UNIVERSITI PUTRA MALAYSIA

EFFECTS OF INDOOR AIR POLLUTION FROM BIOMASS COOKING FUELS AND LPG ON RESPIRATORY HEALTH OF WOMEN AND CHILDREN IN CHUKWANI, ZANZIBAR

AZIZA SIBA ABDULKADIR

FPSK(m) 2015 60

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2015

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

EFFECTS OF INDOOR AIR POLLUTION FROM BIOMASS COOKING FUELS AND LPG ON RESPIRATORY HEALTH OF WOMEN AND CHILDREN IN CHUKWANI, ZANZIBAR

By

AZIZA SIBA ABDULKADIR

September 2015

Chairman : Emilia Zainal Abidin, PhD
Faculty : Medicine and Health Sciences

Introduction: Wood and Charcoal are fuels widely used for cooking by almost 85% of Zanzibar households in both urban and semi-urban areas. This wide spread use of wood and charcoal may impact indoor air quality in homes. Combustion of these traditional fuels produces a range of substances detrimental to human-health. So far, there is lack of data to quantify the levels of pollutants and their impacts in Zanzibar households. This study aimed to assess the levels of exposure to fine indoor particulate matter (PM) with aerodynamic size of 2.5µm ($PM_{2.5}$) and carbon monoxide (CO) emitted by combustion of biomass fuels, and determine any association with the respiratory health of women and children less than 5 years old living in Chukwani-Zanzibar.

Methods: A total of 200 households comprising of a mother–child pair were sampled for the study and 200 questionnaires constituting questions for both mothers and their children were administered. In a sub-sample of 20 households, 24-hour integrated samples were collected in non- uniform households with different kitchen types, using different fuels i.e. wood, charcoal and liquefied petroleum gas. Cumulative and 24-hour Time Weighted Average (TWA) exposure to biomass pollutants among women and children less than five years of old were estimated using information on PM concentration levels, and time-activity patterns. Prevalence of respiratory symptoms associated with biomass fuels use was determined in women ≥25 years and children ≤ 5 living in households using biomass as fuel. Similar procedures and measurement were performed in households using LPG

Results: The measured mean 24-hour TWA concentrations and (standard deviation) for $PM_{2.5}$in all 10 homes cooking with biomass fuels was 329 (121) µg/m^3 (range 28-1600 µg/m^3) with an average of 600 (28-2600) µg/m^3 during

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cooking hours and 12 (10)μg/m^3 (range 0-352 ppm) for CO. Households using cleaner fuel (Liquefied Petroleum Gas) had much lower concentrations 22 (11) μg/m^3 range (4-48 μg/m^3) with an average of 65μg/m^3during cooking hours for PM and 1.5 (3.5) range (0-36 μg/m^3) for CO. From the logistic regression analysis, an increase of 100 μg/m^3 $PM_{2.5}$ was associated with increased frequency of reporting of phlegm in the morning 1.75 (95%, CI 1.40-2.29), and tightness in chest 2.53 (95% CI 1.12 -5.31) for women and between 1.38 (0.87-2.22) - 3.28 (1.56-6.90) for all symptoms in children. The 24-TWA mean exposure hours for women and children were 192.4μg/m^3 and 173.6μg/m^3 respectively.

Conclusion: The results from this study suggest a relationship between respiratory health and biomass smoke exposure, thus emphasizing the need for potential interventions for the reduction of exposure to indoor air pollution in Chukwani.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

PENILAIAN PENDEDAHAN KEPADA PENCEMARAN UDARA DALAMAN DARI BAHAN API BIOJISIM UNTUK MEMASAK DAN GAS PETROLEUM CECAIR TERHADAP KESIHATAN PERNAFASAN DALAM KALANGAN WANITA DAN KANAK-KANAK DI CHUKWANI, ZANZIBAR.

Oleh

AZIZA SIBA ABDULKADIR

September 2015

Pengerusi : Emilia Zainal Abidin, PhD
Fakulti : Perubatan dan Sains Kesihatan

Pendahuluan: Kayu dan arang adalah bahan api yang digunakan secara meluas untuk memasak oleh hampir 85% daripada isi rumah Zanzibar di kedua-dua kawasan bandar dan separa bandar. Penggunaan kayu dan arang sebagai bahan api secara berleluasa boleh memberi kesan kepada kualiti udara dalaman di rumah. Pembakaran bahan api tradisional ini menghasilkan pelbagai bahan yang memudaratkan kesihatan manusia. Setakat ini, data untuk mengukur tahap pencemaran dan kesannya dalam isi rumah Zanzibar adalah terhad. Kajian ini bertujuan untuk menilai tahap pendedahan kepada jirim zarah atau "*Particulate Matter (PM)"* dengan saiz aerodinamik 2.5µm (PM2.5) dan karbon monoksida (*CO*) yang dilepaskan oleh pembakaran bahan api biojisim, dan perkaitannya dengan kesihatan pernafasan wanita dan kanak-kanak berumur kurang dari 5 tahun di Chukwani-Zanzibar. Kaedah: Seramai 200 isi rumah yang terdiri daripada sepasang ibu dan anak telah terlibat dalam kajian dan sebanyak 200 set soal-selidik yang mengandungi soalan untuk ibu dan anak-anak telah diedarkan. Dalam sub-sampel 20 isi rumah, sampel bersepadu 24 jam telah dikumpulkan dalam isi rumah tidak seragam yang menggunakan jenis dapur dan bahan api yang berbeza iaitu kayu, arang dan gas petroleum cecair. Bacaan kumulatif dan 24-jam Purata Wajaran Masa *(TWA)* pendedahan kepada bahan cemar biojisim di kalangan wanita dan kanak-kanak berumur kurang daripada lima tahun telah dianggarkan dengan menggunakan maklumat tahap kepekatan *PM*, dan aktiviti berdasarkan corak masa. Prevalen gejala pernafasan yang berkaitan dengan penggunaan bahan api biojisim dikalangan wanita ≥25 tahun dan kanak-kanak ≤5 tahun dalam isi rumah yang menggunakan biojisim sebagai bahan api adalah ditentukan. Prosedur dan pengukuran yang sama telah dilakukan dalam isi rumah yang menggunakan *LPG*.Keputusan: Purata kepekatan 24 jam *TWA* dan (sisihan piawai) untuk PM2.5 di semua 10 rumah yang memasak menggunakan bahan api biojisim ialah 329(121)µg/m^3 (julat 28-1600µg/m^3) dengan purata 600(28-2600)µg/m^3 semasa

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waktu memasak dan 12(10)μg/m^3 (julat 0-352 ppm) bagi *CO*. Isi rumah yang menggunakan bahan api yang lebih bersih (Gas Petroleum Cecair) mempunyai kepekatan yang lebih rendah 22(11)μg/m^3(4-48 μg/m^3) dengan purata 65μg/m^3 semasa waktu memasak untuk *PM* dan 1.5(3.5) julat (0-36μg/m^3) bagi *CO*. Daripada analisis regresi logistik, peningkatan sebanyak 100μg/m^3 PM2.5 telah dikaitkan dengan peningkatan kekerapan pelaporan kahak pada waktu pagi 1.75(95%, CI 1.40-2.29), dan sesak dada 2.53(95% CI 1.12 -5.31) untuk wanita dan antara 1.38(0.87-2.22)-3.28 (1.56-6.90) untuk semua simptom bagi kanak-kanak. Purata pendedahan 24-*TWA* untuk wanita adalah 192.4μg/m^3 dan kanak-kanak adalah 173.6μg/m^3. Kesimpulan: Hasil daripada kajian ini telah menunjukkan perkaitan antara kesihatan pernafasan dan pendedahan asap biojisim. Justeru itu, penekanan kepada keperluan untuk mengadakan intervensi dalam usaha untuk mengurangkan pendedahan kepada pencemaran udara dalaman di Chukwani.

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ACKNOWLEDGEMENTS

Foremost, I would like to express my sincere gratitude to Allah the Almighty who bestowed upon me the strength, wisdom and perseverance during this Master thesis, and indeed, throughout my life.

My sincere thanks and special appreciation should also go to my supervisor, Dr Emilia Zainal Abidin for her continuous guidance and support which she has given me all the time of my research and writing of this thesis. Indeed I could not have imagined having a better advisor and mentor for my Master study than her. Her wisdom, commitment, encouragement and motivation have enabled me to complete my studies to the highest standard of success .

Moreover, I would also like to extend my sincere gratitude to my beloved mother and father Mrs Fatma Zam and Mr Siba Abdulkadir who have always been eager to see me hiking at the highest degree stage of academic hierarchy

Words are short to express my deep sense of gratitude towards my family for the dedication and support they imparted on me .Special thanks should to go my husband Mr Khalid Muhsin who was always there to give me a helping hand in times of need, my lovely daughter Fatma, who despite her young age has always been my inspiration and without forgetting my son Ahmad Khalid ; the enthusiastic young Scientist and physicist who was always thre to give me a helping hand in all the technical part of my research

Last but not the least, my appreciation should go to all the people who have contributed directly or indirectly to the completion of this thesis

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Emilia Zainal Abidin, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Chairman)

Sharifah Norkhadijah Syed Ismail, PhD
Senior Lecturer
Faculty of Medicine and Health Sciences
Universiti Putra Malaysia
(Member)

Mohd Talib Latif, PhD
Associate Professor
Faculty of Science and Technology
Universiti Kebangsaan Malaysia
(Member)

Sean Semple, PhD
Scottish Centre for Indoor Air, Division of Applied Health Science
University of Aberdeen
United Kingdom
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our Supervision;
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Signature: _____
Name of Chairman of Supervisory Committee: Dr. Emilia Zainal Abidin

Signature: _____
Name of Member of Supervisory Committee: Dr. Sharifah Norkhadijah Syed Ismail

Signature: _____
Name of Member of Supervisory Committee: Associate Professor Dr. Mohd Talib Latif

Signature: _____
Name of Member of Supervisory Committee: Dr. Sean Semple

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LIST OF ABBREVIATIONS

ARI	Acute Respiratory Infection
HAP	Household Pollution
CO	Carbon monoxide
CI	Confidence Interval
DALY	Disability-Adjusted Life Years
EPA	Environmental Protection Agency
IAP	Indoor Air Pollution
LPG	Liquefied Petroleum Gas
MoH	Ministry of Health
OR	Odds Ratio
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
SES	Socioeconomic Status
TSP	Total Suspended Particulate
UNEP	United Nations Environmental Program
WHO	World Health Organization
UNDP	United Nations Development Project
PDR	Personal Data Ram
SSA	Sub Saharan Africa
SA	South Asia
LAC	Latin American And Caribbean
TIMAD	Time Activities Diaries
RAM (PDR)	Real Time Aerosol Monitor

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CHAPTER 1

INTRODUCTION

1.1 Air Pollution and Health

Burning biomass in traditional stoves emits smoke containing large quantities of particulates and gaseous pollutants, which pose serious health consequences for the exposed population. Chronic exposure to these pollutants is recognized as an important risk factor associated with increased prevalence of several health outcomes, with an important consequence on respiratory symptoms, reduced lung functions and development of chronic obstructive pulmonary disease (COPD) in women in developing countries.

Combustion of household fuels is reported to be responsible for a very substantial global burden of disease, estimated at almost 2 million premature deaths caused by a wide range of respiratory diseases, adverse pregnancy outcomes and cancer affecting people across the whole life course World Health Organization (WHO 2009).

The most recent estimate of disease burden published by WHO for the year 2012 reports that Household Air Pollution (HAP),is responsible for 4.8 million deaths almost all in low and middle income countries(WHO 2014).The main reason for the apparent increase being the addition of cardiovascular disease as an outcome (WHO, 2014).

1.2 History of Air Pollution and its Effects on Human Health

The problem of air Pollution and its effect to human health is an old phenomena originating since the down of history of mankind. It in fact, rooted up with the discovery and adoption of fire for cooking and heating tens of thousands of years ago, which marked one of the basic discoveries of mankind (Staton and Harding I998).Fire made possible for the use of a much wider range of foodstuffs and greatly improved food safety and health. Fire also enabled humans to expand their range to higher latitudes and elevations, and it essentially changed the patterns of social and economic developments.

However, though invention of fire was definitely one of the powerful developments in all of human history, with fire also came the first anthropogenic pollution in history (Staton and Hardin 1998). Evidence from the past remains has revealed number of evidence indicating smoke exposure and air pollution episodes in historic era. Some of the obvious evidence includes the existence of layers of soot

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in caves and the presence of black tones in the lungs of mummified bodies from Paleolithic times (Staton and Hardin 1998).

Air pollution was first and officially recognised by medical practitioners and scientists and was considered as a major cause for respiratory diseases, after some dramatic episodes of outdoor air pollution in the developed world. Such episodes include the historic air pollution disasters in Meuse Valley, Belgium in 1930, Donora, Pennsylvania in 1948, and the Big Smoke during the 5-8 December, 1952, in London, that killed more than 4,000 people most of whom were very young or elderly, or had pre-existing respiratory problems because of their heightened susceptibility to the damage that can be done by air pollutants (WHO, 2012).

1.3 History of Biomass Energy Use in the Word

Throughout the history, energy has taken one of the most important fractions in the human life. Primarily, mankind has transformed chemical energy gained by food into heat and mechanical energy. After the discovery of fire people began to use wood with the aim of cooking and lighting. Wood and wood coal (charcoal) had been extensively used since then.

However, with progressive discoveries of new fuels (coal and oil) and improvement of socio-economic profile in developed countries, coal and oil was used in competition with wood with biomass energy taking turn in developing countries. Thus, dividing energy usage today in two forms; traditional fuels used in under developed, and developing countries and modern biomass energy used in developed countries.

Even though in the some parts of the world electricity and gas are preferred as the cooking fuel, whereas biomass and biomass stoves are only used for recreational cooking, biomass like wood, charcoal, and other combustible residues and wastes are burned and used intensively as the primary cooking fuels in the developing and underdeveloped countries (Ahuja and Tatsutani, 2009).

It has widely been reported that biomass fuels including firewood, charcoal, dung and agricultural residues are used worldwide by 3 billion people (WHO, 2014)and in 2030 it is expected that more than 3 billion people will use biomass for cooking although use of electricity is still increasing, too (Renewable Global Status Report, 2007;International Energy Agency, 2007).

This transition in energy use over the past few centuries, have made half of human kind able to afford to switch from traditional biomass fuels (wood, animal dung, crop residues rice husks, etc.) to fossil fuels such as kerosene or gas, or to

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electricity (Malla and Timilsina, 2014), while the remaining half of humankind, almost all in developing countries, continues to use biomass fuels or coal, often in open fires or in inefficient, smoky stoves (Malla and Timilsina, 2014).

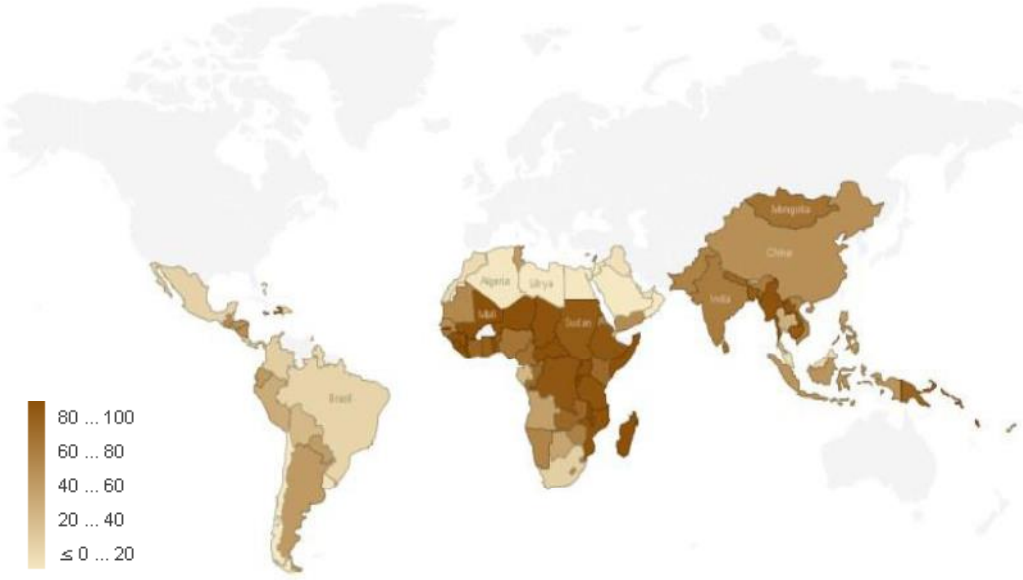

Figure 1.1: Estimated Percentage of Population Using Biomass as Primary Cooking Fuel: Map Created from Tabular Data collected by the World Health Organization

The widespread cooking practices with solid fuels, such as traditional biomass and coal, have been found to have severe implications on human health (Rehfues 2011; Malla Timilsina, 2014). Combustion of household cooking fuels, mainly solid fuels, has been revealed to results in the release of products of incomplete combustion resulting in emission of substantial quantities of harmful air pollutants and contaminants which have numerous implications for both climate and health (WHO, 2009).

These pollutants include toxic particulate matters such as $PM_{10}$and $PM_{2.5}$,toxic air compounds, such as carbon monoxide (CO), poly-aromatic hydrocarbons (PAHs), benzene and formaldehyde, and toxic contaminants such as ash, sulphur and mercury (Smith et al., 2012).

1.4 Global Burden of Diseases Attributable to Indoor Air Pollution

WHO and the United Nations Development Program (UNDP) have recognized indoor air pollution to be one of the major causes of death and ailments in the developing countries, with smoke from indoor cooking fires killing one person every 20 seconds (WHO, 2005). Additionally, WHO has confirmed the existence of the largest indoor pollutant concentrations and exposures in both rural and urban areas of the developing world (WHO, 2012).

Moreover, existing studies, such as Smith and colleagues 2004, WHO (2006); Njeru 2011; Malla and Timilsina, 2014) found that air pollutants, emitted from solid fuels often burned indoors on inefficient cook stoves, is one of biggest challenges to human health in developing countries.

Additionally, Lim and colleagues (2012), estimated that in 2010, about 3.5 million premature deaths were caused by household air pollution (HAP) resulting primarily from cooking with solid fuels. They also estimated that there were 500,000 deaths from outdoor air pollution caused by household solid fuels use for cooking in Asia and Sub-Saharan Africa (SSA) in the same year (Lim et al ., 2012).

Furthermore, WHO has reported that indoor air pollution (IAP) from solid household fuel is associated with a substantial global burden of health. WHO estimates that exposure to smoke from the simple act of cooking constitutes the fifth worst risk factor for disease in developing countries and causes almost two million premature deaths per year exceeding deaths attributable to malaria or tuberculosis (WHO 2011).

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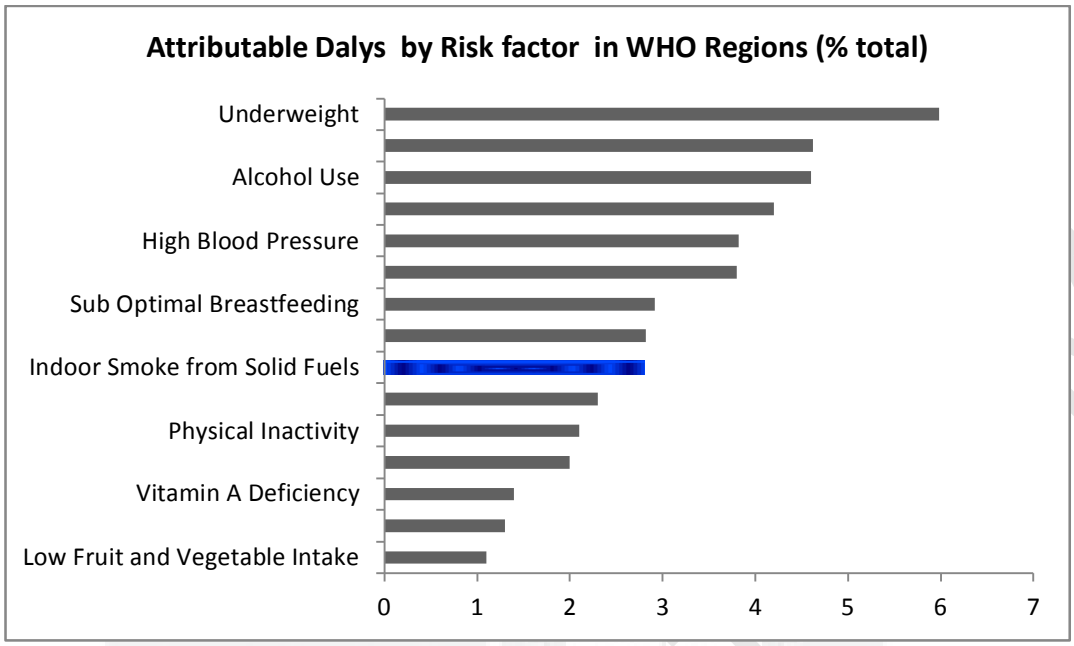

Figure 1.2: DALYs Attributed to Different Risk Factors. Plot created from Image from Data from the World Health Organization (2011)

World Health Organisation (WHO) has also estimated that indoor air pollution from combustion of solid fuels for cooking and space heating is one of the eight most important risk factors in global burden of disease measured as disability adjusted life years (DALY). In poor developing countries, indoor smoke from solid fuels ranking fourth behind only under-nutrition, and unsafe water/sanitation/hygiene, unsafe sex, accounting for an estimated 3.7% of the disease burden (WHO 2011).

Current estimates by WHO also shows that acute respiratory infection (ARI) is one of the leading causes of child mortality in the world, accounting for up to 20% of fatalities among children under five, almost all of them in developing countries (WHO 2014).IAP is thought to cause about one-third of ARI cases which makes solid fuels the second most important environmental cause of disease after contaminated waterborne diseases and the fourth most important cause of overall excess mortality in developing countries after malnutrition, unsafe sex, and waterborne diseases (Bruce et al., 2006).

In addition to impacts on mortality, IAP has been reported to have long lasting effects on general health and well-being. Early exposure to IAP during childhood may inhibit lung development, suggesting that the cost of this pollution may continue later in life. In fact, a growing literature indicates that environmental abuse at early ages can have long lasting influences on human health and productivity.

To date, numerous studies have found associations between IAP and acute lower respiratory infection (Kilabuko et al., 2007, Nandasena and Wickremasinghe, 2013), chronic obstructive pulmonary disease (WHO 2002, Bruce et al., 2000) lung cancer in the case of coal smoke (WHO 2014).

There is also emerging evidence that IAP increases the risk of other child and adult health problems, including low birth-weight, parental mortality, asthma, otitis media or middle ear infection tuberculosis, nasopharyngeal cancer, cataracts, blindness, and cardiovascular disease (WHO 2002),stunting (Machisa et al., 2012).

However, most striking is the imbalance between the developed and developing countries in the burden of ill health attributable to particulate matter (PM) in our air. It is not uncommon for developing countries today to experience the same PM levels that characterized the devastating "London fog episodes" of the 1950s which resulted in thousand s of cases of premature mortality and countless cases of exacerbated morbidity related health endpoints. The severity of the situation in developing countries warrants a closer look at and characterization of the key components that are integral to assessing the human health effects derived from exposure to particulate air pollution.

1.5 Cooking Fuels Use in Developing World

Half of humankind; about 3 billion people in developing world still rely on solid fuels for cooking and heating of which, about 2.5 billion people depend on traditional biomass fuels (wood, charcoal, agricultural waste, and animal dung) while about 400 million people use coal as their primary cooking and heating fuel (United Nation Development Project and WHO 2009).

The most commonly used cooking fuel in the developing world is wood. Wood is the primary cooking fuels for an estimated 2.3 billion worldwide (UNDP and WHO 2009).This accounts for 32% of the developing world's population and 71% of total biomass fuel users. Although wood is the most common fuel in developing countries, the availability and affordability of cooking energy sources and cooking technologies vary widely within and across countries.

Generally households often use a combination of fuels (fuel stacking) and they do not necessarily switch to more efficient or higher quality fuels for cooking (Malla and Timilisna, 2014). Fuel stacking is a common practice and occurs when a home uses multiple fuel types on a regular basis (Masera 2000).

Stacking occurs for a number of reasons. Some factors that affect what fuel is used include the meal to be cooked, the current availability of different fuels, and the

cash currently available to the family (Malla and Timilisina, 2014).Each of these factors may experience seasonal (or even daily) variation. Generally, energy for cooking in less industrialized countries is provided by a heterogeneous mixture of fuels which vary in importance from country to country (Clark 2013).

These fuels are often conceptualized as forming an "energy ladder" (Figure 1.3) which households ascend as soon as their economic circumstances permit because of the greater cleanliness, efficiency, storability and controllability of fuels at higher levels (Malla and Timilsina , 2014).

In Sub-Saharan Africa traditional fuels at the bottom of the energy ladder including wood, charcoal, grasses, animal dung and crop residues supply more than half of all energy needs, including transportation and industrial requirements (Masera et al., 2000).

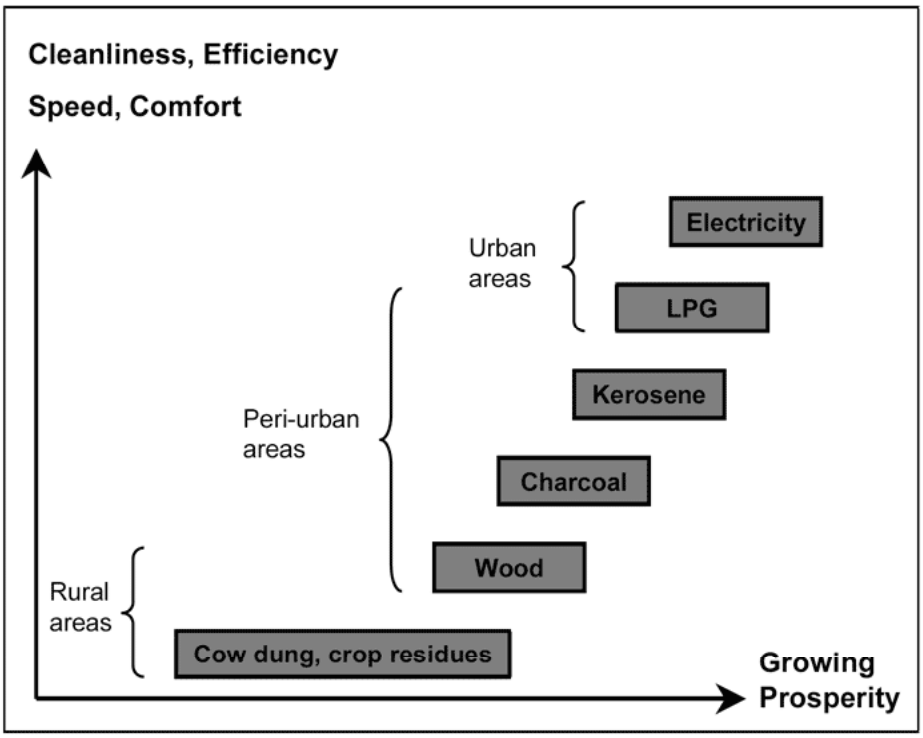

Figure 1.3: Fuels ladder in the Developing World. Plot created from data from the World Health Organization (2006)

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1.6 Problem Statement

Despite numerous evidence indicating that excessive use of biomass fuels in an enclosed space with poor ventilation, and in inefficient stoves, elevates the levels of indoor air pollutants, to 100 folds than the standard set by WHO which consequently impact respiratory health (WHO 2014), firewood and charcoal are still extensively used in Zanzibar.

Report from Households and Budget Survey 2011, has shown that most population in Zanzibar use biomass fuels, wood and charcoal as their major energy source with the estimate of use in 70.8% and 26.2% households respectively (Households and Budget Survey 2011). Due to the fact that, most of it is done in poorly ventilated kitchens, exposure to biomass pollutant is obviously predominant in Zanzibar.

Moreover, a report by the Ministry of Health in Zanzibar, shows that the prevalence of upper and lower acute respiratory infections particularly pneumonia are high, and are the leading causes of morbidity, and mortality in very young children (Ministry of Health Zanzibar, 2011). Table 1.1 shows the incidence of Upper Respiratory Infection among children (37%) which is higher than all other diseases combined.

Thus with the inclusion of pneumonia the overall prevalence of acute respiratory infections is approximately 50% which is exceedingly high. This might explain the reasons why despite an extensive campaign to eliminate the prevalence of ARI and pneumonia among children in Zanzibar, the persistence of these diseases have remained consistently high.

Table1.1 Incidence of ARI among children less than five years old in Zanzibar (Source: Ministry of Health Zanzibar 2011).

Disease /Condition	Number of new cases	Percentage
URTI	178,495	37.25%
Pneumonia	59,795	12.5%
Diarrhoea(other than cholera and dysentery)	56,096	11.7%
Skin disease (other than leprosy and chicken pox)	39,551	8.2%

To date, there are few studies on air pollution done in Zanzibar, most of which based entirely on cook stove emissions and its impacts on climate change and environment. Thus, it is obvious that, the sign and magnitude of the pollution health associated problems are high and need to be explored. Women and children in Zanzibar are therefore most likely exposed to elevated biomass pollutants

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because of their roles in the kitchens, and significant amount of time spent in indoor polluted environments.

It is therefore obvious that, IAP and respiratory health risks are significant environmental health problems in Zanzibar, particularly adding to the fact that upper and lower acute respiratory infections, are listed as the top five leading causes of morbidity for both woman and children in Zanzibar (Ministry of Health Zanzibar 2011).

1.7 Study justification

As noted earlier, to date, no studies on Households Indoor Air Pollution (HAP) and its effects on human health have been done in Zanzibar. Therefore, it is necessary to develop ways to determine pollution exposure measures/estimates by combining the number of people, fuel types, the level of pollution in different household settings, and the amount of time spent breathing polluted air as an indicator of where the health effects are likely to be.

The information obtained will provide public health professionals and environmentalists with knowledge about the true levels of IAP and its impacts to the life of women and children living in the rural and urban setting. This would in turn assist in investing mechanisms that will prevent the poor from paying heavily for their lack of access to clean cooking stoves and fuels, as well as reducing the time wasted in cooking and collecting fuel that could be better spent on income generation, education, or other activities.

Subsequently, better estimates and improved knowledge of exposures that highlights the contribution of various determinants of exposure such as kitchen configurations, ventilation, unsafe cooking habits and time spent in pollutant environments during cooking will become a useful tool that would, assist in targeting promising, long lasting and cost effective interventions to the population subgroups with the highest potential health risks due to IAP and consequently help alter the determinants of exposure.

Apparently, the exposure assessment methodology in this study with the use of primary data on parameters such as household fuel use, household-level characteristics, indoor air pollution measurements, and time activity diary estimates will allows the generation of additional exposure index that can be scaled up to cover whole regions with similar socio-economic and cultural profiles.

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To the best of my knowledge and experience of the matter it's my beliefs that this information will create awareness to the public and sheds a light towards giving more attention to this important but neglected problem (the continuous use of biomass fuel for cooking) hence act as a way forwards to subsequently improve cooking practices as well as strengthen the path towards switching to the cleaner fuels in Zanzibar.

Based on this background, the present study is designed with the following objectives:

1.8 Objectives of the Study

General objectives

To assess the levels of exposure of indoor particulates $PM_{2.5}$ and carbon monoxide emitted by biomass fuels combustion and assess their association to respiratory symptoms among women and children living in households using biomass for cooking.

Specific objectives:

1. To determine the levels of particulates matters $PM_{2.5}$ and carbon monoxide in households using biomass fuels and those using liquefied petroleum gas for cooking.
2. To determine the prevalence of respiratory health symptoms in households using biomass with those using liquefied petroleum gas for cooking.
3. To determine the association between respiratory health symptoms and exposure to particulate matters and carbon monoxide emitted from biomass fuels during cooking.
4. To determine time/activity and other information at the household level so as to estimate the exposure among women and children less than five years old in households using biomass for cooking.

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1.9 Hypotheses

- There is a higher level(s) of particulates matters $PM_{2.5}$ and carbon monoxide in households using biomass fuels compared to those using non-biomass fuels for cooking.
- There is a significant difference in the prevalence respiratory symptoms between women and children living in the households using biomass fuels for cooking compared with those living in households using cleaner fuels.
- There is a significant association between respiratory health symptoms and exposure to particulates matter and CO emitted from biomass fuel combustion.
- The longer the duration an individual spend in the polluted environment, the higher the exposure and the risk of getting respiratory symptoms or disease.

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REFERENCES

Abdul Alim MA., Sarker MA., Selim S., Karim MR., Yoshida Y., Hamajima N.,(214) Respiratory involvements among women exposed to the Smoke of traditional biomass fuel and gas fuel in a district of Bangladesh. Journal of Environ Health Prev Med.19: 126-134.

Akhtar, T., Ullah, Z. & Khan M H., et al. (2007). Chronic bronchitis inwomen using solid biomass fuel in rural Peshawar, Pakistan. *Chest;* 132:1472-5.

Ahuja,D., and Tatsutani M.(2009). Sustainable energy for developing countries. The S.A.P.I.E.N: Vol.2

Albalak, R., Bruce N,. McCraken, JP,. Smith KR. & de Gallardo T. (2001). Indoor Respirable Particulate Matter Concentrations from an Open Fire, Improved Cook Stove, and LPG/Openfire Combination in a Rural Guatemalan community. *Environ Sci Techno*l 35:2650–2655.

Austin, A., Wills K., Blizzard L & Walter E, (2010). Effect of high flow oxygen on mortality in chronic obstructive pulmonary disease patients in pre hospital setting: Randomized Controlled Trial. BMJ 2010: 341

Adonis, M., *Gil*, L. (2001). Indoor Air *Pollution* in Zone of Extreme Poverty of Metropolitan Santiago, Chile. Indoor Built Environ 2001; 10:138–146

Balakrishnan, et al. (2013). State and national household concentrations of $PM_{2.5}$ from solid cook fuel use: Results from measurements and modeling in India for estimation of the global burden of disease. Environmental Health journal 12:77

Balakrishnan, K,. & Cohen, Smith, K.R. (2014). "Addressing the burden of disease attributable to air pollution in India: The need to integrate across household and ambient air pollution exposures." Environmental Health Perspectives 122: (1):A6-A7

Behera, D., & Aggarwal, G. (2011). Domestic cooking fuel exposure and tuberculosis in Indian women: The Indian Journal of chest diseases & allied sciences 52:139- 143.

Bruce, N., Perez-Padilla, R,. & Albalak, R. (2000) Indoor air pollution in developing countries: a major environmental and public health challenge. *Bull World Health Organ*; 78: 1078e92.

Bruce N et al. (2006). Indoor air pollution. In: Jamison D et al., eds. Disease control priorities in developing countries, 2nd ed. Oxford: World Bank and Oxford University Press.

Carlsten , C., Dybuncioa A,. & Allen, A., (2010). Traffic-related air pollution and incident asthma in a high-risk birth cohort: interaction with key candidate genes. *Pediatr. Allergy Immunol*. 21, 740-746,

Clark, M L., Peel JL,. & Balakrishnan K.(2013). ‘;Health and Household Air Pollution from Solid Fuel Use: The Need for Improved Exposure Assessment: *Environ Health Perspect* 121:1120-1128.

© COPYRIGHT UPM

Cynthia, A., Edwards, R,. Johnson M,. Zuk M,. Rojas, L,. Jiminez, R,. et al. (2008). Reduction in personal exposures to particulate matter and carbon monoxide as a result of the installation of a Patsari improved cook stove in Michoacan Mexico. *Indoor Air* 18:93–105

Cotes, J., Medical Research Questionnaire on Respiratory Symptoms.(2007). Oxford University Press, *Oxford Journal*. China.

Dabral, S., Bhatt B. (2012). Indoor Air Pollution: Exposure and its Impact on Health. Indoor Air *Journal of Ecology and Environmental Sciences,* Volume 3, Issue 2, pp.-74-76

Daniel, W., (2005). Biostatistics: a foundation for analysis in the health .365: 1348–53. *John Wiley & Sons, Inc*. Georgia

Dasgupta, S., Khaliquzzaman, M,. Pandey, K,. & Wheeler, D., (2004). Indoor air quality for poor families: new evidence from Bangladesh, *Indoor Air*, 16:426-444

Department of International Development Zanzibar; Assessing the Development of Black carbon Zanzibar: TZ (2012).

Devakumar, D., Semple, S,. Osrin, D., Yadav, S.K., & Kurmi, OP. (2014) Biomass fuel use and the exposure of children to particulate air pollution in Southern Nepal. *Environment International* 66 (78-79).

Dianisio, K., Howie S, Furnaces K, Chimah O, Adegbola R., & Ezzati M. (2012).Measuring the exposure of Infants and Children to Indoor Air Pollution from Biomass Fuels in the Gambia. Indoor Air 18(317-327)

Ellergard, A., (2008). Cooking Fuel Smoke and Respiratory Symptoms among Women inLow- income Areas in Maputo. *Environmental Heath Perspect* 104-9

Elliot, T., Gall, M.S., Catherine, M., et al. (2013).Indoor Air Pollution in Developing countries: Research and implementation Need for Improvement in Global Public Health. *America Journal of Public Health*-1.

Ekici, A., Ekici, M., Kurtipek, E., et al. (2005). Obstructive airway diseases in women exposed to biomass smoke. *Environ Res* 99:

EPA, Susceptible populations. U.S. Environmental Protection Agency, Office of Research and Development, 2525 *Research Triangle Park*, NC. (2009).

EPA, Revised Air Quality Standard for Particulate Matter Pollution, and Updates to Air quality Index (AQI): USA (2012).

Ezzati, M., Saleh, H., Kammen, D. (2000). The contributions of emissions and spatial microenvironments to exposure to indoor air pollution from biomass combustion in Kenya. *Environ Health Perspect*.; 108:833–839.

Fullerton, D., Semple S, Kalmbo F et al. (2008)."Biomass Fuel Use and Indoor Air Pollution in Homes in Malawi, *Occupational and Environmental Medicine* 66:777-783

© COPYRIGHT UPM

Gninafon, M., Ade G, Aït-Khaled N, Enarson DA, Chiang C-Y. (2011). Indoor Solid Fuel Use and Tuberculosis in China: a matched case-control study. *BMC Public Health*11:498

Gupta, P., Christopher SA., Wang J, Gehrig R, Lee Y, and Kumar N. (2005). Satellite remote sensing of particulate matter and air quality assessment over global cities. Atmos Environ 40:5880–5892.

International Energy Agency, World energy Outlook. World Energy; ISBN: 978-92- 64-02730-5 (2007).

IARC, Monographs on the Evaluations of Carcinogenic Risks to Humans, Volume 92. Some Non Heterocyclic Polycyclic Aromatic Hydrocarbons and Some Related Exposures, Lyon (2010).

Jiang, R., Bell M. (2008). A Comparison of Particulate matter from Biomass Burning Rural and non Biomass Burning Urban Households. *Environmental Health Perspectives* 16(17)907-9014.

Jidawy, M., Zanzibar Health Bulletin; Ministry of Health: Zanzibar, 2012.

Jin Y., Zhou Z., He G., Wei H., Liu J., Liu F., Tang N., Ying B., Liu Y., Hu G.Wang H., Balakrishnan K., Watson K., Baris E., Ezzati M (2005). Geographical, spatial, and temporal distributions of multiple indoor air pollutants in four Chinese provinces. *Environ Sci Technol*.; 39:9431–9439.

Margaret Keraka., Carolyne Ochieng., Jacobus Engelbrecht., and Charles Hongoro. (2013). Association between the uses of biomass fuels on respiratory health of workers in food catering enterprises in Nairobi Kenya. Pan African Medical Journal - ISSN: 1937- 8688

Kilabuko, H., Nakai S. (2007). Air Quality and Acute Respiratory Illness in Biomass Fuel Using Homes in Bagamoyo, Tanzania. International *Journal of Environmental Research and Public Health* 4:39-44

Kim, J.J., Smorodinsky, S., Lipsett, M., Singer, B. C., Hodgson, A. T., and Ostro, B. (2004). Traffic-related air pollution near busy roads: The East Bay Children's Respiratory Health Study. *Am. J. Respir. Crit. Care Med*. 170(5):520–526.

Kumar N, Chu AD, Foster AD, Peters T, Willis R. (2011). Satellite remote sensing for developing time and space resolved estimates of ambient particulate in Cleveland , OH. Aerosol. *SciTechnol* 45(9):1090–1108.

Kurmi O.P., Semple S., Simkhada P., Smith W.C.S., and J.G. Ayres. (2010). "COPD and chronic bronchitis risk of indoor air pollution from solid fuel: a systematic review and meta-analysis." *Thorax* 65 (3): 221–228.

Kurmi OP., Semple S, Steiner M, Henderson G, Ayres J. (2008). Particulate matter exposure during domestic work in Nepal .*Ann Occupy Hyg* 52:509-17.

© COPYRIGHT UPM

Lakshmi, P.,V.M., Virdi, N. K ,. Sharma A,.Tripathy J.P, Smith K.R, Bates M.H, and R. Kumar. (2013). "Household air pollution and stillbirths in India: Analysis of the DLHS-II National Survey." *Environmental Research* 121:17-22.

Lawrence, A.J., Masih, A. and Taneja, A. (2005). Indoor/ Outdoor Relationships of Carbon Monoxide and Oxides of Nitrogen in Domestic Homes with Roadside, Urban and Rural Locations in a Central Region. *Indoor Air* 15: 76–82.

Lee, L,. Y-T (2013)." Household energy mix in Uganda." *Energy Economics* 39:252-261.

Lim S., Vos T., Flaxman AD., Danaei G., Shibuya K., Adair-Rohani H., Amann M., et al (2012). "A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010." *The Lancet* 380 (9859): 2224-2260.

Makame MO. (2007). "Adoption of improved stoves and deforestation in Zanzibar", Management of Environmental Quality: An International Journal, 18:353 – 365

Machisa, M., Wichmann, J. and Nyasulu P. (2012). Biomass fuel use for households cooking in Swaziland is there an Association with stunning in children aged 6-36 months?

Masera, O. R., Saatkamp B.D and D. M. Kammen (2000) " From Linear Fuel Switching to Multiple Cooking Strategies: A Critique and Alternative to the Energy Ladder Model."*World Development* 28 (12): 2083-2103.

Mehta and Shahpar C. (2005). "The health benefits of interventions to reduce indoor air pollution from solid fuel use: a cost-effectiveness analysis." *Energy for Sustainable Development* 8 (3):53-59.

Mishra, V., Smith, KR, Retherford RD. (2004). Effects of cooking smoke and environmental tobacco smoke on acute respiratory infections in young Indian children. Popul Environ; 26: 375e96.

Mishra V., (2005). Indoor air pollution from biomass combustion and acute respiratory illness in preschool age children in Zimbabwe. *Int J Epidemiol*; 32: 847e53.

Naeher, L. P., Brauer, M., Lipsett, M., Zelikoff, J. T, Simpson, C. D., Koenig, J. Q., & Smith K. R. (2007). Wood smoke health effects: a review. *InhalToxicol*, 19(1), 67-106.

Nandasena, S., Rajitha W, et al. (2013). Indoor Air Pollution and Repiratory Health of Children in Developing World. *Journ of Pedietr* 8; (2) 6-15.

Nasir, Z., Colbeck I, Ali Z, and Ahmad S (2013).Indoor Air Particulate Matter :a case study in Pakistan and potential intervention strategies. Environmental Res.8

National Bureau of statistics, Population Distribution by Administrative Areas: The united Republic of Tanzania.

Njeru, L. (2011). Indoor carbon monoxide emission and particulates produced from combustion of carbon based fuels and their health implications on rural households of Manyatta Kenya

McCracken, Schwaz, J. Diaz N, Bruce N, and Smith K.R. (2013). Longitudinal Relationship betweenin Guatemala.and Personal PM $_{2.5}$ among women cooking with wood fire Cook stove in Guatemala.

Malla, S., and Timilisna, G. (2014). Households cooking fuels choice and Adoption of improved Cook Stoves in Developing countries. *A review*. The World Bank Development research group 6903

Orange, C.L., (2013). The development of Numerical Tool for Characterising and quantifying Biomass Cook-stove Impacts. Colorado USA.

Patel, N., Okocha B, NaryanS Sheth M (2013) Indoor Air from Burning Biomass &Child Health. *IJSR* 23: 19-7064.

Pennise, D., Brant S, Agbeve S, Quaye W, and Mengesha F., Tadele W., et al. (2012). Indoor Air Quality impacts of improved stove in Ghana and Ethanol Stove in Ethiopia. *Energy for Sustainable Development* 13:71-76

Pit, M., Mark, R. Nazmu, H. (2006). Short and long term effects of Burning Biomass lllLow income Countries.

Po, J., Gerald J, and Carlsten C. (2010). " Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta- analysis."

Pokhrel, A., Bates, M., Verma, S., Joshi, H., Sreeramareddy, C., and K.R. Smith. (2010). "Tuberculosis and indoor biomass and kerosene use in Nepal: a case- control study." *Environmental Health Perspectives* 118:558–564.

Pollard, S., William D'Ann, and Brysse P, Baron P[3], Grajeda L[2], Gilman R[24], J Miranda J[45], Checkley W[124*] and CRONICAS Cohort Study Group.(2013). Determinate of Environmental Exposure in Households with and without chronic exposure to biomass fuel smoke. *Environmental Health Journal* 13-21.

Rehfuess, E, E., Puzzolo, D. Stanistreet, D. Pope, and N.G. Bruce. (2014). "Enablers and barriers to large-scale uptake of improved solid fuel stoves: a systematic review." *Environmental Health Perspective* 122:120–130.

Renewables Global Status Report. Renewable Energy Policy Network for the 21st Century, 2007

Revolutionary Government of Zanzibar, 2009/10 Household Budget Survey: Office of Chief Government Statistician (2011).

Sameet, JM., (2000). Fine particulate air pollution and mortality in 20 US Cities, 1987-1994. N *Engl J Med* 34:1742-1749

Smith, K. R., and Mehta S. (2004). The burden of disease from indoor air pollution in developing countries: comparison of estimates. *Int J Hyg Environ Health* 206: 279-289

© COPYRIGHT UPM

Smith, K.R., Balakrishnan K., Butler C., Chafe Z., Fairlie I., Kinney P., Kjellstrom et al., (2012). *"Chapter 4 -Energy and Health." In Global Energy Assessment- Toward a Sustainable Future*, 255-324. *Cambridge University Press, Cambridge*, UK and New York, NY, USA

Sota, C., Lumbreras, J., Mazorra, J., Narros, A., Fernández, L.. and Borge, R. (2014). Effectiveness of Improved Cook Stove to Reduce Indoor Air Pollution in Developing Countries: *J Geo Scie Env Protect* 2:1-5

Staton DM., & Harding MH.,(1998). Health and Environmental Effects of Cooking Stove Use in Developing Countries.

Strategies: A Critique and Alternative to the Energy Ladder Model." *World Development* 28 (12): 2083–2103.

Tanzania House and Demographic Survey, Tanzania Census Beuro; The United Republic of Tanzania (2012).

Taylor, E., and Nakai, S. (2012). Levels of Toxic Air Pollutants in Kitchens with Traditional Stoves in Rural Sierra Leone. *Journal of Environmental Protection* 3:1353-1363

UNDP and WHO, "The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa." New York (2009)

UNDP, and WHO, The Energy Access Situation in Developing *Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa*. New York: (2009).

Van,Vliet, E., Asante, K., Jack D, Kinney, P., et al (2013). Personal Exposure to fine Particulate Matter and Black Carbon in Households Cooking with Biomass fuels in Rural Ghana. *Env, Research.* Environ Res. 127: 40–48

World Health Organisation, Ambient Air Quality Guidelines Update. (2002).

World Health Organisation, Air quality guidelines global update 2005: Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Denmark: World Health Organization Regional Office for Europe; (2006).

World Health Organisation, Air quality guide lines for particulate matter, ozone, nitrogen dioxide and sulphur dioxide; Global update Summary of risk assessment: Geneva (2005)

WHO, guidelines for indoor air quality for selected pollutants (2010).

World Health Organisation, World Health statistics; Technical Series Report: Geneva (2014).

Zhang, J., and Kotani, K. (2010) . "The determinants of household energy demand in rural Beijing: Can environmentally friendly technologies be effective?" *Energy Economics* 34 (2):381-388.

Zhang, J., & K., Smith. (2007). "Household Air Pollution from Coal and Biomass Fuels in China: Measurements, Health Impacts, and Interventions." *Environmental Health Perspectives* 115(6):848–55.

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