0)	3 271 (73.5:27.3)	72 (1.6:5.1)	6 (0.1:2.4)	2 (0.1:1.4)	**4 453 (100:14.9)**
Total	**12 830 (42.9:100.0)**	**3 268 (10.9:100.0)**	**11 981 (40.1:100.0)**	**1 406 (4.7:100.0)**	**253 (0.9:100.0)**	**147 (0.5:100.0)**	**29 885 (100:100)**
SES							
Low	8 712 (65.0:70.2)	2 141 (16.0:68.3)	1 642 (12.3:14.5)	774 (5.8:57.3)	23 (0.2:10.6)	109 (0.8:76.2)	**13 401 (100:46.9)**
Medium	1 525 (32.7:12.3)	338 (7.3:10.8)	2 369 (50.9:20.9)	371 (8.0:27.4)	33 (0.7:15.2)	23 (0.5:16.1)	**4 659 (100:16.3)**
High	2 169 (20.6:17.5)	655 (6.2:20.9)	7 322 (69.6:64.6)	207 (2.0:15.3)	161 (1.5:74.2)	11 (0.1:7.7)	**10 525 (100:36.8)**
Total	**12 406 (43.4:100.0)**	**3 134 (11.0:100.0)**	**11 333 (39.6:100.0)**	**1 352 (4.7:100.0)**	**217 (0.8:100.0)**	**143 (0.5:100.0)**	**28 585 (100:100)**

Note: Percentages are in parenthesis in the form (row percentage: column percentage)

Table 4.3 Frequency and percentage distributions of household energy source (cooking and heating combined) by selected variables for the study sample

Variable	Unclean sources	Clean sources	Total
Age groups (years)			
00-04	6 734 (65.6:28.5)	3 535 (34.4:28.1)	**10 269 (100:28.4)**
05-09	6 289 (65.8:26.6)	3 265 (34.2:26.0)	**9 554 (100:26.4)**
10-14	6 503 (65.0:27.5)	3 495 (35.0:27.8)	**9 998 (100:27.6)**
15-17	4 118 (64.5:17.4)	2 269 (35.5:18.1)	**6 387 (100:17.6)**
Total	**23 644 (65.3:100.0)**	**12 564 (34.7:100.0)**	**36 208 (100:100)**
Sex			
Male	12 008 (65.9:50.8)	6 203 (34.1:49.4)	**18 211 (100:50.3)**
Female	11 636 (64.7:49.2)	6 361 (35.3:50.6)	**17 997 (100:49.7)**
Total	**23 644 (65.3:100.0)**	**12 564 (34.7:100.0)**	**36 208 (100:100)**
Population group			
African	21 628 (70.0:91.5)	9 269 (30.0:73.8)	**30 897 (100:85.3)**
Coloured	1 731 (48.1:7.3)	Q 867 (51.9:14.9)	**3 598 (100:9.9)**
Indian/Asian	122 (21.2:0.5)	453 (78.8:3.6)	**575 (100:1.6)**
White	163 (14.3:0.7)	975 (85.7:7.8)	**1 138 (100:3.1)**
Total	**23 644 (65.3:100.0)**	**12 564 (34.7:100.0)**	**36 208 (100:100)**
Province			
KwaZulu Natal	4 796 (69.4:20.3)	2 118 (30.6:16.9)	**6 914 (100:19.1)**
Eastern Cape	4 286 (92.3:18.1)	357 (7.7:2.8)	**4 643 (100:12.8)**
Northern Cape	1 384 (61.0:5.9)	884 (39.0:7.0)	**2 268 (100:6.3)**
Free State	1 912 (66.4:8.1)	969 (33.6:7.7)	**2 881 (100:8.0)**
Western Cape	1 737 (53.9:7.4)	1 483 (46.1:11.8)	**3 220 (100:8.9)**
Northwest	1 824 (58.3:7.7)	1 303 (41.7:10.4)	**3 127 (100:8.6)**
Gauteng	1 108 (26.3 (4.7)	3 099 (73.7:24.7)	**4 207 (100:11.6)**
Mpumalanga	2 544 (65.6:10.8)	1 335 (34.4:10.6)	**3 879 (100:10.7)**
Limpopo	4 053 (78.0:17.1)	1 016 (20.0:8.1)	**5 069 (100:14.0)**
Total	**23 644 (65.3:100.0)**	**12 564 (34.7:100.0)**	**36 208 (100:100)**
SES			
Low	8 351 (49.1:37.2)	8 660 (50.9:71.2)	**17 011 (100:49.1)**
Medium	4 246 (74.4:18.9)	1 465 (25.7:12.1)	**5 711 (100:16.5)**
High	9 859 (82.9:43.9)	2 034 (17.1:16.7)	**11 893 (100:34.4)**
Total	**22 456 (64.9:100.0)**	**12 159 (35.1:100.0)**	**34 615 (100:100)**

Note: Percentages are in parenthesis in the form (row percentage: column percentage)

Tables 4.1 and 4.2 show that the majority of children lived in households that used electricity and wood as sources of energy for cooking and for heating. The other sources of energy namely coal, animal dung, paraffin and other individually were not as prevalent as electricity and wood. While electricity was the single most prevalent energy source for cooking and heating, the majority of children in the study sample were exposed to indoor pollution when all energy sources were aggregated and categorised into clean and unclean sources. This is shown in Table 4.3. The descriptive analyses also showed that the African population group had the highest percentage of children who were exposed to indoor pollution, a finding which was supported by regression results presented in the sections below.

4.3 Bivariate and independent logistic regression analysis

Table 4.4 below presents results from bivariate analysis and independent logistic regression analysis. The table contains five columns with the first one comprising the independent and control variables that were used in data analysis. The column title N contains totals per category of a variable. Percent with asthma (row) indicates percentages of the number of children with asthma in a category of a variable. For example, of the 10 090 children in the age category 0-4 years, 0.94 percent had asthma. The last column shows the odds of being asthmatic among children of different categories of an independent variable. Bivariate analysis revealed that a relatively small percentage of children were reported to have been diagnosed of asthma. As shown in table 4.2 below, 1.41 percent of the 35 678 children in the study sample had asthma.

4.3.1 Age, sex and population group

Table 4.4 shows percentages of the study sample observed to have asthma. Out of the total study sample of 35 678 children, 1.41 percent had asthma. Regression analysis showed a negative relationship between the odds of having asthma and age. As age increased, the odds of having asthma significantly decreased to 0.97 (p0.00 < p0.05). Collapsing the sample into four age categories revealed that 10-14 year olds (32.07 percent) accounted for the majority of children with asthma followed closely by 5-9 year olds (31.27 percent), 0-4 year olds (18.99 percent) while 15-17 year olds accounted for 17.73 percent. It is worth noting that 15-17 years age category comprised a range of three years compared to the other categories which had a range of five years which may have impacted on the age category’s share of the total number of children who had asthma. Nonetheless, logistic analysis which regressed the dependent variable and age group variable without controlling for other variables showed that the odds of having asthma were significantly lower for the older age groups compared to the 0-4 age category. Compared to children aged 0-4 years, the odds of having asthma for children aged 5-9 years (0.56) and 10-14 years (0.57) were less by 0.44 and 0.43 times respectively while those for children aged 15-17 years were (0.66) were less by 0.34 times.

Bivariate analysis for sex revealed that almost 60 percent of children with asthma were male (59.76 percent) while females made up 40.29 percent. However, female children were observed to be more likely to have asthma compared to their male counterparts. The odds of having asthma were significantly higher for female children compared to their male counterparts (OR 1.48: $p0.00 < p0.05$).

Table 4.4 Results from bivariate and independent logistic regression analysis

Characteristic	N	Percent with asthma (column)	Odds of having asthma	Standard Deviations of the odds
GHS 2010	35 678	-	0.97**	0.01
Age groups (years)				
00-04	10 090	18.92	(reference)	
05-09	9 422	31.27	0.56**	0.07
10-14	9 998	32.07	0.57**	0.07
15-17	6 387	17.73	0.66**	0.10
		100.00		
Sex				
Male	17 944	59.76	(reference)	
Female	17 734	40.24	1.48**	0.14
		100.00		
Population group				
African	30 435	67.53	(reference)	
Coloured	3 557	18.92	0.49**	0.03
Indian/Asian	570	5.38	0.42**	0.04
White	116	8.17	0.51**	0.04
		100.00		
Province				
KwaZulu Natal	6 847	23.31	(reference)	
Eastern Cape	4 555	11.35	1.37	0.22
Northern Cape	2 235	6.77	1.12	0.22
Free State	2 860	3.78	2.00**	0.65
Western Cape	3 170	20.12	0.53**	0.07
Northwest	3 058	6.77	1.54**	0.30
Gauteng	4 108	11.75	1.19	0.19
Mpumalanga	3 843	10.56	1.24	0.21
Limpopo	5 002	5.58	3.09**	0.65
		100.00		
Energy for cooking				
Electricity	23 048	80.20	(reference)	
Paraffin	1 918	3.20	2.10**	0.54
Wood	9 453	14.40	2.31**	0.30
Coal	780	1.40	1.95	0.74
Animal dung	227	0.20	4.00	4.01
Other	193	0.60	1.12	0.65
		100.00		
Energy for heating				
Electricity	12 615	58.85	(reference)	
Paraffin	3 222	10.97	1.38	0.23
Wood	11 811	25.69	2.17**	0.26
Coal	1 397	3.24	2.03**	0.58
Animal dung	252	0.50	2.38	1.70
Other	147	0.75	0.92	0.54
		100.00		
Household energy sources				
Unclean sources	23 056	53.78	(reference)	
Clean sources	12 352	46.22	0.61**	0.06
		100.00		
SES				
Low	16 576	65.02	(reference)	
Medium	5 665	11.32	1.96**	0.30
High	11 713	23.66	1.94**	0.21
		100.00		

** Significant at p<.05

The distribution of asthmatic sub-sample by population group reflected the racial distribution of the study sample as a whole. African children (67.53 percent) accounted for the majority of children with asthma followed by Coloured (18.92 percent) and White (8.17 percent) while Indian/Asian children made up 5.38 percent. As shown in table 4.4 above, the independent logistic model testing the risk of having asthma for the population group variable found significantly less odds of having asthma for Coloured children (OR 0.49: p0.00 < p0.05) and Indian/Asian children (OR 0.42: p0.00 < p0.05) which were less than half those of African children. The results for White children (OR 0.51: p0.00 < p0.05) also showed significantly less odds of having asthma compared to African children.

4.3.2 Province

Table 4.4 shows that over 75 percent of children with asthma lived in 5 provinces namely KwaZulu Natal (23.31 percent), Eastern Cape (11.35 percent), Western Cape (20.12 percent), Gauteng (11.75 percent) and Mpumalanga (10.56 percent). The remaining less than 25 percent lived in Northern Cape (6.77 percent), Free State (3.78 percent), Northwest (6.77 percent) and Limpopo (5.58 percent). The distribution of the asthmatic sample was not by province of residence was not necessarily correlated with the total number of children living in a province. For example, as shown in Table 4.4 Limpopo province which had 5 002 children accounted for just 5.58 percent of the total number of children with asthma while Western Cape, with 3 170 children, accounted for 20.12 percent of all children with asthma.

The logistic model regressing having asthma with province shed better light on the relationship between province of residence and the risk of having asthma. As shown in Table 4.4 above, the regression analysis produced odds of having asthma which were in the positive direction of KwaZulu Natal for all provinces except Western Cape. This means that children living in the other provinces had greater risk of having asthma compared to their counterparts living in KwaZulu Natal. However, the odds of having asthma for children living in Eastern Cape (1.37), Northern Cape (1.12), Gauteng (1.19) and Mpumalanga (1.24) were not significantly greater than those of children in KwaZulu Natal (p >.05). Nonetheless, the observed odds point to a greater risk of having asthma and their insignificance may have been due to relatively small sample sizes in each province. Relatively small sample sizes require differences in observed odds to be very big before they are judged to be significant. This was the case with Free State (OR 2.00: p0.00 < p0.05) where children were two times more likely to be asthmatic compared to their counterparts in KwaZulu Natal, significantly greater risk. Meanwhile, children living in Limpopo (OR 3.09: p0.00 < p0.05) were more than two times as likely to have asthma as those living in KwaZulu Natal. As for children living in Northwest (OR 1.54: p0.02 < p0.05) their odds of having asthma were significantly greater than those of children living in KwaZulu Natal by 0.54 times, but the risk was not as strongly significant as that for children living in Free State and Limpopo. The least odds of having asthma were observed for children living in Western Cape (OR 0.53: p0.00 < p0.05). The observed odds imply that children living in Western Cape were 0.47 times less likely to have asthma compared to their counterparts living in KwaZulu Natal.

4.3.3 Energy for cooking

Bivariate results presented in table 4.4 show that the majority of children with asthma (80.20 percent) lived in households that used electricity as source of energy for cooking. The second most prevalent source of household energy among children with asthma was wood (14.40 percent) followed by paraffin (3.20 percent). The other sources of energy for cooking namely coal, animal dung and ‘other’ accounted for 1.40 percent, 0.20 percent and 0.60 percent of the total number of children with asthma respectively. The above percentage distribution largely reflect the study sample’s distribution by energy of type for cooking thus cannot be regarded as indicative of the associated risk of having asthma for children living in the households using the different sources of energy for cooking. This is rather reflected in the regression results from the independent logistic model for the variable ‘energy for cooking’.

Logistic regression analysis revealed that children living in households that used energy sources other than electricity for cooking had higher odds of having asthma compared to children living in households using electricity. The regression model found significantly higher odds of having asthma for children living in households that used paraffin for cooking (OR 2.10: p0.00 < p0.05), and wood (OR 2.31: p0.00 < p0.05) who were more than two times as likely to have asthma as their counterparts in households using electricity. Results for children living in households that used coal (1.19), animal dung (4.00) and ‘other’ (1.12) were also in the positive direction but showed insignificant risk of having asthma because of the relatively small sample sizes of children living in the households using the respective energy sources for cooking. Despite the results being insignificant, being in the positive direction help point to the implied increase in odds of having asthma for children.

4.3.4 Energy for heating

There was a similar pattern in the distribution of the asthmatic sample by source of energy for heating with that observed for energy for cooking. Table 4.4 above shows that the majority of children with asthma lived in households that used electricity (58.85 percent) for heating followed by those in households that used wood (25.69 percent) and paraffin (10.97 percent). The respective shares of coal, animal dung and 'other' were respectively 3.24 percent, 0.50 percent and 0.75 percent. As was the case with the distribution by source of energy for cooking, the distribution had a pattern that largely correlated with the distribution of the study sample by energy type.

The logistic model estimating the odds of having asthma by household energy type for heating produced odds on the positive side for all energy sources with the exception of 'other'. The model observed significantly greater risk of having asthma for children living in households that used wood (OR 2.17: $p0.00 < p0.05$) and coal (OR 2.03: $p0.01 < p0.05$) both of which samples were more than two times as likely to have asthma as their counterparts living in households that used electricity for heating. The regression analysis found insignificant results for children living in households using animal dung (OR 2.36: $p0.22 > p0.05$) and paraffin (OR 1.38: $p0.053 > p0.05$) and this was because of the small sample sizes of children living in households using the two energy sources for heating. The overall results from the independent model however, being largely in the positive direction, indicate that the use of polluting fuels indoors increases children's odds of having asthma compared to using electricity.

4.3.5 Household energy sources

The variable 'household energy sources' aggregated and divided energy sources into two categories, clean and unclean sources. Households using energy from electricity or gas were classified as having 'clean sources' while those that included any other form of energy source were classified as having 'unclean sources'. This means that if a household used electricity for cooking and wood for heating, its energy sources qualified as unclean because residents of such a household were exposed to indoor pollution. The majority of children with asthma (53.78 percent) lived in households that had unclean energy sources while 46.22 percent were in households using clean energy sources. The independent regression model observed a significantly less likelihood of having asthma for children living in households that used clean energy (OR 0.61; $p0.00 < p0.05$). The observed results indicate that exposure to indoor pollution was associated with a significantly greater risk of having asthma for children

4.3.6 Socioeconomic status (SES)

Bivariate analysis for socioeconomic (SES) analysis and having asthma showed that 65.02 percent of children with asthma lived in households classified as having low SES. Children from households with high SES made up 23.66 percent of the asthmatic sample while those from medium SES households accounted for 11.32 percent of the asthmatic sample. The observed percentage distribution correlated with the respective total number of children in each SES category and reflects to an extent the socioeconomic inequality in South Africa (Woolard, 2002).

Regression analysis estimating the odds of having asthma by SES category produced odds in the positive direction for both groups of children in households in medium and high SES categories and indicated significantly higher risk. Children living in medium SES households were 96 percent more likely to be asthmatic compared to those living in low SES households, a significantly greater risk (OR 0.96; p0.00 < p0.05). Meanwhile, living in high SES households was associated with risk of having asthma which was 94 percent higher than that of children living in low SES households and was also a significantly greater risk (OR 0.94; p0.00 < p0.05). While the results may be inconsistent with literature that associate asthma with living in low SES households where exposure to indoor pollution is greater than in medium and high SES households, the observations can be explained by two related factors. The first is that children in low SES households may not have easy access to medical attention for health issues such as breathing problems which can be easily dismissed as flu or persistent cold. The second factor is that the majority of children in low SES households live in rural areas where health seeking behaviour is different from urban areas. Thus children in medium and high SES households are more likely to have had access to a doctor who would have confirmed the child's asthma status compared to those in low SES households. Moreover, because of the specification in the survey question which required a doctor's declaration or confirmation of the existence of asthma in a child, children living in medium and high SES households were observed to have higher risk of having asthma than their counterparts in low SES households. Furthermore, the results on SES may be a reflection of weaknesses in the data set which lacks accurate information that can reliably be used to classify households into appropriate SES categories.

4.4 Energy for cooking

Table 4.5 below presents results from nested logistic models that were explored to estimate the role of source of energy for cooking in the odds of having asthma for children. Four models were explored with each nth model adding an extra variable in order for interactions with source of energy to be easily tracked and observed. The reference categories for each variable are indicated in parenthesis. The table reports the observed odds of having asthma and the respective standard deviations of the odds.

4.4.1 Model 1: Age and sex

Model 1 estimated the odds of having asthma for children by source of energy for cooking used in the households they lived controlling for age and sex. The model observed a similar pattern of results as that observed in the independent models for the respective variables reported in table 4.4 in the previous section. There were significant results for paraffin and wood while those for coal and animal dung were insignificant despite being in the positive direction also. Children living in households that used paraffin were more than two times as likely to have asthma compared to those living in households that used electricity (OR 2.08: p0.00 < p0.05). Living in a household that used wood for energy for cooking was associated with odds of having asthma that were also more than two times as high as when living in a household that used electricity (OR 2.33: p0.00 < p0.05). Meanwhile, the odds of having asthma for children living in households that used coal (OR 1.94: p0.08 > p0.05) and animal dung (OR 4.01: p0.17 > p0.05) were insignificant, but mainly due to the small sample sizes of children living in households that used any of the two energy sources for cooking. The observed odds nonetheless help indicate that use of polluting fuels for cooking increases the risk of having asthma for children.

Model 1 found significantly less odds of having asthma for children in the three older age groups compared to the 0-4 year age category. All the odds for the three age groups were in the negative sides implying that controlling for sex and type of energy source for cooking children aged 0-4 years were significantly more likely to have asthma compared to those of any other age group. As shown in table 4.2, children age 5-9 years were less likely to have asthma compare to those aged 0-4 years by 0.45 times (OR 0.55: p0.00 < p0.05). compared to 0-4 year olds, 10-14 year olds were 0.43 times less likely to have asthma (OR 0.57: p0.00 < p0.05) while 15-17 year olds were 0.33 times less likely to have asthma (OR 0.67: p0.01 < p0.05).

Table 4.5 Nested models showing odds of having asthma for sources of energy for cooking controlling for other variables

Variable	Model 1 (N=35 619)		Model 2 (N=35 619)		Model 3 (N=35 619)		Model 4 (N=34 086)	
	OR	SE	OR	SE	OR	SE	OR	SE
Energy (electricity)	-	-	-	-	-	-	-	-
Paraffin	2.08**	0.53	1.64	0.43	1.76**	0.46	1.57	0.42
Wood	2.33**	0.30	1.81**	0.24	1.81**	0.26	1.57**	0.24
Coal	1.94	0.75	1.51	0.58	1.64	0.65	1.60	0.64
Animal dung	4.01	4.03	3.15	3.16	3.76	3.78	3.23	3.26
Other	0.99	0.58	1.04	0.61	1.31	0.77	1.21	0.71
Age group (00-04)	-	-	-	-	-	-	-	-
05-09	0.55**	0.07	0.56**	0.07	0.56**	0.07	0.56**	0.07
10-14	0.57**	0.07	0.58**	0.08	0.58**	0.08	0.60**	0.80
15-17	0.67**	0.10	0.69**	0.10	0.69**	0.10	0.71**	0.11
Sex (male)	-	-	-	-	-	-	-	-
Female	1.48**	0.14	1.49**	0.14	1.50**	1.50	1.50**	0.14
Population group (African)			-	-	-	-	-	-
Coloured			0.49**	0.06	0.69**	0.11	0.71**	0.12
Indian/Asian			0.28**	0.06	0.36**	0.08	0.40**	0.09
White			0.36**	0.06	0.42**	0.07	0.44**	0.08
Province (KwaZulu Natal)					-	-	-	-
Eastern Cape					1.18	0.20	1.22	0.21
Northern Cape					1.38	0.30	1.51	0.33
Free State					3.04**	0.79	3.69**	1.02
Western Cape					0.78	0.14	0.90	0.17
Northwest					1.53**	0.31	1.55**	0.31
Gauteng					1.41**	0.24	1.65**	0.29
Mpumalanga					1.15	0.20	1.13	0.20
Limpopo					2.43**	0.53	2.39**	0.53
SES (low)							-	-
Medium							1.36	0.22
High							1.32**	0.18
Log likelihood	**-2576.574**		**-2539.9863**		**-2513.6312**		**-2430.1229**	

** Significant at p<.05; OR= Odds Ratio; SE=Standard Error; Reference categories are in parenthesis

The estimation of the odds of having asthma by sex controlling for age group and source of energy for cooking produced odds for female children that were significantly in the positive side (OR 1.48: p0.00 < p0.05). This means that girls were significantly more likely to have asthma than boys by 0.48 times.

The results from Model 1 warrant several statements. Firstly, the use of polluting fuels for cooking is associated with high odds of having asthma for children compared to use of clean energy sources. Secondly, the odds of having asthma are high for children below the age of 5 years who are still to go to school. Lastly, female children have higher odds of having asthma than boys due to sex differences in division of labour in households. In light of the research question, it can be concluded from Model 1 findings that the use of polluting fuels for cooking is associated with high risk of having asthma for children compared to clean fuels, and that girls and young children below the age of 5 years are the worst affected.

4.4.2 Model 2: Age, sex and population group

Model 2 estimated children's odds of having asthma by energy type for cooking controlling for age, sex and population group. The addition of the population group variable resulted in changes in the respective odds of having asthma for children in terms of source of household energy for cooking. Compared to Model 1, Model 2 found lower odds of having asthma for children living in households that used paraffin, wood, animal dung and coal and higher odds for children living in households that used energy sources classified as 'other'. All the sources of energy for cooking were associated with positive odds of having asthma for children. However, only the use of wood for cooking was associated with significantly greater odds of having asthma compared to the use of electricity (OR 1.81: p0.00 < p0.05). This means that the odds of having asthma for children living in households that used wood for cooking were 81 percent higher than those of children living in households that used electricity for cooking. The other sources of energy for cooking namely paraffin (OR 1.64: p0.06 > p0.05), coal (OR 1.51: p0.29 > p0.05), animal dung (OR 3.15: p0.25 > p0.05) and other (OR 1.04: p0.94 > p0.05) were associated with positive odds but showed insignificant greater risk of having asthma. Nonetheless, the positive odds help highlight that the use of energy sources for cooking other than electricity was associated with increased risk of having asthma for children. The insignificant results can be interpreted as reflecting the relatively small sample sizes of children living in households that used paraffin, coal, animal dung and other energy sources.

There were slight decreases in the size of the difference of odds of having asthma between 0-4 year olds and children in the older age categories in Model 2 compared to Model 1. The significance of the decreased risk of having asthma for older children compared to their younger counterparts remained the same. From Model 2's estimation, it was observed that children in the 5-9 years age category were 44 percent less likely to have asthma compared to children in the 0-4 years category (OR 0.56: p0.00 < p0.05). Children in the 10-14 years category (OR 0.58: p0.00 < p0.05) were 0.42 times less likely while those 15-17 year category (OR 0.69: p0.01 < p0.05) were 0.31 times less likely to have asthma compared to those in the 0-4 year age category. Despite the slight difference in the odds for age categories in Model 2 and Model 1, the results in the two models highlight the sensitivity of younger children to respiratory complications such as asthma associated to exposure to air pollution. As highlighted in literature by Smith *et al.* (2000), there is a relationship between exposure to household biomass smoke and ALRI in young children in developing countries.

Female children remained significantly more likely to have asthma in Model 2 even with the addition of the population variable into the estimation equation. The odds of having asthma for female children increased from 1.48 in Model 1 to 1.49 in Model 2. The observed odds imply that female children were 0.49 times more likely to have asthma compared to male children controlling for age, population group and source of household energy for cooking (OR 1.49: p0.00 < p0.05). The reasons for this, as has already been highlighted, include playing habits and division of chores between girls and boys with the former more exposed to indoor pollution compared to the latter.

Model 2 observed that Coloured, Indian/Asian and White children were significantly less likely to have asthma compared to African children. Results from Model 2 showed that Coloured children (OR 0.49: p0.00 < p0.05) were 0.51 times less likely to have asthma compared to African children. The same model found that Indian/Asian (OR 0.28: p0.00 < p0.05) and White (OR 0.36: p0.00 < p0.05) children were respectively 0.72 and 0.64 times less likely to have asthma compared to African children.

There was a significant improvement in the ability to explain the odds of having asthma for children with the addition of the population group variable. The log likelihood increased from -2576.574 in Model 1 to -2539.9863 in Model 2. A log likelihood ratio test of Model 1 nested in Model 2 was conducted to test the improvement of Model 2 on Model 1 in predicting and explaining children's odds of having asthma, and it was found that significant improvement was made (LR 73.36: p0.00 < p0.05).

4.4.3 Model 3: Age, sex, population group and province.

Model 3 added province of residence in the estimation equation for children's odds of having asthma. The addition of province of residence in the model resulted in increases in the odds of having asthma for children living in households that used paraffin, coal, animal dung and other energy sources for cooking, but the odds for children living in households that used wood remained the same at 1.81. The increased in the odds of children from households that use paraffin resulted in a significant difference in the risk of having asthma between children living in households that used paraffin and those in households that used electricity (OR 1.76: p0.03 < p0.05). Controlling for age, sex, population group and province of residence, children living in households that used paraffin as a source of energy for cooking were .076 times more likely to have asthma compared to their counterparts who lived in households that used electricity. As was the case in Model 2, Model 3 observed positive odds for children that lived in households using coal (OR 1.64: p0.21 > p0.05), animal dung (OR 3.76: p0.19 > p0.05) and 'other' (OR 1.31: p0.65 > p0.05), but were insignificant results. The positive odds however, reflected increased risk of having asthma associated living in households that used polluting fuels for cooking while the insignificance was due to small sample sizes. In light of research question, it can thus be concluded that indoor pollution caused by use of polluting fuels for cooking increases children's risk of having asthma.

The addition of province variable in Model 3 did not affect the odds of having asthma for the three age groups relative to 0-4 year olds. The odds for 5-9 year olds remained 0.56 while those of Indian/Asian and White children remained 0.58 and 0.69 respectively. This implies that the risk of having asthma between children in the 0-4 age group and those in any other age group was not affected by province of residence. The results can be interpreted as indicating equitable representation of all age groups in the nine provinces of South Africa both in terms of absolute numbers and proportions of asthmatic status.

The odds of having asthma for female children increased by 0.01 in Model 3 to 1.50 from 1.49 in Model 2, indicating the importance of province of residence in explaining the difference in the risk of having asthma between boys and girls. However, the change in the odds for of having asthma for girls was small. Nonetheless, the results in Model 3 imply that female children were 50 percent more likely to have asthma compared to boys when age, population group, province of residence and source of household energy for cooking were controlled (OR 1.50: p0.00 < p0.05).

Model 3 observed a similar pattern of results for population group as that for Model 2, but with greater odds of having asthma. Nonetheless, Coloured, Indian/Asian and White children remained significantly less likely to have asthma compared to African children. Model 3 found that coloured children were 0.31 times less likely to have asthma compared to African children (OR 0.69: p0.00 < p0.05). The same model found that Indian/Asian children (OR 0.36: p0.00 < p0.05) and white children (OR 0.42: p0.00 < p0.05) were respectively 0.63 and 0.58 times less likely to have asthma compared to African children. The decreased gap between African children and other children in terms of having asthma showed the importance of province in explaining children's odds of having asthma by population group, albeit Africans remained significantly more likely to be asthmatic. This can be explained by relative representation of each population group among the provinces whereby high representation of African children in high-risk provinces was controlled in Model 3 unlike in Model 2.

The estimation of odds of having asthma for children by province produced positive odds for all provinces except Western Cape relative to KwaZulu Natal. Four provinces namely Free State (OR 3.04: p0.00 < p0.05), Northwest (OR 1.53: p0.03 < p0.05), Gauteng (OR 1.41: p0.04 < p0.05) and Limpopo (OR 2.43: p0.00 < p0.05) showed significant results although the strengths of the significance levels varied. The results mean that children living in the four provinces were significantly more likely to have asthma compared to children living in KwaZulu Natal. The odds of having asthma for children living in Free State and Limpopo were more than two times as high as those of children living in KwaZulu Natal given observed odds which were more than double the reference base of 1. Children living in Northwest and Gauteng had odds of having asthma greater than those of children living in KwaZulu Natal by 0.53 and 0.41 times respectively. It can be stated that Free State, Northwest, Gauteng and Limpopo had greater proportions of children who were exposed to indoor pollution relative to KwaZulu Natal hence the observed significantly higher odds of having asthma for children resident in the four provinces. This implies that there were greater proportions of children belonging to households in low SES bracket where unclean energy sources were used in the three provinces compared to KwaZulu Natal.

The four provinces that showed insignificant results were Eastern Cape (OR 1.18: p0.33 > p0.05), Northern Cape (OR 1.38: p0.14 > p0.05), Western Cape (OR 0.78: p0.17 > p0.05) and Mpumalanga (OR 1.15: p0.44 > p0.05). The positive odds indicate the direction of risk for children living in Eastern Cape, Northern Cape and Mpumalanga and the insignificance may have been due to small sample sizes because with bigger samples, differences of 0.10 are judged to be significant. The negative odds of having asthma for children living in Western Cape (-0.22) relative to their counterparts in KwaZulu Natal point to reduce risk of having asthma for children living in the province albeit insignificant.

The likelihood ratio test of Model 2 nested in Model 3 showed significant improvement in the ability of the analysis to explain children's odds of having asthma. The test showed that the increase in size of the log likelihood from -2539.9863 in Model 2 to -2513.6312 in Model 3 was significant at 95 percent level of confidence (LR 52.53: p0.00 < p0.05). The likelihood ratio test (LR) test thus shows that the more the constraining variables are controlled in a model, the greater the ability of analysis to establish and explain causal factors in occurrence of asthma in children.

4.4.4 Model 4: Age, sex, population group, province and socioeconomic status

The last model added socioeconomic status (SES) in the regression equation for the estimation of children's odds of having asthma. The inclusion of socioeconomic status (SES) in Model 4 resulted in a pattern of results for energy sources similar to the one observed in Model 2, but with different odds. Only children that lived in households using wood as a source of energy for cooking were found to be significantly more likely to have asthma compared to those that lived in households using electricity (OR 1.57: p0.00 < p0.05). The observed odds imply that the risk of having asthma for children living in households using wood was 57 percent higher than that for children in households that used electricity. The same odds were also observed for children living in households that used paraffin as a source of energy for cooking, but were not shown to reflect a significantly greater risk (OR1.57: p0.09 > p0.05). This shows the importance of sample size in the significance of regression findings. Small sample sizes are judged to be associated with greater chance of occurrence of a phenomenon being due to coincidence and not due to real difference. However, this does not markedly affect the implications of results in this study because wood can cause as similar indoor pollution as paraffin, coal, animal dung and any other energy source other than electricity that can be used by households for cooking as was shown in Mishra (2003). It can be deduced that, if using wood is associated with significantly greater risk of having asthma for children, the same can be stated for any other source of energy that produces similar levels or more of indoor pollution. The insignificance of results for children living in households that used coal (OR 1.60: p0.24 > p0.05), animal dung (OR 3.23: p0.24 > p0.05) and 'other' (OR 1.21: p0.75 > p0.05) may not be as important as their direction which is positive. It can therefore be concluded that controlling for age, sex, population group, province and SES, children living in households that used unclean fuels as source of energy for cooking were observed to be more likely to have asthma than their counterparts living in households that used electricity.

The odds of having asthma among the children by age group slightly changed with the addition of SES in the estimation equation except for the 5-9 age group (OR 0.56: p0.00 < p0.05) which remained 0.44 times less likely to have asthma compared to 0-4 year olds. There were slight increases in the odds of having asthma for children in the 10-14 years and 15-17 years categories although they still remained significantly less likely to have asthma compared to 0-4 year olds. Children aged 10-14 years (OR 0.60: p0.00 < p0.05) were 0.40 times less likely to have asthma compared to those aged 0-4 years while 15-17 year (OR 0.71: p0.02 < p0.05) olds were 0.29 time less likely. Model 4, as was also the case with the three preceding, models showed a positive relationship between age and odds of having asthma

The odds of having asthma for female children remained at 1.50 after SES was added in the regression equation. This implies that the difference in the odds of having asthma between boys and girls was not affected by SES. Neither boys no girls benefited from belonging to any category of SES. The result can also be interpreted as implying equitable representation of boys and girls in all the SES categories, as well as the similar proportional representation of asthmatic status across all SES categories by sex.

Model 4 found slightly higher odds of having asthma for Coloured, Indian/Asian and White children compared to Model 3. The observed increase in odds reflect a slightly higher representation of the three population groups in the medium and high SES categories compared to Africans. Coloured children (OR 0.71 p0.00 < p0.05) were observed to have significantly lower likelihood of having asthma compared to Africans by 0.29 times. The odds of having asthma for Indian/Asian children (OR 0.40: p0.00 < p0.05) were a significant 0.60 times less than those of African children. White children (OR 0.44: p0.00 < p0.05) were 0.56 times less likely to have asthma compared to their African counterparts. The results in Model 4, just like in the preceding models, reflect the relative representation of the four population groups in the category of children living in households that used sources of fuels other than electricity. It can be stated that Coloured, Indian/Asian and White population groups had smaller proportions of children living in households using polluting fuels for cooking hence the significantly greater risk of having asthma associated with being African.

Model 4 results for provinces showed slightly higher odds of having asthma for all provinces besides Mpumalanga and Limpopo which had slightly lower odds. Nonetheless, significant results were observed for children living in Free State, Northwest, Gauteng and Mpumalanga, presenting a pattern of results similar to that observed in Model 3. The odds of having asthma for children living in Free State (OR 3.69: p0.00 <p0.05) were more than three times as high as those of children living in KwaZulu Natal. Living in Limpopo (OR 2.39: p0.00 < p0.05) was observed to be associated with odds of having asthma which were more than two times as high as living in KwaZulu Natal. The high odds of having asthma associated with living in Free State and Limpopo may be indicative of the proportions of children from the two provinces living in rural areas relative to KwaZulu Natal which has a more urbanised population. This is because the use of unclean fuels especially wood is concentrated in rural areas hence the greater the proportion of rural population the greater the associated odds of having asthma. Children living in Northwest (OR 1.55: p0.03< p0.05) and Gauteng (OR 1.65: p0.00 < p0.05) were respectively 0.55 and 0.65 times more likely to have asthma compared to children living in KwaZulu Natal.

Western Cape was again the only province with negative odds of -0.10 albeit insignificant (OR 0.90: p0.57 > p0.05). An important point from this result is the direction of the odds which may be reflective of the level of exposure to indoor pollution in Western Cape compared to KwaZulu Natal. KwaZulu Natal has a relatively greater proportion of rural population compared to Western Cape and this implies a greater proportion of children exposed to indoor pollution due to use of wood and other unclean sources of energy for cooking. The other provinces with insignificant results, although with positive odds were Eastern Cape (OR 1.22: p0.24 > p0.05), Northern Cape (OR 1.51: p0.06 > p0.05) and Mpumalanga (OR 1.13: p0.50 > p0.05). The three provinces are among the least urbanised in South Africa and as a result have greater proportions of rural populations compared to KwaZulu Natal. This means a higher likelihood of exposure to indoor pollution in the provinces, but due to small sample sizes the results were insignificant as was also the case with Western Cape.

Model 4 results for SES showed significantly greater risk of having asthma for children living in households in the high SES category (OR: 1.32: p0.04 < p0.05). The result means that children living in high SES households were 0.32 times more likely to have asthma compared to living in low SES households. Living in the medium SES category was observed to be associated with odds of having asthma greater than living low SES households by 0.36 times (OR 1.36: p0.06 > p0.05). However, the results for the medium SES category were insignificant and this was due to the small number of children living in households classified as having medium SES. The results for SES contradict normal logic because high SES should be associated with use of clean energy source like electricity which should thus be followed by decreased risk of having asthma for children. The cause of the illogic results can be found in access to a doctor, and the way the question for collecting data on asthma was phrased. As has been highlighted above, children in poor households may not have ready access to doctors and as such may not have had the opportunity of having the existence of asthma confirmed by a doctor. It may therefore have been a case of under reporting of asthmatic cases among the poor children which led to the observed results for SES.

Adding an extra variable in Model 4 resulted in increased ability to explain the patterns of odds of asthma among children. This was reflected by significant increase in the log likelihood from -2513.6312 in Model 3 to -2430.1229 in Model 4. A likelihood ration test of Model 3 nested in Model 4 returned a significant result (LR 167.02: p0.00 < p0.05). Overall, the results in from Model 4 showed that use of unclean sources of energy for cooking was associated with increased risk of having asthma for children. Girls were the worst affected compared to boys, as were African children compared to their Coloured, Indian/Asian and White counterparts.

4.5 Energy for heating

Four nested logistic models were also explored to examine the impact of the different sources of energy for heating used in households. The analysis was conducted in a similar method as for energy sources for cooking. The results are presented below in table 4.6.

Table 4.6 Nested models showing odds of having asthma by source of household energy for heating

Variable	Model 1 (N=29 444)		Model 2 (N=29 444)		Model 3 (N=29 444)		Model 4 (N=28 184)	
	OR	**SE**	**OR**	**SE**	**OR**	**SE**	**OR**	**SE**
Energy (electricity)	-	-	-	-	-	-	-	-
Paraffin	1.39**	0.23	1.07	0.18	1.05	0.21	1.07	0.22
Wood	2.19**	0.26	1.70**	0.22	1.67**	0.23	1.54**	0.23
Coal	2.03**	0.58	1.55	0.45	1.63	0.49	1.58	0.48
Animal dung	2.43	1.73	1.80	1.29	2.10	1.51	1.65	1.19
Other	0.83	0.49	1.71	0.42	0.70	0.41	0.66	0.39
Age group (00-04)	-	-	-	-	-	-	-	-
05-09	0.54**	0.08	0.55**	0.08	0.55**	0.08	0.54**	0.08
10-14	0.54**	0.08	0.56**	0.08	0.56**	0.08	0.57**	0.09
15-17	0.71**	0.12	0.72	0.12	0.72	0.12	0.71	0.12
Sex (male)	-	-	-	-	-	-	-	-
Female	1.38**	0.14	1.38**	0.14	1.39**	0.14	1.38**	0.14
Population group (African)			-	-	-	-	-	-
Coloured			0.52**	0.08	0.71	0.14	0.74	0.15
Indian/Asian			0.28**	0.07	0.34**	0.14	0.38**	0.10
White			0.38**	0.07	0.43**	0.10	0.46**	0.09
Province (KwaZulu Natal)					-	-	-	-
Eastern Cape					1.25	0.25	1.25	0.25
Northern Cape					1.32	0.33	1.47	0.38
Free State					2.32**	0.64	3.04**	0.90
Western Cape					0.77	0.16	0.91	0.20
Northwest					1.32	0.29	1.35	0.30
Gauteng					1.46**	0.28	1.73**	0.34
Mpumalanga					1.00	0.19	0.99	0.20
Limpopo					2.19**	0.50	2.14**	0.50
SES (low)							-	-
Medium							1.39	0.26
High							1.32	0.20
Log likelihood	**-2079.2124**		**-2054.365**		**-2037.1423**		**-1959.79**	

** Significant at p<.05; OR= Odds Ratio; SE=Standard Error; Reference categories are in parenthesis

4.5.1 Model 1: Age and sex

Model 1 estimated the odds of having asthma by household source of energy for heating controlling for age group and sex. The model found that children living in households that used paraffin, wood and coal as sources of energy for heating were significantly more likely to have asthma compared to those staying in households that used electricity. Children living in households which used paraffin were 0.39 times more likely to have asthma compared to their counterparts living in households which used electricity (OR 1.39: p0.04 < p0.05). The odds of having asthma observed for children living in households using wood (OR 2.19: p0.00 < p0.00) and coal (OR 2.03: p0.01 < p0.05) meant that the children more than two times as likely to have asthma as their counterparts living in households using electricity. This means that the risk of becoming asthmatic was doubly higher for children in households using wood and coal for heating than for children in households using electricity. The odds of having asthma for children living in households that used animal dung (OR 2.43: p0.21 > p0.05) and other (OR 0.83: p0.75 > p0.05) sources of energy for heating were found to represent insignificant greater risk of being asthmatic. The regression estimation showed that living in households using animal dung for heating was associated with the risk of having asthma which was more than double that of children living in households using electricity. The result was insignificant because of the small sample of children living in households using animal dung for heating. The positive direction of the odds however, is important in intimating the associated risk of having asthma.

The negative odds for 'other' sources of energy imply lower risk of having asthma associated with using the energy sources relative to electricity. Despite being insignificant, it is worth noting that with larger sample sizes, the difference would have been significant. The result can thus be attributed to data collection error associated with self-reported data.

Results for age groups showed significant benefit of being older than four years in terms of risk of having asthma. Children in the 5-9 years age group (OR 0.54: p0.00 < p0.05) were 0.46 times less likely to have asthma compared to their counterparts in the 0-4 years age group. This was the case with children in the 10-14 years age group (OR 0.54: p0.00 < p0.05). The results for the 15-17 years age group were barely significant (OR 0.71: p.04 < p0.05) and this may have been due to the relatively small sample size of children in the oldest age group which accounted for only three cohorts compared to the five cohorts include in the other age groups. Nonetheless, Model 1 showed that younger children had a significantly greater risk of having asthma compared to older children when living in households using unclean fuels for heating.

Model 1 findings on the odds of having asthma by sex showed significantly greater risk of having asthma for girls compared to boys. The observed odds for female children (OR 1.38: p0.00 < p0.05) imply that compared to boys, girls were 0.38 times more likely to have asthma controlling for household source of energy for heating and age group. This means that when exposed to similar conditions, that is, living in same household and being of the same age, girls were more likely to have asthma compared to boys. The difference can be explained by genetic differences and familial concordance as was observed in Sanford and Pare (2000). Another reason may relate to playing habits of girls and boys whereby the former are mostly indoors hence greater exposure to pollution while the latter mostly play outdoors which minimise exposure to pollution.

4.5.2 Model 2: Age, sex and population group

Model 2 added population group in the logistic equation estimating children's odds of having asthma. The inclusion of population group variable resulted in notable changes in the results for the different sources of energy for heating in Model 2 compared to Model 1. There were decreases in the odds of having asthma for children living in households that used paraffin, wood, coal and animal dung relative to electricity while an increase for other sources of energy. This showed that the results observed in Model 1 were affected by differences in population group. Of the three significant results in Model 1, only wood (OR 1.70: p0.00 < p0.05) remained a source of energy associated with significantly greater risk of having asthma for children compared to electricity. The observed odds imply that children living in households that used wood for heating were 0.70 times more likely to have asthma compared to those who lived in households that used electricity controlling for sex, age and population group. The odds for paraffin (OR1.07: p0.70 > p0.05), coal (OR 1.55: p0.13 > p0.05), animal dung (OR 1.80: p0.41) and other (OR 1.71: p0.56 > p0.05) were positive but returned insignificant results meaning that the risk of having asthma controlling for population group, age and sex associated with living in households that used the respective energy sources for heating was not significantly greater compared to electricity. The positive nature of the odds however, point in the direction of increased risk and it can be stated that with bigger sample sizes, the implied differences would have been significant. It is also worth noting that Model 1 negative result for 'other' sources compared to the positive result in Model 2 may imply underlying misreporting by survey respondents so that children living in households that used clean energy sources might have been reported under ‘other’.

The elimination of the effect of population group differences in Model 2 did not greatly change the odds for age groups. There were slight decreases in the benefit of being older than 4 years as slight increases in the odds for the three age groups were observed. The negative odds for children in the 5-9 years age group (OR 0.55: p0.00 < p0.05) and 10-14 years age group (OR 0.56: p0.00 < p0.05) remained significant while those for 15-17 years age group (OR 0.72: p.0.06 > p0.05) were insignificant after population group variable was controlled. Expressed as percentages, the observed odds imply that age groups 5-9 years and 10-14 years were associated with less likelihood of having asthma equivalent to 45 percent and 44 percent respectively compared to age group 0-4 years.

The result for sex in Model 2 remained constant at 1.38 as was in Model 1, meaning that the difference in the odds of having asthma between boys and girls was not affected by population group variations.

Model 2 results for population groups showed significantly reduced risk of having asthma associated with being Coloured, Indian/Asian and White compared to being African. The advantage of being Coloured (OR 0.52: p.0.00 < p0.05) compared to African was reduced risk of having asthma amounting to 48 percent while that for being Indian/Asian (OR 0.28: p0.00 < p0.05) and White (OR 0.38: p0.00 < p0.05) was 72 percent and 62 percent respectively. The results for the population groups can be explained by that African children had a greater proportion living in households that used unclean energy sources for heating which cause indoor pollution compared to children in the other population groups. This makes logical explanation considering that most households using unclean fuels in South Africa are located in rural areas and urban informal settlements were the majority of the population is African.

The importance of population group in the analysis of children’s odds of having asthma was confirmed in likelihood ratio test that was conducted. The test had the assumption of Model 1 nested in Model 2 and revealed that significant improvement occurred in the ability of Model 2 to explain the regression results compared to Model 1 by virtue of having more variables controlled. With the addition of the population group variable, the log likelihood increased from -2079.2124 in Model 1 to -2054.365 in Model 2.

4.5.3 Model 3. Age, sex, population group and province

Model 3 expanded the range of controlled variables by adding province of residence in the equation for estimating the odds of having asthma for children associated with the different sources of household energy for heating. As was the case in Model 2, only the use of wood (OR 1.67: p0. 0.00 < p0.05) was associated with a significantly greater risk of having asthma compared to the use of electricity for heating. Children living in households that used wood were 0.67 times more likely to have asthma compared to those living in households the used electricity for heating. The other sources of energy returned insignificant results, but with notable changes in the observed odds compared to Model 2. The odds of having asthma associated with living in households that used animal dung (OR 2.10: p0.30 > p0.05) relative to electricity were more than double compared to the 1.29 observed in Model 2, but remained insignificant. As has already been pointed out in the preceding sections, such insignificant results were due to small sample sizes thus the positive odds cannot be entirely dismissed as implying absence of increased risk of having asthma even though they were judged insignificant. Another notable change resulting from the addition of province in the estimating equation in Model 3 was for other energy sources (OR 0.70: p0.55 > p0.05) which decreased from 1.71 in Model 2 implying that much of the odds in the preceding model were affected by differences in province of residence between children with asthma and those without.

Model 3 results for age groups were the same as those observed in Model 2. The odds of having asthma for children in the three older age groups remained constant at 0.55, 0.56 and 0.72 for 4-9, 10-14 and 15-17 year age groups respectively. This means that province of residence did not affect differences in the risk of having asthma for children. Furthermore, the constant results imply a proportionate distribution of the two cases, having and not having asthma, across all provinces.

There was a slight increase in the odds of having asthma for girls in Model 3 (OR 1.39: p0.00 < p0.05) compared to the 1.38 observed in the two preceding models. This means that the odds of having asthma for girls relative to boys increased by 1 percent after the effect of province of residence was eliminated. Model 3 shows that controlling for age, source of household energy for heating, population group and province of residence, girls had 39 percent higher probability of having asthma than boys. This can be interpreted as confirming the genetic sex differences between males and females which predispose females to a higher likelihood of having asthma compared males. Physical and hormonal changes at puberty have been argued to increase risk of allergies among females which in turn increases risk of asthmatic attacks among women (Centre for Disease Control, 2013).

There was an average increase of 0.13 in the odds of having asthma for Coloured, Indian/Asian and White children following the addition of province of residence in the regression equation. This resulted in insignificant results for Coloured children (OR 0.71: p0.08 > p0.05) although the observed odds remained negative. The result for Coloured children imply that the significantly less risk observed in Model 2 was due to differences in province of residence between Coloureds and Africans. Coloured children benefited from living in provinces like Western Cape associated with less risk of having asthma compared to Africans living in provinces associated with greater risk, for example, Limpopo. Controlling for province of residence removed this benefit hence the observed insignificant result, although it cannot be overlooked that a difference of 0.29 (1 – 0.71) can be significant with bigger sample sizes. The increases in the odds for Indian/Asian and White children did not affect the significance of not being African with respect to having asthma. Indian/Asian children (OR 0.34: p0.00 < p0.05) and their White counterparts (OR 0.43: p0.00 < p0.05) were respectively 0.46 and 0. 58 times less likely to have asthma compared to African children.

Model 3 results for provinces show positive odds for all provinces except Western Cape which had negative odds and Mpumalanga which had 1. Of all the positive odds, significant results were observed for children living in Free State (OR 2.32: p.0.00 < p0.05), Gauteng (OR 1.46: p0.04 < p0.05) and Limpopo (OR 2.19: p0.00 < p0.05). Children living in Free State and Limpopo were more than two times as likely to have asthma compared to their counterparts from KwaZulu Natal province. The observed odds for Gauteng means that children who lived in the province were more likely to have asthma by 0.46 times compared to those living in KwaZulu Natal. Positive odds were also observed for children living in Eastern Cape (OR 1.25: p0.26 > p0.05), Northern Cape (OR 1.32: p0.27 > p0.05) and Northwest (OR 1.32: p0.22 > p00.05), but the regression analysis judged the indicated increased risk of having asthma to be insignificant. The result for Mpumalanga (OR 1.00: p0.99 > p0.05) implies that children living in the province were as likely to have asthma as those living in KwaZulu Natal. The risk of having asthma was the same in Mpumalanga and KwaZulu Natal. The only negative odds, observed for Western Cape (OR 0.77: p0.22 > p0.05), mean that children living in the province were 0.23 times less likely to have asthma compared to children living in KwaZulu despite the benefit of living in Western Cape being insignificant relative to living KwaZulu Natal. However, the benefit of reduced risk of developing a health problem, no matter how small, cannot be ignored because the cumulative benefits have great implications on the wellbeing of children.

The importance of province of residence as an explanatory factor on the differences in odds of having asthma for children was confirmed by results from a likelihood ratio test that was conducted. The likelihood ratio test, which nested Model 2 in Model 3 showed that Model 3 had significantly greater ability to account for children's odds of having asthma than Model 2 (LR chi2(8) = 34: p0.00 < p0.05). This makes it possible to conclude that the more variables an estimating model includes, the better the ability of the analysis to explain the differences among children regarding risk of having asthma.

4.5.4 Model 4. Age, sex, population group, province and SES

Model 4 added SES on the list of controlled variables in regression equation estimating the children's odds of having asthma by household source of energy for heating. The inclusion of the SES variable altered the size of observed odds for the different sources of energy for heating, but not the pattern of results in Model 4 compared to Model 3. Of all the sources of energy, only the result for wood (OR 1.54: p0.00 < p0.05) was significant. The observed result means that children living in a household that use wood as a source of energy for heating was associated with a likelihood of having asthma that was greater by 0.54 times compared to living in a household that use electricity. Relative to electricity, the odds for children living in households that used coal (OR 1.58: p0.13 > p0.05) and animal dung (OR 1.65: p0.49 > p0.05) were greater than those for wood but returned insignificant estimates from the regression. This was because other than electricity, wood was the most prevalent source of energy used in households thus accounted for a great number of the study sample. With greater sample sizes, observed differences are judged to be real because there is less probability of the observations occurring by chance. The odds for paraffin (OR 1.07: p0.74 > p0.05) were slightly above one implying an insignificant increase in the risk of having asthma associated with living in households that used the source of energy for heating compared to living in households that used electricity.

Model 4 returned positive shifts in the odds of having for 5-9 and 15-17 year olds and a negative shift for 10-14 year olds relative to 0-4 year olds. The positive shifts meant slight increases in the benefit for not being 0-4 years old in the form of reduced risk of being asthmatic while the negative shift implied slightly decreased benefit. However, the shifts did not significantly impact on Model 4 results for the older age groups which were similar to Model 3 results. With the inclusion of SES in the regression equation, the odds of not having asthma for 5-9 year olds increased from 0.45 in Model 3 to 0.46 in Model 4. This means that controlling for source of energy for heating, sex, population group, province of residence and SES, children in the 5-9 years age group (OR 0.54: p0.00 < p0.05) were 0.46 times less likely to have asthma compared to 0-4 year olds. In the other significant result, 10-14 year olds (OR 0.57: p0.00 < p0.05) were less likely to have asthma by 0.43 times compared to 0-4 year olds, although the benefit decreased from 0.44 times following the control of SES n Model 4. The odds for 15-17 year olds (OR 0.71: p0.05 = p0.05) did not imply a significant benefit with respect to risk having asthma for not being in the 0-4 years age group despite a 0.01 increase. The result thus means that there was no significant difference between 0-4 year olds and 15-17 year olds regarding the odds of having asthma.

The odds of having asthma for girls decreased from 1.39 in Model 3 to 1.38 in Model 4. This means that the 0.01 difference was due the socioeconomic status variations which concealed boys' benefit. Controlling for SES eliminated this benefit leading to girls' odds of having asthma relative to boys declining back to 1.38. This however, still signified that girls (OR 1.38: p0.00 < p0.05) were significantly more likely to have asthma compared to boys.

There was a general increase in the odds of having asthma for all three population groups relative to Africans following the inclusion of SES in the regression model without changing the pattern of results observed in Model 3. Indian/Asian children (OR 0.38: p0.00 < p0.05) and White children (OR 0.46: p0.00 < p0.05) were significantly less likely to have asthma compared to African children. Relative to being African, the benefit of being Indian/Asian was reduce risk of having asthma by 0.62 times while for being White was 0.54 times. Coloured children (OR 0.74: p0.14 > p0.05) were not significantly less likely to have asthma compared to their African counterparts despite 26 percent less likelihood of having asthma relative to Africans. The results from Model 4 show that African children were generally more likely to have asthma compared to other children in the other population groups when the effects of sex, age, SES, province of residence were eliminated.

Model 4 results for provinces had a similar pattern to that observed in Model 3. As was the case in Model 3, significant results were observed for Free State (OR 3.04: p0.00 < p0.05), Gauteng (OR 1.73: p0.01 < p0.05) and Limpopo (OR 2.14: p0.00 < p0.05). The odds for Free State mean that children living in the province were more than three times as likely to have asthma as their counterparts living in KwaZulu Natal. Of the significant results, living in Free State was associated with the highest risk of having asthma compared to living in any other province. The second highest risk of having asthma was observed for children living in Limpopo who were more than two times as likely to have asthma compared to those living in KwaZulu Natal. Living in Gauteng was associated with the third highest risk with children in the province 0.73 times more likely to have asthma compared to their counterparts living in KwaZulu Natal. Of the insignificant positive odds, those for Eastern Cape (OR 1.25: p0.27 > p0.05) remained the same as in Model 3 while those for Northern Cape (OR 1.47: p0.14 > p0.05) and Northwest (1.35: p0.18 > p0.05) increased. The increase in the odds implies increased risk of having asthma for children living in the two provinces relative to those living in KwaZulu Natal after the effects of SES differences were eliminated. The odds for Western Cape (OR 0.91: p0.66 > p0.05) also increased and remained insignificant. The increase in the odds for Western Cape implies reduced benefit of living in the province relative to living in KwaZulu Natal. There was a negligible change in the odds for Mpumalanga (OR 0.99: p1.00 > 0.05) in the form of a slight decline following the inclusion of SES in the regression equation. Consequently, the result still implied similar odds of having asthma for children living in Mpumalanga and those living in KwaZulu Natal.

Model 4 results for SES were both insignificant. There were positive odds for medium (OR 1.39: p0.07 > p0.05) and high (OR 1.32: p0.07 > p0.05) SES categories. This means that relative to those in low SES households, living in medium and high SES households was associated with increased risk of having asthma by 0.39 and 0.32 times respectively. However, because the results were both insignificant, it can be concluded that there was no relationship between SES and risk of having asthma although the importance of SES cannot be discounted. The results for SES may be a reflection of the country's success in providing electricity to households across all categories of SES. The importance of the SES variable in the study was confirmed in the results from the likelihood ratio test which nested Model 3 in Model 4. The likelihood ratio test returned significant results at 95 percent level of confidence (LR chi2(2)=154.70: p0.00 < p0.05), confirming the significant increase in the log likelihood following the inclusion of SES in regression, from -2037.1423 in Model 3 to -1959.79 in Model 4.

The overall conclusion from the nested models is that the odds of having asthma generally increase when living in a household using unclean source of energy for heating. Girls were observed to be more likely to have asthma compared to boys. The risk of having asthma was generally highest for African children followed by Coloured, White and Indian/Asian children. Children living in Free State, Gauteng and Limpopo were at higher risk of having asthma compared to those in other provinces.

4.6 Exposure to indoor pollution

The preceding two sections presented results from separate examinations of odds of having asthma for cooking and heating. This section combines both sources of household energy. There were children who lived in households that used electricity for cooking and wood for heating or the opposite or any other clean and unclean energy source combination. This was also possible for any combination of clean and unclean sources of energy and could not be captured in the analysis for the two preceding sections although it was necessary to first conduct the investigation separately for household energy for cooking and heating. Under exposure to indoor pollution, two categories of household energy sources were generated, one for households that did not have indoor pollution and the other for households that had indoor pollution. If a household used any of paraffin, wood, coal and animal dung either for cooking or heating in combination with electricity, it was categorised as having indoor pollution. Logistic regression analysis exploring four nested models was conducted in a similar fashion as in the above sections. The results are presented in table 4.7 below.

Table 4.7 Odds of having asthma by presents of indoor pollution.

Variable	Model 1 (N=29 444)		Model 2 (N=29 444)		Model 3 (N=29 444)		Model 4 (N=28 184)	
	OR	SE	OR	SE	OR	SE	OR	SE
Energy (exposed to indoor pollution)	-	-	-	-	-	-	-	-
Not exposed to indoor pollution	0.61**	0.05	0.78**	0.08	0.78**	0.08	0.83	0.09
Age group (00-04)	-	-	-	-	-	-	-	-
05-09	0.56**	0.07	0.57**	0.08	0.57**	0.07	0.56**	0.07
10-14	0.58**	0.08	0.59**	0.08	0.59**	0.08	0.60**	0.08
15-17	0.67**	0.10	0.69**	0.10	0.68**	0.10	0.69**	0.11
Sex (male)	-	-	-	-	-	-	-	-
Female	1.48**	0.14	1.48**	0.14	1.49**	0.14	1.49**	0.14
Population group (African)			-	-	-	-	-	-
Coloured			0.43**	0.05	0.67**	0.11	0.71	0.12
Indian/Asian			0.26**	0.05	0.33**	0.07	0.39**	0.09
White			0.34**	0.06	0.41**	0.08	0.44**	0.08
Province (KwaZulu Natal)					-	-	-	-
Eastern Cape					1.18	0.20	1.20	0.21
Northern Cape					1.24	0.27	1.42	0.31
Free State					2.45**	0.61	3.42**	0.94
Western Cape					0.68**	0.12	0.84	0.16
Northwest					1.44	0.29	1.49	0.30
Gauteng					1.31	0.22	1.65**	0.29
Mpumalanga					1.13	0.19	1.13	0.20
Limpopo					2.61**	0.56	2.46**	0.54
SES (low)							-	-
Medium							1.48**	0.24
High							1.50**	0.20
Log likelihood	**-2602.2529**		**-2559.8163**		**-2533.5593**		**-2439.984**	

** Significant at p<.05; OR= Odds Ratio; SE=Standard Error; Reference categories are in parenthesis

4.6.1 Model 1: Age and sex

Model 1 estimated the odds of having asthma for children by exposure to indoor pollution controlling for age and sex. The model observed that children who were not exposed to indoor pollution (OR 0.61: p0.00 < p0.05) were a significant 0.39 times less likely to have asthma compared to children who were exposed to indoor pollution

There were significant results for all age groups in Model 1 with the pattern of the results showing a U-shape if they were to be plotted together with the 0-4 year age category. The observed odds for 5-9 year olds (OR 0.56: p0.00 < p0.05) imply that children in the age category were 0.44 times less likely to have asthma compared to those age 0-4 years. In other words, the risk of having asthma was 44 percent higher for 0-4 year olds compared to 5-9 year olds. Being in the 10-14 year age group (OR 0.58: p0.00 < p0.05) was associated with 0.42 times less likelihood of having asthma compared to being in 0-4 year age category. Children in the 15-17 year age group (OR 0.67: p0.01 < p0.05) were 0.33 times less likely to have asthma compared to those in the 0-4 year age group.

Model 1 shows that girls were significantly more likely to have asthma compared to boys. The observed positive odds for girls (OR 1.48: p.00 < p0.05) imply that the risk of having asthma for girls was 0.48 times greater than that of boys. Expressed as a percentage, it means that girls were 48 percent more likely to have asthma compared to boys.

4.6.2 Model 2: Age, sex and population group

Model 2 extended the number of control variables to three by including population group in estimation equation. This resulted in a decrease in the benefit of not being exposed to indoor pollution by 0.17 points, but without affecting the significance of the benefit. Relative to children who were exposed to indoor pollution and controlling for the effects of age, sex and population group, children living in households that used clean energy sources only (OR 0.78: p0.01 < p0.05) were 0.22 times less likely to have asthma. The significantly less likelihood of having asthma associated with not being exposed to indoor pollution enables the conclusion that use of unclean energy sources for household energy supply endangers children's health.

The inclusion of the population group variable in regression equation resulted in slight increases in the odds observed for the three age groups, but did not alter the significance of age with respect to risk of having asthma. The odds of having asthma for 5-9 and 10-14 year olds increased by 0.01 relative to 0-4 year olds while those for 15-17 year olds increased by 0.02. Consequently, the odds of having asthma for 5-9 year olds (OR 0.57: p0.00 < p0.05) and 10-14 year olds (OR 0.59: p0.00 < p0.05) were respectively 0.43 and 0.41 times less than those of 0-4 year olds. As for 15-17 year olds (OR 0.69: p0.00 < p0.05), the odds of having asthma were 0.31 times less than those for 0-4 year olds. Based on the results, it can be stated that age is a significant factor that affects children's risk of developing asthma. This is because the amount of exposure to indoor pollution is correlated to a person's age; as a child grows older, he or she assumes more household responsibilities such as cooking which increases risk of developing asthma especially to girls. Meanwhile, younger children, because they are still largely dependent on their mothers or guardians, spend more time with their carers thus more time exposed to indoor pollution thereby increasing their risk of having asthma.

The odds of having asthma between boys and girls remained the same in Model 2 as in Model 1, implying that population group was an insignificant factor in explaining risk of developing asthma by sex. Considering that the observed odds for girls (OR 1.48: p0.00 < p0.05) were also the same for the independent model for sex presented in table 4.1, it can be stated that the risk of having asthma by sex is underlain by biological differences between men and women. This has been highlighted in studies conducted by Smith et al in 2007 which observed that women were at a greater risk of having asthma compared to men.

Model 2 found significant benefit for not being African regarding the odds of having asthma. Coloured children (OR 0.43: p0.00 < p0.05), Indian/Asian (OR 0.26: p0.00 < p0.05) and White children (OR 0.34: p0.00 < p0.05) were all significantly less likely to have asthma compared to African children. Compared to African children, Coloureds were 0.58 times less likely to have asthma. The observed odds for Indian/Asian children mean that they were 0.74 times less likely to have asthma compared to their African counterparts. As for White children, the benefit for not being African was 0.66 times less likelihood of having asthma. Given that Model 2 odds for Coloured, Indian/Asian and White children are much lower than those observed in the independent model presented in table 4.1 which were respectively 0.49, 0.42 and 0.51, the elimination of the effects of sex and age showed that of all population groups, African children were indeed the most likely to have asthma.

4.6.3 Model 3: Age, sex, population group and province

Model 3 added province of residence in regression equation and resulted in changes in the odds observed for all categories of variables except for 'not exposed to indoor pollution', 5-9 and 10-14 age groups which remained constant at 0.78, 0.57 and 0.59 respectively. The constant result of 0.78 shows that the odds of having asthma by exposure to indoor pollution were independent of province of residence for children. Furthermore, province of residence did not affect the differences in the odds of having asthma between 0-4 year olds and each of the 5-9 and 10-14 year olds. There was a slight decrease in the odds for 15-17 year olds by 0.01 which can be interpreted as denoting increased benefit of being in the age group relative to being 0-4 years old following the elimination of the effects of province. Compared to 0-4 year olds, Model 3 found that 15-17 year olds (OR 0.68: p0.01 < p0.05) were a significant 0.32 times less likely to have asthma.

The odds of having asthma for girls slightly increased by 0.01 in Model 3 reflecting the marginal effect province of residence had on the risk if having asthma by sex observed in the preceding model. Model 3 observed that girls (OR 1.49: p0.00 < p0.05) were 0.49 times more likely to have asthma compared to boys controlling for population group, age group and province of residence. In other words, the risk of having asthma was 49 percent higher for girls compared to boys.

The addition of province in the regression resulted in increase in the odds for Coloured, Indian/Asian and White children by an average of 0.13 indicating decreased benefit of not being African although to an insignificant extent. African children remained significantly more likely to have asthma compared to other children. Based on Model 3 results, Coloureds (OR 0.67: p0.02 < p0.05) were 0.33 times less likely to have asthma compared to Africans. Indian/Asian children (OR 0.33: p0.00 < p0.05) and Whites (OR 0.41: p0.00 < p0.05) were respectively 0.67 and 0.59 times less likely to have asthma compared to their African counterparts. Model 3 results for population groups, as are Model 2 results also, may not entirely be explained by exposure to indoor pollution caused by energy sources for cooking and heating. The results can be a reflection of exposure to atmospheric pollution at the macro scale such as from industrial processes. Given the politico-economic history of South Africa, Africans' residence are generally located close to high polluting industries were they have historically provided wage labour for sustenance. As a result, there is a greater proportion of African children who are exposed to pollution caused by industries hence the higher likelihood of having asthma observed in Model 2 and Model 3.

Model 3 returned positive odds for all provinces except for Western Cape which had negative odds. Of the positive odds, two were significant while five were not. The significant odds were for Free State (OR 2.45: p0.00 < p0.05) and Limpopo (OR 2.61: p0.00 < p00.05) which implied that children living in the two provinces were more than two times more likely to have asthma compared to their counterparts residing in KwaZulu Natal. The result for Limpopo can be regarded as reflecting the impact of urbanisation on exposure to indoor pollution; the province is one of the least urbanised in South Africa thus contains a greater proportion of rural households which use unclean sources of energy**.** Provinces with positive odds but indicating insignificant risk were Eastern Cape (OR 1.18: p0.33 > p0.05), Northern Cape (OR 1.24: p0.31 > p0.05), Northwest (OR 1.44: p0.07 > p0.05), Gauteng (OR 1.31: p0.11 > p0.05) and Mpumalanga (OR 1.13: p0.47 > p0.05) although it can be noted that for some provinces, for example Northwest, the insignificance was only marginal.

4.6.4 Model 4: Age, sex, population group, province and SES

Model 4 extended the multiple regression equation to include SES as one of the explanatory factors for the analysis of children's odds of having asthma. The addition of SES in the regression resulted in a notable decline in the difference between the odds of having asthma for children exposed to indoor pollution and those not exposed. Children who were not exposed to indoor pollution (OR 0.83: p0.07 > p0.05) were no longer significantly less likely to have asthma compared to their counterparts who were exposed to indoor pollution. However, the difference of 0.17 odds in favour of children not exposed to indoor pollution cannot be entirely ignored because the cumulative marginal health benefits of any kind contribute the overall wellbeing of a person, family and society.

The odds of having asthma for age groups changed by 0.01 points, comprising in increases for 10-14 and 15-17 year olds and a decrease for 5-9 year olds. The slight changes were not significant because the benefit of being over 4 years old was significant for all age groups. Children in the 5-9 year age group (OR 0.56: p0.00 < p0.05) were 0.44 times less likely to have asthma compared to 0-4 year olds. The same model found that 10-14 year olds were 0.40 times less likely to have asthma compared to 0-4 year olds while 15-17 year olds were 0.31 times less likely. The results for age groups show that age was an important factor affecting risk of having asthma for children.

The results for girls in Model 4 remained the same at 1.49 odds as in Model 3 following the inclusion of SES in the regression analysis. As has been stated above, constant results imply that the variable last added into the regression equation had no effect on the difference in risk of having asthma between boys and girls. It therefore further supports the argument for biological determinants on asthma between men and women as opposed to socio-economic factors.

Model 4 results for population groups show that the benefit for not being African was eliminated for Coloured children following the inclusion of SES in the regression equation. The odds of having asthma for Coloured children (OR 0.71: p0.05 = p0.05) were not significantly less than those of African children although they were in the negative direction. Model 4 found significant results for Indian/Asian (OR 0.39: p0.00 < p0.05) and White (OR 0.44: p0.00 < p0.05) children. Based on the observed odds, Indian/Asian children were 0.61 times less likely to have asthma compared to African children

The inclusion of SES in the regression in Model 4 resulted in notable changes in the pattern of results for provinces. There were increases in the odds for all provinces except for Mpumalanga which remained constant and Limpopo which recorded a decrease. The composition of significant results also changed as Western Cape (OR 0.84: p0.35 > p0.05), one of the three provinces with significant results in Model 3, recorded insignificant benefit relative to KwaZulu Natal. This implies that a portion of the benefit of not living in KwaZulu Natal for children living Western Cape in light of risk of having asthma was due to SES differences. Meanwhile, the results for Free State (OR 3.42: p0.00 < p0.05) and Limpopo (OR 2.46: p0.00 < p0.05) remained significant following the inclusion of SES in the regression model. Based on the observed odds children living in Free State were more than three times as likely to have asthma as those living in KwaZulu Natal. As for children living in Limpopo, the risk of having asthma was still more than twice that of children living in KwaZulu Natal despite a decrease in the odds amounting to 0.15 odds. Model 4 recorded increases in the odds observed for children living in Eastern Cape (OR 1.20: p0.28 > p0.05), Northern Cape (OR 1.42: p0.11 > p0.05) and Northwest (OR 1.49: p0.05 = p0.05) but the implied increase in risk of having asthma relative to children living in

KwaZulu Natal remained insignificant as in Model 3. It is however, worth noting that the positive odds have important meaning to the health of children because of the implied vulnerability to respiratory health complications. This can be observed in the odds for Northwest which were only just insignificant.

Model 4 found a positive relationship between risk of having asthma and SES. As SES increased, the risk of having asthma also increased. Children living in medium SES households (OR 1.48: $p0.02 < p0.05$) were a significant 0.48 times more likely to have asthma compared to children living in low SES households. As for children residing in high SES households (OR 1.50: $p0.00 < p0.05$), the risk of having asthma was 0.50 times higher compared to their counterparts in low SES households. Model 4 results for SES appear to contradict logic because as SES increases, households are more likely to use clean energy sources like electricity which reduces children's exposure to indoor pollution and consequently reduce the odds of having asthma significantly.

4.7 Summary of the chapter

This chapter has described the results from bivariate, independent and nested logistic regression analyses that were conducted to investigate the impact of indoor pollution on respiratory health of children in South Africa based on GHS 2010 data. Bivariate results showed that electricity and wood were the most prevalent sources of energy. There were related results from the four classes of logistic regression. Use of unclean energy sources was associated with increased risk of having asthma for children. Female children were more likely to have asthma compared to males. The regression analyses also found that younger children below the age of 5 years were generally more likely to have asthma compared to children who were 5 years and older. The comparisons of population groups revealed that African children generally had the highest risk of having asthma followed by Coloureds, Whites and Indian/Asians. With respect to provinces, the worst affected were mostly children residing in Free State and Limpopo. Overall however, the probability of having asthma was higher for children living in any other province relative to KwaZulu Natal except for Western Cape. The odds of having asthma were also observed to increase with SES, and potential reasons for this were highlighted accordingly.

CHAPTER 5: DISCUSSION, RECOMMENDATIONS AND CONCLUSION

5.1 Introduction

This study set out to investigate the relationship between indoor pollution and the respiratory health status of children in South Africa using data from the General Household Survey of 2010. Logistic regression technique was used to analyse the data. The results were presented in chapter 4 in terms of odds of having asthma. This chapter discusses the results with reference to the aims of the study that were identified in chapter 1, identifies limitations and suggests recommendations based on findings as well as providing a general conclusion containing a summary and conclusion of the study. Firstly, the chapter discusses the results, answering the research questions raised in chapter 1. Secondly, it describes the study's possible limitations and suggest recommendations based on study findings. Finally, a general conclusion is provided starting with a brief summary of the whole study and ending with overall concluding remarks for the study.

5.2 Discussion of results

The goal of this study was to investigate the relationship between indoor pollution and respiratory health of children in South Africa using the 2010 General Household Survey data. The study was designed to address the following specific research questions;

i. Which children are most affected by respiratory infections?
ii. Is there a relationship between household energy source and respiratory health status of children in South Africa?

Based on the results reported in chapter 4, this research observed a systematic relationship between source of household energy and respiratory health status of children in South Africa. The results support the suggestion that the use of unclean sources of energy increases the risk of having respiratory infections. The findings are consistent with those from a study by Mishra (2003) cited in Fuentes-Leonarte *et al.* (2009:12) which observed that children living in highly polluted homes were more susceptible to incidence of ARL compared with those who lived in homes in which cleaner fuels were used. Another study with similar results was done by Ezzati and Kammen (2001) in which the incidence of ALRI in young children was considered higher. Indoor air pollution can be considered an environmental contamination factor using the perspective of Mosley and Chen proximate determinants model and as such, exposure to indoor pollution can be considered a determinant of respiratory health to children in South Africa. Support for such a conclusion can be found in case-control studies conducted in Bangladesh and Nairobi (Kenya) by Khalequzzaman *et al.* (2007) and Mohammed *et al.* (1995) respectively. Khalequzzaman *et al.* (2007) studied a sample of children under the age of 5 years and observed increased risk of having asthma for children living in homes where unclean energy sources were used indoors while Mohammed *et al.* (1995) found increased risk of having asthma for school children who were exposed to wood smoke compared to their counterparts who were not. In light of Mosley and Chen's health determinants model, it can be stated that environmental contamination in the form of indoor air pollution has an adverse effect on the respiratory health of children in South Africa.

Chapter 4 explored findings from bivariate analyses, independent logistic regression and three sets of nested logistic regression analyses. The different logistic regression analyses conducted showed that the odds of having asthma were generally greater for children living in households that used unclean fuel sources for household purposes. Consequently, it is plausible to put forth the argument that this study's findings are related to those reported in previous research by Carlsten (2011); Sanyal and Maduma (2007) and Smith (1993). The current study found that the odds of having asthma were significantly higher among children aged 5 years and below compared to children older than 5 years. The negative relationship between risk of respiratory complication and age has been explained by differences in time spent exposed to indoor pollution between young children who are yet to enrol for school compared to pupils. As highlighted earlier in the literature review chapter women and children are most vulnerable to respiratory diseases. According to Warwick and Doig (2004:2) children under the age of five are at greater risk as they spend most of their time with their mothers. This is consistent with Norman *et al*.'s (2007) finding that exposure to indoor air pollution is among the top four causes of ill health and mortality among young children in South Africa. Furthermore, children lungs are not fully developed till they are teenagers therefore breathe faster and that make them more susceptible to inflammation. Evidence from literature revealed that there are other factors such as malnutrition, genetics among others playing a big role in vulnerability of children. With respect to this paper's hypothesis, it can thus be stated that indoor air pollution indeed has negative impact on respiratory health of children.

The odds of having asthma, used in the analysis to depict risk of respiratory infection, were observed to be significantly greater for girls compared to boys. This was true for the independent regression model and the three sets of nested logistic regression models that were conducted. The results of the study with respect to risk of having respiratory infection by sex enables the assertion that girls living in households that used unclean fuel sources were the most affected compared to boys which partly addresses the research question about which children are most affected by respiratory health problems. Given that female children are most likely to spend more time indoors than male children hence greater exposure to indoor pollution, their odds of having asthma thus become higher as observed in the analysis and shown in table 4.1 above. This was highlighted in other studies which highlighted differences in the amount of time spent indoors as one of the explanatory reason for girls' higher risk of being asthmatic compared to boys. The findings are comparable to those reported in a study by Carlsten *et al.* (2011) which observed that exposure to indoor pollution was greater for females compared to males due to differential gender roles hence the higher likelihood of females having respiratory health problems compared to males.

The current study found evidence to suggest that African children have the greatest risk of having respiratory health problems compared to Coloured, Indian/Asian and White children. The results from the analyses generally showed less odds of having asthma for children of other population groups relative to African children. The findings can be regarded as reflecting the racial-socioeconomic dynamics with respect to access to electricity among the South African population. The African population is shown in literature to be over-represented among the poor and the rural population relative to other population groups, implying underlying relatively high usage of unclean energy sources which increases risk of respiratory health problems (Leibbrandt *et al.*, 2009). Consequently, the results on population groups presented in the preceding chapter can be regarded as reflecting on average the socioeconomic inequalities among the major population groups in South Africa which are a legacy of apartheid and colonial policies that largely segregated blacks. Furthermore, it should be acknowledged that there are different factors proxied by household energy sources that can explain the observed results on population groups. African children have a disproportionately higher representation in rural areas compared to their counterparts in the other population groups who mostly reside in urban areas. This is also the case with living in informal settlements in urban areas where electricity is not the overwhelmingly modal source of household energy. Therefore, because of a higher percentage of African children who live in rural areas and informal settlements where unclean energy sources are used, the odds of having asthma become significantly higher for African children compared to non-African children.

The significance of province of residence on children's odds of having asthma is worth noting throughout the analysis. Compared to living in KwaZulu Natal, there was generally greater risk of having asthma associated with living in the other provinces except for Western Cape. There are different factors that can be cited to argue for the observed pattern of results for provinces. The factors include the proportion of rural population relative to urban population in each province and the size of each province's population living in informal houses and in the bottom end of the poverty spectrum. Literature, for example, Balmer (2007) and Aitken (2007) show that the majority of rural populations use unclean energy sources. Consequently, provinces with large proportions of rural populations are most likely to be associated with greater risk of respiratory infections because the majority of children residing in the provinces are exposed to indoor pollution from the use of wood which has been found to be a significant predictor of respiratory infections. The same is true of provinces where greater proportions of households belong to low SES category like Gauteng where most people in informal residences use paraffin because of inability to afford electricity consistently. As a result, the odds of having asthma were observed to be relatively higher in such provinces compared to KwaZulu Natal. It should however, be pointed out that exposure to indoor air pollution has similar consequences on the respiratory health status of a child irrespective of province of residence.

In the instances were a more urbanised province was associated with greater percentage of children with asthma compared to a less urbanised province as was the case with Western Cape relative to Limpopo as reported in the bivariate results, other factors can be cited to explain such findings. The factors may relate to relative access to health care, health seeking habits of rural residents compared to their urban counterparts and the way StatsSA phrased the question on respiratory health. StatsSA specifically asked in its survey instrument of a doctor's confirmation of a person's having asthma which may have resulted in undercount of children with asthma in the less urbanised provinces. This is because due to health centres being sparsely spread in the rural areas, there might have been undercount of children with asthma in less urbanised areas compared to more urban provinces. To apply the perspective of the theoretical model for the study with respect to personal illness control, health seeking behaviours of rural compared to urban residents proxied by accessibility of health facilities and doctors can be used to explain why greater proportions of asthmatic children were observed in Western Cape compared to Limpopo. Lack of easily accessible hospitals with doctors is a social aspect closely tied to economic status that may negatively affect rural residents' ability to obtain a doctor's confirmation of the presence of asthma in children hence the resultant under estimation of children with asthma in a less urbanised province like Limpopo compared to a more urbanised province like Western Cape.

Looking separately at the results for population groups on energy sources for cooking, the findings can be interpreted as reflective of the differences in the relative proportions of children living in households that used electricity or polluting sources for cooking per population group category. There was a greater proportion of children living in households that used energy sources other than electricity for cooking among the African population group compared to their Coloured, Indian/Asian and White counterparts. As a result the odds of having asthma were significantly higher for African children compared to those in the other three population groups. Living standards are closely related with race in South Africa. In South Africa, poverty is more widespread among blacks; even though is not confined to any one racial group (Woolard, 2002). Although many households in South Africa use electricity for lighting, only half use electricity for cooking and heating in 2001 (Norman *et al.*, 2007). However, about one-third of households in the country used solid fuels (wood, coal, dung) for cooking and heating and of these 95 per cent households were black African (Norman, 2007). The choice of sources of energy for household purposes in South Africa given the model of electricity supply in the country is a function of socioeconomic status. Poor households may be unable to afford electricity beyond for lighting thus resort to unclean energy sources for cooking and heating which result in exposure to indoor air pollution and increased risk of having asthma for children.

This study observed comparable patterns of results for the separate analyses on sources of energy for cooking and sources of energy for heating. Throughout the analyses, the odds of having asthma were generally higher for children living in households that used unclean energy sources for household purposes compared to children from households that used clean energy sources.

There were related findings in the nested models that were explored with regards to exposure to indoor pollution whereby children exposed to indoor pollution were more likely to have asthma compared to those that were not exposed. The observed results on source of energy for cooking and heating as well as those for exposure to indoor pollution are comparable to those observed in Mishra's (2003) study although it was based on Zimbabwe and sampled pre-school children only. This study went further to extend the analysis to children in primary and secondary school age groups and demonstrated that indoor pollution is a health hazard to all children regardless of age. This is despite the observed negative relationship between risk of having asthma and age.

This research found that the odds of having asthma were generally higher for children living in households classified in the medium and high SES categories compared to children from low SES households. The results on the relationship between SES and odds of having asthma observed in this study appeared to contradict existing literature, for example Mishra (2003), which maintain that as SES improves, access to clean energy sources also improves thus reducing exposure to indoor pollution, leading to reduced risk respiratory infections. There is an important aspect of the pattern of results on SES and this regards the genetic explanation of chronic respiratory infections as advanced by Franklin (2007); Sanford and Pare (2000); and Rona *et al.* (1997). The genetic explanation can therefore be used to support the argument that respiratory health problems like asthma are linked to genes which predisposes some children to having the disease compared to others. However, given the context within which the data used for this study was collected, it is justifiable to argue that the observed results on SES do not necessarily support the 'genes' argument. This is because of concerns regarding the phrasing of the GHS 2010 questionnaire which specifically asked of the interviewees a doctor's confirmation of the existence of asthma in a child. Furthermore, access to health services is still positively associated with SES such that there was a high likelihood that the existence of asthma among children from low SES households was under reported. Therefore, the findings on SES reported in the previous chapter may have no relation to sources of household energy, rather a depiction on the quality and full integrity of GHS 2010 data set especially for use in academic enquiry. This does not however, imply that results obtained using GHS 2010 are not important for they provide a springboard for further studies, for example, on why children from poor household are less likely to have asthma compared to those from relatively richer households. Nonetheless, in light of the research question, this study found that the use of unclean energy sources for household cooking and heating increases the risk of having asthma for children.

5.3 Study limitations and recommendations

5.3.1 Study limitations

The limitations of this study stem from that the data used for analysis was collected for purposes different from those of this research. Consequently, not all variables could be included in the analyses because they were missing in the data source. For example, the GHS 2010 does not have data about rural-urban residence, role that children play in households with respect to household chores, and birth order which would have been important variables to include in the analysis. The missing variables in the data set compromised to some extent this study's ability to fully incorporate Mosley and Chen's model of proximate determinants of health. The study would therefore have benefitted from using data specifically collected for the purpose of the research objectives. Another limitation of the study is that while its unit of analysis is the individual, GHS 2010 sampled at household level thus the result child sample may not necessarily be representative of the South African child population at the time.

The cross sectional nature of the data collected allows inferences about association between variables but not causality. In addition the outcome variable is based on a reported measure rather than a clinical assessment and diagnosis (Farmer and Lawrenson: 2004). Actual indoor air pollution dimensions may be influenced by quite a lot of factors such as fuel switching, quality of the fuel, appliances used to burn those fuels, stove stacking, ventilation characteristics of dwelling as well as time spent in the vicinity of fires among others (Smith *et al.,* 2000). Furthermore clustering at the the household level was not taken into consideration in the study.

5.3.2 Recommendations

The recommendations suggested in this section pertains to the study and to policy. With respect to the study, it is recommended that improvements on the quality of data are needed in order for more robust analyses of the impact of pollution on respiratory infections to be carried out. A study of this nature would benefit immensely from using census survey data to avoid the limitations from the discrepancy between the sampling unit of household surveys and the unit of analysis at individual level chosen by the researcher. To improve the accuracy of results, proper profiling of the study sample is needed and this include compiling all relevant data about study sample including a scale of measurement of the intensity of indoor pollution.

Based on the findings of this paper, it is recommended that the government should promote through a mix of policies that will improve people's access to clean energy sources. Research on alternative sources of clean energy which are cheaper should be supported and well-funded. It is worth noting that there are positive externalities from policies aimed at providing households with clean energy sources, for example, reduction of morbidity in the population and upholding the citizens' constitutional right to health and life. Furthermore, in light of the HIV/AIDS pandemic, indoor pollution related opportunistic infections such as flu which largely affect infected people can be reduced by removing the use of unclean energy sources from households. This will improve the health of people living with HIV/AIDS, improve the general health of the population. Reduce the overall burden of disease in the population and consequently help maintain a productive labour force. In light of the demographic transition inasmuch as South Africa can be classified as being in the third stage characterised by low birth rates, keeping a healthy population will enable the country to fully capture the demographic dividend whereby the majority of the population is in the working age group and is able to contribute towards creation of national wealth for the present and future generations.

5.4 General conclusion

This study established that indoor air pollution from use of unclean energy sources for cooking and heating negatively affects the respiratory health of children. There exist a relationship between source of household energy and respiratory health of children in South Africa. Use of unclean energy sources for cooking and heating indoors was found to be associated with greater risk of having asthma compared to use of clean energy sources. The most affected children are those aged zero to four years compared to older children aged five to seventeen years. With regards to sex, girls are the most affected compared to boys. The observed differences by age group and sex were explained by probable levels of exposure to indoor air pollution because of relative time amount of time spent by young children and girls indoors compared to older children and boys respectively. The study found population group to be an important factor in understanding the differentials in respiratory health of children. It was established that African children were most likely to have respiratory health problems as measured by asthma compared to Coloured, Indian/Asian and White children. The main underlying reason for the pattern of results observed for population groups was argued to be the current socioeconomic status differences among population groups which is a legacy of the past colonial and apartheid administrations. Province of residence was also observed to be an important factor inasmuch as it is highly correlated with whether a child is situated in urban or rural area. There was a higher risk of having asthma for children living in provinces which are less urbanised such as Free State and Limpopo because of a greater proportion of rural population compared to KZN. Overall, this research concludes that using unclean sources of energy indoors increases children's risk of developing respiratory health complications, and that the worst affected children are girls, Africans and those aged below five years.

References

Aitken, R. 2009. "Household energy use: a comparison of household energy consumption and expenditure across three provinces". *Journal of Energy in Southern Africa,* vol. 18, no.1, p.20-28.

Albalak, R., Bruce N., Perez-Padilla, R. 2000, "Indoor air pollution in developing countries: major environmental and public health challenge". Vol.78, P1078-1092.

Aunan, K., Mestl, H. E. S. 2007, "Health benefits from reducing indoor air pollution from household solid fuel in China-Three abatement scenario", *Environmental international*, vol. 33, no. 6, p. 831-840. Available at http://www.sciencedirect.com/science/article/pii/S0160412007000724. (Accessed on 29 Sep 2014).

Balmer, M. 2007. "Energy poverty and cooking energy requirements: The forgotten issue in South African energy policy?" *Journal of Energy in Southern Africa,* vol.18, no.3, p.138-139.

Bond, P., and Ngwane, T. 2010. "Community resistance to energy privatisation in South Africa." p.1-11

Ballester, F., Fuentes –Leonarte, V., Tennas, J.M., (2009), "Sources of Indoor Air Pollution and Respiratory Health in Preschool Children", *Journal of Environmental and Public Health*. p. 1-19. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2820286/pdf/JEPH2009-727516.pdf. (Accessed on the 29 Sep 2014).

Bruce, N., Romieu, I., Samet, J.M., Smith, R.k., 2000 "Indoor air pollution in developing countries and acute lower respiratory infections in children". Vol.55, p.518-532. http://www.bioenergylists.org/stovesdoc/Environment/WHO/OEH02.5.pdf (Accessed on 29 Sep 2014).

Barnes, B., Bruce, N., Mathee, A., Thomas, E., 2009, "Household energy, indoor air pollution and child respiratory health in South Africa". *Journal of Energy in Southern Africa*.vol.20, no.1. http://www.erc.uct.ac.za/jesa/volume20/20-1jesa-barnesetal.pdf (Accessed on 20 Sep 2014).

Barnes, B., Bruce, N., Mathee. A., Thomas, E., 2006. "Protecting children from indoor air pollution exposure through outdoor cooking in rural South Africa. Medical Research Council of South Africa". http://www.ehrn.co.za/publications/download/125.pdf. (Accessed on 22 Sep 2014).

Bukalasa, J. S., 2011, “Indoor Air Pollution, Social inequality and Acute Respiratory Diseases in Children in Tanzania”. http://www.phmed.umu.se/digitalAssets/76/76118_inlaga---joseph-bukalasa.pdf (3 March 2013).

Bruce, N., Ballad-Tremeer, G,. Ezzati, M., Von Schirnding, Y, Lvovsky, K., 2000. “Addressing the impact of household energy and indoor air pollution on the health of the poor”: Implications for policy action and intervention measures.

Barnes, B., Bruce, N., Romieu, I., Samet, J.M., 2000, “Indoor air pollution in developing countries and acute lower respiratory infections in children”. Vol, 55. p.518-532. http://thorax.bmj.com/content/55/6/518.full.pdf+html. (Accessed on 29 Sep 2014).

Bernstein, J.A., Alexis, N,. Bacchus, H, .Bernstein, I.L., Fritz, P, .Horner, E,. Li, N,. Mason, S, .Nel, A, Oullette, J,.Reijula, K,. Reponen, T,. Seltzer, J, .Smith, A,. Tarlo, S.M., 2008. “The health effects of nonindustrial indoor air pollution”.

http://www.sciencedirect.com/science/article/pii/S0091674907022099. (Accessed on 29 Sep 2014).

Carlsten, C., FitzGerald J.M, Po, J.Y.T., 2011. “Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and Meta-analysis”. vol,66.p.232-239

Chen, C.L, Mosley, H, W. 1984. “An analytical framework for the study in developing countries”. *Population Council*.v10:25-45. http://www.jstor.org/stable/2807954.

Davis, M., 1998. “Rural household energy consumption. The effects of access to electricity-evidence from South Africa”. vol.26, no.3, p.207-217

Davis K, Blake J. Social structure and fertility: An analytic framework. *Economic Development and Cultural Change* (4):211-35.

Dherani, M, Mascarenhas, M, Smith, K.R, Bruce, N,. 2008. “Indoor air pollution from unprocessed solid fuel use and pneumonia risk in children aged under five years: a systematic review and meta-analysis”. *Bulletin of the World Health Organization*.86:390-398. http://www.scielosp.org/pdf/bwho/v86n5/16.pdf (Accessed on 29 Sep 2014).

Duflo, E,. Greenstone, Hanna, R. 2008. “Indoor air pollution, health and economic well-being”. http://sapiens.revues.org/130 (Accessed on the 29 Sep 2014).

Ezzati, M., Kammen, D.M, 2002 “The Health Impacts of Exposure to Indoor Air Pollution from Solid Fuels in Developing Countries: Knowledge, Gas, and Data Needs”. *Environmental Health Perspectives.* vol.110, no. 11, p. 1057-1068.

Farmer, R. D. T., Lawrenson, R. 2004. Survey methods and bias. In Lecture Notes: Epidemiology and Public Health Medicine, 5th Edition, Massachusetts USA: Blackwell Publishing.

Fullerton, D, G., Gordon, S.B., Bruce, N., 2008, "Indoor air pollution from biomass fuel smoke is a major health concern in the developing world". *Society of Tropical Medicine and Hygiene*. Vol.102.p843-851. http://www.sciencedirect.com/science/article/pii/S003592030800271X . (Accessed on 29 Sep 2014)

Franklin, P, J,.2007, "Indoor Air quality and respiratory health of children". *Paediatric Respiratory Reviews.* v8, no. 4, p. 281-286.

Gómez G, Ramos-Galvin R, Cravioto J, Frenk S.,1955, "Malnutrition in infancy and childhood with special reference to kwashiorkor". *Advances in Pediatrics,* Vol. 7:131-69. New York: Yearbook Publication

Heltberg, R., 2003, "Household fuel and energy use in developing countries. A multi country study"..http://siteresources.worldbank.org/INTPSIA/Resources/490023I120845825946/FuelUseMulticountryStudy_05.pdf. (2 March 2013).

Smith, K.R, Zhang, J., 2007, "Household Air Pollution from Coal and Biomass Fuels in China: Measurements, Impacts and Interventions". *Environmental Health Perspectives*.vol.115, p. 845-855 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1892127/pdf/ehp0115-000848.pdf (9 March 2013)

Rutter, D., & Quine, L., 2002, "Changing health behaviour intervention and research with social cognition models". Open press university, Philadelphia Statistics South Africa http://www.statssa.gov.za/publications/P0318/P0318June2010.pdf (5 March 2013).

Smith, K.R, Samet, J.M, Romieu. I., Bruce, N., 2000. "Indoor air pollution in developing countries and acute lower respiratory infections in Children".vol.55.p518-532.

Jin, Y. Ma X, Chen, Y. Chen, X. Baris, E. 2006. "Exposure to indoor air pollution from household energy use in rural China: The interactions of technology, behaviour and knowledge in health risk management for the China Rural Energy and Health Research Group". *Social sciences and medicine.* 62: 3161-3176.

Larson, B.A, Rosen, S., 2002, "Understanding household demand for indoor air pollution control in developing countries". *Social Sciences & medicine*.vol.55, no.4, p.571-584. http://www.sciencedirect.com/science/article/pii/S0277953601001885. (Accessed on 29 Sep 2014).

Mehta, S,. Shahparl,. The health benefits of interventions to reduce indoor air pollution from solid fuel use: a cost-effectiveness analysis. vol.8, no.3, p.53-59. http://www.sciencedirect.com/science/article/pii/S0973082608604664. (Accessed on 29 Sep 2014).

Muller. Diab, R, D, .Hounsome,R. 2003. Health risk assessment of kerosene usage in an informal settlement in Durban, South Africa. *Atmospheric Environment*. 2015-2022 http://www.groundwork.org.za/ClimateHealthRoundtables/Muller%20et%20al,%202003,%20IAP%20kerosene%20Durban.pdf. (Accessed on 24 Oct 2013).

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

Norman, R, Barnes B, Mathee, A, Bradshaw, D., 2007. "Estimating the burden of disease attributable to indoor air pollution from household use of solid fuels in South Africa in 2000".http://www.ehrn.co.za/publications/download/51.pdf (Accessed on 23 Jan 2014).

Ndagurwa, P., 2013, "The impact of family structure on schooling outcomes for children in South Africa". University of KwaZulu Natal, Durban.

Rollin, H.B, Mathee, A, Bruce, Levin, Von Schirnding, Y, E, R., 2004, "Comparison of indoor air quality in electrified and un-electrified dwellings in rural South African villages". *Indoor Air*. Vol.14, no.3, p.208-216. http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.2004.00238.x/pdf. (Accessed on 29 Sep 2014).

Smith, K.R., Mehta's., Maeusezahl-Feuz, M, 2004. Indoor air pollution from household use of Solid fuels, Chapter 18. Pp 1436-1493.

http://ehs.sph.berkeley.edu/krsmith/publications/Chapt%2018%20IAP%20from%20Soid%20Fuels.pdf. (Accessed on 29 Sep 2014).

Sykes, A. 1993, *An introduction to regression analysis,* Law School, University of Chicago.

Smith, K. R., 1993. Fuel combustion, Air pollution exposure, and health: The situation in Developing Countries. *Energy Environment.* Vol.18, p. 529-566.

Sanyal, D.K, Maduna, M, E,. 2000. "Possible relationship between indoor pollution and respiratory illness in an Eastern Cape community". *South African Journal of Sciences*. 96(2):94-96.https://www.zotero.org/groups/eheo/items/itemKey/TTQQJNRP (Accessed on the 24 Oct 2014).

Saatkamp, D.B, Masera, R, O, .Kammen, D.M,. "Energy and health transitions in development: fuel use, stove technology, and morbidity in Jaracuaro, Mexico". *Energy for sustainable development*. Vol.4, no.2, p.7-16.

StatsSA, 2010, General household Survey, 2010.Statistics South Africa.www.statssa.gov.za.

Wichmann, J., Voyi, K.V.V. 2006. "Impact of cooking and heating fuel use on acute respiratory health of preschool children in South Africa". *Journal of Epidemiology and infection*. Vol.21, no.2,p.48-54.http://www.sajei.co.za/index.php/SAJEI/article/viewFile/41/37 (Accessed on 24 Oct 2014).

Warwick, H,& Doig, A., 2004. "Smoke –the killer in the kitchen". Indoor Air Pollution in developing countries. ITDG Publishing, London.

http://ecofogao.com.br/fileadmin/templates/ecofogao/arquivos/thekillerinthekitchen.pdf (Accessed on the 23 Oct 2014).

UNICEF. 2009, "*South Africa country profile*", Available at: http://www.unicef.org/southafrica/SAF_children_profile1109.pdf (Accessed 21 February 2014).