

REGIONAL INSTITUTE FOR POPULATION STUDIES

UNIVERSITY OF GHANA

**BIOMASS BURNING AMONG SMALL-SCALE FISH PROCESSORS
IN COASTAL GHANA: IMPLICATIONS FOR HEALTH AND
CLIMATE**



BY

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ACCEPTANCE

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DECLARATION

I hereby declare that, except for reference to other people's works which have been duly acknowledged, this work is the result of my research and that it has neither in part nor in whole been presented elsewhere for another degree.

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DEDICATION

This piece of work is dedicated to my late mother, Madam Agnes Kumah and to my better half **Patricia Ababio Antwi** and the fruits of our union **Zenora Antwi, Richmond Osei Antwi, Luke Asare Amoah and Prince Papa Yaw Antwi.**

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TABLE OF CONTENTS

ACCEPTANCE.....	I
DECLARATION	I
DEDICATION	III
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	vi
LIST OF TABLES	x
LIST OF FIGURES.....	xii
LIST OF ABBREVIATIONS	xiv
ABSTRACT.....	xvi
CHAPTER ONE	1
INTRODUCTION.....	1
1.1 Background.....	1
1.2 Statement of the Problem	5
1.3 Objective of the Study	10
1.4 Significance of the Study.....	10
1.5 Scope of the Study.....	12
1.6 Key Pollutants Relevant for the Study	13
1.7 Organisation of Work	14
CHAPTER TWO.....	16
LITERATURE REVIEW	16
2.1 Introduction	16
2.2 Biomass Fuel Consumption in Developing Countries	16
2.3 Clean Energy Access versus Socio-economic Status	20
2.4 Implications of Biomass Energy Consumption on Health in Developing Countries	22
2.4.1 Biomass Burning and Specific Health Implications	22
2.4.2 Global Burden of Disease and Biomass Pollution.....	25
2.4.3 The Role of Technology Interventions and Health.....	28
2.5 Biomass Energy - Climate and Environment Nexus	30
2.5.1 Greenhouse Gas Connections	30
2.5.2 Short-Lived Climate Implications.....	31
2.5.3 Local Benefits for Clean Air.....	33
2.5.4 Biomass Consumption and Ghana’s GHG Inventory.....	34

2.5.5 Environmental Implications	36
2.6 Summary of Literature Review	41
2.7 Theoretical and Conceptual Framework	42
2.7.1 Environmental Health Theory.....	43
2.7.2 Drivers-Pressures-State-Impact-Response Model/Framework.....	46
CHAPTER THREE.....	51
FISH SMOKING IN GHANA AND STUDY METHODOLOGY	51
3.1 Introduction	51
3.2 Fish Smoking in Ghana	51
3.3 Oven Types.....	54
3.4 Study Area and Methodology.....	56
3.4.1 Profile of the Study Area	56
3.4.2 Study Design	60
3.4.3 Sources of Data	61
3.5 Sampling Methods	62
3.5.1 Town Selection	62
3.5.2. Sampling Size and Sampling Technique	62
3.6 Carbon Monoxide and Particulate Matter Data Collection	63
3.6.1 Type of Instruments Used for CO and PM Data Collection.....	64
3.7 Pre-deployment Exercise	67
3.8 Fuel Type used by the Fish Smokers.....	68
3.8.1 How Firewood was weighed.....	70
3.9 Data Management.....	71
3.10 Informed Consent and Approval	73
3.11 Description of Variables	73
3.12 Methods of data analysis	75
3.12.1 Computation of wealth quintiles	75
3.12.2. Background characteristics	76
3.12.3 Level of exposure to carbon monoxide (CO) and particulate matter (PM2.5) ..	76
3.12.4 Air pollution-related health outcomes	76
3.12.5 Knowledge and perception about fish smoking.....	78
3.12.6 How GHG emissions were calculated from wood consumption	79
3.13 Limitations of the Study	80

CHAPTER FOUR.....	82
SOCIO-DEMOGRAPHIC CHARACTERISTICS AND PERSONAL EXPOSURE	
LEVELS OF THE STUDY RESPONDENTS.....	82
4.1 Introduction	82
4.2 Background characteristics of respondents	82
4.3 Household characteristics of respondents	85
4.4 Proportion of air pollution related health outcomes measured in the study	87
4.5 Environmental Exposures.....	91
4.6 Hazards of Fish Smoking: Burns and Scalds	92
4.7 Level of Personal Exposure to Carbon Monoxide (CO) and Particulate Matter (PM _{2.5}).....	94
4.7.1 Personal Exposure Level- Mean CO PM _{2.5} Concentration.....	96
4.7.2 Comparison of the personal exposure levels to recognise international standards	96
4.8 Discussions	97
4.8.1 Background Characteristics and Personal Exposure.....	97
4.8.2 Analysis of CO and PM _{2.5} Levels	99
4.8.3 Comparison of the personal exposure levels to recognize international standards	101
4.9 Conclusions	103
CHAPTER FIVE.....	104
ASSOCIATIONS BETWEEN BIOMASS BURNING, OTHER BACKGROUND CHARACTERISTICS, AND AIR POLLUTION RELATED HEALTH OUTCOMES .	
5.1 Introduction	104
5.2 Association between Biomass Burning, Background Characteristics and Smoke Pollution-related Health Outcomes	104
5.3 Discussions	112
5.3.1 Short-Term (Acute) and Chronic Health Effects	112
CHAPTER SIX	117
MULTIVARIATE ANALYSIS OF FISH SMOKING USING BIOMASS FUEL, CONTROLS AND AIR POLLUTION RELATED HEALTH OUTCOMES	
6.1 Results and interpretations	117
6.2 Discussion.....	123

CHAPTER SEVEN	127
FUEL WOOD COSUMPTION, CLIMATE IMPLICATIONS AND KNOWLEDGE SYSTEMS	127
7.1 Introduction	127
7.2 Usage, sources and quantity of fuel wood	127
7.3 Linkages between fuelwood burning from fish smoking and greenhouse gas emissions	128
7.4 Welfare implications about fish smoking as a business	132
7.5 Knowledge and perceptions about fish smoking on the environment and health ...	134
7.6 Discussion.....	135
7.6.1 Fuelwood consumption, GHG emissions and climate change	135
7.6.2 Particulate matter and other short-lived climate pollutants	139
7.6.3 Fuelwood consumption, knowledge and perceptions	141
CHAPTER EIGHT.....	143
MAIN FINDINGS, CONCLUSIONS AND RECOMMENDATIONS	143
8.1 Main Findings.....	143
8.1.1 Human and Environmental Exposure	143
8.1.2 Health Implications	144
8.1.3 Welfare Implications.....	147
8.2 Conclusions	148
8.3 Main Recommendations	150
8.4 Future Research	152
REFERENCES.....	154
LIST OF APPENDICES	163
Appendix A: Exposure Monitoring Data Collection Sheet	163
Appendix B: Ethical Review Clearance	192
Appendix C: How GHG emissions were calculated from wood consumption.....	193

LIST OF TABLES

Table 2.1: Review of biomass technology interventions for improved health.....	29
Table 3.1: Types of oven used for fish smoking	54
Table 4.1: Background characteristics of respondents in the control and treatment groups	84
Table 4.2: Household characteristics of the study respondents	86
Table 4.3: Air pollution related health outcomes	91
Table 4.4: Air pollution related health outcomes	91
Table 4.5: Environmental exposures	92
Table 4.6: Proportion of participants of biomass related burns and scalds during the survey	94
Table 4.7: Carbon monoxide concentration levels of participants for a 24-hour measurement period	96
Table 4.8: Particulate matter concentration level.....	96
Table 4.9: Comparison of field personal exposure data with international standards	97
Table 4.10: The WHO CO standards for specific time periods	102
Table 4.11: Effects of carbon monoxide in relation to the concentration in parts per million in the air.....	103
Table 5.1: Number of years and hours for fish smoking.....	104
Table 5.2: Association between background characteristics and flu, respiratory, eye and neurological symptoms	108
Table 5.3: Association between background characteristics and skin irritation and other allergic symptoms	110

Table 6.1: Linear regression showing relationship between control and treatment groups and air pollution related health outcomes, controlling for background characteristics and environmental exposures.....	120
Table 6.2: Binary logistic regression showing the relationship between control and treatment groups and air pollution related health outcomes, controlling for background characteristics and environmental exposures.....	122
Table 7.1: Percentage weekly fuel wood consumption between fish smokers and non-fish smokers	128
Table 7.2: Sources of fuel wood.....	128
Table 7.3: Weekly quantity of fuelwood consumed by Fish Smokers.....	128
Table 7.4: Net national emissions by Sectors in 2012	130
Table 7.5: Perceptions of respondents about fish smoking as a business	133
Table 7.6: Monthly expenditure on and income from fish smoking.....	133
Table 7.7: Knowledge and perceptions about fish smoking on health and environment..	135

LIST OF FIGURES

Figure 2.1: Global picture of the population using solid fuels.....	19
Figure 2. 2: The energy ladder	21
Figure 2.3: Deaths attributed to indoor air pollution by regions	26
Figure 2.4: Deaths attributable to HAP in 2012 by age and sex	27
Figure 2.5: Historical GHG emissions in Ghana.....	35
Figure 2.6: Woodfuel supply in Ghana from 2006-2015	38
Figure 2.7: Domestic woodfuel consumption in Ghana from 2006 - 2015.....	38
Figure 2.8: Greenhouse gas emissions from a typical biomass cook stove	40
Figure 2.9: High level conceptual linkages of fish smoking using fuelwood	42
Figure 2.10: Prism framework of health and sustainability	44
Figure 2. 11: Drive-Pressure-State-Impact-Response model explaining the smoke from biomass burning with other variables.....	47
Figure 2.12: Conceptual framework explaining the relationships in biomass burning and human health	49
Figure 3.1: Fresh fish being sorted out for smoking in Elmina.....	52
Figure 3.2: Packaged smoked fished waiting to be transported to the market.....	53
Figure 3.3: A Sample of traditional oven and improved oven in Moree	55
Figure 3.4: Map of the study region with clear locations of the study towns	60
Figure 3.5: A study participant wearing the CO Logger posing with a research assistant .	65
Figure 3. 6: A PM2.5 sampling pump and other laboratory gadgets	66
Figure 3.7: A research assistant fixing PM pack on a fish smoker in Moree.....	67
Figure 3.8: Sample of CO Loggers and PM Pump used for personal exposure data collection.....	68
Figure 3. 9: A sample of hard wood packed in a truck spotted in Moree	69

Figure 3. 10: A sample of hard wood used to smoke fish spotted in Elmina	70
Figure 3. 11: Bundled firewood sampled in the study area	70
Figure 4. 1: Proportions of fish smokers and non-fish smokers	82
Figure 4.2: Health indicators measured under flu symptoms domain	88
Figure 4.3: Health indicators measured under respiratory symptoms domain	89
Figure 4.4: Health indicators measured under eye symptoms domain	89
Figure 4.5: Health indicators measured under neurological symptoms domain	90
Figure 4.6: Hourly total CO exposure levels of participants	95
Figure 7.1: Greenhouse gas emissions by gases in Ghana	129
Figure 7.2: Average GHG emissions by gases from fuelwood consumed by fish smokers	131
Figure 7.3: Total GHG emission trends (weekly) from fuelwood consumed by fish smokers	132

LIST OF ABBREVIATIONS

AFOLU	Agriculture, Forestry and other Land Use
ALA	American Lung Association
ALRI	Acute Lower Respiratory Infection
ARI	Acute Respiratory Infection
BC	Black Carbon
BP	Blood Pressure
CCAC	Climate and Clean Air Coalition
CH ₄	Methane
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COPD	Chronic Obstructive Pulmonary Disease
CPC	Carolina Population Center
DALYs	Disability-Adjusted-Life-Years
DPSIR	Driver-Pressure-State-Impact-Response
EF	Emission Factor
EHT	Environmental Health Theory
EPA	Environmental Protection Agency
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GLSS	Ghana Living Standard Survey
GSS	Ghana Statistical Service
GWP	Global Warming Potential
HAP	Household Air Pollution
HFCs	Hydrofluorocarbons
IDRC	International Development Research Center
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
LMIC	Lower Middle Income Country
LPG	Liquefied Petroleum Gas
N ₂ O	Nitrous Oxide
NCV	Net Colorific Value
NIR	National Inventory Report
OECD	Organization for Economic Cooperation and Development
PA	Paris Agreement
PAHs	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
RIPS	Regional Institute for Population Studies
SDGs	Sustainable Development Goals
SLCP	Short-lived Climate Pollutant
SSA	sub-Saharan Africa

TSPs	Total Suspended Particles
UNC	University of North Carolina
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WHO	World Health Organization

ABSTRACT

Over six hundred thousand deaths attributable to household air pollution (HAP) occur annually in Africa. On average, women who smoke fish spend six hours daily exposed to hazardous pollutants from biomass fuel. Continued exposure to household air pollution presents a direct health risk to the fish processors, particularly, women and children who are exposed to air pollutants. The main objective of the study was to assess the health and climate implications of biomass consumption by small-scale fish processing in two selected communities along the coast of Ghana. The study was mainly to investigate whether exposure to smoke from fish smoking has any health implications on the women who smoke fish on a daily basis to earn a livelihood. It was to also explore the implications of wood consumption from small-scale fish smoking on the climate. The study was, therefore, designed to comprise of a treatment group and a control group. The treatment group was made up of women who smoke fish and the control group was women in Moree and Elmina towns (in the Central Region of Ghana) who do not smoke fish. Two main quantitative data sets were used. First of all, using a sample size of four hundred and sixty three (463) households, primary data were collected in both Moree and Elmina through a cross-sectional socio-economic and demographic household survey to answer specific research questions on source of fuel, quantity of fuel wood used as well as the frequency of wood consumption. The survey was also intended to help identify the people who are mainly involved in the fish smoking or processing activity, determine the demographic and socio-economic status of the processors, assess health implications which are attributable to smoke inhalation, and how these variables play out in the outcome variables of the study. Secondly, carbon monoxide (CO) monitors and finite particulate matter of 2.5 micro-diameter (PM_{2.5}) samplers were used to collect data on exposure levels of the fish smokers to CO and PM_{2.5}. In all, one hundred and fifty (150) CO and twenty nine (29) PM_{2.5} real time data were collected from Moree and Elmina to ascertain the exposure levels of the fish processors and the implications thereof for their health. Independent sample t-tests were used to show the mean differences between the control and the treatment groups and other background characteristics of the participants, with regard to experience of flu symptoms, respiratory symptoms, eye symptoms and neurological symptoms. At the multivariate level, multiple linear regressions were used to show the association between the control and treatment groups with respect to flu symptoms, respiratory symptoms, eye symptoms and neurological symptoms controlling for the background characteristics of the participants. Analysis of 24-hour data collected on carbon monoxide and particulate matter (PM_{2.5}) on women in the study area show statistical difference between the control and the treatment groups for both pollutants in terms of personal exposure concentrations. Levels of carbon monoxide and particulate matter were all beyond international permissible standards with PM recording more than three times the levels recorded in similar studies in other developing countries. At the bivariate level, biomass smoke exposure was significantly associated with eye and neurological symptoms. However, there was no statistical difference between the control and treatment groups with respect to flu and respiratory symptoms. Results at the multivariate level show that only eye symptom was statistically significant between the treatment and the control groups.

CHAPTER ONE

INTRODUCTION

1.1 Background

One of the important sources of animal protein in diets taken around the globe is fish. Smoked or dry fish forms part of traditional diet taken by a large section of the world's population (Chukwu & Shaba, 2009). About 25 percent of marine catches are either discarded or get rotten as a result of processing challenges. Available statistics show that close to 30 percent of fish catch is used as fish meal and oil globally. International trade in fish has risen to US \$50 000 million/year, representing 37 percent of fish for human consumption and tending to stimulate distribution of fresh and value-added products (Valdimarsson & James, 2001).

Fisheries sector is an important sector in Ghana's socio-economic development. The contribution of the sector to gross domestic product (GDP) is estimated around GHC 492 million representing one and half percent of the total gross domestic product (GDP) and six percent of the GDP in agriculture (FAO, 2010). About ten percent of Ghana's population is engaged in various aspects of the fishing industry with the fisheries sector seeing about 5.8% growth rate of GDP at 2006 constant prices (Ghana Statistical Service, 2014). The fisheries sector in Ghana mainly includes aquaculture fishery, inland (fresh water) fishery and marine fishery. It also includes related activities as storage, preservation, distribution and marketing. Marine fish serves as a major source of employment for the people living along the coast, while fishing from inland waters in Ghana is mainly for domestic consumption (Fisheries Commission, 2010).

Fish smoking supports many families and households in the coastal communities of Africa with income and also as a source of food. In Cote d'Ivoire for instance, about 20-30

percent of marine and freshwater fish catch is smoked and consumed domestically (Akande & Diei-Ouadi, 2010). Smoked fish has between three and six months shelf-life and has the ability to preserve the nutritional integrity of the fish (Akande & Diei-Ouadi, 2010). Culturally, smoked fish is preferred by many Ghanaians because it is perceived to have nice flavor because of the smoke. Smoked fish has competitive pricing advantage with other perishable protein food sources like fresh meat, eggs and milk.

Traditional kilns or ovens widely used to smoke the fish do pose some health concerns. Fish smoking using traditional methods (ovens) use large quantities of wood as fuel. Burning biomass fuel to smoke the fish in commercial quantities is associated with the production of large volume of smoke which contain a lot of harmful pollutants and gases such as carbon monoxide (CO), particulate matter (PM) of various diameters and polycyclic aromatic hydrocarbons (PAHs), which are known to cause cancers and can also cause harm to the human respiratory system (FAO, 2013). Other gasses which have direct relationship with climate change or global warming such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O) are produced, anytime biomass fuel is burned. Background issues related to fish smoking in Ghana are presented pictorially in figure 1.1.

Figure 1.1: A pictorial presentation of fish smoking issues in Ghana



Source: Research field data, 2016

Non-farm income generating activities constitute a fair share of Ghana's labour force as many people in the country are not engaged in formal or structured wage employment. For example, the 5th round of the Ghana living standards survey (GLSS5) indicates that about 46.4% of the households in Ghana do some form of non-farm enterprise (Ghana Statistical Service, 2014). This percentage translates into approximately 3.2 million people, of which seventy two percent are women (Ghana Statistical Service, 2014). Women contribute 95% labour force to fishery and other post-harvest processing activities such as gari¹ processing (Torell et al., 2015).

The 2014 Ghana Living Standard Survey report indicates that women have a greater share of responsibility among households that process agricultural produce, irrespective of whether they live in urban or rural areas (Ghana Statistical Service, 2014). Though the contribution of women processors to household and national income is remarkable, they often work under very deplorable conditions which put their health at risk (Torell et al., 2015).

Women who engage in fish smoking in Ghana are exposed to fire on average six hours a day during the peak harvest season (UNDP, 2008). Many of these women work within concentrated smoke environments without personal protective gadgets.

Processing raw fish into smoked fish has a number of advantages such as prolonging the shelf-life of the fish, enhancing the flavour in soups and sauces (UNDP, 2005). Wastage of fresh fish at bumper harvest seasons is also reduced by smoking. Further, smoking the fresh fish increases protein availability to people throughout the year as the smoked fish

¹ Gari processing is the transformation of harvested raw cassava into non-perishable form through roasting. Many women in rural farming communities in Ghana engage in gari processing as a means of livelihood. Biomass fuelwood is the main energy used in roasting the grated cassava in Ghana.

can be stored and used later. Again, it is easier to pack and transported to various market centers locally and internationally (UNDP, 2005).

The implications of biomass burning on climate have long been a concern for the international community (scientists and policy makers). The impact of climate change on global and local economies has long been researched (IPCC, 1990, 1995, 2001, 2007, 2013). Greenhouse gases (GHG) especially carbon dioxide (CO₂), which threatens current and future generations than generations before as the CO₂ concentration levels in the atmosphere threatens human and ecosystem existence. Potential feedback systems may exist from fire to the climate. The feedback could emanate from the emission of pyrogenic emissions which happen as a result of the combusting of woodfuel can affect or influence the atmospheric chemistry and the balance of radiation, as well as the feedback through greenhouse gas² emission to the global carbon cycle (Galanter et al., 2000; van der Werf et al., 2004).

Fish smoking in Ghana is a gendered small-scale socio-economic activity which is highly embedded in culture. Women, young adults and children are the main people who are involved in the various aspects of fish processing. Men and boys, on the other hand, by tradition are the ones who go to sea to do the fishing. As a result, there is a clear division of labour within the fishing industry in Ghana even at the household levels between men and women.

² Greenhouse gases are explained as “gases that allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth’s surface, some of it is reflected back towards space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap the heat in the atmosphere leaving the atmosphere to be warmer than normal”.
www.greenhousegasemissions.com

1.2 Statement of the Problem

Biomass fuel burning is an important change factor to be recognized in the global environmental change process. It influences the composition of the atmospheric gases, affects the climate systems, can affect economic activities and could impact on human health (Schultz et al., 2008). There is a growing body of literature on the implications of exposure to pollutants from fuel wood burning and human health (WHO, 2012; Dherani et al., 2008; McCranken et al., 2007; Smith et al., 2004; Ibalid-Mulli, 2001). Particulate matter emissions from open fire cookstoves has been linked with adverse health impacts (Armendáriz-Arnez, et al., 2010) and in some exposure research such as Smith et al., 2011, the amount of pollutant concentrations have been used as proxies for human health. Studies have suggested that personal exposure to smoke from biomass fuel has implications on human health (Zhan & Cao, 2015; Smith et al., 2011; Barregard et al., 2006; Sallsten et al., 2006; Triche et al., 2005; Koenig et al., 2005; Avakian et al., 2002).

The main occupation for the people along the entire coast of Ghana is fishing and quite a large number of people in these areas depend on wood and charcoal fuel to process the fish (smoking and frying) in commercial quantities. About ten percent of Ghana's population depends on fishery related activities with small-scale fish smoking activities mainly dominated by women (USAID, 2015; GLSS, 2014). A recent canoe frame survey (CFS) conducted by the Ghana Fisheries Commission estimates that over 14,000 households along the coast of Ghana engage in fish smoking with over 37,000 smoking ovens (Fisheries Commission, 2010). Studies in Ghana have shown that residents in peri-urban and rural areas still depend largely on traditional biomass fuel³ and kerosene to meet

³ Biomass fuel is defined as “renewable organic materials, such as wood, agricultural crops or wastes, and municipal wastes, especially when used as a source of fuel or energy”. Biomass can either be burned directly or processed into biofuels such as ethanol and methane.

their cooking and lighting needs (GLSS, 2013; GDHS, 2014; Zhou et al., 2011; Dionisio et al., 2010). Part of the reason is that many of the households cannot easily shift to use relatively modern energy forms mainly because they cannot afford to acquire the technology or purchase modern fuels (Wiafe & Kwakwa, 2013).

The use of biomass energy is also dominant for many commercial activities that sustain livelihoods of the urban and rural populations in the country (USAID, 2015). In most settlements in Ghana, charcoal and wood stoves are the main sources of energy for small scale commercial demands. For instance, small scale businesses such as fish smoking, gari processing and kenkey processing largely use fuel wood and charcoal on daily basis and in large quantities.

The smoke from burning wood contains harmful gases and environmental pollutants such as carbon dioxide (CO₂), carbon monoxide (CO)⁴, particulate matter (PM)⁵, etc. that are harmful to human health. The women involved in fish smoking stay within smoking environments for longer period of time in a day making this population vulnerable to high smoke exposure. In terms of the length of exposure of the women to household air pollutants (HAPs), on the average it takes two and half (2.5) hours to prepare a household meal, and for the case of fish smoking, the average number of exposure to smoke is six (6)

4 Carbon monoxide (CO) is defined as “a colourless, odourless, poison gas that is produced when liquid, solid, or gas fuel is burned. It is sometimes confused with carbon dioxide (CO₂). Carbon monoxide can be a poison, even at low levels, while carbon dioxide is a normal part of the breathing process. Breathing low levels of carbon monoxide over a few hours can have just as harmful effect as breathing high levels for a few minutes. Carbon monoxide lowers the body’s ability to carry oxygen to vital organs such as the heart and brain. In general, the more carbon monoxide a person inhales, the more serious the damage that occurs. The elderly, young children, infants, fetuses, and people with anemia or heart or lung problems are more sensitive to the effects of carbon monoxide” (www.healthvermont.org).

5 Fine particulate matter is defined as “a complex mixture of solid and liquid particles consisting mainly of sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water”.

hours. Continued exposure to household air pollution presents a direct health risk to the fish processors, particularly, women and children who are exposed to air pollutants. Estimates from the World Health Organization (WHO) indicate that over six hundred thousand (600,000) deaths occur each year that are attributable to household air pollutants (HAP) in Africa (WHO, 2012). In Ghana, the disability adjusted life years (DALYs) attributable to household pollutants is about 1,000 per 100,000 people (WHO, 2004).

In the area of climate and environment, science, evidenced by the work of the Intergovernmental Panel on Climate Change (IPCC, 2013, 2007), unequivocally underscores the need to immediately reduce emissions of GHGs such as CO₂ and N₂O as well as short-lived climate pollutants (SLCPs), such as black carbon (BC) or soot, methane (CH₄) and other fluorinated gases usually called the F-gases. At the global level, the work done by the IPCC (2013 & 2007) and several other studies (Jagger & Shively, 2014; Takaro et al., 2013; Bremner et al., 2010; Dionisio et al., 2010; Karl, 2009; Kinney, 2008) have established relationship between fuel wood burning and climate change through the emission of greenhouse gases (GHGs). In Ghana, for instance, literature on household cooking and its implications on climate and the environment is growing (Wiafe & Kwakwa, 2013; Toyola Energy Ghana, 2011).

Short lived climate pollutants (SLCPs) are dangerous and strong forcers of global warming compared to the long-lived gases such as carbon dioxide which stay in the atmosphere for longer period (IPCC, 2013). The SLCPs are estimated to be responsible for about 40 percent of current net climate forcing (IPCC, 2013). While the climate impacts of CO₂ reductions take decades or more to materialize, cutting or reducing emissions of SLCPs can immediately slow global warming and reduce the impacts of climate change.

Addressing GHG emissions is mainly driven by international policies and systems under the United Nations Framework Convention on Climate Change (UNFCCC). Countries (or Parties as they are called in international negotiations) develop domestic greenhouse gas inventory systems to address country level GHG emissions which intend to feed into the international system. The main sectors that have been defined by the 2006 IPCC Guidelines are; (1) Energy, (2) Industrial process and product use (IPPU), (3) Agriculture, Forestry and Other Land Use (AFOLU) and (4) Waste.

Ghana's national inventory of greenhouse gases (GHG) currently does not consider emissions from small scale household economic activities such as fish smoking, gari processing and other similar commercial activities that depend on biomass as a recognized GHG emission source. This study makes a case of the significance of the emissions from the small scale economic/commercial activities, using a cross-sectional survey data on wood consumption focusing on CO₂ emissions from small scale fish processing industry. Conceptually, increased consumption of wood for fuel by the small scale economic sector has the potential to contribute to pollutants concentration and deforestation or forest degradation, at least, at the local level. However, the contributions of small scale commercial processing activities such as fish smoking, gari processing, etc using biomass fuel to climate change has not been given much research attention in Ghana.

In line with the above discussions on fish smoking and biomass fuelwood consumption, this study raises two main concerns;

- i. Fish smoking as a small-scale economic activity uses much more volume of firewood compared to household cooking,
- ii. On average, fish smokers spend more hours in a day in biomass smoke related environments compared to women who engage in normal household cooking.

However, research attention has not focused on vulnerable populations that depend on biomass fuel as livelihood activities in developing countries. Current literature on biomass consumption focus on household cooking and mainly look at environmental sustainability as well as the economic implications of using wood as fuel (Ali et al., 2016; Nkegbe et al., 2013; Bissio, 2014; Daioglou, 2015). Other studies that look at health implications of biomass fuel burning again are focused on household air pollution (HAP) [(Bruce, 2006; Smith et al., 2004)]. There appears to be little scientific study on the exposure level of small-scale fish processors (mainly women) to pollutants from their continued exposure to pollution from fuel wood consumption in developing countries.

Again, literature in developing countries on household air pollution has mainly been at macro levels- mainly on aggregated review studies. This study uses primary field data at the micro-environment level to assess the implications of biomass burning on human health, focusing on women small-scale commercial fish smokers and GHG emission implications for the climate with emphasis on wood consumption by small-scale fish smokers.

Based on the above mentioned literature gaps, this study seeks to address the following questions;

- i. What is the level of personal exposure of small-scale fish processors in Ghana to carbon monoxide (CO) and particulate matter (PM_{2.5})?
- ii. How do these levels compare with exposures for women in non-fish processing households?
- iii. Do women who engage in fish smoking have a higher incidence of household air pollution related health outcomes compared with those from non-fish smoking households?

- iv. To what extent does small scale fish smoking contribute to local greenhouse gas emissions?
- v. What is the implication of wood consumption by small-scale fish smokers for the greenhouse gas inventory (GHG) accounting in Ghana?
- vi. How do fish smokers perceive the implications of wood burning on their health and the environment?

1.3 Objective of the Study

The main objective of the study is to assess the health and climate implications of biomass consumption by small scale fish processing in communities along the coast of Ghana.

Specifically, the study has the following objectives:

- i. To assess the personal exposure levels of carbon monoxide (CO) and particulate matter (PM_{2.5}) among small scale fish smokers.
- ii. To find out how fish smokers' personal exposure to CO and PM_{2.5} compares with non-fish smokers.
- iii. To examine the relationship between exposure to pollutants from burning biomass and health of fish smokers along the coast of Ghana.
- iv. To explore the implications of wood consumption by small scale fish smoking for GHG emissions and the implications for the GHG inventory accounting in Ghana.
- v. To highlight how fish smokers perceive the implications of wood burning on their health and the environment.

1.4 Significance of the Study

Though there are quite a number of studies that have looked at the environmental and economic implications of biomass consumption at the macro or global level, studies that

look at the combined effects of personal exposure to biomass fuel pollution from small scale commercial energy consumption on the environment and health of vulnerable populations, at micro level, using field data is not common in developing countries. Currently, there are no studies of the exposure level of small scale fish processors to pollutants from their use of biomass fuel. This study addresses these identified knowledge gaps by contributing to the growing knowledge in household air pollution from biomass emanating from small scale industrial sources in developing countries. In addition, the study has a utility of addressing climate and health risks, using field data which is lacking in most studies in household air pollution.

The promotion of improved cookstoves has been in existence in many developing countries for some time now. In the Ghanaian policy landscape for instance, liquefied petroleum gas (LPG) has been promoted by the government of Ghana since the early 1990s at different levels including households to mainly reduce the pressure on tree cutting for charcoal. The idea was to find out the penetration level of improved technologies, especially ovens within small scale fish smoking business environment and the implications of the uptake of the improved technology on other co-benefits such as human health. Targeted energy policy instruments such as subsidies, technology and financial instruments such as loans for fish smokers in Ghana will improve the health and welfare of vulnerable populations whose livelihoods depend on the fisheries value-chain. There seems to be two conflicting policies operated by two different ministries of Ghana. Whereas the Ministry of Health is promoting public health policies that aim to ensure good health for the populace, the removal of subsidies on LPG by the Ministry of Energy has the potential to affect the likelihood of poor people to afford clean fuel for household and small scale commercial/industrial consumption. The likelihood is that, they will fall back on biomass fuel which has negative implications on their health and the climate.

Further, the outcome of the study could inform policy by seeking the cost-effective means of reducing occupational exposure of vulnerable populations to high environmental/pollutants concentrations.

In addition to the above, the results of the study may also be important in the international negotiations on the reduction of greenhouse gas emissions and resilience building within the Paris Agreement (PA) and the Sustainable Development Goals (SDGs). Ghana signed the Paris Agreement in April 2016 in New York and went ahead to ratify the Agreement in October of the same year. The Paris Agreement uses a bottom-up emission reduction strategy where countries under the agreement have voluntarily committed to emission reduction targets at national levels as their contributions to the global GHG emissions. Results from this study may potentially inform Ghana's GHG emission sources for the national GHG inventory or accounting.

1.5 Scope of the Study

The research work is designed to provide an insight into women's dependence on biomass energy to earn livelihood at the household level and the implications on their health and the GHG accounting in Ghana. The study focuses mainly on personal exposure of fish smokers to pollutants from biomass burning. Biomass energy for fish smoking were mainly limited to fuel wood and charcoal because fuel wood and charcoal constitute the main energy for fish smoking and household cooking in the study area. The analysis is done with data collected from Moree in the Abura Asebu Kwamankese District and Elmina in the Komenda-Edina-Eguafo-Abirem (KEEA) District in the Central Region, which were selected for their peculiar involvement in small scale smoking activities.

1.6 Key Pollutants Relevant for the Study

This study is mainly about certain gases technically known as pollutants that are released into the “environment” as a result of burning wood related products mainly firewood and charcoal. The main air pollutants associated with burning of biomass include carbon monoxide (CO), particulate matter (PM), sulphur dioxide (SO₂), nitrogen oxides (NO_x), ozone (O₃), and sulphuric acid (H₂SO₄). Depending on the origin of the pollutant, they can be classified as primary or secondary. The primary ones are nitrogen dioxide (NO₂) and sulphur dioxide (SO₂) PM from soot. The secondary ones include sulphuric acid (H₂SO₄), also known as acid rain and ground-level ozone (O₃), commonly referred to as smog. The sources of these pollutants are classified as outdoor (ambient) and indoor. The focus of this study is pollution that occurs as a result of small scale commercial activities using firewood. This could be indoor or outdoor depending on where fish smoking takes place.

Particulate matter (PM₁₀, PM_{2.5}) refers to “small solid or liquid particles suspended in the air that can be formed as a result of natural, industrial or other human activities”. It is measured as total suspended particles (TSP) and it encompasses particulate of all sizes as particles with an average diameter of 10 microns or less (PM₁₀) and fine particles with an average diameter of 2.5 or less (PM_{2.5}). The particles which are of the finest sizes are of public health concern since they can travel deeply into the lungs. Apart from that, they can also carry along chemicals into the lungs, e.g., polycyclic aromatic hydrocarbons (PAHs), metals, etc.

Nitrogen dioxide (NO₂) is one of a group of gases called nitrogen oxides, which are composed of nitrogen and oxygen. Like sulphur dioxide, nitrogen oxides can react with other chemicals in the atmosphere in the presence of sunlight to form acidic pollutants,

including nitric acid. Carbon monoxide (CO) which is one of the main pollutants of major concern of this study is a colourless, odourless, poisonous gas caused mainly by incomplete combustion of biomass. The pollutants that are of consideration for this study are CO and PM_{2.5}.

1.7 Organisation of Work

The thesis is organised into eight chapters. Chapter one is the introduction, while chapter two provides literature reviewed on biomass consumption in different settings and the implications for human health and the environment of which climate forms a part. The objective was to understand the previous work done in this field and how they provide the base for extending literature on biomass pollution to small scale and subsistent economic activities.

Chapter three describes the research methodology applied in the study. The various analytical methods employed in the analysis of data are also presented in this chapter. Chapter three, again, discusses the settings within which fish smoking is done in Ghana.

Chapter four of the study deals with the background and household characteristics of the respondents. The chapter further discusses the findings on personal exposure levels of respondents to CO and PM_{2.5}. Chapter five presents bivariate analysis of the relationship between exposure to biomass smoke and the health outcomes measured in the study, while chapter six discusses the associations among the main independent variable and health outcomes at the multivariate level, controlling for other variables. Main health indicators measured in the study for the analysis include: flu, respiratory, eye and neurological symptoms. Chapter seven deals with the fuel wood quantities and their implications on the climate and the environment. The chapter also presents fish smokers' perception on

biomass burning and its implications on their health as well as the environment. The final chapter (chapter eight) deals with the main findings, conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter reviews scholarly work done on the key themes of the study including biomass fuel burning, health and climate change. These sub-themes are discussed in relation to small scale fish smoking as a commercial livelihood activity. The chapter also highlights the theoretical context that underpins this work.

The main theme that drives this chapter is exposure to biomass smoke. Human exposure to pollutants can be measured directly or indirectly. Direct measurement takes place through the use of personal exposure monitors. Indirect exposure measurement could be done by combining information on the pollutant concentration on microenvironments where people spend time with information on what the people do mostly (i.e. activity patterns). For instance, studies conducted in Accra by Dionisio et al., (2010) used air pollution monitors placed at specific locations of neighbourhoods of varied socio-economic status and with the aid of geographic information system data on pollution levels of different neighbourhoods were collected and analysed. This study is focused on direct personal exposure measurement of vulnerable women population who are exposed daily to smoke from burning fuelwood for fish smoking at small-scale level. Pollution concentration levels and human health relation is fluid, so such information patterns is critical for connecting the pollution concentration levels with human health and damages to the ecosystem.

2.2 Biomass Fuel Consumption in Developing Countries

Since the discovery of fire, energy has been a major factor in development (Colombo, 1996). Social and economic change being driven by the discovery or identification of new

energy sources as well as the availability of the requisite technology to exploit the energy to drive social and economic change and transformation has been the bane of many developing countries.

Energy use in the home is a vital and ubiquitous feature of human society. Energy is used for a wide variety of purposes, including cooking, space heating, lighting, small-scale income generation, various household tasks, and entertainment. The varied nature of how energy can be used speaks about how fundamental energy is to human existence. Even though energy is an important household commodity, nearly three billion people worldwide still lack access to clean fuels and technologies for cooking, heating and lighting (Bonjour et al., 2013; WHO, 2012; Lim et al., 2012; Smith et al., 2012; Smith et al., 2004).

Scholarships in household energy consumption in developing countries indicate a heavy reliance on unclean fuel such as wood, charcoal, crop residues, coal and dung as their primary sources of energy for heating, cooking and lighting (Zhou et al., 2013; Gall et al., 2013; Lim et al., 2012; Smith et al. 2012; WHO, 2007, 2006; Smith et al., 2004; Zhang & Smith, 2003; von Schirnding et al., 2002; Ezzati & Kammen, 2001; Ezzati & Kammen, 2000; US EPA, 1997; Reddy et al., 1994). Inefficient stoves mostly open or inadequately vented are used in developing countries to burn solid fuels (WHO, 2012). In Nepal, the 2001 Population Census report estimates that nearly 80% of the households use biomass fuels for cooking using traditional and inefficient stoves (Shresta & Shresta, 2005).

The picture of household access to clean energy in Ghana does not deviate from that of the general energy picture in developing countries. Wiafe and Kwakwa (2013) for instance reports on the heavy dependence on solid fuels for domestic and small scale economic business activities in Ghana. Fuel wood stoves (traditional and modern) have mainly been

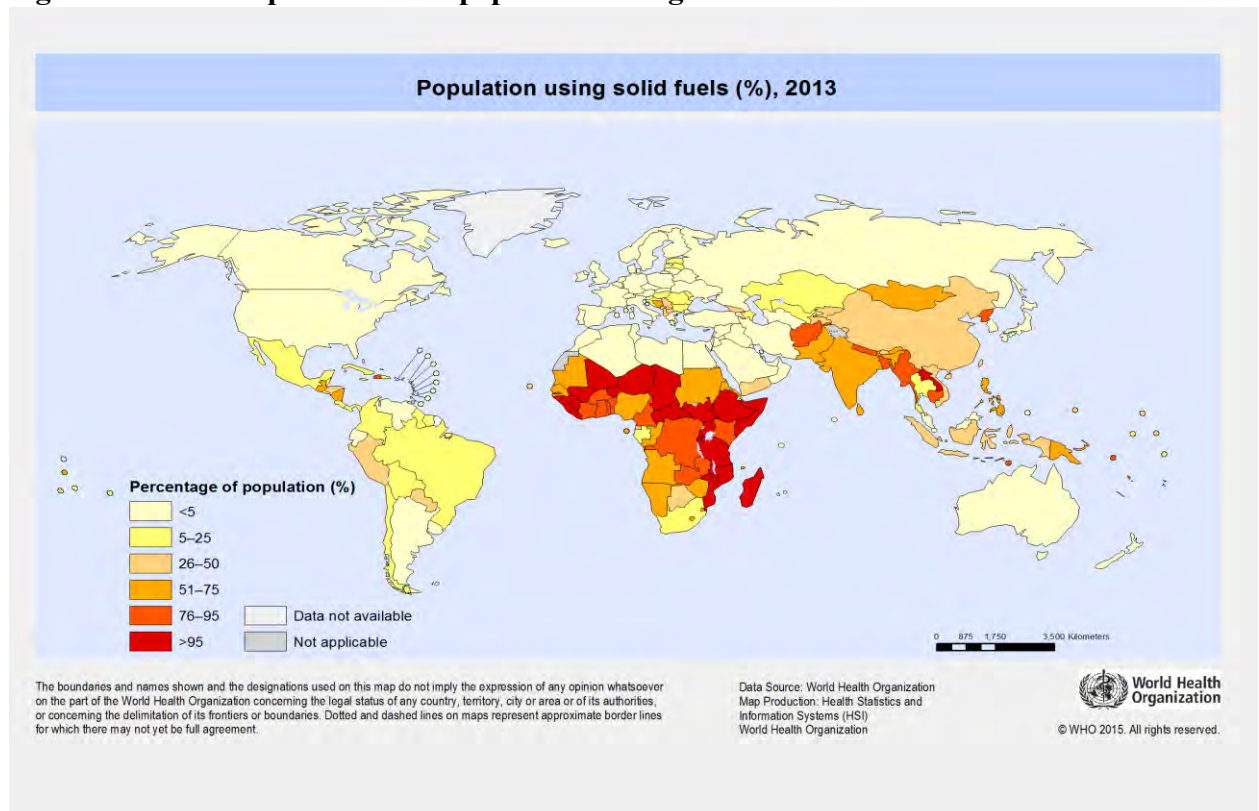
used. These fuel-stove combinations result in high levels of fine combustion-generated particles and other pollutants (McCracken et al., 2007).

A number of factors drive the heavy dependence on unclean fuel, especially fuel wood and charcoal in developing countries, especially in Africa and in Asia. High poverty levels, unavailability of clean fuel technologies, affordability of the available clean fuels and sometimes the perceived “cultural addiction” to the traditionally known fuel technologies could be indicted for the growing consumption level of unclean fuels especially solid fuels in Africa (WHO, 2012). There are indications that household dependence on biomass fuels as the main source of energy in developing countries will continue to increase instead of declining, as cost of clean fuel keeps on increasing and even when people could afford, availability of clean fuels such as liquefied petroleum gas (LPG) continue to be a challenge. Consumption of biomass globally is expected to increase and more so in Africa, at least till 2030 (Bruce et al., 2006). This understanding is common among energy researchers, practitioners and policy makers. For instance, the Organization for Economic Cooperation and Development (OECD) has estimated that by 2015 and 2030, over 2.6 billion and 2.7 billion people respectively of the world’s population will still be dependent on biomass fuels (OECD/IEA, 2011).

A number of research studies on household energy consumption have underscored biomass usage as a primary energy source for cooking and heating in developing countries (von Schirnding et al., 2002; Zhang & Smith, 2003; Zhou et al., 2013; WHO, 2006, 2007; US EPA, 1997; Smith et al., 2004; Reddy et al., 1994; Gall et al., 2013; Ezzati & Kammen, 2000; Ezzati & Kammen, 2001). Part of the reason could be related to lack of access to clean energy in those regions (IEA, 2010). Affordability has also been an issue in most developing countries, even when clean energy is available. Clean energy access is

increasingly becoming difficult and acute for the rural and peri-urban poor in Sub-Saharan Africa and South Asia. Even in economies where clean energy is available such as the United States, Australia and Canada, the use of wood energy for heating in households are shooting up due to persistent rise in the cost of clean energy. Figure 2.1 gives the global picture of the population using solid fuels.

Figure 2.1: Global picture of the population using solid fuels



Source: WHO, 2012

The population which depends mostly on solid fuels (figure 2.1) mainly comes from developing countries with the African continent having the average leading percentages as indicated by the different colours in figure 2.1. Ghana for instance has about 76-95% of her population depending on solid fuels compared to less than five percent (5%) in the North America (WHO, 2012).

The crucial means of meeting basic domestic and small scale business needs through the provision of cleaner fuels and improved cooking stoves is often a financial challenge in developing countries (WHO, 2009a). Even in countries where there is improved access to electricity in rural areas like in South Africa and in India, most households do not use it for their domestic activities (especially for cooking), but depend on biomass fuels in meeting daily cooking energy needs (Ezzati & Kammen, 2001). Electricity is mainly used for lighting in the low income households. Despite users experiencing detrimental health impacts from exposure to indoor air pollution during the burning of biomass fuels, it is still the preferred fuel in most households of developing countries (Ezzati & Kammen, 2001; Bruce et al., 2000; Smith et al., 2000).

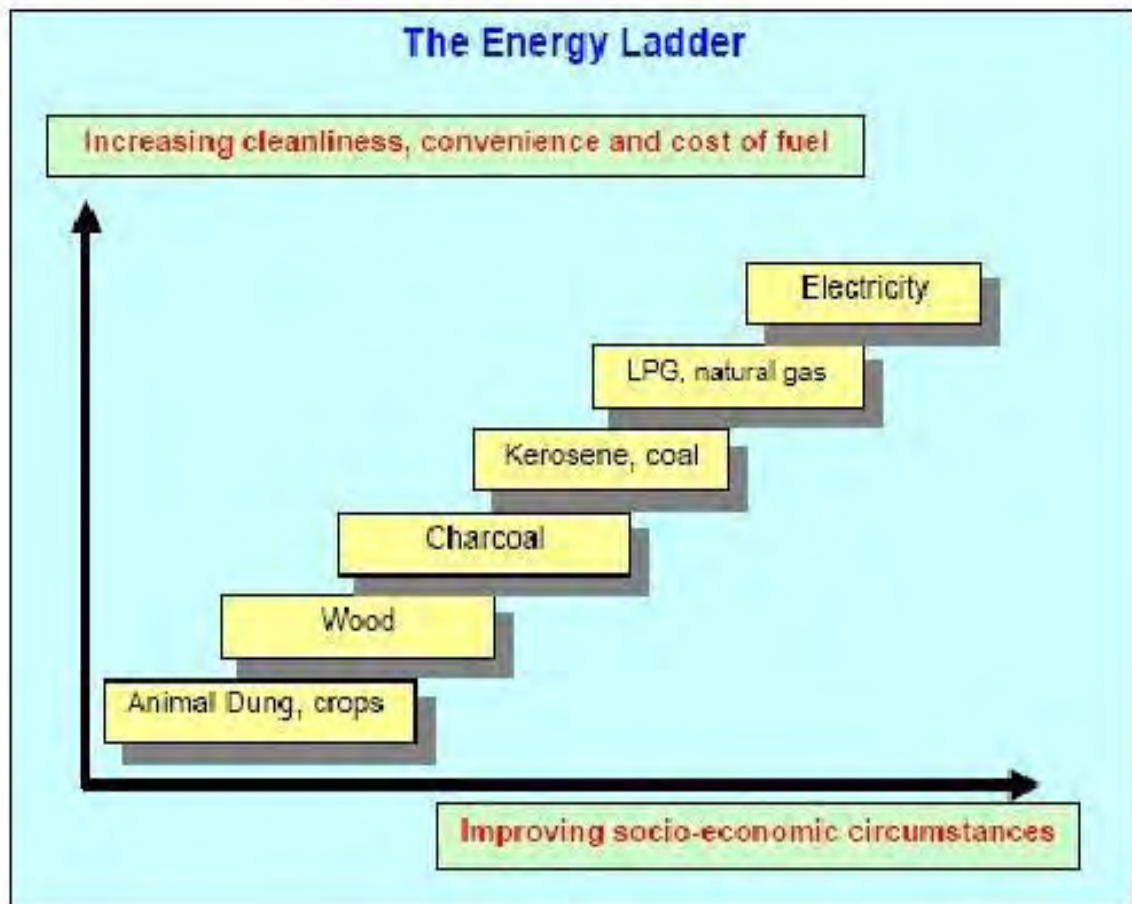
2.3 Clean Energy Access versus Socio-economic Status

Expanding the discussions on clean energy access further in developing countries is the argument of one's socio-economic status and the array of energy services he or she could access. A number of studies have established correlation between type of energy consumption and income levels (Reddy, 2000). Reddy's assertion is that the nexus between energy and poverty does exist and that the dependence on traditional biomass energy and associated technologies is both a cause and result of poverty (Reddy, 2000). It can be deduced from Reddy's argument that energy is both an enabler and a constraint to development and that poverty can constrain peoples' access to clean energy.

The discussion for the nexus between energy and poverty can be taken to the household or individual levels. There are numerous examples where within certain geopolitical boundaries poor people are not able to access clean fuels even if the fuel or technology was available (Reddy, 2001). The different grades of energy that are used in households is known as the "energy ladder" which associates different income levels with dominant fuel

energy used (Reddy & Reddy, 1994). All things being equal, individuals will use cleaner energy as their income or socio-economic status improves as illustrated in figure 2.2.

Figure 2. 2: The energy ladder



Adapted from Smith et al. 1994

From figure 2.2, those who earn higher incomes use fuels of higher quality (higher rungs) and there is a positive relationship between the type of fuel and price. The relationship between the quality of energy and emissions is on the other hand an inverse one. For example, Bloom et al. (1996) write that the cook-stove efficiencies of fuel wood, kerosene, and gas are approximately 15, 50, and 65 percent, respectively. Meaning gas is more efficient than wood and kerosene. Primary energy source for many countries in the developing world are under first category. Smith et al. (2011) for instance describe the use of biomass fuel and coal in simple stoves and ovens as an attribute of poverty.

2.4 Implications of Biomass Energy Consumption on Health in Developing Countries

The acquisition, production and utilization of energy have great adverse effect on a number of outcomes. One of such key variables is human health. There is an association between personal exposure to air pollutants and health (Zhan, 2015; Ward et al., 2015; Smith, 2011; Smith, 2005). The WHO defines exposure “as the concentration of pollution in the immediate breathing environment during a specified period of time”. Globally, household air pollution has a major impact on human health (Ward et al., 2015). Lower respiratory tract infections in children and chronic respiratory and cardiovascular diseases in adults have resulted in a number of premature mortality in developing countries attributable to household air pollution from biomass fuel (Ward et al., 2015). In China, about 1 million premature deaths are believed to be associated with atmospheric fine particulate matter (Lelieveld et al., 2013).

2.4.1 Biomass Burning and Specific Health Implications

Descriptive and quantitative studies on the association between indoor air pollution exposure and certain specific respiratory diseases in certain parts of the world have been conducted.

Although some studies have failed to find association between ambient air pollution and high blood pressure (Brauer et al., 2001; Ibalid-Mulliet al., 2004), several others have established positive associations between ambient air pollutants and blood pressure (BP) [(de Paula Santos et al., 2005; Ibalid-Mulli et al., 2001; Linn et al., 1999; Zanobettiet al., 2004)]. A study conducted in India at household level using data from ever married women aged 15-49 found a positive correlation between household use of cooking fuels (kerosene and biomass) and the risk of still birth (Lakshmi et al., 2012).

Previous systematic reviews and meta-analyses concluded that indoor exposure from unclean biomass fuels potentially increases pneumonia risk in young children by a factor 1.8 and doubles the risk of chronic obstructive pulmonary disease (COPD) [(Pope & Xu, 1993)]. The uncontrolled nature of unvented smoke from inefficient stoves not only put the immediate population at risk but also poses danger for the entire neighbourhood. In Anhui Province, Pope and Xu (1993) found out that non-smoking women who live with smokers had higher levels of cough, phlegm, shortness of breath and other chest illness (Pope & Xu, 1993). A survey of 10,892 Xuanwei residents found that the odds ratio (OR) estimates for smoky coal users compared with smokeless coal users, were 1.73 for shortness of breath, 3.30 for cough, and 4.23 for phlegm, and that the OR estimates for smokeless coal users compared with wood users were 1.35 for cough and 1.67 for phlegm (Zhou et al., 1995). Evidence exist on the relationship between ARI including pneumonia, tuberculosis in children and COPD, low birth weight, cataracts, cardiovascular events in women with biomass smoke from indoors. All the diseases mentioned are causal diseases for mortality in adults and children (Dherani et al., 2016; Gordon et al., 2014; WHO, 2011; Fullerton et al., 2008; Smith et al., 2004; Burnett et al., 2014; Gordon et al., 2014; Sood, 2012; Fullerton et al., 2008).

The WHO also elevates the discussion on the relation between biomass smoke exposure and health outcomes by providing disaggregated data on certain key health outcomes. Health disaggregated data on certain health indices by the World Health Organization, 2014 estimates that out of the 4.3 million people who die each year as a result of household air pollution; thirty four percent is related to stroke, twenty six percent due to ischaemic heart disease, twenty two percent as a result of COPD, twelve percent due to childhood pneumonia and six percent due to lung cancer. These diseases are primarily caused, in part, by high levels of fine particulate matter and carbon monoxide released by

the burning of solid fuels such as wood, coal, animal dung, crop waste and charcoal in inefficient stoves, space heaters, or lamps (WHO, 2014; Barnes et al., 2014, Atkinson et al., 1999, Smith et al., 2004; Dherani et al., 2008; Duflo et al., 2008). Disaggregating data on key health outcomes associated with biomass burning provides clearer understanding for interventions and also provides leads in areas where research attention should focus. For instance, household air pollution is now recognized as the third greatest contributor to global disease burden (Lim et al., 2012). This knowledge could provide clues for research and policy.

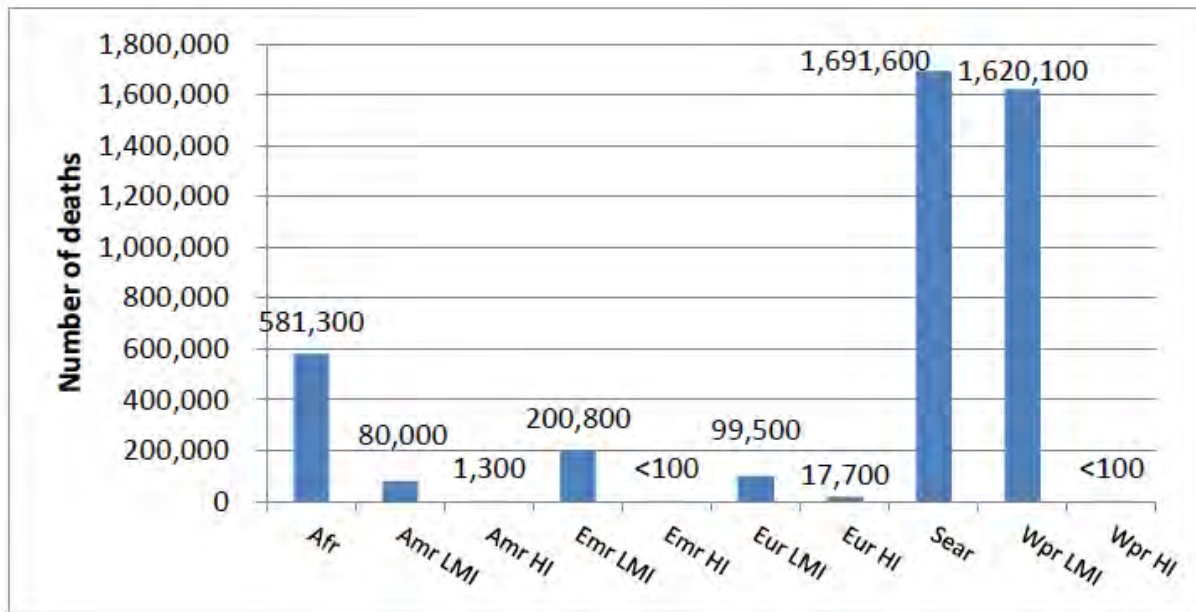
The use of coal at the household level is also associated with lung cancer. Other conditions such as COPD and tuberculosis in men is reported by the WHO to be associated with biomass smoke exposure but the evidence on that is scarce. According to estimates of the World Health Organization, (2014), more than 1.6 million deaths and over 38.5 million Disability-Adjusted Life-Years (DALYs) can be attributable to indoor smoke from solid fuels affecting mainly children and women.

Case studies in Asia, Africa, and the Americas have found particulate levels ranging from 300 to over 30,000 $\mu\text{g}/\text{m}^3$ during stove use, which is several times above the USEPA 24-hour standard for PM₁₀ (Barnes, 2014). The United States Environmental Protection Agency's standards for 24-hour average PM₁₀ and PM_{2.5} concentrations are 150 mg/m^3 and 35 mg/m^3 respectively (US EPA, 1997). The mean 24-hour levels of carbon monoxide in homes using biomass fuels in developing countries are in the range 2-50 ppm; during cooking, values of 10-500 ppm have been reported. The US EPA's 8-hour average carbon monoxide standard is 9 ppm or 10 mg/m^3 (US EPA, 1997). A health effect is determined not just by the pollution level, but also, and more importantly, by the time people spend breathing polluted air, i.e., the exposure level and the length of the exposure.

2.4.2 Global Burden of Disease and Biomass Pollution

Estimates by the WHO indicate that about 1.5 million people die each year as a result of indoor air pollution and the global burden of disease by the same source stands at 2.7 percent (WHO, 2007). What is more troubling is the relationship between indoor air pollution and acute respiratory infection (ARI) among children (Gall et al., 2013).

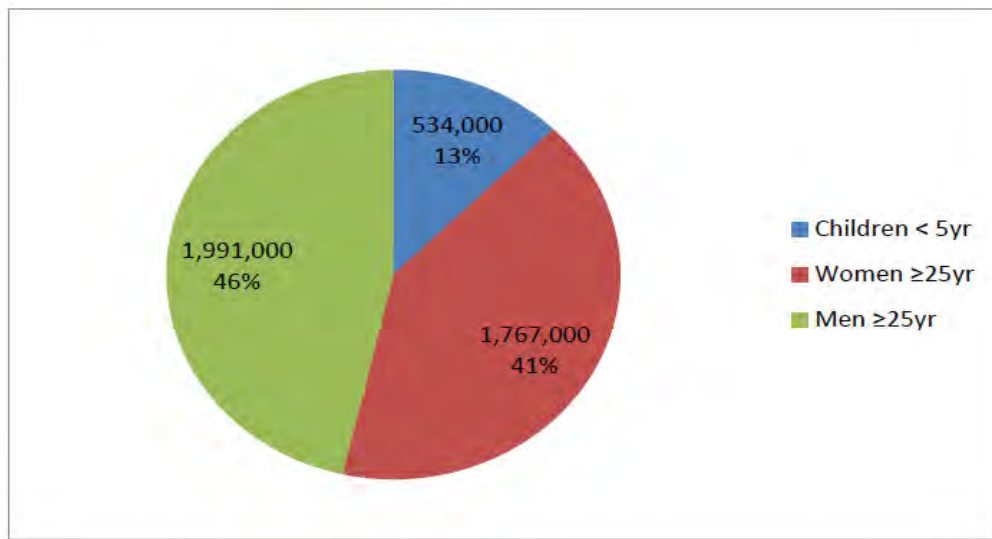
Acute lower respiratory infection (ALRI), for instance, is documented to be the leading cause of death in children less than five years in developing countries (Smith et al., 2011). Even though indoor air pollution is a global health problem, developing countries are affected the most (WHO, 2012). The lower and middle income (LMI) countries are where most of the biomass related deaths happen (WHO, 2012). Recent data by the WHO (2012), indicate that globally, 4.3 million deaths in 2012 were connected to air pollution at the household level (HAP), almost all in low and middle income (LMI) countries. The regions that witness most of the deaths are South East Asia, Western Pacific, Africa and the Eastern Mediterranean. South East Asia and the Western Pacific regions recorded the highest numbers with 1.69 and 1.62 deaths respectively. Africa and the Eastern Mediterranean recorded 600,000 and 200,000 deaths respectively with 99,000 deaths occurring in Europe while the Americas recorded about 81,000 deaths with all the other higher income countries recording about 19,000 deaths (WHO, 2012). The WHO estimates is presented graphically in figure 2.3.

Figure 2.3: Deaths attributed to indoor air pollution by regions

Source: WHO, 2012

Key: HAP: Household air pollution; Amr: America, Afr: Africa; Emr: Eastern Mediterranean, Sear: South-East Asia, Wpr: Western Pacific; LMI: Low- and middle-income; HI: High-income. Percentage represents percent of total HAP burden (add up to 100%). HAP: Household air pollution; ALRI: Acute lower respiratory disease; COPD: Chronic obstructive pulmonary disease; IHD: Ischaemic heart disease.

Figure 2.4 presents a significant number of women (41%) and children (13%) mortality associated with household air pollution. Literature reviewed on epidemiological studies by Smith et al. (2000) suggests that ALRI risks can increase indoor air pollution. ALRI is the most common cause of illness and death in children under five and seven years of age (WHO, 2012). Research by Currie and Neidell (2005) adds significantly to the stock of knowledge of indoor air pollution and human health, showing that some of the costs of pollution can come in the form of elevated infant mortality.

Figure 2.4: Deaths attributable to HAP in 2012 by age and sex

Source: WHO, 2012

The population that is most vulnerable to Acute Respiratory Infections (ARI) which occurs as a result of exposure to indoor air pollution is children under five years of age. They are vulnerable because most of the organs of the under-five population, especially the lungs, are not developed and so pollutant penetration is greater (Pande, 2000). Children under five years have limited defense against infection because they also have less developed immune systems (Smith et al., 2000), their respiratory rates are higher compared to adults, and they have narrow airwaves. They breathe approximately, 50% higher than adults under normal conditions (Moya et al., 2004).

Again, children spend longer times in places close to cooking areas during peak heating and cooking times (Barnes et al., 2005; Ezzati & Kammen, 2000). The strong association between children's exposure to indoor air pollution and respiratory infections calls for interventions to reduce child exposure to biomass related smoke which occur indoors in developing countries (Zhang & Smith, 2003; Smith 2002; Bruce et al., 2000). Identified preventive interventions to reduce child exposure to indoor air pollution are varied (von Schrinding et al., 2002). They range from proper ventilation systems to the use of

improved technologies such as improved cookstoves. Many publications in recent times show that the penetration of improved stoves in developing countries has significantly reduced pollution that occurs in residential places (Smith et al., 2011).

The global burden of disease⁶ attributed to indoor air pollution is extremely high with 53 million disability-adjusted life years (DALYs) lost annually (Smith & Mehta, 2000), because child mortality ratio is substantial in developing countries.

Women are the main cooks, in most cultures, and so women are identified to have higher exposure levels to household biomass smoke related pollution than men (Behera et al., 1988). In developing countries, especially in sub-Saharan Africa (SSA), cooking and heating have customarily been the responsibility of women. Again certain cooking practices and habits bring cooks (women) very close to pollutants which have the potential to increase women's exposure to these pollutants.

2.4.3 The Role of Technology Interventions and Health

Undoubtedly, there are documented health and environmental benefits of ambient air pollution interventions. A study conducted in Turkey Cesur et al., (2013) on indoor air pollution and infant mortality through the installation and expansion of natural gas infrastructure to replace coal in residential areas of low income communities concluded that clean fuels consumption in homes have positive impact on reducing infant mortality. The results of the study were very remarkable in the sense that infant mortality rate in Turkey significantly reduced due to the expansion of natural gas infrastructure system.

⁶ Burden of disease refers to “the loss of health and premature mortality at the population level. Disability-adjusted life years (DALYs) are calculated as the number of years lost due to premature mortality plus the number of years lived with disability due to a disease with appropriate disability weights” (Murray and Lopez 1996).

The gas infrastructure subscription ratio to mortality decline was 4:1 such that one percentage increase in the gas infrastructure in Turkey, reduced child mortality by four percent. This resulted in life savings of 348 infants in 2011 alone in Turkey (Cesur et al., 2013). Table 2.1 gives some examples of body of reviewed literature on indoor air pollution mainly in developing countries and their recommended interventions for addressing the problem.

Table 2.1: Review of biomass technology interventions for improved health

Study	Region of Interest	Pollution Source	Type of Proposed Intervention
Ethan (2004)	Kenya	Indoor air pollution	Improved cook stoves
Surridge et al., (2005)	South Africa	Indoor air pollution	Improved cook stoves
Ezzati and Kummen (2002)	Developing Countries	Indoor air pollution	Integrated method: housing design, cook stoves, etc.
Cesur et al., (2013)	Turkey	Indoor air pollution	Expansion of natural gas infrastructure
Bruce et al., (2002)	Developing countries	Indoor air pollution	Efficient cooking infrastructure
Smith et al., (2011)	Guatemala	Indoor air pollution	Improved cook stoves
Hanna et al., (2012)	India	Indoor air pollution	Improved cook stoves
Zhou et al., (2013)	Ghana	Particulate and chemical pollution	Policies on transportation, urban planning and forestry
Dionisio et al., (2010)	Ghana	Biomass pollution (indoor & outdoor)	Policies on biomass and traffic pollution
Barnes (2014)	Developing countries	Indoor air pollution	Behavioural

Studies reviewed and summarized above have mainly focused on technology within the indoor setting, very little is known about the impact of personal exposures to pollutants from biomass within commercial settings in developing countries, especially in Africa.

2.5 Biomass Energy - Climate and Environment Nexus

2.5.1 Greenhouse Gas Connections

Globally, the greatest contributing sector to greenhouse gas that traps heat within the atmosphere is the energy sector (IEA, 2014). The energy sector burns different forms of energy, especially fossil fuel that have global warming implications. There are varied implications including climate, health and economic associated with the combustion of energy, especially the unclean one. Production and use of energy is crucial for economic growth and development. However, the production and use of energy is associated with air pollution which poses problems to the climate, and in some cases has resulted in economic damages and public health challenges.

Earlier assessment by the Intergovernmental Panel on Climate Change (IPCC) had established a direct relationship between atmospheric greenhouse gas concentrations and atmospheric warming (IPCC, 1998). From 1880 to 2012, the average global temperature has increased by 0.85°C for the period indicated. This increase is largely attributed to human or anthropogenic activities (UNFCCC, 1992). The global implications of this temperature increase are diverse. Oceans have warmed, the amounts of snow and ice have diminished and sea level has risen with its attendant coastal inundations. From 1901 to 2010, the global average sea level rose by 19 cm per year as oceans expanded due to warming and ice melted (IPCC, 2013). The Arctic's sea ice extent has shrunk in every successive decade since 1979, with 1.07 million km² of ice loss every decade (IPCC, 2013).

The current GHG emissions trajectory signals that global temperature will exceed 1.5°C compared to 1850 to 1900 levels by the end of the century (IPCC, 2013). With the continuous warming of the global atmosphere, the world's oceans will warm and ice melt

will continue while average sea level rise is predicted at 24-30cm by 2065 and 40-63cm by 2100 (IPCC, 2013).

2.5.2 Short-Lived Climate Implications

Black carbon is mainly produced as a by-product from incomplete or inefficient combustion of biomass. Black carbon alone is estimated to contribute between twenty five and fifty percent carbon dioxide equivalent to global warming (IPCC, 2013). Unlike carbon dioxide, black carbon has local atmospheric or climate effect. For instance, food security and availability of water for domestic and agricultural purposes in the Himalayan region is threatened as black carbon disrupts the annual monsoons.

The implication of biomass smoke on the regional and global climate is receiving attention in the literature in recent times (Jagger & Shively, 2013; Jacobson et al., 2013; UNEP, 2011). Black carbon from household energy, mainly biomass and kerosene is a potential global climate warmer, though very short lived. Black carbon is the second largest climate warmer after carbon dioxide. It is a strong absorber of sunlight even though it does not stay in the atmosphere longer compared to carbon dioxide. Black carbon is a particle and not a greenhouse gas but it disperses quickly in the atmosphere with heavy global warming potential. Even though black carbon stays only for few days in the atmosphere, one gram of BC is compared to what the same amount CO₂ can do in hundred years. It means that BC has hundred times the global warming potential (GWP) of CO₂ (Jacobson et al., 2013).

Since the atmospheric lifetime of black carbon is only a few days, reducing black carbon emissions can bring about a rapid climate response in a time. Their reduction also produces multiple benefits in areas close to emission sources. In view of this, replacing traditional cookstoves with more efficient ones can have a significant impact on emission

reduction. For instance, the Climate and Clean Air Coalition (CCAC) had indicated that modern cookstoves emit less greenhouse gases and also reduce fuel use by 30-60% and black carbon emissions by 50-90% (CCAC, 2016).

Fire is common in most terrestrial ecosystems and has a geological history as long as that of land plants (Bowman et al., 2009). Galanter et al., (2000) assert that there are potential feedbacks from fire to climate, through pyrogenic emission of trace gases and aerosol precursors that influence atmospheric chemistry and radiative balance, as well as the feedback through CO₂ emission to the global carbon cycle. This pyrogenic emissions and global carbon cycle nexus or interactions have also been illustrated by van der Werf et al., (2004 & 2008).

The work of the Inter-governmental Panel on Climate Change (IPCC) unequivocally underscores the need to immediately reduce emissions of Short-Lived Climate Pollutants (SLCPs), which include black carbon (soot), methane (CH₄), and fluorinated gases (F-gases, including hydrofluorocarbons, or HFCs). Short lived climate pollutants (SLCPs) are powerful climate forcers and dangerous air pollutants that remain in the atmosphere for a much shorter period of time than longer-lived climate pollutants, such as CO₂. SLCPs are estimated to be responsible for about 40 percent of current net climate forcing (IPCC, 2013).

Takaro et al., (2013) reported on new evidence of the relationship between climate change and human health have advanced the understanding that human activity through the emission of greenhouse gases can cause global warming which in turn impacts on human health. Direct health effects include heat-related illness and related exacerbation of underlying cardiovascular disease, chronic obstructive pulmonary disease (COPD) and asthma, increases in hazardous air pollution days from ozone and particulate matter

(including forest fires and desertification) and mortality and morbidity from extreme weather events (McMichael et al., 2006; Kinney, 2008; Pinkerton et al., 2012).

2.5.3 Local Benefits for Clean Air

The type of energy used by a particular country largely depends on the country's development status and also the energy resources available to that country. The energy mix or choices for the global south (developing countries) largely differs from that of the global north (developed countries). Whereas the GHG emission from energy production and consumption implications are global, air quality implications are local.

Rapid industrialization has a history of massive production and consumption of unclean energy with associated increase in air pollutants. Developed countries today went through the trajectory of development versus unclean environment historically, but have put in place environmental regulations and standards to minimize toxins and pollutants from energy combustion in the environment. Urbanization and industrialization in many emerging and developing economies will mean energy consumption will increase in those countries. This consumption with associated air pollution will continue to become a global concern in the twenty first century. This development trend poses risk to public health, ecosystems and the economy (IEA, 2014). Some countries have developed air quality measures mainly to reduce the negative health implications of pollutants with GHG emission reductions as co-benefit. The United States of America for instance has been tightening air quality regulations to force significant emission reductions of sulphur dioxide (SO₂), nitrogen oxide (NO_x), particulate matter (PM), mercury (Hg) and other pollutants. The primary objective is to enhance public health with climate as co-benefit of the air quality measures. As climate change mitigation policies are being developed and strengthened, attention is also being given to the analysis of the potential synergies

between air pollution control and GHG emissions abatement. Policies that address multiple air pollutants and provide consistent and long-term signals can result in cost-effective reductions of both air pollutants and GHGs. Emerging literature on integrated scenario analysis indicates that a simultaneous, integrated approach to GHG mitigation, air quality, and energy security objectives shows high cost-effectiveness compared to a piecemeal approach (Clarke et al., 2014). Many countries recognise the potential to address these dual priorities within the air pollution- GHG emissions nexus. However, the nature and the extent of these issues vary across countries, resulting in diverse responses.

2.5.4 Biomass Consumption and Ghana's GHG Inventory

Ghana signed the United Nations Convention on Climate Change (UNFCCC) in 1992 in Rio and subsequently ratified the Convention to become a party to the Convention. Being a party to the Convention mandates Ghana to regularly communicate to the international community her internal climate actions including the development and updates of national emissions inventory reports (NIR). The preparation and updates of the inventory report is based on financial support received and national capabilities. The NIR publishes net greenhouse gas (GHG) emissions estimate of the main economic sectors for specific reporting period.

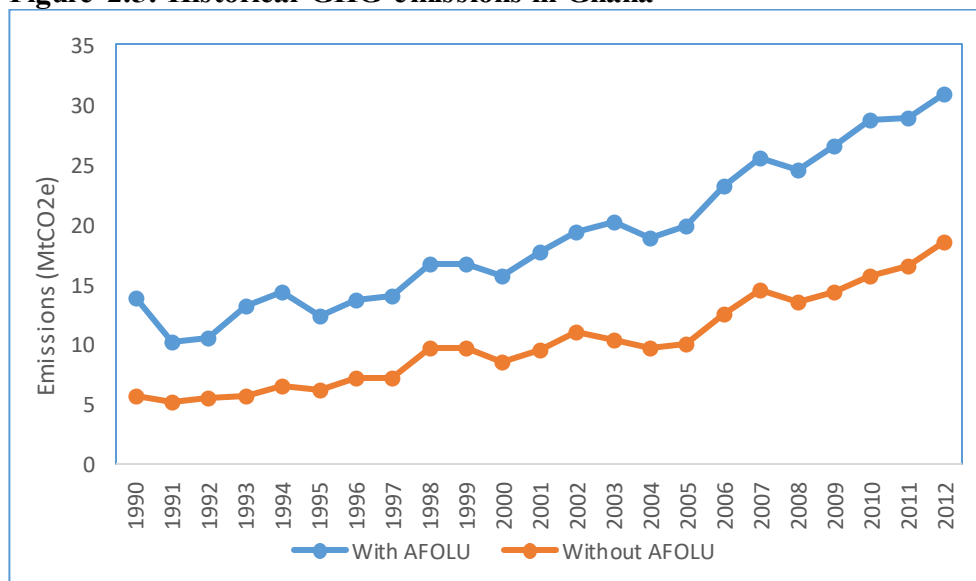
The preparation of the NIR serves a number of purposes. Apart from satisfying the international reporting requirement, the inventory reporting processes also guides national development on emissions trajectories as well enhancing national technical capacities. Continuous capacities for major reporting sectors is being built which the process also offers avenue for setting national emission targets from time to time and developing strategies for meeting the set targets on emissions.

Ghana's GHG emission and removal system covers the main sectors of the economy and also follows the IPCC's GHG sector reporting format under the Convention. The main sectors that Ghana reports on include;

- i. Agriculture, Forestry and other land use (AFOLU)
- ii. Energy
- iii. Waste and
- iv. Industrial process and product use (IPPU).

Ghana's total greenhouse gas emissions were 30.8 million tonnes (Mt) carbon dioxide-equivalent (CO₂e) in 2012 (UNFCCC, 2015). This represents an increase of 6.9% on net emissions recorded in 2010, and an increase of 49.3% and 54% above 2000 and 1990 levels respectively (GNIR, 2015). The net national GHG emission in 2012 was 18.5MtCO₂e when emissions and removals from the Agriculture, Forestry and Other Land Use sector were excluded (GNIR, 2015). Figure 2.5 gives the emission trend from 1990-2012.

Figure 2.5: Historical GHG emissions in Ghana



Source: Ghana's GHG NIR, 2015

Accounting for woodfuels within the national GHG inventory could be challenging because the source of the wood is land based. However, the wood is consumed either as household energy or for industrial purposes such as firing ovens and boilers. The national accounting system for biomass emissions in the inventory in Ghana currently does not include activities from the informal or subsistent economic sectors such as fish smoking, gari processing, local/traditional breweries, kenkey processors and even chop bar operators. Current accounting for biomass burning accounts only for areas affected by fire in cropland, forestland and grassland (Ghana's NIR, 2015). Accounting for national biomass consumption without the informal subsistent economic sector leaves an important accounting gap. The design of the GHG inventory system can be done to accommodate or account for emissions from small scale economic biomass burning activities. It is also possible to differentiate wood fuels that are mainly used for economic activities from those that are purely for household cooking and heating (i.e. domestic). The above mentioned gaps still remain unaddressed.

2.5.5 Environmental Implications

There is a relationship between population growth and environmental outcomes. This has been documented historically by a comprehensive population-environment theory by Malthus (1873). Malthus' theory predicted that population growth will out-pace food production. Assuming technology to be constant, Malthus (1873), postulate that while human population grows geometrically, food production on the other hand grows arithmetically, so famine becomes the obvious result posing danger for the future of humanity. This research though acknowledges population growth as a key predictor for deforestation, the focus of the discussion of current research is on the intensity of wood

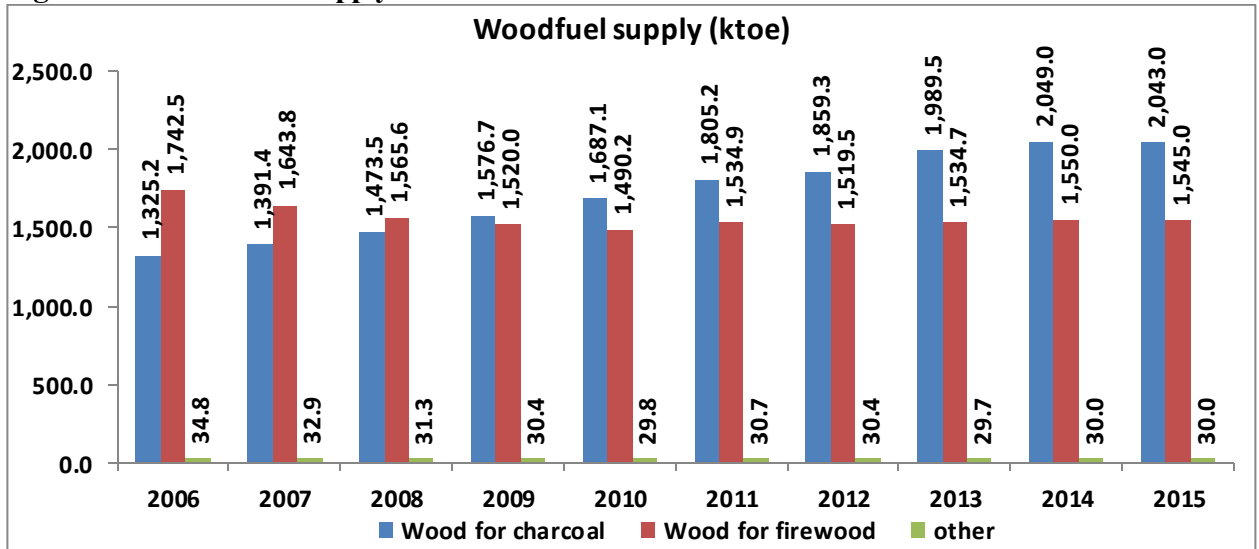
consumption by subsistent economic activities in developing countries and the implications these activities have on the environment.

Expansion of subsistence farming is a key indicator of population growth in Africa (Geist & Lambin, 2002). There were instances where local land users have caused some level of deforestation due to continuous and persistent land use for varied purposes. Again, household demand for fuelwood is seen as proximate driver of deforestation in South Asia and East Africa (Rudel et al., 2000). Land consolidation for pasture by in-migrants has pushed some frontiers and displaced some peasant farmers (Carr, 2004a).

The WHO reports that over 2.4 billion people worldwide burn biomass fuels on a daily basis to satisfy various household energy needs (WHO, 2002, 2012). In relation to this constant burning of biomass is the release of two million tonnes of biomass going up in smoke every day (WHO, 2006). This may not pose a problem where the growth of new trees outpaces human demand. Yet, where wood is scarce and the population is dense, wood collection can put considerable pressure on forests. Particularly in arid and semi-arid regions of the world, the need for fuelwood results in significant deforestation, with all its detrimental consequences. In arid and semi-arid parts of West Africa, fuelwood shortages limit the carrying capacity of the land more so than do low crop and livestock yields.

In Ghana, woodfuels (firewood and charcoal) form significant proportion of domestic and small scale business energy consumption. Figure 2.6 shows the trend of fuelwood supply and consumption from 2006 to 2015.

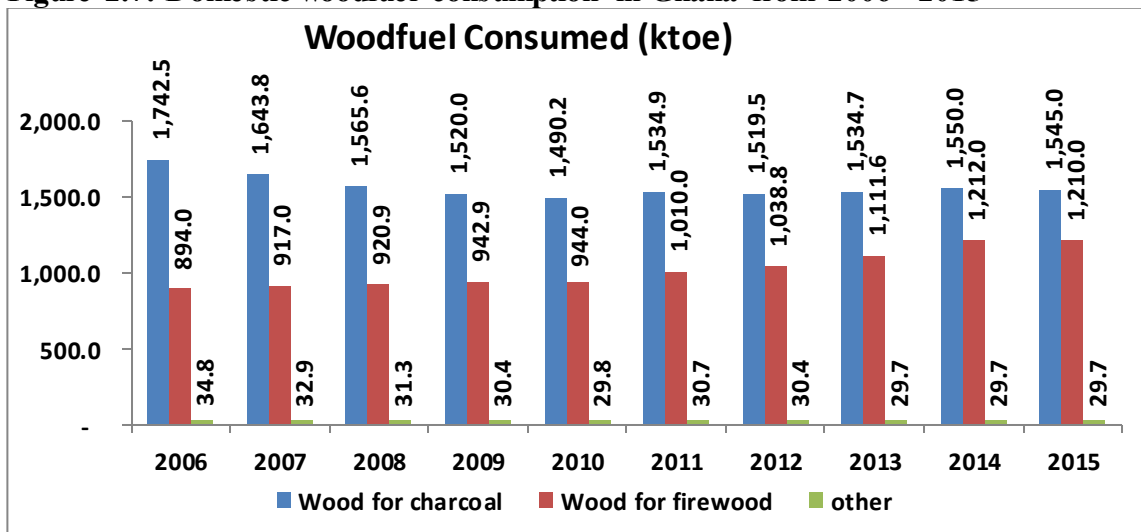
Figure 2.6: Woodfuel supply in Ghana from 2006-2015



Source: Energy Commission, 2016

From figure 2.6, supply of wood for charcoal increased from 1,325 ktoe⁷ in 2006 to 2,043 ktoe in 2015, whereas the supply of wood for firewood had seen a marginal decline from 1,644 ktoe in 2007 to 1,545 ktoe in 2015. Putting charcoal and firewood together, the supply increased from 3,067.5 ktoe in 2006 to 3,588 ktoe in 2015.

Figure 2.7: Domestic woodfuel consumption in Ghana from 2006 - 2015



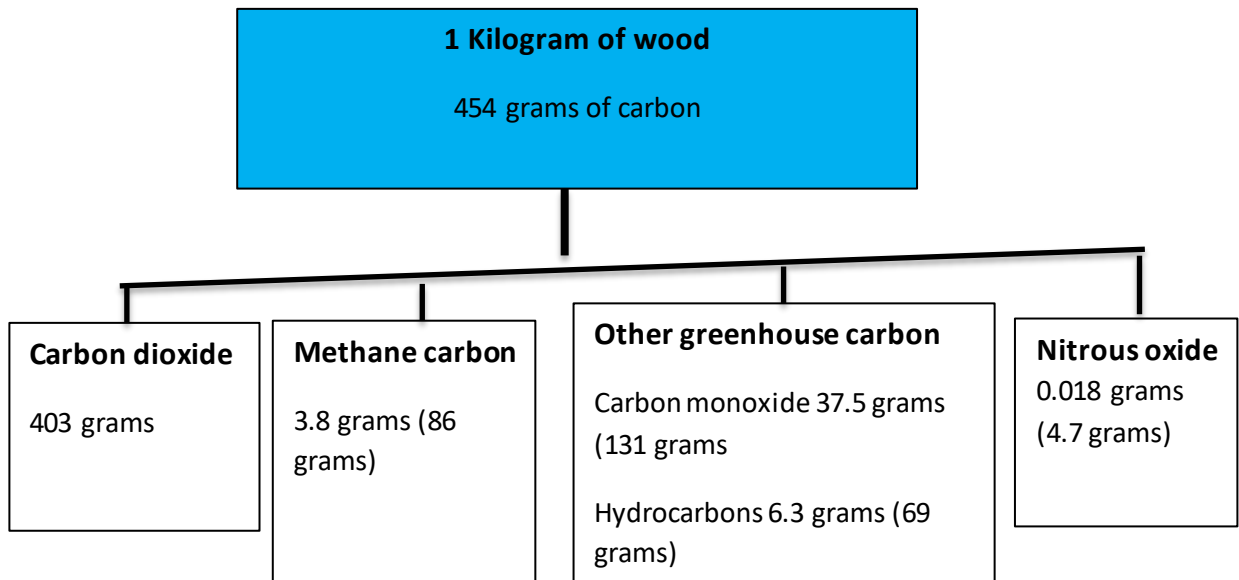
Source: Energy Commission, 2016

⁷ Ktoe (tonne of oil equivalent): it is a unit of energy defined as the amount of energy released by burning one tonne of crude oil

On the consumption trend, wood for firewood increased from 894 ktoe in 2006 to 1,210 ktoe in 2015, whereas wood for charcoal recorded a steady consumption around 1,500 ktoe from 2008 to 2015. The ecosystems implication for wood burning is documented. Excessive consumption of biomass may result in imbalance in biodiversity and hydrology, especially when there is a preference for the planting of certain species of woods for energy use, instead of the natural forests and vegetation of the location (Kammen, 2006). A study in Ethiopia in 1983 has estimated, for example that, if the animal dung used for fuel had been left as soil fertilizer, grain production could have been increased by one to fifteen million tons (Newcombe, 1987).

Biomass combustion is also estimated to contribute 20 – 50 percent of global greenhouse gas (GHG) emissions (Zhang et al., 2002 cited in Crutzen & Andreae, 1990). The main gases associated with biomass burning include carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄) and nitrous oxide (N₂O). The most powerful of these is methane, in terms of global warming potential (GWP). Methane could remain in the atmosphere for over a 20-year period and causes more than 20 times the global warming from the same amount of carbon as carbon dioxide (UNDP, 2000). Smith et al., (2000) which was cited in UNDP (2000) reveal that anytime 1 kilogram of wood is combusted in a typical open stove, 454 grams of gases are released into the environment. This is demonstrated in Figure 2.8. If numbers between parentheses (CO₂ equivalents), in the figure, are added to the CO₂ grams emitted, the total GHGs emissions are 693.7 CO₂ equivalent grams. Because of significant emissions of non-carbon dioxide greenhouse gases, solid biomass fuels, even though renewable, can have a larger greenhouse gas commitment per meal than fossil fuels, kerosene, and liquefied petroleum gas.

Figure 2.8: Greenhouse gas emissions from a typical biomass cook stove



Note: Numbers between parentheses are CO₂ equivalents of non-CO₂ gases

(Source: Adapted from Smith et al., 2000 in UNDP 2000).

From the analysis in Figure 2.8, an average burning of 10 kilogrammes of wood gives an indication of an average carbon emission of 4,540 grams into the atmosphere.

Carbon monoxide (CO) is produced naturally by the body as a byproduct of converting protoporphyrin into bilirubin (Goldstein, 2008). Carbon monoxide when in the body combines with hemoglobin to form carboxyhemoglobin. CO is easily absorbed through the lungs and inhaling CO can affect the central nervous system and could even lead to death (Buckley, et al., 2005).

The main manifestations of carbon monoxide poisoning develop in the organ systems most dependent on oxygen use, the central nervous system and the heart (Kao & Nanagas, 2006). Symptoms known to be associated with CO poisoning include headache, nausea, malaise and fatigue. These symptoms are often mistaken for a virus such as influenza.

Headache is the most common symptom of acute carbon monoxide poisoning; it is often described as dull, frontal, and continuous (Buckley et al., 2005).

Residential combustion of biofuels is the single largest contributor to CO emissions in developing countries (Dickerson et al., 2002). The biofuel sources for domestic emissions are from woody biofuels (fuelwood and agricultural residues) and dried animal waste (dung). Details of how CO exposure of the participants in the study is described in the section 3.7.

2.6 Summary of Literature Review

From the literature reviewed, the following deductions could be made;

- i. Literature on biomass smoke pollution in developing countries is extensive with many authors looking at the subject from different angles.
- ii. Literature reviewed had also focused extensively on the relationship between exposure to biomass smoke and health. Studies reviewed, however, mainly focus on indoor air pollution with most of the studies covering systematic reviews instead of field studies.
- iii. Again, studies reviewed have mainly focused on exposure of women who do normal household cooking without addressing vulnerable women who depend on biomass fuel as the source of energy to earn livelihood.
- iv. For climate change and biomass, some of the studies reviewed have establish relationship between biomass burning and GHG emissions, none of the studies made effort to explore this relationship with field data.

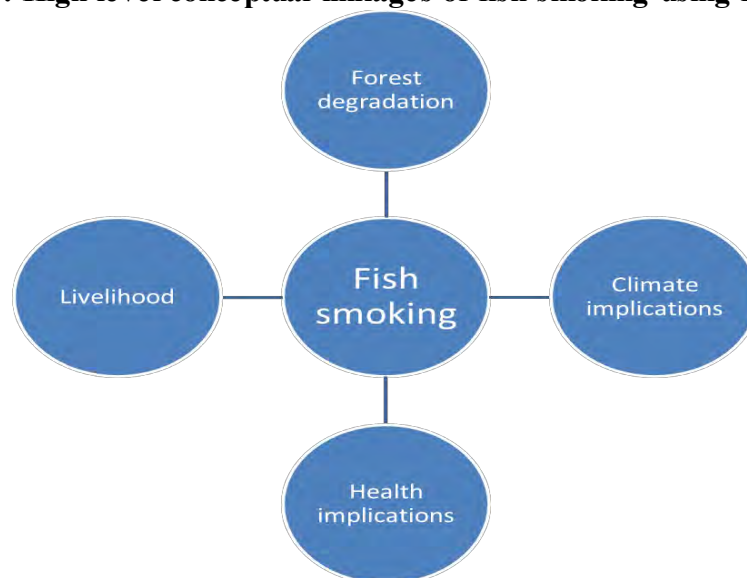
In view of the identified gaps, the study addresses the personal exposure of fish smokers who use biomass fuel in commercial quantities and at the same time stay within smoke

environment relatively longer than those women who do household cooking. It also explores how the quantity of fuelwood consumed by a small-scale biomass dependent activity contributes to the global climate change discourse.

2.7 Theoretical and Conceptual Framework

There are high level conceptual connections of fish smoking with variables such as forest, climate, livelihood and human health. Depending on where the fish smoking is done, the activity could either affect the other variables positively or negatively. The connections of fish smoking with livelihood, forest degradation, emissions concentration and human health are illustrated in Figure 2.9.

Figure 2.9: High level conceptual linkages of fish smoking using fuelwood



Source: Author's construct (2016)

From Figure 2.9, traditional methods of smoking fish using firewood and traditional ovens consume much firewood mainly coming from the forest. Unsustainable harvesting of wood fuel for commercial fish smoking has the potential to cause forest degradation and, in some cases, deforestation. Fish smoking as an economic activity provides income to the women in the business which could improve the livelihoods of the women in particular

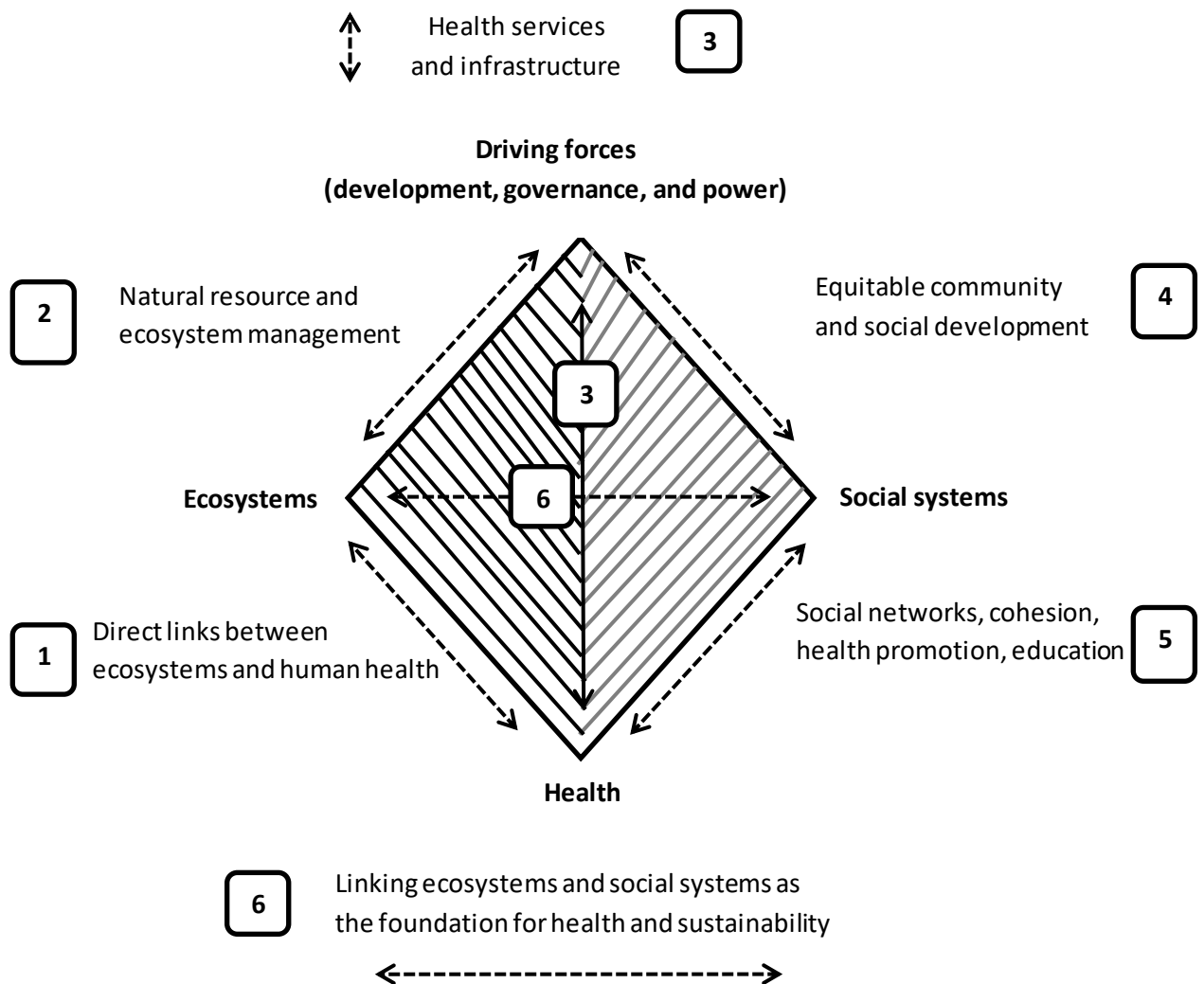
and the household in general. However, the smoke from the firewood could have negative health implications for humans and could also increase the ambient concentration of pollutants such as particulate matter and carbon. The connections among fish smoking, environment (in this case climate) and human health is explained by two theoretical frameworks including the Environmental Health Theory (EHT) and the Drive-Pressure-State-Impact-Response (DPSIR) model.

2.7.1 Environmental Health Theory

Environmental health, ecology and health and human ecology each provide constructs applicable to public health interventions at different scales of temporal, spatial, and conceptual complexity (Parkes et al., 2003). This theory conceptually and methodologically integrates knowledge and action to ensure comprehensive and sustainable environmental health gains. Conceptually, one's understanding of complex ecosystems and social dimensions of the environment could affect health at different scales and time.

Environment, health and human ecology (development) are not mutually exclusive. There are both positive and negative feedbacks among the interactions of these variables. Defining environmental health broadly encompasses “the theory and practice of assessing and controlling factors in the environment that can potentially affect adversely the health of present and future generations” (WHO, 1993). These conceptual relationships are portrayed in Parkes Prism framework of health and sustainability (Figure 2.10).

Figure 2.10: Prism framework of health and sustainability



Key: “1=Direct links between ecosystems and human health (traditional environmental health); 2=natural resource and ecosystem management (including land and water use); 3= health services and infrastructure (including water and sanitation services); 4=equitable community and social development (including socioeconomic determinants of health); 5=social networks, cohesion, health promotion, and education (including social capital); 6= linked socio-ecological systems (synergies between the environmental and socioeconomic determinants of health can arise when social processes generate health benefits through empowerment, justice, and social cohesion while also enhancing ecosystems)”. **Adapted from Parkes (2003).**

As a community-oriented, ecosystem-based example of environmental health study, the emphasis is on the demonstration of practical opportunities for synergies between ecosystems and social systems that foster a double dividend for public health through the environmental and socioeconomic determinants of health (Parkes, 2003). The study highlights the interface between research and practice on health, socio-ecological and

ecosystems. Research in environmental health and practice encourages synergies and yields dividends for public health interventions. Figure 2.10 point to the need to understand the driving forces of governance, development, and power as well as the specific local realities of people and places.

These overlapping themes support the demand for research and practice that focused on enhancing both social and ecological resilience to ensure the creation of double dividend of public health benefits. The “prism” of health and sustainability illustrates the implications for the theory and practice when the interrelationships between driving forces, ecosystems, social systems, and health are made explicit.

In the context of fish smoking, smoke from burning wood to process the fish is associated with the release of pollutants into the environment that have the potential to affect human health negatively as well as damaging the integrity or health of the environment.

Hazards in the physical environment remain disproportionately the burden of individuals, households, and societies that also face inequalities in terms of socioeconomic discrimination and/or psychosocial stress from their social environment (Institute of Medicine, 1999; McMichael et al., 2000; Stephens, 1998). It is postulated that, key contributions of environmental health to human well-being lie in the provision of safe resources (water, air, food) and a safe environment (home, work, leisure) within which society and individuals can thrive.

Fish smoking, using biomass fuel, on the face value promotes environmental pollution and heat conditions that make working within such environment very uncomfortable and unsafe for human health. By focusing on human-environment interrelationships within ecosystems, human ecology highlights direct and indirect health impacts caused by unhealthy trajectories of development, anthropogenic ecosystem change and related social

inequities (Follér, 2001; Levine & Levine, 1994; Marten, 2001). Relationships among social improvement, development and health in most cases are not explicit. However, human ecology is based on the premise that developmental processes and human health gains are entirely dependent on ecosystem services (Costanza et al., 1997; Daily, 1997). The theory is mainly based on the “Agent-Host-Environment triad and addresses key variables such as health and environment that this study focuses on.

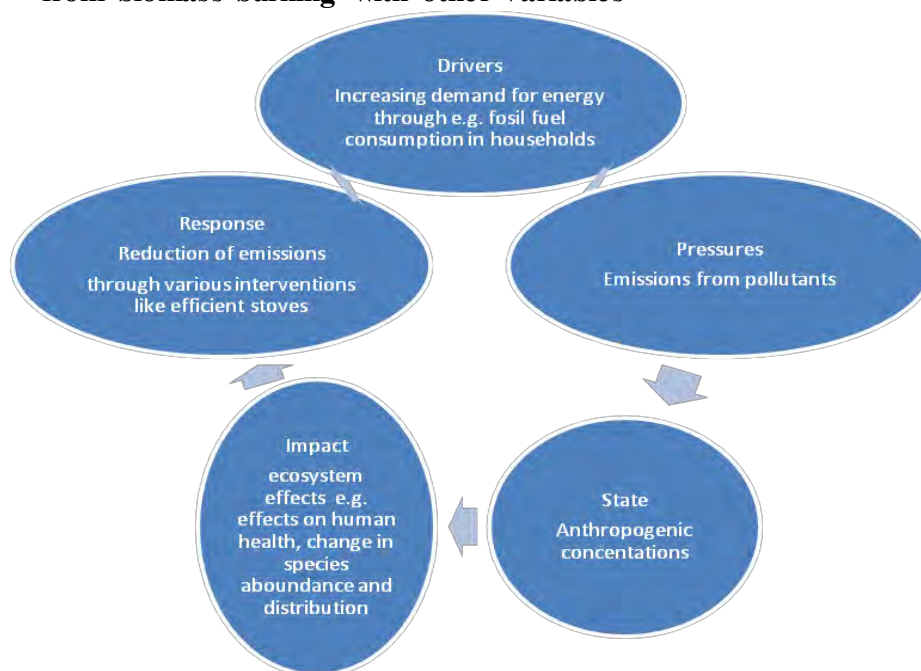
However, the theory fails to propose or suggest any intervention to address the issues identified. In this vein, the study uses the driver-pressure- state -impact-response model (Figure 2.11) to address the intervention gap from the environmental health theory. The second theoretical framework therefore complements the first one.

2.7.2 Drivers-Pressures-State-Impact-Response Model/Framework

The principal human demands for energy, transportation, materials and food processing may be regarded as the “*drivers*” for the production of air pollutants. In order for an economy to continue to develop in a sustainable way, these sources of pollutants must be managed. To do this, society must understand the “*impacts*”- i.e. what type of pollutants affect which part of the environment and human health, and to what extent. To decide whether or not action is necessary, society also needs to know the “*state*” of the environment, i.e., to evaluate whether or not the levels in the environment exceed those which will cause environmental harm. For society to be able to take appropriate action, society must be able to “respond” in a focused way to control and reduce pollution while avoiding causing damage to social and economic foundation of the people. Research and inventories provide policy makers and the public with the understanding of the key polluting sources or “*pressures*”, how these sources have developed with domestic and commercial activities over time and how they are likely to contribute to future

environmental pollution and human health. This understanding is essential or crucial for a focused “*response*” to the problems associated with the pollution and to meet the demands of sustainable development. See Figure 2.11.

Figure 2. 11: Drive-Pressure-State-Impact-Response model explaining the smoke from biomass burning with other variables



Source: OECD, 1993, 2004 modified by Author

Working within this framework for fish processing (mainly smoking and frying at small scale level) in Ghana, processors mainly use wood fuel as energy to smoke the fish meant to be sold to various clients or consumers. Depending on the amount and frequency of wood fuel used, the continued usage of fuel wood has the potential to degrade nearby forest cover, especially when life trees are harvested for this purpose.

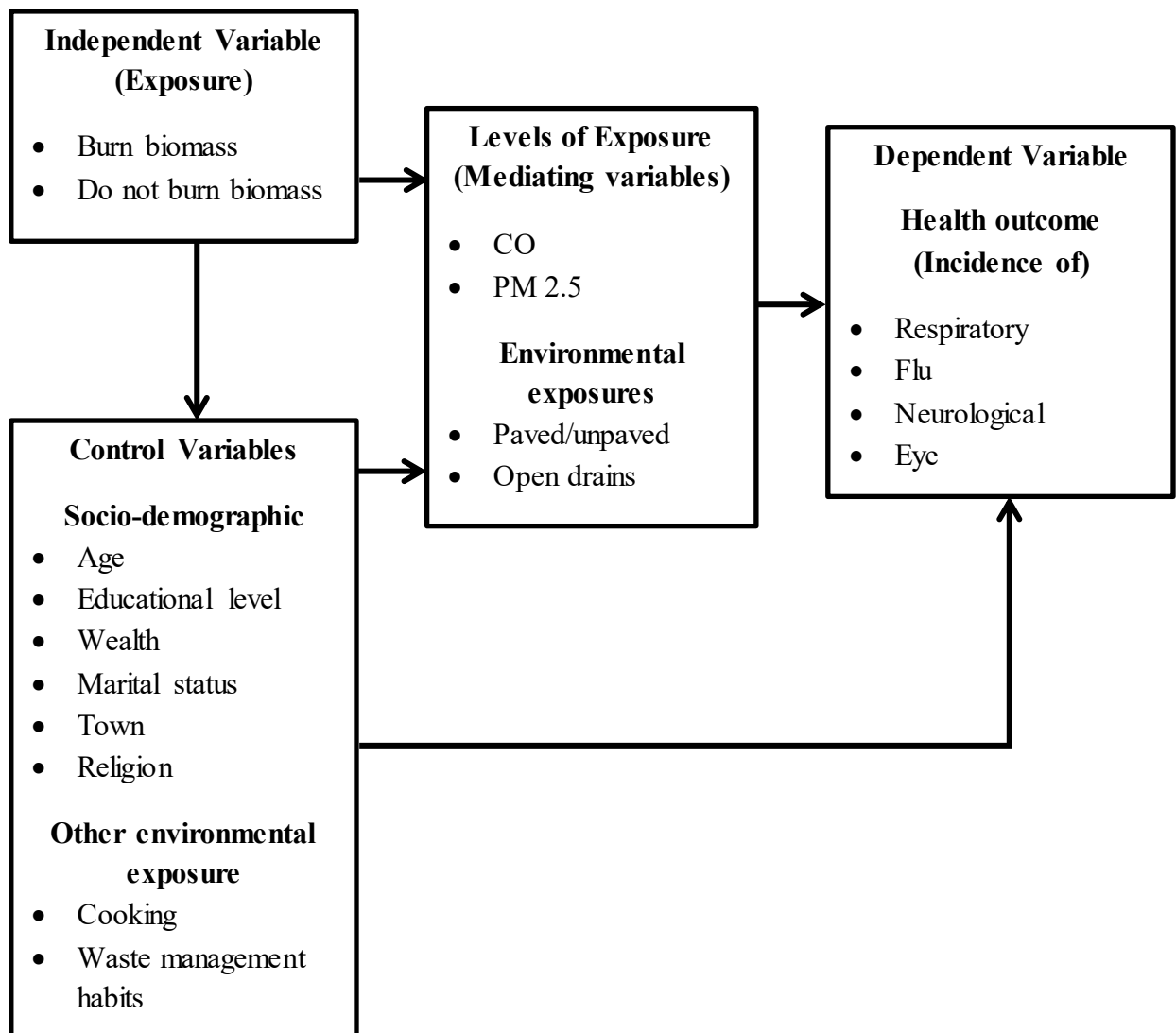
Again, burning of biomass to process fish results in the emission of carbon dioxide, carbon monoxide, particulate matter and other suspended particles that are dangerous to human health and the environment. Carbon monoxide, for example, has negative health effects on humans. Depending on the intensity and the length of exposure to these pollutants, acute toxicity on human health could be recorded. Methane and nitrous oxide are known bi-

products of burning woodfuel. Even though the two gases (methane and nitrous oxide) have short life line within the environment relative to carbon dioxide, their global warming potential is more dreadful than carbon dioxide.

Working within the framework provided in Figure 2.11, traditional fish smoking, as practiced in many developing countries, especially in Ghana, use fuelwood as “drivers” for environmental pollution and degradation. The emissions from this activity subsequently put pressure on the environment. The continuous emissions from fish smoking results in an increased concentration of pollutants in the atmosphere as well as the local environment causing warming of the atmosphere. Increased concentration of gases, especially CO, CO₂, CH₄ and N₂O could negative effect on human health, change in species and distribution. The model then suggests or proposes response measures to address the negative impacts associated with smoking fish through appropriate and efficient methods.

The relationships among the main variables of the study are further conceptualized in figure 2.12.

Figure 2.12: Conceptual framework explaining the relationships in biomass burning and human health



Source: Author's Construction (2016)

From Figure 2.12, the main independent variable is personal exposure to smoke from biomass fuel which is conceptualized to have implications on the population exposed to the smoke. All the study population (both fish smokers and non-fish smokers) is assumed by the model to have some level of exposure. Continuous exposure to smoke from biomass burning has implications on human health. Health outcomes considered in the model are flu, respiratory, eye, and neurological symptoms. The effect of the exposure to smoke on health is mediated by a number of factors such as the level and length of

exposure to pollutants from the smoke and other environmental conditions such as open drains and dust.

In the model, socio-demographic factors such as age, education, town of fish smoking activity, wealth, etc are controlled for to see their effect on the outcome variables. Other control variables that the model recognizes are environmental in nature and they include waste management practices as well as cooking with charcoal.

CHAPTER THREE

FISH SMOKING IN GHANA AND STUDY METHODOLOGY

3.1 Introduction

This chapter discusses fish smoking in Ghana and how this activity is connected with women's exposure to harmful pollutants from smoke. It further talks about the study sites as well as how data were collected. Two types of data were collected comprising a household socio-demographic survey and exposure to biomass pollutants data. The personal exposure data collections deals with how data on carbon monoxide (CO) and particulate matter (PM_{2.5}) were collected within small scale fish smoking environment in Moree and Elmina in the Central Region of Ghana. It gives details of the different fish smoking settings in the two selected communities and how the different settings influence the personal exposure to smoke.

3.2 Fish Smoking in Ghana

Many people in the developing world depend on fish as their main source of income. About 35 million people either partially or wholly depend on fisheries as livelihood in Africa (UNDP, 2005).

Various traditional methods are employed to preserve and process fish for consumption and storage. These include smoking, drying, salting, frying and fermenting and some combinations of the aforementioned methods. In Ghana, smoking is the most widely practised method: practically all species of fish available in the country can be smoked and it has been estimated by the Fisheries Commission that 70-80 percent of the domestic marine and freshwater catch is consumed in smoked form (Fisheries Commission, 2013). The preservative process of smoking combines the effects of drying, heating and smoking, coupled often with salting. The pre-treatment before smoking involves gutting, splitting,

kench salting, brining and/or drying, depending on consumer preferences and the method of smoking. A combined heating-drying-smoking process entails application of smoke using suitable firewood, passing it over the fish in a closed chamber at temperatures of about 30-35°C for a cold smoked product, or alternatively, 80°C and above for a hot smoked product. Cold smoking, on the other hand, is designed to impart the desired flavour to the product (fish) rather than a degree of preservation. Cold smoking is generally not a preferred method in Ghana because the country is a tropical one. Figure 3.1 shows fresh fish being sorted out for processing in Elmina.

Figure 3.1: Fresh fish being sorted out for smoking in Elmina



Photo Credit: Antwi-Boasiako Amoah

Figure 3.1 showcase how fresh fish are sorted out before they are processed. Usually when the fresh fish are brought from the sea, the women will sort out the different sizes and also wash them before they are smoked. The most popular processing method use by women in fish processing communities in Ghana is smoking.

The advantages of smoking fish are many. They include;

- i. Prolonging the shelf life of the fish
- ii. Reducing waste of bumper harvest and making fish available during lean seasons
- iii. Adding flavor when fish is used in soups and sauces
- iv. Easier packaging for transportation
- v. Increasing protein availability to people throughout the year

Figure 3.2 shows packaged smoked fish to be transported to market centres. The packaged smoked fish are mainly sent to cities such Kumasi in the Ashanti Region, Accra in the Greater Accra Region and Mankessim in the Central Region. Interactions with residents in the study areas indicate that, smoked and packaged fish are sometimes exported to the neighbouring countries like La Cote d'Ivoire and Burkina Faso.

Figure 3.2: Packaged smoked fished waiting to be transported to the market



Photo credit: Antwi-B. Amoah (2016)

Photo credit: Antwi-B. Amoah (2016)

3.3 Oven Types

Fish smoking in Ghana is traditionally carried out by women in coastal towns and villages and along river banks and on the shores of Lake Volta. Depending on the type of fish to be smoked, its usage and possible storage period, the smoking process can take the form of “wet” hot smoking or “dry” hot smoking. Both processes are carried out at temperatures above 80°C (UNDP, 2002), which are high enough to cook the fish.

The ovens used for smoking fish are mainly traditional. These traditional ovens are largely cylindrical or rectangular and made of mud or metal.

Table 3.1: Types of oven used for fish smoking

Types of oven	N	%
Traditional	84	87.5
Improved	12	12.5
Total	96	100

Source: Research field data (2016)

Eighty four women, representing 87.5% of the sampled fish smokers from the study area use traditional mud fish smoking oven compared to only 12 women, representing 12.5% who use improved fish smoking ovens. The results further showed that all the participants who used both traditional and improved ovens used fuel wood as their source of fuel. The traditional ovens have low capacities, inefficient in fuel usage and do not have the capacity to cope with the large volumes of fresh fish landed during bumper fish seasons. This contributes to high post-harvest losses.

Figure 3.3: A Sample of traditional oven and improved oven in Moree



Photo Credit: Pamela Jagger (2016)

Photo Credit: Pamela Jagger (2016)

Figure 3.3 shows two different types of ovens depicting samples of traditional and improved ovens for smoking fish. The improved ovens by design use relatively smaller amount of firewood compared with the traditional ovens. They (improved ovens) also have smoke chimneys which vent the smoke away from the immediate smoking environment.

The smoking of fish mainly takes place either inside or outside (i.e. either as indoor or outdoor activity). The settings are such that the sheds within which the women smoke fish are either completely or partially sheltered. There is a slight difference in terms of the oven set-ups within the two study communities (Moree and Elmina). In Moree, the smoking ovens are in front of people's houses and are visibly seen in the township. In Elmina, however, the fish smoking activity is concentrated at some areas of the town. The setting in Elmina depicts a communal smoking environment whereas that of Moree is more or less a house compound activity. An interaction with the study participants during field work reveal that the women in Moree do not have dedicated land allocated by the

town authorities for this livelihood activity. The women do not want to be far away from the seashore where the fresh fish are purchased. The women in Elmina, on the other hand, have an area zoned by the city authorities for this activity. The two settings may have different implications in terms of personal exposure and also ambient concentration of biomass fuel pollutants.

3.4 Study Area and Methodology

3.4.1 Profile of the Study Area

In Ghana, there are four regions that are situated along the Gulf of Guinea. These regions are Western, Central, Greater Accra and Volta. The study focuses on two (2) fishing communities in the Central Region. The communities are Moree in the Abura Asebu Kwamankese District (AAKD) and Elmina in the Komenda–Edina-Eguafo-Abirem (KEEA) District. Moree and Elmina were selected purposefully for this study due to the level of marine fish smoking activities in the two towns after visiting other main fish smoking towns along the coast of Ghana. Study conducted by the Ghana Fisheries Commission had identified Moree and Elmina as the leading fish smoking towns along the coast (Fisheries Commission, 2013). The selection of the two towns is therefore based on literature and field visit.

Until 1970, Central Region formed part of the Western Region which was carved out as a separate entity before the 1970 population census. It occupies an area of 9,826 square kilometres or 4.1% of Ghana's land area, making it the third smallest in area after Greater Accra and Upper East (Ghana Statistical Service, 2010). The region shares boundaries with Ashanti and Eastern Regions on the north, Western Region on the west, Greater Accra on the east and on the south by the Gulf of Guinea.

Central Region is well-known for its many good higher education institutions relative to the other nine regions in Ghana (Ghana Statistical Service, 2010). The region can boast of many tourist attraction sites such as castles, forts and beaches which stretch along the region's coastline (Ghana Tourism Board, 2014). The region's economy is dominated by services followed by mining and fishing. Along the coast of the region is a succession of busy fishing villages and traditional market towns that reflect its distinct cultures.

The region has a population of 2,201,863 accounting for 8.9% of the population of Ghana per the 2010 Population and Housing Census. It has 17 districts and 19 electoral constituencies. Persons living in the region are mainly Akans (Fantis) who constitute 81.7% of the population. The other ethnic groups in the region are Ewes (6.2%) and Guans (5.3%), (Ghana Statistical Service, 2010 Central Regional Report).

Moree, was formerly known as *Mouri* or *Mouree*. It is a small town and a seaside resort in Abura-Asebu-Kwamankese District in the Central Region. Moree developed around Fort Nassau, which was the original fort on the Gold Coast taken over by the Dutch West India Company when it was founded in 1621. Its district capital is Abura-Dunkwa. The district covers a total area of 380 square kilometres. The district shares boundaries with Cape Coast Municipality and Lower Denkyira District to the west, Assin South District to the north, Mfantseman Municipal to the south and the east. It shares part of the coastline of the region (Ghana Statistical Service, 2010 District Report).

Its population, according to the 2010 Population and Housing Census is 117,185, representing 5.3% of the region's total population. The total population of the males in the district is 55,275 which constitute 47.2 % while that of the females is 61,910, representing 52.8% (GSS, 2010). Ninety percent of the district's population is rural. The district has a youthful population, representing 40.5%. It depicts a broad base population pyramid

which tapers off with a small number of elderly persons (6.5%). Migrants form 56.0% in the district (Ghana Statistical Service, 2010 District Report).

The district has an economically active population of which 50.0% is engaged as skilled agricultural, forestry and fishery workers, 14.7% in service and sales, 19.5% in craft and related trade, and 6.7% is engaged as managers, professionals, and technicians. The main occupation in the district is farming with a small number engaged in trading. Maize is the most common agricultural product found in the district together with, cassava, pepper, pineapple, watermelon, sweet potatoes, plantain, yam, cocoyam, okra, tomatoes and others. A section of the population especially the men folk also earn their living through fishing (Ghana Statistical Service, 2010 District Report).

Elmina, the second town in the study area is located in the Komenda-Edina-Eguafo-Abirem (KEEA) District on the south coast of Ghana in the Central Region. It is situated on a south-facing bay on the Atlantic Ocean coast of Ghana, 12 km west of Cape Coast. Elmina is the first European settlement in West Africa (Ghana Statistical Service, 2010). The district is bounded on the south by the Atlantic Ocean (Gulf of Guinea), to the east by the Cape Coast Municipality, the north by the Twifo-Hemang-Lower Denkyira District and the west by the Mpohor-Wassa East District in the Western Region. The Municipality covers an area of 452.5 square kilometers, giving the municipality a population density of 319.8 persons per sq. km (Ghana Statistical Service, 2010 District Report).

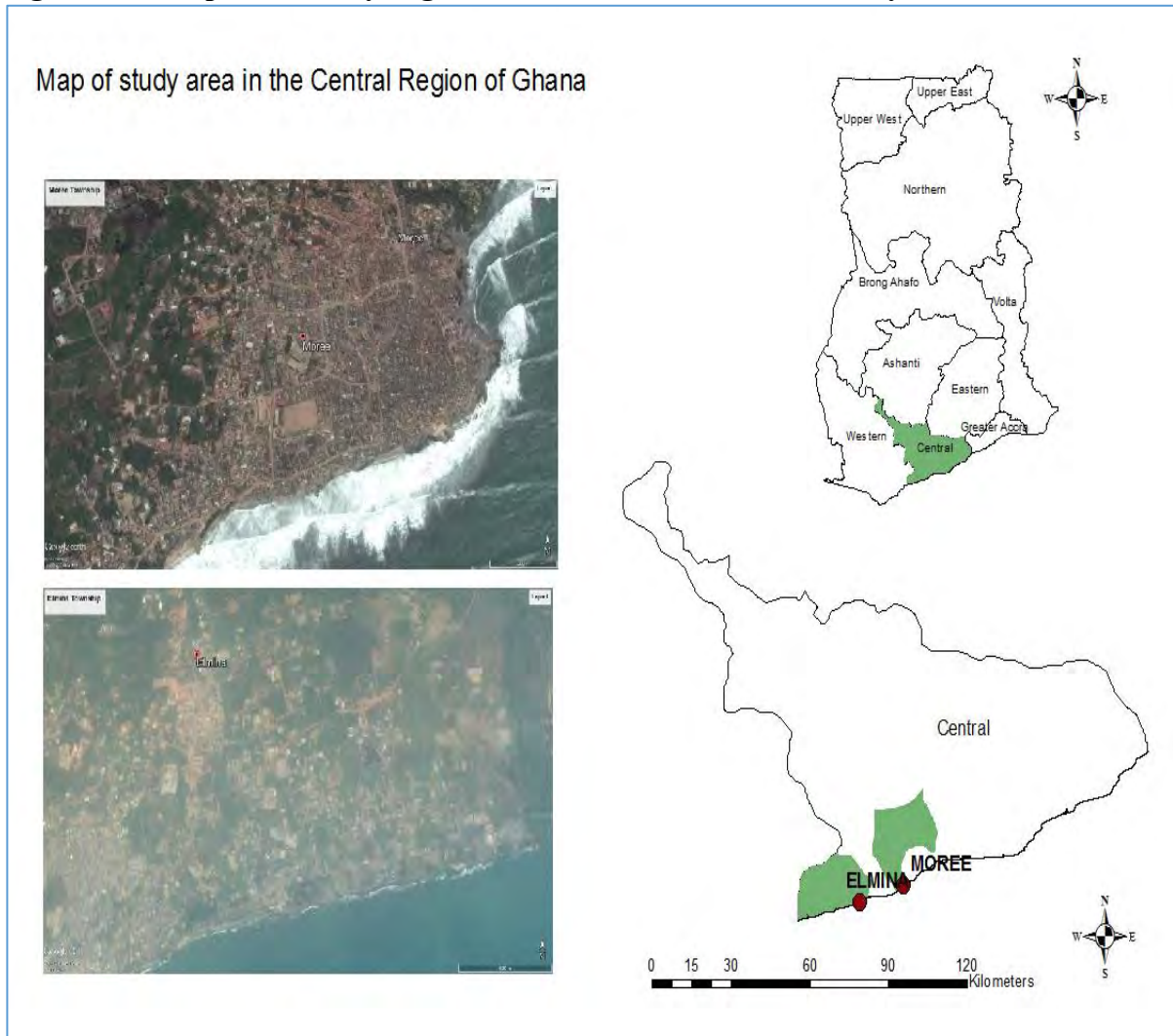
Based on the 2010 Population and Housing Census, the Municipality has a population of 144,705 having increased from the 2000 figure of 112,435 which represents 6.6% of Central Region's population at the time. About 70% of people in the district live in the rural areas as shown in the 2010 Population and Housing report. There are more females (51.8%) than males in the municipality. Elmina, which is the municipal capital, is ranked

as the fourth municipality in the Central Region (Ghana Statistical Service, 2010 District Report). The district has a youthful population. About 40% of the population of the Municipality is below 15 years, depicting a broad base population pyramid with a small number of elderly persons (8.6%) [Ghana Statistical Service, 2010 District Report].

The Municipality can boast of fishing, farming, salt winning and a shipping industry as the main economic activities. Tourism can also be seen as a major potential booming sector which could be developed to become a major economic activity in future. Within the Municipality, about 67.6% of the population aged 15 years and older are economically active while 32.4% are not active economically (Ghana Statistical Service, 2010 District Report). Agriculture is the backbone of the Municipality's economy. Over 85% of the population is engaged in either fishing or production of food and cash crops. Fishing is done along the coastal stretch of the Municipality whilst farming is done inland towards the northern parts of the Municipality (Ghana Statistical Service, 2010 District Report).

The highest proportion (42.2%) of the people are engaged as skilled agricultural, forestry and fishery workers; about 21% are engaged in service and sales; 18.0% is into craft and related trade, 1.3% as technicians and related associate professionals, and 6.7% as managers and professionals (Ghana Statistical Service, 2010). The two study sites with their demarcated geographical boundaries are shown in Figure 3.4. The image on the left side of the map are aerial photograph of Moree and Elmina while right portion of the map shows the two study sites demarcated in the national and regional maps respectively.

Figure 3.4: Map of the study region with clear locations of the study towns



Credit: Daniel Benefoh (2016)

3.4.2 Study Design

The study was mainly to investigate whether exposure to smoke from fish smoking has any health implications on the women who smoke fish on daily basis to earn a livelihood. The study was, therefore, designed to comprise of a treatment group and a control group. The treatment group was made up of women who smoke fish and the control group was women in Moree and Elmina towns who do not smoke fish. They were made up of hairdressers, seamstresses, fish salters, provisions store keepers, and fresh fish sellers.

3.4.3 Sources of Data

Primary data were collected in both Moree and Elmina through a cross-sectional socio-economic and demographic household survey. Socio-economic and demographic survey is seen as an appropriate method/design to answer the specific research questions which seek to collect data on source fuel for the fish smoking, quantity/volume of fuel wood used as well as the frequency of wood consumption. This data collection method also helped to identify the people who are mainly involved in the fish smoking or processing activity, determine the demographic and socio-economic status of the processors, assess health implications which are attributable to smoke inhalation, and how these variables play out in the outcome variables of the study. Health outcome variables that were measured in the questionnaire included flu, respiratory, eye and neurological symptoms. Other health symptoms such as asthma and skin irritation were also included in the questionnaire. Information on the health outcomes variables mentioned were self-reporting by the participants. A total of four hundred and sixty three (463) households were interviewed in both Moree and Elmina. Out of this figure, two hundred and thirty nine (239) were from Elmina and two hundred and twenty four (224) were from Moree.

Carbon monoxide (CO) monitors and finite particulate matter of 2.5 micrograms (PM_{2.5}) samplers were also used to collect real time data on exposure levels of the fish smokers to CO and PM_{2.5}. In all, one hundred and fifty six (156) CO and twenty nine (29) PM_{2.5} real time data were collected from Moree and Elmina. The CO and PM data were collected to ascertain the exposure levels of the fish processors and the implications for their health.

3.5 Sampling Methods

3.5.1 Town Selection

The main population targeted for the study was women who smoke fish along the coast of Ghana. The study identified two fish smoking communities: Moree and Elmina, both of which are in the Central Region of Ghana as study areas. These two towns were purposively selected because they have a very high prevalence of households that engage in fish smoking as a major economic activity. A survey conducted by the Fisheries Commission, Ghana in 2013 and collaborated by the Netherlands Development Agency (SNV) Ghana, identify Elmina and Moree as the two leading fish smoking communities along the coast of Ghana (Fisheries Commission, 2013). These towns are representative of several towns in coastal Ghana for fish smoking and in other parts of Africa where fish smoking is a major economic activity (e.g., Lake Victoria, Lake Malawi, Swahili coast etc.). Three different pre-visibility site tours were undertaken through the main fish smoking towns along the coast of Ghana. These included Keta in the Volta Region, Gashie in the Greater Accra Region, Winneba, Apam, Saltpond, Kromantse, Abandze, Biriwa, Moree and Elmina, in the Central Region. The objective for embarking these site visits was to collect first-hand information from these towns to aide in the selection of the two towns for the study. The study focused on two towns because the population of the fishing communities along the coast have similar characteristics (Ghana Statistical Service, 2010) and also due to limited resources to handle more towns.

3.5.2. Sampling Size and Sampling Technique

Two main conflicting interests are faced when deciding on the sample size for a study. For a study to be worthwhile, one must recruit sufficient subjects to have a „good“ chance of detecting the association, if it exists, while at the same time one would wish to avoid

wasting resources on an unnecessarily large study. Randomness was, therefore, a key guiding principle in the selection of participants for this study. The research employed a clustered sampling method to collect household data. Each of the two research towns was clustered into zones using visible main streets in the towns as the dividing factor. Moree was clustered into three (3) main clusters (A, B, C) using the three main visible streets in the township whereas Elmina was clustered into four (4) zones (A, B, C, D) using the same principle. Research interviewers then recruited every third household (moving systematically from west to east after balloting) in each town. The aim was to get a sample of 432 households over the course of six weeks of data collection. The daily interview target was twelve (12) households for the socio-demographic survey part of the data collection. Part of the sampling plan was to strive for a ratio of 2:1 fish smoking households to non-fish smoking households. At the end of the six weeks data collection period, a total of 463 households were interviewed from the two study areas. The household data were collected with the objective of using the data beyond this student thesis project. As a result, only the women sample (i.e. 347) were used in the background and household characteristics analysis.

3.6 Carbon Monoxide and Particulate Matter Data Collection

The study was designed to link personal exposure data with the socio-demographic data (including health) of respondents. Personal exposure to smoke data was collected on two indicators: carbon monoxide (CO) and particulate matter of two and a half micro-diameter (PM_{2.5}). A total number of 150 and another 29 women were randomly sampled from the household survey to participate in the CO and PM studies respectively.

Ten (10) CO monitors and two (2) PM samplers (see Figure 3.8) were deployed in the two communities for real time data collection. CO monitors and PM samplers were deployed

for a 24 hour period on Monday, Wednesday and Friday and picked-up on Tuesday, Thursday and Saturday, i.e. every other day. Seven (7) fish smoking (treatment) households and three (3) non-smoking (control) households, making a total of ten (10) households for CO and two households for PM were selected based on consent and willingness to participate on each deployment day for real time data sampling/monitoring.

3.6.1 Type of Instruments Used for CO and PM Data Collection

3.6.1.1 Carbon Monoxide

Carbon monoxide (CO) is a common industrial hazard resulting from the incomplete burning of natural gas and any other material containing carbon such as gasoline, kerosene, oil, propane, coal, or wood. CO is a poisonous, colourless, odourless, and tasteless gas. Although it has no detectable odour, CO is often mixed with other gases that do have an odour (OSHA, 2002). Carbon monoxide can be inhaled alongside with other gases without noticing that CO is present. Smoke from burning biomass fuel contains various amount of carbon monoxide. In each day, the women who are doing fish smoking are exposed to CO pollution, at least six hours each day. The calibration was done using the step-by-step procedure as spelt out in the standard operation procedure (SOP) manual for EL-USB-CO Loggers.

CO data were collected using EL-USB-CO Logger. The device could take data size within the range of 0 – 1000 parts per million (ppm) and has the capacity of storing data up to 32,510 measurements. The logger has a user-programmable warning threshold with bright visual and audible warnings with USB interface for set-up and data download that makes it easy for data transfer from the logger to a computer. The audible warning component of the device was not activated anytime data was collected with instrument from the field. The reason was to avoid scaring participants anytime the CO threshold was

exceeded. The CO Logger were calibrated on a personal laptop computer every morning before they were taken to the field to collect fresh data.

CO concentrations data were collected every minute for a 24-hour period placing the CO Logger around the necks of the participants (See figure 3.5). Participants were at liberty to move around with the CO logger at any time. They were, however, advised to take it off when they were going to bath or bed.

Figure 3.5: A study participant wearing the CO Logger posing with a research assistant



Photo credit: Antwi-B. Amoah (2016)

3.6.1.2 Particulate Matter

Particulate matter (PM) is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets. According to the USEPA, particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air. Once inhaled, these particles can affect the heart and lungs and cause serious health effects (USEPA, 2016).

The main source of particulate matter that was measured in this study was smoke from wood burning. The focus of the study was on PM_{2.5} which has been described in literature as finite but very harmful for human health (USEPA, 2016; Bruce et al., 2006).

The instrument used for data collection for PM_{2.5} in this research was SKC XR 5000 pumps for outdoor air and personal exposure sampling. The pump has an inlet port with protective filter and a bright blue pump status LED. It also has an easy-to-read liquid crystal display (LCD) with large single operating keypad (See Figure 3.6).

Figure 3. 6: A PM_{2.5} sampling pump and other laboratory gadgets



SKC XR 5000 Air Pump



A filter taken out in the research mini lab after a 24hr deployment in the field

Photo credit: Antwi-B. Amoah

Before deployment each day, the pump was set to 24 hours (i.e. 1440 minutes) with the pump flow rate set between 1.98 flz and 2.0 flz. The battery level was always checked to make sure there was enough power to run for the 24 hour deployment. The pump was conveniently put in a back pack which the women wore for the period of data collection. Participants could conveniently move around with the pack while carrying on with their normal fish smoking and other household activities. Participants of the personal exposure measurement were given special orientation on how to handle the gadgets. Full consent was received from each participant before allowed to be included in the sample. A demonstration of the back pack fixed on a study participant is shown in figure 3.7.

Figure 3.7: A research assistant fixing PM pack on a fish smoker in Moree



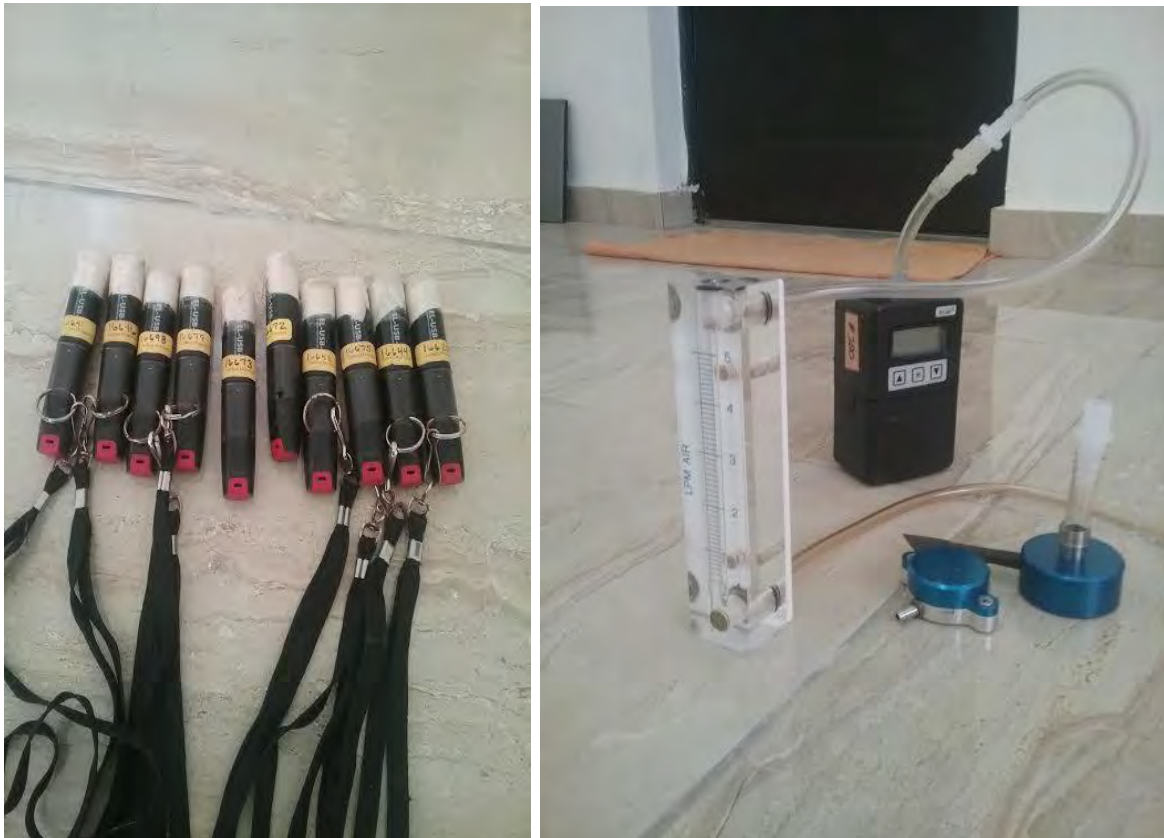
Photo credit: Antwi-B. Amoah (2016)

3.7 Pre-deployment Exercise

The nature of the CO and PM data collection demands that the instruments were set up in a laboratory each morning before they were sent to the field to collect data. A mini-laboratory was therefore created in the field (at the hotel where the team was lodging) to set up the CO loggers and the PM pumps under the right conditions, make sure the flow

meter performed well, the filters were changed and the batteries for both the CO loggers and the PM pumps worked optimally. The mini-laboratory setting created for data collection is demonstrated in figure 3.8. Batteries suspected to be weak and as could not last for the 24 hour (i.e. 1440 minutes) deployment were replaced with new ones. A personal laptop computer was used to calibrate the CO logger in the mini-laboratory each morning before moving to the field to collect data.

Figure 3.8: Sample of CO Loggers and PM Pump used for personal exposure data collection



Field CO and PM data collection mini-lab (Research field work, 2016)

3.8 Fuel Type used by the Fish Smokers

Fish smoking, as an economic activity, is an energy-intensive activity. The energy sector generates both outflows and inflows to the economy and thus contributes to the GDP indirectly through its use as inputs for production. The energy sources for agriculture

related small scale activities, including fish smoking, in Ghana mainly include solar and fuelwood. Solar energy is used by the women to dry the fish in the case of fish salting while biomass fuel energy is used to smoke and fry fish. In the study area, the main source of energy used by the women for smoking fish was firewood. Firewood was cart from the nearby forest communities to the fish smoking towns by firewood vendors. The wood used by the fish smokers were mainly hard wood with high moisture content. The wood are usually tied up in small unit bundles and packed in trucks to be carted to various fish smoking destinations. See figures 3.9 and 3.10.

Figure 3. 9: A sample of hard wood packed in a truck spotted in Moree



Source: Research field data (2016)

Figure 3. 10: A sample of hard wood used to smoke fish spotted in Elmina



Source: Research field data (2016)

3.8.1 How Firewood was weighed

In order to have a fair idea of the amount of firewood consumed by the fish smokers, the researcher weighed the firewood with a weighing scale. The firewood that is used by the women typically comes in wrapped bundles. Figure 3.11 depicts samples of wrapped bundles of firewood used by the fish smokers.

Figure 3. 11: Bundled firewood sampled in the study area



Photo credit: Antwi-B. Amoah (2016)

The weights varied. In Moree, five different wood bundles were sampled and weighed on a scale. The weights for the sampled bundles ranged between 8 and 10 kilograms. High sense of judgment was used to record the weight of the firewood between 8 and 10 kilograms.

In Elmina, the bundles of the firewood sighted at the time of data collection were heavier relative to those found at Moree. Using the same criteria as used in Moree, five different bundles were randomly sampled and weighed and the weight ranged between 18 and 19 kilograms. The weight of firewood recorded in Elmina were between 18 and 19 kilograms.

3.9 Data Management

Two structured data collection instruments were designed. Firstly, a structured questionnaire was used to illicit responses from the households on general household characteristics such as age, sex, educational level, assets, household size, main occupation, main source of energy for lighting and cooking, quantity of fuel wood consumed, common self-reported sicknesses and sanitation conditions (See Appendix B). The questionnaire was administered to household heads but it was designed to give flexibility for persons who are the most economically active in the household to respond to the questionnaire on behalf of the household head in case the latter was not present. This was only for cases where the representative of the household head has knowledge and information about the key indicators/characteristics of the questionnaire about the household in question. Looking at the nature of the study, the focus was mainly on the most economic active woman in the household, so design of the questionnaire was flexible such that the woman respondent could respond to her own economic activities and also provide household information, if known.

Secondly, emission exposure monitoring data collection questions were designed and administered to only females who are lead⁸ fish smokers in the already sampled households for the household interviews mentioned above. This set of questions was only given to females who were randomly selected to wear the CO and PM gadgets meant for biomass smoke exposure measurement. A sample Emission Monitoring (EM) questionnaire is provided in Appendix A. Participants for the EM were both female fish smokers and non-fish smokers.

The administration of the data collection instruments was done for a period of six weeks spanning between July 18 and August 27, 2016. Research assistants for both the household survey and the emissions monitoring data collection were given a 4-day training from June 28 to July 1, 2016 at the Conference Room of the Regional Institute for Population Studies (RIPS), University of Ghana by survey and exposure data collection experts from the Carolina Population Center (CPC) of the University of North Carolina (UNC) in the United States of America (USA). The training sought to equip the research assistants with the requisite skills to collect data a peculiar population as fish smokers. Data were collected electronically using tablets powered by the open data kits (ODK) software. The CPC provided data collection in-kind training support as well as laboratory and field data collection tools such as tablets, CO monitors (Lascar EI-USB), PM samplers (SKC Inc. USA), etc., while the International Development and Research Center (IDRC) of Canada through the Regional Institute for Population Studies (RIPS), University of Ghana provided financial support for the training and field data collection.

⁸ There could be many fish smokers in one household. However, in the event that there were more than one fish smoker in the same household, only one person identifies herself as the main fish smoker with the rest providing assistance to the lead fish smoker.

3.10 Informed Consent and Approval

All participants of the study were provided with written informed consent which was read to them by the Research Assistants in Fanti language which happens to be the local language spoken in the study area. The research team then addressed all questions and issues for clarification regarding the consent before they were made to either sign or thumb print the consent form. The informed consent was verbally read because of the high rate of illiteracy in the study population even though there were few cases where participants could read and understand the content themselves. Respondents were also made to understand that, the project was collecting data and information only for academic purposes and so it had no intention to provide financial aid (whether immediate or in distant future) to respondents. In this regard, it was just for academic exercise and not government or donor sponsored project. The study was approved by the Institutional Review Board of the College of Humanities of the University of Ghana, Legon. A sample consent form and Institutional Review approval are presented in Appendix B.

3.11 Description of Variables

A) Independent variable:

The main independent variable of the study was personal exposure to smoke. The study assumes that all participants are exposed to some level of biomass fuel related smoke. The smoke from biomass is conceptualized to contain harmful pollutants that could have negative implications on human health and the climate. The study is designed to consist of two different groups (i.e. women who smoke fish and those who do not smoke fish). These two groups are exposed to some level of smoke from biomass and its associated pollutants. The study intends to measure the personal exposure levels of both fish smokers and non-fish smokers to carbon monoxide (CO) and particulate matter of micro-diameter

of 2.5 (PM2.5). The idea is to relate their exposure levels with their reported health symptoms.

B) Dependent variables:

The main dependent or outcome variables from the study are;

- i. Health outcomes: these were self-reported ill-health status by respondents. The health variables or indicators considered in the study framework include flu, respiratory/COPD, eye, and neurological symptoms. These were measured for both fish smokers and non-fish smokers.
- ii. Environment/climate health: this dealt with the amount of GHG emissions as a result of fish smoking using biomass fuel. The study, however, did not measure GHG emissions directly from the model/framework but used the amount of fuel wood consumption as proxy for measuring GHG emissions from fish smoking.

C) Mediating variables

A number of variables mediate between the exposure to biomass smoke and the health outcomes for the study. Between exposure and health, factors or variables on how much CO and/or PM2.5 one inhales could be a mediating factor as not all the respondents will be exposed to the same amount of pollutants. Again, open drains and other environmental factors such as the place where the respondent spend the greater part of her day is critical. In the current study, whether or not a respondent spent the day mostly in paved or unpaved places have implications on their self-reported health outcomes. Dust particles for instance contain PM2.5 that could affect the PM sample collected from smoke.

D) Control variables

The study controlled for socio-demographic and environmental variables. The socio-demographic variables controlled for in the model include education level of respondents, wealth, marital status, town, and religion. The other variables that the study controlled for are environmental in nature. These include the smoking habits of the respondents, household cooking experience, previous experience in fish smoking, whether the household used kerosene lantern, waste management practices and whether or not the female respondent spent most of her time during the day in an unpaved or paved environment.

3.12 Methods of data analysis

3.12.1 Computation of wealth quintiles

The following variables were used in computing the household wealth quintiles: main source of drinking water, type of toilet facility, use of electricity, main type of cook stove used, main cooking fuel, main source of lighting, number of rooms in the household, type of roofs, type of walls, type of floor materials, and number of assets currently owned by the household (e.g refrigerator, generator, motorcycle, electric fan, television, bicycle, cars, mobile phone, furniture, wardrobe, bed, chair, mattresses, fish smoking oven, fish smoking trays, hoes, fishing net, fishing boat, outboard motor, mosquito net, and sewing machine).

The first step in creating the wealth quintiles was to generate dummies for each of the variables. After this, a principal component factor analysis was run for all the indicator variables and one factor was extracted and saved, using SPSS 20. Further, the extracted factor scores were cut into five equal parts. A new variable was created for the quintiles and recoded for the wealth score values less than or equal to the first cutpoint, greater than

the first and less than or equal to the second cutpoint, greater than the second and less than or equal to the third cutpoint, greater than the third and less than or equal to the fourth cutpoint, and greater than the fourth cutpoint. These cutpoints were labelled respectively as: poorest, poorer, middle, richer and richest.

3.12.2. Background characteristics

Descriptive statistics such as mean and frequency tables were used to examine the background characteristics of the participants as well as the household characteristics.

3.12.3 Level of exposure to carbon monoxide (CO) and particulate matter (PM2.5)

Independent sample t-tests were used to show the mean differences in carbon monoxide (CO) and particulate matter (PM2.5) between the control and the treatment group.

3.12.4 Air pollution-related health outcomes

Three questions were used in generating the *flu symptoms* and these focused on: experience of fatigue in the past 12 months/two weeks⁹; experience of fever in the past 12 months/two weeks, and; experience of chest infection in the past 12 months/two weeks. The *respiratory symptoms* focused on: experience of shortness of breath when walking up hills; difficulty in breathing/chest tightening; experience of chronic cough; production of phlegm at night, and; coughed up blood in the past 12months/two weeks. The *eye symptoms* focused on: experience of irritation/burning/watering of eyes; experience of green/yellow sticky secretion from eyes, and; the effect of vision problem on ability to

⁹ Measurement for some of the disease symptoms were done for both two weeks and twelve months. The design of the study was done this way so as to give room for recall challenges. Besides some of the disease symptoms, for example headache, last for shorter periods and so it was very appropriate to allow for shorter recall period.

perform usual household activities, in the past 12 months/ two weeks. *Neurological symptoms* focused on: experience of headache; difficulty in concentration; experience of forgetfulness and dizziness in the past 12 months/ two weeks. Further, *asthma symptoms* focused on: experience of wheezing or whistling in the chest; experience of sleep disturbance by wheezing, and; experience of chest tightness after waking up from sleep, in the past 12 months. The responses to each of these questions were No coded as “0” and Yes coded as “1”. The questions for each of the domains were put together and a higher score indicated higher level of symptoms.

Since the raw domain scores differ for each of these domains of air pollution-related health outcomes, comparison becomes difficult. In order to address this, it is important to transform the raw domain scores so as to make them comparable. The first step involved in the transformation of the scale was that a raw score was calculated for each domain. After this, each raw score was transformed to a 0-100 scale using the following formula:

$$\text{Transformed Scale} = \frac{\text{Actual raw score} - \text{lowest possible raw score}}{\text{Possible raw score range}} * 100$$

Where “Actual raw score” is the value achieved through item summation; “lowest possible raw score” is the lowest possible value that could occur through item summation, and; “Possible raw score range” is the difference between the maximum possible raw score and the lowest possible raw score. This transformation converts the lowest and highest possible scores to zero (0) and 100, respectively, with higher score indicating higher level of symptoms.

3.12.4.1 Analysis of other forms of air pollution-related health outcomes

Other forms of air pollution-related health outcomes included whether respondents had ever experienced: skin irritation symptoms, other allergic symptoms, and non-pregnancy related nausea and vomiting.

Independent sample t-tests were used to show the mean differences between the control and the treatment groups and other background characteristics of the participants with regard to experience of flu symptoms, respiratory symptoms, eye symptoms, neurological symptoms and asthmatic symptoms. At the multivariate level, multiple linear regression was used to analyse the association between the control and treatment groups with respect to flu symptoms, respiratory symptoms, eye symptoms, neurological symptoms and asthma symptoms, controlling for the background characteristics of the participants.

On the other hand, Chi-Square tests were used to examine the association between the control and treatment groups and other background characteristics, with regard to skin irritation symptoms, other allergic symptoms, and non-pregnancy related nausea and vomiting. At the multivariate level, binary logistic regression was used to analyse the relationship between control and treatment groups with respect to skin irritation symptoms, other allergic symptoms, and non-pregnancy related nausea and vomiting, controlling for the background characteristics of the participants.

3.12.5 Knowledge and perception about fish smoking

Descriptive statistics such as proportion was used to describe the knowledge and perceptions of participants about fish smoking. With regard to usage of fuel wood, Chi-Square test was used to show the association between control and treatment groups and fuel usage.

3.12.6 How GHG emissions were calculated from wood consumption

Greenhouse gas emissions have been calculated using tier 1 (simple method) using IPCC¹⁰ default emission factor for CO₂, CH₄ and N₂O emission and net calorific value (NCV). The emission estimates were derived based on the stated average weekly firewood consumption in a typical inefficient traditional woodstove. Level of greenhouse gas emission was estimated as the product of appropriate emission factor for each gas and the weekly firewood consumption. The calculation steps are provided below;

1. Unit of weekly quantity of fire wood converted from kilogramme (kg) to gigatonne (Gg) by dividing by a factor of 1,000,000
2. Convert quantity of firewood consumption in Gg to energy unit by multiplying with the IPCC default NCV of wood in terajoure (TJ)
3. Apply the appropriate emission factors (EF) to the wood consumption in energy unit(TJ) to get the emission per week
4. Cumulative value of weekly emission was generated for 48 weeks (1 year)
5. Total sample size used for the analysis is two hundred and fifty-two (252) fish smokers
6. Conversion factor to energy unit (Net Calorific Value) based on IPCC default value = 15.
7. CO₂ emission factor (kg CO₂/TJ) based on IPCC default value = 112000
8. CH₄ emission factor (kg CH₄/TJ) based on IPCC default value = 300
9. N₂O emission factor (kg N₂O /TJ) based on IPCC default value = 4

¹⁰ The IPCC has classified the methodological approaches in three different Tiers, according to the quantity of information required, and the degree of analytical complexity (IPCC, 2003, 2006). Tier 1 employs the gain-loss method described in the IPCC Guidelines and the default emission factors and other parameters provided by the IPCC. There may be simplifying assumptions about some carbon pools (IPCC, 2003; 2006).

Two main scenarios have been developed using the weekly average as well as the lower and upper limit weekly consumptions. See appendix C for the two scenarios developed.

3.13 Limitations of the Study

The following factors account for the study's limitations;

- i. Unavailability of longitudinal measurements: The cross-sectional nature of the study design imposes a limitation because it becomes difficult to relate the implications of the fish smokers' exposure to the key outcome variables of the study especially those variables on health. The study could not collect longitudinal data because of cost implications and also time limitations. However, current data collected has utility of serving as baseline data for possible longitudinal data for such a vulnerable population.
- ii. The study was not able to measure area concentrations for the ambient where the non-fish smokers do their normal daily activities due to cost implications for a student project of this nature. However, measuring personal exposures gives some indication about the ambient concentrations.
- iii. Limited data collected on PM makes it very challenging to make meaningful conclusions about the implications of particulate matter on human health and the environment from burning biomass by small scale household economic activities such as fish smoking.
- iv. Data on fuel wood consumed by fish smokers cannot be directly linked to a particular source to make a case for deforestation or forest degradation. Responses from the field indicate only local or non-local sources, which do not actually tell the exact source. However, large volumes of wood from nearby communities were reported by the respondents of the survey. In lieu of the

above, the study uses data on fuel wood consumption as proxy for GHG emissions from the small scale fish smoking industry.

- v. The personal exposure data collected using the CO loggers and the PM_{2.5} instruments were worn for a 24-hour period by participants. It is likely some participants may have compromised on the full functionality of the instruments, even though they gave their full consent before participating in the study.

CHAPTER FOUR

SOCIO-DEMOGRAPHIC CHARACTERISTICS AND PERSONAL EXPOSURE LEVELS OF THE STUDY RESPONDENTS

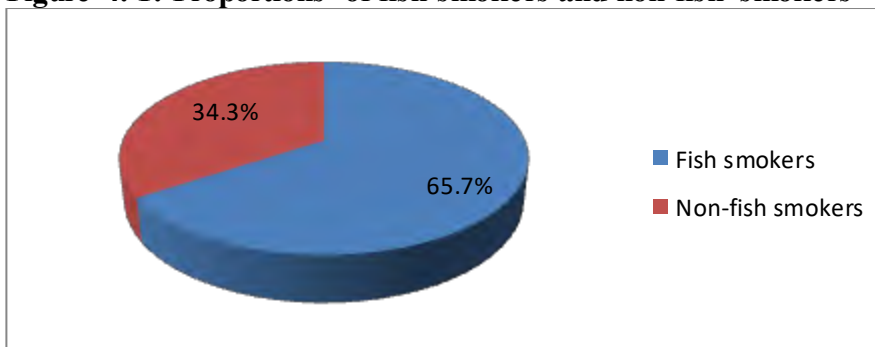
4.1 Introduction

Generally, socioeconomic factors such as income and education level, type of occupation, employment status, access to health care, adequacy of nutrition, social support (e.g. family and community), and physical environment (e.g. housing) have impact on personal exposure to environmental pollutants and human health. The physical environment has a greater influence on personal exposure (specific pollutant, level of exposure) while personal conditions and habits (e.g. nutrition, personal and home hygiene) tend to have a greater effect on health outcome of household environmental exposure. The socioeconomic conditions as well as the physical environment in the study area are discussed in the context of personal exposure to biomass smoke in the study area.

4.2 Background characteristics of respondents

Figure 4.1 shows the proportions of those who burn biomass (fish smokers) and those who did not. From the Figure, while 65.7% were fish smokers who burnt biomass, 34.3% were non-fish smokers.

Figure 4. 1: Proportions of fish smokers and non-fish smokers



Source: Research field data, 2016

The background characteristics of fish smokers and non-fish smokers are shown in Table 4.1. The mean age of those in the control group (41.45 ± 13.06 years) was lower than those of the treatment group (46.00 ± 13.01 years). In addition, while the largest proportion of those in the control group (35.2%) was 30-39 years, the largest proportion of those in the treatment group (30.3%) was 40-49 years. With respect to level of education, a larger proportion of those in the treatment group had no education (64.1%) compared to 44.0% of those in the control group. On the other hand, while more than one-third (34.6%) of those in the control group had middle education and above, slightly more than one-tenth (14.1%) of those in the treatment group had middle level education and above.

Further, while a higher proportion of those in the treatment group (42.2%) were in the poorest and poorer wealth quintiles, a higher proportion of those in the control group (47.0%) were in the richer and richest wealth quintiles. The results further showed that a larger proportion of the participants in the control and treatment groups lived in Elmina town (52.8 and 51.0%, respectively). Majority of the participants in the control and treatment groups were Christians (89.3% and 87.8%, respectively) and Fantes (96.9% and 99.3%, respectively).

Table 4.1: Background characteristics of respondents in the control and treatment groups

Characteristics	Control (N=159)		Treatment (N=304)		Total (N=463)	
	N	%	N	%	N	%
Age						
20-29	24	15.1	22	7.2	46	9.9
30-39	56	35.2	72	23.7	128	27.6
40-49	41	25.8	92	30.3	133	28.7
50-59	16	10.1	63	20.7	79	17.1
60+	22	13.8	55	18.1	77	16.6
Level of education						
No education	70	44.0	195	64.1	265	57.2
Primary	34	21.4	66	21.7	100	21.6
Middle/JHS	44	27.7	38	12.5	82	17.7
SHS	8	5.0	5	1.6	13	2.8
Tertiary	3	1.9	0	0.0	3	0.6
Wealth quintiles						
Poorest	21	13.2	71	23.4	92	19.9
Poorer	36	22.6	57	18.8	93	20.1
Middle	27	17.0	66	21.7	93	20.1
Richer	32	20.0	61	20.1	93	20.1
Richest	43	27.0	49	16.1	92	19.9
Marital status						
Never married	24	15.1	23	7.6	47	10.2
Married	93	58.5	184	60.5	277	59.8
Formerly married	42	26.4	97	31.9	139	30.0
Town						
Elmina	84	52.8	155	51.0	239	51.6
Moree	75	45.5	149	49.0	224	48.4
Religion						
No religion	12	7.5	34	11.2	46	9.9
Christianity	142	89.3	267	87.8	409	88.3
Islam	5	3.1	1	0.3	6	1.3
Spiritualist	0	1.0	2	0.7	2	0.4
Ethnicity						
Fante	154	96.9	302	99.3	456	98.5
Other Akan	1	0.6	0	0.0	1	0.2
Ga-Dagme	1	0.6	0	0.0	1	0.2
Nzema	1	0.6	1	0.3	2	0.4
Other	2	1.3	1	0.3	3	0.6

Source : Research field data, 2016

4.3 Household characteristics of respondents

Table 4.2 shows the household characteristics of the participants. From the Table, more than six out of ten (63.3%) of the household heads use mobile phones and the proportion of use was higher in the control group. With respect to source of drinking water, majority (88.1%) of the participants used pipe water and the least proportions used borehole and protected well. Slightly more than half of the heads of household (51.0%) used communal toilet, 40.4% used bush/field/beach and less than one-tenth (8.6%) have toilet within their own compound. The table shows that a higher proportion of those in the control group had toilet within their own compounds. More than sixty percent of the households have electricity. With respect to the main type of cook stove, they mostly used (79.5%) locally produced charcoal stove for cooking and this use was higher among the control group. In addition, less than one-tenth used three stone fire/tripod, improved wood burning stove, improved charcoal stove and LPG stove (8.2%, 0.4%, 7.6% and 4.3%, respectively). Further, participants mostly used three stone fire/tripod as their secondary type of cook stove while 63.1% did not have secondary cook stove.

More than eight out of ten (87.3%) used charcoal as their main cooking fuel, fuel wood (8.2%), crop residue (0.3%), LPG (4.1%) and kerosene/paraffin (0.2%). While 73.6% of those in the control group used electricity as their main source of lighting, 63.3% of those in the treatment group did so (Table 4.2). The use of touch/flash light also featured prominently as main source of lightening. A total of 31.1% of the respondents indicated they use touch light with 36.2% and 21.4% representing treatment and control groups respectively. With respect to the type of roofing, majority of the participants (88.3%) used slates/asbestos and the least proportion used thatch and canopy (0.6% each). A higher proportion of those households in the control groups (88.1%) used concrete blocks/cement

compared to those in the treatment group (82.2%) as wall material. The type of floor material mostly used by the participants was cement/concrete.

Table 4.2: Household characteristics of the study respondents

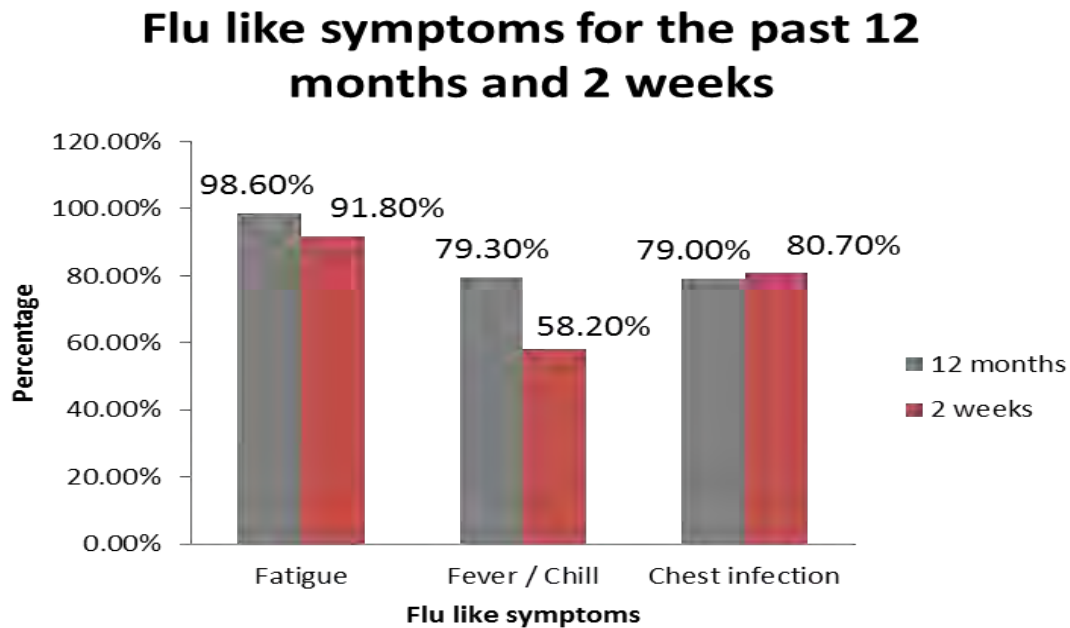
Characteristics	Control (N=159)		Treatment (N=304)		Total (N=463)	
	N	%	N=304	%	N	%
Mobile Phone Use						
No	56	35.2	114	37.5	170	36.7
Yes	103	64.8	190	62.5	293	63.3
Source of drinking water						
Pipe water	138	86.8	270	88.8	408	88.1
Borehole	0	0.0	1	0.3	1	0.2
Protected well	0	0.0	1	0.3	1	0.2
Sachet/bottled water	21	13.2	32	10.5	53	11.4
Type of toilet facility						
Toilet within own compound	24	15.1	16	5.3	40	8.6
Communal toilet	78	49.1	158	52.0	236	51.0
Bush/field/beach	57	35.8	130	42.8	187	40.4
Electricity						
No	42	26.4	128	42.1	170	36.7
Yes	117	73.6	176	57.9	293	63.3
Main type of cook stove						
Three stone fire/tripod	8	5.0	30	9.9	38	8.2
Locally produced charcoal stove	129	81.1	239	78.6	368	79.5
Improved wood burning stove	0	0.0	2	0.7	2	0.4
Improved charcoal stove	9	5.7	26	8.6	35	7.6
LPG stove	13	8.2	7	2.3	20	4.3
Secondary type of cook stove						
Three stone fire/tripod	24	15.1	82	27.0	106	22.9
Traditional charcoal stove	12	7.5	27	8.9	39	8.4
Improved wood burning stove	1	0.6	0	0.0	1	0.2
Improved charcoal stove	6	3.8	6	2.0	12	2.6
LPG stove	5	3.1	8	2.6	13	2.8
No other cook stove	111	69.8	181	59.5	292	63.1
Third type of cook stove						
Three stone fire/tripod	2	1.3	2	0.7	4	0.9
Traditional charcoal stove	1	0.6	0	0.0	1	0.2
LPG stove	0	0.0	1	0.3	1	0.2
No other cook stove	156	98.1	301	99.0	457	98.7

Main Cooking Fuel						
Fuel wood	9	5.7	29	9.5	38	8.2
Charcoal	137	86.2	267	87.8	404	87.3
Crop residues	0	0.0	1	0.3	1	0.3
LPG	12	7.5	7	2.3	19	4.1
Kerosene/paraffin	1	0.6	0	0.0	1	0.2
Main Source of Lighting						
Electricity	117	73.6	176	57.9	293	63.3
Kerosene/paraffin	7	4.4	15	4.9	22	4.8
Candles/reeds	0	0.0	1	0.3	1	0.2
Flashlight/torch	34	21.4	110	36.2	1	31.1
Lantern	1	0.6	0	0.0	1	0.2
Mobile phone light	0	0.0	2	0.7	2	0.4
Type of roofing						
Thatch/palm fronds/rustic mat	0	0.0	3	1.0	3	0.6
Wood	8	5.0	15	4.9	23	5.0
Metal/iron sheets	8	5.0	17	5.6	25	5.4
Slates/asbestos	1	89.3	267	87.8	409	88.3
Canopy	1	0.6	2	0.7	3	0.6
Type of Wall material						
Mud/soil	2	1.3	4	1.3	6	1.3
Wood/plywood	16	10.1	46	15.1	62	13.4
Cane/Palm/Trunks	1	0.6	4	1.3	5	1.1
Concrete blocks/Cement	140	88.1	250	82.2	390	84.2
Type of Floor material						
Dirt/Sand	10	6.3	28	9.2	38	8.2
Cement/Concrete	146	91.8	269	88.5	415	89.6
Tiles	1	0.6	0	0.0	1	0.2
Wood	2	1.3	7	2.3	9	1.9

Source: Research field data, 2016

4.4 Proportion of air pollution related health outcomes measured in the study

Flu, respiratory, eye and neurological symptoms were the broader health domains the study measured. The indicators for flu, respiratory, eye and neurological symptoms are presented in Figures 4.2, 4.3, 4.4 and 4.5 respectively. The questions were asked for two weeks and twelve months to give room for easy recall.

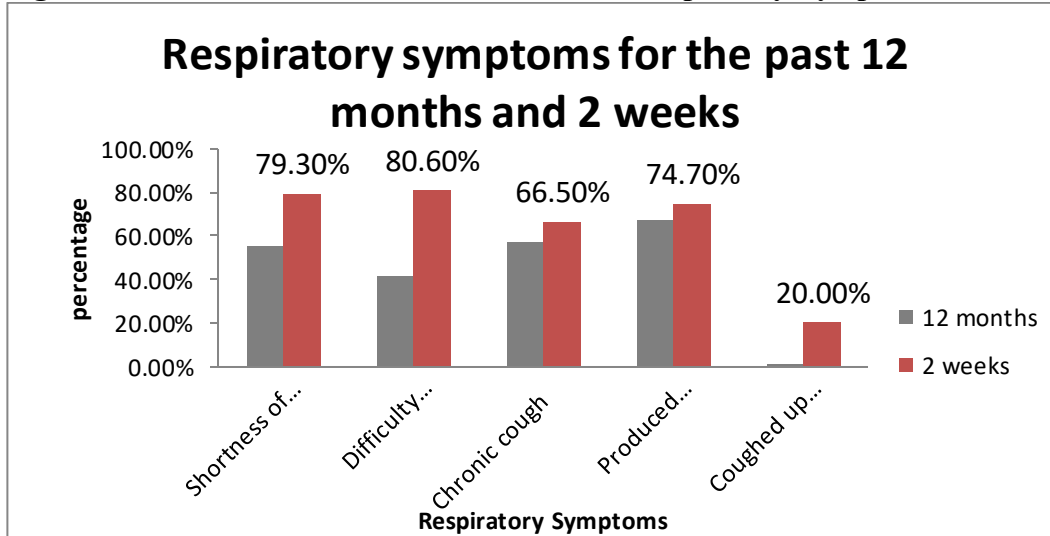
Figure 4.2: Health indicators measured under flu symptoms domain

Source: Research field data, 2016

Three main health indicators (Figure 4.2) measured under flu symptoms were fatigue, fever or chill and chest infection in the last two weeks and twelve months prior to the survey. Fatigue recorded the highest proportion for the both two weeks and twelve months with 91.8% and 98.6% respectively. Fever or chill and chest infection equally recorded high symptoms with the least being 58.2%.

For respiratory symptoms (Figure 4.3), five indicators were measured. They included shortness of breath, difficulty in breathing when climbing hills, chronic cough, production of phlegm when coughing and coughing of blood. Recall for all the indicators were higher for the two-week recall period that the twelve month recall period. The higher recall figures for the two week period is understandable because the health symptoms usually last for shorter periods when they occur. Respondents reported 79%, 80.6%, 66.5%, 74.7% and 20% respectively.

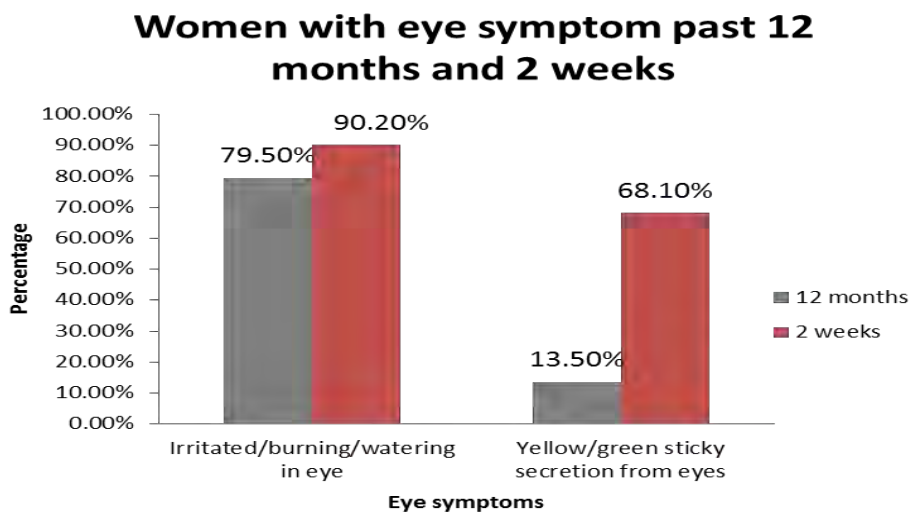
Figure 4.3: Health indicators measured under respiratory symptoms domain



Source: Research field data, 2016

For eye symptoms (Figure 4.4), respondents consistently reported high proportions on irritated/watering eye symptoms for both twelve months and two weeks recall periods with 79.5% and 90.2% respectively. Respondents had mainly reported on yellow/green secretion from the eye for the two weeks recall period (68.1%).

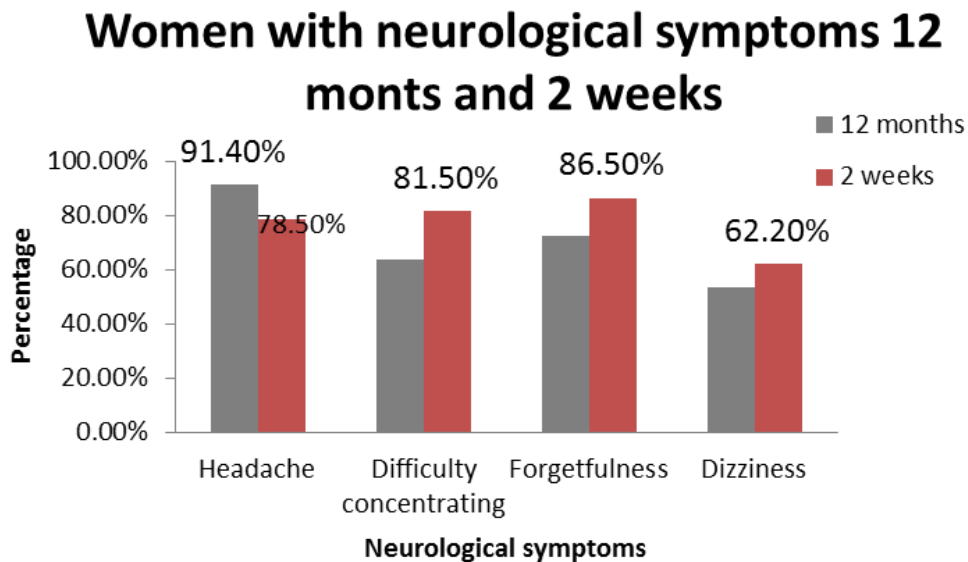
Figure 4.4: Health indicators measured under eye symptoms domain



Source: Research field data, 2016

With respect to neurological symptoms (Figure 4.5), respondents reported similarly high values for headache, difficult to concentrate, forgetfulness and dizziness for both two weeks and twelve months recall periods.

Figure 4.5: Health indicators measured under neurological symptoms domain



Source: Research field data, 2016

The transformed proportions for the health indicators are presented in 4.3 using the four main health domains (flu, respiratory, eye and neurological) used in the study. Tables 4.3 and 4.4 show the different types and levels of symptoms experienced by the participants in two weeks and 12 months prior to the survey. The results show that flu symptoms was the highest symptom (66.8%) experienced by the participants two weeks prior to the survey while other allergic irritation was the least (13.1%). Other symptoms reported by the participants two weeks prior to the survey include: respiratory symptoms (33.1%); eye symptoms (40.1%); neurological symptoms (55.0%); skin irritation symptoms (62.6%) and non-pregnancy related nausea and vomiting (24.2%).

For the 12 months prior to the survey, the results showed that flu symptoms constituted the highest symptoms (85.6%) reported by the participants and the lowest was eye symptoms

(35.5%). Other symptoms reported by the participants two weeks prior to the survey include: respiratory symptoms (44.5%); neurological symptoms (70.3%); skin irritation symptoms (54.8%) and non-pregnancy related nausea and vomiting (41.5%). Asthma symptoms and other allergic symptoms were not reported by the participants for the air pollution related symptoms experienced 12 months prior to the survey.

Table 4.3: Air pollution related health outcomes

Ill-Health Symptoms	2 weeks	12 months
	Mean (SD)	Mean (SD)
Flu symptoms	66.76 (29.17)	85.59 (23.17)
Respiratory symptoms	33.14 (24.76)	44.50 (24.90)
Eye Symptoms	40.11 (25.08)	35.45 (20.67)
Neurological symptoms	54.97 (31.56)	70.32 (29.20)
Asthma symptoms	13.06 (1.70)	-

Note: The mean level of symptoms were transformed to a scale which ranged from 0 to 100% and higher score indicates higher level of symptoms

Table 4.4: Air pollution related health outcomes

Ill-health Symptoms	2 weeks	12 months
	%	%
Skin irritation symptoms	62.6	54.8
Other allergic irritation	7.8	-
Non-pregnancy related nausea and vomiting	24.2	41.5

Note: The mean level of symptoms were transformed to a scale which ranged from 0 to 100% and higher score indicates higher level of symptoms

4.5 Environmental Exposures

The environmental exposures consist of those variables or factors that have the potential to influence or affect the health of the respondents apart from their exposure to smoke (the independent variable). They are in effect, potential risks factors to health of the respondents.

The environmental exposures in respect of the control and treatment groups are shown in Table 4.5. Generally, more than half of the study participants (51.6%) did not have an open sewer within 20 meters of the location where they spent a greater part of their day. Slightly more than one-quarter (28.5%) had a trash pit within 20 meters of where they spent a greater part of their day. Further, while 14.7% burnt trash within 20 meters of where they spent most of their days, about 93.3% spent a greater part of their days in an unpaved area.

Table 4.5: Environmental exposures

Characteristics	Control (N=159)	Treatment (N=304)	Total (N=463)
	%	%	%
Environmental exposure			
<i>Open sewer</i>			
No	52.2	51.3	51.6
Yes	47.8	48.7	48.4
<i>Trash pit</i>			
No	72.3	71.1	71.5
Yes	27.7	28.9	28.5
<i>Burn trash within 20 meters</i>			
No	84.3	85.9	85.3
Yes	15.7	14.1	14.7
Spent day in paved area			
Paved	11.9	3.9	6.7
Unpaved	88.1	96.1	93.3

Source: Research field data, 2016

4.6 Hazards of Fish Smoking: Burns and Scalds

With regard to the actual effect of fish smoking on participants, about 43.0% have experienced burn in the past 12 months due to the fish smoking activities and this was higher among those in the treatment group. However, 34.9% experienced burn in the past 2 weeks preceding the survey and this was also higher among those in the treatment group. With respect to the seriousness of the burn, 61.1% mentioned that they had light scar,

close to one-third (32.2%) said they had moderate scar (smaller than Fanta bottle top) and 6.7% had serious scar (scar larger than Fanta bottle top).

When participants were asked how they got the scar, the largest proportion (88%) of the treatment group got burnt while smoking fish. In addition, 6.0% fell in the cooking fire, 14.8% got burned with hot object while cooking, 2.0% got burned from spilled container with hot liquid while cooking, 9.4% got burned through other cooking related burn while 1.3% got burned through baking and trade related activities.

With respect to the severity of burn, more than one-tenth (15.0%) had experienced severe burn and this was higher among those in the control group (16.4%) compared to those in the treatment group (14.3%). Burns for the control group might have occurred during cooking. More than half of the participants (53.8%) experienced severe burn while smoking. Other sources of severe burn occurrence include: falling in the cooking fire (3.8%), being burned with hot object while cooking (32.7%), spilled container with hot liquid while cooking (3.8%), and other cooking related burn (5.8%).

Table 4.6: Proportion of participants of biomass related burns and scalds during the survey

	Control		Treatment		Total	
	N=110	%	N=237	%	N=347	%
<i>Experienced burn in the past 12 months</i>						
No		64.5		53.6		57.1
Yes		35.5		46.4		42.9
<i>Experienced burn in the past 2 weeks</i>						
No		79.5		60.0		65.1
Yes		20.5		40.0		34.9
<i>Seriousness of burn/scald</i>						
Light (no scar)		51.3		64.5		61.1
Moderate (scar smaller than Fanta bottle top)		43.6		28.2		32.2
Serious (scar larger than Fanta bottle top)		5.1		7.3		6.7
<i>Experience of severe burn/scald</i>						
No		83.6		85.7		85.0
Yes		16.4		14.3		15.0
<i>How participants got burned/scalded</i>						
Fell in cooking fire		15.4		2.7		6.0
Burned with hot object while cooking		48.7		2.7		14.8
Spilled container with hot liquid while cooking		7.7		0.0		2.0
Other cooking related burn		20.5		5.5		9.4
Burned /scalded while smoking		5.1		88.2		66.4
Others (Trade related and while baking)		2.6		0.9		1.3
<i>How burn/scald occurred</i>						
Fell in cooking fire		5.6		2.9		3.8
Burned with hot object while cooking		77.8		8.8		32.7
Spilled container with hot liquid while cooking		5.6		2.9		3.8
Other cooking related burn		11.1		2.9		5.8
Burned/scalded while smoking		0.0		82.4		53.8

Source: Research field data, 2016

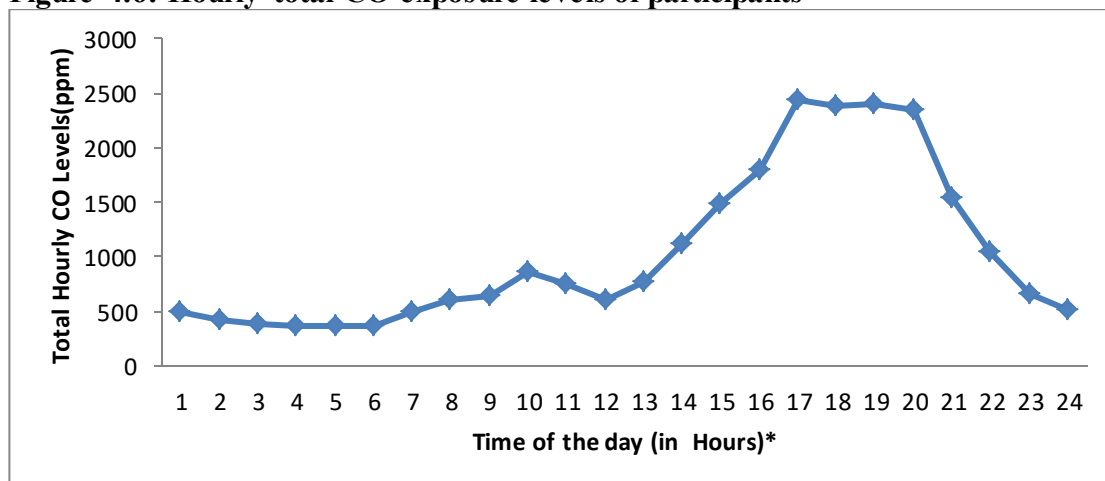
4.7 Level of Personal Exposure to Carbon Monoxide (CO) and Particulate Matter (PM_{2.5})

This section of the chapter discusses the fish smokers' personal exposure to carbon monoxide and particulate matter within the context of small scale economic activity. It

further showcases the results from the field on women’s personal exposure to pollutants from smoke from burning wood and the risks associated with this exposure.

The study sampled 156 females (both fish smokers and non-fish smokers) to measure their personal exposure levels to CO. Measurements were done for a 24-hour period with different start times. The data are irrespective of whether participants belong to either the control group or the treatment group. Figure 4.6 shows the total CO levels measured in parts per million (ppm).

Figure 4.6: Hourly total CO exposure levels of participants



*The hourly interval starts from 1 am to 12 midnight. So 1 indicates 1 am whereas 24 indicates 12 midnight
(Source: Research field data, 2016)

From the total hourly exposure as shown in Figure 4.6, total CO levels of respondents start increasing from 12 noon and peaks at 5pm, then start going down from 8pm. What it means is that, respondents of the study get much exposed to smoke between mid-day and 5 pm each day of the field data collection.

4.7.1 Personal Exposure Level- Mean CO PM2.5 Concentration

The level of personal exposure of small-scale fish smokers and non-fish smokers in the study area to carbon monoxide (CO) and particulate matter (PM2.5) is shown in Tables 4.7 and 4.8, respectively. From Table 4.7, the mean CO concentration level for the fish processors was 6.69ppm (SD=6.76ppm) and there was a statistically significant difference between the control and the treatment group. The treatment group specifically had higher mean CO concentration level than the control group [(8.23ppm (SD=7.32ppm) and 3.04 (SD=2.84ppm), respectively].

Table 4.8 shows that the mean particulate matter (PM2.5) concentration level for the participants was 3046.80 ug/m³ (SD=3597.41 ug/m³) and this level was significantly higher for the treatment group (4351.81 ug/m³) compared to the control group (1553.47 ug/m³).

Table 4.7: Carbon monoxide concentration levels of participants for a 24-hour measurement period

Group (N=156)	Mean (ppm)	SD (ppm)	t-test	P-values
Control (N=46)	3.04	2.84	-4.658	0.000
Treatment (N=109)	8.23	7.32		
Total	6.69	6.76		

Source: Research field data, 2016

Table 4.8: Particulate matter concentration level

Group (N=29)	Mean (ug/m ³)	SD (ug/m ³)	t-test	P-values
Control (N=7)	1553.47	1765.40	-2.642	0.015
Treatment (N=22)	4351.81	3858.67		
Total	3046.80	3597.41		

Source: Research field data, 2016

4.7.2 Comparison of the personal exposure levels to recognise international standards

Table 4.9 is discussed in comparison with Tables 4.7 and 4.8. The results of the overall means and standard deviations of CO for 156 women and PM2.5 for 29 women monitored

for a 24 hour period compared with international standards are presented in table 4.9. The mean 24 hour measurement for the fish smokers (treatment group) indicate they were exposed to 6.23 ppm of carbon monoxide and 4351.81 $\mu\text{g}/\text{m}^3$ (SD 3858.67 $\mu\text{g}/\text{m}^3$) of particulate matter. The result for PM_{2.5} concentration level is extremely high relative to international PM_{2.5} permissible levels stated in table 4.9.

Table 4.9: Comparison of field personal exposure data with international standards

Pollutant	24-hr Mean Concentration (in this study).	WHO interim target -1 (WHO 2005) and final target (WHO 2014)	WHO Air Quality Guideline (WHO 2006)	US EPA Guidelines (US EPA 1997)
PM _{2.5}	Control 1553.47 $\mu\text{g}/\text{m}^3$	75 $\mu\text{g}/\text{m}^3$ (24-hr mean)	25 $\mu\text{g}/\text{m}^3$ (24-hr average)	35 $\mu\text{g}/\text{m}^3$ (24-hr average)
	Treatment 4351.81 $\mu\text{g}/\text{m}^3$			
CO	Control 3.04 ppm	7 mg/m^3 [\sim 6 ppm](24-hr average)	10 mg/m^3 (8-hr average)	9 ppm or 10 mg/m^3 (8-hr average)
	Treatment 8.23 ppm			

Source: Research field data (2016), WHO (2005, 2006, 2014) and USEPA (1997)

4.8 Discussions

4.8.1 Background Characteristics and Personal Exposure

The results from the field reveal that the mean age of women who do not involve in fish smoking activity, i.e., the control group (41.45 ± 13.06 years) was lower than those involved in fish smoking activity, i.e., the treatment group (46.00 ± 13.01 years). While the highest proportion of those in the control group (35.2%) was recorded in the 30-39 age group, the highest proportion of those in the treatment group (30.3%) was among those aged 40-49 years suggesting that young women prefer other small scale economic enterprises to fish smoking.

Some studies suggest (Akani et al., 2011; Gregg, 1989) that the rigorous and tedious nature of fish smoking means fewer women engage in the business as they grow older. However, the results from this study suggest otherwise. The results suggest that even at age 59, more women smoke fish than age 29. This result supports earlier studies by Peters

et al. (1999) and Okorley (2010) which suggest that biomass smoke related businesses are more attractive to older women than younger ones. The indication is that fish smoking in Ghana is a profession for old women and does not attract the youth who may have the physical capabilities to manage things better.

The findings of the study also indicate a higher illiteracy rate among the fish smokers in the study area. Sixty four percent (64%) of the sampled population had no formal education with 21.7% having primary education. A plausible explanation to the higher illiteracy rate among this group could be that, because fish smoking appears to be an not too difficult job to find in the study areas due to geography, and because little or no education is needed for this type of business, more illiterate are funnelled into the only readily available job. Through this, the fish smokers are exposed to smoke compared to the other women in the area. Even though there might not be a direct relationship between formal education and personal exposure to smoke, Bruce et al. (2000) underscore the importance of both formal and non-formal education in environmental decision making. Acknowledging that environmental decision making hinges on a number of complex factors and structures, people's ability to read and comprehend basic materials on environmental protection and human health aide decision making on the environment and health. Perhaps, self-awareness and insights of some important environmental risk factors can improve environmental decision making.

Literature has established a relationship between the type of household energy consumption and income status (Reddy, 2001). Reddy (2001) uses wealth as proxy for income levels for the study population. It is evident in the data collected that, more than 40% of the fish smokers fall within the poorest and the poorer brackets indicating low income status of the people studied. Many studies have explored the differences in terms

of harm from air pollution to people who are in a low socioeconomic position, those who have less education, or those who live nearer to major sources. Socioeconomic position has been more consistently associated with greater harm from air pollution. Recent studies show evidence of that link. Low socioeconomic status consistently increased the risk of premature death from fine particle pollution among 13.2 million Medicare recipients studied in the largest examination of particle pollution mortality in the United States.

Results from the field show that fish smokers, apart from using firewood to smoke fish, also do household cooking using charcoal. Almost 88% of the fish smokers use charcoal as their primary cooking fuel/energy while only 2.3% of the fish smokers use liquefied petroleum gas (LPG). The personal exposure sources and characterization of the study population (women fish smokers) is complex and different from other biomass exposure studies. Many studies (Barnes, 2014; Baumgartner et al., 2011; Bruce et al., 2006) on people's exposure to biomass smoke pollution have focused mainly on single emission source mainly biomass smoke from household cooking. Fish smokers face double exposure risks since the women involved in fish smoking who use firewood for this activity are the same people who do the household cooking using charcoal as revealed in the study. Both firewood and charcoal are rated low on the clean energy ladder.

4.8.2 Analysis of CO and PM_{2.5} Levels

Even though the mean CO concentration level is low among the control group (non-fish smokers) compared to the fish smokers, the CO concentration levels of the control group raise a lot of concern. The analysis of the CO data from the field showed a mean CO concentration level of 3.04ppm with a standard deviation (SD) of 2.84ppm for the non-fish smokers compared to 8.23ppm with a SD of 7.32 for the fish smokers. The data suggest that the non-fish smokers are equally at risk in terms of exposure to CO. During the data

collection in the field, it was observed that the nature of the fish smoking settings in both Elmina and Moree could or may easily facilitate what may be described as communal pollution from fish smoking. Communal pollution in the sense that the design of the fish smoking settings facilitates easier diffusion of smoke and its associated pollutants into the immediate environment posing possible second hand exposure challenge to the whole community. Reported symptoms of flu, respiratory and neurological diseases by the non-fish smokers (control group) were equally as high as that of the treatment group. This is discussed in detail in the next chapter on health implications. Figure 3.7 showcases a typical fish smoking setting in the study area. Carbon monoxide is lethal and so continuous exposure, even in minimal amount or level could pose problems to the community, especially the very vulnerable (the aged and infants) within the community.

Currie and Neidell (2005) use data from California for the 1990s to investigate the impact of three key pollutants on infant mortality rates: carbon monoxide (CO), particulate matter less than 10 microns in diameter (PM₁₀), and ozone (O₃). They find that although particulate matter and ozone have no discernible impact on infant deaths, exposure to higher levels of ambient carbon monoxide does elevate the infant mortality rate.

One particularly striking feature of Currie and Neidell (2005) study is the authors' finding of lethal effects of carbon monoxide at the relatively low levels to which infants were exposed. The data used was from a period in which CO levels in California were on average about two-thirds *below* the national ambient air quality standards established by the Environmental Protection Agency. The hazards of CO in higher concentrations are well known, but this is the first time significant adverse effects of the pollutant have been observed at such low concentrations. This study corroborates the findings of Currie and Neidell (2005) because the study population according to the data collected is vulnerable

because they have low income status; they are mainly women of relatively older age; they in addition lack easy access to modern health facilities.

Even the non-fish smokers for the current study are equally vulnerable even at low dosage of continued and cumulative CO and PM_{2.5} exposure. Non-fish smokers for the study were mainly market women, head porters, fashion designers, hair dressers, and food vendors. Most of these women operate their businesses with accompanying children some of whom are under age five years.

4.8.3 Comparison of the personal exposure levels to recognize international standards

Case studies in Asia, Africa, and the Americas have found particulate levels ranging from 300 to over 30,000 $\mu\text{g}/\text{m}^3$ during stove use, several times above the USEPA 24-hour standard for PM₁₀ (Barnes, 2014). Mean PM_{2.5} concentration for current study (Table 4.9) is way outside the range of similar studies in selected developing countries. Chengappa et al. (2007), Dutta et al. (2007), Masera et al. (2007), Northcross et al. (2010), Pennise et al. (2009), Hankey et al. (2015) have done similar studies in, India, Mexico, Guatemala, Ghana, Uganda and found PM_{2.5} concentration levels ranging between 320 $\mu\text{g}/\text{m}^3$ -1160 $\mu\text{g}/\text{m}^3$ compared to 4352 $\mu\text{g}/\text{m}^3$ found with the treatment group of current study suggesting that the respondents of current study are at higher exposure risk.

The United States Environmental Protection Agency's standards for 24-hour average PM₁₀ and PM_{2.5} concentrations are 150 mg/m^3 and 65 mg/m^3 respectively (US EPA, 1997). The mean 24-hour levels of carbon monoxide in homes using biomass fuels in developing countries are in the range 2–50 ppm; during cooking, values of 10–500 ppm have been

reported. The US EPA's 8- hour average carbon monoxide standard is 9 ppm¹¹ or 10 mg/m³ (US EPA, 1997). A health effect is determined not just by the pollution level but also, by the time people spend breathing polluted air, i.e., the exposure level and the length of exposure. The length of exposure is critical in setting standards or permissible levels of lethal pollutants such as carbon monoxide. The longer the hours of exposure, the stricter the standard. For instance, the World Health Organisation (WHO) issues the following guidelines for levels of CO in the air, to prevent blood carboxyhemoglobin¹² (COHb) levels from rising above 2.5%. Table 4.10 demonstrates the WHO CO standards for different time periods.

Table 4.10: The WHO CO standards for specific time periods

Measurement in mg/m ³	Measurement in ppm	Time (Period)
100	87.1	15 minutes
60	52.3	30 minutes
30	26.1	1 hour
10	8.7	8 hours
7	~6	24 hours

Source: WHO, 2005, 2006, 2014

The mean 24-hour measurement of CO for the current study is 8.23ppm (see table 4.6) and this amount is about 2.23ppm higher than the WHO 2014 permissible limit. The WHO has listed different concentration levels of CO and some identified health symptoms associated with them.

¹¹ ppm means parts per million. Carbon monoxide is measured in ppm.

¹² Hemoglobin is a protein on red blood cells which functions to carry oxygen in the blood stream throughout the body. Carbon monoxide is absorbed through the lungs into the blood and combines with hemoglobin to form carboxyhemoglobin (COHb).

Table 4. 11: Effects of carbon monoxide in relation to the concentration in parts per million in the air¹³

Concentration	Symptoms
35 ppm (0.0035%)	Headache and dizziness within six to eight hours of constant exposure
100 ppm (0.01%)	Slight headache in two to three hours
200 ppm (0.02%)	Slight headache within two to three hours; loss of judgment
400 ppm (0.04%)	Frontal headache within one to two hours
800 ppm (0.08%)	Dizziness, nausea, and convulsions within 45 min; insensible within 2 hours
1,600 ppm (0.16%)	Headache, increased heart rate, dizziness, and nausea within 20 min death in less than 2 hours
3,200 ppm (0.32%)	Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes
6,400 ppm (0.64%)	Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes
12,800 ppm (1.28%)	Unconsciousness after 2–3 breaths. Death in less than three minutes

Source: Goldstein, 2008

4.9 Conclusions

The results from the study reveal that fish smoking in Ghana is mainly done by women who are older and with little or no educational background. It also reveals that fish smoking in Ghana uses mainly traditional ovens and the main energy used for the processing is biomass fuel. Personal exposure to CO and PM_{2.5} of people who do small scale fish smoking are higher relative to the WHO and USEPA standards with current study recording PM_{2.5} levels of more than 20 times the international standards.

¹³ For indoor air quality 7 mg/m³ (6 ppm) for 24 h (so as not to exceed 2% COHb for chronic exposure)

CHAPTER FIVE

ASSOCIATIONS BETWEEN BIOMASS BURNING, OTHER BACKGROUND CHARACTERISTICS, AND AIR POLLUTION RELATED HEALTH OUTCOMES

5.1 Introduction

This chapter addresses research question three of the study. The chapter discusses how fish smokers' exposure to smoke from fish smoking relates to their health. Flu symptoms, respiratory symptoms, eye symptoms, neurological symptoms and asthma symptoms were the health indices that respondents self-reported on. Respondents also reported on other environmental risks factors that have the potential to confound the results. The number of years and hours per week for fish smoking is shown in Table 5.1.

Table 5.1: Number of years and hours for fish smoking

	N	Minimum	Maximum	Mean	Std. Deviation
Years Engaged in Fish Smoking	347	0	65	21.12	15.824
Hours per week for fish smoking	347	0	112	45.49	22.845

Source: Research field data, 2016

Table 5.1 shows that the average years that the participants have been engaging in fish smoking was 21.12 years (SD=15.8). Also, the average hours spent on this activity per week was 45.49 years (SD=22.8). The analysis was done for 12 months and 2 weeks reported health experiences by the respondents.

5.2 Association between Biomass Burning, Background Characteristics and Smoke Pollution-related Health Outcomes

Tables 5.2, and 5.3 are the bivariate analysis showing the relations between biomass burning and the health outcomes (flu, respiratory, eye and neurological symptoms) that

were measured in the study. The Tables show that those who burnt biomass and those who did not were significantly different with respect to eye and neurological symptoms. However, there was no statistical difference between these two groups with respect to flu, respiratory, asthma, skin irritation, other allergic irritation and non-pregnancy related nausea and vomiting symptoms. For those who did not burn biomass, the results showed that the symptoms' scores ranged from 8.79% (asthma symptoms) to 64.55% (flu symptoms), while that of those who burnt biomass ranged from 15.05% (asthma symptoms) to 67.79% (flu symptoms). The results showed that the levels of eye symptoms (46.16%) and neurological symptoms (57.59%) were significantly higher among those who burnt biomass compared to those who did not.

Further, exposure to CO was negatively correlated with eye symptoms and the magnitude of the association was 19.4% (Table 5.2). However, CO was not significantly correlated with other air pollution related symptoms. On the other hand, exposure to PM was not significantly correlated with any of the air pollution related symptoms.

Age was associated with flu, eye and respiratory symptoms. The general pattern shows that fish smoking related symptoms were higher among the older age groups. Specifically, Table 5.2 shows that the mean flu symptoms ranged from 59.65% for those who were 20-29 years to 76.72% for those who were 60 years and above. Also, the mean eye symptoms were 36.32% for those who were 20-29 years and 48.89% for those who were 60 years and above. Further, while the mean neurological symptoms for those who were 20-29 years were 47.37%, the mean neurological symptoms for those aged 60 years and above were 65.46%.

Level of education was significantly associated with eye and neurological symptoms. Tables 5.2 and 5.3 show that these symptoms were highest among those with no formal

education. Table 5.2 shows that while the mean eye symptoms for those with no formal education were 42.56%, they were 41.77% and 28.77% for those with primary education and middle education and higher, respectively. Also, the mean neurological symptoms for those with no formal education, primary education and middle education and higher were 58.65%, 55.38% and 40.79%, respectively (Table 5.3).

Further, wealth quintiles were significantly associated with eye and neurological symptoms (Tables 5.2 and 5.3). Generally, the mean levels of eye and neurological symptoms were higher among those in the poorest wealth quintile. Specifically, the mean eye symptoms were significantly higher for those in the poorest wealth quintile (48.41%) compared to those in the richest wealth quintile (38.26%). Also, while the mean level of neurological symptoms was 57.61% for those in the poorest wealth quintile, it was 48.21% and 47.46% for those in the richer and richest wealth quintile, respectively. Tables 5.2 and 5.3 show that marital status was not significantly associated with any of the symptoms.

With respect to environmental exposures, participants who had an open sewer within 20 meters of the location where they spent most of their day significantly had lower levels of flu and respiratory symptoms compared to those who did not (Table 5.2). On the other hand, a higher proportion of those who had an open sewer within 20 meters had skin irritation symptoms (63.2%) compared with those who did not (62.1%) (Table 5.3). Those who had a trash pit within 20 meters of the location where they spent a greater part of their day significantly had lower levels of flu symptoms, but higher levels of respiratory symptoms, compared to those who did not (Table 5.2). Those who burnt trash within 20 meters of the location where they spent most of their day significantly had higher levels of respiratory, neurological, asthma, skin irritation and other allergic symptoms, compared with those who did not (Tables 5.2 and 5.3). Participants who spent a greater part of their

day in an unpaved area significantly had higher levels of flu, respiratory and eye symptoms, compared to those who spent a greater part of their days in a paved area (Table 5.2). None of the background characteristics was significantly associated with non-pregnancy related symptoms. The results showed that charcoal use was significantly associated with asthma and skin irritation symptoms. Specifically, while asthma symptoms were higher among those who used charcoal, skin irritation symptoms were higher among those who did not use charcoal.

Table 5.2: Association between background characteristics and flu, respiratory, eye and neurological symptoms

Characteristics	Flu symptoms score		Respiratory symptoms score		Eye symptoms score		Neurological Symptoms score	
	Mean	t/F	Mean	t/F	Mean	t/F	Mean	t/F
Burning of Biomass								
Yes	67.79 (27.93)	-0.9664	34.77 (24.83)	-1.802	46.16 (22.27)	-7.038***	57.59 (30.45)	-2.287*
No	64.55 (31.70)		29.64 (24.34)		27.09 (25.93)		49.32 (33.26)	
<i>Exposure to CO</i>	<i>0.01</i>		<i>0.067</i>		<i>-0.194</i>		<i>0.073</i>	
<i>Exposure to PM</i>	<i>-0.165</i>		<i>-0.19</i>		<i>0.225</i>		<i>-0.05</i>	
Age								
20-29 (RC)	59.65 (33.02)	3.671**	31.58 (23.08)	1.552	36.32 (27.84)	5.060**	47.37 (31.19)	3.605**
30-39	60.99 (31.16)		31.06 (25.50)		32.55 (25.73)		50.27 (34.10)	
40-49	69.62 (27.66)		30.67 (24.94)		40.22 (24.45)		51.94 (29.56)	
50-59	65.59 (28.29)		39.68 (26.24)		44.84 (23.94)		60.48 (30.21)	
60+	76.72 (23.67)		34.29 (22.27)		48.89 (20.88)		65.48 (29.25)	
Level of education								
No education	69.35 (28.32)	2.700	34.69 (24.19)	1.631	42.56 (23.24)	7.259**	58.65 (30.07)	7.465**
Primary	64.98 (30.62)		32.66 (25.66)		41.77 (26.83)		55.38 (32.69)	
Middle/SHS	59.65 (29.37)		28.07 (25.32)		28.77 (26.46)		40.79 (31.91)	
Wealth quintiles								
Poorest	66.67 (28.01)	1.826	37.97 (24.05)	1.896	48.41 (23.61)	2.835*	57.61 (26.19)	3.182*
Poorer	72.38 (28.92)		33.72 (23.97)		39.14 (27.54)		60.00 (33.89)	
Middle	70.05 (26.90)		35.65 (25.87)		40.00 (23.76)		61.59 (30.19)	
Richer	60.48 (32.74)		30.86 (24.24)		34.86 (25.41)		48.21 (34.14)	
Richest	64.25 (28.19)		27.54 (24.99)		38.26 (23.45)		47.46 (30.66)	
Marital status								
Never married	61.48 (31.75)	1.794	33.33 (26.97)	0.008	39.11 (30.44)	0.203	47.22 (31.18)	1.647
Married	65.45 (28.96)		32.97 (25.45)		39.51 (24.09)		55.45 (33.37)	

Formerly married	70.07 (28.38)		33.28 (23.99)		41.17 (24.47)		56.93 (29.19)	
Environmental exposure								
<i>Open sewer</i>								
No	71.89 (27.85)	3.559***	36.32 (25.44)	2.580*	39.46 (25.32)	-0.52	54.45 (46)	-0.322
Yes	60.91 (29.62)		29.51 (23.51)		40.86 (24.86)		55.56 (32.73)	
<i>Trash pit</i>								
No	68.62 (29.38)	1.998*	30.70 (25.23)	-3.115**	38.75 (24.95)	-1.706	53.52 (32.50)	-1.443
Yes	61.54 (28.08)		40.00 (22.11)		43.96 (25.16)		59.07 (28.51)	
<i>Burn trash within 20 meters</i>								
No	65.90 (29.84)	-1.469	31.18 (24.18)	-3.999***	39.28 (24.93)	-1.661	53.70 (31.87)	-2.003*
Yes	72.87 (23.29)		46.98 (24.64)		46.05 (25.65)		63.95 (27.98)	
Spent day in paved area								
Paved	51.85 (34.72)	-2.240*	18.89 (4.98)	-2.528*	27.78 (27.56)	-2.155*	50.00 (37.38)	-0.686
Unpaved	67.58 (28.68)		33.92 (24.73)		40.79 (24.80)		55.24 (31.25)	

Note: The figures in italics are correlation coefficients; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5.3: Association between background characteristics and skin irritation and other allergic symptoms

Characteristics	Skin irritation symptoms		Other allergic symptoms		Non-pregnancy related symptoms		Asthma symptoms	
	%	Chi-square	%	Chi-square	%	Chi-square	Mean	t/F
Burning of Biomass								
Yes	59.7	1.668	8.9	1.215	23.2	0.408	15.05 (2.18)	
No	69.6		5.5		26.4		8.79 (2.54)	
<i>Exposure to CO</i>	-0.127		-0.048		-0.144		0.002	
<i>Exposure to PM</i>	-0.045		-0.153		-0.122		-0.071	
Age								
20-29	56.0	3.961	7.9	0.717	31.6	7.86	3.51 (2.75)	1.202
30-39	63.3		8.5		29.8		12.77 (3.19)	
40-49	72.1		6.7		16.7		16.67 (3.70)	
50-59	65.0		9.7		29		14.52 (4.38)	
60+	51.5		6.3		17.5		12.70 (30.78)	
Level of education								
No education	64.5	0.478	7.6	1.121	23.7	1.815	12.32 (2.12)	1.946
Primary	59.5		10.1		29.1		18.57 (36.88)	
Middle/SHS	59.3		5.3		19.3		8.19 (25.41)	
Wealth quintiles								
Poorest	57.9	8.448	7.2	5.779	30.4	8.87	10.63 (3.54)	1.041
Poorer	67.3		11.4		34.3		15.24 (4.05)	
Middle	63.4		10.1		17.4		18.84 (4.49)	
Richer	45.5		8.6		18.6		10.95 (3.37)	
Richest	79.3		1.4		20.3		9.66 (3.38)	
Marital status								
Never married	67.9	2.849	15.6	4.516	33.3	3.141	11.11 (4.49)	0.223

Married	56.5		6.1		24.8		12.53 (2.45)	
Formerly married	68.6		7.3		20.4		14.36 (2.76)	
Environmental exposure								
<i>Open sewer</i>								
No	62.1	0.024	8.6	0.416	27.6	2.438	13.33 (2.39)	0.169
Yes	63.2		6.8		20.4		12.76 (2.41)	
<i>Trash pit</i>								
No	60.7	0.712	7.8	0.001	24.2	0	13.28 (1.99)	0.214
Yes	67.3		7.7		24.2		12.45 (3.24)	
<i>Burn trash within 20 meters</i>								
No	59.0	5.924*	5.9	11.827***	24	0.05	10.86 (1.67)	-3.521***
Yes	82.8		20.9		25.6		28.6.52)	
Spent day in paved area								
Paved	62.5	0.000	0.0	1.602	11.1	1.775	3.70 (3.70)	-1.292
Unpaved	62.6		8.2		24.9		13.58 (1.77)	

Note: The figures in italics are correlation coefficients; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

5.3 Discussions

Individual reactions to air pollutants depend on the type of pollutant, how much of the pollutant is present, the degree of exposure and the kinds and levels of individual activity. Age and health status are also important. In general, the more susceptible populations include women, children, elderly and those with cardiac or respiratory diseases such as asthma, emphysema and chronic bronchitis.

The main objective of this chapter was to find out whether fish smokers' exposure to smoke from fish smoking relates to their health. Flu symptoms, respiratory symptoms, eye symptoms, and neurological symptoms were the health indices that respondents self-reported on. Respondents also reported on asthma symptoms, skin irritations and other non-pregnancy related symptoms in the survey to get understanding beyond the main four health variables which were the focus of the study. Respondents' exposure to CO and PM_{2.5} is linked to their self-reported health status from the survey questionnaire in relation to the above mentioned health indices believed to be connected to peoples' exposure to biomass smoke.

5.3.1 Short-Term (Acute) and Chronic Health Effects

Myers et al. (1998) reported seven cases of chronic, sub-acute CO poisoning, in which patients experienced many similar symptoms, even after the source of CO was identified and removed.

Hemoglobin, a protein on red blood cells, functions to carry oxygen in the blood stream throughout the body. CO is absorbed through the lungs into the blood and combines with hemoglobin to form carboxyhemoglobin (COHb). CO binds to hemoglobin more strongly than oxygen does and so denies the transportation of oxygen, therefore depriving tissues and organs of oxygen. The effects of CO are related to the CO concentration in the air, the

duration of the exposure, a person's health status, and the activity level of the individual. Symptoms in order of increasing severity of CO poisoning are headache, dizziness on exertion, fatigue, palpitations, nausea, vomiting, difficulty breathing on exertion, mental confusion, rapid heartbeat, visual disturbance, and muscle twitch. These health indicators were put in broader categories as flu, respiratory/COPD, eye and neurological symptoms in the current study for fish smokers in the Central Region of Ghana. Fish smokers had, on average, 21 years of experience in fish smoking. They also spend on average 45 hours per week in smoking fish.

The results from the study show that flu symptoms were not significant for both the control and the treatment group for the 2 weeks and 12 months preceding to the survey. Even though the results showed no statistical difference between the control and the treatment groups on flu, respiratory and neurological health symptoms, there were high mean values recorded by these health indicators. Mean values of [67.79 (SD 27.93), 37.77 (SD 24.83) and 57.59 (SD 30.45)], 64.55 (SD 31.70), 29.64 (SD 24.34) and 49.32 (SD 33.26) were recorded for flu, respiratory and neurological symptoms respectively for the treatment and control groups. However, eye symptom was significant for the treatment group (fish smokers) both for the 2 weeks and 12 months preceding the survey. Questions on eye symptoms that were asked include: irritation/burning/watering of eyes, yellow/green sticky secretion from the eyes as well as whether or not the respondent has a problem with vision. This result was not surprising especially for the last 2 weeks prior to the study looking at how closely and deeply the fish smokers were engulfed in the smoke during the data collection. What is of a major health concern in this study is that, the women had reported of eye problems even in the past 12 months. Other studies have found association between personal exposure to smoke from wood burning and eye diseases. In a qualitative study on indoor air pollution from household cooking using biomass fuel

conducted in the Bongo District of Northern Ghana by Odoi–Agyarko (2009), a respondent claimed she got blind in one eye as a result of exposure to smoke from cooking. Other personal exposure studies (Balakrishnan, 2013; Pokhrel et al., 2005; Zodpey & Ughade, 1999; Mishra et al., 1999) provide confirmatory evidence that the use of solid fuels is associated with increased risk of cataract in women who do the cooking.

Fish smoking is more intensive than household cooking and the women involved in fish smoking use more hours per day relative to household cooking making the fish smokers more vulnerable to eye problems than household cooks. Data collected on the field indicate that women spend on average 3 hours per a day for cooking whereas those smoking fish spend an average of 6.5 hours per day.

A closer look at the responses from the field indicated that respondents have reported high values for both flu and neurological symptoms. And this was the case for both treatment and control groups. This could be explained by some common health risks/hazards that the study population is exposed to within the community. Conditions such as poor drainage systems, lack of proper toilet facilities as well as poor waste management systems could expose the residents to bacterial and viral conditions that have the potential for increasing flu and neurological diseases in the community. Moreover, the ill-symptoms of flu and neurology in most cases looked alike and professional diagnoses will be needed to be able to distinguish between the two. This may also account for why respondents reported high values on flu and neurological symptoms compared to respiratory and eye symptoms.

Respiratory symptoms known to be experienced by people exposed to continuous smoke from biomass burning that were included in the questionnaire were shortness of breath, difficulty in breathing, chronic cough with or without phlegm and coughing blood. It is

possible that 2 weeks was such a short period of time for the respiratory symptoms to have become obvious to the respondents.

On the other hand, the treatment group was significantly different from the control group in terms of neurological symptoms. The study asked fish smokers and non-fish smokers to report on their past 2 weeks and 12 months on neurological symptoms such as headache, difficulty in concentrating on a particular activity, forgetfulness and dizziness. Carbon monoxide is known to affect oxygen flow within the brain and could cause many health disorders both short and long term. Chronic exposure to low levels of CO can lead to a cluster of symptoms resembling the flu and neurological symptoms: headache, fatigue, muscle aches, nausea, vomiting, and a change in sensitivity to light, odour, and taste. Because symptoms of chronic exposure may differ from acute symptoms and are likely to be attributed to more common causes such as stress, infections, allergies, or psychological distress, chronic CO poisoning may have been misdiagnosed by the respondents. Even medical professionals sometimes misdiagnose CO symptoms (Myers et al., 1998).

The results further show that age is associated with flu, eye and respiratory symptoms. These symptoms were higher among older groups. Level of education was also associated with eye and neurological symptoms. Finally, wealth was significantly associated with eye and neurological symptoms as these symptoms were highest among those within the poorest wealth quintile. This finding is consistent with the American Lung Association's (ALA, 2011) analysis of the 2009 State of the Air report of the population and air quality. Socioeconomic position has been more consistently associated with greater harm from air pollution. One of the key findings of the 2011 analysis by the ALA (2011) was that, non-Hispanic Blacks and Hispanics were more likely to live in counties that had worse

problems with particle pollution. Non-Hispanic Blacks were also more likely to live in counties with worse ozone pollution.

CHAPTER SIX

MULTIVARIATE ANALYSIS OF FISH SMOKING USING BIOMASS FUEL, CONTROLS AND AIR POLLUTION RELATED HEALTH OUTCOMES

6.1 Results and interpretations

This section presents the findings of the study after the multivariate analysis. The analysis looked at the relationships among biomass burning and health outcomes after controlling for other variables.

Table 6.1 and 6.2 show the relationships between control and treatment group and air pollution related health outcomes. The Tables show that the control group was significantly different from the treatment group with respect to experience of eye symptoms, when the background characteristics and environmental exposures were controlled for. However, there were no significant differences between the control and treatment groups with regard to the experiences of flu symptoms, respiratory symptom, neurological symptoms, asthma symptoms, skin irritation symptoms, other allergic symptoms and non-pregnancy related symptoms. Table 6.1 specifically show that eye symptoms were significantly higher among the treatment group compared to the control group ($\beta = 17.398$, $P < 0.001$).

The results showed that there was a significant relationship between age and other allergic symptoms (Table 6.2). However, age was not significantly related with other air pollution related health outcomes. From Table 6.2, those who were 40-49 years and 50-59 years were 6.3% and 4.4% respectively more likely to experience other allergic symptoms compared to those who were 20-29 years. Further, there was a significant relationship between level of education and experience of other allergic symptoms. Specifically, those with middle education or more were more likely to experience other allergic symptoms

compared with those with no education (Odds Ratio= 1.003, $P < 0.001$). However, there was no significant difference between those with primary education and those with no education with respect to experience of other allergic symptoms. There was no significant relationship between level of education and other air pollution related health outcomes.

There was a significant relationship between wealth quintiles and experience of eye symptoms and other allergic symptoms (Tables 6.1 and 6.2). Table 6.1 shows that eye symptoms were lower among those in the richer wealth quintiles compared with those in the poorest wealth quintiles ($\beta = -10.284$, $P < 0.05$). In addition, those in the middle wealth quintiles were significantly less likely to experience other allergic symptoms compared with those in the poorest wealth quintiles (Odds ratio= 0.939, $P < 0.01$). Wealth quintile was not related to the other air pollution related health outcomes. Marital status and religion were not related with any of the air pollution related health outcomes.

Further, Table 6.1 shows that there was a relationship between town and experience of respiratory and eye symptoms. Table 6.1 specifically shows that eye symptoms and respiratory symptoms were significantly lower for those living in Moree town compared with those living in Elmina ($\beta = -10.345$ and $\beta = -9.122$, respectively) (Table 6.1).

With respect to the relationship between environmental exposures, Table 6.1 shows that while those who had an open sewer within 20 meters of the location where they spent most of their day and those who had a trash pit within 20 meters of the location where they spent most of their day had experienced lower levels of flu symptoms compared to their respective counterparts ($\beta = -10.659$ and $\beta = -7.947$, respectively). In addition, those who burnt trash within 20 meters of the location where they spent most of their day experienced higher levels of flu symptoms ($\beta = 9.995$, $P < 0.05$), respiratory symptoms ($\beta =$

13.732, $P < 0.01$), and were more likely to experience skin irritation and other allergic symptoms (Odds ratio= 2.480 and 5.417, respectively) (Tables 6.1 and 6.2).

Table 6.1 shows that there was a significant relationship between the concentration level and eye symptoms. The results specifically show that a unit increase in the concentration level reduces eye symptoms by 0.301 points. However, concentration level did not show significant relationship with the other air pollution related symptoms. Charcoal use did not show significant relationship with any of the other air pollution related symptoms.

Table 6.1: Linear regression showing relationship between control and treatment groups and air pollution related health outcomes, controlling for background characteristics and environmental exposures

Characteristics	Flu Symptoms Score		Respiratory Symptoms Score		Eye Symptoms Score		Neurological Symptoms Score		Asthma Symptoms Score	
	B	Std error	B	Std error	B	Std error	B	Std error	B	Std error
Group										
Control (RC)										
Treatment	1.231	3.490	3.149	2.925	17.398***	2.834	3.494	3.855	4.558	3.917
Concentration level										
Age										
20-29 (RC)										
30-39	1.597	5.956	2.314	4.991	-4.79	4.837	-0.219	6.578	9.740	6.685
40-49	10.662	6.153	2.253	5.156	1.862	4.996	1.716	6.795	13.52	6.906
50-59	4.870	6.579	10.11	5.513	3.954	5.342	8.287	7.266	7.229	7.384
60+	15.785*	6.963	7.673	5.835	10.33	5.654	14.089	7.690	7.979	7.815
Level of education										
No education (RC)										
Primary	-2.173	3.948	-0.48	3.308	3.734	3.206	-0.354	4.360	7.740	4.431
Middle/SHS	-5.837	4.731	-1.639	3.964	-6.600	3.842	-10.02	5.225	-0.320	5.310
Wealth quintiles										
Poorest (RC)										
Poorer	5.328	5.015	-0.021	4.316	-3.860	4.073	4.057	5.688	0.998	5.629
Middle	3.351	4.965	0.190	4.497	-5.550	4.032	3.242	5.927	4.586	5.573
Richer	-6.038	5.150	-3.480	4.368	-10.284*	4.182	-8.377	5.756	-3.01	6.023
Richest	-4.977	5.367	-7.307	4.497	-2.410	4.358	-7.274	3.886	-5.77	5.850
Marital status										
Married (RC)										
Never married	-2.918	5.212	-0.967	4.368	3.448	4.232	-8.718	5.756	-0.090	5.850
Formerly	-0.929	3.518	-3.443	2.948	-3.070	2.857	-4.133	3.886	-0.110	3.949

married										
Town										
Elmina (RC)										
Moree	-1.159	3.572	-10.345**	2.994	-9.122**	2.901	-2.044	3.945	-0.140	4.010
Religion										
No religion/Islam (RC)										
Christianity	-3.732	3.428	-1.765	2.873	0.649	2.784	0.687	3.786	5.963	3.847
Environmental exposure										
Open sewer										
No (RC)										
Yes	-10.659**	3.619	-4.490	3.033	5.283	2.939	-0.860	3.997	1.471	4.062
Trash pit										
No (RC)										
Yes	-7.947*	3.889	5.231	3.259	0.352	3.158	2.731	4.295	-4.800	4.365
Burn trash within 20 meters										
No (RC)										
Yes	9.995*	4.929	13.732**	4.131	6.059	4.003	8.649	5.444	18.807**	5.533
Spent day in paved area										
Paved (RC)										
Unpaved	11.254	7.253	8.022	6.078	2.774	5.890	-2.653	8.010	9.910	8.141
Charcoal use										
No (RC)										
Yes	8.102	7.871	7.395	6.460	3.351	6.554	0.418	8.628	9.822	5.438

*Note: std error- standard error; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; Concentration level was not included in asthma symptoms model because the addition makes the model to be non-significant*

Model summary: $F = 2.077^{**}$; $R^2 = 15.5\%$ $F = 3.279^{***}$; $R^2 = 28.0\%$ $F = 2.881^{***}$; $R^2 = 24.3\%$ $F = 2.342^{**}$; $R^2 = 18.6\%$ $F = 1.767^*$; $R^2 = 4.3\%$

Table 6.2: Binary logistic regression showing the relationship between control and treatment groups and air pollution related health outcomes, controlling for background characteristics and environmental exposures

Characteristics	Skin irritation symptoms		Other allergic symptoms		Non-pregnancy related symptoms	
	Odds ratio	Std error	Odds ratio	Std error	Odds ratio	Std error
Group						
Control (RC)						
Treatment	0.864	0.274	1.673	0.538	0.933	0.301
Concentration level						
	0.986	0.011	-	-	0.985	0.013
Age						
20-29 (RC)						
30-39	0.732	0.471	1.526	0.818	1.318	0.494
40-49	0.769	0.484	1.063**	0.871	0.579	0.537
50-59	0.947	0.512	1.044**	0.885	1.369	0.553
60+	0.423	0.558	0.786	0.95	0.744	0.613
Level of education						
No education (RC)						
Primary	0.663	0.314	1.178	0.53	1.249	0.331
Middle/SHS	0.506	0.391	1.003***	0.751	0.678	0.438
Wealth quintiles						
Poorest (RC)						
Poorer	1.832	0.389	1.092	0.671	1.496	0.407
Middle	1.219	0.389	0.939**	0.676	0.519	0.448
Richer	0.636	0.434	0.793	0.744	0.631	0.456
Richest	1.297	0.424	0.113	1.22	0.749	0.462
Marital status						
Married (RC)						
Never married	1.316	0.403	2.042	0.616	1.432	0.426
Formerly married	1.12	0.277	1.262	0.527	0.760	0.320
Town						
Elmina (RC)						
Moore	1.466	0.283	1.835	0.512	0.592	0.317
Religion						
No religion/Islam (RC)						
Christianity	1.117	0.271	2.194	0.464	0.960	0.894
Environmental exposure						
Open sewer						
No (RC)						
Yes	0.809	0.287	0.724	0.507	0.749	0.317
Trash pit						
No (RC)						
Yes	1.271	0.301	0.578	0.596	0.945	0.352
Burn trash within 20 meters						
No (RC)						

Yes	2.480*	0.373	5.417**	0.564	1.083	0.439
Spent day in paved area						
Paved (RC)						
Unpaved	1.192	0.589			1.794	0.820
Charcoal use						
No (RC)						
Yes	1.702	0.674	2.334	0.618	2.229	0.807

Note: CO Concentration level was not included in the other allergic symptoms model because its addition made the model to be non-significant.

Model Summary: $\chi^2=5.370^*$; $R^2=23.8\%$ $\chi^2=150.520^{***}$; $R^2=8.9\%$ χ^2 $R^2=27.4\%$
 $=29.664^{***}$;

6.2 Discussion

Personal exposures of biomass dependent small scale businesses to smoke related diseases in developing countries to the best of my knowledge, has received less research attention. Many respiratory diseases have been found to be associated with the exposure of biomass fuels such as acute lower respiratory infections, chronic obstructive pulmonary disease, lung cancer, pulmonary tuberculosis, and asthma (Barnes, 2014; Bruce et al., 2006; Dherani et al., 2016). These studies have been conducted mainly focusing on using biomass fuel for household cooking. This study was conducted to find out the relationships among biomass fuel usage and four health indicators including flu, respiratory, neurological and eye symptoms focusing on women fish smokers.

Data collected from the field indicate that women fish smokers were significantly higher in terms of personal exposure to both CO and PM2.5 (Tables 4.7 and 4.8). At bivariate level, it was found out that those who burnt biomass and those who did not were significantly different with respect to eye and neurological symptoms. However, flu and respiratory symptoms were not significant at the bivariate level. The analysis showed similar results at the multivariate level when other variables were controlled for. All the four health indicators used for the analysis did not show any statistical significance

between the treatment and the control groups, except for eye symptoms. The association between eye symptoms and fish smoking may be explained by the closeness of the eyes of the women to smoke during fish smoking. To ensure that the fish are well smoked, the women keep their eyes on constant checks of the fish smoking trays and nets as well as the firewood in the ovens. During data collection, it was observed that none of the women interviewed wore protective glasses when smoking fish. The absence of protective gadgets exposes the eye directly to smoke and its associated pollutants. Eye and respiratory symptoms were also significantly different between fish smokers in Moree and Elmina as the measured health outcomes or symptoms were lower in Moree than in Elmina ($\beta = -10.345$ and $\beta = -9.122$ for eye and respiratory respectively). The difference could be attributed to the fish smoking settings of the two towns. Even though the two towns have mainly open fish smoking environment, Elmina has a more centralized smoking environment where fish smoking ovens are largely concentrated in common areas unlike in Moree where the ovens are located in front of most households. Fish smoking for commercial purposes in the study area is mainly done in residential places making it difficult to classify the smoke source as either household air pollution or an industrial pollution. The source classification is very vital for interventions especially those that are meant to reduce health risks associated with biomass smoke exposure.

With respect to the relationship between flu, respiratory and neurological symptoms, the study did not find any significant difference between those who smoke fish and those who did not. Even though, there were no significant difference between the fish smokers and non-fish smokers, respondents (both treatment and control) have reported on high incidence of flu, respiratory and neurological symptoms. The fish smokers had reported 67.8%, 34.8% and 58% on flu, respiratory and neurological symptoms respectively while 64.6%, 29.6% and 49% had reported on flu, respiratory and neurological symptoms

respectively. The seemingly no difference between the two groups on the measured health outcomes in the study could be attributed to the obvious common exposure of the general population in the study sites to biomass smoke due to fish smoking. Both groups had reported similarly on the health outcomes used in the study.

Respiratory disease outcomes that most studies measure include acute lower respiratory infection (ALRI), chronic obstructive pulmonary disease (COPD), bronchitis and asthma. This study put all these indicators, except asthma under respiratory as one variable. Studies (Dherani et al., 2016; Barnes, 2014; Bruce et al., 2006; Bailis et al., 2003; Ezzati et al., 2000) have reported on the association between biomass fuel smoke and respiratory diseases. For instance, published evidences from India suggest association of the respiratory diseases particularly tuberculosis, COPD, and lung cancer with biomass fuel exposure and also it contributes heavily to the burden of diseases (Prasad & Garg, 2014).

Even though this study collected few samples on particulate matter (n=29) for the analysis, the results show that PM_{2.5} pollution is still a matter of public concern for the people in the study areas. The analysis on the 29 samples showed high exposure values that were extremely beyond the international permissible limits (75 $\mu\text{g}/\text{m}^3$ (24-hr mean) for the WHO and 35 mg/m^3 (24-hr average) for the US EPA, posing health risks to the women. Rylance et al. (2010) talked about the vulnerability of rural women to biomass smoke exposure and Anenberg et al. (2010) for instance have indicated that global mortality associated with outdoor ozone and particulate matter (PM) exposure has been underestimated and that anthropogenic atmospheric PM rather than ozone is the main contributor to death. Rural populations and women especially who burn biomass fuel continuously and consistently produce PM concentrations above recognized standards which is confirmed in this study. However, Anenberg et al., (2010) and several other

studies such as Dionisio et al. (2010) and Ezzati and Kummer (2002) have lean heavily on outdoor exposure and mainly in urban areas.

Other variables that the study controlled for include age, education and environmental exposures. The poor environmental sanitation conditions in the two study towns could partly explain why both fish smokers and non-fish smokers reported very high incidence of flu symptoms. Variables that the study measured for under flu symptoms were fatigue, fever or chill and chest infection. These health outcomes have mainly been associated with poor environmental conditions apart from exposure to smoke. There were many open gutters in the study with filth. Again quite significant number of the respondents spent most time of their day in unpaved areas full of dust. This partly explains why flu, respiratory and neurological symptoms were high for both fish smokers and non-fish smokers in the study area.

CHAPTER SEVEN

FUEL WOOD CONSUMPTION, CLIMATE IMPLICATIONS AND KNOWLEDGE SYSTEMS

7.1 Introduction

The implication of fuel wood consumption by small scale fish smoking activity on the climate has been conceptualized in this study (see chapters 1 and 2) mainly focusing on woodfuel consumption. Wood burning emits numerous pollutants and gases some of which are harmful to the climate. The United Nations Convention on Climate Change (UNFCCC) is much particular about the anthropogenic (human induced) activities that potentially impact negatively on the climate. Small scale fish smoking is fuel wood intensive activity. The study collected data on the quantity and sources of fuel wood used by small scale fish smokers to ascertain the potential of this small scale commercial activity on wood stock (carbon sink) and greenhouse gas emissions from wood burning from fish smoking. The objective was to use the quantity of fuelwood consumed weekly from fish smoking activity to do a crude estimation of GHG emissions from this sub-sector using the IPCC tier one methodology for GHG emission calculation. The chapter also examines how fish smokers perceive the implications of wood burning on their health and environment.

7.2 Usage, sources and quantity of fuel wood

Table 7.1 shows the proportion of participants who used fuel woods. Table 7.1 shows that there was significant difference in fuel use between the control group and treatment group. In total, 72.6% of the participants used fuel wood and this was significantly higher for those in the treatment group (99.6%) compared to those in the control group (14.5%). With respect to the sources of fuel wood, Table 7.2 shows that 75.4% came from local

source, 24.2% were purchased from non-local source and 0.4% was purchased from other sources. In addition, the quantity of fuel use ranged from 7kg to 26,640kg (Table 7.3), with a mean of 1,587.89kg (SD=2955.34kg).

Table 7.1: Percentage weekly fuel wood consumption between fish smokers and non-fish smokers

Fuel wood usage	Control (N=110)		Treatment (N=237)		Total (N=347)		χ^2	P-values
	N	%	N	%	N	%		
No	94	85.5	1	0.4	95	27.4	273.223	0.000
Yes	16	14.5	236	99.6	252	72.6		

Source: Research field data, (2016)

Table 7.2: Sources of fuel wood

Sources of fuel wood	N=252	%
Local source	190	75.4
Purchased from non-local source	61	24.2
Other sources	1	0.4
Total	252	100.0

Source: Research field data, (2016)

Table 7.3: Weekly quantity of fuelwood consumed by Fish Smokers

	N	Minimum (kgs)	Maximum (kgs)	Mean (kgs)	Std. Deviation (kgs)
Fuel wood quantity	252	7	26640	1587.89	2955.343

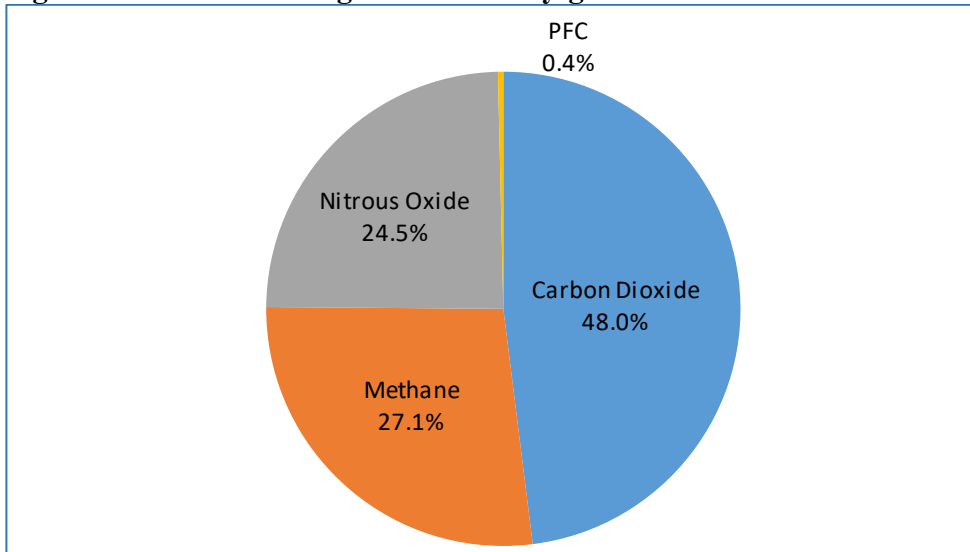
Source: Research field data, (2016)

7.3 Linkages between fuelwood burning from fish smoking and greenhouse gas emissions

Data from the field indicated that the fuelwood used for smoking fish come from the forest, even though the actual source was not known from the data collected. Ghana's greenhouse gas inventory report indicates that carbon was the most important of the greenhouse gases in Ghana, including those from agriculture, forestry and land-use

(AFOLU) with a large share of 48% (14.81Mt) of the total national emissions, followed by CH₄ and N₂O, which comprised 27.1% (8.36 MtCO₂e) and 24.5% (7.56MtCO₂e) respectively (see figure 7.1). The remaining 0.4% of the total national emission was made up of perfluorocarbons (PFCs) [(0.11 MtCO₂e)].

Figure 7.1: Greenhouse gas emissions by gases in Ghana



Source: EPA¹⁴, 2014

The land subsector alone accounted for forty one percent (41%) of the emissions with only two percent (2%) coming from the industrial sector while the waste sector contributes fifteen percent (15%) of the net national emissions in 2012. This is provided in Table 7.4. Emissions from the land sector is mainly due to deforestation, forest degradation and wild fire (EPA, 2014).

¹⁴ The Environmental Protection Agency (EPA) is the responsible institution data collection, management and publication on greenhouse gases to the United Nations Framework Convention on Climate Change.

Table 7.4: Net national emissions by Sectors in 2012

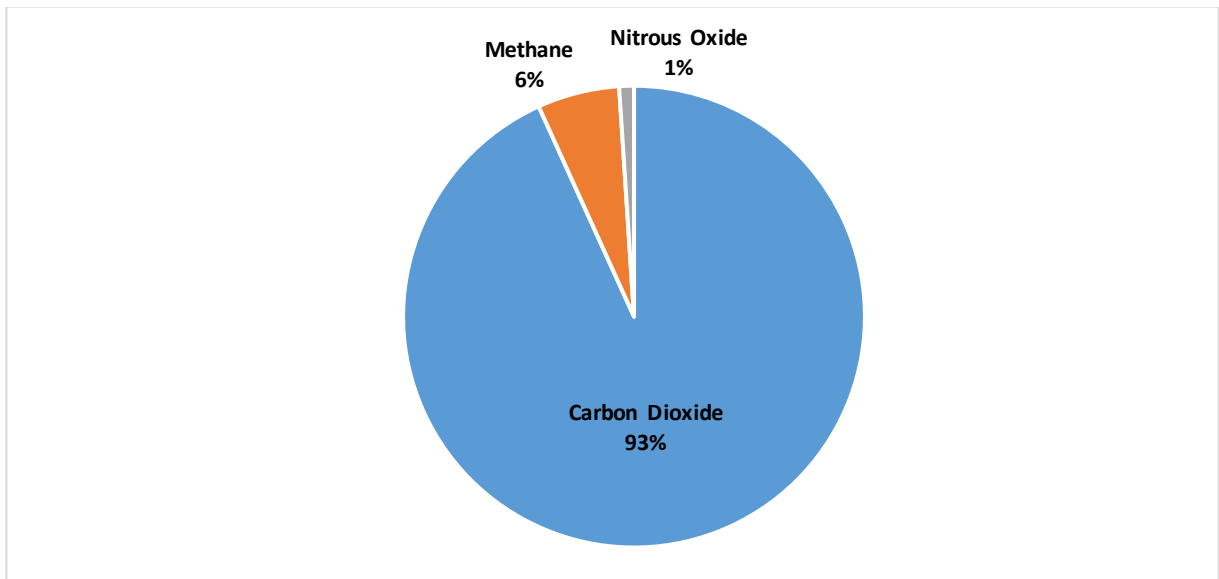
Sectors & Sub-sectors	Emissions					Share of Total Emissions
	Mt	Mt CO ₂ e				
	CO ₂	CH ₄	N ₂ O	PFC	Total	%
1. All Energy (combustion & fugitive)	12.59	0.64	0.27	0	13.51	44
2. Industrial Process & Product Use	0.35	0.00	0	0.11	0.47	2
3. AFOLU	1.86	3.70	6.80	0.00	12.54	41
4. Waste	0.00	4.02	0.49	0.0	4.5	15
Total net emissions	14.81	8.36	7.56	0.11	30.85	100

Source: EPA, 2014

To situate the GHG emissions discussion within the context of fish smoking and fuel wood consumption, the data collected from the field (refer to Table 7.3) was analysed using the IPCC tier one¹⁵ methodology. The weekly data on fuelwood consumed was extrapolated to get a sense of the annual total GHG emissions from the fish smokers from the study area. How the calculations were done can be found in the methodology section (see section 3.12.6) of the thesis. Detail calculation tables can be found in the appendix (see Appendix C). The proportion of GHG emissions by gases are presented in figure 7.2.

¹⁵ The IPCC has classified the methodological approaches in three different Tiers, according to the quantity of information required, and the degree of analytical complexity (IPCC, 2003, 2006). Tier 1 employs the gain-loss method described in the IPCC Guidelines and the default emission factors and other parameters provided by the IPCC. There may be simplifying assumptions about some carbon pools (IPCC, 2003; 2006).

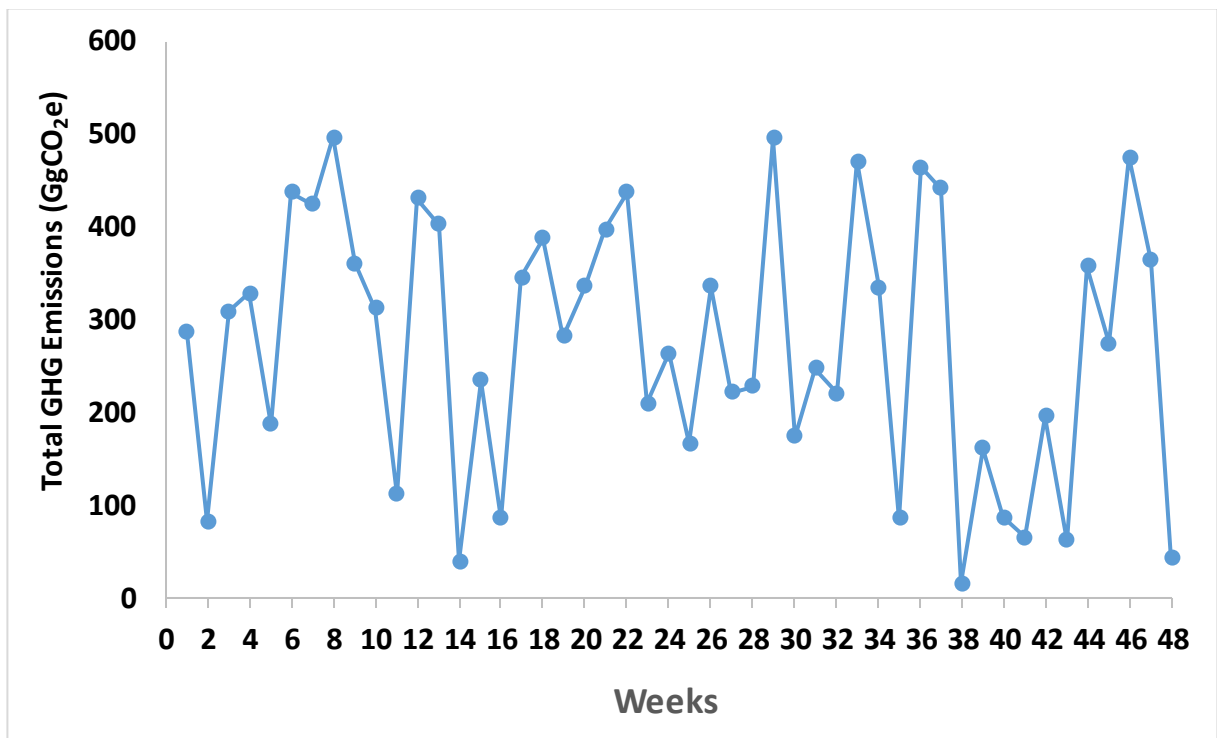
Figure 7.2: Average GHG emissions by gases from fuelwood consumed by fish smokers



Source: Research field data, 2016

From Figure 7.2, carbon dioxide (CO₂) emissions account for 93% with methane (CH₄) and nitrous oxide (N₂O) accounting for 6% and 1% respectively.

The weekly fuelwood consumption by fish smokers using the lower and upper limits was used to generate the GHG emissions from wood burning by fish smokers in the study area. The result is presented in Figure 7.3. The graph indicates that more than half of the forty eight projected weeks (1 year) showed total emissions of 300 (Gg CO₂e) or even more.

Figure 7.3: Total GHG emission trends (weekly) from fuelwood consumed by fish smokers

Source: Research field data, 2016

7.4 Welfare implications about fish smoking as a business

To be able to get a complete picture of the fish smokers' continuous stay in the fish smoking business even though the environment within which they work look hazardous, the study collected information about factors that account for that. The findings are presented in tables 7.5 and 7.6. Table 7.5 shows that majority of the participants (86.8%) agreed that fish smoking is a good business in the community. More than half (52.4%) considered themselves to be average when they compared themselves with other women in the community. More than one-quarter (26.8%) and one-fifth (20.7%) considered themselves to be worse-off and better-off, respectively. With respect to household differences, 25.1% considered themselves to be worse-off than other households in the community, 54.5% considered themselves to be average and 20.5% considered they were better-off.

Table 7.6 presents basic income and expenditure from fish smoking reported by respondents during the survey. From the table, participants earned on the average, Ghc 570 per month from fish smoking and spent on average Ghc 2,589 per month. The main expenditure lines included firewood, fresh fish and transportation.

Table 7.5: Perceptions of respondents about fish smoking as a business

Variable	Number	Percentage
<i>Fish smoking is good business in the community</i>		
Strongly disagree	2	0.6
Disagree	44	12.7
Agree	148	42.7
Strongly agree	153	44.1
<i>Comparison with other women in the community</i>		
Worse off	93	26.8
Average	182	52.4
Better off	72	20.7
<i>Comparison with other households in the community</i>		
Worse off	87	25.1
Average	189	54.5
Better off	71	20.5

Source: Research field data, (2016)

Table 7.6: Monthly expenditure on and income from fish smoking

	Amount (GHC) for treatment group only			
	Minimum	Maximum	Mean	Standard error
Amount spent on Fuel wood	24	6,000	622.87	66.06
Amount spent on Transportation	0	500	69.28	7.81
Amount spent on fresh fish for processing	0	24,000	1897.27	334.76
Amount earned from fish smoking	10	16,000	569.96	96.01

Source: Research field data, (2016)

7.5 Knowledge and perceptions about fish smoking on the environment and health

Table 7.7 describes how fish smokers perceive the implications of wood burning on their health and environment. The results showed that close to eight out of ten respondents have heard that the smoke from cooking with fuel wood and charcoal could affect health negatively (77.8%) and a higher proportion of those in the control group had this perception. Further, about 82.0% perceived that fish smoking negatively impacts health.

With regard to the perception of participants on the effect of fuel wood on the environment, slightly more than one-tenth have heard that smoke from cooking with fuel wood and charcoal has negative effect on forest and that fish smoking has negative impact on forests (12.4% and 12.7%, respectively). In addition, more than six out of ten (67.4%) knew that smoke from cooking with fuel wood or charcoal negatively impact local air quality while 71.2% knew that fish smoking negatively impact air quality.

Table 7.7: Knowledge and perceptions about fish smoking on health and environment

Knowledge and perceptions	Control		Treatment		Total	
	N=110	%	N=237	%	N=347	%
<i>Ever heard that smoke from cooking with fuelwood and charcoal negatively impact health?</i>						
No		17.3		24.5		22.2
Yes		82.7		75.5		77.8
<i>Ever heard that fish smoking negatively impacts your health?</i>						
No		14.5		19.8		18.2
Yes		85.5		80.2		81.8
<i>Ever heard that smoke from cooking with fuelwood and charcoal has negative impacts on forests?</i>						
No		82.7		89.9		87.6
Yes		17.3		10.1		12.4
<i>Ever heard that fish smoking has negative impacts on forests?</i>						
No		81.8		89.9		87.3
Yes		18.2		10.1		12.7
<i>Ever heard that smoke from cooking with fuelwood or charcoal negatively impacts local air quality?</i>						
No		33.6		32.1		32.6
Yes		66.4		67.9		67.4
<i>Ever heard that fish smoking negatively impacts air quality?</i>						
No		30.9		27.8		28.8
Yes		69.1		72.2		71.2

Source: Research field data (2016)

7.6 Discussion

Objective five of the study sought to ascertain from the respondents about their personal feelings about fish smoking as a business as well as their perception and knowledge about the implications of the business on the environment (climate) and their own health. This is to inform policy recommendations from this study.

7.6.1 Fuelwood consumption, GHG emissions and climate change

Burning biomass returns to the atmosphere in the form of carbon dioxide that has been absorbed as the plants grew. The absorbed carbon in the mass of the wood is exposed into the air or the environment any time the wood is burned.

Fish smoking relies heavily on firewood which comes from the nearby forests (refer to Tables 7.2 and 7.3) and this is collaborated in the study by the results between the treatment and the control group in terms of the weekly quantity of wood consumed. There was a significant difference between the control and treatment in the amount of firewood consumed by the two groups as shown in Table 7.1 (X^2 273.223; $p=0.000$) with almost 100% (99.6%) of the treatment group indicated they used firewood for smoking fish as against 14.5% of the control group for cooking.

The results on the amount of firewood consumed weekly by the study indicate that large volume of wood is used. Table 7.3 indicates that a mean amount of 1587.87 kg (1.59tonnes) and a maximum of 26640 kg (26.64tonnes) with a standard deviation of 2955.343 kg were consumed weekly. This quantity of woodfuel when calculated using the IPCC tier 1 methodology for biomass fuel burning, gives a crude annual GHG estimation of about 1428 Gg CO₂e (see Appendix C for detail calculations). Carbon dioxide is a major greenhouse gas, contributing over 75% to global warming (IPCC, 2014). The share of CO₂ in Ghana's GHG emission profile is 48%, taking about half of the country's total GHG emissions. Data from this study indicate that CO₂ account for 93% of the GHG emissions from fish smoking in the study area. Enhancing systems to address CO₂ emissions from the fish smoking sub-sector in Ghana will make the national GHG inventory system more robust.

The quantity of wood consumed weekly by fish smokers also raises issues of deforestation and/or forest degradation, though direct source attribution cannot be made by this study. Respondents indicated they purchased the wood from wood vendors who bring their ware from the nearby communities. Most of the wood were fresh hard wood with heavy moisture content, suggesting that fresh trees are cut to be used as fuelwood for fish

smoking activities. The wet woods have to be kept dry by the fish smokers to reduce the moisture content before they are used. Presumably, the wood is harvested unsustainably without re-planting the harvested trees which may contribute to deforestation or forest degradation, depending on the source of the wood.

This study did not collect data on where exactly the wood was coming from in order to directly connect the fish smoking activity with an area specific deforestation or forest degradation. However, the figures on the amount of wood consumed by fish smokers every week gives an indication of fish smoking to forest degradation in general in Ghana. Deforestation and forest degradation are known to be accounting significantly to global GHG emissions (IPCC, 2013; Kato et al., 2011; Fearnside, 1996a). Carbon balance in the global atmosphere is a shared resource and responsibility as well. Greenhouse gas emissions from deforestation can be avoided or reduced by taking conscious steps to reduce deforestation. The IPCC encourages Parties under the UNFCCC to adopt a more robust GHG inventory and accounting systems to enhance reporting especially from developing countries, where reliable land-use data has always been a challenge. More reliable quantification of the impact of deforestation on global warming is a prerequisite for assessing the value of avoiding the impacts of negative land-use practices to sustain the environmental service of the forest (Fearnside, 1996a).

The high quantity of fuel wood consumed by this small scale commercial activity has implications on Ghana's GHG inventory data source categorization as well as GHG emissions into the environment.

Ghana's GHG emissions have been increasing in the past two decades, although the emissions are relatively small compared to the global average and emissions from other developing countries (Ghana TNC Report, 2015). From the national GHG emissions

scenarios, the country's emissions has increased significantly in the past two decades and has the potential to grow more in the coming years if the country remains on the same developmental pathway. The agriculture, forestry and land use (AFOLU) sector was the largest source of greenhouse gas emissions followed by the Energy sector. In 2012, the emissions from the AFOLU sector constituted 45.1% (15.2 MtCO₂e) of total net emissions with AFOLU emissions increasing by 3.5% between 2010 and 2012. Globally, carbon dioxide concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions (IPCC, 2013).

From 1990 to 2012, when the last GHG inventory was updated, the emissions from the industrial sector have seen a decline of fifteen percent (15%), with consistency in the trend of decline. However, the emissions from the land sector for the same reporting period has witnessed over five percent (5.3%) increase. Part of the reasons for the decline in GHG emissions from the industrial sector could be attributed to the culture of developing and implementing environmental management plans (EMPs) as part of the permitting conditions of the environmental impact assessment (EIA) administration system regulated by law in Ghana. The rise in emissions from the land sector could be attributed to unsustainable land practices, mainly deforestation and forest degradation (EPA, 2014). Currently, GHG inventory national accounting does not disaggregate data on the land sector emissions, especially for small scale activities. There are a number of small scale biomass fuel dependent businesses such as gari processing and local gin brewery (i.e. Akpeteshi) other than fish smoking which on aggregate constitutes fair share of the GHG emissions in Ghana. However, data and information about their GHG emissions is currently not existent. Further, because fish smoking in Ghana is largely done within residential environment, it is considered as a domestic or household activity. In view of

this, GHG emissions from this activity are at the moment classified as non-industrial activity. The IPCC currently does not recognize domestic GHG emissions in the national accounting framework. This is misleading and may not give realistic GHG emission figures from the economic sector. Brazil for instance has a national GHG emissions accounting system that addresses emissions from certain small scale commercial activities such as restaurants but cautions on the reliability of data from this sub-sector (FAO, 2010). Figures on hardwood consumed by small scale fish smokers in the study as indicated in Table 7.3 signal a national attention on emissions from this sub-sector for national accounting.

7.6.2 Particulate matter and other short-lived climate pollutants

Emissions of short-lived gases contribute to the total anthropogenic radiative forcing¹⁶ (RF). Emissions of carbon monoxide (CO) are virtually certain to have induced a positive RF, while emissions of nitrogen oxides (NO_x) are likely to have induced a net negative RF.

Burning firewood, especially those with high moisture content, is synonymous with high emissions of particulate matter into the ambient air with health implications for people within the immediate environment (Baumgartner et al., 2011, 2014; Kurmi et al., 2010; Dherani et al., 2008; Bruce et al., 2000). The implication for climate change is also negative because the accumulated carbon in the wood is released back to the atmosphere in various forms of gases and pollutants. These gases have both short-term and long-term

¹⁶ RF is the change in energy flux caused by a driver, and is calculated at the tropopause or at the top of the atmosphere. The strength of drivers is quantified as Radiative Forcing (RF) in units watts per square metre ($W m^{-2}$) as in IPCC assessment reports. In calculating RF for well-mixed greenhouse gases and aerosols, physical variables, except for the ocean and sea ice, are allowed to respond to perturbations with rapid adjustments. The resulting forcing is called Effective Radiative Forcing (ERF) as contained in the fifth assessment report (AR5) of the IPCC.

implications once they are released into the atmosphere. Carbon monoxide, nitrogen dioxide, black carbon and particulate matter, which are bi-products of biomass burning, are all short-lived pollutants. Short-lived climate pollutants (SLCPs) are dangerous climate forcers. The recorded PM_{2.5} during the study shows that the mean total particulate matter (PM_{2.5}) concentration level for the participants was 3046.80 ug/m³ (SD=3597.41 ug/m³) and this level was significantly higher for the treatment group (4351.81 ug/m³) compared to the control group (1553.47 ug/m³). The figures are way beyond the international personal exposure permissible levels. There are consequential health implications of the women's high exposure to PM concentration. Carbonaceous aerosols are known to play an important role in the Earth's radiative balance and in climate. High concentrations of particulate organic carbon (OC) and black carbon (BC) also called elemental carbon or soot cause warming of the atmosphere, particularly, in the short time (IPCC, 1996; NRC, 1996; Jacobson, 2001).

Trees that are burned not only have emissions implications but also lose their intrinsic value for the ecosystem. The intrinsic value of native forests is greater than that currently perceived for environmental services. Forests hold an incalculable genetic heritage, most of which is still unknown. Forest plantations, whether for the reconstitution of ecosystems or for economic use, create significant environmental services, as they preserve water flows, reduce or prevent river and lake siltation, improve the micro-climate and allow the preservation of native species of fauna. In Ghana, there is no data or information on forests that are owned by communities that could sustainably be used for the benefit of those communities.

7.6.3 Fuelwood consumption, knowledge and perceptions

Only 13% of the study respondents understood that the burning of firewood and charcoal have negative implications on the forest ecosystem. However, more than half (67%) of the respondents know that the smoke from fish smoking affect ambient air quality as well as health of people living within smoke polluted environment. The data suggest that respondents could easily link the implications of fish smoking activity with their immediate environment, including their health. They were, however, not able to link the implications of using fuelwood to smoke fish with the distant environment like forest where the wood come from. Their knowledge level on distant questions like environment and forest were low compared to those on their health. This result is an important signal for policy in terms of the provision of technologies for improvement as well as interventions for behavioural change. A comprehensive Chinese behavioural trial (Jin et al., 2006) tested the effectiveness of „health education and behavioural activities“ (HEBA) together with improved cook stoves in four rural provinces in China (Gansu, Guizhou, Shaanxi and Inner Mongolia). An extensive baseline monitoring including knowledge, practices, indoor air pollution exposure (PM10, CO and SO₂) and health outcomes were conducted before the intervention. Results suggest that although there were incremental increases in knowledge of indoor air pollution, the HEBA on its own showed no impact on indoor air pollution exposure (PM10, CO and SO₂). The combination of HEBA with improved stoves showed measurable improvements in indoor air quality (by as much as 85%) and efficiency.

Regarding respondents perception about fish smoking business, forty one percent (41%) and forty seven percent (47%) of the women who smoke fish agreed and strongly agreed respectively that fish smoking is a good business. However, the data from economics aspect of the study do not support this perception. Data from Table 7.6 below indicate that

the women on the face value make net loss in the business. The table shows that the mean monthly expenditure on buying fresh fish for processing is three times more than the mean the mean monthly income from the activity. In addition to the expenditure on fish, the women also spend money on fuel wood and transportation which are not even factored into the above equation. It is likely respondents under-reported their income status from the business. This data need further interrogation, presumably using qualitative research approach to explore further in order actually do a proper welfare analysis.

CHAPTER EIGHT

MAIN FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

8.1 Main Findings

Literature reviewed in the study indicate that quite a number of studies have looked at indoor air pollution at the household level and its implication for human health. Biomass fuel consumption at the household level is mainly for cooking and heating. This study looked at vulnerable women who depend on biomass fuel to earn a livelihood. In terms of the length of exposure, the small scale fish smokers spend more hours in a day and they also use more quantities of woodfuel compared to normal household cooking. The main objective of the study was to assess fish smokers' personal exposure to pollutants from biomass smoke and how this exposure relates to their health. The study was also to explore the implications of wood consumption by small scale fish smoking for GHG emissions and the implications for the GHG inventory accounting in Ghana. After analyzing data collected from two fish smoking communities along the coast of Ghana, the findings are summarized as: i) human and environmental exposure ii) health implications and iii) welfare implications.

8.1.1 Human and Environmental Exposure

The level and length of exposure of fish smokers to biomass pollution is a matter of public concern. Dwelling on data collected from the field, it was observed that fish smokers are exposed to high levels of carbon monoxide and particulate matter. Women who smoke fish had higher concentrations of carbon monoxide and particulate matter compared to non-fish smokers and the concentration levels were above international personal exposure permissible levels and they were statistically significant from the non-fish smokers. Data analysis shows that users of biomass fuels' exposure to PM 2.5 concentrations are about

sixty times higher compared to those allowed by international organizations such as WHO. The findings suggest that household air pollution (HAP) is indeed a problem in the study area, and that residents are currently facing health risks from exposure to HAP.

It was also revealed that, the women spend an average of 8 hours per day exposed to smoke and its associated pollutants. The average length of exposure of the women to biomass pollutants is far beyond the average exposure time of women who do normal cooking. On average, women spend 2.5 hours a day for normal household cooking and heating. Again, the eight hour exposure time of fish smokers from this study is not consistent with that of existing literature on the same population. Earlier studies indicate an average of six hours exposure time for women who smoke fish.

There was evidence of GHGs including CO₂, CH₄, N₂O and other short-lived climate pollutants in the form black carbon which have potential of warming the atmosphere in the short-term. Black carbon in this study is synonymous with high amount of smoke that comes from fish smoking activity. The Inter-governmental Panel on Climate Change (IPCC) expresses concerns about the contribution of the short-lived climate forces to global warming, especially, in the short-term. The IPCC had indicated that short-lived climate pollutants contribute about 40% of the short term atmospheric warming.

8.1.2 Health Implications

Flu symptoms, respiratory symptoms, eye symptoms and neurological symptoms were the health indices that respondents self-reported on. From the data, fish smokers and non-fish smokers did not report any significant difference on flu, respiratory and neurological symptoms. However, eye symptom was associated with fish smoking and was more prevalent with older women. Even though there was no significant difference between the treatment and the control groups on flu, respiratory and neurological symptoms, values

recorded in the study indicate high risk of prevalence of these health symptoms among the study population. The high reported flu and neurological symptoms by both the treatment and control groups may be explained by the general poor sanitation conditions witnessed in the study area. The study area visibly lack drainage systems, proper solid waste disposal facilities and toilet facilities. The absence of these facilities are potential risk factors for ill-health of the population.

On the issue of background characteristics, neurological and eye problems were associated with wealth as those on the lower wealth quintile reported higher neurological and eye symptoms. Age is also associated with eye, flu and respiratory symptoms. Again, fish smoking is attractive for older women than younger ones with most of the women having no formal education.

Contrary to the general understanding that improved biomass stoves have well penetrated in the Ghanaian market, evidence by this study shows that penetration of improved stoves is only focusing or targeting household cooking and not small scale biomass dependent economic activities like fish smoking. The study indicates a heavy dependence on traditional ovens for fish smoking. Over 90% of the sampled population use traditional ovens to smoke fish.

Traditional methods for smoking fish pose health threats not only to the women who smoke fish, but also to the entire community members, especially the most vulnerable such as the aged and children. The study observed that “communal pollution” was common as the control group (non-fish smokers) exhibited high concentration levels of $PM_{2.5}$. This communal pollution may be attributed to the settings where the fish smoking takes place in the study area. The setting is mainly traditional and partially enclosed which allows smoke to be easily vented into the community posing exposure risks to non-fish

smokers in general. This situation may explain why even the non-fish smokers showed high concentration levels of PM_{2.5} and CO and it is an important indicator for the kind/type of mitigation or intervention(s) to be provided for the community.

The study also found out that the setting or the environment within which fish smoking is done is significantly associated with reported respiratory and eye symptoms in the study area. Respondents from Moree reported less symptoms compared with respondents from Elmina in all the health indicators measured in the study. The fish smoking settings in Moree is more ventilated than those in Elmina because the ovens in Moree are sited in open areas whereas those in Elmina are more concentrated in an enclosed common fish smoking areas.

Fish smoking relies heavily on firewood which comes from the nearby forests and this was corroborated in the study by the results between the treatment and the control group in terms for wood consumption. However, there is a general disconnect between participants understanding of the use of firewood and its implication on ambient air pollution as well as forest degradation, even though a small proportion demonstrated that connection. The study revealed a high consumption of firewood, supposedly, coming from the nearby communities but participants showed little knowledge in the connection between firewood consumption and environmental degradation and pollution. Data on fuelwood consumption by fish smokers in the study show that over 300 (Gg CO₂e) of greenhouse gases are emitted annually into the atmosphere by this activity with CO₂ constituting ninety three percent of the GHGs from this activity. Even though the connection between woodfuel and climate change was weak in terms of analysis in the study, it was remarkably established that high volumes of hard wood was being burnt on regular basis

by fish smokers that the national greenhouse gas (GHG) inventory system is not currently accounting for.

8.1.3 Welfare Implications

Contrary to the general perception by the respondents that fish smoking is a good business, the data collected suggest otherwise. The data indicate that fish smokers on the face value make a net loss in the business. The cost of doing business is more than three times higher than the income earned from the business. The study did not, however, explore the possible underlying reasons or factors accounting for the net loss. The study did not also ask participants about their continuous stay in business even though they continue to make loss. This is seen as one of the limitations of the study. Most respondents have indicated they inherited the business from the parents and so they see it more as a family heritage instead of profit making entity. That could possibly be one of the underlying factors for their continuous stay in the fish smoking business. The research acknowledges that the above stated reason might not be scientifically enough and recommends further scientific investigation.

It could also be possible that respondents under-reported their income from the business, thinking that they could lose any future financial support and/or aid from the Government or the Assembly, as this has always been the perception of many respondents on income surveys in Ghana. Meanwhile, respondents were told in plain language that, the research was not a government or donor funded one but a student project that seeks to collect data and information mainly for academic purposes. Fish smokers during the study indicated that their livelihoods depend mainly on this business and so thorough research is needed to make a business case or otherwise for fish smoking.

8.2 Conclusions

Fish smoking is considered as an important economic activity for women along the coast of Ghana. The activity is mainly small-scale which uses biomass fuel as energy to process the fish. Using biomass fuel to smoke the fish exposes the women to harmful pollutants that has implications on their health. It was revealed in the study that, on average, the women spend eight hours daily in fish smoking environments with the women doing this business averagely for twenty one years. The method used by the women is still crude with over 86% of the sampled population still using traditional fish smoking ovens.

The first and second objectives of the study sought to assess the personal exposure levels of small scale fish smokers to CO and PM_{2.5} and how this exposure compares with non-fish smokers in the study area.

From the data collected and analysed, the study concludes that women who engage in small scale fish smoking activities in the study area have higher personal exposure risk to CO and PM_{2.5} coming from fuelwood burning. The results show a significant difference between fish smokers and non-fish smokers regarding participants' personal exposure to CO and PM_{2.5}. The length of exposure of fish smokers is more than twice compared to non-fish smokers. Even though the findings suggest higher exposure of those who smoke fish, those who do not engage in fish smoking activity in the study area who were sampled for the study are also at risk.

The third objective of the study was to examine the relationship between exposure to pollutants from burning biomass and health of fish smokers along the coast of Ghana. Health indicators such as flu, respiratory, neurological and eye symptoms were self-reported by respondents. Even though the study recorded high reported incidence of flu, respiratory and neurological symptoms, there were no significant difference between those

who smoke fish and non-fish smokers in the study area. However, data analysed showed significant difference between fish smokers and non-fish smokers on eye symptoms. The absence of any significant difference between fish smokers and non-fish smokers on flu, respiratory and neurological health outcomes suggests that there are other conditions contributing to those health problems rather than smoke from fish smoking. Other environmental factors such as drainage systems, waste management practices, etc. could account for those reported symptoms in the study area.

On objective four which sought to explore the implications of wood consumption by small scale fish smoking for GHG emissions and the implications for the GHG inventory accounting in Ghana, the study concludes that, fish smoking is seen to consume large volumes of fuelwood which could have potential impact on the climate in terms of greenhouse gas emissions. Crude estimation using the IPCC tier one methodology on emissions from biomass burning using weekly quantity of wood consumed by fish smokers in the study area calls for a critical look at this sub-sector as a potential GHG emission source as part of the national GHG accounting. Large quantities of wood, mainly coming from the nearby forests, were recorded to be been consumed weekly by fish smokers. This may not be healthy for the climate and also for the environment.

The fifth and last objective of the study was to highlight how fish smokers perceive the implications of wood burning on their health and the environment. The study concludes that, fish smokers are well aware that smoke from fuelwood and charcoal impacts negatively on their health and the ambient air quality. They are also aware that they use large quantities of woodfuel to smoke fish. However, there was a general disconnect between respondents' understanding of the use of firewood and its implication on their distant environment.

8.3 Main Recommendations

From the findings and conclusions discussed above, the study would like to point out some specific recommendations. The study reveals that fish smoking is the main livelihood for the women in the study area and the mean number of years for fish smoking is 21 years with none of the women sampled using personal protective gadgets. Again, 86% of the fish smokers use traditional ovens within very hazardous working environment. The study as result recommends the following;

- i. **Technology:** there should be a targeted campaign drive for the provision of improved technology in the form of improved ovens to replace the traditional ovens used currently by the fish smokers. This proposal has multiple benefits of improving the health conditions of the people involved, reducing the amount of hard wood associated with fish smoking as well as reducing GHGs emission into the atmosphere.
- ii. **Education and awareness raising:** Fish smoking in Ghana is mainly done by women as none of the sampled respondents for fish smoking was a male. It was also observed that children are involved as helpers. Both groups are exposed to smoke pollution without using any protective gadgets. There should, therefore, be a focused education on health and environmental implications of biomass burning. The programme should have a component on awareness creation that focuses on behavioral change. The recommended education and awareness programme could jointly be designed and implemented by the Ministry of Fisheries and Aquaculture, the Ministry of Health, the Ministry of Gender, Children and Social Protection, the Ministry of Food and Agriculture and the ministry of Energy so as to draw synergies and complementarities to reach out to a wider coverage and to also ensure effectiveness and sustainability.

- iii. **GHG inventory system:** There is a huge data accounting gap in terms of unaccounted for GHG emissions from small-scale biomass dependent economic activities like fish smoking, gari processing, etc. The IPCC GHG inventory under the UNFCCC does not currently consider GHG emissions from domestic activities. However, fish smoking and gari processing in Ghana, for instance are commercial activities even though they are largely done as household domestic activities. Looking at the amount of fuelwood consumed by these small-scale economic activities and the level of emissions involved, it is recommended that Ghana's national GHG inventory system designs the GHG inventory system to disaggregate data from the purely commercial activities from the normal household cooking and heating emissions. This will help to separate household emissions from small-scale industrial GHG emissions.
- iv. **Design and settings:** the study found an association between the design/settings of the fish smoking environment and respiratory as well as eye symptoms. It is therefore recommended that interventions to reduce personal exposure of fish smokers to pollutants from biomass fuel smoke take into consideration ventilation.
- v. **Subsidy:** The Government of Ghana should revisit the policy on subsidy on LPG that was scrapped in 2015. The Government in early 1990s implemented a policy that sought to provide LPG and cylinders to populace at a subsidized rate. The idea was to reduce deforestation rate as many Ghanaians depend on solid wood fuels for cooking and heating. The policy, however, failed to address the targeted objective, hence the government in 2015 fully de-regulated LPG price at the pump. Looking at the non-economic benefits of using LPG as energy for cooking and heating, the study recommends that the subsidy on

LPG be re-introduced but this time should be more targeted to the very vulnerable households and small scale businesses that depend on biomass fuel. The implementation should model the pre-mix fuel system that supports fishermen in the country.

- vi. **Protective gadgets:** the study found a strong association between exposure to smoke from biomass and eye symptoms. Many of the respondents reported of severe eye problems as a result of smoking fish. Ironically, none of the fish smokers interviewed wore any protective gadget for the eye. It is therefore, recommended that the district and municipal assemblies where fish smoking businesses are prevalent enact and enforce bi-laws to ensure that the workers within those harmful environments acquire and use protective gadgets to minimize the negative health effects (especially for the eye) associated with biomass smoke exposure.

8.4 Future Research

The study aimed to investigate whether fish smokers have poorer health conditions compared to non-fish smokers in fish smoking communities in Ghana. The study employed mainly quantitative methodology (household survey and real time measurements) for data collection and analysis. The results did not show significant difference on respiratory and flu symptoms among the fish smokers and the non-fish smokers (i.e. the treatment and the control groups). Further research could use qualitative approach to explore the lived experiences of the two groups.

Current data collected on CO and PM2.5 could serve as baseline data for a longitudinal study for trend analysis of this vulnerable population since there appears to be no longitudinal data on the study population in Ghana currently.

Again, during data collection, it was observed that most of the women do the fish smoking business with children under 10 years around the fish smoking environment. It is recommended that future research looks at the exposure levels of children under 10 years to biomass related pollution.

Finally, future research could look at why people still engage in fish smoking activity despite the seeming economic down turn.

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LIST OF APPENDICES

Appendix A: Exposure Monitoring Data Collection Sheet

HEALTH AND WELFARE IMPACTS OF FISH SMOKING IN GHANA (July/August 2016)

Exposure Monitoring Data Collection Sheet

RIPS, University of Ghana and FUEL Lab University of North Carolina at Chapel Hill
(Studies on Small-Scale Biomass Burning Industries (SSBBI))

IN OFFICE BEFORE DEPLOYMENT:

A. ID (ALL)

#	Question	Response key	Response
A1	Interviewer Name		
A2	Interviewer code		
A3	Date of interview	dd:mm:year	
A4	Household ID		
A5	Female respondent ID		
A6	Name of female respondent		
A7	Type of monitoring	1 = CO only 2 = CO and PEM	
A8	Is household involved in fish smoking?	0 = No (Control) 1 = Yes (Treatment)	

B. Personal Monitoring (ALL)

B1	Personal CO data logger number		
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(PEM ONLY)

B2	Personal PEM number		
B3	Personal PEM Filter number		
B4	Personal PEM Pump number		
B5	Personal PEM Pump flow rate (pre-deployment) (2 lpm)	LPM	

CHECK ALL PUMP SETTINGS

START OF EXPOSURE MONITORING PERIOD IN FIELD

C. Ventilation of fish smoking area (TREATMENT ONLY)

#	Question	Response key	Response
C1	During the past 7 days has the fish smoking process taken place mainly inside or outside?	1 = Inside 2 = Outside	
C2	Is the fish smoking area partially or completely sheltered?	0 = No 1 = Yes	

D. Fish smoking oven (TREATMENT ONLY)

#	Question	Response key
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D1	What type of oven was the most commonly used to smoke fish during the past 7 days? CHOOSE ONE	1= Traditional 2= Improved 9 = Other, specify
D2	What fuel is usually used in this oven? (most common during past 7 days) CHOOSE ONE	1= Charcoal 2= Fuelwood 9= Other, specify
D3	How do you usually light the oven? SELECT ALL THAT APPLY	1= Small sticks/fuel wood 2= Grass/reeds/straw 3= Plastic bag or flip flop 4= Kerosene 5= Matches 6= Neighbors fire 7 = Coconut husks/palm nut fiber 9= Other, specify

E. Personal Monitoring (ALL)

#	Question	Response key	Response
E1	Time started CO monitor	hh:mm	

(PEM ONLY)

E2	Time started PEM	hh:mm	
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 PLEASE TELL RESPONDENT:

- **SHE CAN RESUME NORMAL ACTIVITIES**
- **SHE MUST WEAR THE EQUIPMENT**
- **TO REMOVE MONITOR WHEN BATHING AND KEEP NEARBY**
- **TO REMOVE MONITOR WHEN SLEEPING AND KEEP NEARBY**
- **TO KEEP MONITOR AWAY FROM WATER**

END OF EXPOSURE MONITORING PERIOD IN FIELD.**EQUIPMENT PICK UP IN FIELD:****F. Personal Monitoring (ALL)**

F1	Was the personal exposure monitoring unit taken off since yesterday for any reason other than bathing or sleeping? <i>(Ask respondent)</i>	0 = No 1 = Yes	
F2	Personal CO data logger number		
F3	Time ended CO monitor	hh:mm	

(PEM ONLY)

#	Question	Response key	Response
F4	Minutes indicated remaining on Personal		

	PEM pump		
F5	Personal PEM number		
F6	Personal PEM Filter number		
F7	Personal PEM Pump number		
F8	Time ended Personal PEM	hh:mm	
F9	Personal PEM pump flow rate (post-retrieval)	LPM	

END OF EQUIPMENT PICKUP

IN LAB AFTER EQUIPMENT PICKUP

DOWNLOAD PERSONAL CO MONITOR DATA

PUT PERSONAL PEM FILTER IN CASE

RECORD OTHER NOTES:

APENDIX B: SURVEY QUESTIONNAIRE

SURVEY QUESTIONNAIRE

HEALTH AND WELFARE IMPACTS OF FISH SMOKING IN GHANA

RIPS, University of Ghana & FUEL Lab University of North Carolina at Chapel Hill, (Studies on Small-Scale Biomass Burning Industries (SSBBI))

July/August 2016

A. Identification Information

A1	Name of interviewer/Interviewer ID	Antwi=1 John=2 Desmond=3 Frank=4 Yaw=5 Emma=6 Reuben=7 Paul Fenny=8 Sandra=9 Paul Adzakro=10	
A3	Date of interview	dd:mm:year	
A4	Name of Town/Town ID	1=Elmina 2=Moree	
A7	Household ID		
A8	Household ID (double enter)		
A9	Name of household head (hhd)		
A10	Household head ID	HHDID+01	
A11	Is the household engaged in fish smoking for commercial purposes?	0=No (control) 1=Yes (treatment)	
A12	Is female respondent the same as household head?	0=No 1=Yes	
A12a	Name of female with largest role in fish	<i>Ask only if head and</i>	

	smoking OR woman with greatest economic power in the hhd (for non-fish smoking households)	<i>woman are different</i>	
A13	Female respondent ID	HHDID+01 (if also head) HHDID+02 (if diff than head)	
A14a	Does anyone in the household have a mobile phone?	0=No 1=Yes	
A14b	Mobile phone number for household		
A15	Name of person owning mobile phone		
A16	GPS Latitude (at oven (T); household (C))		
A17	GPS Longitude (at oven (T); household (C))		
A18	Altitude (at oven)		

B. Household Head and Household Composition/Female Respondent Demographics

B1	Age of household head (years)		
B2	Gender of household head	Male=0 Female=1	
B3	Education of household head	None=0 Primary=1 Middle School/JHS=2 Secondary/Vocational/Technical=3 Tertiary=4	
B4	Marital status of household head	Single=1 Married (monogamous)=2 Married (polygamous)=3 Widowed=4 Divorced/separated=5 Cohabitation (not legally married)=6 Other=9	
B5	Was the household head born in Elmina/Moree?	No=0 Yes=1	
B6	Ethnicity/tribe of household head	Fante=1 Other Akan=2 Ewe=3 Ga-Dangme=4 Nzema=5 Guan=6 Other, specify=9	
B7	What is the religion of the household head?	Catholic=1 Protestant (e.g., Methodist,	

		Anglican, Presbyterian)=2 Charismatic/Pentecostal=3 Other Christian=4 Muslim/Islam=5 Traditional=6 Spiritualist=7 No religion=8 Other=9	
B9	Total number of adults older than 65 who eat here		
B10	Total number of children (<15) who eat here		
B10 a	How many school aged children are in the household? (6-15 years)		
B10 b	How many of these children were registered in the most recent school term?		
B10 c	Do any of these children ever missed school for fishing or fish smoking related activities?	No=0 Yes=1	
B8	Total number of adults aged 15 to 65 who eat here		
B11	Years of residence of household head in Elmina/Moree?		
B12	What is the main source of drinking water for the household?	Piped water=1 Water truck/tanker=2 Borehole=3 Protected well=4 Unprotected well=5 Rivers/stream/spring=6 Rainwater=7 Dugout/pond=8 Sachet/bottled water=9 Other, specify=99	
B13	What type of toilet facility do you typically use?	Toilet within my own compound=1 Communal toilet=2 Bush/field/beach=3	
B14	Does the household have electricity?	No=0 Yes=1	
B15	What is the main type of cookstove used by your household?	Three stone fire/tripod=1 Locally produced charcoal stove=2 Improved wood burning stove=3 Improved charcoal stove=4	

		LPG stove=5 Hot plate (electric)=6 Other, specify=9	
B15 a	What is the secondary type of cookstove used by your household?	Three stone fire/tripod=1 Traditional charcoal stove=2 Improved wood burning stove=3 Improved charcoal stove=4 LPG stove=5 Hot plate (electric)=6 No other cookstove=7 Other, specify=9	
B15 b	What is the third type of cookstove used by your household?	Three stone fire/tripod=1 Traditional charcoal stove=2 Improved wood burning stove=3 Improved charcoal stove=4 LPG stove=5 Hot plate (electric)=6 No other cookstove=8 Other, specify=9	
B16	What is the main cooking fuel used by your household?	Fuelwood=1 Charcoal=2 Crop residues=3 LPG=4 Kerosene/Paraffin=5 Electricity=6 Biogas=7 Coconut husk=8 Other, specify=9	
B16 a	What is the main source of lighting used by your household?	Electricity=1 Kerosene/Paraffin=2 Solar=3 Candles/reeds=4 Flashlight/torch =5 Other, specify=9	
B17	How many rooms does this household occupy? (count living, dining, bedrooms, but not bathrooms, toilet and kitchen)	Number	
B18	What is the roof made of?	Thatch/palm fronds/rustic mat=1 Wood=2	

		Metal/iron sheets=3 Tile=4 Slates/asbestos=5 Other, specify=9	
B19	What are the walls made of?	Mud/soil=1 Wood/plywood=2 Metal/iron sheets=3 Mud bricks=4 Fired bricks=5 Cane/palm/trunks=6 Concrete blocks/cement=7 Slates=8 Other, specify=9	
B20	What is the floor made of?	Dirt/sand=1 Cement/Concrete=2 Tiles=3 Burnt bricks=4 Other, specify=9	
Female Respondent (if different than household head)			
B21	Age of female respondent (years)		
B22	Education of female respondent	None=0 Primary=1 JHS/Middle=2 Secondary=3 Tertiary=4	
B23	Relation of female respondent to household head	Spouse=1 Child=2 Daughter in law=3 Grandchild=4 Parent=5 Mother in law=6 Sister=7 Sister in law=8 Aunt=9 Niece=10 Step or foster child=11 Other family member=12 Not related=13 Other=99	
B24	Years of residence of female respondent in Elmina/Moree Town?		
B25	Was the female respondent born in the	No=0	

	Elmina/Moree Town?	Yes=1	
B26	Ethnicity/tribe of the female respondent	Fante=1 Other Akan=2 Ewe=3 Ga-Dangme=4 Nzema=5 Guan=6 Other=9	
B27	What is the religion of the female respondent?	Catholic=1 Protestant (e.g., Methodist, Anglican, Presbyterian)=2 Charismatic/Pentecostal=3 Other Christian=4 Muslim/Islam=5 Traditional=6 Spiritualist=7 No religion=8 Other=9	
B28	Does the female respondent do most of the cooking in the household?	No=0 Yes=1	
B29	Did you grow up in a household where fish smoking was a major economic activity?	No=0 Yes=1	
B30	How many years has the female respondent been engaged in fish smoking? (years) <i>Only ask if a fish smoking household</i>		
B31	Is your fish smoking oven in your home compound? <i>Only ask if a fish smoking household</i>	No=0 Yes=1	

C. Assets (Ask Household Head if available and female respondent)

How many of the following assets does your household currently own and what is the present value of these assets? (for example, if you were to buy in present condition)		Number	Estimated total value (Ghc)
C1	Refrigerator		
C2	Generator		
C3	Motorcycle		
C4	Electric fan		
C5	Working television and/or radio		
C6	Bicycle		
C7	Car/small truck		
C8	Mobile phone		
C9	Furniture, sofa		
C9a	Furniture, wardrobe/cupboard		
C9b	Furniture, bed		
C9c	Furniture, chair/stool/bench		
C9d	Furniture, table		
C10	Mattresses		
C11	Fish smoking oven (traditional) *count number of fuel chambers)		
C12	Fish smoking oven (improved) *count number of fuel chambers)		
C12a	Fish smoking trays		
C13	Hoes/axes and other small farm implements		
C14	Fishing net		
C15	Fishing boat		
C15a	Outboard motor		
C16	Improved fuelwood or charcoal cookstove		
C17a	LPG stove		
C17b	Electric stove/hot plate		
C18	Lantern (paraffin/solar/other)		
C19	Mosquito net		
C19a	Sewing machine		
C20	Other major items (>80 Ghc) <i>about \$20 USD, specify</i>		

D. Home, Land and livestock ownership (Ask Household Head if available and female respondent)

D0	Do you rent or own your house?	1=Rent 2=Own	
D1	Agricultural land owned (acres) (including fallowed land)		
D2	Natural forest owned (acres)		
D4	Other land owned by household (acres)		
D5	Total land owned (including land rented out)? (acres)	Sum of D1-D4	
		Number mature livestock currently owned	Total value of mature livestock in Ghc
D6	Chickens/duck		
D8	Goats/sheep		
D10	Pigs		
D11	Cattle		
D12	Other, specify		

E. Primary/Secondary and Tertiary Economic Activities of Household Head and Female Respondent

Household head (ask female resp. if head not present)			
E1	What is your primary economic activity ?	Fishing=1 Fish smoking=2 Farming/ agriculture=3 Raising livestock=4 Hair dressing=5 Fashion design/tailor=6 Wage employment=7 Salaried employment=8 Business/trade=9 Other, Specify=99	
E2	What months of the year do you engage in this activity?	List all months	Select all that apply
E3	How many years have you been doing this activity? (years)		
E4	When you are most busy with this activity how many hours in a week do you spend on it? (hours)		
E5	Does this activity involve the production or use of woodfuels (i.e. fuelwood or charcoal)? <i>If no, skip to E6</i>	No=0 Yes=1	
E5a	If yes, where do you obtain the woodfuels from?	Collected from other people's forested land=0 Collect from own forested land=1 Collect from community owned forest=2 Collect from state owned forest=3 Purchase from local source=4 Purchase from	

		non-local source=5 Other, specify =9	
E5b	If yes, what quantity of woodfuels do you use on a weekly basis? (kgs)		
E6	What is your secondary economic activity ?	Fishing=1 Fish smoking=2 Farming/ agriculture=3 Raising livestock=4 Hairdressing=5 Fashion design=6 Wage employment=7 Salaried employment=8 Business/trade=9 No secondary economic activity=10 Other, Specify=99	
E7	What months of the year do you engage in this activity?	List all 12 months	Select all that apply
E8	How many years have you been doing this activity?		
E9	When you are most busy with this activity how many hours in a week do you spend on it?		
E10	Does this activity involve the production or use of woodfuels (i.e. fuelwood or charcoal)? <i>If no, skip to E12</i>	No=0 Yes=1	
E11a	If yes, where do you obtain the woodfuels from?	Collected from other people's forested land=0 Collect from own forested land=1 Collect from community owned forest=2 Collect from state owned forest=3 Purchased from	

		local source=4 Purchased from non-local source=5 Other, specify =9	
E11b	If yes, what quantity of woodfuels do you use on a weekly basis? (kgs)		
Female Respondent (if different than household head)			
E12	What is your primary economic activity ?	Fishing=1 Fish smoking=2 Farming/ agriculture=3 Raising livestock=4 Hairdressing=5 Fashion design/tailor=6 Wage employment=7 Salaried employment=8 Business/trade=9 Other, Specify=99	
E13	What months of the year do you engage in this activity?	List all months	Select all that apply
E14	How many years have you been doing this activity?		
E15	When you are most busy with this activity how many hours in a week do you spend on it?		
E16	Does this activity involve the production or use of woodfuels (i.e. fuelwood or charcoal)? <i>If no, skip to E17</i>	No=0 Yes=1	
E16a	If yes, where do you obtain the woodfuels from?	Collect from own forested land=1 Collect from community owned forest=2 Collect from state owned forest=3 Purchased from local source=4	

		Purchased from non-local source=5 Other, specify =9	
E16b	If yes, what quantity of woodfuels do you use on a weekly basis? (kgs)		
E17	What is your secondary economic activity ?	Fishing=1 Fish smoking=2 Farming/ agriculture=3 Raising livestock=4 Hairdressing=5 Fashion design/tailor=6 Wage employment=7 Salaried employment=8 Business/trade=9 No secondary economic activity=10 Other, Specify=99	
E18	What months of the year do you engage in this activity?	List all months	Select all that apply
E19	How many years have you been doing this activity?		
E20	When you are most busy with this activity how many hours in a week do you spend on it?		
E21	Does this activity involve the production or use of woodfuels (i.e. fuelwood or charcoal)? <i>If no, skip to section F</i>	No=0 Yes=1	
E21a	If yes, where do you obtain the woodfuels from?	Collected from other people's forested land=0 Collect from own forested land=1 Collect from community owned forest=2 Collect from state	

		owned forest=3 Purchased from local source=4 Purchased from non-local source=5 Other, specify =9	
E21b	If yes, what quantity of woodfuels do you use on a weekly basis? (kgs)		

F. Cash income Earned (Household head if available and/or female respondent)

Please list all sources of income that your household received

	Item	Ghc	Frequency (circle one)		
F1	Fishing		<i>per week</i>	<i>per month</i>	<i>per year</i>
F2	Fish smoking		<i>per week</i>	<i>per month</i>	<i>per year</i>
F3a	Farming (e.g., cocoa, cassava, etc.)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F3b	Livestock (goat, sheep, pig, rabbit, etc.) and livestock products		<i>per week</i>	<i>per month</i>	<i>per year</i>
F4	Hair dressing		<i>per week</i>	<i>per month</i>	<i>per year</i>
F5	Fashion designing/tailoring		<i>per week</i>	<i>per month</i>	<i>per year</i>
F6	Wage income (worker 1)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F7	Wage income (worker 2)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F8	Wage income (worker 3)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F9	Salary		<i>per week</i>	<i>per month</i>	<i>per year</i>
F10	Cash gifts from friends		<i>per week</i>	<i>per month</i>	<i>per year</i>
F11	Non-cash gifts		<i>per week</i>	<i>per month</i>	<i>per year</i>
F12	Remittances from family		<i>per week</i>	<i>per month</i>	<i>per year</i>
F13	Gross business income (specify type of business if different from options above 1: _____)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F14	Gross business income (specify type of business if different from options above 2: _____)		<i>per week</i>	<i>per month</i>	<i>per year</i>
F15	Pension		<i>per week</i>	<i>per month</i>	<i>per year</i>
F16	Proceeds from land/house rental		<i>per week</i>	<i>per month</i>	<i>per year</i>
F17	Other: specify		<i>per week</i>	<i>per month</i>	<i>per year</i>

G. Household cash expenditures and purchases in the past 12 months

	Item	Ghc	Frequency (circle one)		
G1	Staple foods (e.g. maize, rice, cassava)		<i>per week</i>	<i>per month</i>	<i>per year</i>
G2	Other food items		<i>per week</i>	<i>per month</i>	<i>per year</i>
G3	Non-food staple items (e.g. dish soap, match boxes)		<i>per week</i>	<i>per month</i>	<i>per year</i>
G4	Firewood/charcoal for cooking		<i>per week</i>	<i>per month</i>	<i>per year</i>
G4a	Firewood for fish smoking or other business				
G5	Health/medicines/health insurance		<i>per week</i>	<i>per month</i>	<i>per year</i>
G6	Church/mosque donations		<i>per week</i>	<i>per month</i>	<i>per year</i>
G7	Community contributions		<i>per week</i>	<i>per month</i>	<i>per year</i>
G8	Beer/Liquor		<i>per week</i>	<i>per month</i>	<i>per year</i>
G9	Furniture		<i>per week</i>	<i>per month</i>	<i>per year</i>
G10	Ceremonies (e.g. wedding/funeral)		<i>per week</i>	<i>per month</i>	<i>per year</i>
G11	Clothing		<i>per week</i>	<i>per month</i>	<i>per year</i>
G12	School fees/uniforms		<i>per week</i>	<i>per month</i>	<i>per year</i>
G13	Land renting		<i>per week</i>	<i>per month</i>	<i>per year</i>
G14	Loan repayment		<i>per week</i>	<i>per month</i>	<i>per year</i>
G15	Membership fees (e.g. clubs, savings groups etc.)		<i>per week</i>	<i>per month</i>	<i>per year</i>
G16	Fish for fish smoking and/or other wholesale purchases for a business		<i>per week</i>	<i>per month</i>	<i>per year</i>
G16a	Transportation, personal		<i>per week</i>	<i>per month</i>	<i>per year</i>
G16b	Transportation, business related		<i>per week</i>	<i>per month</i>	<i>per year</i>
G16c	Communications (air time/internet)		<i>per week</i>	<i>per month</i>	<i>per year</i>
G16d	Water		<i>per week</i>	<i>per month</i>	<i>per year</i>
G17	Other: specify		<i>per week</i>	<i>per month</i>	<i>per year</i>

H. Shocks and Crises Experienced by the Household

H1	Has the household experienced any major income shortfalls or unexpectedly large expenditures during the past 12 months? <i>If no, skip to Section I</i>	Serious crop failure=1 Failure to catch enough fish from the sea=2 Failure to get enough fish for processing=3 Serious illness in the family=4 Death of a productive age-group adult (15-65 years)=5 Land loss=6 Major livestock loss/theft/death=7 Other major asset loss/theft/damage (e.g., fishing nets/boats/fire etc.)=8 Lost wage employment=9 None=10 Other, specify=99	Indicate all that apply
H2	If yes, how severe was the crisis?	Mild=0 Moderate=1 Severe=2	
H3	If yes, estimate income loss from shock or crisis during the past 12 months? (Ghc)		
H4	How did you cope with the income loss or shock?	1=Harvest more forest products or fish; 2=Harvest more wild products not from the forest (e.g., bush meat; wild vegetables etc.); 3=Harvest more agricultural products; 4=Spend cash savings; 5=Sell assets (i.e. land, livestock, phones etc.); 6=Do extra casual labor work; 7=Assistance from friends and relatives; 8=Assistance from NGO, community organization, religious organization or similar; 9=Get loan from money lender, credit association, bank etc.; 10=Tried to reduce household spending; 11=Did nothing in particular; 99=Other, specify	

Ask Sections I/J/K only to Household head

Is the household head present for the interview? No/Yes

I. Risk Preferences

I1	I am going to ask you about a hypothetical situation . Please think about what you would do if this situation were to occur. Suppose you suddenly find that a relative has left you Ghc 100. You can choose to receive the Ghc 100 now or an amount at a later date. What would you chose? This is not a real situation and there is no real money.			
	Choice A	Choice B	A=1; B=2	
I1a	Ghc 100 today	Ghc 100 in one month	A=1; B=2	
I1b	Ghc 100 today	Ghc 400 in one month	A=1; B=2	
I1c	Ghc 100 today	Ghc 130 in one month	A=1; B=2	
I1d	Ghc 100 today	Ghc 225 in one month	A=1; B=2	
I1e	Ghc 100 today	Ghc 140 in one month	A=1; B=2	
I1f	Ghc 100 today	Ghc 200 in one month	A=1; B=2	
I2	Now I'm going to ask you about a hypothetical game . In this game you can choose to get Ghc 50 or you can choose a lottery that will give you a 50% chance of winning an even greater amount than Ghc 50 or a 50% change of getting less than Ghc 50. Do you chose Ghc 50 for sure, or do you want to play the lottery? This is not a real situation and there is no real money.			
I2a	50 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
I2b	450 Ghc (50%) OR 0 Ghc (50%)		Ghc 50=1 Lottery=2	
I2c	250 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
I2d	100 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
I2e	170 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
I3	If you need to borrow 50 Ghc in an emergency, how many people could you go to for this money?			
I4	If you need to borrow 500 Ghc in an emergency, how many people could you go to for this money?			
I5	Do you think your life will be better 1 year from now?		0=No 1=Yes 8=I don't know	
I6	Do you think your life will be better 5 years from now?		0=No 1=Yes 8=I don't know	

J. Time use (past 7 days) (Household head)

Please indicate the **number of hours** you have spent on each of the following activities during the past 7 days?

J1	Collecting water	
J2	Collecting firewood or other goods from the wild (e.g. salt, wild fruits, bush meat etc.)	
J3	Cooking	
J4	Taking care of children and/or cleaning	
J5	Fishing	
J6	Fish smoking	
J6a	Fish salting	
J7	Household agriculture and livestock related business	
J8	Household non agriculture and livestock related business	
J9	Employed for a wage, salary or commission or any payment in kind, excluding day labor	
J10	Casual, part-time or day labor outside of the household	

K. Expenditures (past 7 days)

Please indicate the amount of any expenditures you have made over the past 7 days?

K1	Staple foods (e.g. maize, rice, cassava)	
K2	Other food items	
K3	Non-food staple items (e.g. dish soap, match boxes)	
K4	Fuelwood/charcoal for cooking	
K4a	Fuelwood/charcoal for fish smoking or other business	
K5	Health/medicines/health insurance	
K6	Church/mosque donations/offering	
K7	Community contributions	
K8	Beer/Liquor	
K9	Furniture	
K10	Ceremonies (e.g. wedding, funerals)	
K11	Clothing	
K12	School fees/uniforms	
K13	Land/house renting	
K14	Loan repayment	
K15	Membership fees (e.g. clubs, savings groups etc.)	
K15a	Fish for smoking and/or other wholesale purchases for a business	
K15b	Transportation, personal	
K15c	Transportation, business related	
K15d	Water	
K15e	Communications (e.g. mobile phone, internet, airtime)	
K16	Other: specify	

Ask Sections L/M/N/O/P only to female respondent**L. Risk preferences (ask female respondent if not household head)**

L1	I am going to ask you about a hypothetical situation. Please think about what you would do if this situation were to occur. Suppose you suddenly find that a relative has left you Ghc 100. You can chose to receive the Ghc 100 how or an amount at a later date. What would you chose? This is not a real situation and there is no real money.			
	Choice A	Choice B	A=1; B=2	
L1a	Ghc 100 today	Ghc 100 in one month	A=1; B=2	
L1b	Ghc 100 today	Ghc 400 in one month	A=1; B=2	
L1c	Ghc 100 today	Ghc 130 in one month	A=1; B=2	
L1d	Ghc 100 today	Ghc 225 in one month	A=1; B=2	
L1e	Ghc 100 today	Ghc 140 in one month	A=1; B=2	
L1f	Ghc 100 today	Ghc 200 in one month	A=1; B=2	
L2	Now I'm going to ask you about a hypothetical game. In this game you can choose to get Ghc 50 or you can choose a lottery that will give you a 50% chance of winning an even greater amount than Ghc 50 or a 50% change of getting less than Ghc 50. Do you choose Ghc 50 for sure, or do you want to play the lottery?			
L2a	50 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
L2b	450 Ghc (50%) OR 0 Ghc (50%)		Ghc 50=1 Lottery=2	
L2c	250 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
L2d	100 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
L2e	170 Ghc (50%) OR 5 Ghc (50%)		Ghc 50=1 Lottery=2	
L3	Do you think your life will be better 1 year from now?		0=No 1=Yes 8=I don't know	
L4	Do you think your life will be better 5 years from now?		0=No 1=Yes 8=I don't know	
L5	If you need to borrow 50 Ghc in an emergency, how many people could you go to for this money?			
L6	If you need to borrow 500 Ghc in an emergency, how many people could you go to for this money?			

M. Time use (past 7 days) (female respondent if not household head)

Please indicate the **number of hours** you have spent on each of the following activities during the past 7 days?

M1	Collecting water	
M2	Collecting firewood or other goods from the wild (e.g., salt, wild fruits, bush meat etc.)	
M3	Cooking	
M4	Taking care of children or cleaning	
M5	Fishing	
M6	Fish smoking	
M6a	Fish salting	
M7	Household agriculture and livestock related business	
M8	Household non agriculture and livestock related business	
M9	Employed for a wage, salary or commission or any payment in kind, excluding day labor	
M10	Causal, part-time or day labor outside of the household	

N. Expenditures (past 7 days) (female respondent if not the household head)

Please indicate the amount of any expenditures you have made over the past 7 days?

N1	Staple foods (e.g. maize, rice, cassava)	
N2	Other food items	
N3	Non-food staple items (e.g. dish soap, match boxes)	
N4	Fire wood/charcoal for cooking	
N4a	Firewood/charcoal for fish smoking or other business	
N5	Health/medicines/health insurance	
N6	Church/mosque donations/offerings	
N7	Village contributions	
N8	Beer	
N9	Furniture	
N10	Ceremonies (e.g. wedding)	
N11	Clothing	
N12	School fees/uniforms	
N13	Land renting	
N14	Loan repayment	
N15	Membership fees (e.g. clubs, savings groups etc.)	
N15a	Fish for fish smoking and/or other wholesale purchases for a business	
N15b	Transportation, personal	
N15c	Transportation, business related	
N15d	Water	
N15e	Communications (e.g., mobile phone, internet, airtime etc.)	
N16	Other: specify	

O. Bargaining power (female respondent)

State whether you agree or disagree with the following statements and how strong your agreement/disagreement is:			
O1	I have control of the income I earn from my primary and secondary economic activities	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O2	I have control of the household income	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O3a	I have freedom to make important decisions within my household about educating children	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O3b	I have freedom to make important decisions within my household about health care (e.g. purchase health insurance, vaccination, doctor's visits etc.)	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
Q3c	I have freedom to make important decisions within my household having children (e.g., birth control, family planning etc.)	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
Q3d	I have freedom to make important decisions within my household about purchasing major household consumption goods (e.g., TV, fridges, furniture)	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
Q3e	I have freedom to make important decisions within my household about purchasing daily consumption goods (e.g., food, salt, soap etc.)	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O4	I am satisfied with my role in the household over the past 12 months?	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O5	Fish-smoking is a good business in this community	Strongly disagree=1 Disagree=2 Agree=3 Strongly agree=4	
O6	Compared with other women in this community, how well-off are you?	1=Worse off 2=Average 3=Better-off	

O7	Compared with other households in the community, how well-off is your household?	1=Worse off 2=Average 3=Better-off	
O8	Have you ever heard that smoke from cooking with fuelwood and charcoal negatively impacts your health?	0=No 1=Yes	
O8a	Have you ever heard that fish smoking negatively impacts your health?	0=No 1=Yes	
O9	Have you ever heard that smoke from cooking with fuelwood and charcoal has negative impacts on forests?	0=No 1=Yes	
O9a	Have you ever heard that fish smoking has negative impacts on forests?	0=No 1=Yes	
O10	Have you ever heard that smoke from cooking with fuelwood or charcoal negatively impacts local air quality?	0=No 1=Yes	
O10a	Have you ever heard that fish smoking negatively impacts air quality?	0=No 1=Yes	

P. Health of woman leading fish smoking activities/most economically active woman in the household

	Have you experienced:		
	<i>Flu like symptoms....</i>		
P1a	Fatigue in the past 12 months? (BRƐ) <i>If no, skip to P2a</i>	0=No; 1=Yes	
P1b	Fatigue in the past 2 weeks?	0=No; 1=Yes	
P2a	Fever/chill in the past 12 months? (FEVER) <i>If no, skip to P3a</i>	0=No; 1=Yes	
P2b	Fever/chill in the past two weeks?	0=No; 1=Yes	
P3a	Chest infection in the past 12 months? (PAIN IN UPPER RESPIRATORY + FEVER + PHLEGM (MAYBE)) <i>If no, skip to P4a</i>	0=No; 1=Yes	
P3b	Chest infection in the past 2 weeks?	0=No; 1=Yes	
	Have you experienced:		
	<i>Respiratory/COPD symptoms...</i>		
P4a	Shortness of breath when walking up hills in past 12 months? <i>If no, skip to P5a</i>	0=No; 1=Yes	
P4b	Shortness of breath when walking up hills in past 2 weeks?	0=No; 1=Yes	
P5a	Difficulty breathing/chest tightening in past 12 months? <i>If no, skip to P6a</i>	0=No; 1=Yes	
P5b	Difficulty breathing/chest tightening in past 2 weeks?	0=No; 1=Yes	
P6a	Chronic cough in past 12 months? <i>If no, skip to P7a</i>	0=No; 1=Yes	
P6b	Chronic cough in past 2 weeks? (ƐWA)	0=No; 1=Yes	
P7a	Produced phlegm during the night in past 12 months? <i>If no, skip to P8a (AMAMAN)</i>	0=No; 1=Yes	
P7b	Produced phlegm during the night in past 2 weeks?	0=No; 1=Yes	
P7c	Coughed up blood in the past 12 months? <i>If no, skip to P8a</i>	0=No; 1=Yes	
P7d	Coughed up blood in the past 2 weeks?	0=No; 1=Yes	
	Have you experienced:		
	<i>Irritation symptoms.....</i>		
P8a	Skin irritation without a rash in past 12 months? <i>If no, skip to P9a (AHOKEKA A ENSAWA ENGU WO HO)</i>	0=No; 1=Yes	
P8b	Skin irritation without a rash in past 2 weeks?	0=No; 1=Yes	
	Have you experienced:		
	<i>Eye symptoms...</i>		
P9a	Irritated/burning/watering eyes in past 12 months? <i>If no, skip to P10a</i>	0=No; 1=Yes	

P9b	Irritated/burning/watering eyes in past 2 weeks?	0=No; 1=Yes	
P10a	Yellow/green sticky secretion from eyes in past 12 months? <i>If no, skip to P11</i>	0=No; 1=Yes	
P10b	Yellow/green sticky secretion from eyes in past 2 weeks?	0=No; 1=Yes	
P11	How often do problems with your vision affect your ability to perform your usual household activities?	Never=1 Seldom=2 Often=3 Always=4	
	Have you experienced:		
	<i>Neurological symptoms...</i>		
P12a	Headache in past 12 months? (TIPAYE) <i>If no, skip to P13a</i>	0=No; 1=Yes	
P12b	Headache in past 2 weeks?	0=No; 1=Yes	
P13a	Difficulty concentrating in past 12 months? (W“ADWEN TUMI FIRI ADE A WOREYE NO SO) <i>If no, skip to P14a</i>	0=No; 1=Yes	
P13b	Difficulty concentrating in past 2 weeks?	0=No; 1=Yes	
P14a	Forgetfulness in past 12 months? (AWIREFIE) <i>If no, skip to P15a</i>	0=No; 1=Yes	
P14b	Forgetfulness in past 2 weeks?	0=No; 1=Yes	
P15a	Dizziness in past 12 months? (ANISOBIRI) <i>If no, skip to P16a</i>	0=No; 1=Yes	
P15b	Dizziness in past 2 weeks?	0=No; 1=Yes	
	Have you experienced:		
	<i>Other...</i>		
P16a	Non-pregnancy related nausea or vomiting in past 12 months? (WOBOSO FONO WO ANAA WOFE ABRE A WORENNYEM) <i>If no, skip to P17a</i>	0=No; 1=Yes	
P16b	Non-pregnancy related nausea or vomiting in past 2 weeks?	0=No; 1=Yes	
	Have you experienced:		
	<i>Wheezing/asthma symptoms...</i>		
P17a	Have you ever had wheezing or whistling in the chest? <i>If no, skip to P18a</i>	0=No; 1=Yes	
P17b	During the past 12 months have you had wheezing or whistling in the chest? <i>If no, skip to P17d</i>	0=No; 1=Yes	
P17c	During the past 12 months has your sleep been disturbed by wheezing?	0=No; 1=Yes	
P17d	In the past 12 months have you woken up in the morning with chest tightness or feeling pressure on your chest?	0=No; 1=Yes	
	Have you experienced:		

	<i>Other allergic disease symptoms... eczema and rhinitis</i>		
P18a	Have you ever had on your skin an itchy rash that appeared and disappeared for periods that lasted a total of at least 6 months ? (HONAM ANI YAREE ANAA NSAA EKEKA) <i>If no, skip to P19a</i>	0=No; 1=Yes	
P18b	Have you had this itchy rash at any time during the past 12 months? <i>If no, skip to P19a</i>	0=No; 1=Yes	
P18c	Have you had this itchy rash in the past 12 months in any of the following places: fold of your elbow; behind your knee; fold of your ankle; below your buttocks; around your neck, ears or eyes?	0=No; 1=Yes	
P18d	During the past 12 months have you ever had problems with sneezing, mucus, or blocked nose when you DID NOT have a cold or flu? <i>If no, skip to P19a</i>	0=No; 1=Yes	
P18E	In the past 12 months, has this nose problem been accompanied by itchy watery eyes?	0=No; 1=Yes	
	Have you experienced:		
	<i>Burns and scalds...</i>		
P19a	A burn or scald in the past 12 months? (EHYEE) <i>If no, skip to P19e</i>		
P19b	A burn or scald in the past 2 weeks?		
P19c	If yes, how serious was your burn/scald? <i>(ask for most serious burn or scald that occurred any time during the past 12 months)</i>	1=Light (no scar) 2=Moderate (scar smaller than Fanta bottle top) 3=Serious (scar larger than Fanta bottle top)	
P19d	How did you get burned/scalded? <i>(ask for most serious burn or scald that occurred any time during the past 12 months)</i>	1=Fell in cooking fire 2=Burned with hot object while cooking 3=Spilled container with hot liquid while cooking 4=Other cooking related burn 5=Burned/scalded while smoking fish 9=other, specify	
P19e	Other than burns or scalds in the past year, have you ever experienced a severe burn or scald? (larger than a Fanta bottle top with scaring?)	0=No 1=Yes	

	<i>If no, skip to P20a</i>		
P19f	If yes, how did that burn or scald occur?	1=Fell in cooking fire 2=Burned with hot object while cooking 3=Spilled container with hot liquid while cooking 4=Other cooking related burn 5=Burned/scalded while smoking fish 9=other, specify	
	<i>Smoking, alcohol and salt intake...</i>		
P20a	Have you ever smoked cigarettes? <i>If no, skip to P20d</i>	0=No; 1=Yes	
P20b	Do you smoke cigarettes now? <i>If no, skip to P20d</i>	0=No; 1=Yes	
P20c	How many cigarettes do you smoke per day?	Number	
P20d	Do you live with someone who smokes?	0=No; 1=Yes	
P20e	Have you ever drunk alcohol? <i>If no, skip to P20g</i>	0=No; 1=Yes	
P20f	How often do you drink alcohol?	1=Every day 2=2 to 3 times per week 3=Once a week 4=Less than once a week 5=No longer drink	
P20g	Do you generally add salt to your food?	0=No; 1=Yes	
	<i>General health and well-being.....</i>		
P21a	Have you ever been diagnosed with malaria? <i>If no, skip to P22</i>	0=No; 1=Yes	
P21b	If yes, when was your most recent bout of malaria?	Month/Year	
P22	Have you ever been diagnosed with tuberculosis?	0=No; 1=Yes	
P23	Have you ever been diagnosed with bronchitis or emphysema?	0=No; 1=Yes	
P24	Have you ever been diagnosed with high blood pressure?	0=No; 1=Yes	
P24a	Have you ever been diagnosed with diabetes?	0=No; 1=Yes	
P25	Are you generally satisfied with your health?	0=No; 1=Yes	
P26	Are you pregnant?	0=No; 1=Yes; 2=Don't know	
P27	How many children under 5 from your household are generally around when you are fish smoking?	Number	

P27a	How many children under 2 from your household are generally around when you are fish smoking? ²	Number	
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Q. Other Environmental Exposures (in the place where you spend most of your day)

Q1	Do you have an open sewer within 20 meters of the location where you spend most of your day?	0=No 1=Yes	
Q2	Do you have a trash pit within 20 meters of where you spend most of your day?	0=No 1=Yes	
Q3	Do you or anyone else burn trash within 20 meters of where you spend most of your day?	0=No 1=Yes	
Q4	How many fish smoking ovens (that you do not own) are within a 20 meter radius of where you spend most of your day?	Number	
Q5	Do you spend most of your day in an area that is tarmac/paved, or unpaved?	1=Tarmac/paved 2=Unpaved	

Appendix B: Ethical Review Clearance



UNIVERSITY OF GHANA
ETHICS COMMITTEE FOR THE HUMANITIES (ECH)

P. O. Box LG 74, Legon, Accra, Ghana

10th October 2016

My Ref. No.....

Mr. Antwi Boasiako Amoah
Regional Institute for Population Studies
University of Ghana
Legon

Dear Mr. Amoah,

**ECH 005/16-17: BIOMASS BURINING AMONG SMALL-SCALE FISH SMOKERS IN GHANA:
IMPLICATIONS FOR CLIMATE CHANGE AND HEALTH**

This is to advise you that the above reference study has been presented to the Ethics Committee for the Humanities for a full board review and the following actions taken subject to the conditions and explanation provided below:

Expiry Date: 30/08/17
On Agenda for: Initial Submission
Date of Submission: 15/07/16
ECH Action: Approved
Reporting: Bi-Annually



Please accept my congratulations.

Yours Sincerely,

Rev. Prof. J. O. Y. Mante
ECH Chair

CC: Prof. Samuel N. A. Codjoe, Regional Institute for Population Studies

Appendix C: How GHG emissions were calculated from wood consumption

Approach

Greenhouse gas emission have been calculated using tier 1 (simple method) using IPCC default emission factor for CO₂, CH₄ and N₂O emission and net calorific value (NCV). The emission estimates were derived based on the stated average weekly firewood consumption in a typical inefficient traditional woodstove. Level of greenhouse gas emission was estimated as the product of appropriate emission factor for each gas and the weekly firewood consumption. The calculation steps are provided below

1. Unit of weekly quantity of fire wood converted from kilogram (kg) to Gigagramme (Gg) by dividing by a factor of 1,000,000
2. Convert quantity of firewood consumption in Gg to energy unit by multiplying with the IPCC default NCV of wood in TJ
3. Apply the appropriate emission factors (EF) to the wood consumption in energy unit(TJ) to get the emission per week
4. Cumulative value of weekly emission was generated for 48 week (1 year)
5. Total sample size used for the analysis is two hundred and fifty-two (252) fish smokers

Two main scenarios have been developed using the weekly average as well as the lower and upper limit weekly consumptions.

Scenario 1 based on constant average weekly consumption

Table x: Total GHG emissions based on weekly consumption of firewood for fish smoking

Period	Quantity (kg)	Quantity (Gg)	Energy Unit (TJ)	CO ₂ (kg)	CH ₄ (kg)	N ₂ O (kg)	Total emissions (kg CO ₂ e)	Total emissions (Gg CO ₂ e)	Total emissions (Gg CO ₂ e) – cumulative
Week 1	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	29.75998
Week 2	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	59.51996
Week 3	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	89.27994
Week 4	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	119.0399
Week 5	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	148.7999
Week 6	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	178.5599
Week 7	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	208.3199
Week 8	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	238.0798

Week 9	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	267.8398
Week 10	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	297.5998
Week 11	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	327.3598
Week 12	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	357.1198
Week 13	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	386.8797
Week 14	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	416.6397
Week 15	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	446.3997
Week 16	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	476.1597
Week 17	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	505.9197
Week 18	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	535.6796
Week 19	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	565.4396
Week 20	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	595.1996
Week 21	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	624.9596
Week 22	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	654.7196
Week 23	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	684.4795
Week 24	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	714.2395
Week 25	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	743.9995
Week 26	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	773.7595
Week 27	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	803.5195
Week 28	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	833.2794
Week 29	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	863.0394
Week 30	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	892.7994
Week 31	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	922.5594
Week 32	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	952.3194
Week 33	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	982.0794
Week 34	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1011.839
Week 35	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1041.599
Week 36	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1071.359
Week 37	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1101.119
Week 38	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1130.879
Week 39	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1160.639
Week 40	1587.89	0.015878 9	0.24771084	27743.6 1408	74.313 252	0.990 843	29759.980 32	29.759980 32	1190.399
Week	1587.89	0.015878	0.24771084	27743.6	74.313	0.990	29759.980	29.759980	1220.159

41		9		1408	252	843	32	32	
Week 42	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1249.919
Week 43	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1279.679
Week 44	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1309.439
Week 45	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1339.199
Week 46	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1368.959
Week 47	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1398.719
Week 48	1587.89	0.0158789	0.24771084	27743.61408	74.313252	0.990843	29759.98032	29.75998032	1428.479

Conversion factor to energy unit (Net Calorific Value) based on IPCC default value = 15. 6

CO₂ emission factor (kg CO₂/TJ) based on IPCC default value = 112000

CH₄ emission factor (kg CH₄/TJ) based on IPCC default value = 300

N₂O emission factor (kg N₂O/TJ) based on IPCC default value = 4

Scenario 2 based on weekly consumption randomly generated between stated minimum and maximum

Table x: Total GHG emissions based on weekly consumption of firewood for fish smoking

Period	Quantity (kg)	Quantity (Gg)	Energy Unit (TJ)	CO2 (kg)	CH4 (kg)	N2O (kg)	Total emissions (kg CO2e)	Total emissions (Gg CO2e)	Total emissions (Gg CO2e) cumulative
Week 1	20172	0.20172	3.146832	352445.184	944.0496	12.58733	378060.3965	378.0603965	378.0604
Week 2	3996	0.03996	0.623376	698112	187.0128	2.493504	74892.39264	74.89239264	452.9528
Week 3	4385	0.04385	0.68406	7661472	205.218	2.73624	82182.9684	82.1829684	535.1358
Week 4	24715	0.24715	3.85554	43182048	1156.662	15.42216	463204.5756	463.2045756	998.3403
Week 5	10743	0.10743	1.675908	187701696	502.7724	6.703632	201343.5871	201.3435871	1199.684
Week 6	13880	0.1388	2.16528	24251136	649.584	8.66112	260136.7392	260.1367392	1459.821
Week 7	19936	0.19936	3.110016	348321792	933.0048	12.44006	373637.3222	373.6373222	1833.458
Week 8	25143	0.25143	3.922308	439298496	1176.6924	15.68923	471226.0831	471.2260831	2304.684
Week 9	7114	0.07114	1.109784	124295808	332.9352	4.439136	133329.4498	133.3294498	2438.014
Week 10	3161	0.03161	0.493116	55228992	147.9348	1.972464	59242.95624	59.24295624	2497.256
Week 11	13211	0.13211	2.060916	230822592	618.2748	8.243664	247598.4482	247.5984482	2744.855
Week 12	129	0.00129	0.020124	225388	6.0372	0.080496	2417.69736	2.41769736	2747.273
Week 13	24570	0.2457	3.83292	42928704	1149.876	15.33168	460487.0088	460.4870088	3207.76
Week 14	15237	0.15237	2.376972	266220864	713.0916	9.507888	285569.4161	285.5694161	3493.329
Week 15	15255	0.15255	2.37978	26653536	713.934	9.51912	285906.7692	285.9067692	3779.236
Week 16	13054	0.13054	2.036424	228079488	610.9272	8.145696	244655.9794	244.6559794	4023.892
Week 17	24689	0.24689	3.851484	431366208	1155.4452	15.40594	462717.2878	462.7172878	4486.609
Week 18	4206	0.04206	0.656136	73487232	196.8408	2.624544	78828.17904	78.82817904	4565.437
Week 19	12483	0.12483	1.947348	218102976	584.2044	7.789392	233954.3887	233.9543887	4799.392
Week 20	7348	0.07348	1.146288	128384256	343.8864	4.585152	137715.0403	137.7150403	4937.107
Week 21	24201	0.24201	3.775356	422839872	1132.6068	15.10142	453571.2698	453.5712698	5390.678
Week 22	12158	0.12158	1.896648	212424576	568.9944	7.586592	227863.2907	227.8632907	5618.541
Week 23	22948	0.22948	3.579888	400947456	1073.9664	14.31955	430087.7443	430.0877443	6048.629
Week 24	5184	0.05184	0.808704	90574848	242.6112	3.234816	97157.69856	97.15769856	6145.787
Week 25	3435	0.03435	0.53586	6001632	160.758	2.14344	64378.2204	64.3782204	6210.165
Week 26	17285	0.17285	2.69646	30200352	808.938	10.78584	323952.7044	323.9527044	6534.118

Week 27	13575	0.13575	2.1177	237182.4	635.31	8.4708	254420.478	254.420478	6788.538
Week 28	9837	0.09837	1.534572	171872.064	460.3716	6.138288	184363.4801	184.3634801	6972.902
Week 29	6615	0.06615	1.03194	115577.28	309.582	4.12776	123977.2716	123.9772716	7096.879
Week 30	14507	0.14507	2.263092	253466.304	678.9276	9.052368	271887.8729	271.8878729	7368.767
Week 31	24203	0.24203	3.775668	422874.816	1132.7004	15.10267	453608.7535	453.6087535	7822.375
Week 32	10840	0.1084	1.69104	189396.48	507.312	6.76416	203161.5456	203.1615456	8025.537
Week 33	20362	0.20362	3.176472	355764.864	952.9416	12.70589	381621.3461	381.6213461	8407.158
Week 34	6292	0.06292	0.981552	109933.824	294.4656	3.926208	117923.6573	117.9236573	8525.082
Week 35	8352	0.08352	1.302912	145926.144	390.8736	5.211648	156531.8477	156.5318477	8681.614
Week 36	6606	0.06606	1.030536	115420.032	309.1608	4.122144	123808.595	123.808595	8805.422
Week 37	21497	0.21497	3.353532	375595.584	1006.0596	13.41413	402893.3345	402.8933345	9208.316
Week 38	5981	0.05981	0.933036	104500.032	279.9108	3.732144	112094.945	112.094945	9320.411
Week 39	9188	0.09188	1.433328	160532.736	429.9984	5.733312	172200.0259	172.2000259	9492.611
Week 40	5100	0.051	0.7956	89107.2	238.682	3.1824	95583.384	95.583384	9588.194
Week 41	14599	0.14599	2.277444	255073.728	683.2332	9.109776	273612.1222	273.6121222	9861.806
Week 42	20691	0.20691	3.227796	361513.152	968.3388	12.91118	387787.4114	387.7874114	10249.59
Week 43	2130	0.0213	0.33228	37215.36	99.684	1.32912	39920.1192	39.9201192	10289.51
Week 44	1655	0.01655	0.25818	28916.16	77.454	1.03272	31017.7452	31.0177452	10320.53
Week 45	22768	0.22768	3.551808	397802.496	1065.5424	14.20723	426714.2131	426.7142131	10747.25
Week 46	22687	0.22687	3.539172	396387.264	1061.7516	14.15669	425196.1241	425.1961241	11172.44
Week 47	4775	0.04775	0.7449	83428.8	223.478	2.9796	89492.286	89.492286	11261.93
Week 48	25440	0.2544	3.96864	444487.68	1190.592	15.87456	476792.4096	476.7924096	11738.73

Conversion factor to energy unit (Net Calorific Value) based on IPCC default value = 15. 6

CO₂ emission factor (kg CO₂/TJ) based on IPCC default value = 112000

CH₄ emission factor (kg CH₄/TJ) based on IPCC default value = 300

N₂O emission factor (kg N₂O/TJ) based on IPCC default value = 4