EXPOSURE TO CARBON MONOXIDE IN RURAL HOUSEHOLDS IN KINTAMPO-NORTH MUNICIPALITY, GHANA

BY

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DECLARATION

I hereby declare that this submission is my own work and that to the best of my knowledge, it contains no material already published or written by someone else nor material which has been acknowledged for the honor of some other degree or diploma at Kwame Nkrumah University of Science of Technology, Kumasi or any other educational institution, aside from where due affirmation has been made in the thesis.

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ABSTRACT

Carbon monoxide (CO) is a colorless, scentless and profoundly poisonous gas, virtually undetectable by an individual during exposure and causes non-specific side effects such as headache or nausea. Accurate estimation of health risks has been hampered by a paucity of quantitative exposure information, with women and children being the main groups exposed to this form of smoke. This study looked at the environmental health risk of exposure to CO from biomass fuel smoke. Carbon monoxide monitoring took place in a total of 60 households purposively selected from Babatokuma, in the Kintampo-North Municipality of Ghana. The cooking technologies studied were the tripod stove of the area, LPG stoves, and a modified version of the tripod stove. Measurements were made on a minute basis using Aeroqual Series 500 (S500) gas monitor. It was discovered that CO concentrations produced during the use of the tripod stove surpassed background values by a large margin (on average by a factor of around ten to twenty times) with high levels of COHb of 23.44 % compared to 7.13 % of the cohort group (LPG). With regards to the improved tripod stove, an independent test revealed that, despite a reduction in CO concentration (of 47.91- 26.703 ppm), the rate of impact is not significant ($p = 0.208$). The study further revealed that, an increase in the number of windows, significantly reduced CO concentration ($r = -0.666$, p-value < 0.001). The study results further revealed that, almost all the study population showed mild symptoms from CO exposure, with only few within the moderate zone. LPG users showed no symptoms. Chronic exposure could further worsen the situation, therefore, the improved stove should be constructed by the Municipality as fast as possible to help salvage the situation.

DEDICATION

This work is dedicated to my lovely kids; Sterling, Kendria and Felicity, to my lovely wife Kandis who has been with me throughout this difficult moment and finally, to all rural women in Ghana.

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LIST OF ABBREVIATIONS AND ACRONYMS

ATP	Adenosine Tri- Phosphate
CDC	Centre for Disease Control and Prevention
CO	Carbon monoxide
COHb	Carboxyhaemoglobin
COPD	Chronic Obstructive Pulmonary Disease
LPG	Liquefied Petroleum Gas
UNEP	United Nations Environment Programme
UNDP	United Nations Development Programme
UNICEF	United Nations Children Emergency Fund
BMF	Biomass Fuel
EPA	Environmental Protection Agency
WHO	World Health Organization
NIOSH	National Institute for Occupational Safety and Health

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Carbon monoxide (CO) is basically without color, scents and extremely harmful gas. Virtually difficult to be detected by an individual during exposure and it presents many side effects such as headache or nausea, yet can likewise drive the victim into coma and finally death (Prockop e*t al.,* 2007). Contamination from carbon monoxide originated from ancient days when people initially migrated to cold regions and decided to develop shelters, utilize fire in these shelters for cooking, warming and lighting. Flames from these shelters led to exposure to large amounts of carbon monoxide, proved by the smoke found in antiquated caverns (Albalak, 1997). Carbon monoxide is as a result of inadequate ignition of biomass fuel. Biomass fuel is any material derived from plants or creatures which is purposely burnt by people, with wood being the most well-known illustration. The utilization of this type of fuel is widespread (De Koning, 1985) and still continues to increase due to the increasing levels of poverty. Other scholars define biomass as natural materials created in inexhaustible way, classified into woody fuels and animal products (Panepinto *et al.*, 2017; Rada, 2017).

More than 3 billion individuals worldwide, most of whom are in developing countries, depend on solid fuels, for example, wood, waste, or harvest deposits for cooking and warming (Rehfuess *et al.*,2006), of which Ghana is no exception. Many international organizations such as World Resources Institute (WRI), United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP) and World Bank have recognized that majority of individuals living in rural communities in unindustrialized countries rely entirely on biomass fuels such as wood, crop residue and many more (WRI, 1999). A publication by EPA in 1997 showed that about 68% of the people in Kenya depend on biomass fuel (EPA, 1997). There are many negative health implications associated with the use of biomass and these are well documented in literature (Ezzati and Kammen, 2002; Goldstein, 2008; Hoskins, 2011), paramount among which is the use of these fuels indoors. The usage of this fuel type in various homes produces much smoke, particularly, when using tripod stove, with no chimney or any other ventilation systems to expel generated smoke out of the premises. These smoke exposes families to destructive quantities of gases such as carbon monoxide, benzene, etc. (WHO, 2004).

It is a verifiable truth that air pollution has various harmful impacts on human health and as such considered as a major issue for the global community (Mannucci *et al.,* 2015, Franchini *et al.,*2015; Mannucci and Franchini, 2017). Global statistics from the World Health Organization (WHO) estimated that air contamination is associated with an unexpected 9% of lung cancer deaths, 17% chronic obstructive pulmonary ailment, over 30% ischemic coronary illness and stroke, and 9% respiratory diseases (WHO, 2010). Exposure to carbon monoxide both acute and chronic is dangerous. At concentration surpassing 100 mg/m^3 averaged over 15 minutes, there is a limitation in the maximum exercise capacity, thereby increasing symptoms of heart disease, and reduces brain function (WHO, 2011). At the point when the concentration of carboxyhaemoglobin (COHb) in blood surpasses 25%, cognizance is lost; an expected demise level of 60% is normal. Chronic exposure above 7 mg/m^3 is associated with cardiovascular issues, which may likewise be related with respiratory ailments including asthma and pneumonia, neurological and psychiatric effects, and negative consequences for fetuses (WHO, 2010).

In Ghana, households are the leading consumer of biomass energy, especially among rural residents (Inkoom and Crentsil, 2015). Available statistics by the Energy Commission (2014) showed that the volume of traditional biomass that Ghanaian households consume accounts for an estimated 50% of the energy volume consumed nationally. Juxtaposing the increasing consumption of biomass in Ghana vis-a-viz the negative health implications associated with the use of biomass, it will not be wrong to attribute the many health-related sicknesses and deaths, especially in rural Ghana to the use of biomass.

1.2 Problem Statement

Carbon monoxide is one of the world's most pervasive natural toxins. Its exposure regularly goes unrecognized and can prompt huge morbidity and mortality. Studies have shown that CO poisoning can lead to mental injury, seizures, coma, and demise (Townsend *et al.*, 2002). CO poisoning can be classified as a serious public health issue (Wright, 2002). The International Energy Agency predicts that by 2030, annual deaths from exposure to biomass will increase whiles biomass utilization will likewise increase to 2.8 billion (International Energy Agency, 2010). The most extreme danger of CO poisoning in Ghana (as in many developing nations) is from exposure to biomass fuel smoke, especially in rural kitchens, given the pervasive use of firewood among rural household. What further worsens the danger is the poor ventilation of rural houses, as they lack chimneys to expel smoke from the kitchen environment. This has led to many hospital visitations in many rural parts of Ghana such as Babatokuma and in many developing countries (Duflo, 2008). In 2009, Kintampo-North and Offinso-South Municipality recorded as high 46.2% cases of headache, 31.9% of fatigue, 9.3 % of nausea, 13.2% of dizziness, 18.7% of drowsiness, 40.7% fever cases etc. (Dennis et al., 2018). These are peculiar symptoms of CO intoxication. The acute effects of CO exposure are well documented, however there is scarcity of knowledge regarding chronic effects especially in Ghana, hence the need for this research work.

1.3 Research Objectives

The general objective of the study was to assess the environmental health risk of exposure to CO from biomass fuel smoke in Kintampo-North Municipality, Ghana.

The specific objectives were to:

1. Monitor the level of CO in the kitchen environment of rural households in Kintampo-North Municipality.
2. Assess the carboxyhaemoglobin and hemoglobin response(s) from CO exposures among rural households in Kintampo-North Municipality.
3. Determine the impacts of the improved tripod stove on CO reduction.
4. Identify simple symptoms for reliable and early diagnosis of CO intoxication among rural households in Kintampo-North Municipality.

1.4 Research Questions

In order to meet the set objectives, the study answered the following questions:

1. What is the level of CO in the kitchen environment of rural households in Kintampo-North Municipality?
2. What are the carboxyhaemoglobin response(s) from CO exposures among rural households in Kintampo-North Municipality?
3. What are the simple reliable symptoms for diagnosis of CO intoxication at chronic levels among rural households in Kintampo-North Municipality?

1.5 Justification for the Study

Kintampo-North is one of the deprived Municipalities in Ghana, with farming as their major occupation (Ghana Statistical Service, 2015). The level of poverty in this Municipality compels majority of the people to resort to the use of fuel woods for their household activities, since it is relatively expensive to use other improved energy source. Many researches have suggested that CO exposures and biomass usage strongly correlates to poverty, particularly in regions where per capita income is less than US$1 per day (Jan *et al*., 2012; Nasir *et al*., 2015).

It must be noted that the problem of illness and death resulting from CO poisoning may be far greater than what has been recorded, since there are few data to quantify those who do not report to health facilities after being exposed (Townsend, 2002). Nevertheless, the magnitude of this dangers and the outcomes of intervention techniques implemented are likewise not clear. A publication from All-Party Parliamentary Carbon Monoxide Group (APPCMG), stress on the urgent need for research into the impacts and occurrence of CO, with the purpose of identifying the occurrence of CO and to offer precise data on the number of people affected (APPCMG, 2011), This research is of much essence since most of the people affected in this Municipality are rural folks, lack knowledge on CO poisoning, exposed throughout their life time and also fail to report to hospital after been exposed.

This is important, considering recent evidence that exposure to CO may be associated with higher blood pressure in pregnant women in rural Ghana and may cause predisposition to hypertensive complications (Quinn *et al*., 2016). Women are obviously more vulnerable to CO exposures in rural kitchens in this Municipality, Ghana and most African communities considering the traditional role they play in cooking for the household. It is anticipated that the findings would help inform policy makers on the health dangers of chronic sub-clinical exposures to CO, which otherwise might proceed covertly.

CHAPTER TWO

LITERATURE REVIEW

2.1 Carbon Monoxide

Carbon monoxide (CO) is a potentially fatal, colourless, odourless, and tasteless gas that results from the incomplete combustion of carbon-containing fuels. Carbon monoxide is nonpolar and therefore lipophilic, diffuses rapidly across pulmonary epithelium when inhaled and it binds tightly to the central iron atom in the heme moiety of heme-containing protein such as hemoglobin, myoglobin, cytochromes, etc. (Dydek, 2009).

Families in various parts of the world have varying concentrations of indoor pollutant which prompt different health problems. In developed countries, health problems emanating from indoor air contamination include allergies and respiratory infections because of large amounts of biological or natural pollutants, connected to tobacco smoke as well as radon gas (Sundell, 2004). As developing countries continue to increase their wealth, these issues particularly ETS, are bringing up more common issues, adding to the burden of diseases currently being experienced due to the usage of unprocessed solid fuels (Bruce *et al.*, 2002).

2.2 Sources of Carbon Monoxide in the Environment

Incomplete incineration of biomass fuels is a major contributor to indoor air pollution globally (WHO, 2011). In many developing nations, burning of Biomass fuel (BMF) is done in the open which generates more smoke (Akunne *et al.*, 2006). Common sources of CO production include; exhaust from internal combustion engines, improperly ventilated gas appliances, malfunctioning heating, ventilation and air conditioning systems and open fires. Biomass combustion in tripod stoves, with little ventilation produces fumes having extensive amounts of destructive contaminants (Cooper, 1980; Smith, 1987; Smith and Liu, 1994) with severe health concerns, particularly to women engaged in cooking and children around their mothers (Bruce *et al.,* 2000; Smith*et al.,* 2000). Andreae and Merlet (2001), also supported the findings by Bruce and Smith (2000), by stating in their report that, vapor contaminants, for example, CO, CO_2 and O_3 are released during biomass combustion in these type of stoves.

2.3 Education and its Impacts on Carbon Monoxide Exposure

Level of education has direct impacts on the levels of CO exposure in rural communities' in Kintampo and Ghana as a whole. Education has a fundamental relationship to adult mortality (Lleras-Muney, 2005). A research across 22 European nations found that overall, individuals with low education will probably report poor general health and functional limitations (von dem Knesebeck et al., 2006). Feinstein et al., (2006), in their recent review about the impacts of education on health concluded that, there is strong documentations which shows how education affects health. Evidence shows that the individuals who attain a higher level of education will probably take part in sound practices and be more averse to embrace healthy behaviors, such as the use of clean energy to help avert CO intoxication (van Oort FVA et al., 2004).

2.4 Population Mostly Affected

Exposure to these toxins is especially articulated for women and for young children, as these individuals spend the best measure of time inside the home and close to a stove (Balakrishnan, 2002; Ezzati, 2002; Mestl *et al.*, 2006, 2007; Jiang, 2008). In homes with low salary inflow, especially in deprive communities like my study area, women frequently spend about three to seven hours daily close to tripod stoves, preparing food. In most cases, they also get close to fire sources for quite some times in order to get their body heated in chilly days. Young children are often carried at the back of their mother's during these periods, exposing them also to the dangers of this gas (CO). Subsequently, these children spend several hours taking in these gases into their body, during their developmental stages (WHO, 2004). Most people affected greatly by increments in encompassing carbon monoxide are those already susceptible to coronary illness. An increase in CO may compound their side effects, prompting hospitalization (Morris et al., 1995).

2.5 Mechanisms of Action of Carbon Monoxide

Carbon monoxide gets into the body via the lungs and is successively absorbed by the blood. It then bonds with hemoglobin located in red blood cells. CO absorption in the human system is very rapid such that, the capillaries actions remain low (Prockop *et al.*, 2007). CO and Oxygen compete for similar binding site on the hemoglobin molecule. CO in the body inhibits the amount of oxygen reaching these sites, and end up binding to the hemoglobin molecule located at this site. This result in the formation of Carboxyhaemoglobin (COHb). At the cellular level, carbon monoxide binds with heme-proteins such as myoglobin, cytochrome oxidase, mixed function oxidases (cytochrome P-450), tryptophan oxygenase, and dopamine hydroxylase. The protein, most likely to be inhibited at relevant levels of COHb is myoglobin, which abounds in skeletal muscle and the myocardium. By this procedure, CO weakens the capacity, in a process known as allosteric binding. CO intoxication impairs the capacity of hemoglobin to release oxygen at tissue delivery sites. Oxygen deprivation attributed to the restraint of hemoglobin is a dominant mechanism resulting in demise through an exposure incident. Furthermore, not exclusively does CO limits the aggregate sum of oxygen being transported, yet the idea of allosteric restricting delays delivery also, while high concentrations of CO end-up disrupting cell action specifically (Nelson *et al.*,1998).

Carbon monoxide applies consequences for cell absorption through both hypoxic and non-hypoxic systems. The two sorts of impacts are believed to be to a great extent (however not so much) the aftereffect of the capacity of carbon monoxide to tie to heme and modify work as well as digestion of heme proteins. The coupling affinity of carbon monoxide for hemoglobin is in excess of 200 times more unmistakable than that of the proclivity of oxygen for hemoglobin (Chakraborty et al., 2004). Development of COHb diminishes the O_2 conveying limit of blood and debilitates arrival of O_2 from Hb for its use in tissues. Through comparative mechanisms, carbon monoxide diminishes Oxygen (O_2) stockpiling in muscle cells by binding to, and displacing O_2 from myoglobin. Despite the fact that all tissues are defenseless to carbon monoxide-instigated damage, those with the greatest O_2 request are most helpless, together with the mind and heart. Developing fetus are mostly delicate focus of carbon monoxide, through hypoxic or potentially non-hypoxic mechanisms (Carratu *et al.,* 1993, 2000a, 2000b; De Salvia *et al.,* 1995; Lopez *et al.,* 2003, 2008; Stockard-Sullivan *et al.* 2003; Webber *et al.*, 2003).

2.6 Carboxyhaemoglobin Formation

The "hypoxic hypothesis" which clarifies the logic of CO poisonous quality was first portrayed by Douglas and Haldane in the twentieth century. Their work is still being used crosswise over numerous health institutions all inclusive (Haldane, 1895; Douglas *et al.*, 1912). Lippi *et al. (*2012) in their research work clarified that carbon monoxide is nonpolar and in this manner lipophilic, which diffuses quickly across pulmonary epithelium when breathed in and binds firmly to the central iron atom in the heme moiety of heme-containing proteins, for example, hemoglobin (Hb), myoglobin, cytochromes, and NADH reductase. Carboxyhaemoglobin is formed as a result of the binding of CO to Hb, which makes the hemoglobin incapable for binding and transporting oxygen, resulting in a reduction of the amount of hemoglobin, causing a functional anemia.

2.7 Health Effects of Exposure to Carbon Monoxide

The poisonous and destructive properties of carbon monoxide (CO) have been known for a considerable length of time; old Greeks and Romans used the gas for execution purposes (Ganong, 1995). It was named as "the silent killer" because of its capacity of not having colour, scent, or taste, formed from fragmented ignition of hydrocarbons and other carbon-containing compounds. Most recently, a faulty ventilation system in a New York restaurant led to a mass CO exposure which caused one death and hospitalized dozens of employees and restaurant patrons, according to a news report (CNN, 2014).

This shows how severe exposure to this dangerous gas can cause to population. In the up land area of Comitancillo, Guatemala, two ladies and two children passed on when utilizing a customary wood-fired steam bath termed as the *temazcal*. A Guatemalan daily paper detailed that the family, with age ranging from 10 months to 48 years, were overwhelmed by the vapor from the stem when performing a "Mayan rituals." (Barrios, 2010). Another article announced the real reason for death—harming from carbon monoxide was as a result of inadequate ignition of wood used to warm the steam bath setup (Marroquin, 2010).

Household air contamination from biomass was among the major cause of diseases in many sub-Saharan Africa and the fourth driving danger issue worldwide, ascribing to 3.5 million deaths and 4.5% of disability-adjusted life years (DALYs) (Lim *et al.*, 2012). Epidemiologic investigations have connected Biomass fuel (BMF) to lung cancer, asthma, tuberculosis, cardiovascular results, cataracts, visual deficiency, infant mortality, low weight babies and pre-birth mortality (Malvalankar *et al.*, 1991; Albalak *et al.*, 1999, 2001; Bruce *et al.*, 2000; Smith *et al.*, 2000; Boy *et al.*, 2002; Ezzati and Kammen, 2002; von Shirnding *et al.*, 2002; Warwick and Doig, 2004). Global Burden of Disease examined (GBD-2010) cooking with solid fuels (wood, dung, crop squanders, charcoal and coal). It was evaluated that, solid fuels caused about 3.5 million unexpected losses in that year, with a further 0.5 million outdoor air pollution deaths being ascribed to discharges from household cooking (Lim *et al.* 2012, Smith *et al.*,2014).

An investigation by Goldstein (2008) demonstrated that, CO was among the main source of death through poisoning in the United States (US) from 1979 to 1988. It continues to claim a total number of 438 lives annually as of late "1999-2012" in the US alone (Sircar, 2016), whereas accountable for around half the quantity of casualties globally in 2011 (Stefanidou et al., 2012).

2.7.1 Coronary Heart Disease

Many researches has been conducted to determine the negative impacts of CO poisoning to heart diseases, prior to exposure from the use of BMF. Lee *et al.* (2012), made a discovery that household utilization of solid fuels (wood) has a relation with increased risk of self-detailed coronary heart disease. Morris *et al.* (2000), envisaged the part carbon monoxide played regarding heart failure among old people in 1995. The group stated that, an escalation in surrounding CO levels prompted an increase in admissions to health facilities with heart failure. They recommended that, encompassing CO could fuel existing wellbeing conditions. A comparable report by Burnett et al. (1997), maintained this speculation, in their investigations, in 10 biggest Canadian cities. They discovered a positive connection among surrounding levels of CO and health facilities admission rates for congestive heart failures, especially in old people. The authors additionally uncovered more grounded association with CO than with different toxins, and specified that this observation was in connection with two different research works.

In any case, as in any investigation of this kind, they were not capable of deciding whether other components had influence on their outcomes, as it was hard to separate CO from various poisons. Regardless, after adjustment for confounding factors, a connection between encompassing CO levels and health facility admissions remained. Experimental studies have additionally shown that, low levels of CO antagonistically impact on patients with coronary illness during exercise. Allred et al. (1989), analyzed the impact of CO on myocardial ischemia. They discovered that, in the course of an exercise, COHb levels of 2% or 4% limits the length of time (by 4.2% and 7.1% respectively) before the start of angina (severe chest pain). A study by Dydek (2009) and Kao et al. (2005) grouped signs and indications associated with carbon monoxide poisoning and their equivalent carboxyhaemoglobin saturation as follows;

Table 2.1: Symptoms of diseases with their specific percentage carboxyhaemoglobin

Signs and Symptoms	COHb%
MILD	**0–30**
Mild/moderate headache	
Chest pain with cardiac disease	
Shortness of breath	
Nausea/vomiting	
Dizziness	
Fatigue	
Blurred vision	
MODERATE	**30–40**
Severe headache	
Chest pain	
Nausea/vomiting	
Disorientation	
Memory loss/confusion	
Syncope/loss of consciousness	
SEVERE	**> 40**
Cardiac dysrhythmias	
Cardiac arrest, Coma, Seizures	
Hypertension, Apnea, Death	

Gao and Mann (2009), Lee *et al.* (2005) and Mann *et al.* (2007), clearly suggested that, chronic breathing of biomass smoke may result in irritation and oxidative pressure which, thus, result to arterial blood pressure. According to a report by the WHO, one million individuals from all over the world pass on yearly due to lung cancer, with indoor air pollution contributing to 1.5% of these deaths (WHO, 2004). Many research has exhibited that, indoor air contamination is connected to an expanded danger of sicknesses, for example, tuberculosis (TB), tumor of the lungs, acute lower respiratory infection (ALRI), chronic obstructive pulmonary disease (COPD), stroke and eye infection, for example cataract (Dasgupta *et al.*, 2004).

2.7.2 Effects of CO on the Brain

2.7.2.1 Acute Pathophysiology

CO binds to cytochrome c oxidase in the cerebrum which brings about interruption of Adenosine Tri-Phosphate (ATP) amalgamation and expanded generation of receptive oxygen species (Brown *et al.*, 1992, Zhang *et al.*, 1992). Inflammatory changes in intense CO poisoning includes intravascular neutrophil initiation because of its associations with platelets. This prompts neutrophil degranulation and perivascular oxidative pressure (Thom *et al.*, 2006).

CO poisoning is associated with a wide range of acute and chronic neurological sequelae ranging from mild to extreme. Mild CO exposure is frequently connected with headaches, dizziness, nausea, and behavioral changes. Extreme CO exposures are associated with seizures, changed mental status, loss of awareness, cerebral edema and neuronal necrosis. The brain is the absolute most oxygen-demanding organ in the body with roughly 50% of that oxygen being used by the positively charged Sodium ion or positively charged potassium ion (Na+/K+) ATP-ase, which maintains resting neuronal membrane potential (Mayevsky *et al.*,1995).

2.7.2.2 Delayed Pathophysiology

In spite of the return of COHb to normal useful levels after exposure, mitochondrial dysfunction can persist on for a considerable length of time, prompting neuronal harm and demise through necrosis and apoptosis (Miró*et al.*, 1998). This produces neurological shortages in up to 33% of patients that can keep going for quite a long time following exposure. Symptoms mostly appear within a week following exposure and can include; Parkinsonian tremors, depression, learning impairments. (Thom *et al.*, 2006, Shprecher *et al.,* 2010). These delayed neurological shortages are known as delayed neurological sequelae (DNS) or prolonged neurological sequelae (PNS) (Thom *et al.*, 2004, 2006).

Yang *et al. (*2010) also made a similar discovery, when trying to have an in-depth knowledge of carbon monoxide intoxication. They came out also with the view that, CO intoxication may lead to necrosis, resulting to persistent neurological sequelae (PNS) and programmed cell death (apoptosis), resulting in delayed neuropsychological sequela (DNS), either because of CO-actuated damage alone or in mix with potentially hypoxia, in the same direction to the discovery also made by Miró *et al.* (1998). They reported that, patients with DNS experience symptoms like depression, anxiety, amnesia, cognitive dysfunction and that similar to those of Parkinson's ailment.

2.7.3 Respiratory Illness

Several documentations connect biomass combustion to increased dangers of acute lower respiratory infections in children and chronic obstructive pulmonary disease in adults (Malvalankar *et al.*, 1991; Albalak *et al.*, 1999, 2001). Several researches have determined the relationship among ambient carbon monoxide concentration and extent of clinic affirmations identified with respiratory disorders. Altogether, these examinations give confirmation to the relationship between increasing carbon monoxide concentrations and increasing danger of respirational manifestations which necessitates medical aid. (Burnett *et al.*, 2001; Cakmak *et al.*, 2006; Karr *et al.*, 2006, 2007; Linn *et al.*, 2000; Lin *et al.*, 2003; Slaughter *et al.*, 2005; Schwartz and Zanobetti 2006; Yang *et al.*, 2003).

A research by United Nations International Children Emergency Fund (UNICEF) uncovered that the predominance of acute respiratory infections in the Central Region of Kenya was because of overcrowding of families, living in small spaces and use of biomass fuels for cooking and warming, particularly amid chilly conditions (United Nation, 1998).

Children within rural homes exposed to BMF are prone to acute lower respiratory tract infections (ALRI), when equated to children residing in families utilizing biomass free energies. Within children below 5 years, the mortality owed to ALRIs was assessed to be more than 2 million losses annually (Smith *et al.*, 2000). Several studies in Lower Developing Countries (LDCs) have reported on the association between Indoor Air Pollution (IAP) exposure and ARLI (Armstrong & Campbell, 1991; Aderele and Johnson, 1992; Campbell et al., 1989; Cerquiero et al., 1990; Depmsey et al., 1996; De Francisco et al., 1993; Ezzati and Kammen 2001; Kossove 1982; Lopez-Bravo et al., 1997; Victora et al., 1994; Wesley and Loening 1996) and two further studies among Navajo Indians in the US

(Morris et al., 1990; Robin et al., 1996). The initial report of indoor cooking smoke connected to children pneumonia and bronchiolitis was in Nigeria (Sofoluwe, 1968). In 1980s was this trailed by reports from various domains (Collings *et al.*, 1990; Mtango *et al.*, 1992; O'Dempsey *et al.*, 1996; Pandey *et al.*, 1985; Shah *et al.*, 1994). Similar investigation which took place in Kenya revealed that, the proportion of contamination a kid is presented to, specifically connects with the peril of getting pneumonia (Ezzati and Kammen, 2001).

A confirmation in the health records at the Kericho District Hospital, Kenya, stated that, respiratory tract infections (RTIs) is the regular surely understood illness among children above and below five years. The research zone is largely rustic with their primary source of energy for cooking being biomass fuel. Women exposed to BMF smoke are more likely to experience the ill effects of Chronic Obstructive Pulmonary Disease (COPD), for example, chronic bronchitis than women who cook with electricity, gas and other cleaner fuels. Subsequently, indoor air contamination was accountable for more than 700,000 out of 2.7 million worldwide deaths because of COPD. In the African Region, indoor air contamination is accountable for 41,000 passing for every year because of COPD and 350,000 passing because of ALRI (WHO, 2004). More than one-third of all child demises causes via air contamination happen in the African Continent (WHO, 2004).

2.7.4 Cardiovascular Effects

Carbon monoxide is suspected to assume a major role in inducing cardiovascular diseases. There are epidemiologic confirmations that individuals exposed to high CO concentration have more cardiovascular morbidity and mortality than the normal rate in the populace (Lee *et al.*, 2012). Bell et al., (2009), reported that exposure to CO from biomass fuel may trigger cardiovascular diseases. Biomass fuel (BMF) contamination is factually and consequently associated with expanded cardiovascular illness (Brooket al., 2004). Later information has demonstrated that non-deadly ischemic occasions are likewise connected with an expansion in carbon monoxide fixations in most communities (Miller *et al.,* 2007). As of late, biomass smoke in Guatemalan ladies appeared to increase diastolic circulatory strain (McCracken *et al.,* 2007). Thus, it is likely that BMF addresses a great peril to cardiovascular health.

2.7.5 Developmental Toxicity

A Study conducted in Jumla, Nepal by Hessen *et al,* (2004), demonstrates that 8 h and 24 h total suspended particles and CO concentration are observed to be 8420 lg/m^3 and 13.5 ppm; 5000 lg/m^3 and 23.42 ppm, respectively. This high concentration causes low birth weight and infant mortality (Warwick and Doig, 2004; WHO, 2005). As women continue to undertake cooking activities throughout pregnancy, the developing fetus is exposed to these toxins indirectly. Also, children regularly spend their time close to their mothers while they are occupied with cooking assignments. In this way, women and children are greatly affected by the high concentrations of poisons accumulated inside their homes. Children younger than five (5) years are also in great danger since they spend greater part of their time with their mothers, often the younger ones (babies) are tied to their mother's body. The effect this length of exposure has on little adolescents is aggravated by various factors. These children have smaller airway, hence more vulnerable to inflammation. Their lungs are not completely developed until they are teenagers, so they breathe quicker. Likewise, their immune systems are not completely developed – a manner that may be further delayed by malnourishment. These evidences suggest that children absorb toxins more readily than adults and also retain them in their system for longer period (Budds *et al.,* 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and Size

Kintampo-North Municipality is located between latitudes 8º45’N and 7º45’N and Longitudes 1º20’W and 2°1’E. It shares boundaries with five other Municipals namely; Central Gonja Municipal to the North; Bole Municipal to the West; East Gonja Municipal to the North-East, Kintampo South Municipal to the South; and Pru Municipal to the South-East.

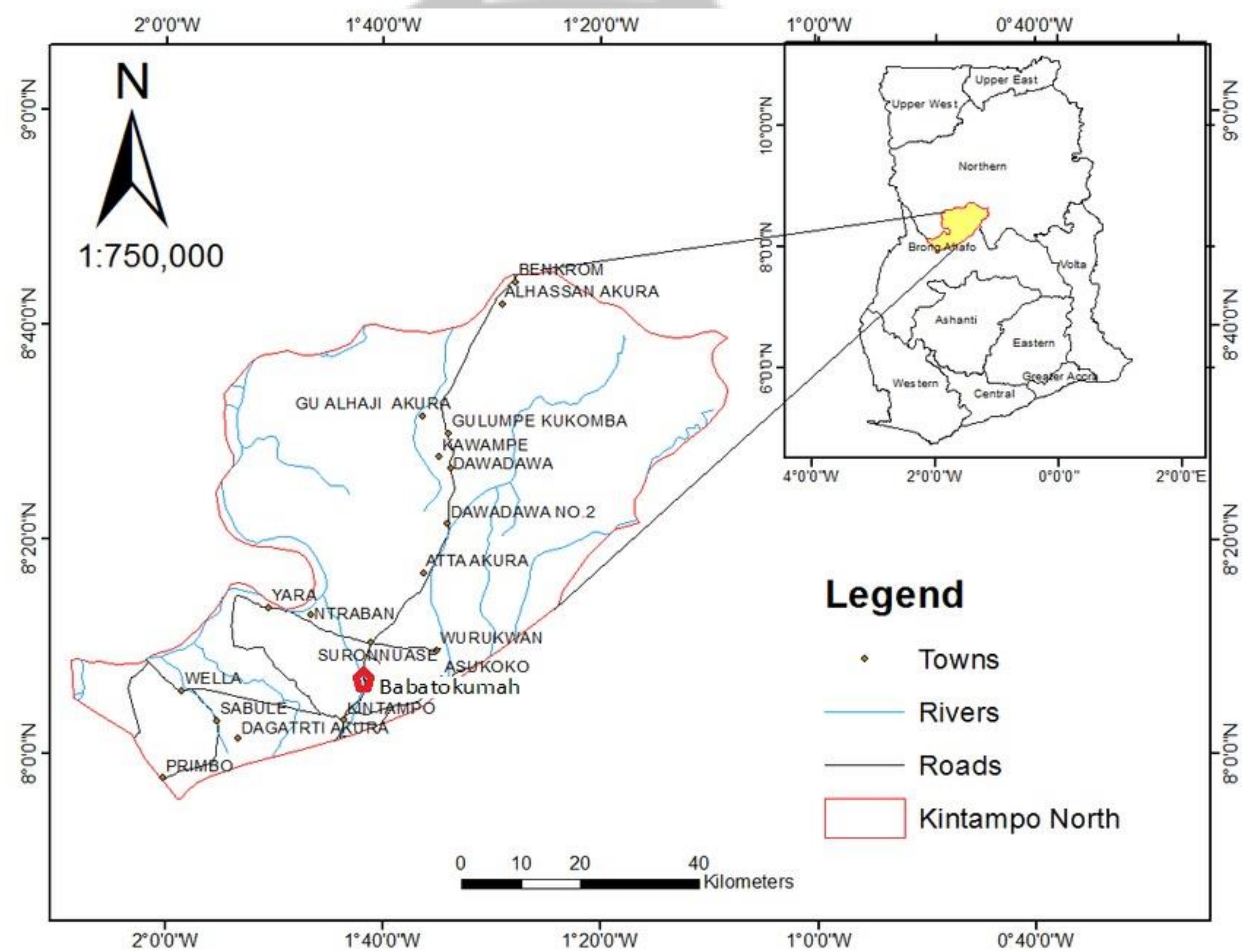

Figure 3.1: Map of Ghana showing Kintampo-North Municipality

3.1.2 Population Size, Structure and Composition

The number of inhabitants in Kintampo-North Municipality, as per the 2010 Population and Housing Census, was 95,480 representing 4.1 percent of the district's entire populace. Males constitute 49.6 percent and females represent 50.4 percent. Around 56.8 percent of the populace live in urban zones. The Municipality has a sex proportion of 98.2. The number of inhabitants in the Municipality is young (under 15 years) (42.4%) portraying an expansive base populace pyramid which decreases with few elderly people, 60 years or more (6.1%). The aggregate age reliance proportion for the Municipality is 88.2, the reliance proportion in the rustic regions is higher (98.2) than that of the reliance proportion in the urban regions (81.2).

3.1.3 Climate

The Municipality experiences the Tropical Continental climate, which is an altered type of the Tropical Continental or the Wet-Semi Equatorial kind of climate. This is expected to a great extent since the Municipality is in the transitional Zone between the two noteworthy climatic zones in Ghana. The mean yearly precipitation is between 1,400 - 1,800mm and happens in two seasons; from May to July and from September to October (Ghana Statistical Service, 2014).

3.1.4 Occupation/Economic activity

The main occupation in the Municipality is agriculture. Yam is basically the main crop cultivated in the area, being the main source of income to the residents. Different crop types grown in the area includes maize, cowpea, cassava, rice, plantain, egushie, groundnut and beans. Cashew, mango, tomatoes, onions, water melon, garden eggs and soya beans which have potential to increase the incomes of farmers, are also being grown on large scale.

3.2 Data Collection

3.2.1 Stakeholders Consultation

Several meetings were held with stakeholders in the community to make known the objectives of the study to them, and at the same time to seek their permission and views on the exposure to carbon monoxide resulting from cooking activities. The stakeholders that were involved included; the Unit Committee Chairman as well as the entire committee members, the Assembly Member for the area, the Chief and Elders of the area and the entire community members. The plate 3.1 depicts one of such meetings.

Plate 3.1: Stakeholder consultation

3.2.2 Selection and Enrolment of Study Participants for the Study

The study consisted of 57 healthy women and 3 males, purposively selected from the Babatokuma Community within the Kintampo-North Municipality. The consent of the participants was sought. The participants freely expressed their interest to participate in the study. Thus, none of the respondents was coerced to participate in the study. Their voluntary participation was ensured.

The inclusion criteria were;

(i) Participants were the primary cooks of the household, applied firewood as the primary source of fuel for cooking and non-smokers. Control cohorts were also selected from individuals living in the community but who applied liquefied petroleum gas (LPG) for cooking and were also non-smokers.

Exclusion criteria were

(i) Mixed fuel user (ii) pregnant, (iii) currently under medication, (iv) family history of TB or complicated cardiovascular disease

3.2.3 Questionnaire Administration

60 Questionnaires were administered to 60 households in the community to capture information on;

Table 3.1: Items on questionnaire administered

Theme	Items
Demographic characteristics	Age, religion, gender, educational status, occupation, level of income, principal cook
Kitchen characteristics	Size of the kitchen, number of windows, roofing material, type of stove, type of fuel, cooking duration, duration of exposure to CO
Health Impacts	Knowledge on hazardous nature of smoke, awareness of the dangers, simple symptoms from these exposures

3.2.4 Measurement of the Kitchen Environment

The volume of the kitchen or the cooking area from various households were determined. This was done to determine whether the volume would have influence on the amount of gas the cook is exposed to during cooking or warming of the household. Measurement was done by taking the length, breadth and height with the use of a tape measure.

3.2.5 Methods for Measuring Carbon Monoxide in Ambient Air

Carbon monoxide levels were determined from 60 households in the Babatokuma community. The level of CO in the kitchen environment of rural households was determined by placing Aeroqual Series 500 (S500) gas monitor in the kitchen to determine the gas levels. Instruments was positioned at a distance of 1.5 m away from the tripod stove and at a breathing stature. (Padhi *et al.,* 2010). The gas monitor measures to a range of (0-1000ppm), with an accuracy of ±10% and a resolution of 1ppm. The monitor was set to capture exposure trends for every minute, for an hour period. The data was then transferred to a computer.

The device is then connected to a laptop and data transferred, averaged to give the gas level for the one-hour period.

Plate 3.2: Measurement of CO using Aeroqual series S500

Plate 3.3: CO monitoring using Aeroqual series S500 at Babatokuma zongo

3.3 Laboratory Analyses

3.3.1 Carboxyhaemoglobin Analysis

Spectrophotometric method for estimating carboxyhaemoglobin was adapted in this study. This was based on the production of two-pigment mixture, by reducing oxyhemoglobin and methemoglobin with sodium hydrosulfite (Sodium dithionite). Absorbance of the pigment were measured at 420 and 432 nm, values were stable and reproducible when the solutions were buffered at a pH of 6.85. Venous blood was collected from all the 60 people, into an evacuated tube containing EDTA (potassium salt). 25 µL of the collected blood was added to 3mL of the hemolyzing solution (which is buffer: KH_2PO_4/K_2HPO_4 with 10-fold of diluted water) in a small test tube, mixed by inverting two or three times. 0.1 mL of this mixture was pipetted after 5 minutes into a cuvette having a critical volume of less than 1.2 mL, which already contains 1.15mL of the CO-Hb diluting solution. The cuvette was covered with Parafilm, mixed by inverting gently for several times and allowed to stand at room temperature for 10 minutes. Absorbance was read at 420 and 432 nm against a matched cuvette containing only COHb diluting solution.

Carboxyhaemoglobin was determined using an equation adapted from Rodkey *et al.* (1979);

$$S_{CO} = \frac{1 - (A_R \times F_1)}{A_R (F_2 - F_1) - F_3 + 1}$$

Where S_{CO} is the fraction of COHb in a hemolysate.

A_R is the ratio A420/A432nm of the samples in COHb diluting solution.

The three constants F_1, F_2 and F_3 were computed from the published molar absorptivity of reduced hemoglobin and COHb at 420 and 432 nm, with F_1=1.33330, F_2= 0.4787 and F_3= 1.9939.

Plate 3.4: Laboratory analysis for Carboxyhaemoglobin

3.3.2: Hemoglobin Analysis

This was determined in the laboratory with the use of URIT-3000 plus Hematology Analyzer, for both BMF and LPG users. Lytic reagent was added to the blood sample, which cracked the membrane of red blood cells promptly and transferred it into a compound which absorbed the wavelength of 540nm. The sample was taken to the analyzer, then the sample taking tube draws the blood to the analyzer. The blood was calibrated automatically and the results displaced on the screen.

3.4 Improved Traditional Stove as Intervention

An improved traditional stove was constructed as an intervention to the tripod stove used locally in the community. The stove was built with bricks, mud sand, iron rods, connected with a metal pipe, large in size to serve as a chimney to expel smoke from the kitchen environment to the atmosphere, thereby reducing the total amount of CO in the kitchen environment. Three locations from the sample households were chosen for the construction of the improved traditional stove. These areas were places with high CO emissions.

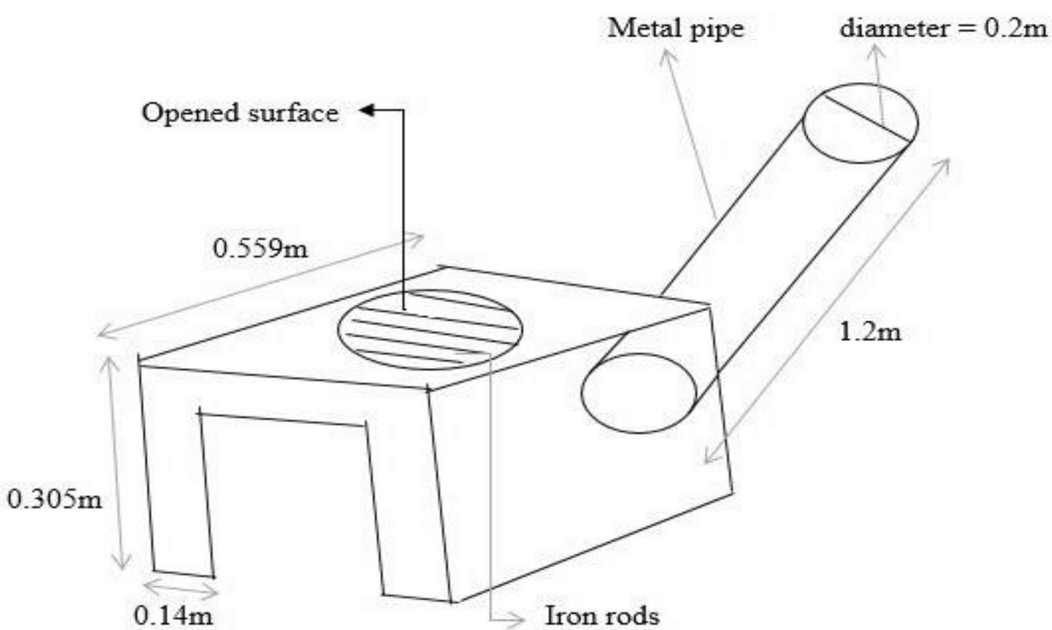

Figure 3.2: Schematic design of an improved stove

Plate 3.5: Construction and operational phase of improved traditional stove

3.5 Statistical Analysis

Questionnaires were analyzed using SPSS software version 21 after the questionnaire from the survey was checked for completeness and accuracy. The data was coded into an SPSS software for descriptive statistical analysis. Correlation analysis was performed to explain how kitchen characteristics impacted on CO exposure. Multiple regression analysis was also done to predict which symptom (s) was the major predictor of CO intoxication. Again, linear regression was also done to determine the effects of CO on COHb. Significance value was assigned at $p < 0.05$. Data was organized into tables, frequency and percentages. Other graphical representation in the form of graphs and charts were also used to present a pictorial representation of the findings.

The model below was developed to predict which symptoms shows CO intoxication.

$$CO = \beta_0 + \beta_1 COHbF + \beta_2 COHbD + \beta_3 COHbH + \beta_4 COHbEI + \beta_5 COHbCP + e$$

Where;

CO = carbon monoxide exposure

COHbF = COHb for fatigue

COHbD = COHb for dizziness

COHbH = COHb for headache

COHbEI = COHb for Eye Irritation

COHbCP = COHb for chest pain

e = standard error

3.6 Ethical Considerations

Ethical approval was sought and granted by the Committee on Human Research, Publications and Ethics at Kwame Nkrumah University of Science and Technology, School of Medical sciences and Komfo Anokye Teaching Hospital at each setting involved in the study. Participation was voluntary and anonymous (no personal identification was recorded) and confidentiality of the participants was ensured.

CHAPTER FOUR

RESULTS

4.1 Socio-Demographic Characteristics of Respondents

4.1.1 Demographic Characteristics

From the survey conducted, 95.0 % of the sample population were female while only 5.0 % were males. The results further show that majority of the respondents were within the age group of 36-60years, representing 51.6% of the total sample size. This was followed by those within the age bracket of 18-35 years, which accounted for 26.7%. Those who were above 60 years accounted for 15.0 % of the total sample and finally those below 18 years were only 6.7%. The marital status analysis showed that majority of the respondents were married. Those who were married formed 68% of the sample population whiles those unmarried were also 25.0 %. The divorced group formed 6.7%.

Majority of them had no formal education. As high as 68.0 % of the sampled population had no formal education and this is not surprising because in the rural areas, majority of the adult population either have no formal education or have lower levels of education. Those with basic education constituted 20% and those with secondary level of education were 10%. Only 1 person out of the 60 respondents had tertiary education. Majority of the respondents (53%) were Christians and 43% were moslems. Only two people, representing about 3% were traditionalists.

Table 4.1: Demographic characteristics of respondents

Variable	Frequency	Percentage (%)
Gender		
Male	3	5.0
Female	57	95.0
Age Category		
Below 18	4	6.7
18-35	16	26.7
36-60	31	51.7
Above 60	9	15.0
Marital Status		
Single	15	25.0
Married	41	68.3
Divorced	4	6.7
Level of Educational Attainment		
No formal education	41	68.3
Primary/ Junior High	12	20.0
Senior high/ O, A level	6	10.0
Tertiary	1	1.7
Religious Affiliation		
Christian	32	53.3
Muslim	26	43.4
Traditional	2	3.3

4.1.2 Income Status

Results presented in Figure 4.1 provides a summary on the income status of the respondents. The results showed that a large proportion of the respondents earned less than GH¢100 a month. Also, 30% of the respondents indicated that they earn between GH¢100 and GH¢250 a month and 25% earned above GH¢250 a month.

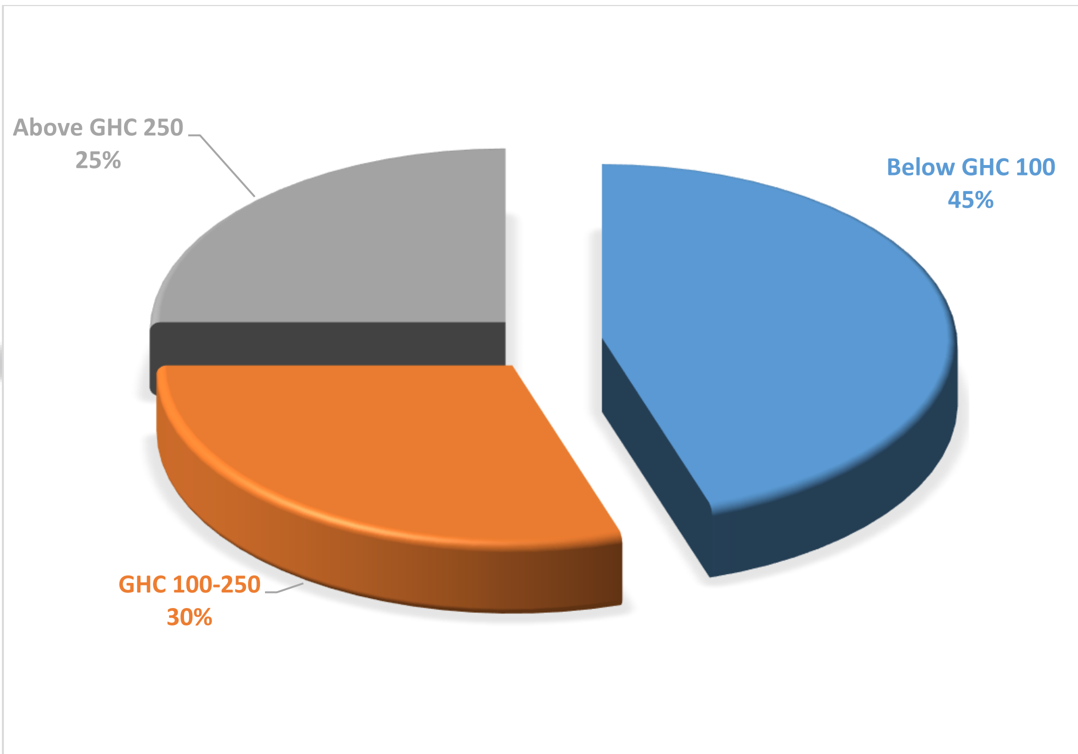

Figure 4.1: Income status of respondents

4.1.3 Type of Stove Used

The results presented in Figure 4.2 below showed that from the sampled population of 60, 45 of them used tripod stoves, which is the traditional way of cooking in many rural communities. In percentage wise, tripod stove had a percentage of 75, followed by LPG (15), which recorded very low percentage of 25.

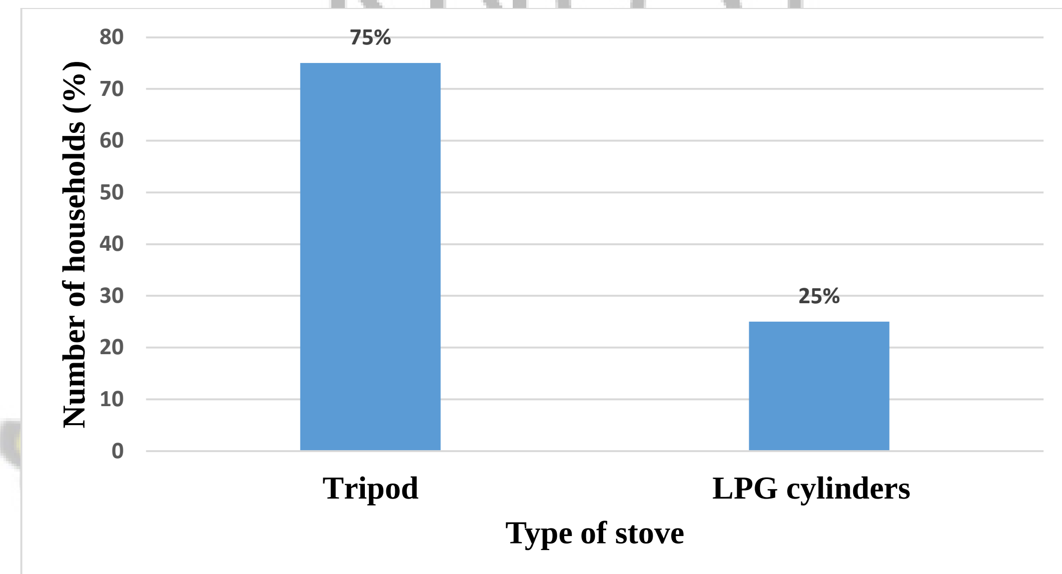

Figure 4.2: Type of stove used

4.1.4 Cooking Frequency

Figure 4.3 shows the distribution of respondents cooking frequency. From the sampled households, it was discovered that on a typical day, majority of the household's cooked twice a day: morning and evening. Only 17% and 5% of the households indicated that they cooked more than twice in a day and once a day, respectively.

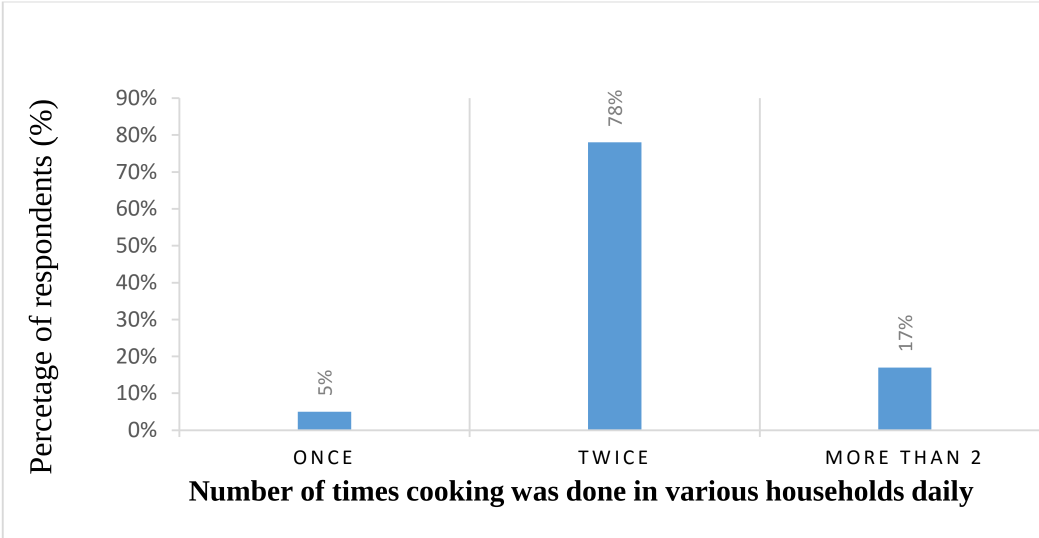

Figure 4.3: Frequency of cooking

4.2 Level of CO in the Kitchen Environment in Rural Households

4.2.1 Duration of Cooking

Figure 4.4 describes how long it took to cook a meal in the kitchen. It also depicted duration of exposure to carbon monoxide during cooking. From the figure, it was evidently clear that people who spent less than one hour in the kitchen environment were few with a percentage of only 5, followed by people who spent 1-2 hours in the kitchen and lastly 2-3 hours having the highest percentage of 75%. This clearly shows that majority of people were exposed to carbon monoxide daily for 4-6 hours, when they cooked twice.

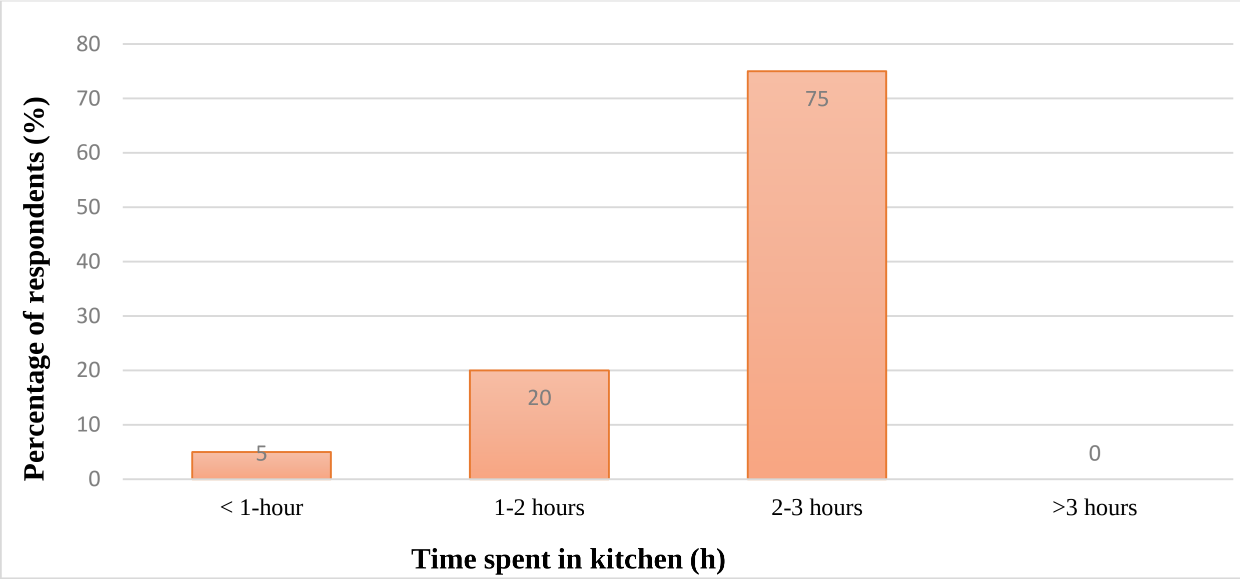

Figure 4.4: Approximate time spent in the kitchen during cooking

4.2.2 Duration of Exposure

Table 4.2 shows the distribution pattern of respondents in relation to duration of potential exposure to carbon monoxide. Duration of exposure in this context measured how long the people have been using biomass fuel for cooking. The results showed that 39 respondents, representing 65% of the sample may be potentially exposed to carbon monoxide for over twenty (20) years. Fourteen (14) respondents, representing 23.3% may be potentially exposed for 10-20 years and only 11.7% of the respondents might have been exposed for 5-10 years.

Table 4.1: Duration of potential exposure to carbon monoxide

Duration	Frequency	Percentage (%)
5-10 years	7	11.7
10-20 years	14	23.3
>20 years	39	65.0
Total	60	100

4.2.3 Levels of CO Contamination from BMF and LPG

Figure 4.5 showed the averaged carbon monoxide levels from households using BMF and LPG. From the survey, it was realized that, BMF recorded the highest value of carbon monoxide emission, whiles the lowest exposures were recorded in kitchens using LPG. BMF usage recorded mean CO levels of 21.054 (ppm), while LPG usage recorded mean value of 3.013 (ppm).

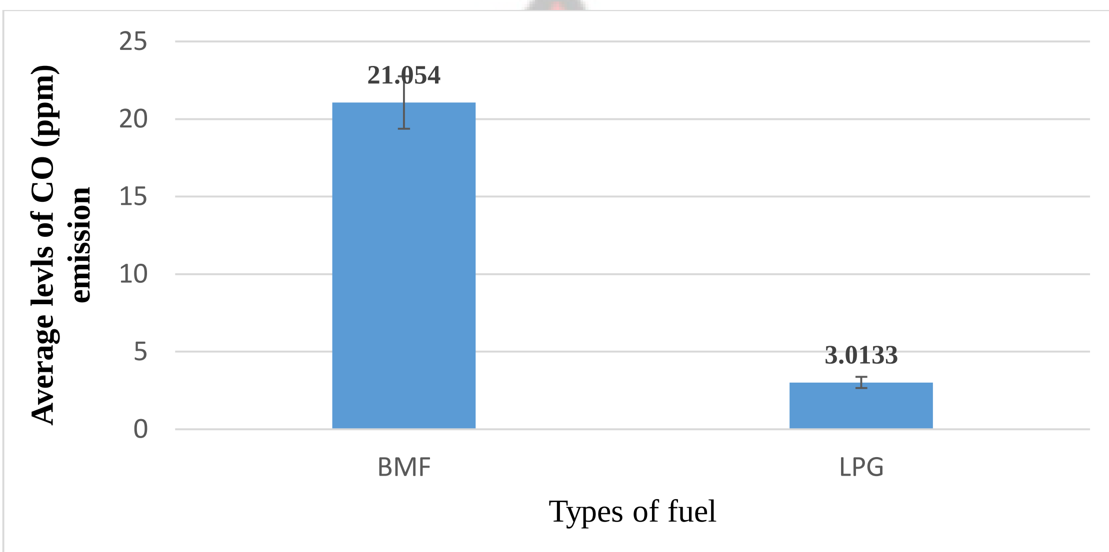

Figure 4.5: Emissions of CO (ppm) from usage of BMF and LPG

A test was conducted to examine the extent to which the difference in means was significant. The results of the test showed that, the difference in means in terms of CO emission levels from BMF and LPG usage was statistically significant ($p<0.001$). Thus carbon monoxide levels in households using BMF was greater than households using LPG.

4.3 Improved Traditional Stove (Tripod Stove)

The table below shows the average CO levels before and after the introduction of the improve tripod stove.

Table 4.4: CO levels in kitchen environment when improved stove was used (ppm)

	CO conc. (Mean)	**Mean Difference**	**Std. Deviation**
Local tripod stove	47.910	21.207	24.282
Improved stove	26.703		3.294

From the Table 4.4 it could be observed that there has been a drastic reduction in the total amount of CO levels when the improved stove was applied. When the normal tripod was used, CO emission was averagely 47.91ppm. This reduced to 26.703ppm, with improved stove. The difference between the two stove was 21.207ppm. A test was needed to examine whether the difference in means was statistically significant or not. The results of the test showed that, the difference in means between the improved stove and the old tripod stove was statistically not significant (p-value > 0.208). This meant that, the impact of the improved stove in CO reduction was minimal.

4.4 Relationship between Kitchen Characteristics and CO Concentration

A correlation analysis was conducted to examine the strength and direction of relationship between kitchen characteristics and CO emission. The results showed that the volume of the kitchen had significant nagetive relationship to the CO concentration ($p<0.001$, $r = -0.549$). This meant that, an increased in the volume of the cooking area or the kitchen, reduced CO concentration. The number of windows also had significant negative relationship with the CO concentrations. The results showed a strong negative relationship between number of windows and CO concentraion ($r = -0.666$). This also meant that an increase in the number of windows, reduced the CO concentration in the kitchen. Relative humidity (RH) in the kitchen was also found to have a significant positive relationship with CO concentration ($r = .475$). This meant that, an increase in RH increases the level of CO concentration in the kitchen.

Table 4.6: Correlation between kitchen characteristics and CO concentration

		Volume of kitchen (m^3)	**No. of windows**	**RH (%)**	**CO (ppm)**
Volume of Kitchen (m^3)	Pearson Correlation	1			
	Sig. (2-tailed)				
No. of windows	Pearson Correlation	.372**	1		
	Sig. (2-tailed)	.003			
RH (%)	Pearson Correlation	.113	-.386**	1	
	Sig. (2-tailed)	.390	.002		
CO (ppm)	Pearson Correlation	-.549	-.666**	.475**	1
	Sig. (2-tailed)	.000	.000	.000	

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

4.5 Carboxyhaemoglobin and Hemoglobin Response

Hemoglobin and carboxyhemoglobin levels in the blood of the respondents were measured. The results showed that the average carboxyhaemoglobin levels of respondents in households using BMF were higher than those who used LPG, whiles hemoglobin levels of respondents in households that applied LPG were almost similar to those that applied BMF. The results as presented in Table 4.7 showed that the average carboxyhaemoglobin level of households using BMF was 23.44% while that of those using LPG was 7.13%. The hemoglobin level of BMF households was 12.13 g/dl while that of LPG households was 12.20 g/dl.

Table 4.7: Average Hemoglobin (g/dl) and Carboxyhaemoglobin Levels (%)

	Energy Use	N	Mean	Mean Difference	Std. Deviation
Carboxyhaemoglobin	BMF Users	45	23.44	16.311	6.504
	LPG Users	15	7.13		2.800
Hemoglobin	BMF Users	45	12.13	-.067	1.057
	LPG Users	15	12.20		1.014

The results of the t-test showed that the difference in mean in terms of the carboxyhaemoglobin level between the households using BMF and those using LPG was statistically significant (p-value < 0.001). Thus carboxyhaemoglobin levels of households using BMF was significantly greater than households using LPG. The test showed that the difference in means in terms of the hemoglobin between households using BMF and LPG was not statistically significant ($p > 0.05$).

Table 4.8: Samples test between groups that used BMF and LPG with respect to their COHb and Hb

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
COHb	Equal variances assumed	5.050	.028	9.385	58	.000
	Equal variances not assumed			13.49	54.04	.000
Hb	Equal variances assumed	.237	.628	-.214	58	.832
	Equal variances not assumed			-.218	24.94	.829

4.6 Effect of CO on COHb

A regression analysis was further conducted to assess the change in carboxyhaemoglobin when there is a unit increase in CO. The regression model, which uses CO to predict the level of carboxyhaemoglobin was found to be statistically significant. The $F (1, 58) = 112.99$, with $p < 0.000$. The R-squared of the regression model was 0.665, which meant that CO alone can explain as high as 66.5% of the variations in carboxyhaemoglobin. This meant CO was a major predictor of carboxyhaemoglobin. A unit increase in the level of CO increased the level of carboxyhaemoglobin by 0.589 and this is statistically significant ($p < 0.001$).

Table 4.9: Regression Analysis showing the effect of CO and COHb

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	**Std. Error**	**Beta**		
1	(Constant)	9.648	1.149		8.398	.000
	CO (ppm)	.589	.055	.813	10.630	.000

a. Dependent Variable: Carboxyhaemoglobin

b. $R^2 = .665$ $F (1, 58) = 112.99$, Prob > F = 0.000

4.7 Health Related Issues Associated with CO

4.7.1 Awareness of Health Impacts Associated with Smoke

From the survey, it was discovered that, majority of the respondents had no idea of the dangers associated with being exposed to smoke. As high as 82% of the respondents had no idea of the dangers from this form of exposure and only 18% had some idea of the dangers associated with the exposure. This is a serious public health concern.

4.7.2 Symptoms for Reliable and Early Diagnosis of CO Intoxication

Research has shown that exposure to CO can have certain health effects on the person. The respondents were asked to outline some of the major health problems they usually experience due to exposure to smoke over the years. The results showed that the major symptom they experienced was fatigue (85%). This was followed by eye irritation (63%), headaches (62%) and dizziness (62%). Only 35% reported that they have chest pains. Respondents in the cohort group (those who relied solely on LPG) reported no particular symptoms from CO exposure.

Table 4.10: Self-reported symptoms due to exposure to smoke

	Freq.	Percent
Headache		
Yes	37	62
No	23	38
Angina (Chest Pain)		
Yes	21	35
No	39	65
Fatigue		
Yes	51	85
No	9	15
Dizziness		
Yes	37	62
No	23	38
Eye Irritation		
Yes	38	63
No	22	37
Total	**60**	**100**

4.8 Predictors of CO Poisoning

A multiple linear regression was performed to determine which symptoms predict CO poisoning in the community. From the test, it was determined that, fatigue was the major indicator of CO poisoning, and this was statistically true (p-value < 0.001). The R- squared value of 51 percent meant that, fatigue is 51 percent predictor of CO intoxication in the exposed population.

Table 4.11: Multiple regression showing which symptom is a major predictor of CO poisoning

Variables	Unstandardized Coefficient (B)	Std. Error	Standardized Coefficient (Beta)	t	Sig.
Constant	2.252	2.341		.962	.340
COHb for fatigue	.740	.139	.650	5.332	.000
COHb for dizziness	-.223	.219	-.225	-1.017	.314
Chest pain	.012	.125	.011	.096	.924
COHb for Headache	.379	.219	.378	1.730	.089
COHb for Eye Irri.	-.106	.266	-.105	-.400	.691

**Significant at the 0.05 level.

Model utility

R^2 = .510

Adjusted R^2 = .464

Standard error = 9.223

Highest VIF = 7.639

Final Condition Index = 11.906

a. Dependent variable: CO (ppm)

b. Predictors: (constant), COHb for Eye Irritation, Chest pain, COHb for fatigue, COHb for headache, COHb for dizziness

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.1 Socio-demographic Characteristics of Respondents and CO Exposure

Gender plays a vital role when it comes to household cooking in Ghana. Generally, women are engaged in these activities more than the men. The rationale for female domination is simply that, they are the mothers of the house and local traditions and culture puts the responsibility of cooking, domestic chores and child care on them. The descriptive statistics from the research revealed that 95% of the sample population were female while only 5% were males. This is because of the role women play in the various homes. Thus, the issue of domestic exposure to CO may be more problematic for women than men. This is in agreement with earlier research by many scholars (Balakrishnan, 2002; Ezzati, 2002; Mestl, *et al.*, 2007; Jiang, 2008). All these studies focused on women because in their view, women were mostly exposed due to their role in homes, followed by children due to their closeness to their mother in the kitchen environment.

Level of education has serious impacts on CO exposure. From the survey, it was discovered that, majority of the respondents had no formal education, accounting for 68.33% of the entire sample size. Only one person had tertiary education, accounting for 1.67%. It was also discovered that, most of the educated elites within the sampled communities had some knowledge on the dangers associated with BMF, and therefore spend lesser time in the kitchen environment, to reduce the level of exposure. On the other hand, those in the category of not having any formal education had no knowledge on the dangers of CO exposure and therefore spend much time in the exposed area.

It has been suggested that there is a causal link between educational patterns and exposure to CO (Lleras-Muney, 2005). Del Ser *et al.* (1999) also made similar discoveries by drawing a link between education and diseases likely to be encountered prior to CO exposure. Religion has significant impacts on studies which involves blood sampling. A major contirbuting factor as to why the sample population was 60, is simple because most of the people were reluctant to donate their blood for the exercise, attributed to religious reasons. This confirms a similar studies by Masser *et al*. (2008) when researching on why most people refused to donates blood samples for research of this nature in Jordan. They found that majority of people have various faith-based and doctrine-based beliefs that prohibit them from allowing their blood samples to be used for any clinical trials.

The community in which this research was conducted was rural, with low income status. Only few people from this community were able to afford the use of LPG due to their economic status. Majority of the people earned as low as below 100 Ghana cedis at the end of the month, which made it very difficult for them to resort to the use of cleaner energy (LPG). This group dominated in the research, with a percentage of 45 from the sampled population. The second group also earning a bit higher than the earlier group also receives between 100 and 250 Ghana cedis at the end of the month, making it difficult for them to also resort to the use of cleaner energy. The only group who were able to use cleaner energy were those on government payroll, earning more than what most people earned in the rural community. Among these groups are teachers and community health nurses posted to these locations. These groups were 25%. Poverty has been the major challenge as to why most people cannot afford the use of cleaner energy. These findings confirmed the studies of Jan *et al.* (2012) and Nasir *et al.* (2015).

5.2 Level of CO in the Kitchen Environment in Rural Households

The first objective of this study sought to assess the level of CO in the kitchen environment of rural households. The results of the study showed that majority of the rural households use biomass fuel (BMF) and only a few of the rural folks used cleaner energy. The major factor accounting for this was their lower level of income (i.e. below GH¢ 100). This finding confirmed the work of De Koning (1985) who noted that the increased utilization of biomass fuel was widespread among rural residents mainly because of the increasing levels of poverty. The findings further supported the work of Jan *et al.* (2012) who found a very strong positive correlation between poverty and the use of biomass, particularly in regions where per capita income was less than US$1 per day.

Other recent study by Nasir *et al.* (2015) found that poverty is a major antecedent to the use of biomass fuel. The CO levels of households that used BMF was significantly greater than the households that used LPG. The correlation analysis however showed that CO levels were relatively reduced with increased number of windows in a kitchen. This finding supports many earlier studies that have been conducted. For instance, Dasgupta, (2013) found that the more the number of windows and doors, the less the concentration of the carbon monoxide because ventilation safeguards the environment from CO concentration. Earlier studies confirmed that the higher the degree of ventilation, the less the concentration of CO in a kitchen environment (Brauer and Saxena, 2002; Moschandreas *et al.*, 2002; Dasgupta *et al.*, 2006; Dasgupta *et al.*, 2009).

Research has shown that more than 3 billion individuals worldwide, most of whom are in developing countries, depend on biomass fuel for cooking and warming (Rehfuess *et. al.*, 2006). Many International Organizations (such as World Resources Institute, UNEP, UNDP and World Bank) have recognized that majority of individuals living in rural communities in developing nations depend entirely on biomass fuels in the form of wood, dung and crop residue for cooking and other residential purposes. This study supports the work that was done in Kenya where as high as 68% of the populace (mainly rural residents) were found to depend on biomass fuel for their household's activities. 95% of energy used in rustic regions are mostly biomass, with women in these areas, exposed to the dangers associated with the biomass fuel chain (EPA, 1997). This clearly shows that biomass fuel is of great value to rural residents.

5.3 Improved Stove

From the study, it could be observed that there was a reduction in the total amount of CO levels when the improved stove was applied. The results showed that, a difference of about 21.207 ppm was realized after the intervention process. Though there seems to be a reduction but statistically, the difference in means between the improved stove and the old tripod stove was not significant ($p\text{-value} < 0.208$). This means the impact of the improved stove in CO reduction was minimal. This could be attributed to several reasons. One of which was that, the numbers of windows within the kitchen space was minimal, which prevented easy flow of air from the environment. Again the diameter of the metal pipe used, was small and therefore, prevented more smoke from getting out of the cooking area.

5.4 Carboxyhaemoglobin and Hemoglobin Responses from CO Exposure

The results showed that the hemoglobin level of members of households using LPG was similar to those of households using BMF. However, the average carboxyhemoglobin level of members of households using BMF was found to be significantly greater than those of households using LPG ($p < 0.001$). Carboxyhemoglobin level of households using BMF was 23.44% while that of those using LPG was 7.13%. According to the classification by Dydek, (2009) and Kao *et al.* (2005), COHb poisoning level of between 0 – 30% is considered mild and hence, it could be concluded that the COHb poisoning level within the rural communities that were studied for both households using BMF and LPG was mild. The correlation analysis showed a very strong significant positive relationship between CO level and COHb level. This meant that an increase in the level of CO significantly increased the level of COHb. The simple linear regression analysis showed that a unit increase in the level of CO significantly increases the level of COHb by 0.7.

5.5 Simple Symptoms for Reliable and Early Diagnosis of CO Intoxication

From the survey, it was discovered that majority of the respondents have no idea of the dangers associated with being exposed to smoke. However, the respondents indicated when they were exposed to the smoke for quite a long time, some of the major health symptoms they experienced were: fatigue, eye irritation, headaches, dizziness and angina. According to Dydek, (2009) and Kao *et al.* (2005), some of the signs and symptoms of the mild COHb poisoning are mild/moderate headache, decreased exercise tolerance with pulmonary disease, chest pain with cardiac disease, shortness of breath, nausea/vomiting, dizziness, fatigue and blurred vision. The symptoms reported by the respondents clearly showed that they were within the mild COHb poisoning level.

Other empirical studies have found many negative health implications to be associated with the use of biomass and they all found that the worst form which has serious negative impact is the use of biomass fuel (Ezzati and Kammen, 2002; Goldstein, 2008; Hoskins, 2011). The usage of this fuel type in various homes produces much smoke, particularly, when using tripod stove, with no chimney or any other ventilation systems to expel generated smoke out of the premises. The smoke in these homes exposes families to destructive quantities of gases such as carbon monoxide, benzene, etc. (WHO, 2004). These contaminations, according to the World Health Organization (2014) are associated with an unexpected 9% of lung cancer deaths, 17% chronic obstructive pulmonary ailment, over 30% ischemic coronary illness and stroke, and 9% respiratory diseases (WHO, 2014).

Many studies have established a link between CO poisoning and many other health implications such as lung cancer, asthma, tuberculosis, cardiovascular results, cataracts, visual deficiency, infant mortality, low weight babies and pre-birth mortality (Warwick and Doig, 2004; Boy, *et al.*, 2002; Ezzati and Kammen, 2002; von Shirnding, *et al.*, 2002; Smith et al., 2000; Bruce, *et al.*, 2000; Malvalankar, *et al.*, 1991; Albalak, *et al.*, 1999, 2001). These clearly show that indoor carbon monoxide contamination has serious negative health impact on the general health of people, especially the rural folks, who largely depend on it for their survival. A regression analysis performed showed that, fatigue was the major predictor of carbon monoxide intoxication in the community.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

The study has established that, exposure to carbon monoxide indeed increased the level of carboxyhaemoglobin in study participants. In many rural households, women continued to be exposed to CO given their role in the household, coupled with their inability to afford improved and clean energy. The case worsened if the kitchen has fewer windows. Many of the households had only one or two windows and this condition increased the level of carbon monoxide concentration in the cooking area and in their blood as well. The levels of CO in households which used BMF was significantly higher than those that used LPG.

Even though most of the women were at risk of many health complications, unfortunately, many of them had no knowledge on the effect of the continued inhalation of carbon monoxide. Nevertheless, continued exposure to the smoke was associated with fatigue, eye irritation, headaches and dizziness. Given the fact that many rural households cannot afford to use LPG because of the relative high cost and their low income, an improved stove, was constructed as an intervention to help replaced the old tripod stove, which was found to produce more carbon monoxide. After the introduction of the improved stove, carbon monoxide levels dropped with a mean difference of 21.207ppm.

6.2 Recommendations / Proposed Intervention

Base on the outcomes of this research, the following are the recommendations proposed to address the issue of CO poisoning.

- The National Commission for Civic Education (N.C.C.E) in the Municipality must carry out an intensive campaign on awareness creation, on the dangers associated with exposure to CO, since its dangers go covertly.
- Ideally, LPG usage is the best in addressing CO exposure. This form of energy, which is cleaner comes with a cost, of which residents within this community (Babatokuma) could not afford. Based on this, it is recommended that, the use of the improved version of the tripod stove is encouraged given the reduced CO emissions associated with it but also need a lot of improvement, to help reduce CO to the barest minimum.

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APPENDIX

Appendix 1: List of tables showing sample test conducted

Table 4.3 Sample test of CO levels between groups that used BMF and LPG

Difference	18.040
t (Observed value)	6.099
|t| (Critical value)	2.002
DF	58
p-value (Two-tailed)	< 0.0001
alpha	0.05

Table 4.5 Sample test of CO between improved stove and the tripod stove usage

Difference	21.207
t (Observed value)	1.499
|t| (Critical value)	2.776
DF	4
p-value (Two-tailed)	0.208
alpha	0.05

Appendix 2: A sample of the questionnaire issued to the subjects

QUESTIONNAIRE

This questionnaire is aimed at eliciting information, which will facilitate completion and writing of a thesis report as part of a Master of Philosophy degree program. It will also assist in policy formulation concerning environmental exposures that may affect the health of people using Biomass fuels. The information that will be given to me will be treated in strict confidence and the identity of the respondent will not be disclosed under whatever circumstances. Please feel free and give appropriate answers as sincere as possible.

Thank you.

SECTION A: Demographic characteristics

1) Name of respondent ……………......................

2) Community …………………………………

3) Suburb………………………………….……

4) Age of respondent

A. Below 18 years [ ] B. 18 – 35 years [ ] C. 36 – 60 years [ ] D. Above 60 years [ ]

5) Gender A. Male B. Female

6) Marital Status; A. Married [ ] B. Single [ ] C. Divorced [ ]

7) Religion: A. Christian [ ] B. Muslim [ ] C. TR [ ] D. Other [ ]

8) Educational Level of respondents

A. No formal education [ ] B. Primary school / Junior Sec [ ]

C. Senior Sec./O-level/A-level [ ] D. Tertiary level [ ]

9) How many people constitute your household? ……. No. of males …. No. of females…….

10) How many people in your household work/are employed? Please specify……………...…

11) What is your occupation?

A. Farmer B. Trader C. Government/Formal private employee D. Self-employed

Other (Please specify) ……………………….

12) What is your average monthly income?

A. Below GH₵ 100.00 B. GH₵ 100.00 - GH₵ 250.00 C. Above GH₵ 250.00

13) Who is the principal cook in this household?

a. Father

b. Mother

c. Children

d. others, specify:______________________

Kitchen Environment

14. What is the size of the kitchen? Please specify: ________________________

15. Is the kitchen well ventilated? A. Yes [ ] B. No [ ]

16. How many windows are in the kitchen environment?

A. One (1) [ ] B. Two (2) [ ] C. Three (3) [ ]

17. What material is use in roofing the kitchen?

A. Thatch [ ] B. Tiles [ ] C. Aluminum sheets [ ] D. other_________

18. Type of stove used in the kitchen? A. Open fire stove [ ] B. Gas cylinder [ ]

C. other, specify;__________

19. Type of fuel use in cooking

A. Wood [ ] B. Charcoal [ ] C. Crop residue [ ] D. LPG [ ]

20. During cooking, how long do you spend in the kitchen?

A. < 1-hour B. 1-2 hours C. 2-3 hours D. > 3 hours

21. Do you have children? A. Yes B. No

22. If yes to question 15, how long do they spend with you in the kitchen during cooking?

A. throughout the cooking activities

B. they leave immediately they enter into the kitchen

C. Not sure how long they stay in the Kitchen.

Health Impacts

23. How often do you cook in the house? A. Once a day [ ] B. Twice a day [ ]

C. More than 2 times [ ] D. Do not cook at all [ ]

24. Do you know that the smoke from your cooking activities is hazardous to your health?

A. Yes [ ] B. No [ ]

25. For how long have you been expose to these smoke through cooking?

A. < 5 years [ ] B. 5-10 years [ ] C. 10-20 years [ ] D. > 20 years [ ]

26. Has there been any health personnel in the community to educate you people about the dangers of exposure to carbon monoxide through biomass fuel? A. Yes [ ] B. No [ ]

27. Have you experience any form of angina (pains in the chest)? A. Yes [ ] B. No [ ]

28. Have you experience any of the following recently or for the past one year?

A. Headache [ ] B. Fatigue [ ] C. Dizziness [ ] D. Others, specify____________

29. Have you experience any other forms of sickness apart from the ones stated?
A. Yes B. No
If yes, can you please describe it; ____
____
____

30. How frequent do you visit the hospital? Please specify:____________________

Appendix 3: Copy of ethical clearance

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY
COLLEGE OF HEALTH SCIENCES

SCHOOL OF MEDICAL SCIENCES / KOMFO ANOKYE TEACHING HOSPITAL
COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

6th February, 2018.

Ref: CHRPE/AP/042/18

Mr. Alexander Appiah
c/o The Proprietor,
Modern Preparatory School
Post Office Box 115
KINTAMPO

Dear Sir,

LETTER OF APPROVAL

Protocol Title: ***"Exposure to Carbon Monoxide in Rural Households in Kintampo-North Municipality, Ghana."***

Proposed Site: ***Babatokuma, Kintampo-North Municipality.***

Sponsor: ***Principal Investigator.***

Your submission to the Committee on Human Research, Publications and Ethics on the above named protocol refers.

The Committee reviewed the following documents:

- A notification letter of 15th January, 2017 from the Assemplyman of Babatokuma (study site) indicating approval for the conduct of the study in Babatokuma.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning 6th February, 2018 to 5th February, 2019 renewable thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Yours faithfully,

Rev. Prof. John Appiah-Poku.
Honorary Secretary
FOR: CHAIRMAN

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