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SELF-REPORTED HEALTH STATUS OF FISH SMOKERS AT ABUESI, A FISHING COMMUNITY IN THE WESTERN REGION OF GHANA

BY

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Thesis submitted to the Department of Environmental Science of the School of Biological sciences, Collage of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfillment of the requirements for the award of Master of Philosophy degree in Environmental Science

JANUARY 2018

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:.. Date:..........................

Name: Gifty Mensah Obeng

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

The aim of the study was to assess the reported health problems associated with the burning of biomass fuel for fish smoking. A cross-sectional study was conducted from December 2016 to May 2017 among fish smokers at Abuesi in the Western Region of Ghana. A total of 434 fish smokers were selected to assess their level of knowledge of health effects associated with fish smoking as well as disease symptoms they have encountered as a result of smoking fish. Additionally, 60 smoke houses were monitored for particulate matter (PM2.5) and volatile organic compound concentrations. Measurements were taken at indoor, outdoor and control locations. The highest concentration of (PM2.5) was recorded in the indoor environment. The mean concentration of (PM2.5) between the indoor and control environment was significantly different unlike between the outdoor and control environments. The concentration of Volatile Organic Compounds (VOCs) systematically varied across three locations. The most reported disease symptoms were eye infection and cough. There was a strong positive association between the number of years spent smoking fish and frequency of eye problems reported by the fish smokers. Educational attainment was a significant predictor of the level of knowledge of fish smokers on the health effects associated with fish smoking. There is therefore the need for further studies to explore other energy sources which may have lesser negative effect on human health.

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DEDICATION

To my loving parents, Mr. John Obeng and Mrs. Esther Obeng

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TABLE OF CONTENTS

	Page
DECLARATION	ii
ABSTRACT	iii
ACKNOWLEDGMENTS	iv
DEDICATION	v
TABLE OF CONTENTS	vi
LIST OF TABLES	xi
LIST OF FIGURES	xii
LIST OF ABBREVIATIONS	xiv
CHAPTER ONE: INTRODUCTION	
Background to the Study	2
Statement of the Problem	3
Purpose of the Study	4
Research Objectives	4
Hypotheses	5
Delimitation	6
Significance of the Study	7
Limitations of the Study	8
Definition of Terms	8
Organization of Study	9
CHAPTER TWO: LITERATURE REVIEW	
Introduction	11
The Use of Biomass Fuel and Air Pollution	11
Biomass Fuel, Indoor Air Pollution and Health Outcomes	16

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Capture Fisheries, Smoking and Consumption in Ghana 28

Factors Influencing the Extensive Use of Biomass Fuel 31

Volatile Organic Compound Exposure 34

Biomass Fuel and Particulate Matter Exposure 35

Acute Respiratory Infections 43

Eye infection or Visual impairment/ Sever headache 44

Lung Cancer 44

Asthma 45

Pneumoconiosis 45

Chapter Summary 46

CHAPTER THREE: MATERIALS AND METHODS

Introduction 48

Research Design 48

Study Area 49

Location 49

Climate 49

Topography 49

Population 50

Occupation 50

Fish Smoking Process 50

Social Amenities 52

Community Entry 52

Sampling Procedure 52

Sample Size 53

Data Collection Instrument 53

Digitized by Sam Jonah Library

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Particulate Matter (PM2.5) and Volatile Organic Compound Monitoring 54
Reliability and Validity 56
Informed Consent 56
Study Variables 56
Data Processing and Analysis 57
CHAPTER FOUR: RESULTS
Introduction 59
Demographic Characteristics of the Study Population 59
Health Related Hazards Associated with Fish Smoking in Abuesi 60
Relationship between Number of Years Spent Smoking Fish and the Frequency of Self-Reported Eye Problems 64
Association of Level of Awareness of Respondent and Fish Smoking 65
Knowledge of Fish Smokers on the Human Health Problems Associated with Exposure to Smoke Based on Educational Attainment 66
Association of Fish Smoking and Educational Attainment of Fish Smokers 67
Association of Fish Smoking and Years Spent in Fish Smoking 68
Association of Fish Smoking and Age of Fish Smokers 69
Association of Fish Smoking and Religion of Fish Smokers 69
Association of Fish Smoking and Marital Status of Fish Smokers 70
Association of Fish Smoking and Cough 71
Association of Fish Smoking and Headache 71
Levels of Particulate Matter (PM2.5) and Volatile Organic Compounds in Relation to the Smoking of Fish 72
Correlation Coefficient Analysis 72
Regression Analysis of Pollutants and Environmental Factors Studied 75

Digitized by Sam Jonah Library

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Association between Particulate Matter inside and Relative Humidity Inside 75
Association between Particulate Matter inside and Temperature Inside 76
Association between VOCs inside the Smoke House and Humidity Inside 76
Association between VOCs Inside the Smoke House and Temperature Inside 77
Levels of Particulate matter (PM2.5) 78
Volatile organic compounds 78
Temperature 79
Relative Humidity 79
Temporal Distribution of Particulate Matter (PM2.5) and Volatile Organic Compounds in the Indoor and Outdoor Environments 80
Relative Humidity 80
Particulate Matter 81
Temperature 82
Volatile Organic Compounds 83
CHAPTER FIVE: DISCUSSION
Introduction 85
Characteristics of Women in Fish Processing in Abuesi 85
Energy source used for smoking at Abuesi 86
Reported Health Related Issues Associated with persistent Exposure to Biofuel Combustion 88
Knowledge of Female Fish smokers about Health Consequences of persistence Exposure to Smoke 89

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Fluctuations and Health Implications of Temperature, Humidity, Particulate matter (PM 2.5) and Volatile organic compounds in Smoke Houses 90

Temperature and Humidity 90

Particulate Matter 92

Volatile Organic Compounds in Smoke Houses 95

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary 97

Conclusions 97

Recommendations 99

REFERENCES 100

APPENDIX 118

Questionnaire 118

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LIST OF TABLES

Table		Page
1	Some Health–Damaging Products of Incomplete Combustion (PIC) in Wood Smoke	25
2	Summary Characteristics of Respondents	60
3	Identified Fish Smoking related Health Hazards	62
4	Relationship between Exposure to Smoke and Eye Problems	65
5	Knowledge that High Exposure to Smoke is a Human Risk	67
6	Correlation Matrix of Environmental Variables Studied	74
7	Descriptive Statistics of Variables	80
8	Non-parametric tests of the Distribution of Relative Humidity across the Study Location	81
9	Non-parametric tests of the Distribution of Particulate Matter across the Study Location	82
10	Non-parametric tests of the Distribution of Temperature across the Study Location	83
11	Non-parametric tests of the Distribution of Volatile Organic Compounds across the Study Location	84

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LIST OF FIGURES

Figure		Page
1	Pollutants generated from 1kilogram of wood burn	26
2	Drying of fish	51
3	Smoking of fish	51
4	A diagram showing sampling procedures for particulate matter (PM2.5) and volatile organic compound data sampling	55
5	Association of eye problems and numbers of years spent smoking fish	64
6	Association of fish smoking- and level of awareness of Occupational health hazards	66
7	Association of fish smoking and educational attainment of fish smokers	68
8	Association of fish smoking and years spent in fish smoking	68
9	Association of fish smoking and age of fish smokers	69
10	Association of fish smoking-related health hazards and religion	70
11	Association of fish smoking-related health hazards and marital status	70
12	Association of fish smoking and cough	71
13	Association of fish smoking and headache	72
14	Association between particulate matter inside smoke house and relative humidity inside smoke house	75
15	Association between particulate matter inside and temperature inside	76
16	Influence of VOCs on humidity inside smoke house	77

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17 Influence of VOCs on temperature inside smoke house 77

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LIST OF ABBREVIATIONS

ARI	Acute Respiratory Infections
AER	Air exchange rate
BMF	Biomass Fuel
BaP	Benzo[a]pyrene
CCN	Cloud Condensation Nuclei
CO	Carbon Monoxide
CH4	Methane
CAO	Chronic airway obstruction
DSO	Distribution System Operator
EF	Emission Factor
EFPM	Particle mass
EFPN	Particle Number
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
IAP	Indoor Air Pollution
IARC	International Agency for Research on Cancer
ISAAC	International Study of Asthma and Allergies in Childhood
LHV	Low heating values
NOx	Oxides of Nitrogen
O	Obstructive airways disease
PM	Particulate Matter
PAHs	Polycyclic Aromatic Hydrocarbons
SVOCs	Semi organic compounds
TB	Tuberculosis

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VOCs	Volatile Organic Compounds
WHO	World Health Organization
UNDP	United Nations Development Programme

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CHAPTER ONE

INTRODUCTION

Clean air is considered to be a basic necessity for human health and well-being. Globally, many people obtain their daily domestic energy from the use of solid fuels such as wood, coal and crop residue (Fullerton, Bruce & Gordon, 2008). The extensive use of solid fuels for domestic cooking activities is probably the main source of indoor air pollution worldwide (Kim, Jahan & Kabir, 2011).When biomass fuel is incompletely burnt harmful particles are released such as particulate matter, carbon monoxide and nitrogen dioxide which can cause harm to human health (Bruce, Perez-Padilla & Albalak, 2000; Naeher et al., 2007). These pollutants are tiny in size and can easily cross to the alveolar–capillary barrier and enter into deeper parts of the lungs (Tesfaigzi et al., 2002).

Women and young children are mostly exposed to these high levels of indoor air pollutants because they spend most of the time indoors especially kitchen (Von et al., 2002). Indoor air pollution associated with combustion of solid fuels is a major contributor to respiratory diseases. Indoor air pollution cause between 1.6 and 2 million deaths each year in developing countries (Smith, 2000). Murray and Lopez (1996) indicated that the burning of wood, dried animal compost and other biomass fuel such as twigs and shrubs is the chief cause of acute respiratory infections such as pneumonia which leads to the death of children under 5 years in most developing countries.

Poverty- related risk factors, including water quality, hygiene and household air pollution from the use of solid fuels, account for a large proportion of under-five deaths (Smith, Mehta, & Maeusezahl-Feuz, 2004).

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Among children lower than five years of age, 3 - 5 million deaths have been attributed to acute respiratory infections yearly (Standsfield & Shepard, 1993).

Background to the Study

Almost 3 billion people globally obtain their daily domestic energy needs from the use of biomass fuel such as solid fuels (Rehfuess & Mehta, 2006). The outcome of indoor air pollution resulting from the extensive use of biomass fuel reduces the quality of life of many people in developing countries (United Nations Development Programme &World Energy Commission, 2000).

The case is not different from Ghana since most of the country's energy consumption is derived from combustion of biomass in the form of firewood and charcoal accounting for nearly 60% of both domestic and commercial energy consumption (Odoi-Agyarko, 2009). Many people who live in urban areas frequently consume the majority of charcoal produced in the country while most people in rural areas often use firewood which are all kinds of biomass fuel (International Energy Agency, 2002). The frequent use of solid fuels such as logs, charcoal, animal dung, crop waste and coal for cooking and household warming activities mostly leads to indoor air pollution which is a serious environmental health concern in several nations especially developing ones (Smith, Samet, Romieu & Bruce, 2000). Carbon monoxide, nitrogen dioxide, particulate matter, trace metals, fluorine, polycyclic aromatic hydrocarbons, volatile organic compounds such as benzene and formaldehyde are all kinds of chemicals that are emitted into the atmosphere when biomass fuel is partially burnt. (Ge et al., 2004). The size of these air pollutants are very tiny in nature and therefore could be easily inhaled into the deepest part of the

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body such as heart and lung which could be very detrimental to human health (Hoet, Brüske- Hohlfeld, & Salata, 2004).

Statement of the Problem

Biomass fuel produces different chemical compounds of which most are easily inhaled due their size. These chemicals emitted into the atmosphere through the incomplete burning of biomass fuel leads to the emission of air pollutants like carbon monoxide, nitrogen dioxide, chlorinated dioxins, arsenic, lead, fluorine and vanadium which are all noxious to human health **(**Flintwood–Brace, 2016). Exposure to indoor air pollution resulting from the incomplete burning of biomass fuels has been linked to many diseases in several studies **(**Fullerton et al., 2008).

Pneumonia which cause most deaths in young children particularly those under five is associated with indoor air pollution resulting from the incomplete combustion of solid fuel (Bryce, Boschi-Pinto, Shibuya & WHO, 2005; Dherani et al, 2008). Other diseases that has been linked to smoke from biomass fuel includes acute and chronic respiratory diseases such as asthma. However, little studies has been conducted on the effect of smoke generated in the fish smoking environment where mostly inappropriate stoves are used on human health.

In Abuesi, a major fishing community in the Western Region of Ghana, for instance, fish smoking is the commonest fish preservation method used and most women who are fish smokers use outdated smoking stoves with the use of biomass fuel such as wood as the main source of energy. These women mostly work carrying their young children at their backs and spend several hours smoking. Not enough studies have been conducted the health hazards related to

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air pollution from the burning of biomass fuel for the smoking of fish with the use of outdated smoking stoves and the outcome of this study will help provide information on levels of harmful chemicals emitted into the environment, those mostly affected by these chemicals and the associated human health risk.

Although emerging evidence, across the world, suggests that the use of unprocessed solid fuel for cooking is related to a number of blinding, and painful, eye conditions (Fullerton et al., 2008; West et al., 2013), there has been little research in developing countries such as Ghana to ascertain this link. Besides, there is paucity of research on this environmental risk factor for eye diseases in the context of fish smoking. This study seeks to fill this gap in the literature.

Purpose of the Study

The study sought to assess exposure of fish mongers to biomass fuel smoke and its associated health symptoms (eye symptoms, headache and cough) at Abuesi in the Western Region of Ghana. In this community, the use inappropriate stoves and ill-ventilated smoke houses is common.

Research Objectives

The objectives of the study were to:

1. Investigate the knowledge of fish smokers on human health risks associated with the use of biomass fuel.
2. To determine the proportion of fish smokers reporting health symptoms (e.g. headache, cough and eye symptoms).
3. Assess the levels of particulate matter (PM2.5) emanating from the burning of biomass fuel from the smoking of fish.
4. Assess the levels of volatile organic compounds emanating from the

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burning of biomass fuel from the smoking of fish.

5. Assess the temporal distribution of particulate matter (PM2.5) in the indoor and outdoor environments.
6. Assess the temporal distribution of volatile organic compounds in the indoor and outdoor environment.
7. To determine the effects of long duration exposure to smoke on reported health implications of fish smokers at Abuesi.

Hypotheses

1. **Ho:** Educational attainment does not influence the knowledge of fish smokers on health outcomes associated with the use of biomass fuel for smoking of fish**.**
2. **H1:** Educational attainment influences the knowledge of fish smokers on the health risks associated with the use of biomass fuel for smoking of fish**.**
3. **Ho:** There is no statistically significant difference in the proportion of fish smokers reporting health symptoms (e.g. headache, cough and eye symptoms).
4. **H1:** There is statistically significant difference in the proportion of fish smokers reporting health symptoms (e.g. headache, cough and eye symptoms).
5. **Ho**: There is no statistically significant difference in levels of particulate matter (PM2.5) in the smoke house and the external environment.
6. **H1**: There is statistically significant difference in levels of particulate matter (PM2.5) in the smoke house and the external environment.
7. **Ho**: There is no statistically significant difference in levels of volatile organic compound (VOCs) in the smoke house and the external environment.

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8. **H_1**: There is a statistically significant difference in levels of volatile organic compound (VOCs) in the smoke house and the external environment.
9. **Ho:** There is no statistically significant difference in the temporal distribution of particulate matter (PM2.5) concentrations in the smoke house (indoor) and external environment (outdoor).
10. **H_1:** There is statistically significant difference in the temporal distribution of particulate matter (PM2.5) concentrations in the smoke house (indoor) and external environment (outdoor).
11. **Ho:** There is no statistically significant difference in the temporal distribution concentrations of volatile organic compound (VOCs) in the smoke house (indoor) and external environment (outdoor)
12. **H_1:** There is statistically significant difference in the temporal distribution of volatile organic compounds (VOCs) concentrations in the smoke house (indoor) and external environment (outdoor).
13. **Ho:** There is no significant difference in the effects of long duration exposure to smoke on reported health implications of fish smokers at Abuesi.
14. **H_1:** There is significant difference in the effects of long duration exposure to smoke on reported health implications of fish smokers at Abuesi.

Delimitation

The study seeks to find out the self-reported non-respiratory human health problems associated with exposure to fish smoking-related smoke using inappropriate smoking stoves in Abuesi in the Western Region of Ghana. The study does not consider self – reported problems associated with the burning of biomass fuel for other household heating and cooking activities in the study area.

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Significance of the Study

Exposure to indoor air pollution (IAP) from the combustion of biomass fuels such as wood, charcoal, twigs, shrubs, animal dung, and crop wastes is a major public health concern predominantly affecting poor rural and urban communities in developing countries. According to Kaplan (2010) indoor air pollution is more in rural areas and among poor families who tend to use biomass fuel in traditional stoves.

Despite many studies on burning of biomass fuel for cooking in developing countries, emphasis has hitherto been placed on its relationship to respiratory diseases. Only few studies have been conducted on non-respiratory diseases such as eye problems, whether self-reported or medically diagnosed. There is need to identify and quantify relationships between years of exposure to biomass smoke and reporting of non-respiratory diseases among fish smokers. Given that there are substantial variations in education, poverty and level of knowledge of the health risks associated with biomass smoke even within the same community, there are gaps in existing understanding of heterogeneities in exposure and risk to the sub-groups engaged in fish smoking. For instance, in terms of their knowledge of the health risks associated with the job, how is a fish smoker with no formal education but extensive experience in fish smoking who spends 4 hours in the smoke house different from her counterpart who has tertiary education, limited experience and who spends 6 hours in the smoke house? To address these gaps, this study specifically focused on socio-demographic risk factors or determinants of disease risk. The findings obtained from this study will enrich existing body of literature on biomass combustion in the context of deprived communities in developing countries. It

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will also help support evidenced-based exposure reduction interventions especially in fish smoking communities in Ghana.

Limitations of the Study

This study which seeks to find out the self-reported health status of fish smokers in Abuesi from the use of biomass fuel for the smoking of fish was only limited to the use of current energy sources and how these materials impact on indoor air quality in terms of concentrations of particulate matter and volatile organic compounds. In spite of the efforts and measures put in place to ensure quality delivery, the study was limited to only the two pollutants although several indicators have been reported in other studies. The researcher had no control over the responses to questions provided by participants for the study. Also, the research design is cross sectional and can assess association between study variables. However, it cannot specifically indicate the sequential change.

Definition of Terms

Biomass fuel-Biomass fuel are renewable organic materials mostly derived from plant or animal such as wood and agricultural waste that is usually burnt to obtain energy from for both domestic and commercial purpose.

Particulate matter (PM 2.5) - Particulate matter (PM 2.5) are mixture of tiny particles and small droplets less or equal to 2.5 micrometer in diameter in the air which reduces visibility and cause the air to appear hazy when levels are elevated, many of which are hazardous.

Relative Humidity: Is the ratio of partial pressure of water vapor to the equilibrium vapor pressure of water at a given temperature.

Temperature: The degree of hotness or coldness of the environment.

Volatile organic compounds (VOC's) - Is an organic compound that easily

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becomes vapor or gas. Volatile organic compounds contain elements such as hydrogen, oxygen, fluorine, chlorine, bromine, sulfur or nitrogen.

Indoor air pollution (IAP) - It refers to the physical, chemical and biological characteristics of air in the indoor environment within a home or commercial facility.

Pollutants-A pollutant is a substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource

Smoke house-A structure designed for the purpose of smoking fis

Smoking stove- Smoking stove is heating structure capable of burning wood fuel in for the purpose of smoking.

Organization of Study

The study is made up of six chapters. The first chapter provides the general overview of the study, which include the research background, research problem, the purpose and objectives of the study, significance, scope and limitation of the study. Chapter two focuses on the review of relevant literature on fish smoking and its health implications on women. The chapter also includes information on indoor air pollution, sources which comprises analysis of particulate matter in various fuel wood used for smoking and effects on health of people exposed to it. Chapter Three deals with the methodological approaches used for the research which highlights on the study area, sources of data and study population, sampling techniques used, sample size, data collection instrument, data processing and mode of analysis and ethical considerations. In chapter Four, the findings of the research were presented and this is followed with a comprehensive discussion of how the current results relates, confirms or discredit previous studies. Finally, chapter five comprises

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the summary of findings, conclude the study based on objectives set for the research. The chapter ends by providing recommendations that could be used by policy makers and other decision-making bodies as well as gabs identified in this field of study.

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CHAPTER TWO

LITERATURE REVIEW

Introduction

There are no more than three (3) studies in the scientific literature on the health symptoms associated with exposure of fish mongers to biomass fuel smoke and this review will focus on studies on indoor biomass smoke exposure and health. This chapter situates the thesis in the existing literature on human health problems associated with the use of biomass fuel for fish smoking. Specifically, the literature review considers the assessment in the areas of air pollution, fish smoking, and factors for the extensive use of biomass fuel and health implication of biomass fuel.

The Use of Biomass Fuel and Air Pollution

Energy is needed to sustain basic human needs such as cooking, home heating activities, lighting and temperature regulation. Several people in contemporary towns use varieties of energy to satisfy their domestic and commercial energy needs and these range from the use of liquefied petroleum gas to solar power but often biomass fuel is mostly used. Duflo, Greenstone and Hanna (2008) reported that, the usage of biomass fuels as source of energy has continuously been in existence since 1975.

Biomass (wood, charcoal, animal dung and agriculture residues) is the main source of fuels used by poor households in developing countries who can hardly afford other fuel types (kerosene, liquefied petroleum gas, electricity) (Fullerton et al., 2009). About 2.5 to 3 billion people and about 90% of rural families in developing countries rely on biomass fuels in traditional ways for household energy necessities (World Resources Institute, United Nations

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Environmental Protection, United Nations Development Plannig & World Bank 1998). Solid fuels usage occurs mostly in emerging countries of the world where households prefer the use of wood and crop residues for cooking and heating (Balakrishnan et al., 2004). According to WHO (2005), countries like India, Nepal, Pakistan and Sri Lanka use biomass as fuel (72%, 88% and 67% respectively) for daily household cooking. It is also estimated that nearly 3 billion people depend on solid fuels (biomass and coal) for cooking and heating and this number is expected to grow until at least 2030 (Kim, Jahan & Kabir, 2011)

The partial burning of biomass fuel results in the emission of harmful particles such as particulate matter, carbon monoxide and nitrogen dioxide which are detrimental to human health (Bruce, Perez-Padilla & Albalak, 2000; Naeher et al., 2007). General evidence suggests that women are mostly exposed to these high levels of indoor air pollution because they spend most of the time cooking indoors and also young children because they often remain near cooking areas with their mothers (Von et al, ,2002).

The World Health Organization (WHO) identifies a number of emissions of biomass combustion that affect human health, and places them into a number of classes: particulate matter, polycyclic aromatic hydrocarbons (PAH), Carbon monoxide (CO), aldehydes, organic acids, semi-volatile and volatile organic compounds, nitrogen and sulphur-based compounds, ozone and photochemical oxidants, inorganic fraction of particles, and free radicals.

Polycyclic aromatic hydrocarbons (PAHs) are known as carcinogenic particles contributing to huge effects on human health, especially in the development of cancer in the human body (Smith, 2013). The mechanisms of

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PAH formation during burning of organic matter is not fully understood, particularly the basics of formation of PAH that happens when the radicals produced by burning at high temperatures recombine to become PAH at lower temperatures (Sumpter & Chandramohan, 2013). PAHs including acenaphtene, dibenz[a.h]anthracene, fluoranthene, naphthalene, phenanthrene, and pyrene have been identified as having serious effects on human health (Kurmi, Lam & Ayres, 2012). Benzo[a]pyrene is one of the PAHs contributing to cancer development in human cells. PAH compounds were found in wood burning (Diette et al., 2012). Zhang and Smith (2007) detected more than 30 PAHs emitted by burning of different kinds of wood. Obstructive lung disease has also been associated with exposure to burning biomass fuel in the indoor environment.

Several of these PAHs were identified as mutagenic and having genotoxic potential, such as benzo[a]anthracene, benzo[a]pyrene, and cyclopenta[c,d]pyrene (Clark et al; 2013). Diette et al. (2012) reported that fluorene, phenanthrene, anthracene, fluoranthene, and pyrene contributed to more than 70 % of the mass of PAHs for birch wood burning. Another study measuring PAH emissions of wood burning found PAH and genotoxic PAH levels of 11,508 μg/kg and 953 μg/kg respectively (Clark et al., 2013). Alsoa study found 110,200 μg/kg for the total PAHs and 13,400 μg/kg for genotoxic PAHs (Kurmi et al., 2012). Characteristics of PAH emission from biomass burning were investigated as a factor of type of wood and combustion appliances (Li et al., 2011), and moisture (Shen et al., 2013). The results showed that these factors influenced PAH emissions from biomass burning.

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Carbon monoxide (CO) is a colourless and odourless toxic gas produced by the incomplete burning of biomass, such as wood burning (Smith et al., 2011) and agricultural and grassland burnings (Li et al., 2011). Carbon monoxide is a major compound produced by biomass burning, with emission factors of about 130 g/kg wood burned (Naeher et al., 2007). Po and colleagues reported that carbon monoxide emission factors from peat combustion was 37 g/kg (Po, Fitz, Gerald & Carlsten, 2011). Burning of cereal emitted carbon monoxide with an emission factor of 35 g/kg per kilogram (Sumpter & Chandramohan, 2013). Carbon monoxide originating from biomass burning was reported to contribute 32 % of the total of carbon monoxide produced from other sources (Kurmi et al., 2012).

Aldehydes are chemical compounds also recognized as toxic gases that are extremely irritating and cause respiratory problems. A number of aldehydes were found as products of wood burning, including formaldehydes, acetaldehyde, crotonaldehyde, benzaldehyde, isovaleraldehyde, and tolualdehydes (Smith et al., 2013). Schauer, Kleeman, and Simoneit (2001) reported emission factors for aldehydes resulting from wood burning of 4.1 g/kg for pine, 2.1 g/kg for oak, and 2.7 g/kg for eucalyptus. The major aldehydes found in this case were acetaldehyde and formaldehyde. Pine produced more acetaldehyde and formaldehyde than oak and eucalyptus. Organic Acids are produced by biomass burning. The organic acid (3, 4, 5)-trimethosybenzoic (TMBA) was found in emissions from the burning of birch wood (Bonjour et al, 2013) and oak wood (Kim et al., 2011), with emission factors of 26 mg/kg and 23 mg/kg respectively. Other types of organic acids were also emitted by the burning of oak and eucalyptus.

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Semi-volatile and volatile organic compounds (SVOCs and VOCs) were found in biomass burning emissions. Bonjour et al. (2013), measured a number of VOC emissions from birch wood burning, including toluene, benzene, and acetone; with emission factors of 740 mg/kg, 1500 mg/kg, and 366 mg/kg respectively. Schauer, Kleeman, and Simoneit (2001) measured the emission factors of VOCs for several types of wood burning. Benzene and toluene were reported with emission factors of 383 mg/kg and 158 mg/kg respectively. Acetone was found with a variety of emission factors depending on the type of wood: 462 mg/kg for oak, 749 mg/kg for pine, and 79 mg/kg for eucalyptus (Schauer, Kleeman & Simoneit, 2001). Another study of VOCs from wood burning was conducted by Laumbach and Kipen (2012) using different combustion appliance. The study reported that the emission factors of ketones, benzene and toluene released from hard wood were greater than those measured for soft wood (Laumbach & Kipen 2012). Monitoring of biomass burning gases in South-east Asia and India found VOCs such as methanol, acetone, acetonitrile, isopere and methyl vinyl ketone (MVK), and methacrolein (MACR) in significantly high quantities (Li et al., 2011).

Biomass burning has been recognized as producing nitrogen and sulphur-based compounds (Ezzati & Kammen, 2001; Smith, K. 2013; Fullerton et al. 2008; Laumbach et al., 2012; Granier et al., 2011). Ammonia gas is one of the compounds found in several kinds of biomass burning. Ammonia gas is known to have a relatively short lifetime in the atmosphere of a few hours to a few days (Zhou et al; 2011). In contrast, ammonium ions as an aerosol categorized in $PM_{2.5}$ have a lifetime in the order of 1 – 15 days (Ezzati & Kammen, 2001). Inorganic elements such as Cu, Fe, Pb, Mn, Zn, Al, Mg, Si,

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Ca, Ti, Mn, Ni, Po, Cd, Na, Cl, S, K and V were commonly found from biomass burning (Ezzati & Kammen, 2001). Granier and colleagues measured inorganic elements from wood burning and found most of these elements in the diameter range of coarse particles and fine particles (Granier et al., 2011). A study of wood burning was conducted and showed that the emission factors of inorganic compounds depended on the kind of wood burned. It was reported that most of the inorganic particles had diameters less than 2.5 μm (Fullerton et al., 2008).

In summary, it could be observed that significant amounts of emissions are associated with biomass burning into the atmosphere every year. The emissions have been recognized as a major contributor of particulate matter and gases to the atmosphere. Most of the emissions have been known to have serious effects on the environment and human health.

Biomass Fuel, Indoor Air Pollution and Health Outcomes

Approximately half the world's population and up to 90% of rural households in developing countries still rely on unprocessed biomass fuels in the form of wood, dung and crop residues (Li et al., 2011). These are typically burnt indoors in open fires or poorly functioning stoves. As a result, there are high levels of air pollution, to which women, especially those responsible for cooking, and their young children, are most heavily exposed.

Incomplete combustion of biomass is the main source of indoor air pollution worldwide and in most developing countries; it is burned in the open which produces a lot of smoke (Akunne, Louis, Sanon & Sauerborn, 2006). Biomass smoke contains a wide spectrum of potentially health damaging pollutants that include coarse, fine, and ultrafine particles, carbon monoxide (CO), oxide of nitrogen and sulphur, transition metals, polycyclic aromatic

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hydrocarbons, volatile organic compounds and bio-aerosols (Fullerton et al. 2008; Laumbach & Kipen, 2012).

Recent studies (McCracken et al., 2013; Smith et al., 2013) in rural households had shown that indoor air pollution is due to combustion of biomass fuels. However, in various developing countries wood stove emission is the main source of kitchen-related indoor air pollution in many poor households (Huboyo, Tohno & Lestari, 2014). Biomass is the only source which produces a lot of pollutants that are harmful for human health and also have effects on climate change (McCracken et al., 2013). During burning of biomass many gaseous pollutants such as CO, CO2 and O3 including humidity and temperature are produced (Akunne et al., 2006). These pollutants may alter the properties of the atmosphere since the particles can absorb and reflect solar radiation (Huboyo et al., 2014). Studies on indoor air pollution is a well-established and interdisciplinary approach to measure the effect of indoor air pollution on populations and sub-groups that are exposed to various sources of air pollutants. Of particular importance to this chapter is how biomass fuel especially in households contributes to indoor air pollution.

In a study by Behera and Yadav (1991), it was suggested that the domestic cooking fuel was producing many respiratory symptoms. From the 3,701 women, 3,608 were non-smokers but theyused different types of fuel for cooking such as biomass, Liquefied Petroleum Gas, kerosene, and mixed fuels. Of the lot, 13% had respiratory infections. Women who were smokers and exposed to cooking fuels experienced respiratory symptoms more often than their counterparts who were non-smokers (33.3 percent vs. 13 percent).

Moreover, Colbeck, Nasir and Ali, (2010) conducted a study on the

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relationship between urban and rural environmental conditions. They found out that 58% of urban and 94% of rural households were using biomass fuel in the Pakistan. The study also further investigated variations in indoor/outdoor concentrations of particulate matter and found a high level of it in three different micro-environments in Pakistan. The study concluded that there was high level of concentration of particulate matter in the kitchen because of the use of biomass fuel for cooking than the living area. Due to the fact that women had to spend most time in the kitchen, they faced greatest exposure due to these indoor and particulate pollutants. The foregoing brought about the need for countrywide awareness and advocacy campaigns to shift behaviour towards more sustainable fuel use.

Khushk, Fatmi, White and Kadir (2005) compared household using improved stove and the population using traditional stove in two villages of the district of Thatta and Hyderabad Sindh in Pakistan. In a sample of 114 women who used traditional stove and 45 women who used improved smoke-free stove majority of women said there was less smoke associated with the smoke-free stove and found good impact on their health. It was also found that dry cough (AOR=0.61; 95% CI 0.26-1.41), sneezing (AOR=0.54; CI 0.22-1.30) and tears while cooking (TWC) (AOR=0.51; 95% CI 0.21-1.21) were 95% less reported in the women who used smoke-free stove than the women who used traditional smoke stove but the results were not statistically significant possibly due to the small sample. The level of CO was 15.4±3.4 ppm in smoke-free stove and 28.5±5.7 ppm in the traditional stove. The result showed a favourable trend for the smoke-free stove. In order to increase the indoor air quality in developing countries, stoves for burning of biomass should be constructed in a way that the

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emission of fuel gases is low. It would lead to a reduction in the adverse health risk.

Furthermore, Mehta and Shahpar (2004) conducted a study in South and South- East Asia, Africa, and America to ascertain the effect of using solid cooking fuels on health. Three circumstances were considered namely offering part of the population with access to cleaner fuels, providing access to improved stoves, and providing part of the population with approach to cleaner fuels and part of the population with improved stoves. Two major health effects of indoor air pollution were found, namely severe lower respiratory infections in young children under five years of age and chronic disruptive lung disease in adults over twenty.

While providing approach to cleaner fuels has a larger health impact on the population than improved stoves, there is much health benefit associated with improved stove use. Expanded stoves were also much more price than cleanser fuels, oil, or paraffin, was seen as being more cost- active than watery gas , since fuel is cheaper than liquefied petroleum gas. It was suggested that kerosene use, comprising harming, blasts and possible poisonous outcomes, should be carefully considered before mentioning its prevalent use over liquefied petroleum gas. Moreover, investigation deals spread support for the elevation of improved stoves, as well as other locally proper means to decrease disclosures within solid fuel used in households, until everyone can be given access to cleaner fuels.

In a similar study, Qasim, Usman, Anees and Bashir (2013) conducted their survey in Pakistan and concluded that indoor pollution is detrimental to human health. The Health outcomes related with indoor biomass burning

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particularly in rural areas were Acute Respiratory Infections in children, Lung Cancer, Tuberculosis, poor pregnancy outcomes. They relied on the premise that children are more vulnerable to health problems by indoor air pollutants as compared to the youth. The inhabitants who depended on biomass fuel in Pakistan were 94% in the countryside areas and 60% in the city areas.

Also, some common infections and diseases were evaluated in the dwelling of Sabour village. It was observed that 50.3% family members had Chronic Obstructive Pulmonary disease, 12.7% family members had Respiratory Infection, 9.6% had asthma and 6.4% respondent's family members of respondents had lungs cancer which is was due to the extensive use of biomass fuel in the aforementioned community. Majority of women in the village depended on biomass fuel because of poverty, lack of knowledge level, unavailability of natural gas and easy availability of biomass fuel.

Odoi-Agyarko (2009) conducted a study in Bongo Ghana, the outcome of the study was that women of Bongo mostly relied on the use of biomass fuel as the main source of energy for preparing meal for their family. The choice of using charcoal for cooking which was the most common type was not only because of low income level of households but other socio-cultural factors like time of cooking and type of meal prepared was a factor.

Also it was found out that, majority of the study respondents were aware that smoke from cooking and heating with biomass fuel was detrimental to their health but had no idea regarding the causes of indoor air pollution. Self -reported respiratory infections like severe cough, chest cold and breathlessness and also symptoms like eye tearing, growth on the eye and severe headache was pointed out by the study respondent which was associated to the use of biomass fuel for

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household cooking that is men, women and children with the most affected being women.

In the same vain, Edelstein et al. (2008) conducted their study in the Ethiopia. This study explained women awareness about health problems related to indoor air pollution caused by the use of biomass fuel for the cooking. This study was conducted with the intention of giving education to the women to change their cooking practices and its impact on the health and willing choice of the women. Ethiopian society is characterized by extremes of household income and exposure to indoor air pollution. There were 80% population living in the rural areas and using biomass fuel for cooking. Women are often found cooking in non-ventilated areas and have poor living conditions. There was no access to clean water no sewage system and no electricity and household members live, cook and sleep at the same place.

The middle class family had good condition than the poor family in that they had access to clean water, electricity, good sewage condition and comfortable living house. They had also good income so they had the ability to get better fuel for the cooking. It was realized that if the rural women had knowledge about biomass smoke and its negative impact on their health and their children health, it would help drop 20% in the rural population, the most vulnerable group, in which biomass smoke is not seen by the majority as a cause for concern. They had less awareness about the health although the women interviewed did consider some fuels as cleaner than others.

With regards to Mariana and Sims, (2002) the research was conducted at Bolivia. The Study was about indoor air pollution and human health. The data was collected through questionnaire and household survey. The survey was

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carried in two days, 19th and 20th of August 2002 in 448 families. Most of the residential were distributed in both sides of the main road of access. The questionnaires were distributed randomly and data was analyzed by SPSS. In the process of gathering the data, it was observed that sometimes the women only start to answer questions after their husband's participation. 70 % of questionnaires were filled by women, 10% husband and wife, 8% daughter, 12% by husbands. Questions were asked about the kitchen environment, then about the climate and source of income etc. Ayopaya and Trinitarians were the communities where the survey was conducted.

These communities belonged to Chimore, a small rural town located in a tropical lowland region of Cochabamba, Bolivia with a total of 8,555 inhabitants. The climate in Chimore was hot and humid, and the year is separated by dry and a wet season. In 52% of the residents, the kitchens were located inside the houses in the ground floor. The rest, 36%, were independent structures separated from the house. Relating the effects with the main fuel used to cook, it was possible to notice that between the wood users, stomach, lung and eyes affections were common. The users of gas only pointed out temperature. The investments in the kitchen were out of women control because of depending factor on family income and husband decision. The women though responsible for the activities at the kitchen, management of the kitchen and responsibility of fuel due to economic condition were the responsibilities of men. There were no reactions to the negative effects of the smoke. The women were somehow willing to do some changes in their kitchen; but however, did not express a need to change the fuel.

A study was conducted in Ghana by Flintwood–Brace (2016) and it was

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find out that the use of biomass fuel for smoking fish was closely associated to chronic cough, phlegm production and wheezing in women who have being smoking fish for long. Most of the respondents used in the study were aware that them being exposed to smoke is very detrimental to health, have worked for more than 3 years and spend more than 3 hours a day in the smoke house.

To Zafar, Ambreen, Kadir and Nalini (2010), indoor air pollution was the major concern of health in both developed and developing countries. But the condition was worse in the developing countries. Biomass fuel was obtained from plant and animal waste material which was burned incompletely by humans mostly for the purpose of cooking. It included wood, coal, agricultural residues and dung. They seconded the estimation that almost 3 billion population of the world depended on the biomass fuel. Out of this, 2.4 were using coal and mostly used in China. There were regional variation in the use of biomass fuel with only 20% biomass fuel used in the Europe and majority 80% were used in central Asia, sub Saharan Africa and south Asia.

It must however be noted that social and economic development are necessary requirement for the access of modern energy. Majority population of the world had not yet access to the modern energy. This is largely because of lack of availability of energy and due to low economic status. Incompletely burning of biomass fuel is the cause of many diseases. The pollutants emitted when biomass fuel is burned leads to the emission of harmful particulates which leads to high risk of pneumonia, chronic respiratory diseases, lung cancer and skin infections.

Another factor worth discussing in the context of indoor pollution and fish smoking is that proper stoves and good fuel burning practices, fuel wood

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and charcoal as well as other biomass can be burned cleanly, producing mostly carbon dioxide (CO_2) and water (Akunne et al., 2006). Such conditions are difficult to achieve in poor rural and urban areas where small-scale inexpensive wood-burning stoves are used. However, wood fuel which is not properly burned to carbon dioxide is diverted into products of incomplete combustion (PIC) posing health hazards. Table 1 below lists a few health-damaging products of incomplete combustion (PIC) in wood smoke. Leading the list of PIC in terms of total mass and number of carbon atoms is carbon monoxide (CO), an invisible odourless but nevertheless toxic gas with a number of potential short-term and long-term impacts on health. Following are dozens of simple and complex hydrocarbons and organic compounds, some in gaseous and some in solid form. In addition, a portion of the PIC is released as elemental carbon, or "soot" in the form of small particles (PM). The quantity of each pollutant released is dependent on combustion conditions such as energy density, combustion temperature and air flow, and pollutant emission rates which vary with time and stove geometry (Qasim et al., 2013).

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Table 1: Some Health–Damaging Products of Incomplete Combustion (PIC) in Wood Smoke

Chemical	Emission Factor (g/kg)	Chemical	Emission Factor(g/Kg)
Carbon Monoxide	80 - 370	Methyl chloride	0.01 – 0.04
Methane	14 – 25	Naphthalenes	0.24 – 1.6
VOCs (C2-C7)	7 – 27	Substituted Naphthalenes	0.3 – 2.1
Aldehydes	0.6 – 5.4	Oxygenated Monoacromatics	1 – 7
Substituted Furans	0.15 – 1.7	Oxygenated PAHs	0.15 – 1
Benzene	0.6 – 4.0	Polycyclic Aromatic Hydrocarbons	7×10-3 –4.3×10-3
Alkyl Benzenes	1 – 6	Elemental Carbon	0.3 – 5
Toluene	0.15 – 1.0	Particulate Organic Carbon	2 – 20
Acetic Acid	1.8 – 2.4	Chlorinated dioxins	1×10-5 – 4×10 -5
Formic Acid	0.06 -0.08	Particulate Acidity	7×10-3 – 7×10 -2
Nitrogen Oxides (NO, NO2)		0.2 -0.9	

Source: United States Environmental Protection Agency (USEPA) cited in (Zhou et al, 2011).

Furthermore, ventilation characteristics, unique to each dwelling, also add temporal and spatial variation to pollutants, and as such, the level of exposure to occupants in the dwellings is varied and often unpredictable. Past and current literature illustrates this point: While mean averages of particulate matter (PM) are generally higher for solid coal or biomass fuels when compared

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to cleaner fuels, there is still a high degree of variance and overlap in the distribution of values across fuel groups (Smith et al., 2011). Studies have even found that although paraffin is less polluting than biomass fuels, women using paraffin had similar exposure to respirable particles as women using wood for cooking (Zafar et al 2010; Zhou et al., 2011).

Consequently, levels of IAP (indoor air pollutant) from fuel burning, exposure levels and potential health risks to individuals can vary greatly amongst dwellings. It is instructive to see what a kilogram of wood will generate. On a typical three stone wood-fired stove, about 18% of the energy goes into the pot, 8% into the smoke and 74% is waste heat (Banerjee, Mondal, Das, & Ray, 2012). But it is the pollutants that are of more concern. A kilogram of burning wood can produce significantly harmful levels of gases, particles and dangerous compounds. Figure 1 shows the Pollutants generated from burning one kilogram of wood are well beyond World Health Organization guidelines.

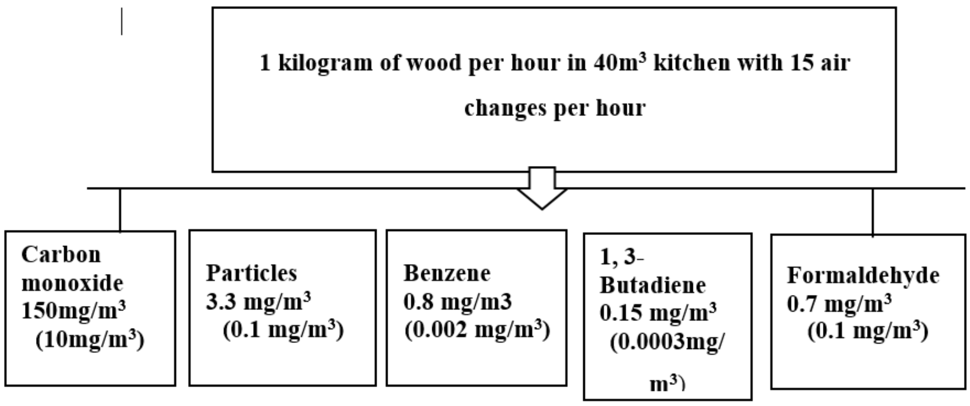

Figure 1: Pollutants generated from 1kilogram of wood burn

Source: Smith et al, 2011 cited in UNDP 2000.

Although by no means representing the entire panoply of chemicals, CO and small particles are considered as reasonable indicators of the relative health risk from combustion smokes that do not contain toxic chemicals such as fluorine and lead (as is found in some types of coal, for example) (Smith et al.,

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2011). This study has therefore chosen to examine the levels of particulate matter (PM2.5) and volatile organic matter that exist in dwellings, based upon emissions released from the combustion of household fuels currently in use in Abuesi for fish smoking in Ghana.

From the various studies above, it could be observed that biomass fuel and indoor air pollution pose a lot of risk to many people especially to sensitive people thus women and children. The various observations made through the studies reflect fish smoking in Abuesi in the Western of Ghana. Indoor kitchen pollution are caused by the burning the traditional biomass fuel included crops residues, wood and dung in inappropriate stoves.

The health effects of particles deposited in the airways depend on the defense mechanisms of the lung, such as aerodynamic filtration, and in sit detoxification. Most studies on the health effects of biomass combustion have been observational in nature and have relied on proxy measures of exposure (such as reported hours spent near the stove, years of cooking experience, or child being carried by mother while cooking), the reliability of evidence from studies utterly carried out in developing countries, together with loyal evidence provided by outdoor air pollution and environmental tobacco smoke studies, indicates that there is likely to be a strong association between indoor smoke exposure and acute respiratory infections in children and chronic bronchitis in women. The evidence for other health outcomes including asthma, tuberculosis, and cataracts is in need of further amplification from studies that have better indicators for exposure and control for confounders. Associations with adverse pregnancy outcomes (including low birth weight and stillbirth) and ischemic heart disease are biologically reasonable, as they have been associated with

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outdoor air pollution smoking (passive and active), but have not been satisfactorily explored for exposures from of solid household fuels.

The main diseases according to the literature were asthma, respiratory tract infections, chronic pulmonary diseases, and lung cancer. The studies were conducted in Pakistan, India, Bangladesh, Uganda, Sri Lanka, China, Ethiopia, and Nepal. It was observed that developing countries had major health hazards as a result of use of biomass fuel for the purposes of cooking. Mostly women and children were affected because they spent most of the time at home. Improper ventilation systems were linked to asthma, chronic obstructive pulmonary disease, as well as weaknesses of the immune system.

Capture Fisheries, Smoking and Consumption in Ghana

Fish is nutritious food and it constitutes a reasonable percentage of protein to human diets when processed (Amegah et al., 2012). The principal nutritional constituents of fish are: proteins, lipids, minerals and vitamins such as B2. Fish is the most important animal protein in Ghana, accounting for the about 82% of protein consumption. The FAO (2014) estimates a total marine catch of about 206,477 tons from 900 powered and 8,526 unpowered fishing vessels employing just over 70 thousand people directly in Ghana. Ignoring exports and losses, this equates to about 80 grams/person/day of fresh fish or about 20 grams/day of dried smoked fish, and this 20 grams/day is somewhere between 65% and 90% of the animal protein consumed. In effect, the fishery sector plays a major role in the nation’s economy, contributing 3% of the GDP providing employment to the labor force which includes the fishers, their wives, children, close relatives, canoe carvers, input suppliers as well as office workers for industrial fleet accounting an estimated number of 1.5-2 million of the

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nation's population. (Holma & Maalekuu, 2013).

With a population of about 27 million people, the average per capital fish consumption is 27 kg per annum, which is higher than the world's average of 13 kg. It is noticeable that a significant plentiful (bumper) harvest occurs as well as lean seasons. Hence to ensure the availability of fish throughout the year, particularly during the lean seasons, it is essential to preserve fish in appreciable quantities and good conditions until it is needed (Holma & Maalekuu, 2013).

In Ghana, fish smoking is one of the most widely used traditional fish-processing methods. Studies on fish consumption patterns in Ghana show that fish is consumed more in the smoked form (Van Vliet et al., 2013). It is estimated that 80 per cent of processed fish is smoked. Various species of fish are smoked, on availability. *Chrysichthys* species are among the most commonly caught and smoked freshwater fish in Ghana where there are seven known species in various water bodies. *Chrysichthys auratus* occurs in the Volta Lake, C. *walkeri* in the Pra Basin, C. *maurus* from the Bia, Tano and Pra Basins, C. *johnelsi* in the Bia and Tano Basins, and C. *nigrodigitatus* occurs widely (Amegah et al., 2012).

There is no denying the fact that smoking is one of the oldest food preservation technologies and can be used to achieve the characteristic taste, colour and aroma for food especially meat and meat products, fish and fish products. The process of fish smoking combines salting or brining, equilibration, drying on traditional mud ovens and finally smoking in traditional smokehouses made from bamboo or cement. There are mainly two types of smoked fish, the hot- smoked fish and the dry- smoked fish and the choice of

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whether the fish should be hot smoked or dry smoked solely depends on the type of fish and how long it is going to be stored for future use.

The hot smoking process could last for about 3 hours and the resulting smoked fish have a moisture content of about 35% - 45% with a limited shelf-life of 1-3 days. A smoked- dry process may take about 10 - 18 hours, and sometimes 3 – 4 days and the resulting smoked fish have a moisture content of about 10% -15% with a shelf-life of 3 - 9 months when stored properly (Omodara & Olaniyan, 2012). However, fish is nowadays smoked for sensory quality rather than for the preservative effect. Amegah et al. (2012) reported that the acceptance of smoked fish in developed countries is based primarily on the sensory characteristics it imparts to the product while Gordon et al. (2011) confirmed the nutritional qualities and adequacies. In addition to this, smoking enhances preservation due to the dehydrating bactericidal and antioxidant properties of smoke such as phenol derivates, carbonyls, furan derivates, organic acids and their esters (Openshaw, 2011).

PAHs are released through the absorption and deposition of particulates during food processing such as smoking, grilling, boiling and toasting, the pyrolysis of fats and the incomplete combustion of charcoal. The actual levels of PAHs in smoked foods depend on several variables in the smoking process, including type of smoke generator, combustion temperature, and degree of smoking (Manyo-Plange, 2011). Smoke is generated by thermal pyrolysis of a certain kind of wood when there is limited access of oxygen. Temperature of smoke generally plays a very important role, because the amount of PAHs in smoke formed during pyrolysis increases linearly with the smoking temperature within the interval 400-1000°C (Rooney et al., 2012).

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In modern industrial ovens, the smoke is usually generated in a separate chamber cleaned by using various techniques, such as electrostatic filters or smoke washing, and then led into the smoking chamber. This, together with the control of some important parameters such as temperature, humidity, smoke concentration, and circulation rate, can contribute to the minimization of PAHs contamination (Amegah et al., 2011). Incomplete wood combustion during smoking can produce considerable amounts of PAHs which can penetrate through the surface of products (Jira et al., 2006). In a study performed by Zhou et al. (2011), the total PAH concentrations detected were between 2.6-29.8 and 9.3-86.6 µg/kg in smoked meat and fish, respectively. In another study conducted by Rooney et al (2012) in Canada, smoked fish and meat samples were analysed and PAH compounds were detected in 18 out of 25 smoked fish samples (maximum of 141 µg/kg) and in 19 out of 43 smoked meat samples (maximum of 13 µg/kg). Kshirsagar and Kalamkar (2014) found that the levels of PAH ranged from 4.2 to 60 µg/kg in hot and cold-smoked fish samples. In their study, Fullerton et al. (2008) reported that the concentration of total PAHs in seafood varied from 46.5 to 124 µg/kg. These studies point to facts leading to PAHs in smoked fish. The current study is more concerned with the exposure and health risk associated with fish smoking.

Factors Influencing the Extensive Use of Biomass Fuel

Biomass is a fuel that is obtained from organic materials, a renewable and sustainable source of energy used to create electricity or other forms of power. Some examples of materials that make up biomass fuels are twigs, wood, forest debris, dried animal dung (manure) and some types of waste residues. The most common type of biomass fuel used is wood, but the use of dried

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animal dung and crop remains is also common (Bruce et al., 2000). The high demand for these biomass fuels comes as a result of several factors which could be categorised into economic, social and environmental. Fuel wood in most cases is free, probably is the reason for the extensive use of it. The search for biomass fuel is not as difficult as the search for other alternative fuels like LPG and ethanol which is expensive and often limited in supply.

Clean fuel is not always available or the demand for clean fuel cannot be met consistently as needed and therefore makes rural dwellers continue to use biomass fuels (Kurmi, Lam, & Ayres, 2012). The high cost of using or purchasing cleaner fuels is the main reason why rural folks continue to use biomass fuel (Akintan, 2014). Heltberg (2005) in his study in Guatemala indicated that, the inability of households to afford clean energy was because their income level are low. It could be noted that the extensive use of biomass fuel mostly in many developing countries in the world is to the fact that clean energy fuels are costly whereas biomass fuel such as wood and twigs are cheaper and easy to come by.

Boadi and Kuitunen (2016) in their study indicated that socio-economic status and educational status play a key role in the selection of a specific source of energy in Ghana. Many people who use biomass fuel are not aware of the health impact associated with using it and therefore the fact that limited time is spent in fetching, they tend to derive their daily domestic energy from burning.

To Miah, Foysal, Koike & Kobayashi (2011) socio-economic factors such as earnings, job, household size, gender and frequency of cooking determines energy choices in Naoki, Bangladesh. In Ghana, many rural household are large in size and meals are mostly prepared not less than three

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times in a day. The type of food cooked, ingredients used in preparing the meal, how often is prepared and cooking practices influences the choice of energy source made by household in carrying out their daily activities (Kowsari and Zerriffi, 2011).

Culture also plays a crucial role in the selection of house hold energy type. Parikh (1995) in his study of energy choice opined that every household in a specific community has its own reason for choosing a type of energy over the other. Quagraine and Boschi (2008) emphasized that cultural practices contribute to the choice of the extensive use of biofuels is less industrialized countries. In Ghana, people continue to use biomass fuel because they grew up seeing their people using it for household heating and cooking activities.

Kowsari & Zerriffi (2011) stressed that additional factors such as education level, scarce information, and social knowledge determines energy choice amongst householders. Most often rural households as well as urban household in developing countries are not aware of the health benefits associated with using clean fuels and therefore continue to use of biomass fuel such as twigs, animal dung and wood.

In summary, it could be noted that the extensive use of biomass fuel mostly in many developing countries in world is to the fact that clean energy fuels are costly and not easy to come by (limited), whereas biomass fuel such as wood and twigs are cheaper and easy to come by. Socio cultural characteristic such as family size, availability, type of meals cooked and ingredients used for preparing and how often meals are prepared is also a crucial factor for the extensive use of biofuel now.

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Regardless of the various reasons enumerated for the extensive use of biomass, it must be noted that there is a harmful effect associated with it use. Such emission brings about risk factors to users and can cause a lot of harm than good. The following paragraphs take a closer look at biomass fuel as used by fishmongers or smokers and PM and Volatile compound exposure.

Volatile Organic Compound Exposure

Indoor pollution has received much attention for the past years now as compared to outdoor pollution. Human beings spend more than 80% of their time indoors such as living rooms, apartment and work dwelling places like work shops and offices. (WHO 2000; Weschler, 2009). Nitrogen oxides (NOx), carbon monoxide (CO), particulate matter and volatile organic compounds (VOCs) are all air pollutants but VOCs has received much attention and is a good representative when monitoring indoor quality (Bolden, Kwiatkowski & Colborn, 2015 Salthammer, Mentese & Marutzky, 2010).

VOCs are organic compounds emitted as gases from certain solids and liquids used in dwelling places with benzene and formaldehyde as examples. Li, Wang & Gong (2009) defined VOCs as organic compounds with a boiling point in the range of 50–260 C at room temperature and atmospheric pressure. VOCs are mostly abundant in the indoor environment (Guo, Murray & Wilkinson, 2000; Guo et al; 2009).Tanyannont & Vichit -Vadakan (2012) projected VOCs levels in indoor air to be usually higher than that of outdoor air (Jedrychowski et al., 2005).

Several indoor activities lead to the emission of Vocs and it includes combustion processes such as the burning of biomass fuel for cooking, use of adhesives and the utilization of construction materials (Guo et al., 2009;

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Wolkoff, 1995**;** Hodgson, Beal &, McIlvaine, 2002**).** Burning of biomass fuel is a major source of volatile organic compounds, some of which are known for their carcinogenic effects (WHO, 2010) VOCs can penetrate to deepest part of the skin and very easy to be inhaled and the outcome is an increased long-term health problems in human (Walther and Crinion, 2000)

Formaldehyde is one of the commonest Vocs that has been associated with health outcomes and a good indicator when dealing with indoor air quality. It is known to be cancer-causing agent when inhaled by humans and therefore has received much attention because of its adverse health effects (Ewlad-Ahmed, Morris & Patwardhan, 2012).

According to USEPA, (2007) one exposed to VOCs can suffer short term health effects like eye, nose, throat and skin irritation as well as headaches, nausea, dizziness, fatigue and breathing problems and a long term effect like acute and chronic toxicity in humans. Women and young children suffer most of these emissions because they spend most of their time indoors.

It could be noted that exposure to VOCs is very detrimental to human health and therefore the is a need to attach particular attention to such emissions since many activities home and at work places leads to such emission of such air pollutant.

Biomass Fuel and Particulate Matter Exposure

Both developing and developed countries are largely dependent on fossil fuels (Agrawal, 2012). Renewable energy is now being encouraged as an alternative to fossil fuel (Baumgartner et al., 2011; Colbeck et al., 2010; Tanner et al., 2014).As indicated from the beginning of the chapter, Colbeck et al (2010) reported that more than three billion people use solid fuels as the main

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source of energy in their homes. Kim et al. (2011) affirmed that biomass has been extensively used in developing countries such as India, Malawi, Kenya and the Caribbean. The situation is not different from Ghana since a lot of people obtain their daily energy from using biomass fuel.

Charcoal, harvest residues and wood materials are the most common biomass fuels used as energy source (Odoi-Agyarko, 2009). Not only is the use of natural biomass fuel becoming more common, compacted biomass, such as briquettes and pellets, is also being used more frequently. According to Kurmi et al. (2012), one of the most important advantages attributed to the use of renewable fuels such as biomass is its low cost and widespread distribution.

Biomass burning, however, is frequently cited as one of the main channels through which particles and pollutant gases enter the atmosphere (Kim et al., 2010; Colbeck et al., 2010; Bonjour et al., 2013; Tanner et al., 2014).When solid fuels are mostly burnt in traditional stoves such as the three stones, clay stoves or other inefficient devices in inappropriate ventilated spaces the outcome is the emission of very high exposures of particulate matter and other products of incomplete combustion such as volatile organic compounds. During biomass burning, particle matter (PM) emissions are dominated by sub micrometric particles (Tanner et al., 2014).

Particulate matter also referred to as particle pollution is linked to a number of significant health effects. Depending on the aerodynamic diameter of the particles, the term PM_{10} is used to indicate particles with a diameter up to 10 μm and $PM_{2.5}$ for particles with a diameter up to 2.5 μm. Within the PM 2.5 category there is a distinction between fine (≤ 2.5 μm) and ultra-fine (<0.1 μm) particles. The largest particles, are the coarse fractions that are

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mechanically produced by the break-up of larger solid particles. These particles include wind-blown dust from agricultural processes, soil, unpaved roads or mining operations and suspended particles from the road surface.

Particulate matter less than or equal to 10 micrometers in diameter are very tiny and can penetrate to the deeper part of many internal organs in the body such as lungs and heart. $PM_{2.5}$ (fine particles) are 2.5 micrometers in diameter or smaller, and can only be seen with an electron microscope.

These particles as aforementioned can cause severe health effects such us lung cancer, chronic lung and heart diseases (Colbeck et al, 2010 ; Tanner et al, 2014). The damage to human health is mainly linked to exposure to PM_{10} and $PM_{2.5}$ (Agrawal, 2012).According to Kim et al., (2010) the report about Global Disease estimated that in 2010 approximately 3.5 million deaths worldwide were attributed to smoke exposure from residential solid fuel combustion. Long-term exposure to particle pollution is an important risk factor which brings about cardiovascular disease which include pulmonary and systemic swelling, accelerated atherosclerosis and cardiac autonomic function (Pope et al., 2004). Fine particulate air pollution exposure is linked to lung cancer mortality (Turner et al., 2011). Link between increased fine particulate levels and asthma have been reported in town air pollution (Garcia-Marcos et al., 1999).

The effect of particulate matter goes beyond risks to human health. $PM_{2.5}$ and PM_{10} affect weather and reduce visibility, as reported by Sumpter and Chandramohan (2013). Li et al. (2011) described that atmospheric aerosol alters the Earth's radiation balance and causes significant impacts on the weather system. Black carbon that is produced through incomplete combustion

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contributes to global warming because these particles absorb solar light. In the studies of Granier et al, (2011) it was observed that the concentration of black carbon particles has a positive correlation with environmental heat.

The negative aspects related to biomass combustion emissions may prevent its use as a sustainable fuel. In order to overcome this disadvantage, detailed information is necessary regarding emissions of particulate matter from burning of different types of biomass. This information will help identify the types of biomass that emit more particles during combustion and may lead to measures for reducing this pollutant. Few review articles described particle emissions from burning of biomass as fuel (Granier et al., 2011; Li et al., 2011; Sumpter & Chandramohan, 2013).

Review articles, in general, do not simultaneously address the emission factor (EF) of this pollutant from different emission sources. For the purposes of this review the emissions factors of biomass sampled in an open environment and in a closed environment are considered. The characteristics of particle emission are usually related to physical and chemical parameters. The most reported of them being mass concentration, diameter distribution, concentration in number and size distribution in number (Openshaw, 2011). Another particulate measurement is the emission factor. The emission factor quantifies the magnitude of emissions (Smith et al., 2011). The EF has been used in a number of different studies to quantity aerosol emissions an emission factor is a representative value that relates the quantity of pollutant released to the atmosphere with an activity associated with the release of that pollutant. EFs are usually expressed as the mass of the pollutant divided by unit mass, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of

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particulate emitted per mega gram of coal burned).These factors make it possible to estimate emissions from various sources of air pollution. In most cases, they are simply averages of all available data of acceptable quality. They are generally assumed to be representative of long-term averages for all facilities in the source category (i.e., a population average).

Emission factor have long been fundamental in developing national, regional, state, and local emissions inventories for air quality management decisions and in developing emission control strategies (Amegah et al., 2012). For example, in biomass combustion the EF relates the mass of pollutant emitted into the atmosphere to fuel consumption. Kshirsagar and Kalamkar (2014) and Amegah et al. (2012) described that the emission factor can be discussed in terms of particle mass (EFPM) or particle number (EFPN). If the particle concentration and the volume of air sampled over time are determined, the emission factor in mass can be calculated. The emission factor of PM, considering the particle concentration, can be calculated using Equation (1) (McCracken et al., 2011)

$$EF\ \mathrm{PM} = \frac{\mathrm{C.VTOTAL}}{Mfuel\ (dry\ basis)} = \frac{(gPM)}{Kg\ fuel}$$

Where C is the average concentration of PM (mg/m3), VTOTAL is the total volume of the gas sampled during the experiment (m3), and mfuel (dry basis) is the mass of dry fuel consumed (kg). The emission factor in mass quantifies the emission of a pollutant in terms of amount of dry fuel that is actually burned (Amegah et al. 2012) or as a function of energy produced in a burned (mg/MJ) (Rooney et al, 2012). EFs can be given in energy units (mg/MJ) using the low heating values (LHVs) of the burned fuels for units conversion.

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Natural detritus and anthropogenic emissions are responsible for the emission of aerosol particles (Huboyo et al., 2014). Granier et al. (2011) mentioned that burning fossil fuels and biomass are the largest sources of particulate matter emissions. Sumpter and Chandramohan (2013) described that wood burning in residences is one of the main contributors to the emission of fine particles during European winter. There are many sources of biomass combustion, including forest fires, controlled burns, agricultural residues, wood fuel in residences, algae treatment residues, and energy generation (Granier et., al. 2011; Li et al., 2011). Granier et al. (2011) mentioned other sources of particle emission from biomass burning, such as dung burning and domestic waste burning. Fast growing wood, forest and agriculture residues, and the sub-products of municipal and industrial processes are the main sources of biomass.

The properties and uses of different types of biomass vary significantly, as well as their advantages and disadvantages (Gordon et al., 2011). Huboyo et al (2014) report that these properties can significantly affect the air quality during combustion processes. Biomass can be employed either in compacted form or in its natural state. Granier et al. (2011) described that the biomass can be compacted by mechanical processes (for example, bales, pellets, cubes, and briquettes) and by pyrolysis (for example, slow pyrolysis, and fast pyrolysis). Due to the impact of PM on the health of people some scholars have underscored the need to measure the PM level under different circumstances. Banerjee et al. (2012) and Openshaw (2011) emphasized the importance of measuring particle emission concentrations and amounts. They stated that the impact of particles on human health and the environment can be determined by their PM parameters. With the knowledge of such parameters, emission

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standards can also be developed and implemented. Among the measuring parameters, Banerjee et al. (2012) mentioned the measurement of the particle shape and its morphology. The characteristics of particle emission are usually related to physical and chemical parameters. The most reported of them being mass concentration, diameter distribution, concentration in number and size distribution in number (Openshaw, 2011). Another particulate measurement is the emission factor. The emission factor quantifies the magnitude of emissions (Smith et al., 2011). The EF has been used in a number of different studies to quantify aerosol emissions. Most studies of sampling of atmospheric pollutants from biomass combustion involve two main types of sampling: open and closed environment. Field measurements in an open environment yield very reliable results, even though they are more labor intensive, expensive, and time consuming (Manyo-Plange, 2011; Amegah et al., 2012).

According to the authors, simulation studies in the closed environment of a laboratory have the advantage of being able to study different pollutants in different burning conditions in a relatively timely manner. Fuel properties can also be studied in laboratory, as well as the effects of different burning conditions on pollutant emissions. Van Vliet et al. (2013) commented that pollutants can also be measured by sampling using airplanes or by remote sensing.

A number of studies was carried out with forest biomass, agricultural and garden waste in natural (71%). However, only 16% of the studies were of these types of biomass in the compacted form. Compacted biomass tends to emit different levels of pollutants in relation to in natural biomass (Zhou et al, 2011; Banerjee et al., 2013). According to Zhou et al. (2011) biomass pellets are high

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quality fuel. Fuel in the form of pellets generates less particle matter emissions than other types of wooden fuels. Zhou et al. (2011) reported that emissions of particulate matter can be well below the emissions limit, when wood pellets are burned in grid burners equipped with electrostatic precipitators. According to Banerjee et al. (2013) biomass pellets can be a clean substitute for biomass in its traditional form. These facts justify further study of emissions from compacted biomass combustion.

Empirically, some authors studied about PM emission in the environment and come out with numerous interesting results. Banerjee et al. (2013) evaluated the PM2.5 emission markers in several different types of controlled burns. Emissions were characterized through prescribed burns in the Western of the United States. Openshaw (2011), as well as Banerjee et al (2013), also evaluated emissions from burns in the Western of the United States. The authors determined the contributions from biomass burning to the PM2.5 emissions. The objective of their study was to identify potential sources of PM2.5 emissions. Samples were collected in Chengdu, in China, during 2009 and 2010. The annual average concentration of PM2.5 was 85.1 mg/m^3.

After analyzing such an extensive information on smoke emissions. It is very important to take a critical look at the health effect of PM and VOCs and general health problems associated with biomass fuel use. Such a survey would be important in this study as it could be identified with fish smoking in the western region of Ghana. The following paragraphs is not only limited to PM and VOCs but also indoor air pollution as a result of the use of biomass fuel.

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Acute Respiratory Infections

Acute respiratory infections (ARI) are the leading cause of burden of disease worldwide and account for the deaths of 4-5 million children under five in developing countries each year. Several studies in developing countries (Argentina, Brazil, the Gambia, India, Kenya, Nepal, Nigeria, South Africa, the United Republic of Tanzania and Zimbabwe) have quantified the relative risk of Acute lower respiratory infections (ALRI), for children in households where biomass burned often biomass often burned (Armstrong & Cambell, 1991;Ezzati & Kammen, 2001).

A recent review examined the relationship between indoor air pollution from domestic biomass fuels in developing countries and acute lower respiratory infections, the major killer of children (Laumbach & Kipen, 2012). The authors concluded on the basis of nine case control studies (n=4311, OR 2.2-9.9), four cohort studies (n=910, OR 2.2-6.0) and one case fatality study (n=206, OR 4.8), that pneumonia/ARI is probably the largest disease outcome from air pollution exposure worldwide. More minor symptoms such as cough, cold, congestion and phlegm have been associated with kerosene and mixed fuel use in India (Kim et al, 2011) Among Jordanian (Li et al., 2011) and Indian (Po et al., 2011) school children exposure to wood and kerosene cooking smoke was associated with sharp reductions in pulmonary function. In Turkey (Smith, 2013) and Malaysia (Granier et al., 2011) children in households where cooking was done with the burning of wood had similar reductions in lung function. In Ghana, a study conducted by Flintwood-Brace (2016) showed that the burning of biomass fuel leads to respiratory infections such as breathless are chronic cough.

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Eye infection or Visual impairment/ Sever headache

Studies conducted in India have showed an increased risk of cataracts among people using biomass fuel; Mohan et al. (1989) determined an odds ratio of 1.6; (Zodpey and Ughade, 1999) found an adjusted odds ratio of 2.4. Indoor air pollution resulting from the burning of biomass has also been linked to blindness through trachoma (Prüss & Mariotti, 2000). Exposure to smoke is associated to eye infections or irritation such as growth on the eye, redness of the eye and eye watery. Studies conducted in Ghana also showed that high exposure to smoke leads to severe headache and eye infections (Odoi-Agyarko., 2009).

Lung Cancer

Lung cancer is one of the leading causes of death, accounting for 1.3 million deaths annually worldwide. Emissions from combustion of solid fuels have been shown to have high concentrations of PAHs, BaP and PM2.5, which in turn have been associated with high lung cancer rates (Gordon et al, 2014).

A meta-analysis studies relating to lung cancer in subjects exposed to solid fuel smoke showed a greater effect of coal smoke on lung cancer rates (OR 1.82, 95% CI =1.60–2.06) with biomass smoke, predominantly wood (OR 1.50,95% CI =1.17–1.94) and mixed biomass fuel smoke (OR 1.13, 95% CI 0.52– 2.46), showing lesser effects (Kurmi, Lam, & Ayres, 2012). The general mechanism emerging from the study of PAHs such as BaP is genotoxicity, where BaP is metabolized to an electrophilic form that adducts DNA (Hecth, 1999).

Data from China imply that domestic coal smoke is a significant risk factor for the development of lung cancer (Sanbata et al., 2014). In studies from

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India and Mexico, data of non-smoking women exposed to BMF smoke for a number of years suggest that long-term exposure to BMF smoke from cooking may contribute to the development of adenocarcinoma of the lung (Sanbata et al., 2014). The International Agency for Research on Cancer (IARC) recently termed biomass smoke a 'probable carcinogen' and coal (used as domestic fuel) was termed carcinogenic to humans.

Asthma

Evidence regarding a causal role of indoor cooking smoke in asthma has been mixed. A possible reason for this is that defining asthma for epidemiological studies can be problematic, and criteria vary from study

It is often difficult to separate acute infections from asthmatic disease in children, and other chronic obstructive pulmonary diseases from asthma in adults. Increasingly, however, studies are using specific criteria such as those in the International Study of Asthma and Allergies in Childhood (ISAAC), and there is much research underway. A recent study summarized findings of fourteen studies which looked at asthma and biomass smoke from indoor combustion (Umoh & Peters, 2014). Overall, seven studies found a significant association with biomass smoke exposure, four found no association, and one found mixed results (no asthma association with kerosene or wood fire smoke, but an association with mosquito coil smoke). Two studies showed a protective effect, but these were done in Australia and Germany, where exposure was possibly quite different from that of the other studies in developing countries.

Pneumoconiosis

The combined respiratory infections of domestic cooking smoke and other respiratory exposures such as tobacco or occupational exposures in developing countries has thus far received little attention, but may have

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significant dimensions. Indoor cooking smoke probably contributes to domestically acquired pneumoconiosis (Bruce et al., 2000).

Chapter Summary

From the literature review, much information have been gathered about biomass fuel and its associated risk. It is also revealed that nearly 3 billion people depend on solid fuels (biomass and coal) for cooking and heating and this number is expected to grow until at least 2030 (Kim, Jahan & Kabir, 2011). It was also realized that incomplete combustion of biomass is the main source of indoor air pollution worldwide (Zhang & Smith, 2007). In most developing countries; it is burning of fuel wood in open that produces a lot of smoke (Akunne, Louis, Sanon & Sauerborn, 2006). Biomass smoke contains a wide spectrum of potentially health damaging pollutants that include coarse, fine, and ultrafine particles, carbon monoxide (CO), VOCs, oxide of nitrogen and sulphur, transition elements, polycyclic aromatic hydrocarbons, volatile organic compounds and bio-aerosols (Fullerton et al., 2008; Laumbach et al., 2012).

With regards to the indoor pollution it was further observed that biomass fuel and indoor air pollution poses a lot of risk to many people especially women and children. The various observation made through the studies could be identified with fish smoking in Abuesi in the Western of Ghana.

Moreover it was realized that health outcomes including asthma, tuberculosis, and cataracts needs of further amplification from studies that have better indicators for exposure. In the review, fish smoking was observed to be the most widely practiced method of fish preservation in Ghana, accounting for smoked fish being the commonest form of fish consumption. Tanner et al. (2014) on their search found that the shelf life of the smoked fish depends more

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on the cooking and the state of dryness than the smoke itself. Hence the process of fish smoking combines salting or brining, equilibration, drying on traditional mud ovens and finally smoking in traditional smokehouses made from bamboo or cement. There are mainly two types of smoked fish, the hot- smoked fish and the dry- smoked fish and the choice of whether the fish should be hot smoked or dry smoked solely depends on the type of fish and how long it is going to be stored for future use.

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CHAPTER THREE

MATERIALS AND METHODS

Introduction

In this chapter the various approaches and techniques used in data collection activity and analysis are explained. The order of presentation is; research design, study area, population, sampling procedure, data collection instrument and procedure and how the data obtained was analyze.

Research Design

A cross-sectional study which is a type of study which makes comparisons at a single point in time was the research study employed for this research. This study was conducted from December 2016 to May 2017 among fish smokers who have been in the smoking business for a year or more and smoke fish in old smokehouses at Abuesi in the western region.

Quantitative approach was employed in a form of field survey with the use of structured questionnaire to investigate the relationship or link between the number of years spent smoking fish in Abuesi and experience of eye problems and also to find out the knowledge of fish smoking on human health risk associated with the use of biomass fuel as the main source of energy for the smoking of fish. With this approach four hundred and thirty-four (434) fish smokers were selected and interviewed to help achieve the aforementioned objectives.

A field experimentation was also employed by assessing the level of concentration of particulate matter (PM2.5) and volatile organic compounds (VOC) from biomass combustion for the smoking of fish through measurement with the help of the Air Quality Meter (UNI-T,UT338C)

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Study Area

The study area is Abuesi which is a local fishing community well noted for fish smoking. The natives especially the men are mostly fishermen and the women are noted for smoking of fish as their major occupation.

Location

Abuesi is located in the Shama district in the Western Region of Ghana. Abuesi is 20 kilometers from the Western Regional capital, Takoradi and is about 5 kilometers from Shama Junction. It is bordered on the east by Shama, the north by Inchaban, the west by Injreisia and the south by the Atlantic Ocean. Its coordinates are 4°58'60" N and 1°37'60" W in DMS (Degrees Minutes Seconds) or 4.98333 and -1.63333 (Decimal degrees) (Ghana Statistical Services, 2014)

Climate

According to the Ghana Statistical Services (2014), Abuesi lies within the tropical climate zone and experiences two rainy seasons. The major season is between March and July and the minor rainy season occurs between September and November. The highest rainfall is 170mm, while the lowest is 100mm. The average annual rainfall is 1,1820.00mm/p.a. The District has a relatively mild temperature ranging between 22 ° C and 28 ° C. In terms of humidity, precipitation occurs mainly from March to July where close to 70 percent of the rainfall takes place.

Topography

The landscape of Abuesi is generally undulating. Abuesi has faulty shelves and sand stones latent on a hard basement of granite, gneiss and schist (Ghana Statistical Services, 2014).

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Population

Abuesi is a populated area with a population of about 3,190 with about 70% of them being females and married as well (Ghana Statistical Services, 2014). About 800 of the women in Abuesi are fish smokers and most of them have been smoking fish for more than nine years with few doing other work like petty trading. Most of the fish smokers are between the ages bracket of 23-48 years.

Occupation

The main occupation of the people of Abuesi is fishing and fish smoking by men and women respectively. Fish smokers do the smoking work alone or employ fish smoking helpers to assist them. Fish mongers in Abuesi mostly use old smoking stoves normally made out of mud with the smoking done either in an enclosed smoke house. Most of the women who are involved in the fish smoking business started or learnt immediately they turn ten (10) years. Herrings, salmon and red grouper are the types of fish smoked and most of the fish smokers start the smoking business with a limited capital and with the help of few smoke helpers.

Fish Smoking Process

Fish in Abuesi is normally smoked in traditional smokehouses which is built normally with wood and/or bricks. Smokehouses are usually located few kilometers away from the community while others are located inside the community.

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Fish smokers mostly buy the fish at the bank of the sea or buy them from fish sellers who make it available to them at their smoke houses. Fish are washed and arranged on a metal wiring nets with holes inside to help get rid of water by drying it under the sun for 20-30 minuits then after smoked on mud ovens with fuel wood mostly burnt inside.

Figure 2: *Drying of fish*

Figure 3: *Smoking of fish*

Two main fishing seasons are observed by the people of Abuesi that is the lean seasons which starts from April and ends in the middle of July and the bumper season which also starts from August to October and ends in December. Few of natives in Abuesi do other work like trading in retail products, sale of firewood and civil jobs.

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Social Amenities

The main source of drinking water for the natives of Abuesi is pipe borne water. There is no clinic or hospital in Abuesi so most of the natives seek medical care from the neighboring community, Aboadze where the Volta River.

Authority (VRA) hospital is located or buy medicine from the few chemist shops in the town. About 75% percent of the houses in Abuesi are built with cement block/bricks with few been constructed with mud. The people of Abuesi have access to portable roads, public toilet facility and electricity. There are four first cycle schools in Abuesi, two of them are private schools and the other two are public schools. There is market for general public use in Abuesi but no waste bins for the collection of rubbish so natives often throw off garbage anywhere appropriate to them example at the bank of the sea and in gutters. There are about six religious centers like churches and mosques in Abuesi town as well.

Community Entry

Stage 1: Leaders meeting: The researcher met the Chief of Abuesi together with opinion leaders to enlighten them about the project and ask for permission to conduct the study.

Stage 2: Meeting with Fish smokers: After permission was granted, a meeting was held with fish smokers of Abuesi to also let them know specifically what this project is about. And right after the researcher identified all enclosed smokehouses in the Abuesi and listed the names of owners of these smokehouses.

Sampling Procedure

The target population included adult fish smokers who smoke fish in

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smokehouses and have been in the smoking business for a year or more. For the purpose of this study, the study population was confined to only fish smokers who operates in the study area. Participants were selected based on their availability to respond to questions as well as their willingness to participate in the experiments.

Sample Size

Fish smokers in Abuesi are estimated to be about 800 (Personal communication with Mr. Micheal Abban, 2016). The sample size of 260 respondents was calculated using the sample size calculator based on 5% margin of error, confidence level of 95% and an estimated population of 800 fish smokers in Abuesi. In all 434 respondents were employed in this research based on the increasing level of respondents who were willing to participate in the research.

$$Sample\ size = \left[\frac{\frac{Z^2\ x\ p\ (1-p)}{e^2}}{\left(1 + \frac{Z^2\ x\ p\ (1-p)}{e^2\ N}\right)} \right]$$

Where:

N = Population size

e = Margin of error

Z= Z score

Data Collection Instrument

Survey

Surveying which is a type of data collection method was employed in this study. Structured questionnaire which is a data collection instrument was used to help investigate the relationship between the smoking of fish in Abuesi and experience of eye problems and the perception of fish smokers on health

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outcomes associated with the use of biomass fuel as the main source of energy for the smoking of fish. Information on age, awareness level, number of years spent smoking, type of biomass fuel used, education level and personal protective materials used, number of hours spent smoking were all obtained with the aforementioned data collection tool. Only one participant was eligible to respond to the questionnaire. In all, the survey was conducted on four hundred and thirty four fish smokers who were selected for the study. The design of the questionnaire was based on the research objectives and in relation to current literature. This included both close-ended and open- ended and the Linkert scale responses. To avoid confusion, the questionnaire was interpreted in a local language (Fante).

Particulate Matter (PM2.5) and Volatile Organic Compound Monitoring

Data on PM and VOCs were collected by means of Air Quality Meter (UNI-T, UT338C). Sixty (60) fish smokers were randomly selected due to time constraint and also because just one air quality meter was available for this exercise and monitored for particulate matter (PM2.5) and volatile organic compound using their smoking house as reference for a period of three months depending on the day and time smoking was done by the selected participants. All enclosed smoke houses within the study area were given numbers from the 1 to 243 to avoid double monitoring. A systematic sampling approach was then employed to choose 60 out of the total number. This was done by systematically selecting counting and selecting every 4^{th} smokehouse within the clustered areas where these smoke houses were located and names of owners of these smoke houses were listed and a follow up monitoring. Monitoring readings were then taken from three locations; 1= inside the smokehouse (indoor), 2=

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outside the smokehouse (outdoor) which is 10 meters from the smoke house and a location outside the environment of the smoke house = control 20m (external environment) based on the arrangements of selected smoke houses. The 10 m interval was used to determine the differences in the distribution levels of particulate matter (PM2.5) and volatile organic compounds (VOCs). Measurement were taken with the help of an Air Quality Meter (UNI-T, UT338C, China) to help obtain the levels of particulate matter (PM 2.5) and volatile organic compounds (VOCs). A description of the study procedures is presented in Figure 4

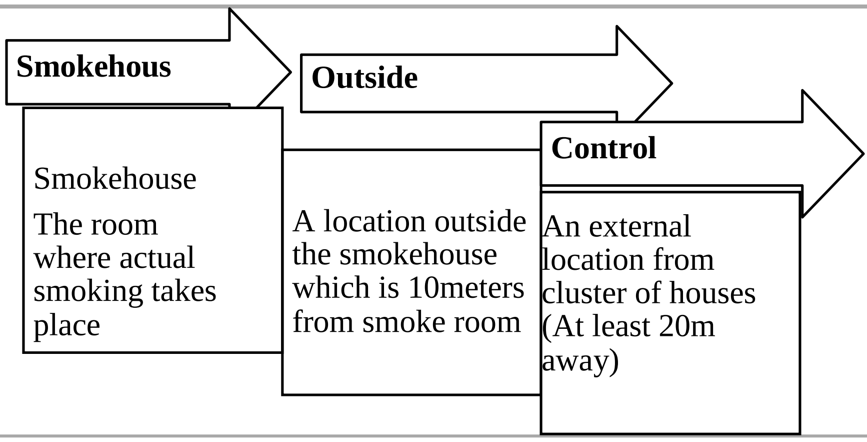

Figure 4: A diagram showing sampling procedures for particulate matter (PM2.5) and volatile organic compound data sampling.

Duration of the PM2.5 and VOCs monitoring covered a period of three months (March, 2017 - May, 2017). Readings were taken only on working days taking into account the time smoking was done. PM2.5 and VOCs monitoring were conducted in at least three times a week for 4 -5 hours a day due to the difficulties in meeting smokers. Fish smoking normally starts after 12 noon since the fishes are mostly dried on sieve under the sun first before smoking.

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Reliability and Validity

To ensure that the questionnaire used for the data collection is reliable such that the results obtained were valid, samples of the questionnaire was pre-tested among 15 fish smokers in Abuesi. Identified errors such as difficulties in the interpretation of the questions were worked on by using simple and meaningful sentences. The exercise therefore allowed for restructuring of the final research instrument before administration.

Air Quality Meter (UNI-T, UT338C) which is a hand held digital device used for taking $PM_{2.5}$ and Vocs levels was calibrated by restarting using the user manual before taking to the field to help avoid errors.

Informed Consent

Permission was sought from the Chief of Abuesi. Participants were not forced to participate in the study or financially induced to participate in this study and therefore could choose to either participate or not. They were informed that information provided will contribute to the overall knowledge about biomass exposure and health problems among traditional fish smokers.

Study Variables

Independent variables: The main independent variables (predictors) that were considered in the study were number of years spent smoking fish, particulate matter (PM 2.5) and volatile organic compound levels (VOCs) on the basis that they are good predictor of study outcomes.

Dependent variable: Health outcomes reported such as eye problems, headache and cough were the dependent variable (outcome) used in the study.

Covariates: The covariates or confounding variables used in this study were level of education, religion and age.

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Data Processing and Analysis

The questionnaire was cross checked and coded well to help prevent errors and ensure internal consistency. Data obtained from the field was subjected to statistical analysis using the computer software the Statistical Package and Service Solution (SPSS version 20) and Excel 10 (Microsoft). The software was mainly used to provide descriptive statistics of the various variables studied. The results were presented in tables and graphs. Parametric tests such as correlation was used to find out the relationships between variables measured. Correlation coefficient also helps in making predictions about one variable based solely on knowledge of the other variable and also shows the strength of the relationship. Another important reason for running correlation is to find the cause and the direction of a relationship whether positive or negative. In a positive relationship, as one variable increases the other variable also increases.

Similarly, as one variable decreases the other variable goes down thus both variables tend to move in the same direction. With the negative relationship the variables tend to move in the opposite direction meaning as one variable decreases the other increases and as the other variable increases the other increases. A good correlation ranges from 0.5 to 1. The effect of socio-demographic variables (age, years of experience in smoking fish, duration spent in smoke house continuously, education, etc.) on the fish monger’s likelihood of reporting specific health outcomes (eye infections/irritation, coughing, etc.) were analyzed by using odds ratios (ORs) (Logistic regression), established by binary complementary log-log regression (a generalized linear model) adjusted for the remaining independent variables included in the regression models.

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The generalized linear model (GLM) generalizes linear regression by allowing the linear model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value (Armah, 2014). OR=1 implies that higher values of the predictor do not affect odds of reporting a particular health outcome (e.g., eye problems and headche); OR>1 implies that higher value of the predictor is associated with higher odds of reporting a particular health outcome, and OR<1 implies that higher values of the predictor is associated with lower odds of reporting a particular health outcome. Reporting eye infection was dichotomized based on whether it was reported by fish smoker or not, coded as (unreported=0, reported=1).

Under the assumption of binary response (unreported=0, reported=1), there are three potential alternatives: the logit model, probit model and complementary log-log model depending on the link function of the GLM (Aitkin et al., 2005; Fahrmeir and Tutz, 2001). Both logit and probit link functions have the same property, which is link $[(x)] = \log[-\log(1 \ -\pi(x))]$. This means that the response curve for π(x) has a symmetric appearance about the point π(x) =0.5 and so π(x) has the same rate for approaching 0 as well as for approaching 1 (Aitkin et al. 2005; Fahrmeir and Tutz, 2001); that is approximately 50% of fish mongers responded in the affirmative and the other 50% did not. In this study, the health outcome (reporting eye problems) did not satisfy this property of symmetry. More fish mongers reported eye problems, which signifies asymmetry in the distribution of yes and no responses. Therefore, the complementary log-log model gives a better representation, and was used in the analysis of the health outcomes.

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CHAPTER FOUR

RESULTS

Introduction

This chapter presents the findings on self–reported health problems associated with the use of biomass fuel for the smoking of fish by fish smokers at Abuesi in the Western Region of Ghana. The study captured a total of four hundred and thirty-four female adult fish smokers from Abuesi who work in smoke houses or smoke rooms.

This chapter briefly describes the survey which describes the characteristics of the study respondents such age, marital status, educational attainment and religious affiliation. The chapter also discusses the knowledge of fish smokers regarding human health problems associated with the smoking of fish in Abuesi, the relationship between numbers of years spent smoking fish and reported eye infection or problems and the association between age and experience in fish smoking. It further describes the association between fish smoking – related health hazards and education, religion and marital status.

The chapter findings presents the levels of particulate matter (PM 2.5), volatile organic compounds (VOCs), temperature and relative humidity and the temporal variations of particulate matter (PM 2.5) and volatile organic compounds (VOCs) inside the smoke house (indoor) and the external environment (outdoor).

Demographic Characteristics of the Study Population

The characteristics of the study population are shown in Table 2. Most of the participants were above 44yrs (38%), married (76%), with no formal education (58%). Majority of these fish smokers have been in the smoking

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business for more than 9yrs (75%), Christians (80%), work for more than 3 hours (94%) each smoking day. Most the participants were aware of the health implications associated with exposure to fire and have at least suffered health hazards like severe headache and eye problems.

Table 2: Summary Characteristics of Respondents

Age bracket of Respondent	Frequency (N=434)	Percent (%)
15-20yrs	6	1
21-26yrs	39	9
27-32yrs	77	18
33-38yrs	81	19
39-44yrs	67	15
Above 44yrs	163	38
Marital Status of respondent		
Single	39	9
Married	330	76
Divorced	44	10
Widow	21	5
Highest Educational attainment		
Non Formal Education	220	51
Primary Education	133	30
Junior High/ Middle School	56	13
Senior High/ Vocational Training School	20	5
Tertiary	5	1
Number of Years in fish Smoking		
1-4years	50	12
5-8years	58	13
9 years or Above	326	75
Religious Affiliation		
Christian	347	80
Moslem	83	19
Traditional	4	1

Health Related Hazards Associated with Fish Smoking in Abuesi

Table 3 depicts the self-reported health hazards identified during the survey at Abuesi. Three main health symptoms namely eye problems, cough and headache were the most reported health related cases. The findings revealed that age of the respondents and educational levels had no significant effect on

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all three reported cases. However it was observed that the prevalence of eye related problems were influenced by the number of years the women had been in the fish smoking business ($p = 0.043$).

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Table 3: Identified Fish Smoking related Health Hazards

	Eye problem (N=434)				Cough (N=434)				Headache (N=434)			
Variable	1	2	3	4	1	2	3	4	1	2	3	4
Age	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
15-20	0.00	25.00	25.00	5.00	66.67	16.76	16.76	0.00	16.67	0.00	16.67	66.67
21-26	41.67	25.00	8.33	25.00	35.90	12.82	5.13	46.15	66.67	0.00	16.67	16.67
27-32	29.17	12.50	29.17	29.17	45.45	12.99	2.60	38.96	66.67	8.33	12.50	12.50
33-38	29.17	27.17	4.17	37.50	46.91	13.58	0.00	39.51	62.50	12.50	4.17	20.83
39-44	13.33	33.33	0.00	53.33	46.27	11.94	2.99	38.81	46.67	0.00	13.33	40.00
>44	24.32	10.81	13.51	51.35	36.50	9.20	1.84	52.76	35.90	7.69	7.69	48.72
Pvalue		P=0.161				0.154				0.115		
Edu. Level												
No formal education	24.14	18.97	13.79	43.10	42.47	9.59	2.28	45.66	50.82	11.48	3.28	34.43
Primary	25.53	17.65	8.82	50.00	37.50	10.53	3.76	48.12	55.88	2.94	17.65	23.35
Jnr. High/Middle school	27.78	27.78	22.22	22.22	37.59	10.53	3.76	48.12	42.11	0.00	21.05	36.84
Snr. High/Voc.	40.00	20.00	0.00	40.00	32.14	25.00	0.00	42.86	60.00	0.00	0.00	42.00
Tertiary	100.00	0.00	0.00	0.00	100	0.00	0.00	0.00	0.00	0.00	0.00	100.00

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Table 3: Continued

Pvalue		P=0.731				P =0.006					P=0.205	
Years spent smoking fish												
1-4yrs	38.46	19.23	11.54	30.77	52.00	12.00	4.00	32.00	50.00	14.29	10.71	25.00
5-8yrs	45.45	22.73	4.55	27.27	51.72	12.07	3.45	32.76	50.00	9.09	13.64	27.27
9 or more	14.71	19.12	16.18	50.00	38.65	11.35	1.84	48.16	51.43	2.86	8.57	37.14
Pvalue		P=0.043				0.162					P=0.452	

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Relationship between Number of Years Spent Smoking Fish and the Frequency of Self-Reported Eye Problems

Figure 5 shows the association between the frequency of reported eye problems and number of years spent smoking fish in Abuesi. It is clear that fish smokers who had worked for more than 9 years reported most of the eye infections or irritations. Seventy-one of them reported experience of eye problems several times a week, 73% reported that they experienced eye infection twice a week and lastly 55% reported experience of eye infection or problems once a week. It is evident that there is an association between eye problems and number of years spent smoking fish. The p value indicated that there is a statistically significant difference or association between eye infection or irritation and number of years spent smoking fish, (Pearson χ^2 (6) = 13.0249, Pr = 0.043). The Cramér's value of 0.2369 indicates that the association between them is moderately strong.

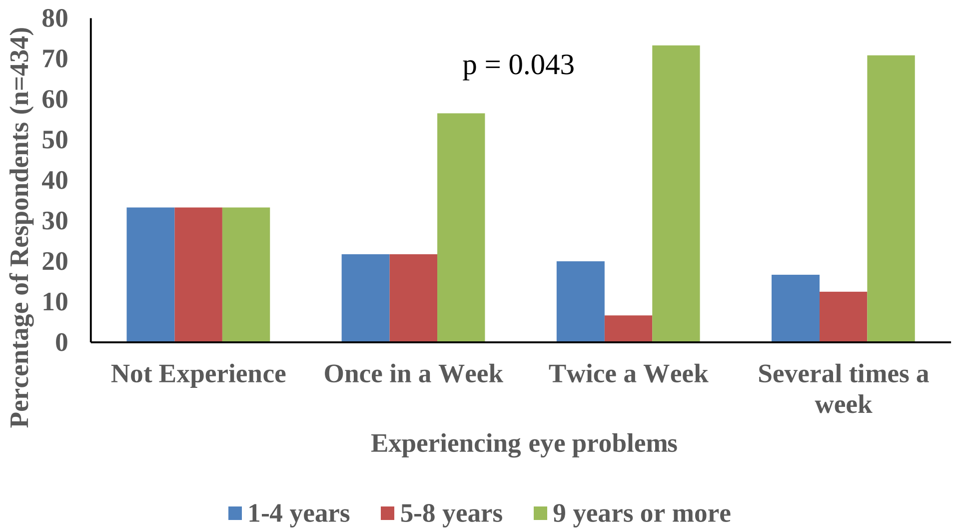

Figure 5: Association of eye problems and numbers of years spent smoking

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Table 4 helps supports the fact that there is a strong relationship between number of years spent smoking fish and self- reported eye problems. A logistic regression analyses was run to find out or measure the association between variables that is, number of years spent smoking fish (independent variable) and self- reported eye problems (dependent variable/outcome).This analyses was used to find out how likely eye problems will be reported by fish smokers based on the number of years spent in fish smoking. Using 1-4 years as reference it could be noted that 172% that is, (2.72 – 1) 100 of fish smokers who have engaged in fish smoking for 9 years or more were more likely to complain the more of experienced eye problems as compared to those who have been smoking for lesser years.

Table 4: Relationship between Exposure to Smoke and Eye Problems

Frequency of experience of eye disease	N	OR	95% CI	
<4 years	50	1.00		
5-8 years	58	0.721	0.231	2.246
9 years or more	326	2.723	1.138	6.513

Association of Level of Awareness of Respondent and Fish Smoking

Figure 6 explains the association of level of awareness of respondent and fish smoking. As indicated in table 7, most of the fish smokers in Abuesi have knowledge about the health implications associated with the use of biomass fuel for the smoking of fish. There was a statistically significant difference between fish smoking and level of awareness of fish smokers (Pearson χ^2 (1) = 44.7471 Pr = 0.000, Cramér's V= -0.6106).

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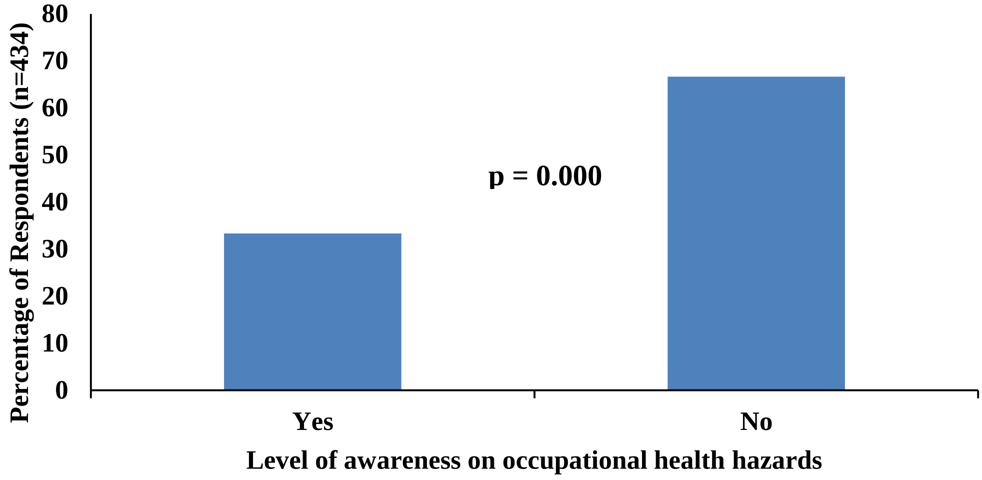

Figure 6: Association of fish smoking and level of awareness of occupational health hazards (n=434)

Knowledge of Fish Smokers on the Human Health Problems Associated with Exposure to Smoke Based on Educational Attainment

Table 5 below shows the knowledge of fish smokers on the human health risk associated with exposure to smoke based on educational level of respondents. A logistic regression analyses was run to find out the association between two nonlinear variables that is, educational attainment (independent variable) and knowledge of fish smokers about the human health outcomes associated with high exposure to smoke (dependent variable/outcome).This analyses was used to find out how education influences the knowledge of fish smokers. Using respondent who had no formal education as a reference point it could be observed that those who attended Tertiary (107%) that is (11.72 – 1) ×100 were more likely to know about the human health outcomes associated with high exposure to smoke as compared to those who were enrolled in primary school, junior high school and senior high school.

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Table 5: Knowledge that High Exposure to Smoke is a Human Risk

Knowledge that high exposure to smoke is a human health risk	N	OR	[95% C I]	
No education	219			
Primary education	133	0.335	0.731	2.106
Junior high/middle school	76	0.657	0.991	3.762
Senior High/Vocational Training	5	0.803	0.441	4.315
Tertiary	1	2.141	8.242	16.814

Association of Fish Smoking and Educational Attainment of Fish Smokers

Educational attainment at the Abuesi community spreads through no formal education, basic, high education through to tertiary. As shown in figure 8 75% of the fish smokers had no formal education, 82% went to primary school, 73% attended Junior high school, 80% went to Senior High School and greater percentage of them had tertiary education as well. It is clear that there was no statistically significant difference between fish smoking and educational attainment (Pearson (4) χ^2 = 1.0789 Pr = 0.898 Cramér's V = 0.0948).

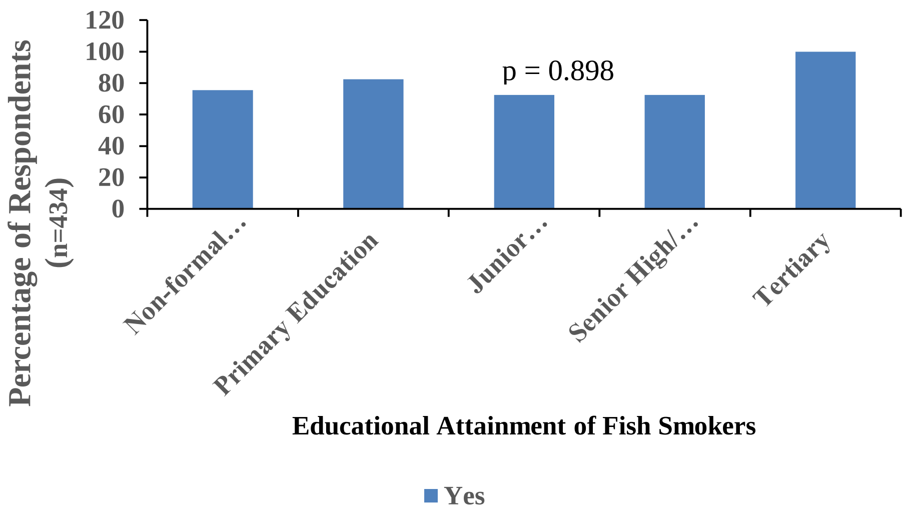

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Figure 7: Association of fish smoking and educational attainment of fish smokers (n = 434)

Association of Fish Smoking and Years Spent in Fish Smoking

Generally most of the fish smokers have been smoking fish for many years. As indicated in Figure 8 many of the fish smokers have been doing the fish smoking business for 9 years or more (83%). The result indicated that there was no statistically significant difference between fish smoking related hazards and number of years of experience fish smoking (Pearson χ^2 (2) = 2.8395, Pr = 0.242, Cramér's V = 0.1538) .

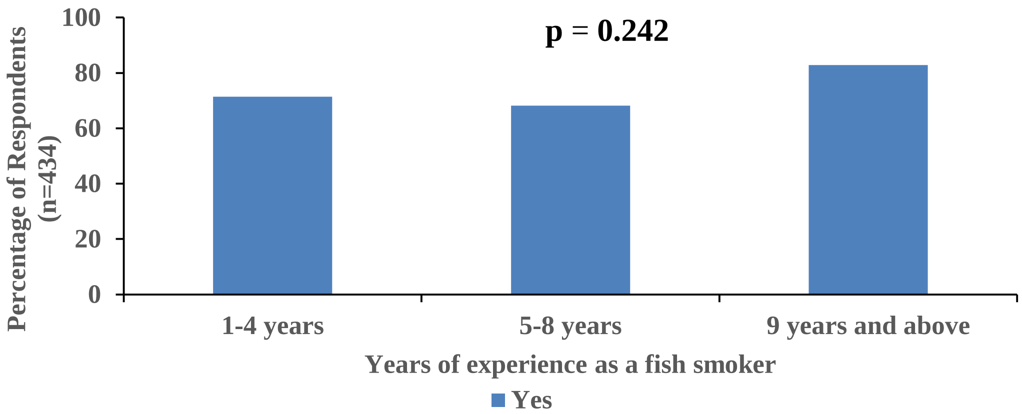

Figure 8: Association of fish smoking and years spent in fish smoking

Association of Fish Smoking and Age of Fish Smokers

As shown in figure 9 it is clear that most of the fish smokers were youth. It is evident that there is a statistically significant difference between fish smoking and age of fish smokers, (Pearson χ^2 (5) = 11.5136 Pr = 0.042). The Cramér's V of 0.30 indicated that the association between fish smoking related health hazards and age of fish smoker was strong.

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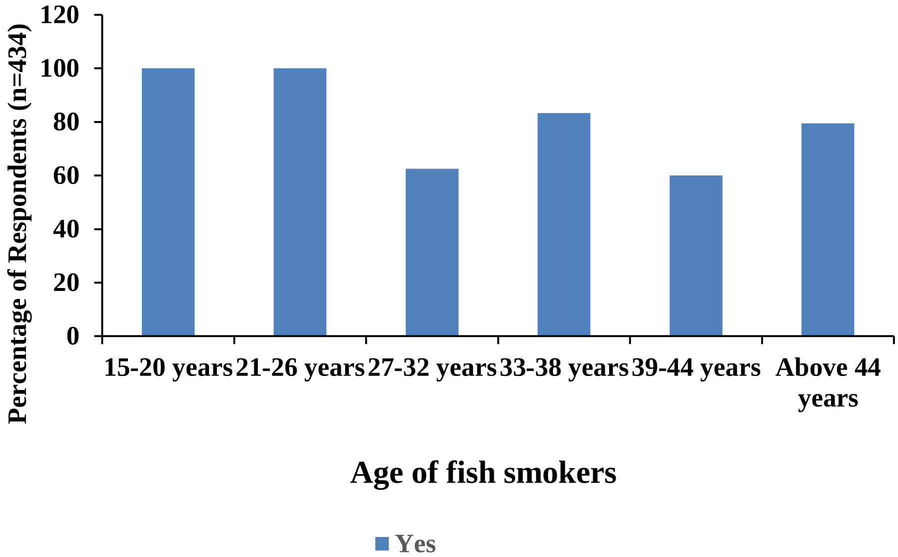

Figure 9: Association of fish smoking and age of fish smokers (n=434)

Association of Fish Smoking and Religion of Fish Smokers

Generally fish smokers in Abuesi were either Muslim or Christians. From figure 11, it is indicated that 83% of the fish smokers were Muslim and 76% were Christians. The p value indicates no statistically significant difference between fish smoking and religion which explains that religion does not influence fish smokers and reported health (Pearson χ^2 (1) =0.5854 Pr = 0.444 Cramér's V = -0.0698

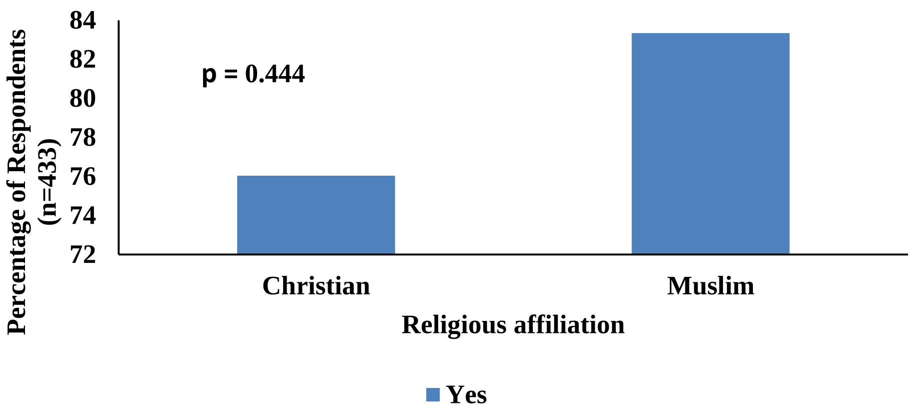

Figure 10: Association of fish smoking-related health hazards and religion (n=434)

Association of Fish Smoking and Marital Status of Fish Smokers

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It is clear in figure 11 that, most of the fish smokers were divorced (92%), 78% reported that they were single and married respectively with 40% indicating that they were widows. It is also marked in the figure below that there is no statistically significant difference or association between fish smoking-related health hazards and marital status, (Pearson χ^2 (3) = 5.4152 Pr = 0.144 Cramér's V = 0.2124)

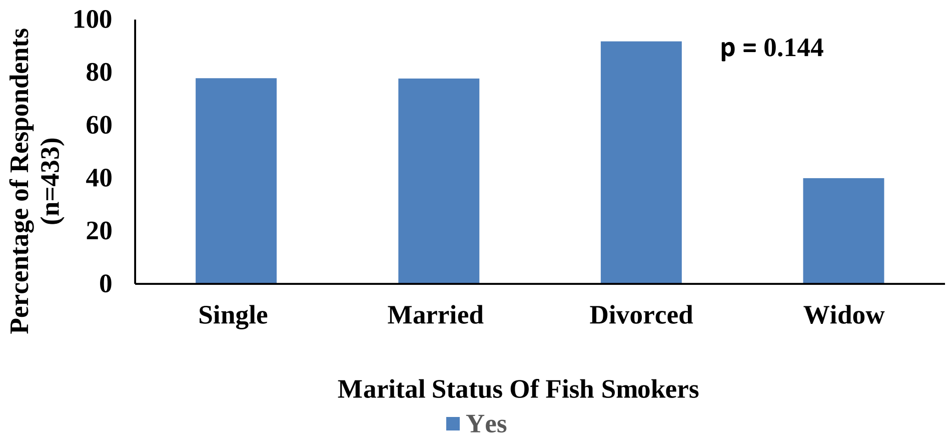

Figure 11: Association of fish smoking-related health hazards and marital status (n = 434)

Association of Fish Smoking and Cough

With reference to Figure 12, 72% of the fish smokers reported that they did not experience cough while a greater percentage of them reported of experiencing of cough once, twice and several times in a week respectively. The result also showed that there was an association or statistically significant difference between fish smoking - related health hazards and cough, (Pearson χ^2 (3) = 8.7097 Pr = 0.033). The Cramer's value of 0.26 indicated that the association between them were strong.

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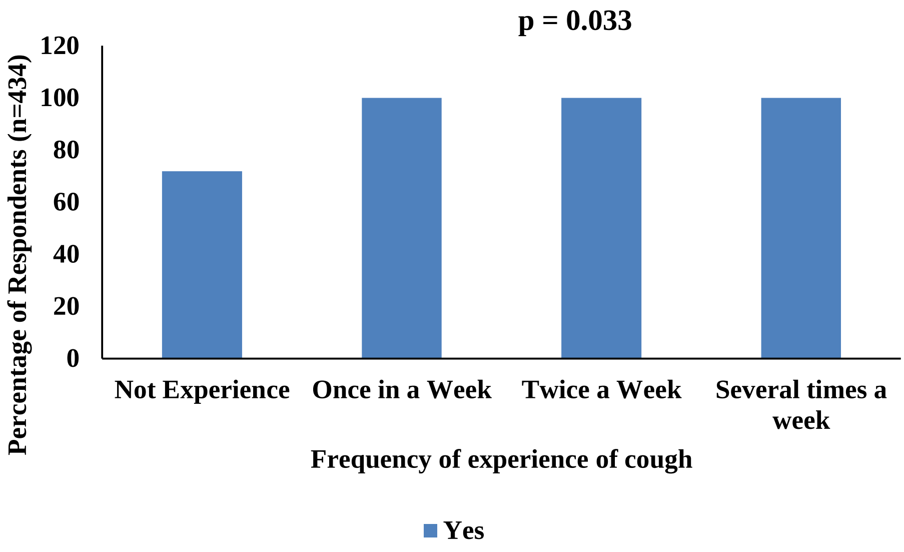

Figure 12: *Association of fish smoking and cough (n = 434)*

Association of Fish Smoking and Headache

It is evident from figure 14 that, 72% of the fish smokers reported headache while 50%, 75% and 92% reported experiencing of headache once, twice and several times in a week respectively. The P value indicated a statistically significant difference between fish smoking and headache (Pearson χ^2 (3) = 9.4249 Pr = 0.024). The Cramér's Value 0.28 indicates that the association between them is moderately strong.

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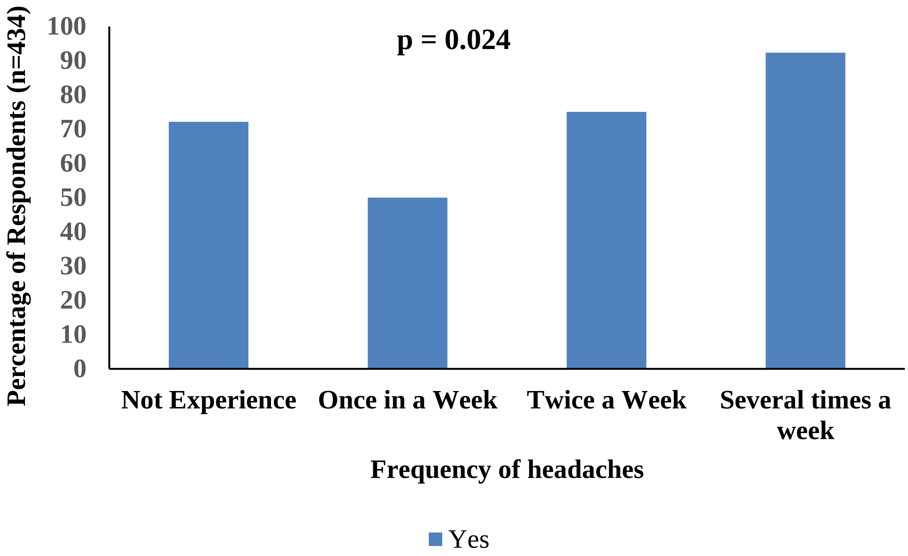

Figure 13: Association of fish smoking and headache

Levels of Particulate Matter (PM2.5) and Volatile Organic Compounds in Relation to the Smoking of Fish

Correlation Coefficient Analysis

Table 5 presents the correlation coefficients of mean levels of particulate matter (PM2.5), volatile organic compounds (VOCs), temperature and relative humidity levels of the three locations where reading were taken.

Particulate matter inside smoke house correlated with volatile organic compound inside (r =.461) significantly ($p < 0.05$). Particulate matter outside correlated strongly with volatile organic compound outside (r =.620) significantly ($p< 0.005$) and with temperature inside (r = -.386) significantly (p < 0. 05).

Similarly, particulate matter control correlated with volatile organic compounds outside (r =.356, $p< 0.05$) and also with volatile organic compound from the control locations strongly (r=.627) ($p < 0.05$) and lastly with temperature outside (r = .373, $p < 0.05$) significantly. Volatile organic compound outside correlated with volatile organic compound control (r =.-631,

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$p < 0.05$) negatively in significant manner indicating that as the other variable decreases the other increases.

Likewise temperature inside smoke house correlated with temperature outside smoke house strongly ($r = .862$, $p > 0.05$) but not significantly and with relative humidity inside ($r = 380$) ($p < 0.05$) significantly.

Lastly relative humidity inside correlated with relative humidity outside ($r = .383$, $p < 0.05$) while relative humidity outside correlated with relative humidity from the control locations strongly and ($r = 737$, $p < 0.05$) significantly.

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Table 6: Correlation Matrix of Environmental Variables Studied

	Pm Inside	Pm Outside	Pm Control	Vocs Inside	Vocs Outside	Vocs Control	Temp. Inside	Temp. Outside	Temp. Control	el. Hum Inside	Rel. Hum Outside	Rel. Hum Control
PM Inside	1											
PM Outside	-.024	1										
PM Control	-.038	.334**	1									
VOC Inside	.461**	-.005	.132	1								
VOC Outside	.029	.620**	.356**	.247	1							
VOC Control	-.063	.417**	.627**	.209	.631**	1						
Temperature Inside	.057	-.386**	-.260*	-.057	-.316*	-.316*	1					
Temperature Outside	.051	-.304*	-.373**	-.140	-.248	-.238	.862**	1				
Temp. Control	-.137	-.191	-.120	-.160	-.037	-.068	.324*	.297*	1			
Rel. Hum Inside	.189	-.138	-.121	-.085	-.241	-.139	.380**	.249	.295*	1		
Rel. Hum Outside	.135	-.150	.078	-.034	-.123	.038	.254	.163	.024	.383**	1	
Rel. Hum Control	.077	-.231	.048	.009	-.098	-.075	.157	.070	-.016	.264*	.737**	1

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed).

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Regression Analysis of Pollutants and Environmental Factors Studied

Figures 14 to 17 indicate the influence of key environmental factors studied that is temperature and relative humidity on key air quality pollutants (PM and VOCs) over the study period. A regression analysis was used to assess whether there was direct or indirect association between these variables.

Association between Particulate Matter inside and Relative Humidity Inside

As shown in Figure 14, the scatter plot between PM $_{2.5}$ and relative humidity inside showed that the particulate matter distribution were clustered around between 0-8 and 80 – 100% relative humidity with particle size ranging between 150 and 500 µg/m^3 . The regression coefficient revealed a positive relation between particulate matter inside and relative humidity inside, Y = 0.3824x + 295.5 (R^2=0.0305). The coefficient of determination indicated that a unit change in relative humidity could cause a corresponding change of about (3%) in particulate matter inside smoke room

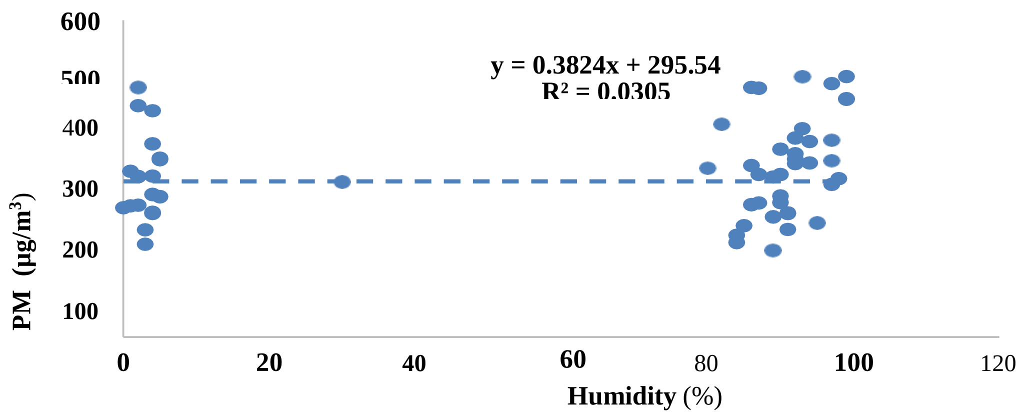

Figure 14: Association between particulate matter inside smoke house and relative humidity inside smoke house

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Association between Particulate Matter inside and Temperature Inside

Figure 15 indicates the association between particulate matter inside smoke rooms and temperature inside smoke rooms. The regression coefficient in Figure 16 suggested virtually no relationship between particulate matter inside and temperature inside y= 3.4319x+210.24 (R^2=0.003). This simply means that variations in temperature inside could be accounted for, virtually by variations in concentration of particulate matter inside smoke house recorded.

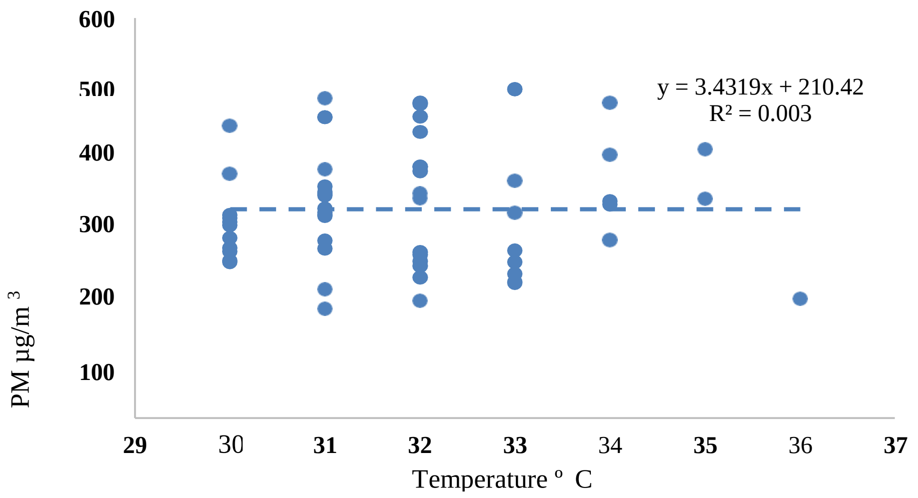

Figure 15: Association between particulate matter inside and temperature inside

Association between VOCs inside the Smoke House and Humidity Inside

As shown in Figure 16 below, the coefficient value obtained between VOCs inside and relative humidity inside was negative as shown in the regression equation y = - 0.0034x +8.7826, (R^2=0.0073). The regression coefficient indicated that a change in relative humidity inside is likely to cause a corresponding decrease in volatile organic compounds.

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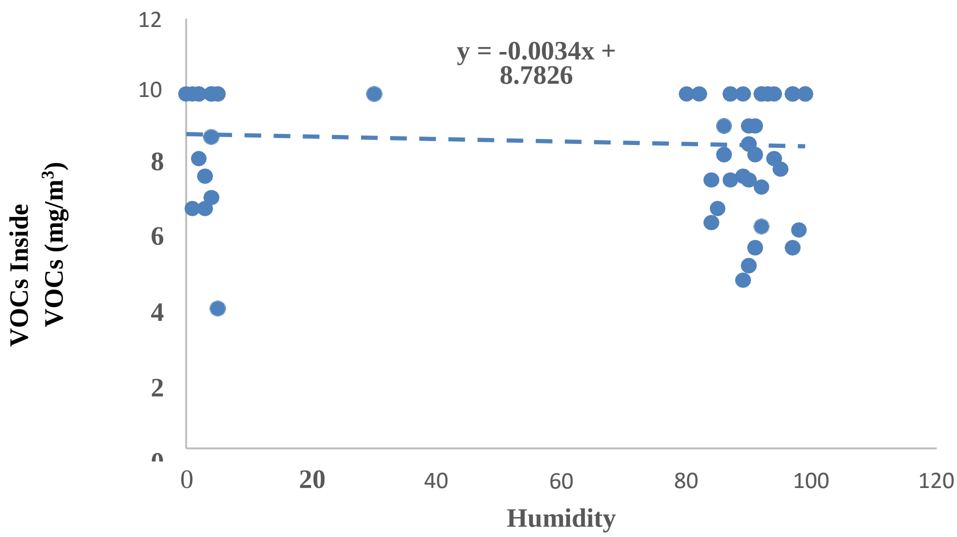

Figure 16: Influence of VOCs on humidity inside smoke house

Association between VOCs inside the Smoke House and Temperature Inside

As shown in Figure 17, the regression equation revealed a negative relationship between temperature inside and VOCs inside, y = -0.065x +10.636 (R= 0.0032). The coefficient indicates that a unit change thus decrease in temperature will cause a corresponding decrease in particulate matter inside by an average 7%

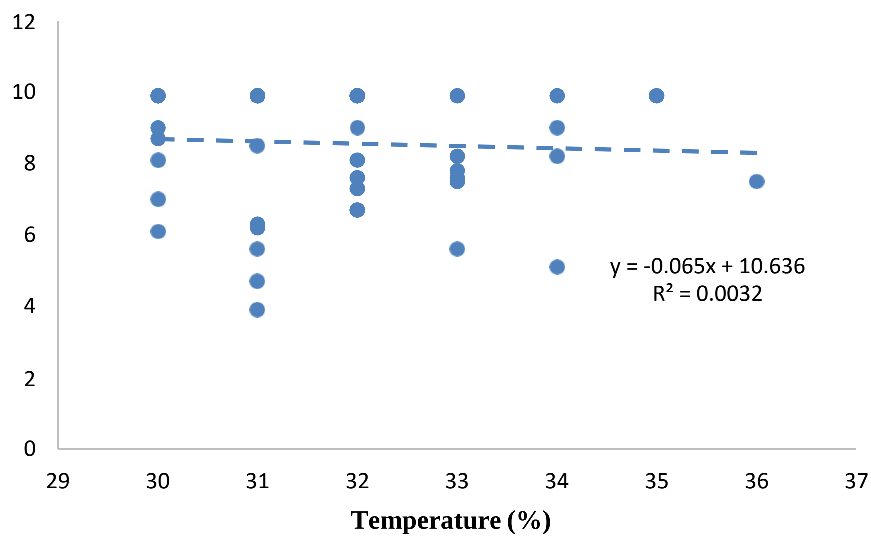

Figure 17: Influence of VOCs on temperature inside smoke house

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Levels of Particulate matter ($PM_{2.5}$)

Table 6 present the mean levels of the variables studied in all locations. As shown in Table 4, the mean level of particulate matter inside the smoke house recorded was 321.58 μg/m^3 with a minimum and maximum value of 164 μg/m^3 and 493 μg/m^3 respectively at a standard deviation of 90.527. The range of particulate matter outside recorded was 155 μg/m^3 and 255 with a mean value 178.60 μg/m^3. Whereas the particulate matter recorded at the control point also ranged from 42 μg/m^3 to 266 μg/m^3 with a mean of 175.80 μg/m^3.

Comparing the mean values of PM2.5 in the various locations revealed that, PM2.5 found in the indoor and outdoor were significantly different ($t = 11.9$, $p < 0.05$), PM2.5 in the indoor and control were significantly not the same ($t=12.0$, $p < 0.05$). However, the PM2.5 found in the outdoor and control locations were significantly not different ($t = 0.69$, $p > 0.05$). The outcomes of the results using the t-test implies that mean concentrations of PM 2.5 recorded inside the smoke house and outside locations were significantly different indicating a possible differential impact.

Volatile organic compounds

The mean levels of volatile organic compounds found inside the smoke house was 8.56mg/m^3 with minimum and maximum values ranging from 3.90 mg/m^3 to 9.90 mg/m^3. The mean volatile organic compounds levels recorded outside levels was found to be lower than VOCs inside (5.25 mg/m^3) with minimum and maximum values recorded at 1.90 mg/m^3 and 9.90 mg/m^3 whilst volatile organic compound control levels recorded ranged from 1.60 mg/m^3 and

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9.90 mg/m^3 with 4.38 mg/m^3 as the mean.

Similar to PM, findings of the research revealed a significant difference in the levels of Volatile Organic Compounds (VOCs) between the indoor and outdoor locations ($t=10.8$, $p < 0.05$), indoor and control ($t= 13.9$, $p < 0.05$) as well as VOCs of outdoor and control ($t=2.83$, $p < 0.05$), respectively.

Temperature

Temperature gradients also fluctuated over the three month study period. Mean temperature levels recorded inside was 31.85 ^{o}C with minimum and maximum values ranging from 30 ^{o}C and 36 ^{o} C. Mean temperature levels outside the smokehouse rose relatively to 31.98 ^{o}C with mean readings recorded between 30 ^{o}C to 35 ^{o}C. In the control regions, temperature mean levels recorded was 31.98 ^{o} C and with a range from 5 ^{o}C to 38^{o} C as the mean.

Relative Humidity

Relative humidity values were found to fluctuate from locations where reading was taking over time. For instance, mean relative humidity levels recorded inside was 63.80 % with minimum and maximum values ranging from 0% and 9 %. The relative humidity levels recorded outside the smokehouse also ranged from 0% to 99% with a mean of 80.97% while the control levels ranged from 1% to 99% with 31.47 % as the mean, respectively.

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Table 7: Descriptive Statistics of Variables

Variables	Minimum	Maximum	Mean	Std. Deviation
Pm Inside	164	493	321.58	90.527
Pm Outside	155	255	178.60	19.840
Pm Control	142	266	175.82	23.737
VOC Inside	3.90	9.90	8.5650	1.6380875
VOC Outside	1.90	9.90	5.2550	1.7041748
VOC Control	1.60	9.90	4.3883	1.6459598
Temperature Inside	30	36	31.85	1.436
Temperature Outside	30	35	31.78	1.329
Temperature Control	5	38	31.47	3.864
Rel. Hum Inside	0	99	63.80	41.088
Rel. Hum Outside	0	99	80.97	25.534
Rel. Hum Control	1	99	83.88	21.091

Temporal Distribution of Particulate Matter ($PM_{2.5}$) and Volatile Organic Compounds in the Indoor and Outdoor Environments

Tables 8-11 shows the non-parametric analysis of data using the Krustal-Wallis test. Non-parametric statistics is used mostly when the sample size used for a study is not normally distributed and not that large (Bluman, 2004). The essence of employing a non-parametric test is that it helps in testing hypothesis better especially when not dealing with human population

Relative Humidity

As shown in table 8 , It is observed that relative humidity measured inside the sixty (60) selected smoke house was same across the three months monitoring was done that is March, 2017- May, 2017 meaning there is no significant difference or variations ($p > 0.05$) in relative humidity measured

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inside the sixty selected smoke houses therefore the null hypothesis is retained.

Relative humidity outside (10 meters from the smoke house) levels taking across the categories of the months (March, 2017 – May, 2017) in the 60 locations was significant at 99% Confidence level indicating that there are variations in the distribution of relative humidity outside across the three months, therefore the null hypothesis is not true and therefore rejected. Lastly on relative humidity, the relative humidity control (20 meters from the smoking rooms) was ($p < 0.05$) significant at 95% confidence level indicating that there are differences in the distribution of relative humidity control across the three months therefore the null hypothesis is rejected.

Table 8: Non-parametric tests of the Distribution of Relative Humidity across the Study Location

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of REL HUM INSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.440	Retain the null hypothesis.
2	The distribution of REL HUM OUTSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
3	The distribution of REL HUM CONTROL is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Particulate Matter

In table 9 , Particulate matter levels recorded outside the smokehouse or smoking rooms and particulate matter levels recorded at the control points in all the sixty locations were significant ($p < 0.05$) at 95% respectively indicating that there are differences or variations in the distribution of particulate matter inside and outside the smoke house across the three months. Particulate matter

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inside the smoke house and particulate matter outside the smoke house however did not show significant difference ($p > 0.05$) therefore the null hypothesis is retained.

Table 9: Non-parametric tests of the Distribution of Particulate Matter across the Study Location

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of PM INSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.068	Retain the null hypothesis.
2	The distribution of PM OUTSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.001	Reject the null hypothesis.
3	The distribution of PM CONTRO is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.008	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Temperature

As shown in table 10, temperature inside the smoke house levels recorded, temperature outside the smoke house and temperature control were all significant ($p < 0.05$) at 95% level indicating that there are differences in the distribution of temperature across the three months that is March, 2017- May, 2017.

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Table 10: Non-parametric tests of the Distribution of Temperature across the Study Location

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of TEMPERATURE INSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
2	The distribution of TEMPERATURE OUTSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.
3	The distribution of TEMPCONTROL is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.000	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Volatile Organic Compounds

In table 11, Volatile Organic Compound levels recorded inside the smoke house did not show significant differences in the distribution ($p > 0.05$) across the categories of months that is from March 2016-May 2017, the null hypothesis was retained but for volatile organic compound outside ($p < 0.05$) and volatile organic compound control ($p < 0.05$) the null hypothesis is therefore rejected indicating that there are significant differences in the distribution of volatile organic compounds across the study months.

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Table 11: Non-parametric tests of the Distribution of Volatile Organic Compounds across the Study Location

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of VOC INSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.233	Retain the null hypothesis.
2	The distribution of VOC OUTSIDE is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.021	Reject the null hypothesis.
3	The distribution of VOC CONTROL is the same across categories of MONTH.	Independent-Samples Kruskal-Wallis Test	.003	Reject the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

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CHAPTER FIVE

DISCUSSION

Introduction

This chapter discusses the findings of this study. The chapter starts by describing the current findings relating to indoor air quality and how it affects the health of fish smokers. The chapter also compares the result to international standards (WHO and Ghana EPA) and implications of variables studied on the health of humans as has been discussed in related studies. The purpose of the chapter is to help analyze the trends in terms air quality in fish smoke houses and also help draw conclusion based on research objectives and hypothesis.

Characteristics of Women in Fish Processing in Abuesi

A total of four hundred and thirty-four female fish smokers from Abuesi were drawn to participate in the research. Majority of the women were middle aged women who were above 40 years old and have lived and depended on this economic activity for their livelihoods for a longer period of time. The findings suggest that the fish processing enterprise in the District was ageing and not attracting the young literate generation who may have the capacity to manage things better.

In Ghana, women are dominant in traditional fish processing and trade be it in relation to large or small-scale operations (Finegold et al., 2010). This position is long-standing as indicated by their traditional roles, which, interestingly, include roles in coastal areas and inland markets (underlining the historical importance of fish trade in Ghana) (Ferraris & Koranteng, 2004). At landing centers, the "konkohene" (whose role dates to the early 20th century) sets or influences the prices at which fish is sold from the boats and although

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these women traders may advance fishing trip costs to boat-operators, which in turn will give them access to that boat's catch, the price-setting mechanism means that they will not buy at the preferential prices that so often result from trader-credit relationships in fisheries (Finegold et al., 2010).

There is some indication of erosion of these systems (e.g., in Sekondi, where prices are negotiated on an individual basis), particularly in places with improved landing facilities notably where landing fees are payable – or where there are particularly successful and powerful fish mongers. In Western Region, smoking is the most common form of fish processing (Finegold et al., 2010). Women use so-called Chorkor kilns, where fish is slowly smoked on stacked racks, with relatively efficient use of fuel wood, producing a relatively evenly-smoked product (Gordon & Owusu-Adjei 2011)

The level of literacy among fish smokers in Abuesi was low. In the findings of this research, about 72% of the respondents had only completed primary school. This result confirms Ghana Statistical Service report (2010) that formal education among most coastal dwellers of Ghana is low.

Energy source used for smoking at Abuesi

Fire wood which is termed "Ehena" was the main source of energy used by fish smokers at Abuesi. The biofuels and smoking practices used were not different from those used by fish smokers in other coastal areas in the Country (Neequaye-Tetteh et al., 2002; Kogbe, 2015).

As discussed earlier, fish smoking is done at the artisanal level by women in coastal towns and villages and in areas along rivers and the shores of Lake Volta. The reasons for smoking fish are varied but, as far as Ghana is concerned, the process has proved relevant to prolonging shelf life; enhancing

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taste and increasing utilization in food preparation; reducing waste at times of bumper catches; storing for the lean season; increasing protein availability to people throughout the year (Neequaye-Tetteh, 1989). Therefore, depending on the purpose, fish smokers choose a type of biofuel that would be perfect for their work.

The findings obtained through this study was not different from others conducted in most developing countries across the globe. For example, a study by Ezzati et al. (2002) have reported that close to 50% of the world population, around 3 billion people, use biomass fuels as their primary source of domestic energy for cooking, home heating, and light, ranging from near 9% in developed countries to more than 80% in China, India, and Sub-Saharan Africa. In the rural areas of Latin America, approximately 30 to 75% of households use biomass fuels for cooking. Wood is the biomass fuel most frequently used both as unprocessed wood and as charcoal, the latter having far lower impact in indoor air pollution. In some regions, especially in sub-Saharan Africa, approximately 20% of the wood energy harvested is processed into charcoal and could reach 50% in some countries. Use of animal dung, crop residues, corncobs, and grass increases when wood is scarce or the forests are situated far away from the community.

The global energy derived from biomass fuels has fallen from 50% in 1900 to nearly 13% in 2000, but recently it seems to be increasing, especially among the poor. The current socioeconomic situation in many developing countries suggests that the use of biomass fuels will continue in the coming decades. In these countries, nearly 2 million tonnes of biomass are burned every day. In rural India, nearly 90% of the primary energy is derived from biomass

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(wood, 56%; crop residues, 16%; dung, 21%). The total annual average of wood production used for fuel in developing countries increased approximately 16.5% over the past decade to about 1, 550.000 tonnes (Balakrishnan et al., 2002).

Research conducted on the constituent of these biofuels shows that, a significant number of these wood smoke constituents are known to be toxic or irritants for the respiratory system, including respirable PM (PM_{10}), carbon monoxide (CO), nitrogen and sulphur oxides (NO_2, SO_2), aldehydes (e.g., formaldehyde), polycyclic aromatic hydrocarbons (e.g., benzo- pyrene), volatile organic compounds, chlorinated dioxins, and free radicals. Many substances can act as primary pollutants, irritants, and co-carcinogenic compounds (Larson & Koenig. 1994).

Reported Health Related Issues Associated with persistent Exposure to Biofuel Combustion

Health reported cases in relation to combustion of biofuels used includes eye infections, headache and cough. Most of the reported health cases resulted from persistent exposure to smoke from fire wood used by fish smokers of Abuesi. This observation confirms with the self-reported symptoms associated with biomass fuel use reported by (Odoi – Agyarko, 2009). The research however found that, prevalence health symptoms was influenced by factors such as age and number of years' experience in fish smoking but not one's marital status, educational level and religious affiliation.

With regards to the link between number of years spent smoking fish and the frequency of self-reported eye problems, it was found that, prolonged exposure to biofuel for smoking fish is likely to cause eye infection or in some

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cases resulted in the loss of one eye or both (Odoi-Agyarko, 2009). Eye irritation, mostlyincur in the form of tearing whiles smoking (Khushk, Fatmi, White & Kadir, 2005). There was a massive exposure response between number of years of employment as a fish smoker with chronic cough, eye problems and other symptoms. A similar observation was made by Flintwood – Brace, (2016). This study showed that several factors in synergy increase health risk from indoor air pollution resulting from extensive use of biomass fuel for fish smoking. Consequently, the likelihood of fish smokers to experience health symptom in her lifetime is high (Armah, Odoi & Luginaah, 2015).

Knowledge of Female Fish smokers about Health Consequences of persistence Exposure to Smoke

In order to know the extent of vulnerability to health-related problems as a result of fish smoking, the study further investigated the awareness of respondents to the health consequences of their daily endeavors. The findings of study revealed that, most of the fish smokers had limited knowledge about the implications of their work.

Understanding the health of complication or risks associated with fish smoking was more related to one's educational background (Table 5). As shown in this study, respondents who had attained formal education knew that, they are at risk or can face health problems because of their work. However, most of them did not know the actual health complications of smoking. In some occasions victims have experienced symptom of which they believed to have been caused by constant exposure to fire or smoke. The result was expected since the literacy levels recorded was low.

Across socio-demographic groups, the majority of respondents were

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aware that smoke from cooking and heating was a health hazard. Majority of the respondents thought that there was nothing they could do to help reduce them been exposed high levels of smoke. Analyses of the results indicated that the awareness about interventions for reducing indoor smoke was relatively low, except for a few respondents who cited using protective materials. In a study by Odoi-Agyarko (2009), dried biomass fuels could also be used in a judicious way to reduce health risk from biofuel combustion. Prevention of health problems may perhaps require continuous Health education for individuals and other organized groups at fish smoking communities. Health education involves provide information and training individuals and communities how to prevent diseases (Flintwood-Brace, 2016).

Fluctuations and Health Implications of Temperature, Humidity, Particulate matter (PM 2.5) and Volatile organic compounds in Smoke Houses

Temperature and Humidity

Temperatures recorded throughout the study period ranged from 30 ^{o}C to 36 ^{o}C. The temperature values recorded were above recommended standards which is similar to the temperature levels recorded in the study of Sonnie and Andrews (2012). The temperature values recorded was considered high especially inside the smoke house where the women spend about 90% of their time smoking. On the other hand, humidity values fluctuated from sampling locations; inside, outside and the control respectively. Exposure to high temperatures has the ability to cause severe damages to health of fish smokers. Indoor temperature and humidity are intertwined. Humidity levels are likely to drop in places or areas where temperatures are so high. This scenario can

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explain the low humidity levels inside the smoke house**.**

The Canadian Standards Association recommends maintaining even office temperatures below approximately 26°C under conditions of typical relative humidity (CAN/CSA Z412-00). This suggest that the temperatures recorded between 30 ^{O}C and 36 ^{O}C can be considered as unhealthy for the fish smokers at Abuesi (Anderson, Carmichael, Murray, Dengel & Swainson, 2013). Thermal comfort is important for health and well-being. An environment that is too warm can result in people feeling tired and uncomfortable which may impact their well-being and quality of life.

However, a limitation of these standards is that thermal comfort is subjective and influenced by several factors, including clothing, activity level, metabolic rate, age and pre-existing medical conditions (Anderson et al., 2013). Also, thermal comfort temperatures may not reflect the temperatures at which people experience health impacts from heat. From a health perspective, it is important that any maximum indoor temperature standard considers health based evidence rather than comfort thresholds alone. Reports by the World Health Organization (WHO) provide guidance on thermal comfort and suggest that there is minimal risk to health when indoor temperatures are between 18°C and 24°C.

This temperature range is based on research examining the health impacts of temperature for healthy individuals under conditions of appropriate clothing, humidity and air movement (i.e. not under high winds). The temperature range identified by the WHO has been acknowledged as the range within which health is optimally protected and is supported by recent scientific findings.

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The health impacts of extreme heat include heat stress, heat stroke, morbidity and mortality. People who experience high temperatures for prolonged periods, or are sensitive to heat, are the most vulnerable. This suggest that the female fish smokers are also vulnerable to these health problems.

There is still little evidence that specifically examines how indoor temperatures influence the health risk from heat. Indoor and outdoor heat are related, although there are some differences (Höppe, 2002). Indoor temperature is modified by other factors related to building design and construction (e.g. quality of insulation), location of apartment unit (level of building, orientation), room type, and occupant behavior (e.g. activity levels, density of occupants). Yet unlike outdoor temperature, indoor thermal conditions are not routinely monitored which makes studying the association between indoor temperature and health challenging. However, a limited number of studies have focused specifically on the effects of high indoor temperatures, and demonstrate increased health impacts. For example, research from New York City, US found a greater proportion of emergency service distress calls for cases of respiratory illness in people in buildings with indoor temperatures above a 26° threshold than in buildings with temperatures lower than 26°C (Uejio et al., 2015).

Particulate Matter

Particulate matter is a complex mixture of particles of several sizes and chemical compositions. Depending on the aerodynamic diameter of the particles, the term PM_{10} is used to indicate particles with a diameter of up to 10 μm and PM 2.5 for particles with a diameter up to 2.5 μm. Within the PM 2.5 category there is a distinction between fine (≤ 2.5 μm) and ultra-fine (<0.1 μm) particles. The largest particles, are the coarse fractions that are mechanically

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produced by the break-up of larger solid particles. These particles include windblown dust from agricultural processes, soil, unpaved roads or mining operations. Traffic produces road dust suspended from the road surface. Near coast, evaporation of sea spray can produce large particles as well. The brakes of vehicles produce particles in somewhat smaller sizes. Fine fractions are largely formed from gases. The smallest particles, less than 0.1 μm, are formed by condensation of substances or combustion. Hence, the size and composition of particles in the ambient air varies.

This study measured and compared the PM2.5 inside the smoke houses, outside the smoke house and an area used as control point. As seen in this study, the highest mean values were found inside the smoke followed by outdoor locations and control locations respectively. All the PM2.5 obtained were above both the WHO (25 μm) and Ghana environmental Protection Agency (35 μm) threshold for indoor air quality. The PM2.5 recorded in all locations were about 3-6 times higher than permissible levels fish which tells the extent at which fish smokers at Abuesi are exposed these harmful emissions since they spend more than 4 hours a day inside their smoke rooms.

These results were consistent with that of Babcock (2006) who studied the effects of traditional cooking technologies and small control interventions on indoor air quality in Capo Paloma, Panama. Further test also suggest a significant difference ($p < 0.05$) in the PM 2.5 inside and outside, inside and control but no significant difference was found in the reported PM 2.5 of the outdoor and control locations ($p > 0.05$). This trend also suggests that, the presence of PM2.5 were distributed evenly in the environment of the smoking house. This also accept the null hypothesis that, there are statistical difference

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in the PM 2.5 levels in of the indoor and that of the outdoor environment. The similarities in PM 2.5 between indoor environment and outdoor locations might be caused by environmental conditions such as wind directions, time, and topography. Based on this result, it is believed that women inside the smoke house are likely to experience the negative outcomes of high values.

Particles in the atmosphere have received much interest in the last decade due to the fact that increasing epidemiological and experimental evidence reflect a negative impact on human health and the environment (WHO 2003 & EPA 2004). However, it is still not clear which substances in PM cause the observed adverse effects.

To investigate the health effects of PM, it is significant to take particle size, chemical composition and number-concentrations into account, since these metrics reflect the biological mechanism through which particle pollution is assumed to cause health effects (Weijers et al., 2001). Particulate matter arrives in several places in our air ways and lungs through inhalation. Particles up to PM10 are called inhalable particles, ranging from particles with an aerodynamic diameter below 0.1 µm to 10 µm (Heinrich et al., 2007).

Epidemiological studies reflect that particles smaller than 10 µm, can penetrate into the air ways by inhalation and penetrate deeper into our respiratory system than larger particles to cause severe health hazards and even premature mortality. Short-term effects of people exposed to PM 2.5 may include inflammatory reactions in the lung, respiratory symptoms, adverse effects on the cardiovascular system and increases in medication use, hospital admissions and premature mortality (WHO, 2005). Long term exposure to PM is also coherent with severe (chronic) health effects such as increases in lower

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respiratory symptoms and chronic obstructive pulmonary disease, reduction in lung function in children and adults, and premature mortality. Reduction of life expectancy is mainly due to cardiopulmonary (affecting both the heart and the lungs) mortality and probably to lung cancer (WHO, 2005). The exact long-term effects from exposure to particulate matter are however still ambiguous, as a result of conflicting results in long-term exposure studies (Folkert &Wieringa 2005).

Apart from the fish smokers themselves, young children of fish smokers are also vulnerable to smoke related diseases. Children, infants and fetuses differ strongly from adults in toxico-kinetic processes, e.g. lower body weight, higher relative weight of liver, higher ratio between body surface and body weight, smaller lung calibre, higher particle deposition in the respiratory tract, immature lungs etc. Moreover, the lungs are completely formed at birth and remain immature until about 6 years (Schwartz, 2004). According to Heinrich et al, (2007), children are likely to experience health complications due to the fact that the lungs are not fully developed, toxins and other substances can pass more easily through the epithelial layer. Immature lung tissue makes children more vulnerable to (fine) particulate matter.

Volatile Organic Compounds in Smoke Houses

Higher levels of VOCs were recorded in this study most in the smoke houses. The mean VOC concentrations also reduced from inside the smoke house to the immediate environment (outdoor) through to control locations respectively. This also accept the null hypothesis that, there are statistical difference in the VOCs levels in of the indoor and that of the outdoor environment. This study demonstrated that fish smokers inside the smokehouse

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were exposed to higher VOCs levels than people who had no direct contact with VOCs.

The concentrations of common VOCs in a given indoor environment strongly related to the existence of emission sources and the efficiency of ventilation (Kim, Harrad & Harrison, 2001). In this present study, the emission source was mainly from the combustion of fuel wood which produce relatively high amount of VOC. In some cases, indoor VOCs levels were extremely high especially inside the smoke house where smoking took place owing to low air exchange rates (AER) and poor ventilation (Huang et al., 2016).

Occupational exposure to VOCs are known to be very detrimental to human health. Volatile organic compounds (VOCs) are ubiquitous in indoor environments. As reported by Huang et al. (2016) inhalation of VOCs can cause irritation, difficulty breathing, and nausea, and damage the central nervous system as well as other organs. These symptoms however may depend on the number of years' victims have been exposed to fire or smoke and duration, age and experience gained in the fish smoking activity. As seen from Table 5 there was association between number of years spent smoking fish and eye infections

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CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The study sought to find out the health problems of fish smokers at Abuesi in relation to exposure to smoke due to the extensive use of biomass fuel as the main source of energy for fish smoking. The study was carried out to achieve these objectives, to:

1. Investigate the knowledge of fish smokers on human health risks associated with the use of biomass fuel,
2. To determine the proportion of fish smokers reporting health symptoms (e.g. headache, cough and eye symptoms),
3. Assess the levels of particulate matter (PM2.5) emanating from the burning of biomass fuel from the smoking of fish,
4. Assess the levels of volatile organic compounds emanating from the burning of biomass fuel from the smoking of fish,
5. Assess the temporal distribution of particulate matter (PM2.5) in the indoor outdoor environments,
6. Assess the temporal distribution of volatile organic compounds in the indoor and outdoor environment and
7. To determine the effects of long duration exposure to smoke on reported health implications of fish smokers at Abuesi.

Conclusions

In this study the relationship between numbers of years spent smoking fish and the frequency of reported eye infection or problem were examined and it was found out that the number of years spent smoking fish is closely

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associated with the frequency of reported eye cases. Fish smokers who had been in the smoking business for more than 9 years reported the most eye problems as well as cough and headache as compared to those who had worked less than 9 years.

It was also found out that one's educational background is associated with the understanding of health risks associated with the burning of biomass fuel for fish smoking. Fish smokers who had formal education were aware or had knowledge that been exposed to high smoke is detrimental to their health as compared to those who never had formal education. Therefore, based on the findings from the study educational attainment plays a crucial role in the level of awareness or knowledge of fish smokers on the health implications associated with the combustion of fuel wood as the main source of energy for the smoking of fish but whether the respondent is educated or not cannot prevent her from being exposed to high smoke.

Particulate matter ($PM_{2.5}$) monitored in all the three locations were all above the WHO (25 µm) and Ghana Environmental Protection Agency (35 µm) standards for indoor air quality especially those recorded in the smoking rooms which indicates that fish smokers are exposed to large levels of Vocs which is risky and their health is at stake as well as young children who are mostly carried at the back of their mothers during smoking. Same could be said about those who are not directly involved in the smoking activity, they are exposed to the smoke due to the movement of the smoke emitted but the impact not as compared to those who work inside enclosed smoke house with no appropriate ventilation and stay in the smoke hours for more than 4 hours a day. The study also demonstrated that fish smokers inside the smokehouse or smoking rooms

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were exposed to higher VOCs levels which is detrimental to their health since they spent more hours in the smoking rooms.

Recommendations

With the established findings derived from the study, the following recommendations have been made out.

1. Ministry of Fisheries and Aquaculture Development should conduct routine educational seminars and programmes to help inform fish smokers on the human health risk associated with high risk of exposure to smoke.
2. Fish smokers should be educated on the need for fish smoking to be done in appropriate ventilated smoke houses.
3. There is the need for further research to be conducted on PM2.5 and VOCs and their related human health exposure (non-respiratory symptoms) in relation to fish smoking.

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APPENDIX

APPENDIX A

QUESTIONNAIRE

SAMPLE OF THE STRUCTURED QUESTIONNAIRE USED IN THE STUDY

SCHOOL OF BIOLOGICAL SCIENCES UNIVERSITY OF CAPE COAST

DEPARTMENT OF ENVIRONMENTAL SCIENCE

QUESTIONNAIRE

SELF-REPORTED HEALTH STATUS OF FISH SMOKERS AT ABUESI: A FISHING COMMUNITY IN THE WESTERN REGION OF GHANA

INTERVIEWER

This is an academic research on self-reported health status of fish smokers from the use of biomass as the main source of energy for the smoking of fish being undertaken by student of the above institution. This exercise is strictly for academic purpose and respondent is fully assured that any information given will be treated as confidential. Thanks for your cooperation.

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SECTION A: SOCIO-DEMOGRAPHIC CHARACTERISTICS OF RESPONDENT

1	What is your Age?	15-20years	1
		21 - 26years	2
		27 - 32 years	3
		33 - 38 years	4
		39 - 44 years	5
		Above 44 years	6
2	What is your Marital status?	Single	1
		Married	2
		Divorced	3
		Widow	4
3	What is your highest level of educational attainment?	Non-Formal Education	0
		Primary Education	1
		Junior High School/ Middle School	2
		Senior High School / Vocational Training	3
		Tertiary	4
4	Number of years experienced smoking	1-4	1
		5-8	2
		9 or above	3
5	What is your religion?	Christian	1
		Moslem Traditional	2 3
		Other	7

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SECTION B: TYPE OF BIOFUEL USED FOR SMOKING

6	Material used in constructing smoking stove	Wood	1
		Stone	2
		Mud	3
		Cement	4
		Others	7
7	Type of fuel wood used for smoking	Firewood (plant, sugarcane, coconut, pal	1
		Animal dung	2
		LPG	3
		Charcoal	4
		Others	7
8	Which is the most common and available type used?	Firewood (plant, sugarcane, coconut, pal	1
		Animal dung	2
		LPG	3
		Charcoal	4
		Others	7
9	Which among the fuel wood do you prefer?	Firewood (plant, sugarcane, coconut, pal m kernel)	1

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		Animal dung	2	
		LPG	3	
		Charcoal	4	
		Others	7	
10	What is the reason for your choice?			
11	Do you use this regularly?	No	0	
		Yes	1	
12	Duration of hours spent smoking	< 1 hour	1	
		1 hour	2	
		2 hours	3	
		3 hours and more	4	

SECTION C: SAFETY PRACTICES AND PRECAUTIONS EMPLOYED DURING SMOKING

13	Do you protect yourself during smoking? If no skip to question 15.	No	0	
		Yes	1	
14	Which of these safety materials do you use during smoking?	Safety boots	No	0
			Yes	1
		Safety goggles	No	0
			Yes	1
		Hand gloves	No	0
			Yes	1
		Protective clothing	No	0
			Yes	1

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		Other		7
15	Which of these safety materials do you use most often during smoking?	Safety boots		1
		Safety goggles		2
		Hand gloves		3
		Protective Clothing		4
		Others		7
16	Do you practice any safety measures during smoking? If no skip to 18	No		0
		Yes		1
17	Which of the following safety measures do you practice during smoking?	Avoidance of eating	No	0
			Yes	1
		Avoidance of talking	No	0
			Yes	1
		Other		7
18	In case you have any accident or health issue as a result of smoking fish, where do you go for treatment?	Hospital		1
		Traditional healer		2
		Drug store		3
		clinic		4
		Others		5

19	Do you have any alternative work apart from fish smoking?	No	0
		Yes	1

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SECTION D: HEALTH HAZARDS AND PERCEPTION OF FISH SMOKERS ON HEALTH OUTCOMES OF BIOFUEL USAGE

20	Are you aware exposure to smoke can affect your health?	No	0
		Yes	1
21	Have you ever encountered any health hazards as a result of smoking?	No	0
		Yes	1
22	If yes, what was the symptom?	Headache	1
		Cough	2
		Phlegm/Wheezing	3
		Breathlessness	4
		respiratory disease (Chest cold, chest illness)	5
		Eye disease (redness, cataract, Pterygium etc.)	6
		Asthma	7
		Pneumonia	8
		Others Specify	

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23	Have you ever been hospitalised since the past two years?	No	0
		Yes	1
24	If yes, what were you diagnose of?		
25	Do you believe the disease you mention have any association with your current job?	No	0
		Yes	1
26	If yes, what relationship does smoking of fish using biofuels have on the disease mention?		

HOW OFTEN DO YOU EXPERIENCE THE FOLLOWING SYMTOMS/DISEASE

27		**0**	**1**	**2**	**3**
	Symptoms	Not experience	Once in a week	Twice in a week	Several times in a week
A	Headache				
B	Cough				
C	Phlegm/Wheezing				
D	Breathlessness				
E	Respiratory disease (Chest cold, chest illness)				
F	Eye disease (redness, cataract, Pterygium etc.)				
G	Asthma				
H	Pneumonia				

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28	Are you a member of association/group doing anything with fish smoking or processing?	No	0
		Yes	1
29	Does the association/group educate you about the health implication of continues smoking with biofuels	No	0
		Yes	1
30	When was the last time you had formal education on health implications of smoking	Less than a yr.	1
		1-3 yrs.	2
		4-6 yrs.	3
		7-10 yrs.	4
		10 yrs. and above	5

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