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HOUSEHOLD BIOMASS FUEL USE AND RESPIRATORY HEALTH AMONG CHILDREN LIVING IN MADINA ZONGO: AN INFORMAL SETTLEMENT IN ACCRA, GHANA

BY

FRANCISCA AKORFA ADIKA-BENSAH

10702763

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DECLARATION

I hereby declare that excluding precise references which have been duly acknowledged, this submission is my own work toward my MSC Occupational Hygiene dissertation and that, to the best of my knowledge, it contains no material previously published by another person nor material

which has been accepted for the award of any other degree of the University or elsewhere.

Francisca Akorfa Adika-Bensah
(Student)

14/10/2019
Date

Dr. John Arko-Mensah
(Supervisor)

14/10/2019
Date

Prof. Julius Fobil
(Supervisor)

14.10.2019
Date

DEDICATION

I dedicate this work to my ever loving and supportive mum, Mrs. Annie Roselyn Mortey and my son Jaysen Seyram Adika-Bensah.

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I stand in awe of your mercies Lord, despite the many challenges, you gave me good health and wellbeing throughout the programme.

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ABSTRACT

Background: Incidentally, more than 95% of Zongo communities in Ghana, often considered to live in deplorable conditions rely on the use of traditional biomass fuels (BMFs) for cooking and heating. Burning of BMFs can release harmful substances such as sulfur dioxide, carbon monoxide and particulate matter, direct exposure of which could be harmful to human health.

Objective: The primary objective of this study was to assess the relationship between biomass fuel exposure and respiratory health of children aged 5-15 years, living in households at Madina Zongo, an informal settlement in the Accra Metropolis.

Methods: A cross-sectional analytical study was conducted from May to July, 2019, which included 400 children (aged from 5 to 15 years) selected from two hundred (200) households in Madina Zongo. A structured questionnaire was used to obtain demographic data of households including heads and children, household cooking characteristics and child exposure to biomass fuel. Weight and height measurements of the children were taken to assess their nutritional status. Data on respiratory symptoms of the children were also collected. An Easy One Spirometer was used to assess Lung function, Forced Expiratory Volumes (FEVs) and Forced Vital Capacities (FVCs) of the children. Instantaneous concentrations of PM were measured during data collection with a portable Met one Aerocet 831 particle counter.

Results: The mean age of children was 9.2 ±2.6 years. The most commonly self-reported respiratory symptoms included Cold (90%), Occasional dry cough (71.8%) and 4.2% of the children reported of persistent dry cough. Itchy and watery eyes, sore throat, excessive phlegm was reported by 79.5%, 71.5% and 62.0% of the children respectively. From the results of the Spirometry, a higher percentage (60.5%) of the children presented with reduced lung function and 39.5% were normal. A higher average exposure rate score was significantly associated with the increased likelihood of persistent dry cough (aOR=8.51, p-value =0.039), repeated sneezing (aOR= 1.97, p-value =0.003), itchy and watery eyes (aOR= 4.35, p-value<0.0001), shortness of breath (aOR= 3.22, p-value<0.034) and difficulty breathing (aOR= 9.21, p-value<0.028). Also, a significant association was observed between years of BMF exposure and lung function of the participants.

Conclusions: In conclusion, this study demonstrated a significant statistical relationship between biomass fuel exposure and respiratory health (respiratory symptoms and lung function indices).

Keywords: Biomass fuel, Respiratory health, spirometry, Particulate matter, Lung function, children, Madina-Zongo

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LIST OF ABBREVIATIONS

μg/m3	microgram per meter cube
μm	micrometer/micron: an SI unit of length equal to 10^{-6}meters
BMFs	Biomass Fuels
COPD	Chronic obstructive pulmonary disease
FAO	Food and Agricultural Organization
FEV	Forced Expiratory Volume
FEV1	Forced Expiratory Volume in one second
FVC	Forced Vital Capacity
HAP	Household air pollution
IAP	Indoor Air pollution
IEA	International Energy Agency
LANMA	La-Nkwantanang Madina Municipal Assembly
LPG	Liquefied petroleum gas
PM	Particulate matter
PM10	Particulate matter with aerodynamic diameter less than or equal to 10 microns
PM2.5	Particulate matter with aerodynamic diameter less than or equal to 2.5 microns
UNDP	United Nations Development Programme
WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Indoor air pollution (IAP) exposure from the burning of traditional biomass fuels (BMFs), namely wood, animal dung, charcoal, and crop wastes, is a major public health risk worldwide that primarily impacts poor disadvantaged rural and informal urban communities in developing nations. A vast number of individuals are exposed to damaging emissions and other health hazards from biomass and coal combustion on a daily basis, typically occurring in partly enclosed cooking areas, open fires or low-efficiency cookers with insufficient ventilation (Po et al., 2011). Biomass remains the primary source of energy for 60–90% of homes in developing nations since it is inexpensive and easily accessible (WHO, 2015).

In Ghana, it is estimated that 2.2 million households depend on firewood as their primary source of cooking fuel, with a further 1 million using charcoal (Kwakwa, Wiafe, & Alhassan, 2013). This indicates that about 86% of the total household population uses biomass fuels (Arthur, Baidoo, & Antwi, 2011). Based on the World Health Organization (WHO) reports, indoor air pollution from the combustion of biomass is responsible for 2.7% of the global burden of disease, where it is the major cause of death in most developing nations for children under five (WHO, 2015). The global disease burden estimates indicated an estimated 4.3 million fatalities in 2012 due to the household exposure to air pollution, which informed the decision of most stakeholders to look into this area (Nsoh et al., 2019). Combustion of BMF leads to the release of air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), sulfur and nitrous oxides, carbon monoxide (CO), aldehydes, para amino hydrocarbons, formaldehyde, benzo-pyrene, and benzene (Clark et al., 2013). The resulting mechanisms underlying the effects of BMFs on health, especially the respiratory health of children have been attributed to the inhalation of these poisonous particulates which are able to cross the alveolar-capillary barrier and infiltrate deep into the lungs causing a significant effect on respiratory health (Tesfaigzi et al., 2002). Thus, it is conceivable that biomass smoke exposure results in substantial systemic health impairment (Padhi & Padhy, 2008).

A number of studies have associated biomass smoke with adverse effects on respiratory health (acute lower respiratory infections, Pneumonia, chronic cough, phlegm production, and lung cancer), cardiovascular health, and other organ systems (Armah, Odoi, & Luginaah, 2015). According to the reports of some related previous studies, women and children stand the greatest danger relative to the fact that their gender roles and family duties and conduct give them the maximum exposure beyond the threshold (Armah, Odoi, & Luginaah, 2015). Thus, it is evident that the greater benefits of studies related to this area will be beneficial to public health, as well as decisions and policies related to human settlement and living.

1.2 Problem Statement

Biomass fuels (BMFs) usage results in indoor air pollution (IAP), which is significantly associated with infant mortality and childhood respiratory symptoms (Nsoh et al., 2019). BMFs used for cooking and heating have been documented to have deleterious health effects due to acute and chronic exposure to particulates and other harmful pollutants (Fullerton, Bruce, Gordon, & Hygiene, 2008). In Ghana, estimates indicate that exposure to IAP accounts for 16,600 fatalities annually and reportedly high proportions of this total involve women and children (Armah et al., 2015). The percentage of the national burden of disease associated with solid fuel use in Ghana is 2.2% (Stein et al., 2007). However, little or no evidence exists on the effects of this health determinant on the respiratory health of children within age 5-15 years. Thus, a study assessing the significant impact of household biomass use on children's respiratory health in Ghana would be beneficial to inform health interventions and preventive strategies.

In most areas of rural Ghana, the dependence on biomass fuels for cooking is very high (94%) (R. J. E. e. Heltberg, 2004). This study was conducted in Madina Zongo, a predominantly poor rural settlement with a high population density, presented under the category of 'slums and deprived areas' in Ghana. Zongo communities are classified with large household sizes (overcrowding), inadequate sanitation and ventilation. Due to the rising cost of clean fuels (e.g. liquefied petroleum gas) and energy, more households are turning to the use of inexpensive sources of energy such as wood, charcoal and/or agricultural waste for heating/cooking, which may increase the proportion of all-cause mortality in the country. Food meant for domestic consumption and even sales are prepared inside homes with BMF.

In Ghana, some studies conducted on adults have shown positive associations between biomass exposure levels and respiratory health. A recent study in Ghana on pregnant women showed a positive association between BMF exposure and respiratory symptoms (Mocumbi, Stewart, Patel, & Al-Delaimy, 2019). Another research in Ghana also discovered that the prevalence of respiratory health diseases among homes that burn solid fuels, especially firewood and coal, was high (Odoi-Agyarko, 2009). Despite this mode of settlement, no studies exist in Ghana to explore the effect of BMF use on children's health residing in such communities.

1.3 Conceptual Frame-Work

Respiratory health is dependent on a number of demographic and environmental factors, especially factors akin to BMF use and indoor air pollution. Exposure could be attributed largely to the route of exposure (mostly inhalation); a number of mediating parameters such as kitchen characteristics (if cooking is done indoors or outdoors), history of respiratory conditions, and also the duration of exposure. The early exposures of children to BMF and consequent effects on lung function depend on the mother and their prospective surrounding features. Children are disproportionally exposed due to the increased time spent with their mothers in the kitchen during cooking and the performance of other delegated chores. The socioeconomic status, age and level of education of the child and parents highly influence the choice of energy usage (BMF). The poisonous agents released from the burning of BMF such as PM, CO, Polycyclic aromatic hydrocarbons etc. which enter into the lungs mainly through inhalation may induce an allergic or inflammatory response leading to respiratory symptoms such as sneeze, cough, sore throat, wheeze and breathlessness which then leads to reduced lung function in the exposed children.

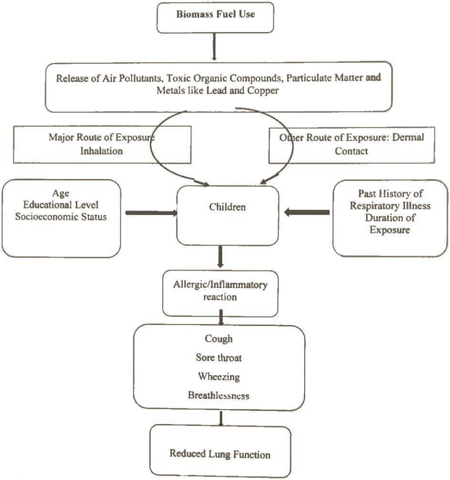


Figure 1.1 Conceptual framework of Biomass Fuels use and respiratory health

1.4 Justification

This study aims at establishing the association between BMF use and the prevalence of respiratory symptoms and pulmonary dysfunction in children within age 5-15 years. Air pollution from BMF smoke is of global public health concern for which policy intervention is urgently needed to halt its harmful effects on human lives and the environment (Fullerton et al., 2008). The proposed project will increase scientific knowledge concerning the health impacts of exposure to high concentrations of pollutants from incomplete combustion of biomass fuel indoors. A broader perspective and knowledge of these could help provide extra information to support exposure reduction measures for biomass smoke produced in rural/urban households and could also provide an important basis for Government to roll out regulations on the use of open-air burning of BMF and rather promote the use of cleaner fuels.

1.5 Research Questions

1. What is the prevalence of respiratory symptoms among children between 5-15 years living in households at Madina Zongo?

2. What are the Lung function indices of the children?

3. Is there an association between BMF exposure and respiratory symptoms among the children?

4. Is there an association between BMF exposure and Lung function among the children?

1.6 General Objective

To assess the relationship between biomass fuel exposure and respiratory health in children between 5-15 years living in Madina Zongo.

1.6.1 Specific objectives

1. Determine the prevalence of respiratory symptoms among the children using a standardized questionnaire.

2. Assess Lung function (Forced Expiratory Volumes (FEVs) and Forced Vital Capacities (FVCs) among the children by Spirometry.

3. Determine the association between BMF use and respiratory health symptoms and lung function among the children.

4. To determine whether there is an association between PM2.5 levels and respiratory health

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Insights

One-third of the world's population burns organic material such as wood, dung or charcoal (biomass fuel) for cooking, heating, and lighting (Fullerton et al., 2008). Biomass fuel (BMF) is a renewable source of energy and a primary source of domestic energy and is linked with elevated toxic emissions during burning leading to indoor air pollution and increased incidence of respiratory infections such as pneumonia, tuberculosis and chronic obstructive pulmonary disease to the extent of causing mortality in children and adults. There is not a complete understanding of the mechanisms behind these associations.

Ninety percent of rural households and 32% of urban households cook their meals on a biomass stove (Prasad, Singh, Garg, & Hosmane, 2012). On average, 24-hour concentrations of PM_{10} in households using biomass stoves surpass guidelines for ambient air pollution levels espoused by developed nations by a factor of 2 to 60 (M. J. T. L. Ezzati, 2005).

The respiratory system is the main target for air pollutants leading to a broad spectrum of restrictive pulmonary diseases and chronic obstructive pulmonary diseases (COPDs). These negative respiratory reactions span between mild subclinical changes and mild symptoms to life-threatening diseases, and possible loss of lives (Bentayeb et al., 2013). Children are more prone to respiratory health problems from air pollution because their lungs are still growing and because they are so active and breathe in more air.

Biomass smoke inhalation causes oxidative stress and DNA damage in the lungs which is believed to be the possible mechanism for the pathogenesis of Chronic obstructive pulmonary disease (COPD); and an interstitial lung disease also known as 'hut lung' (Kodgule, Salvi, & immunology, 2012).

2.2 Global Energy Resources and Consumption Rate

The type of energy and fuel technology used can have a significant effect on enabling sustainable livelihood, enhancing health and education, and decreasing poverty considerably. Access to appropriate energy service levels is a key fundamental requirement for the growth of any nation (Omer & reviews, 2008). It is obvious that every significant financial and social change in the globe has been accompanied by the emergence and accessibility of the technology of exploitation and social demand for new energy sources and a significant boost in energy consumption rates. It is quite evident that energy sources are one of the many characteristic features that define the socioeconomic state of a nation. Energy for cooking enabled the consumption of a much wider range of food products and significantly improved food safety. Thus, energy remains a vital determinant of industrialization and health safety. As countries develop economically, their energy consumption habits tend to alter, and the household energy consumption share decreases while industrial consumption increases.

As centuries go by, many energy sources have emerged. These include wind mill in the 12th century, hydraulic energy and steam engine in the 17th century, hydropower and coal in the 19th century. Electricity and Liquid Petroleum Gas (LPG) appeared later after world war III, which has been in place till now. In Africa and most developing nations, traditional fuels account for an estimated one-third of primary energy consumption. Among these nations, the biomass share of primary energy surpasses 70%. According to UNDP reports, more than two billion individuals cook by direct burning of biomass (Balat, Acici, & Ersoy, 2006), mainly in rural regions. The traditional use of biomass fuels is typically inefficient, depends heavily on inexpensive energy sources such as forests, which in turn contributes to deforestation (Demirbaş & Management, 2001).

2.2.1 Energy availability per capita income

According to the International Financial Statistics; International Energy Agency; World Bank, World Development Indicators; and International monetary staff calculations Mehrara (2007) energy demand growth has closely followed growth in per capita income in low and middle-income economies, whereas high-income economies can sustain GDP growth with little if any increase in energy consumption (Figure 2.1). Compared to developed nations, developing countries use far less total energy per capita and still need a significant share of worldwide energy. Less developed nations use energy differently, consuming much more at the household level, largely for cooking and lighting, but partly for heating purposes in cooler climates. Household fuel demand still account for more than half of total energy needs in more than 100 countries (Williams, Westover, Emerson, Tumuluru, & Li, 2016). Energy for cooking in less developed nations is provided by a diverse combination of fuels which differ in importance from one country to the other. These fuels are often conceived as an energy ladder (Figure 2.2) that defines transitions in fuel consumption at various stages of economic development (Holdren et al., 2000).

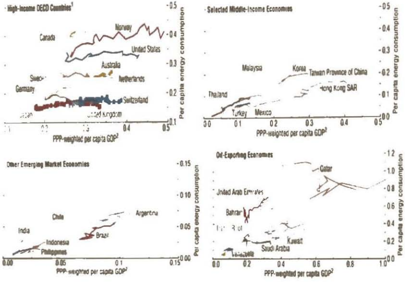


Figure 2.1 Relationship between per Capita Energy Consumption and GDP Growth

Source: Adopted from Mehrara (2007)

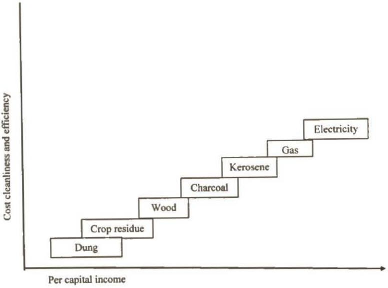


Figure 2.2 Schematic Illustration of the energy ladder hypothesis: Change in fuel with increasing income level

2.3 Global Trends on biomass energy consumption

According to FAO's Unified Bioenergy Terminology, bio-energy can be described as energy derived from biological and renewable sources (biomass) (Schlamadinger & Jürgens, 2004). Bio-energy can be obtained in heat form or converted into electricity for distribution. Biomass can also be turned into biofuels. Biofuels are defined as feedstock produced directly or indirectly from biomass for the production of bio-energy (Karekezi & Kithyoma, 2002). Biofuels are either solid (fuel wood, charcoal, wood pellets, briquettes etc.) or liquid (bioethanol, biodiesel). The IEA reported that the average energy consumption per individual increased by 10 percent from 1990 to 2008, while the world population increased by 27 percent (Adib et al., 2015). In the same time frame, regional energy consumption grew tremendously: the Middle-East 170%; China, 146%; India, 91%; Africa, 70%;Latin America, 66%; the USA, 20%; the EU-27 block, 7%; while the rest of the world grew by 39% (Thrän, Hennig, Rensberg, Denysenko, & Eppler, 2015). In 2008, total global energy consumption was 474 exajoules (474×1018 J=132,000 TWh). This is equal to an average power use of 15 terawatts (1.504×1013 W). The global potential for biomass energy is 250 EJ (70,000 TWh) (Adams, Klobodu, & Opoku, 2016).

2.3.1 Trends on biomass energy consumption in Africa

According to UN-DESA report (2004), households utilize energy principally for heating, cooking and lighting (Atkinson & Atkinson, 2005). Cooking in Africa often makes up for about 90 to 100% of household energy usage due to limited space conditioning loads (Karekezi & Kithyoma, 2002). Household energy usage levels and the kinds of energy consumed depends on a multitude of reasons but mainly on accessibility and cost. (Mansur, Mendelsohn, Morrison, & Management, 2008)

Biomass dominates energy consumption in sub-Saharan Africa even in comparatively advanced countries such as Botswana and prominent oil producers such as Nigeria (Iiyama et al., 2014). For instance, Botswana's energy industry is defined by both domestic and commercial sources of energy, with fuel wood as the primary source of energy, with residential, transportation, industrial and commercial industries being the primary consumers (Mathangwane, Utke, Bok, Kealotswe, & Best, 2001).

2.3.1.1 Biomass energy consumption in Ghana

Biomass is Ghana's major energy source, responsible for 65% of the total energy consumed in 2001(Arthur et al., 2011). The types of biomass products in Ghana are firewood and charcoal (Fuel wood), wood residues, agricultural residues, and human/animal waste. Fuel wood is primarily consumed in households for cooking and heat production (Arthur et al., 2011). The African sub-Saharan nation focuses primarily on the significance of biomass and the household industry that depends heavily on biofuels. However, the Ghanaian case illustrates how biomass and the household industry in Sub - Saharan Africa should be significant targets for sustainable energy consumption projects. Coal and electricity supply the industrial base in Ghana with three-quarters of total energy consumption (Edjekumhene et al., 2001). Sectorial energy usage in South Africa between 1992 and 2000 in contrast, indicates that transport and industrial consumption increased by 27% and 22% respectively ; mining and quarrying, agriculture and trade and public service shares decreased by 15%, 18%, and 25% respectively ; and domestic energy usage remained nearly steady (Akarakiri, 2002). While in the past the use of coal and electricity in the industry was seen as the primary objective for sustainable energy usage projects, the rapidly increasing energy consumption in the transport sector justifies the evaluation of this strategic focus.

2.4 Biomass fuel Types in developing nations (Africa)

Biomass Fuel (BMF) is any organic material from crops or livestock burned for domestic use. Wood is the most common instance, but there is also extensive use of animal dung and agricultural residue (Bruce, Perez-Padilla, & Albalak, 2000). BMFs, in terms of combustion efficiency and cleanliness, are found at the lowest end of the energy ladder (Figure 2.2). Biomass accounts for an estimated one-third of developing countries ' primary energy consumption. The biomass share of primary energy in many developing nations exceeds 70% (Larson & development, 2000). The various types of energy are discussed below:

2.4.1 Wood-based energy product

Wood-based energy is the key element of the sub-Saharan household energy composition (75-90%). Charcoal is consumed primarily by the urban populace and rural homes mainly use firewood. Firewood is burned in so-called three-stone fires with efficiencies ranging from 7% to 20%. Some writers have characterized traditional charcoal stoves as the main facilities for charcoal use, while others report much greater efficiencies. The low efficiencies of conventional charcoal and firewood combustion are accelerators of the degradation of forest resources. Increasing efficiency may lead to reducing that rate, but would not essentially address the resource depletion problem, especially considering the high population growth, and is often less effective than presumed based on gains in technical and economic efficiency measured in trials and experiments. For a number of solid reasons, biomass fuels are the major source of household energy: wood and charcoal are comparatively inexpensive, and traditional stoves are affordable. They are reliable sources of energy as they are accessible throughout the year and can be easily and efficiently preserved. Also, cooking practices, existing kitchen utensils, negligence of health issues, and other behavioural factors issues favour the traditional energy carriers.

2.5 Global and National Efforts and Promotions to Reduce BMF Use and Subsequent Respiratory Health.

Air pollution from the use of solid fuels for household cooking is a major global risk factor for respiratory, cardio-vascular and ocular diseases (WHO, 2017), therefore the need for global and national efforts in reducing the use. In Ghana, biomass fuels are the primary cooking fuels for 86% of households. Biomass fuels contribute to ambient and indoor air pollution and is also responsible for 16,600 deaths and the loss of 502,000 disability adjusted life-years annually (Inkoom & Crentsil, n.d.). Thus, there is a need to promote the use of cleaner fuels such as low emission fuels like LPG which will go a long way to improve respiratory health.

2.5.1 WHO benchmarks to reduce health damage from indoor air pollution

WHO guidelines for indoor air quality: household fuel combustion stress the need to improve access to cleaner home energy sources such as liquefied petroleum gas, biogas, natural gas and ethanol, or electricity, particularly in low- and middle-income countries. These new guidelines came after WHO findings revealed that more than 7 million deaths – one in eight of total global deaths – are due to indoor or outdoor air pollution exposure. According to the estimates, some 4.3 million people worldwide die every year from household air pollution emitted by rudimentary biomass and coal cook stoves (WHO, 2014). The recommendations include general considerations for policy, a set of four specific recommendations, and a best-practice recommendation addressing linked health and climate impacts. Among the general considerations, or overarching advice, is that policies should promote community-wide action, and that the safety of new fuels and technologies must be assessed rather than assumed. The recommendations are;

2.5.1.1 Recommendation 1: Emission Rate Targets (ERTs)

Emission rates from household fuel combustion should not exceed the following targets (ERTs) for particles with aerodynamic diameters of less than 2.5 µm (PM2.5) and carbon monoxide (CO), based on the values for kitchen volume, air exchange and duration of device use per day.

PM2.5	(unvented):	0.23	(mg/min)
PM2.5	(vented):	0.80	(mg/min)
CO	(vented):	0.16	(g/min)
CO	(vented):	0.59	(g/min)

The vented ERTs assume an average value of 25% of total emissions entering the room. Recommendation 1 aims to provide guidance on predicted area concentrations of PM2.5 and CO in kitchens, based on emission rates from testing of the stove or other devices. Effective management of household air pollution, however, also requires that assessment of actual use and performance in homes is also done as part of a monitoring and evaluation strategy("WHO | WHO indoor air quality guidelines: household fuel combustion," 2018).

2.5.1.2 Recommendation 2: Policy during transition to technologies and fuels that meet WHO air quality guidelines

Governments and their implementing partners must develop strategies to accelerate efforts to meet these air quality guidelines emission rate targets stated above. This can be achieved by ensuring emissions performance of improved devices and fuel. The device or fuel needs to be capable of meeting the specified emissions target and to be used more or less exclusively. Across whole communities, therefore, it must displace the more polluting technology and be maintained and, eventually, replaced by technology of the same or higher air-quality performance standards. The term "improved stove" should also be used with explicit reference to the parameter claimed to have been improved(WHO, 2017).

2.5.1.3 Recommendation 3: Household use of coal

Unprocessed coal should not be used as a household fuel. Unprocessed coal is that which has not been treated by chemical, physical, or thermal means to reduce contaminants. The International Agency for Research on Cancer has FOUND that indoor emissions from household combustion of coal are carcinogenic (WHO, 2017)

2.5.1.4 Recommendation 4: Household use of Kerosene (Paraffin) is discouraged

The household use of kerosene is discouraged while further research into its health impacts is conducted. Existing evidence shows that household use of kerosene can lead to levels of particulate matter and other pollutants that exceed WHO guidelines (WHO, 2017).

2.5.1.5 Good Practice: securing health and climate co-benefits

Considering the opportunities for synergy between climate policies and health, including financing, WHO recommends that governments and other agencies developing and implementing policy on climate change mitigation consider action on household energy and carry out relevant assessments to maximize health and climate gains("WHO | WHO indoor air quality guidelines: household fuel combustion," 2017).

2.5.2 Ghana Rural liquefied petroleum gas promotion Programme

The Ghana Ministry of Energy's LPG promotion Programme started in 1990 with short and long term aims of eliminating flaring of LPG at Tema Oil Refinery and ensuring that households that use wood fuel (charcoal and fire wood) for cooking adopt to the use of better and cleaner fuel like LPG. Extensive promotional and educational campaigns were carried out to educate the public on the environmental, health and safety regulations as well as the dangers of using fuelwood and the benefits of switching to LPG (Asante et al., 2018). The

Government of Ghana launched the Rural LPG (RLP) promotion program in 2013 as part of its efforts to reduce fuelwood consumption. The aim of the RLP is to contribute to Ghana's overarching goal to provide LPG access to 50% of Ghana's population by 2020. The RLP targeted a cumulative total of 170,000 LPG cook stoves to rural households by the end of 2017 as a short-term objective. It has not yet made public its long-term program objectives. As of November 2017, 149,500 rural households had received the LPG cook stoves (Asante et al., 2018).

2.6 Factors for Using Biomass Fuel

The age of household heads is one of the major contributors of BMF use in a community. According to some studies, household heads older than 40 years are responsible for the provision and making decisions on the energy type to be used in a household (Gatama & Planning, 2014). A research also revealed that the age of household heads influenced the probability of consuming a specific form of fuel (Nyang, 1999) such that households with older family heads are more prone to using wood based fuels. Again, families with elderly heads were much more likely to use wood and kerosene in main Ethiopian towns than electricity and charcoal, while usage of wood increased with age (Mekonnen & Köhlin, 2009). Thus, the age of household head represents an important factor that determines the choice of BMF use.

Studies have also shown that the higher the household size the more the household used charcoal fire wood and kerosene as compared to the use of the LPG and electricity (Gatama & Planning, 2014). Gatama and Planning, 2014 showed that households with above five member's majority use charcoal. It has been noted that family size is sometimes a more significant determinant of household energy consumption than revenue. More family members (more people contributing to household revenue) have been connected with high revenue, thus increasing total household demand.

Another significant factor for the selection of BMF is the family heads ' education level. According to, household head educational level is observed to have an inversely proportional connection with less clean fuels consumption and demand (Mekonnen & Köhlin, 2009). Energy costs is also one of the key factors influencing the type of used by a family. It has been determined that for the energy that costs more than what the household head can afford is not an option for the majority of households (R. J. T. W. B. Heltberg, 2003), observed that the structure of energy expenditure of homes varies widely across nations. Electricity is the main source of energy in wealthier nations. Among cooking fuels, hydrocarbons (LPG and kerosene) are preferably where income-rich families spend most of their energy budget, although such homes can spend as much or more on wood and hydrocarbons (R. J. T. W. B. Heltberg, 2003). Moreover, the frequency of cooking times for a household as well as the time spent in preparing a single meal determines the amount of energy a household consumes. A household that cooks more frequently in one day tends to use more energy than homes that cook in a single day for much less time. It is established that households that cooked more than four times used firewood at 8.3%; for those who cooked four times, used charcoal at 11.1% and this was attributed to the availability and the cost of the type of the energy consumed (Mekonnen & Köhlin, 2009).

2.7 Indoor Air Pollution

Smoke from the burning of biomass contains impurities such as particulate matter (PM), carbon monoxide, nitrogen dioxide, sulphur oxides, formaldehyde, and carcinogens (benzopyrene and benzene) (Sacks et al., 2010). The resulting indoor air pollution (IAP) exposures are many times greater than those allowed by international guidelines and even in extremely polluted areas greater than outdoor exposures (Smith et al., 2004). Typical daily levels of PM10 in homes using biomass fuels vary from 500 to 1,000μg / m3, with peak levels in the immediate proximity of the fire above 30,000μg / m3 (Lewis & Pattanayak, 2012), whereas PM2.5 levels have been recorded at more than 2,000μg / m3 (Oluwole et al., 2013). It is estimated that in developing countries as much as 80% of total worldwide exposure to airborne PM occurs indoors (M. Ezzati & Kammen, 2002). Particles smaller than PM10 in diameter can effortlessly penetrate deep into the lungs and tend to have the greatest negative pulmonary health implications. (Terzano, Di Stefano, Conti, Graziani, & Petroianni, 2010).

2.7.1 Particulate Matter

Particulate matter is the combination of all solid and liquid particles suspended in the air withmostbeing extremely hazardous.This intricate blend comprises organic and inorganic particles such as dust, pollen, soot, smoke and liquid droplets (Brook et al., 2010). The size, structure, and origin of these particles differ significantly. Particles' aerodynamic characteristics influence how they are carried in the air and how they can be eliminated from it.

These features also regulate the extent to which they enter the air passages of the respiratory system. They also provide data on chemical structure and particle sources. Particles have uneven forms and are generally described using their particle size. Sampling and characterization of Particulate matter are dependent on this aerodynamic diameter. Particles similar in diameter sometimes vary in size and shape. In essence, some airborne particles are many times larger compared to others. The respirable fraction of Particulate matter is based on size/aerodynamic diameter:

• The coarse fraction includes the bigger particles sizes between 2.5 and 10 µm (PM10-PM2.5).

• The fine fraction has sizes up to 2.5 µm (PM2.5).

•The ultra-fine particles that are smaller than 0.1 µm.

Majority of the total mass of airborne particles is made up of 0.1 to 2.5 µm of particulate matter. Particles smaller than 0.1 µm usually are just a small percentage, although most dominant, accounting for more than 90 percent of the particle count (Schauer et al., 1996).

2.7.1.1 Effects of Long-Term Exposure to Levels of PM and Respiratory Health

Long-term PM exposure can result in a marked decrease in life span. The decrease in life expectancy is mainly due to a rise in cardiopulmonary and lung cancer mortality (Braun-Fahrlaender et al., 1997). These dangers are more prone in lower respiratory symptoms (Cough, chest pains, sore throat, wheezing, shortness of breath, palpitations, dizziness, phlegm production, itchy ear and throat) and decreased pulmonary function in adults and children, and COPD (Boldo et al., 2006; Penard-Morand et al., 2005). Several cohort studies have indicated that being exposed to PM for a long duration decreases life expectancy. Very recent analyses of time series studies supports the above claims which also found increased fatalities over short durations of at least a few months due to causes such as cardiovascular and chronic respiratory disease (Götschi, Heinrich, Sunyer, & Künzli, 2008; Künzli et al., 2000). A significant association between ambient PM and mortality and morbidity was observed in large multi-city epidemiological studies. In the cohort studies of the Six Cities and American Cancer Society, mortality was associated with PM but not gaseous pollutants except sulphur dioxide (Schikowski et al., 2005). Time series studies have evaluated whether particles sizes bigger than 2.5 µm (PM2.5) are connected with negative impacts separately from sizes up to 2.5 µm. They found inadequate proof of an association with fatality and negative impacts (morbidity endpoints) such as increased visits or admissions at the hospital (Aunan & Pan, 2004; Brunekreef, 2005). One research that also explored the effect on life expectancy of prolonged exposures to coarse PM established no link (Boldo et al., 2006). However, researches considering how varying particles ends up in the lungs, its chemical structure and toxicity have offered additional proof of coarse PM's negative health impacts (Boldo et al., 2006; Penard-Morand et al., 2005). For instance, owing to the existence of microbial structures and toxins that are often connected with coarse particles, some impacts that are observed with coarse particles may not be found in sizes up to 2.5μm. Therefore, the health implications of coarse particles are sufficient enough to warrant their management. Substantial evidence implies that very tiny particles (≤2.5 μm) are extremely dangerous when it comes to fatalities and respiratory health effects in panel studies than coarse particles. The coarse proportion of PM10 however does not appear to be harmless. Many physical, biological and chemical attributes of PM were discovered to induce cardiovascular and respiratory reactions in most toxicological and controlled human exposure research. Metal content, presence of PAHs, other organic components, endotoxin and both small (< 2,5 μm) and extremely small (< 0,100 μm) PM are among the features observed to contribute to toxicity in epidemiological and controlled exposure studies.

2.8 Biomass fuel Use and Respiratory Defects

Air pollutants act on several host defense mechanisms against pathogens in the respiratory tract triggering oxidative stress, local and systemic inflammation, enhanced respiratory epithelial sensitivity and permeability, reduced macrophage reactions to microorganisms resulting in adhesion of microorganisms to the respiratory tract and bronchial irritation. These mechanisms vary by pollutant type and exposure magnitude. It has been noted that PM10 emitted from a combination of fossil and biomass fuels increases the ability of pneumococci to bind to human lower airway cells in vitro (Boldo et al., 2006; Penard-Morand et al., 2005).

Numerous animal studies have shown biological mechanisms of negative effects of air pollution on respiratory health. Hsu et al noted that when subjected to wood smoke, guinea pigs experienced broncho-constriction, and continuous exposures enhanced the reaction.

The instillation of PM produced from fossil fuel into mice's lower airways compromised phagocytosis and Streptococcus pneumonae clearance. During the infection, the quantity of ciliated and non-conciliated airway epithelial cells was decreased in a concentration-dependent way with increased lung pathogenesis. While some of these researches were not centred on indoor pollutants, it is rational to think that there is also a comparable pathology for IAP sources. (Bentayeb *et al*., 2013).

According to WHO reports, smoke exposure from the burning of solid fuel is listed as the leading environmental risk factor accountable for a global annual mortality rate of 3.3 percent. Many sources of outdoor and indoor air pollution are directly impacted by the selection of energy techniques and fuel usage, the energy efficiencies of household and transport systems, and energy transmission and distribution patterns. Preventing air pollution-related illnesses, therefore, rests on implementing appropriate sector policies that relieve air pollution (for example, energy and power generation, transport, industry, and agriculture).

CHAPTER THREE

3.0 METHODS

3.1 Overview

This gives description of the study area; La Nkwantanang Madina Municipality (Madina Zongo). It also outlines the methods used in the study, giving detailed descriptions of the Study design, study procedures, data collection tools, data analysis and ethical considerations.

3.2 Profile of the Study Area

Madina Zongo is a suburb of the La Nkwantanang Madina Municipal Assembly located in Accra Metropolis. It is an informal settlement with a densely populated community of about 38,515 and 797 households. La Nkwantanang Madina Municipal Assembly (LANMMA) was created on June 2012 by Legislative Instrument (L.I.) 2131. La-Nkwantanang-Madina Municipal with its Administrative capital **Madina** was drawn from the Ga East Municipal Assembly and is situated in the northern portion of the Greater Accra region. It is among the 16 Metropolitan, Municipal and District Assemblies in the Greater Accra region, covering 166 square kilometers of land area. It has on the west side the Ga East Municipal Assembly (GEMA), the Adentan Municipal Assembly (AdMA) on the east, the Accra Metropolitan Assembly (AMA) on the south and the Akwapim South District Assembly on the north. La Nkwantanang Madina Assembly is predominantly an urban municipality with rapidly evolving rural settlements into peri-urban settlements. The municipality has a large percentage of migrants because the Municipality used to be a cosmopolitan Municipality which drew migrants across the nation to the city in search of employment and financial prospects (GSS, 2014).

3.2.1 Brief description of the Study Area

Madina-Zongo in LANMMA, is subdivided into four different sections namely, Main Zongo, Washington, Libyan Quarters and UN, which comprises Chicago and SDA sub-sections. Madina-Zongo falls under the Madina West Electoral Area in the Municipality and is made up of mixed tribes including Akan, Ewe, Krobos Gonja, Dagomba, Wala, Akans, and Nzemas (LANMMA)

The dominant religion in the area is Islam. Educational attainment among people living in Zongo areas, in general, has been very low, compared to other communities in the Municipality. Majority of the Zongo people are traders and hustlers, who relocated from the Northern Region of Ghana and neighboring Benin, Togo, and Nigeria. In terms of housing conditions, the Madina-Zongo can only be described as livable, compared to other areas in the municipality. Madina-Zongo is described as congested and highly dense in population, a situation likely to have profound ramifications on sanitation in general. The continued influx of people into the area have had an outward demand shift for housing units, compelling some of the immigrants to settle in unplanned and makeshift dwelling units. These structures are constructed regardless of the serious implications they have on congestion, sanitation, and poor ventilation.

The primary financial operations in LANMMA, are Trade, agriculture, services, and manufacturing. Commerce is one of the main financial activities in the Municipality with the Madina market as the primary trading hub. The major agricultural activities are farming and livestock rearing. The livestocks are reared in the already congested households making the whole environment crowded.

Over half of the dwelling units are compound houses with shared facilities, while separate houses, improvised homes (kiosk/container, etc.). Huts/Buildings (different compound) are just but a few in the Municipality. The types of cooking fuel and cooking space used was reported, with the use of charcoal dominating in rural areas than urban while cooking was done more in the veranda and open spaces in the compound of households.

Approximately 60 percent of the homes in the Municipality occupied only one bedroom which was clear evidence of overcrowding. The relationship between family size and the number of rooms accessible for sleeping shows the extent of congestion in households. Congested rooms have health consequences as a result of, among others, disturbed sleep, infectious diseases, and respiratory infections. In spite, all these aforementioned there is no information on the air quality in LANMMA.

Figure 3.1: Map of the study area

3.3 Study Design

A household cross-sectional study was carried out at Madina Zongo community in the Accra Metropolis from May to June 2019 to assess the respiratory health of children under 15 years residing in households using biomass fuels. This was achieved by conducting an interview with a standardized respiratory health questionnaire to collect data on participant's socio-demographic (age, sex, household size, household structure, education and parent's occupation), life-style exposures (smoking, household fuel exposure, exposure duration, total amount and average whole life exposure), and state of respiratory health of the children. An interpreter was recruited to translate questions from English to their local language Hausa for easy understanding and to facilitate better communication. This was followed by conducting lung function tests by a professional for all participants using a spirometer. Average household air quality (particulate matter) was also measured for selected households.

3.4 Variables of Interest

Outcome Variables (Dependent variables): Respiratory Function Indices and Symptoms

- Forced expiratory volume over one second (FEV1), forced vital capacity (FVC), and FEV1/FVC ratio expressed as a percentage.
- Respiratory symptoms: Cough, chest pains, sore throat, wheezing, shortness of breath, palpitations, dizziness, phlegm production, itchy ear and throat

The explanatory variables (Independent variables):

- BMF exposure
- The covariates/Confounding variables: Age, sex , cigarette smoke exposure, household size, respiratory conditions such as asthma and socio-economic factors

such as educational level ,marital status, employment status, average annual income and education.

3.5 Determinants and Outcomes of Interest

The main determinants of interest included levels of particulate matter with an aerodynamic diameter of ≤ 10 μm (PM 1, 2.5, 4, 10) and total suspended particulate. The outcomes of interest were measures of lung function (e.g. FEV1, FVC, and FEV1/FVC) and respiratory symptoms including cough, cold, sore throat, sneezing, phlegm production, breathlessness, chest pain, wheezing, itchy ear, eyes, itchy throat conditions, chest tightness and difficulty in breathing. The confounding factors were age, sex, cigarette smoke exposure, educational level, home exposures and respiratory conditions such as asthma.

3.6 Study Procedures

The fieldwork was implemented in four (4) phases: (1) stakeholder meeting, (2) Community Survey (3) selection and recruitment of study participants (4) data collection and household air quality (PM) monitoring.

Phase 1: Stakeholder meeting: The Principal investigator together with the study team first visited the chief of Madina Zongo to inform him of the commencement of data collection and timelines. He introduced other opinion leaders who lauded the intentions of the study after the objectives had been declared and explained in detail. They then mentioned that an announcement has been made during one of their prayer sessions known as Jumu'ah in all the mosques about the study, therefore all households were patiently waiting for our arrival.

Phase 2: Community Survey: With permission given by the community leaders, the team together with the community guide appointed by the chief, embarked on a quick walk-through of the town to create awareness and familiarize with the people and surroundings.

We were taken to communities within Madina Zongo where BMF use was high such as madina zongo mosque area, Libya Quarters, and communities with low usage such as UN, and Washington down to Agbogba road. We noted times the children will be available, cooking times and availability of household heads. On average about 400 households were noted for BMF use.

Phase 3: Recruitment of Study Participants: The 400 households identified were visited by the research team. All household heads that consented to be a part of the study, as well as children that satisfied the inclusion criteria, were enrolled to partake in the study. However, household heads that were unwilling to give consent or children who had any history of respiratory defect were not allowed to take part in the study. A total of 200 households were selected.

Phase 4: Data Collection: The tools for data collection included a modified respiratory health questionnaire a spirometer to measure lung function indices and household air quality monitoring with a Met one Aerocet 831 particle counter. First, data on demography of Household heads (age, sex, household size, occupation, marital status, educational level, income, lifestyle exposures, and kitchen characteristics) were collected then their wards followed. All 400 study participants were interviewed by trained research assistants with the questionnaire in English for those comfortable with the English language and translated into the local language (Hausa) for those not able to communicate and understand the English too well. The questionnaire ascertained information on age, gender, type of fuel used, cooking practices and child exposure. There were also questions on experience of respiratory symptoms in the last 3 months. The principal investigator who is a nurse carried out the anthropometric measurements and with the assistance of a qualified technician, the lung function indices were measured using a portable spirometer. Participants after careful demonstration of the spirometry maneuvers, performed the spirometry maneuvers for at least three intervals to meet reproducibility criteria and the best efforts were used for the analysis. Fifty households were conveniently selected and concentrations Of PM $\leq$10 μm were monitored from 14:00 to 18:00 in the cooking area for the period of no cooking until cooking starts and at least one hour after cooking has ceased (4 -hour period). The particle counter was placed 0.5 m above the ground at a location distal to the cooking area during cooking, noting the wind direction and 1m away from the cookstove at a height close to the breathing zone. The monitor records real-time levels of particulate matter at a minute interval

3.7 Study Population

The study population were all children within age 5-15 years residing in households that use biomass fuels for their energy needs within Madina Zongo community, in the Accra Metropolis.

3.8 Eligibility Criteria

All the children who satisfied the inclusion criteria and whose parents gave consent and who assented to be part of the study.

3.8.1 Inclusion Criteria

All individuals within age 5-15 years residing in households within Madina Zongo community that use BMF were invited to participate in the enumeration exercise. As many as the number accepting to give informed consent by both parents and children were allowed to participate in the study.

3.8.2 Exclusion Criteria

All individuals within age 5-15 years residing in households within Madina Zongo community that use clean fuels as well as, Parents and children not willing or unable to understand or comply with study procedures were excluded. All children with the history of chronic or acute respiratory conditions such as asthma were also excluded.

3.9 Sample Size Calculation

From a total estimated children population in the La Nkwantanang district of 20,084 (between 5-15 years) at a confidence interval of 95%, and 5% margin of error, the minimum required sample size for the study was 392 using the formulae for population survey below:

$$n = \frac{N}{1 + N(e)^2}$$

Where N= total children population, n= sample size, e= margin of error.

Hence:

$$n = \frac{20084}{1 + 20084(0.05)^2}$$

$= \frac{20084}{51.21} = 392.20$

However, to ensure high statistical power (between 80-90%) and a representative sampling from a total of 797 households in the community, a sample size of 400 was used.

3.10 Sampling Method

A mixed sampling method was used for selecting the study participants. The first stage of sampling included a selection of households in the community using systematic sampling. The first house in the community was visited and afterward every fifth house until the last house. The second stage of sampling was an uncontrolled quota sampling method where participants were selected at the researcher's discretion. Sampling convenience was used based on the usage of BMF use in the household and the availability of participant's parent at the time the research team visited the household. Two hundred (200) households were included with a total of two people from each household representing a quota (One girl, one boy).

3.11 Data Collection Tools

Different data collection tools were used in collecting the data. These were a modified respiratory questionnaire, a Spirometer for measuring pulmonary function, a seca stadiometer with an incorporated weighing scale for measuring anthropometric characteristics (weight and height) and Aerocet 831 designed by met one technologies was used to collect by minute concentrations of particulate matter data.

3.11.1 Questionnaire

A modified respiratory questionnaire was used to obtain information on participants in a face-to-face interview. The questionnaire was in four parts. The first part sought to gather demographic and personal data of the Household head such as age, gender, household size, household structure, education, occupation, marital status (single, married, De-facto) and the number of years lived in Madina Zongo. Part 2 asked information on the demography of child (age, gender, nutritional status and history of respiratory defect). Part 3 was about lifestyle exposures such as smoking, cooking practices and child exposure, kitchen characteristics, exposure duration, total amount and average whole life exposure. The final part assessed the respiratory health of the child (cough, cold, sore throat, sneezing, phlegm production, itching eyes, wheezing, difficulty in breathing and shortness of breath).

3.11.2 Measurement of Weight, Height and Body Mass Index

Anthropometric measurements were taken using Seca stadiometer with an incorporated weighing scale. The participants' weights were recorded in kilograms (kg), whilst wearing their indoor clothes, but without their shoes. Their heights were also measured with their feet together, heels against the stadiometer, standing as tall and straight as possible, and recorded in centimetres (cm). The body mass index of each child was determined by dividing their weight in kilograms by a square of their height in metres.

3.11.3 Assessment of Lung Function by Spirometry

Each child underwent Spirometry to assess their lung function using Easy One Spirometer. The spirometer Easy One utilizes digital ultrasonic flow measuring technology that delivers precise outcomes, repeatable performance and quality control without the movement of its parts and does not demand daily calibration.This battery-powered equipment comes with disposable mouthpieces (Spirette) Forced Vital Capacity (FVC) and Forced Expiratory Volume over one second (FEV1) and FEV1/FVC ratio were measured according to the American Thoracic guidelines (Miller & Enright, 2012). Standing height in centimeters and weight in kilograms were measured before the performance of the lung function test. Measurement of stature is a necessity for determining normal lung function and reference equations are dependent on stature (standing height). The individual weight and height of each child were taken while wearing their indoor clothes, without their shoes, with their feet together and heels against the stadiometer standing tall and erect and the shoulders in an upright position. Participant's details such as name, weight, height, gender, date of birth, ethnicity are entered into the spirometer. After data entry, the participants were instructed to inhale and have their lips sealed around the spirometer's mouthpiece, and then exhale as fast and as forcefully as they could over at least a 6- second period through the mouthpiece of the spirometer to measure forced vital capacity, vital capacity and maximum ventilation volume. The FVC, FEV1 and FEV1/FVC and percentage of predicted values are then automatically stored on the spirometer. Computation of lung function volumes was based on variations in the height, weight, sex and respiratory history of respondents. Participants with FEV1/FVC ratio <0.85 were considered as having reduced lung function (Vogt *et al.*, 2014).

3.11.4 Monitoring of Household Air Quality

Air quality of the household specifically the cooking area was measured using a Met One Aerocet 831 particle counter. The portable Aerocet 831 operates by counting individual particles using scattered laser light and simultaneously provides five important mass ranges in one minute Particulate matter (PM) 1, PM 2.5, PM 4, PM10 and total suspended particulate matter (TSP) . The particle counter was placed 0.5 m above the ground at a location distal to the cooking area for the period of no cooking until cooking starts and at least one hour after cooking has ceased for a four-hour period, noting the wind direction and 1m away from the cook stove at a height close to the breathing zone. The monitor records real-time levels of particulate matter at a minute interval. Cooking in most of the households is done in verandas or open space, which is usually the middle of the compound house. More time is spent by the children in this location after school. They are mostly found playing and helping their mothers in the performance of house chores.

3.12 Quality Control

The following measures were taken to guarantee that the data collected was of superior quality to assure its validity: The three Research assistants who were health personnel (Nurses and Laboratory technician) and are also fluent in Hausa, Twi and Ga were adequately trained in questionnaire administration, Spirometry performance and air quality monitoring. The principal researcher was actively involved in and also ensured thorough supervision of the data collection procedures to avoid any deviation from the protocol. The purpose and nature of the study were fully explained to the parents and participants to gain their committed involvement. All the completed questionnaires were given unique identification numbers to help trace every information. The spirometer was disinfected with mild soapy solution before and after daily use and kept dry and clean. Every document was handled and stored in a safely and confidentially. All the data sheets were signed and filed by the appropriate research assistants. The data was stored on an external storage device and rights to the information was restricted to the principal investigator.

3.13 Data Management

3.13.1 Data Processing

The Data was crossed checked to identify missing values and to correct inconsistencies. Each questionnaire was coded, for example, 001, 002, 003, etc. to help avoid double entry and easy verification of any detected error. Data was organized in Microsoft Excel and analysed using SPSS statistical software version 25.

3.13.2 Data Analysis

Categorical data were presented using frequency and compared using Chi-square while continuous variables were presented as mean and compared using t-test. Intensity of BMF exposure was determined as a calculated score from BMF use and exposure. Scores were dichotomised in high and low exposure where distribution of respiratory conditions was determined across the categories. A statistical model (stepwise regression) was used to predict household biomass fuel use and its effect on respiratory health after controlling for potential confounders.

3.14 Ethical Consideration

Ethical clearance was sought from the Noguchi Memorial Institute for Medical Research Ethical Review Board before the commencement of the study. Permission was obtained from the chief and opinion leaders in the community and parents of children involved after the objectives and the methodology of the study had been explained to them. The Children's assent was also sought for before they were enrolled in the study.

They were informed that they had the liberty to ask questions and to seek clarifications or opt-out of the study at any point in time. The participants were assured of confidentiality and privacy. This was ensured during data collection and processing. Children with abnormal Spirometry results that required medical attention were counseled and referred to the hospital for further attention and management.

CHAPTER FOUR

4.0 RESULTS

4.1 Demographic characteristics of study households

The basic features of the households included in the study are presented in **Table 4.1.** The mean age of the study subjects was 9.2 (±2.6) years. Most of the children were aged between 5-10 years (61.8%) and 11-15 years age bracket were 37.9%. Study involved 208 (51.9%) males and 192 (48.1%) females. Majority, 288 (72.0%) of the children were malnourished and only 1.0% were overweight. The mean BMI of the children was 17.5±2.7. None of the children had chronic respiratory defects.

Majority of the household heads of the study area were males (86.0%) with a mean age of 39.4±12.5. Most (64.0%) were full-time employees and had no formal education (60.0%). All the household heads were married (100.0%). The average income of most of the household heads was <500 cedis (78.0%). There was no cigarette smoker in any of the households (100.0%). About 62.0% of the households consisted of members above 6 and the average family size was 7.7±3.1. The average time spent in the community by household heads was 14.4±8.6.

Table 4.1 Demographic characteristics of the study households

Child demographic	Category/response	Frequency (N)	Percentage (N)
Age (years)	**9.2±2.6***	-	-
	5-10 years	248	61.8
	11-15 years	152	37.9
Sex	Male	208	51.9
	Female	192	48.1
	Child in School	400	100.0
	Child not in School	0	0
Weight (Kg)	**130.4±16.0**		
Height (m)	**31.7±12.2**		
Nutritional status (BMI, Kg/m^2)	**17.5±2.7***		
	Underweight	288	72.0
	Normal weight	25	25.0
	Overweight	4	1.0
	Missing	8	2.0
History of respiratory defect	No	400	100.0
Household head			
Sex	Male	344	86.0
	Female	56	14.0
Employment	Full-time	256	64.0
	Part-time	72	18.0
	Unemployed	72	18.0
	No formal education	240	60.0
Level of education	Basic education	80	20.0
	Secondary	48	12.0
	Tertiary	24	8.0
Marital Status	Married	400	100.0
Average annual income (Cedis/monthly income)	<500	312	78.0
	501-1000	56	14.0
	1001-1500	8	2.0
	>1500	24	6.0
Household size	3-4	72	18.0
	5-6	80	20.0
	>6	248	62.0
Family size*	7.7±3.1	-	-
Age of household head*	39.4±12.5	-	-

*All values are presented as frequencies and percentages unless otherwise specified. * Values are presented as means and standard deviations*

4.2: Type of biomass fuel used by households

All (100.0%) of the households routinely used charcoal (a BMF) for cooking and heating. About 24.5% of the households used Agric crop residue and only 2.0% used firewood (Figure 4.1)

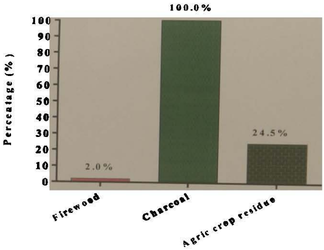


Figure 4.1: Type of biomass fuel used by the participating households

Figure 4.2: Type of biomass fuel and cooking technologies used by the participating households

a, e, f, g -Charcoal

b, c- Firewood

d - Agric. Residue / charcoal

4.2 Household cooking characteristics

The cooking characteristics of households is shown in **Table 4.2**. The median duration of charcoal usage was 10.0 (5.0-17.0 interquartile range). About 92 (28.4%) of the households have used charcoal for more than 15 years, 90 (27.8%) have used it for a period between 10-12 years. Median charcoal usage per week was 5.0 (2.0-7.0) and most 164 (41.0%) of the households use charcoal seven times a week. Majority of the study participants (70.5%) use charcoal 1-4 hours on average in a day. With regard to type of cooking facility, 68.0% use open space cooking facility and 32.0% use enclosed space cooking facility. The median closeness of kitchen to living room was 3.0 meters (3.0-5.0 interquartile range).

Table 4.2 Household cooking characteristics

Variable	Category/response	Frequency (N)	Percentage (%)
Median duration of charcoal usage (n=324)	**10.0 (5.0-17.0)***	-	-
	<3 years	44	13.6
	3-6 years	44	13.6
	7-9 years	20	6.2
	10-12 years	90	27.8
	12-15 years	34	10.5
	>15 years	92	28.4
Median charcoal usage per week	**5.0 (2.0-7.0)***	-	-
	Once	2	0.5
	Twice	100	25.0
	Thrice	34	8.5
	Four times	58	14.5
	Five times	34	8.5
	Six times	8	2.0
	Seven times	164	41.0
Average usage of charcoal per day	0-15 mins	2	0.5
	16-59 mins	72	18.0
	1-4 hours	282	70.5
	5-8 hours	44	11.0
Type of cooking space	Open	272	68.0
	Enclosed	128	32.0
Closeness of kitchen to living room	**3.0 (3.0-5.0)***	-	-

All values are presented as frequencies and percentages unless otherwise specified. * Values are presented as median (interquartile range).

4.3 Exposure characteristics of children to BMF

Children on the average spend 2-4 days (48.0%) or 5-7 days around their mothers when cooking. About 79.5% of the children are exposed to BMF on average between 1-4 hours within a day. The average years of exposure of children to BMF from birth were 8.10±3.02). Average exposure rate to BMF score was 10.04±1.80. Most (66.5%) of the children had an exposure score 10 and above.

Table 4.3 Exposure characteristics of children to BMF

Variable	Category/response	Frequency (N)	Percentage (%)
Average number of days child is around during cooking	One day	2	0.5
	2-4	192	48.0
	5-7	198	49.5
	unanswered	8	2.0
Average duration per day child is around during cooking	0-15 mins	8	2.8
	16-59mins	58	14.5
	1-4 hours	318	79.5
	5-8 hours	8	2.0
	Unanswered	8	2.0
Average years of exposure			
	8.10±3.02*		
	3-4 years	62	15.5
	5-6 years	98	24.5
	7-8 years	52	13.0
	9-10 years	84	21.0
	>10 years	104	26.0
Average exposure score	**10.04±1.80***	-	-
	<10	134	33.5
	≥10	266	66.5
BMF exposure index of the children	**29.14±14.92**		
	T1 (<24)	126	31.5
	T2 (24-40)	178	44.5
	T3 (>40)	96	24.0

*All values are presented as frequencies and percentages unless otherwise specified. * Values are presented as mean and standard deviation. T1-lower tertile, T2-middle tertile, T3 upper tertile*

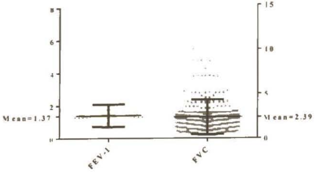
4.4 Self-reported respiratory symptoms of children

Self-reported respiratory symptoms of the study participants is presented in **Table 4.4.** Occasional dry cough was prevalent among 71.8% of the children and 4.2% of the children reported of persistent dry cough. Itchy and watery eyes, sore throat, excessive phlegm was reported by 79.5%, 71.5% and 62.0% of the children. The least signs reported among the children were wheezing (2.0%), shortness of breath (7.0%), difficulty breathing (5.3%) and chest tightness (0.5%). Cold was the most reported respiratory symptoms reported among the children. Fifty-six percent of the children indicated that their respiratory symptoms is corrected when away from BMF source.

Table 4.4 Self-reported respiratory symptoms of children

Sign/symptoms	Category/response	Frequency (N)	Percentage (%)
Cough	No	96	24.0
	Persistent dry cough	17	4.2
	Occasional dry cough	287	71.8
Colds	No	40	10.0
	Yes	360	90.0
Repeated sneezing	No	122	30.5
	Yes	278	69.5
Easy tiredness	No	254	63.5
	Yes	146	36.5
Chest pains	No	232	58.0
	Yes	168	42.0
Sore throat	No	114	28.5
	Yes	286	71.5
Excessive phlegm	No	152	38.0
	Yes	248	62.0
Itchy ears and throat	No	122	30.5
	Yes	278	69.5
Itchy and watery eyes	No	82	20.5
	Yes	318	79.5
Wheezing	No	392	98.0
	Yes	8	2.0
Shortness of breath	No	372	93.0
	Yes	28	7.0
Difficulty in breathing	No	379	94.7
	Yes	21	5.3
Chest tightness	No	398	99.5
	Yes	2	0.5
Do these symptoms stop when you are away from BMF source	No	176	44.0
	Yes	224	56.0

Results of Spirometry is presented in **Figure 4.2**. The mean FEV1 of the children was 1.37 which ranged from 0.28 to 6.49. Also the range of values obtained for FVC among the children was 0.38-10.07 with an average of 2.39. The ratio of FEV1 to FVC ranged from 12.70% to 100.0% with an average value of 69.78 (**Figure 4.2**).



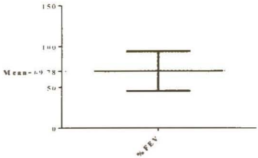


Figure 4.3 Lung function parameters among children studied

The result of lung function defined by FEV1 to FVC ratio <85% is presented in **Figure 4.3**. A higher percentage (60.5%) of the children presented with reduced lung function and 39.5% were normal.

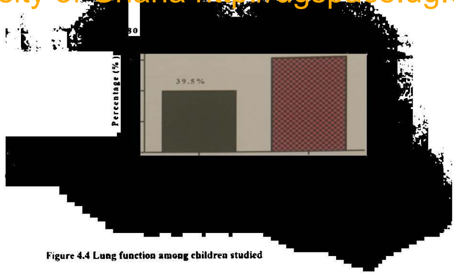


Figure 4.4 Lung function among children studied

4.5 Association of Child BMF exposure to lung function indices

The average BMF exposure rate score and duration of BMF exposure showed a significant positive association with FEV1 (r=0.36 and 0.55), FVC (r=0.19 and 0.26) and FEV1/FVC ratio (r=0.17 and 0.15), respectively. Average BMF exposure rate score accounted for 13.0%, and 3.0% of the variations observed in FEV1, FVC and its ratio measurements among the children. The highest variation in FEV1 measurements among the children was observed for duration of BMF exposure (r^2=0.20). About 7.0% and 2.0% of the observed variation in FVC and FEV1/FVC ratio was accounted for by duration of BMF exposure (Table 4.6).

Table 4.5 Association of BMF exposure and lung function indices

Variable		Average exposure rate score	Duration of exposure	Exposure Index
FEV1	β (SE)	0.14 (0.018)	0.12 (0.009)	0.01 (0.002)
	R^2	0.13	0.30	0.096
	R	0.36	0.55	0.31
	P-value	<0.0001	<0.0001	<0.0001
FVC	β (SE)	0.20 (0.053)	0.17 (0.031)	0.02 (0.006)
	R^2	0.03	0.07	0.03
	R	0.19	0.26	0.18
	P-value	<0.0001	<0.0001	<0.0001
FEV1/FVC	β (SE)	2.3 (0.668)	1.25 (0.399)	0.25 (0.081)
	R^2	0.03	0.02	0.03
	R	0.17	0.16	0.16
	P-value	**0.001**	**0.002**	**0.002**

4.6 Association between average child exposure to BMF and respiratory function

The association between average BMF exposure and respiratory symptoms is shown in **Table 4.6.** A higher average exposure rate score was significantly associated with the increased likelihood of persistent dry cough (aOR= 8.51, p-value =0.039), repeated sneezing (aOR= 1.97, p-value =0.003), itchy and watery eyes (aOR= 4.35, p-value<0.0001), shortness of breath (aOR= 3.22, p-value<0.034) and difficulty breathing (aOR= 9.21, p-value<0.028) after adjusting for age, gender, and socioeconomic status (educational level of household head and average annual income).

Table 4.6 Association between average child exposure to BMF and respiratory function

Respiratory symptoms	BMF exposure rate score		aOR (95% CI)	P-value
	<10 (n=134)	≥10 (n=266)		
Persistent dry cough	1 (0.7)	15 (6.0)	8.51 (1.12-64.89)	**0.039**
Occasional dry cough	98 (73.1)	114 (42.9)	0.73 (0.45-1.17)	0.194
Colds	122 (91.0)	238 (89.5)	0.84 (0.41-1.70)	0.621
Repeated sneezing	80 (59.7)	198 (74.7)	1.97 (1.26-3.0)	**0.003**
Easy tiredness	58 (43.3)	88 (33.1)	0.65 (0.42-0.99)	**0.046**
Chest pains	54 (40.3)	114 (42.9)	1.11 (0.73-1.70)	0.625
Sore throat	90 (67.2)	196 (73.7)	1.37 (0.87-2.15)	0.174
Excessive phlegm	76 (56.7)	172 (64.7)	1.40 (0.91-2.13)	0.123
Itchy ears and throat	88 (65.7)	190 (71.4)	1.31 (0.84-2.04)	0.238
Itchy and watery eyes	84 (62.7)	234 (88.0)	4.35 (2.62-7.24)	**<0.0001**
Wheezing	2 (1.5)	6 (2.3)	1.52 (0.30-7.65)	0.609
Shortness of breath	4 (3.0)	24 (9.0)	3.22 (1.10-9.49)	**0.034**
Difficulty in breathing	1 (0.7)	18 (6.8)	9.21 (1.29-73.71)	**0.028**
Chest tightness	0	2 (0.8)	NC	-

As shown in **Figure 4.4 and 4.5**, there was a significant difference in the Spirometry results for the different BMF exposure rate category. The mean values of FEV1 and FVC for children with scores 10 or more was higher compared with those with scores <10. These differences was not observed for FEV1/FVC ratio.

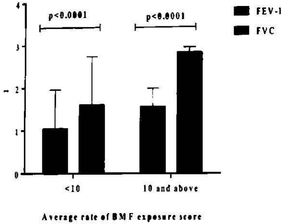


Figure 4.5 Association between lung function parameters and average BMF rate of exposure score

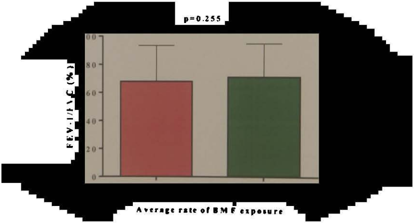


Figure 4.6 Association between lung function parameters and average BMF rate of exposure score

4.7 Association between BMF exposure index and respiratory health of the children

The prevalence of persistent dry cough was significantly associated with BMF exposure index tertiles (χ^2=6.17, p-value =0.046). Also, the prevalence of repeated sneezing increases with increasing tertile of the BMF exposure index. A major percentage of children with scores within the upper tertile had symptoms of repeated sneezing, chest pains, itchy ears and throats, and itchy and watery eyes compared with the lower tertile. Thus, BMF exposure index was significantly associated with these symptoms (p-value <0.0001). As shown in Figure 4.5, FEV-1 and FEV-1/FVC ratio increases with increasing tertiles of BMF exposure index.

Table 4.7 Association between BMF exposure index and respiratory health of the children

Respiratory symptoms	BMF exposure index			χ^2	P-value
	T1	T2	T2		
Persistent dry cough	2 (1.6)[a]	7 (3.9)[a,b]	8 (8.3)[b]	6.17	**0.046**
Occasional dry cough	100 (79.4)	121 (68.0)	66 (68.8)	5.28	0.071
Colds	112 (88.9)	164 (92.1)	84 (87.5)	1.74	0.419
Repeated sneezing	76 (60.3)[a]	122 (68.5)[a]	80 (83.3)[b]	13.76	**0.001**
Easy tiredness	52 (41.3)[a]	40 (22.5)[b]	54 (56.3)[a]	32.51	**<0.0001**
Chest pains	58 (46.0)[a]	40 (22.5)[b]	70 (72.9)[c]	66.38	**<0.0001**
Sore throat	96 (76.2)[a]	110 (61.8)[b]	80 (83.3)[a]	16.18	**<0.0001**
Excessive phlegm	78 (61.9)[a]	90 (50.6)[a]	80 (83.3)[b]	28.43	**<0.0001**
Itchy ears and throat	86 (68.3)[a]	104 (58.4)[a]	88 (91.7)[a]	32.64	**<0.0001**
Itchy and watery eyes	82 (65.1)[a]	142 (79.8)[b]	94 (97.9)[c]	36.07	**<0.0001**
Wheezing	2 (1.6)	6 (3.4)	0	3.78	0.151
Shortness of breath	2 (1.6)	10 (5.6)	16 (16.7)	19.97	**<0.0001**
Difficulty in breathing	3 (2.4)	8 (4.5)	8 (8.3)	4.22	0.121
Chest tightness	2 (1.6)	0	0	4.37	0.112

T1-lower tertile, T2-middle tertile, T3 upper tertile

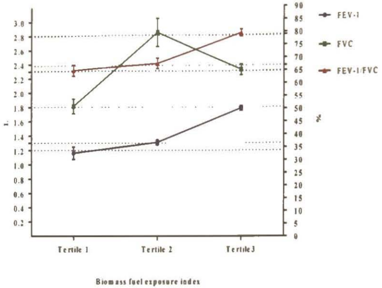


Figure 4.7 Association between BMF exposure index and respiratory health of the children

4.8 Air Quality monitoring in the households

Levels of particulate matter with an aerodynamic diameter ≤2.5 µm ($PM_{2.5}$) were recorded over a continuous 4-hour duration in selected households (n = 50) using a Met one Aerocet 831 particle counter from which mean 24-h $PM_{2.5}$ (µg/m^3) was obtained. The results from all 50 households which had at least 3 hours: 30mins data is presented in Table 4.9. The mean peak $PM_{2.5}$ was 141.16. Also, the mean average $PM_{2.5}$ was 39.01 which was similar to the reference value in Ghana (Figure 4.8). The mean peak PM_{10} was 594.97. Also, the mean average PM_{10} was 150.43 higher than the reference value in Ghana and WHO standard (**Figure 4.8**).

Table 4.8 Air Quality monitoring in the study households

Particulate matter	Mean	SEM	Min	Max
Peak PM_1	54.73	5.29	16.9	148.2
Average PM_1	21.38	2.07	13.24	76.45
Peak $PM_{2.5}$	141.16	23.50	26.67	694.20
Average $PM_{2.5}$	39.01	3.19	20.88	123.31
Peak PM_4	195.20	32.43	47.02	999.50
Average PM_4	73.50	5.30	31.65	172.80
Peak PM_{10}	594.97	100.60	111.30	3207.20
Average PM_{10}	150.43	9.68	61.76	307.44

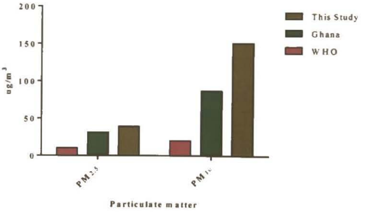


Figure 4.8 Comparison of particulate matter obtained in this study to reference data

4.9 Association between lung function and particulate matter

The association between particulate matter and lung function is presented in Table 4.9. Peak $PM_{2.5}$ but not average had a significant positive correlation to FEV1/FVC ratio (r= 0.376, p-value=0.007). Also, peak PM_1 and PM_4 showed a significant positive correlation to FEV1/FVC ratio. Average PM_{10} showed significant positive correlation to FEV1 (r=0.324, p-value = 0.020).

Table 4.9 Association between lung function indices of the study subjects and particulate matter

Lung function indices	Statistics	FEV1	FVC	FEV1 FVC
Peak PM_1	R	0.157	-0.186	0.376
	P-value	0.271	0.191	**0.007**
Average PM^1	R	0.223	-0.008	0.129
	P-value	0.116	0.956	0.365
Peak $PM_{2.5}$	R	-0.054	-0.230	0.306
	P-value	0.707	0.105	**0.029**
Average $PM_{2.5}$	R	0.158	-0.099	0.173
	P-value	0.270	0.488	0.224
Peak PM_4	R	-0.098	-0.250	0.310
	P-value	0.496	0.077	**0.027**
Average PM_4	R	**0.493**	0.191	0.006
	P-value	0.000	0.179	0.967
Peak PM_{10}	R	-0.018	-0.138	0.233
	P-value	0.900	0.333	0.100
Average PM_{10}	R	0.324	0.080	0.007
	P-value	**0.020**	0.576	0.962

4.10 Association between respiratory symptoms and Particulate matter

A shown in **Table 4.10**, a unit increase in peak $PM_{2.5}$ was significantly associated with increased likelihood of cold symptoms (OR =1.08). Also a unit increase in average $PM_{2.5}$ was associated with increased odds of repeated sneezing, and easy tiredness. Moreover, a unit increase in peak PM_{10} was associated 3%, 2% and 1% increased chances of excessive phlegm, itchy ears and throat and chest tightness, respectively.

Table 4.10 Association between respiratory symptoms and Particulate matter

Respiratory symptoms	Particulate matter			
	Peak $PM_{2.5}$	Average $PM_{2.5}$	Peak PM_{10}	Average PM_{10}
Occasional dry cough	1.01 (0.93 to 1.08)	1.29 (0.71 to 2.32)	1.02 (1.0 to 1.04)	0.96 (0.89 to 1.04)
Colds	1.08 (1.02 to 1.15)*	1.20 (0.94 to 1.52)	0.99 (0.98 to 0.99)*	0.97 (0.94 to 1.01)
Repeated sneezing	1.02 (1.0 to1.05)	1.11 (1.03 to1.21)*	1.0 (0.99 to 1.00)	0.95 (0.90 to 0.99)*
Easy tiredness	1.01 (1.0 to 1.03)	1.11 (1.01 to 1.22)*	1.0 (0.99 to 1.00)	0.96 (0.93 to 0.99)*
Chest pains	1.0 (0.98 to 1.02)	0.98 (0.89 to 1.07)	1.0 (1.0 to 1.01)	1.01 (1.0 to 1.03)
Sore throat	1.0 (0.98 to 1.02)	1.02 (0.92 to 1.12)	1.00 (1.0 to 1.01)	0.99 (0.98 to 1.01)
Excessive phlegm	0.96 (0.91 to 1.02)	0.93 (0.85 to 1.02)	1.03 (1.0 to 1.05)*	0.97 (0.94 to 1.01)
Itchy ears and throat	0.97 (0.93 to 1.02)	0.95 (0.89 to 1.03)	1.02 (1.0 to 1.04)*	0.98 (0.95 to 1.01)
Itchy and watery eyes	NC	NC	NC	NC
Wheezing	NC	NC	NC	NC
Shortness of breath	NC	NC	NC	NC
Difficulty in breathing	NC	NC	NC	NC
Chest tightness	0.99 (0.97 to 1.01)	1.0 (0.94 to 1.06)	1.01 (1.0 to 1.02)*	1.0 (0.97 to 1.00)

*NC- not computed; * value represent statistically significant values*

CHAPTER FIVE

DISCUSSION

5.1 Demography of the study Household and biomass fuel usage

From the findings of this study, charcoal was the major type of BMF used by the household (100%), followed by agriculture product residues (24.5%) and firewood (2.0%). In most poor settings, wood and charcoal are the primary sources of BMF, but the use of animal dung and agricultural residues is also commonplace (Bruce et al., 2000). Factors including energy cost, household size, daily cooking frequency, and age of household head determine the choice and type of biomass energy consumption. This study demonstrated, that, generally the households representing the study area have poor socio-economic status. A higher percentage of the household heads were not formally educated (about 60%) or earn an annual income was < 500 cedis (about 78% of the total household studied). A study by Gatama and Planning (2014), demonstrated that the family head's educational level influenced the type of energy used by the household where those with lower education status tend to use less clean fuels. Also, a study by Mekonnen and Köhlin (2009) demonstrated that the family heads ' educational attainment tend to have an inverse proportional relationship with usage and demand of less clean fuels. Thus, those who are educated up to the university level are less likely to use firewood or charcoal whiles house heads with lower education status have a higher demand for charcoal, kerosene, and firewood. These findings are in accordance with this present study results. Other factors that have been outlined in literature to affect BMF use which was common among the surveyed households were low annual income, a family size of more than six and an average cooking time of 6 times a week. One unique finding was that the mean age of the household heads was 39.4 years.

This is inconsistent with the fact that younger household heads (<40 years) show a preference for wood based fuels.

5.2 Households Air Quality and cooking Characteristics

The mean peak $PM_{2.5}$ obtained in this study was 141.16 μg/m³ and was associated with cold, repeated sneezing and lung function. This value obtained in this study is 4.5 times higher than the annual mean concentrations of 31.1 μg/m³ reported in Ghana and 14 times higher than the WHO annual recommended guideline of 10 μg/m³. Compared with the WHO annual recommended guideline (20 μg/m³), the mean PM_{10} values obtained in this study was 25 times higher. The mean peak PM_{10} was 594.97 and was associated with respiratory symptoms of excessive phlegm, itchy ears and throat, and chest tightness. Moreover, the mean average PM_{10} was 150.43. Significantly higher PM concentrations have been measured in similar studies (Rajagopalan, Al-Kindi, & Brook, 2018; Terzano et al., 2010). It is estimated that developing countries contribute as much as 80% of total indoor airborne PM worldwide (M. Ezzati & Kammen, 2002).

5.3 Effect of Biomass exposure on respiratory symptoms of children

Respiratory symptoms were self-reported without further clinical evaluation, which may have the limitation of misclassification. It has been shown that individuals from low-income countries often consider some respiratory symptoms such as cold, wheeze, breathlessness and bringing out phlegm as ordinary which might have caused under-reporting of symptoms and if this was differentially expressed between duration categories this may underestimate the real danger. Moreover, some terminologies for respiratory symptoms in the Ghanaian society have names which define the source of the symptoms other than what is known in literature. Besides these limitations, the study was strengthened by the adjustment for confounders, often insufficiently handled in previous studies.

This study demonstrated that children within the Madina Zongo community manifest one or more respiratory symptoms which had a significant association with Average BMF exposure score and BMF exposure index. Persistent dry cough was significantly associated with higher BMF exposure score (10 and above) and increases with increasing tertile of BMF exposure index. Similar association was observed between the prevalence of symptoms of repeated sneezing, easy tiredness, chest pains, and sore throat, and excessive phlegm production, shortness of breath, itchy ears and throat, as well as itchy and watery eyes with BMF exposure index. This observation is in line with the reports of Kurmi et al. (2014), who reported similar results. Previous studies on the effect of BMF use and child respiratory health are focused exclusively on populations using varying kinds of biomass fuel, at different durations. Hence, making comparisons of these findings to previous findings complicated particularly, when confounding variables are ineffectively resolved. Moreover, to the understanding of the author, few number of studies have reported on the association between child respiratory symptoms, average BMF exposure score and BMF exposure index especially among the age group considered in this study (5-15 years). However, considering the pathophysiology of these symptoms, the early exposure of children to BMF (average exposure age of 1 year), lack of secondary smoking sources like cigarette and the location of the community free from dusty pollution, the associations observed in this study is a reflection of reality.

5.4 Association between Lung Function and Child BMF Exposure

About 65.0% of the children seemed to have reduced lung function defined by FEV_1/FVC ratio <85% (Vogt, Falkenberg, Weiler, & Frerichs, 2014). This observation was observed to be associated with exposure of children to BMF for a longer duration and at a higher concentration. A direct positive correlation was observed for lung function indices FEV1, FVC and FEV1/FVC ratio and BMF exposure duration, average BMF score and BMF exposure index. Long-term environmental exposure to present levels of ambient biomass fuel (particulate matter) leads to a significant decrease in lifespan. This decrease in lifespan is mainly due to an increase in cardiopulmonary and lung cancer fatalities that are probable in lower respiratory symptoms and decreased lung function in children. There are numerous reports (Viegi, Maio, Pistelli, Baldacci, & Carrozzi, 2006): (Kim et al., 2005);(Zhang & Smith, 2007)) jointly indicating that chronic inhalation of biomass smoke may result in lung obstruction, inflammation, and oxidative stress associated with chronic obstructive pulmonary diseases, particularly asthma. Although limited studies in children exist to compare our findings with, it is in line with evidence from literature.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

1. The study reported respiratory symptoms, including persistent dry cough, repeated sneezing, easy tiredness, chest pains, and sore throat, and excessive phlegm production, shortness of breath, itchy ears and throat, as well as itchy and watery eyes are common among children living in the Madina Zongo.
2. Reduced lung function was observed at a higher percentage (60.5%) among many children within the Madina Zongo community
3. Respiratory symptoms and reduced lung functions shows a positive trend with BMF use. That is, a higher average exposure rate to BMF was more associated with respiratory symptoms.
4. Peak and average $PM_{2.5}$ were associated with respiratory symptoms of cold, repeated sneezing and easy tiredness

6.2 Recommendations

1. It is recommended that awareness and preventive programs on indoor air pollution and effect on children's respiratory health should be designed and advocated for Zongo communities in Ghana.

2. There is also the need for regional and national policies aimed at reducing indoor air pollution through the use of cleaner technologies. Finally, the study must be conducted on a population with a larger sample size to improve the study outcomes.

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APPENDICES

Appendix 1: Questionnaire for Health Status

(NOTE: THE QUESTIONNAIRE WILL BE ADMINISTERED BY STUDY PARTICIPANTS WITH ASSISTANCE FROM VOLUNTEERS ON HARD COPY BEFORE AND DURING THE VISIT)

ID ______________

Date ______________

1 **Demography of Household Head**

Instruction: The section includes multiple-choice and completion questions. For multiple-choice questions, please tick the box. For completion questions, please fill in the line.

1.1	Age	
1.2	Sex	□ Male □ Female
1.3	Family size	________
1.4	Employment (Please fill in the blanks following the choice of status)	Employed: □ Full-time □ Part-time Current occupation or position (e.g. Manager) : ____________ Primary work experience in the past (if different from above) : ________ □ Unemployed □ Retired Last job occupation or position : ____________ Primary work experience in the past (if different from above) : ________
1.5	Education level	□ No Formal Education □ Primary school □ Junior High school □ Senior High school □ University □ Postgraduate or higher
1.6	Marital status	□Single □Married □Widowed □Divorced □Separated □De facto
1.7	Average annual total household income before tax	*All figures in Ghana cedis* □Less than 500 □ 501 to 1000 □1001 to 1500 □1501 to 2000 □2001 to 2500 □More than 2500 □Prefer not to say
1.8	Number cigarette smokers in the house	□ None □3-4 □ 1-2 □>4
1.9	What is the total number of people living in your household?	□ 1-2 □3-4 □ 4-6 □>6
1.10	How many years have you lived in this community?	Record as mentioned:

2 **Demography of Child**

Instruction: This section includes multiple-choice and completion questions. For multiple-choice questions. please tick the box. For completion questions, please fill in the line.

2.1	Age	____,__,__
2.2	Sex	▫ Male ▫ Female
2.3	Nutritional status	Height ………………cm Weight…………… Kg BMI……………………
2.4	History of respiratory defect?	▫ Yes ▫ No If yes, what type: -- ---------

3 **Lifestyle and Cooking**

Instruction: This section includes multiple-choice and completion questions. For multiple-choice questions, please tick the box. For completion questions, please fill in the line.

3.1 Cooking practices		
3.1.1	Type of biomass fuel use	▫ wood/Firewood How long: ------------------ ▫ Charcoal How long: ----------------------- ▫ Animal dung How long: ---------------------- ▫ Agricultural crop residue How long: -----------------------
3.1.2	How many times in a typical week on average do you use BMF?	▫ Less than one ▫ Once ▫ Two times ▫ three times ▫ Four times ▫ Fife times ▫ Six times ▫ Seven times
3.1.3	What is the average duration per day you are passively exposed to BMF smoke?	▫ 0~15min ▫ 16~59min ▫ 1~4hours ▫ 5~8hours ▫ 9~12hours ▫ >12hours
3.1.4	How close is the kitchen to your living room	--------------------------------

3.2 Cooking Practices and Child exposure		
3.2.1	How many days in a week is your child around you when cooking?	▫ One day ▫ 2-4 days ▫ 5-7 days ▫ None
3.2.2	What is the average duration per day when your child was with you when cooking?	▫ 0~15min ▫ 16~59min

		□ 1~4hours □ 5~8hours □ 9~12hours □ >12hours
3.2.3	How old was your child when you first took him/her with you to the kitchen when cooking	----------------------------- years

4 Assessment of respiratory Health

4.1	Has child ever been diagnosed of any chronic respiratory illness?	□ Yes □ No
4.2	If yes, was it diagnosed by a doctor?	□ Yes □ No
4.3	Is the illness brought on or made worse by the smoke from the biomass?	□ Yes □ No
Have you experienced any of the following symptoms in the last 3 months?		
4.4	Cough	□ Yes □ No □ Persistent dry cough □ Occasional dry cough
4.5	Colds	□ Yes □ No
4.6	Prolonged or repeated sneezing	□ Yes □ No
4.7	Easy tiredness	□ Yes □ No
4.8	Chest pains	□ Yes □ No
4.9	Sore throat	□ Yes □ No
4.10	Bringing out excessive phlegm	□ Yes □ No
4.11	Itchy ears and throat	□ Yes □ No
4.12	Itchy and watery eyes	□ Yes □ No
4.13	Wheezing Observation or history of wheeze signs	□ Yes □ No □ Life time wheezing signs □ Wheezing signs during the past 12 months □ Wheezing or rhonchi on auscultation
4.14	Shortness of breath	□ Yes □ No
4.15	Difficulty in breathing	□ Yes □ No
4.16	Chest tightness	□ Yes □ No
4.17	Do these symptoms stop when you are not close to biomass source?	□ Yes □ No
4.18	Respiratory rate	....

5 Spirometry

Height	Weight	SPo2	FEV-1	FVC	%FEV	TEST GRADE

Additional Test Comments:

This is the end of the questionnaire. Thank you for your participation and patience.

Appendix 2: Parental Consent Form

NMIMR-IRB PARENTAL CONSENT FORM TEMPLATE

Title: **Household Biomass fuel use and Respiratory Health among children living in Madina Zongo: An informal settlement in Accra, Ghana.**

Principal Investigator: **Francisca Akorfa Adika-Bensah**

Address: School of Public Health, University of Ghana, Legon

General Information about Research

The Objective of the study is to establish if there is a relationship between using Biomass Fuels (wood, charcoal, animal dung, and crop wastes) and the prevalence of respiratory symptoms (e.g. runny nose, cough, sore throat, phlegm production, body aches, fatigue and breathlessness) and pulmonary dysfunction in children below 15 years. Data will be collected on your ward and it will be collected in a day (within 2 hours). Your ward will be asked series of questions to which he/she may provide answers to. He/she will also be required to blow air into a device which will record how his/her lung is functioning. Height and weight will be measured as a requirement for accurate spirometry readings.

Possible Risks and Discomforts

There is no associated risk to this study and the processes of Data collection. Means of collecting data is non-invasive, hence no harm or injury will be done to participants. However, signs such as slight dizziness and slight discomfort in the throat due to the blowing of air into the device, may occur among some participants in the process of checking for their lung function. . You are to discontinue the maneuvers if you feel dizzy or have any discomfort.

Possible Benefits

If your ward is found out to have reduced lung function, appropriate medical advice will be given as well as possible referral to a medical facility for further medical management. Information gathered will be shared with stakeholders which could influence future planning and interventions.

Confidentiality

All data collected and field notes will be kept confidential by principal investigator. The field note will be developed and saved in files on the computer with security codes that will only be known by the principal investigator. Data on participants will not be labelled. Identification numbers will be used. These ID numbers will be known only to the principal investigator in the person of Francisca Akorfa Adika-Bensah (Student), School of Public Health, University of Ghana.

Compensation

No compensation will be given for participation in this research.

Voluntary Participation and Right to Leave the Research

Your ward will participate in this study by their own volition and refusing to participate or answer a particular question or even partake in the spirometry will have no negative consequence or penalty.

Contacts for Additional Information

Please contact Francisca Akorfa Adika-Bensah on **020-6699112** if you have any concerns or questions about the study

Your Child's Rights as a Participant

This research has been reviewed and approved by the Noguchi Memorial Institute for Medical Research Institutional Review Board (NMIMR-IRB). If you have any questions about your child's rights as a research participant you can contact the IRB Office between the hours of 8am-5pm through the landline 0302916438 or email addresses nirb@noguchi.ug.edu.gh

VOLUNTEER AGREEMENT

The above document describing the benefits, risks and procedures for the research title entitled (***Household Biomass fuel use and Respiratory Health among children living in Madina Zongo: An informal settlement in Accra, Ghana***) has been read and explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree that my child should participate as a volunteer.

Date ______________ Name and signature or mark of parent or guardian ______________

If volunteers cannot read the form themselves, a witness must sign here:

I was present while the benefits, risks and procedures were read to the child's parent or guardian. All questions were answered and the child's parent has agreed that his or her child should take part in the research.

Date ______________ Name and signature of witness ______________

I certify that the nature and purpose, the potential benefits, and possible risks associated with participating in this research have been explained to the above individual.

Date ______________ Name Signature of Person Who Obtained Consent ______________

Appendix 3: Child Assent Form

NOGUCHI MEMORIAL INSTITUTE FOR MEDICAL RESEARCH INSTITUTIONAL REVIEW BOARD (NMIMR-IRB)

CHILD ASSENT FORM

General Information

My name is **Francisca Akorfa Adika-Bensah** and I am from the Behavioral, Environmental and Occupational Health at School of Public Health, University of Ghana, Legon I am conducting a research study entitled **Household Biomass fuel use and Respiratory Health among children living in Madina Zongo: An informal settlement in Accra, Ghana**. I am asking you to take part in this research study because I am trying to learn more about Biomass fuel smoke exposure and how often you get respiratory symptoms and associated factors. This should take about 2 hours of your day.

If you agree to be in this study, you will be asked to answer a set of questions and blow air into a tube (Spirometer). Your height and weight will also be measured as a requirement for accurate spirometry readings.

Possible Benefits

Your participation in this study will result in us finding out how well your lungs are functioning, and if any problem is identified, appropriate medical advice will be given as well as possible referral to a medical facility for further medical management.

Possible Risks and Discomforts

However, the risk associated is, you may feel some slight dizziness because of the force that will be used to blow air into the tube. You are to discontinue the maneuvers if you feel dizzy or have any discomfort.

Voluntary Participation and Right to Leave the Research

You can stop participating at any time if you feel uncomfortable. No one will be angry with you if you do not want to participate.

Confidentiality

Your information will be kept confidential. Data will be kept in restricted access on a secure laptop with passcodes.No one will be able to know how you responded to the questions and your information will be anonymous.

Contacts for Additional Information

You may ask me any questions about this study. You can call me at any time on 020-6699112 or talk to me the next time you see me.

Please talk about this study with your parents before you decide whether or not to participate. I will also ask permission from your parents before you are enrolled into the study. Even if your parents say "yes" you can still decide not to participate.

Your rights as a Participant
This research has been reviewed and approved by the Institutional Review Board of Noguchi Memorial Institute
for Medical Research (NMIMR-IRB). If you have any questions about your rights as a research participant you
can contact the IRB Office between the hours of 8am-5pm through the landline 0302916438 or email
addresses: nirb@noguchi.ug.edu.gh

VOLUNTARY AGREEMENT

By making a mark or thumb printing below, it means that you understand and know the issues concerning this research study. If you do not want to participate in this study, please do not sign this assent form. You and your parents will be given a copy of this form after you have signed it.

This assent form which describes the benefits, risks and procedures for the research titled **Household Biomass fuel use and Respiratory Health among children living in Madina Zongo: An informal settlement in Accra, Ghana** has been read and or explained to me. I have been given an opportunity to have any questions about the research answered to my satisfaction. I agree to participate.

Child's Name:................................. **Researcher's Name:**................................

Child's Mark/Thumbprint........................

Date:..

Researcher's Signature:...........................

Date:..

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Established 1979A Constituent of the College of Health Sciences
University of Ghana

INSTI[redacted]OARD

Phone: +233-302-916438 (Direct)
+233-289-522574
Fax: +233-302-502182/513202
E-mail: nirb@noguchi.ug.edu.gh
Telex No: 2556 UGL GH

Post Office Box LG 581
Legon, Accra
Ghana

My Ref. No: DF.22
Your Ref. No:

8th May, 2019

ETHICAL CLEARANCE

FEDERALWIDE ASSURANCE FWA 00001824 | **IRB 00001276**

NMIMR-IRB CPN 068/18-19 | **IORG 0000908**

On 8th May, 2019, the Noguchi Memorial Institute for Medical Research (NMIMR) Institutional Review Board (IRB) at a full board meeting reviewed and approved your protocol titled:

TITLE OF PROTOCOL : **Household biomass fuel use and respiratory health among children living in Madina Zongo: An informal settlement in Accra Ghana**

PRINCIPAL INVESTIGATOR : **Francisca Akorfa Adika-Bentil MSc Cand.**

Please note that a final review report must be submitted to the Board at the completion of the study. Your research records may be audited at any time during or after the implementation.

Any modification of this research project must be submitted to the IRB for review and approval prior to implementation.

Please report all serious adverse events related to this study to NMIMR-IRB within seven days verbally and fourteen days in writing.

This certificate is valid till 7th May, 2020. You are to submit annual reports for continuing review.

Signature of Chair ....
Mrs. Chris Dadzie
(NMIMR – IRB, Chair)