SCHOOL OF PUBLIC HEALTH

COLLEGE OF HEALTH SCIENCE

UNIVERSITY OF GHANA, LEGON

HOUSEHOLD AIR POLLUTION AND PREVALENCE OF HYPERTENSION AMONG MALE ADULTS IN A RIPARIAN COMMUNITY ALONG THE LOWER VOLTA LAKE

BY

JOHNSON ADE

10933181

THIS DISSERTATION IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PUBLIC HEALTH DEGREE

NOVEMBER 2024

DECLARATION

I, Johnson Ade, hereby declare that this thesis is the result of my own research, conducted under the guidance and supervision. All other literature used in this work have been duly acknowledged. To the best of my knowledge, this thesis has not been previously submitted, either in whole or in part, for the award of any degree at this university or any other institution.

..... DATE: 28th November 2024

Johnson Ade

Student

..... DATE: 28th November 2024

Dr. Reginald Quansah

Supervisor

DEDICATION

This work is dedicated to my wife and family, whose unwavering support and encouragement have been the cornerstone of my journey. To my mentors at the School of Public Health and work colleagues at the Environmental Protection Agency Ghana, whose guidance has fueled my academic pursuits, and to the resilient communities of Kpong, whose lives inspired this study. May this research contribute to the understanding and improvement of public health, especially in addressing the critical challenges posed by household air pollution.

ACKNOWLEDGMENT

I am deeply grateful to the Almighty God for granting me the strength, wisdom, and resilience to complete this work. I extend my heartfelt gratitude to my supervisor, Dr Reginald Quansah, for their invaluable guidance, encouragement, and constructive feedback throughout this research journey. Your mentorship has been a beacon of light and inspiration.

I would like to express my profound appreciation to the faculty and staff of the School of Public Health, University of Ghana, for their support and the resources provided to make this research possible.

Special thanks go to the participants from the Kpong community, whose willingness and cooperation were essential for the success of this study. I am deeply inspired by their resilience which have enriched the insights of this work.

I am sincerely grateful to my family and friends for their unwavering support, patience, and understanding during this challenging yet rewarding process. Your constant encouragement has been my greatest source of strength.

Finally, I acknowledge the contributions of my colleagues and peers for their camaraderie and constructive discussions, which have shaped this work and made the journey more fulfilling.

To all who have contributed in one way or another to the completion of this research, I am eternally thankful.

ABSTRACT

Household air pollution (HAP) is a significant public health issue globally, with its effects often studied in women and children, leaving gaps in research on adult males. This study investigates the association between exposure to household air pollutants, including particulate matter (PM2.5, PM10) and carbon monoxide (CO), and hypertension among adult males in Kpong, Ghana. A cross-sectional study involving 110 participants was conducted, measuring pollutant levels and blood pressure. Logistic regression was used to analyze the relationship between pollutant exposure and hypertension, while one-way ANOVA and t-tests assessed differences in exposure based on demographic and lifestyle factors. Results indicated that mean PM2.5 and CO levels exceeded recommended thresholds, with CO exposure showing a significant association with increased systolic and diastolic blood pressure ($p < 0.05$) and hypertension risk. Conversely, PM2.5 exhibited weak or negligible correlations with blood pressure outcomes. Smoking was identified as a significant contributor to elevated CO exposure among participants. These findings underscore the critical need for policies to reduce HAP and promote clean air initiatives, particularly targeting CO exposure to mitigate hypertension and related health burdens in riparian communities.

Keywords: Air pollution, household, particulate matter, personal PM2.5, personal CO, indoor PM10, hypertension, Ghana

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

B4C	–	Brickette for cooking
CDC	–	Center for Disease Control
CO	–	Carbon Monoxide
DBP	–	Diastolic Blood Pressure
EPA	–	Environmental Protection Agency Ghana
GS	–	Ghana Standard
HAP	–	Household Air Pollutants
LPG	–	Liquefied Petroleum Gas
mg/m3	–	milligram Per Meter Cube
PAH	–	Polycyclic Aromatic Hydrocarbons
PM10	–	Particulate Matter
PM2.5	–	Particulate Matter
ppm	–	Parts Per Million
SBP	–	Systolic Blood Pressure
SSA	–	Sub Sahara Africa
ug/m3	–	microgram Per Meter Cube
WHO	–	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Household air pollution (HAP) is a major global health concern, particularly in low- and middle-income countries where solid fuels, such as wood, charcoal, and crop residues, are commonly used for cooking and heating (Smith et al, 2018). The incomplete combustion of these fuels produces harmful pollutants, including fine particulate matter ($PM_{2.5}$ and PM_{10}), carbon monoxide (CO), and other toxic substances. Exposure to these pollutants, especially in poorly ventilated spaces, poses significant health risks (Kumar et al,2023). Globally, HAP is estimated to cause over three million premature deaths annually and is recognized as a major risk factor for non-communicable diseases (NCDs) such as cardiovascular diseases, chronic obstructive pulmonary disease, and hypertension (Tawiah et al,2022).

Hypertension, a leading risk factor for cardiovascular morbidity and mortality, has emerged as a pressing public health challenge in Ghana (Konlan et al, 2023). Research indicates that prolonged exposure to air pollution contributes to elevated blood pressure through mechanisms such as systemic inflammation, oxidative stress, and impaired vascular function (Kelly et al, 2017). While the link between outdoor air pollution and hypertension has been extensively studied, limited attention has been given to the effects of household air pollution, particularly in sub-Saharan Africa, where the prevalence of solid fuel use remains high.

In Ghana, over 70% of households rely on biomass fuels for cooking, with rural and peri-urban communities disproportionately affected. Male adults in these communities, often involved in household activities or occupational tasks that expose them to biomass smoke, face unique risks.

However, most studies on household air pollution have focused on women and children, leaving a critical knowledge gap regarding the impact on adult men.

This study was situated in Kpong, a riparian community in the Eastern Region of Ghana, where the use of biomass fuels is prevalent, and hypertension rates are increasing. Kpong's geographical and socio-economic context, characterized by limited access to clean cooking technologies and healthcare resources, highlights the urgency of understanding the health impacts of household air pollution in this setting.

1.2 Problem Statement

Three (3) billion people worldwide rely on polluting solid fuels like wood, charcoal or kerosene for domestic cooking and heating their households (Lee et al, 2020). Exposure to the air pollutants from the burning of these solid fuels increases the risk of pneumonia particularly in children under 5 years, respiratory and cardiovascular disease incidence among adults. Women also experience adverse pregnancy outcomes (Giordano et al, 2021). Ambient air pollution has caused an estimated 4.2 million deaths annually. It is associated with diseases like heart disease, lung cancer stroke, acute and chronic respiratory diseases among others (Simkovich et al, 2019).

The WHO has stringent limit for air quality index and is unachievable by a whopping 99% of the municipalities and cities where people reside worldwide. This prompted regions and countries to conduct research for long periods to be able to set their own limits tailored for their peculiar environment.

In Africa, particularly sub-Saharan Africa, a vast proportion of people use solid fuels for cooking. Smoke from cooking with biomass fuel or its mixture with smoke from burning fossil fuels, emits atmospheric particulate matter and reduces air quality (Wen et al, 2019). Some studies in Asia

have shown that household and restaurant cooking are a major human activity that contributes to high concentrations of indoors household pollution (Wang et al, 2017).

Systematic studies and reviews have revealed that hypertension is a widespread problem in Sub-Saharan Africa (SSA). An estimated 10 to 20 million out of a population of 650 million reportedly have experienced hypertensive symptoms (Argyropoulos et al, 2022). A study by Kofi Amegah in 2020 showed that early life HAP exposure is associated with increased Systolic Blood Pressure (SBP) in early childhood amongst girls. Similarly, a study in 2022 by Reginald Quansah and associates titled: The Association between Household Air Pollution and Blood Pressure in Obuasi Municipality, Ghana using a linear regression model described the association between personal exposure to PM2.5 and the respondent's SBP as well as Diastolic Blood Pressure (DBP) was elevated in cooks using solid fuels for cooking during the research period than in those using clean fuels like LPG.

Carbon Monoxide exposure has also been associated with blood pressure among pregnant women in rural Ghana (Ashlinn Quinn in 2016). The study concluded that HAP from wood-burning fires is related with higher blood pressure, particularly diastolic blood pressure, in pregnant women at early to mid-gestation.

1.3 Justification

Globally, air pollution has been implicated as a major risk factor for mortality and morbidity. It has been estimated that air pollution was responsible for 6.7 million deaths according to the Global Burden of Disease (GBD) reports in the year 2019. To put this figure in perspective, ambient air pollution was responsible for 4.1 million of these deaths. The remaining 2.3 million were due to sources from household air pollution. Air pollution was responsible for an estimated 1.1 million deaths in Africa in the year 2019. Since most sub-Saharan African nations were still

in the early stages of economic growth, household air pollution was the main cause of pollution-related mortality, accounting for 697,000 of these deaths, while ambient air pollution was responsible for 394,000 (Taghian et al, 2024).

Numerous and different kinds of pollutants emanate from burning these solid fuel and a greater percentage of them are particulate matter and CO which has adverse health effect (Eljarrat et al, 2020). Several studies on the effect of HAP in SSA have been geared towards women and children (Adekoya et al, 2022). The reason for all these studies undertaken are because women are mostly the primary cooks in SSA and is typical in Ghana as well (Adusah-Poku et al, 2021). Children health is most paramount because of their vulnerability, and they usually stay with their mothers during the cooking processes in the home setting (Holmes et al, 2018).

Cognizance to the effect of HAP in women and children clearly indicate a gap in male studies in Ghana. This study will investigate the health effect of prolonged exposure to HAP by adult males within the study area and investigate some heath effect especially hypertension.

Hypertension which occurs because of elevated blood pressure is influenced by a complex interplay of environmental, educational, and lifestyle factors (Biino et al, 2013). Adult men are also likely to be exposed to outdoor air pollution due to their occupations and trades. Exposure from both sources could raise their risk of developing hypertension. In low and middle - income nations like Ghana, it is imperative to investigate how household air pollution interacts with other environmental factors that impact on men's health. The study on adult males in the study area will bridge the gap with the numerous research on women and children. This will provide additional information and compliment the effect of HAP on homes in Ghana.

1.4 Study objective

1.4.1 General objectives

To provide understanding on the levels of household air pollutants and the burden of hypertension among adult males in Kpong in the Eastern Region of Ghana.

1.4.2 Specific objective

1. Determine the prevalence of hypertension among the males and measure the mean systolic and diastolic blood pressures.
2. Quantify the concentrations of personal 24 - hour $PM_{2.5}$ and CO and the indoor PM_{10}
3. Assess the association between household air pollution and elevated blood pressures.

1.4.3 Research Question

1. Are males in the households of the study area exposed to significant levels of household air pollution

1.5 Conceptual Framework

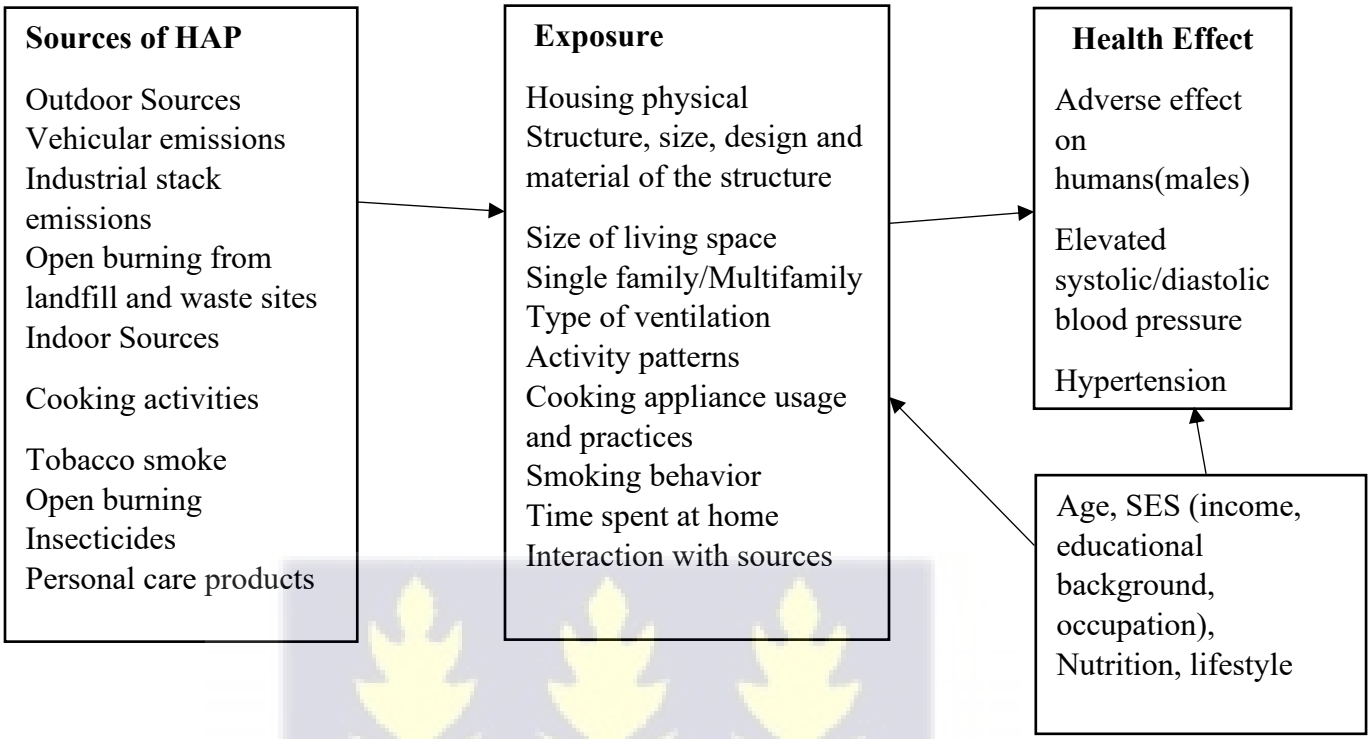


Figure 1: conceptual framework depicting sources of household air pollutants and their effect on humans

1.6 Conceptual framework's narrative

The use of inefficient and polluting fuels and technologies within and around the home, which contain a variety of pollutants that are harmful to health. Smoke generated from burning the fuels is what causes household air pollution(Ashmore, 2024). These are tiny particles that can permeate the bloodstream and travel deep into the lungs. Fine particle levels in indoor smoking can be 100 times higher than the permissible threshold in homes with inadequate ventilation(Z. Li et al., 2017).

Outdoor sources that contribute to HAP are vehicular emissions, industrial stack emissions, open burning in the environment, outdoor smoke from bush fires and burning from farming activities

among others. Indoor sources include smoke from cooking activities, tobacco smoking and open burning within the household. There is always some level of synergy between the outdoor and indoor sources and the end result aggravates the effect on humans who are vulnerable(Rohra & Taneja, 2016).

The physical structure of the housing design can affect the level and concentration of particulate matter and carbon monoxide within the household. Some factors including the size, design and building material of the housing structure can also aggravate the levels of pollution(Katsoyiannis et al., 2012). The size of the living space and whether the house is occupied by a single - family or multi - family can affect the levels of pollutants. i.e, the number of occupants within a single household can also increase the effect of HAP(Karpinska & Śmiech, 2022).

Furthermore, activity patterns within the household also affect human exposure to pollutants. The improper usage and maintenance of cooking appliance can cause them to release excessive pollutants. Human smoking behaviors can also aggravate the effect of household air pollutants on health. The human respiratory tract is exposed to between 10,000 and 40,000 μg particulate matter only by smoking. This has an adverse effect on the lungs. Meanwhile the time, extent of exposure and interactions of human to the source can also affect the levels (On & Engineering, 2019).

The effect of exposure to CO and PM may have adverse effect on humans causing lower respiratory infections and ultimately may cause death. However, there are potential confounders that may affect human exposure to CO and Particulate matter. These include a person's social economic status, age, educational background and assess to clean energy source (Carter et al., 2017).

CHAPTER TWO

LITERATURE REVIEW

The home is regarded as the most single structure to protect man from the elements of the environment. The house is the most secure and healthy environment for mankind (Mallett, 2024). In contrast, a building that houses individuals can also be a source of harmful pollutants that can have an adverse impact on one's health.

In Ghana, privileged homes have access to electricity that serves as a clean source of energy for powering homes and for cooking purposes whereas other portion of the Ghanaian households do not have access to electricity (Adusah-Poku et al, 2021). This is because of individual household socio-economic status making such energy sources a luxury. Underprivileged homes in Ghana, use materials like grass, wood, dried animal excreta, and charcoal as fuel for cooking and heating (Abdul-Wakeel Karakara & Dasmani, 2019). Sixty-four (64%) of Ghana's primary energy supply is from the use of biomass (Kuamoah, 2020).

According to the Ghana Statistical Service's (GSS) fifth round Ghana Living Standard Survey (2008), over half of Ghana's households rely on both traditional and unconventional energy sources. In Ghana electricity and Kerosene are the main sources of energy for illumination (Aboagye et al, 2021). About 49.3 % of all houses in Ghana currently use kerosene for lighting, while a slightly lower percentage (49.2 %) use grid-connected electricity. Candles, generators, and/or other light sources are used by only 1.5 % of households. Cooking is a major activity in homes in Ghana, the fuel used are in the following percentages, wood (53.5 %), charcoal (30.6 %), and gas (9.5 %) respectively. Also the percentages of urban to rural utilization of charcoal for the households are 52.6% and 30.6% respectively (Abdul-Wakeel Karakara & Dasmani, 2019).

The policy makers in Ghana in contemporary times have systematically and consistently increase the national electricity gridlines and subsidized Liquefied Petroleum Gas (LPG) for home use. This has helped in the reduction of usage of wood and charcoal as fuel thereby conserving the natural vegetation (Kwakwa et al., 2013). Household air pollution (HAP), which is usually caused by using solid fuels, is still a global health concern. Solid fuels such as wood, crop waste and animal dung are relied upon by about three billion people worldwide to meet their energy demands. Majority of the people that fall in this category are underprivileged and live predominantly in Asia and Sub-Saharan Africa (Khan et al, 2017).

The World Health Organization (WHO) recently reported that on average 8 million people die annually because of air pollution. Death from sources of air pollution from household recorded about 4.3 million of the total mortality. The remaining 3.7 million deaths were from ambient air pollution sources (Ahmed, 2019). The Global Burden of Disease also reported that household air pollution is third among the various the various causes of disability-adjusted life years (DALYs) globally. Interestingly, ambient air pollution is ranked ninth among the causes of DALYs in the world. The perception that air pollution from vehicular and industrial stack emissions were bigger threat to human health has been debunked, because research has brought to light the enormous adverse impact of household air pollution on human health (Gan et al., 2022).

In most developed countries, homes are built with concrete foundations, hardwood frameworks, and asbestos sheeting. Additionally, to lessen the risk of fire, fire-retardant materials are added to the building materials for these houses and wood that has been polished with varnish typically makes up the flooring. Carpets or vinyl flooring are also common in many homes (Salvi & Apte, 2016). To smooth out the wooden parts of furniture used in the home, polish and varnish are applied. Because particle boards are inexpensive and easy to work with, they are often used in

furniture building. Using frankincense, air fresheners, scented candles, and other similar products is standard practice to keep odors in homes at bay (Vardoulakis et al., 2020). Air conditioners have been installed in homes recently to maintain a comfortable indoor temperature.

Upholstery, including thick sofa covers, thick drapes, cushions, and decorative throws, is a common feature in homes nowadays. In these days of cutting-edge advancement in technology, most homes are installed with the latest appliances like copiers, fax machines, and printers. Improved personal hygiene also requires regular painting, varnishing, polishing floors and furniture, and other regular upkeep (Salvi & Apte, 2016). However, in most developing countries homes are built with cement, concrete, and bricks. The majority of these houses rely on open windows for natural ventilation (Udoudoh & Bassey, 2021).

Housing is now found near to industry and heavily used highways as a result of overcrowding and rising industrialization (Hussain, Anwar, Huggins, 2021). In these nations, the underprivileged socioeconomic classes live in homes that have poor ventilation, dimly illuminated homes composed of bamboo, wood, agricultural waste and used cloth. In developing countries, biomass is the preferred and affordable fuel that is used for cooking, lighting and cooking (Ahmad et al., 2022). Paints and whitewash are frequently used in underprivileged societies to beautify homes (Toqeer Ahmed, Muhammad Usman, 2018). The growing demand for better houses has led to a surge in housing developments with a speedier turnover period. Poor construction materials, malfunctioning plumbing and electrical systems, and other factors expose people to HAP.

2.1 Particulate matter (PM)

Generally, particulate matter is used to describe a mixture of solid particles and liquid droplets in the air. They are in groups such as aerosols, fumes, smoke, dust, ash and pollen. Their

classification is in accordance with a respective aerodynamic diameter: less than10 µm (PM_{10}), less than 2.5 µm ($PM_{2.5}$), less than 1 µm (PM_1) and from 2.5 to 10 µm ($PM_{2.5-10}$)(Sulovcova et al, 2016).

Findings from epidemiological studies demonstrate that particulate matter could significantly increases BP levels when an individual is exposed short or long-term particularly in regards to exposures to $PM_{2.5}$ (Giorgini et al., 2015). A majority of studies have also shown the relationship between $PM_{2.5}$ levels, the levels of pollutants and BP increase observed within some period and daily exposure (Prabhakaran et al, 2020). Toxicological evidence suggested that $PM_{2.5}$ contributes to the elevation and increase of high BP and development of hypertension (Lin et al, 2021).

2.2 Carbon monoxide

Carbon monoxide (CO) is gaseous in nature. It has no color, taste or odor. It is produced in the air by burning fuel from different sources. These include cooking stoves and combustible engines. The CDC a leading science-based, data-driven, service organization in the United State of America reported that 500 in the US get non-fire-related CO poisoning annually (Stec et al, 2008). Inhaled carbon monoxide is absorbed in the gas exchange region of the respiratory tract after air is inhaled. When it is absorbed carbon monoxide is produced through the metabolism of the compound methylene chloride (Wilbur et al, 2012). Because of ongoing absorption and metabolism, the half-life of carbon monoxide after exposure to methylene chloride may be extended. Trace amounts of carbon monoxide either bind to cellular cytochromes or remain in solution.

The majority of carbon monoxide binds reversibly to hemoglobin (Hb) in red blood cells (Livshits et al, 2012). Because of how CO interacts with hemoglobin, CO poisoning frequently results in

death. This prevents it from transporting oxygen, resulting in severely hypoxic organs which leads to hypertension (Sykes & Walker, 2016).

2.3 Sources of household air pollution

Over the years, more than 60 risk variables related with the increased burden of household air pollution in addition to the usage of solid cooking fuels (Argyropoulos et al, 2022). While LPG is largely propane gas, it can also be composed of two gases namely propane and butane. Natural gas, which is predominantly methane burns more easily because it needs less air (10:1 air to gas ratio). LPG, in contrast, releases nearly three times as much energy per cubic meter of fuel as natural gas and has energy of 93.2 MJ/m3 and 38.7 MJ/m3 respectively. LPG requires adequate air to burn (an air-to-gas ratio of 25:1). LPG has a higher density than air (1.52:1:0.55), which has a higher density than natural gas (Senewa et al, 2018). In contrast to natural gas, which rises toward the roof and has less adverse effects on health. When LPG leaks it tends to settle in the home's environment air at levels were human brief. Natural gas burns in the environment and generates several gases, including oxides of sulfur, mercury compounds, and particulate matter. It also creates nitrogen oxides, particularly nitrogen dioxide, which is extremely harmful to human health.

Nearly 3 billion people amounting to half of the population of the world consume biomass every day and burn about 2 million kg of it for cooking and heating (Bawakyillenuo et al, 2021). Particulate matter and gaseous air pollutants, including phenols and free radicals, carbon monoxide (CO), nitrogen dioxide, sulfur dioxide, formaldehyde, hydrocarbon complexes, and other inorganic and organic substances like polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds, and chlorinated dioxins, are present in extremely high concentrations in these homes (Clark et al, 2020).

Studies have shown that the average levels of particulate matter (PM2.5) with a mean aerodynamic size of less than 2.5 microns (PM2.5) are between 500 and 1,500 g/m3, which is extremely high considering that the WHO considers 10 to 50 g/m3 to be the permissible indoor PM2.5 level (Bruce et al, 2015). When burning charcoal high volumes of CO are generated. Taking into consideration all the various forms of biomass fuels, wood burning results in the least amount of released PM2.5 and CO emissions (Kansiime et al, 2022). The amount of particulate matter discharged into the air depends on the cooking technique. Particulate matter emissions vary depending on whether food is stir-fried, deep-fried, shallow-fried, charbroiled, roasted, or grilled. Fat containing meat and the kind of cooking oil used to fry meat affect the emission levels. For instance, charbroiling meat produces significant amounts of particulate matter with a mean aerodynamic diameter of 0.1 to 0.2 m. About 21% of the particulate matter released comes from frying and charbroiling meat (Abdullahi, 2016).

2.3.1 Smoking

Any kind of tobacco use contributes to one of the highest indoor air pollutions determinants in the home. There are about 1.1 billion smokers worldwide, and the count of smokers is rising quickly (WHO, 2025). There are 7,357 different chemical compounds found in cigarette smoke,

such as nicotine, heavy metals, benzoic compounds, aromatic amines, PAHs, prussic acid, and methanal. Additionally, smoking tobacco releases a significant quantity of fine particulate matter. A stick of cigarette releases between 7 and 23 mg of fine particulate matter (Jebet et al, 2018). Particles of smoke wind up on people's hair, clothes, furniture, and floors. These particles stay in suspension in the atmosphere for a hours before they fall, even when the smoker vacate the household (Mihalis, 2010).

2.3.2 Vehicular Emissions

Indoor air pollution is especially common in residences close to busy highways where a lot of diesel-powered vehicles are driven. Particulate released from the exhaust of vehicles have often condensed on pollen from trees by the roadside and then finds its way into households with closed doors and windows. Thus, it is demonstrated that very high concentrations of carbon particles, soot, pollen grains, and particulate matter from organic sources are present in these naturally ventilated homes (Muthu et al, 2021).

2.3.3 Biomass

In most countries across the world, biomass is used for heating homes. This process releases a considerable amount of PM10, up to 5,000 g/m3, in addition to PM2.5 (the WHO's permitted limits are 100 g/m3 on an average daily basis). Burning charcoal releases a significant amount of particulate matter and polyaromatic hydrocarbons as compared to burning wood (Vicente et al, 2018)

2.3.4 Insecticides and pesticides use

In poor and rural settings there is always a struggle with diseases that are infectious and communicable. These diseases are typically spread by vectors like mosquitoes, ticks, and other insects. Malaria and dengue are two mosquito-borne illnesses that pose one of the largest threats.

Mosquito management is urgently needed to reduce the rising mortality and morbidity rates of various diseases transmitted by mosquitoes. Chemical repellents are used to achieve this. The mosquito coil is the most popular and often used repellent (Mullié et al, 2021).

For people to protect themselves from the risks associated with mosquito-borne diseases, almost 2 billion individuals use mosquito coils worldwide. The amount of active pyrethroids in a typical mosquito coil is 0.1%, with the rest of the percentage made up of resins, binders, and combustible materials like coal dust and coconut coir. Large quantities of mosquito coil, approximately 12,000,000, are sold worldwide annually. After being lit, coils are left to burn in a closed environment for about 7 hours to get the desired effect. One of these coils emits the same amount of PAH and particulate matter as burning 50 cigarettes, according to prior study. According to earlier research, smoking one of these coils releases the same amount of PAH and particulate matter as burning 50 cigarettes (Atkinson et al, 2009).

2.3.5 Perfumes, deodorants, and cleaning agents

In homes with inadequate ventilation, the concentration of indoor air pollution and kitchen scents is higher. This explains why using fragrances and perfumes to improve the cleanliness of the house is justified. Using cleaning goods, scented candles, fragrances, deodorants, and other items to make the house cozier and more pleasant is necessary for improved hygiene. Volatile organic compounds are released by frequently used consumer goods, such as cleaning agents, laundry products, air fresheners, and personal care items (Johnson et al, 2019)

2.3.6 Religious Activities

Almost all faiths use perfumes in some capacity throughout their regular religious exercises. During their daily prayers, Hindus and Buddhists burn dhoop, or smoke sticks, incense sticks, scents, and oil-lit lamps. Hindu wedding ceremonies frequently entail blazing a holy fire made of

wood and cakes of animal excrement for at least two to three hours each. Islamic houses frequently utilize brickettes of Oudh and Bakhoor. These releases scent when set over hot charcoal. According to several studies, burning these scents releases dangerous quantities of air pollutants into the atmosphere. Over 90% of Chinese people have been burning incense for more than 20 years, and 76.9% of them burn it daily at home. Significant levels of PAHs, benzene, nitrous oxide, and CO2 are emitted when these scents are burnt. Candles emit 1,200 and 200 g/m3 of PM2.5 and PM10, respectively (Jilla, 2017)

2.3.7 Building material

Household paints and varnishes generate large volumes of VOCs, adding to the load of indoor air pollution. These products are held together by VOCs producing adhesives. Furniture made of particle board is also a source of emissions like those of VOCs. Volatile organic compound emissions have also been linked to construction materials used as insulation (Katsoyiannis et al, 2012). Fine asbestos dust particles are left in the finished homes due to the usage of asbestos in building materials. Like how there are lots of silicon particles in brick and cement homes. As a result of technological advancements, homes are becoming digital. Modern homes are equipped with high-tech devices including tablets, iPads, mobile phones, printers, and computers. These devices have been known to release high ozone levels in homes. Electronics and furniture made of foam include fire retardants called polybrominated diphenyl ethers (PDBEs). These barely detectable emissions of PentaPDBEs and DecaPDBEs contribute to home air pollution (Ceballos et al, 2022). Indoor wall moisture is becoming more common because of poor plumbing, either alone or in conjunction with environmental factors like weather. These walls provide the ideal environment for the growth of fungus such as Alternaria, Aspergillus, Cladosporium, and Penicillium (Agyekum et al, 2013).

2.4 Adverse effects of household air pollution

Out of the 4.3 million individuals' mortality recorded annually due to indoor air pollution. 60% of this figure have cardiovascular ailments, and 40% have lung disorders.1. The short-term consequences of exposure to indoor air pollution increase the chance of mortality from cardiovascular and respiratory conditions (Raju et al, 2020). Research indicates that for every 10 g/m3 in indoor PM10, cardiovascular mortality increases by 0.36% and respiratory mortality increases by 0.42%. A 10 g/m3 rise in indoor PM2.5 has been shown to raise respiratory and cardiovascular mortality by 0.75% and 0.63%, respectively. Over time, the mortality risk increases by 23% to 67% for every 10 g/m3 increase in household PM10 (Sokoty et al, 2020).

A fetus is typically safest and purest in the uterus of its mother. However, in a study of ten newborns in New York, the Environmental Work Group discovered that the cord blood taken at birth contained up to 232 contaminants circulating in the babies whose mothers had been exposed to pollution (Rani & Dhok, 2023). Third-trimester pregnant women exposed to greater levels of PM2.5 and black carbon (found in households that use biomass for heating or cooking) had children with higher systolic blood pressure, according to research from Harvard University in Cambridge, Massachusetts, USA (L. Li et al, 2022).

Similar to this, using biomass fuels indoors increases the risk of developing asthma, recurrent respiratory tract infections, poor lung development, and chronic obstructive pulmonary disease, which has recently been linked to people as young as 35 years old (Raju et al, 2020). Patients with sickle cell disease have increased oxidative stress due to their exposure to the household air contaminants that were previously described. Due to the endothelial damage caused by this, hemolysis and hypercoagulability are enhanced. Additionally, this causes decreased nitric oxide

bioavailability and results in vaso-occlusion, which increases the number of sickle cell disease patients who must be hospitalized when they experience pain crises (Tewari et al, 2015).

Long-term exposure to PM2.5 and nitric oxide has been shown to dramatically increase systolic blood pressure, mean arterial pressure, and pulse pressure (Honda et al, 2018). The main cause of these blood pressure fluctuations is increased oxidative stress caused by indoor air pollution exposure. The main cause of these blood pressure fluctuations is increased oxidative stress caused by indoor air pollution exposure response to domination. People who are exposed to home air pollution are more likely to develop atherosclerosis, angina, ventricular hypertrophy, hypertension, pulmonary hypertension, ventricular conduction abnormalities, and arrhythmias. These conditions increase the risk of cardiovascular death and serious morbidity (Lee et al, 2020).

High systolic blood pressure has a relationship to an abrupt rise in biomass fuel smoke. Moreover, insulin resistance, which is linked to type 2 diabetes mellitus, is exacerbated by oxidative stress brought on by exposure to indoor air pollution. The development of non-obese type II diabetes mellitus and insulin resistance are similarly impacted by third-hand smoking exposure55. These diabetic patients are more vulnerable to the harmful effects of PM2.5 and lower-sized particulate matter, which can raise serum levels of coagulation factors, vasoconstrictor mediators, and inflammatory biomarkers. This puts them at risk for increased cardiovascular morbidity and, ultimately, increased mortality

CHAPTER THREE

METHODS

3.1 Study Area

Kpong is a town in the Manya Krobo Municipality in Eastern Region of Ghana was the study area. The Eastern Region occupies a land area of 19,323 kilometres and constitutes 8.1 per cent of the total land area of Ghana. It is the sixth largest region in terms of land area and has a population of 121,478. According to 2021 population and housing census, there were 56,662 males and 64,816 females. The Municipality's borders are shared by the Asuogyaman District to the east, Yilo Krobo Municipal to the west, Shai Osudoku District to the south, and Upper Manya Krobo District to the north. Sixteen (16) communities make up the municipality and is mostly dominated by the Krobos, other ethnic groups like the Akans, Ewes, Hausas, and Gas are residents. The major landmark in the municipality is the Volta Lake that serves recreational, transportation, occupational and as a food source for the populace. The Kpong lorry park enclave which includes the market has geographical coordinates 6^0 09'38.44" N $0^0$03'29.94" E with an elevation of 88ft above sea level. Also, a landmark in Ahodwzo the Multihotel limited has geographical coordinates 6^0 09'29.12" N 0^0 03'44.95" E with an elevation of 60ft above sea level.

Specifically, participants were drawn from the eight (8) local areas within the metropolis and at Asutuare junction. The areas in kpong were Bartokoge, Anlokoge, Ahodwzo, Weapong, Kpong quarters, Abesakope, Ayikpala and the Kpong lorry Park/ Market.

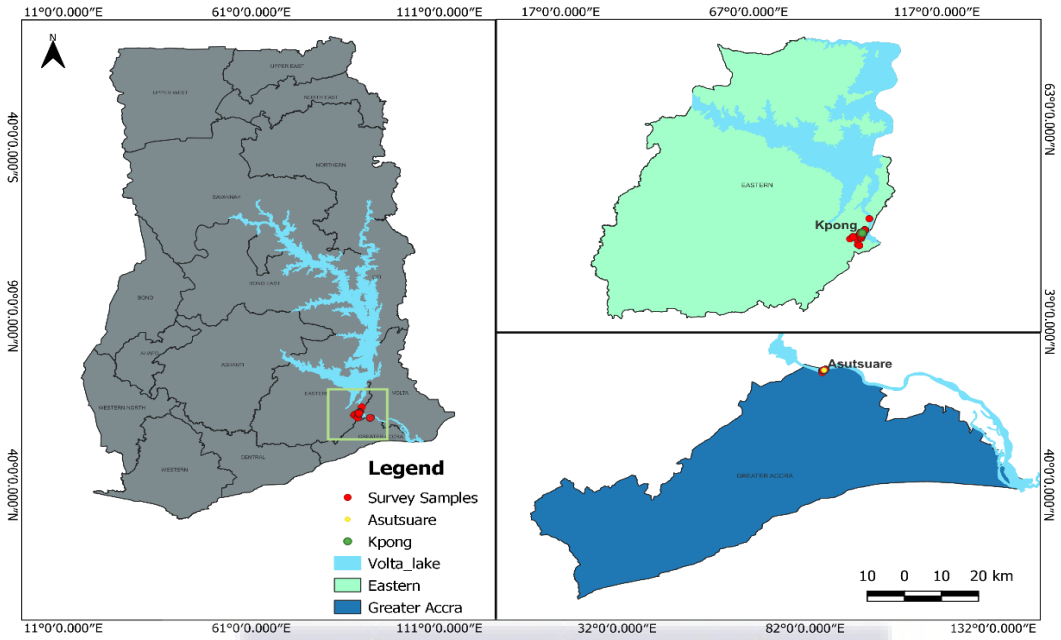


Figure 2: Map of study area

3.2 Study Design

This cross-sectional baseline study was part of a clustered randomized control trial (B4C) project which tested the impact of the utilization of aquatic biomass briquette in riparian communities of the lower Volta Lake. The study's population diastolic and systolic blood pressure, CO, and particulate matter concentrations were measured quantitatively. A modified questionnaire was designed to get more information on participants' demography and their exposure to household air pollutants. An activity diary was designed and research assistants followed participants marking their daily routine.

3.3 The Study Population

The study's source population consisted of adult males residing in Kpong villages. They were selected from Bartokoge, Anlokoge, Ahodwzo, Weapong, Kpong quarters, Abesakope, Ayikpala

and the Kpong lorry Park/ Market. From the source population, 110 adult males (aged above 18 years) were selected randomly to be participants.

3.4 Sampling Size and Strategies

Sampling was selected randomly from a previous brickette for cooking clustered randomized control trial project in Kpong where 420 households were selected. 110 participants were selected randomly using the prevalence of hypertension and cardiovascular diseases of 34% (0.34) obtained from a study by Fedelis Atibila in 2021in a similar Ghanaian setting.

A $Z_{1-\alpha/2}$ score at 95% confidence interval of 1.96 and a margin of error of 8%.

Sample size $n = \frac{\left(Z_{1-\frac{\alpha}{2}}\right)^2 pq}{e^2}$

n is the sample size

e is the margin of error

p is the prevalence of hypertension in a previous study

q is population without hypertension (1-P)

$n = \frac{1.96^2\ (0.34)\ (0.66)}{(0.08)^2} = 100.2 = 101$

About one hundred and ten (110) eligible male participants were recruited for the study.

3.5 Inclusion Criteria

i. All the selected participants were male aged above 18 years.

ii. Participants lived in households that took part in the B4C project.

iii. Participants lived in the area during the study.

iv. Participants lived in households with more than one room. This was done to avoid selecting participants residing in an overcrowded environment.

3.5.1 Exclusion Criteria

i. Adult males with underlying respiratory diseases were excluded.

ii. Adult males who lived in a one room household were not selected.

3.5.2 Study Instruments

Some measurements were done during the study using various specialized instruments. These were: Particle and Temperature Sensor (PATS+) and Lascar U500 for measurement of personal exposure to particulate matter and CO. Clarity node air sensors were also used to measure ambient particulate matter within the environs of the study area through the period of the study. An Omron blood pressure monitor was used to measure the blood pressure of study participants.

3.5.3 Study Variables

3.6.1 Main Determinants

Personal CO measured in ppm, personal PM2.5 and indoor PM10 measured in ug/m3 were the primary factors of interest.

3.6.2 Primary factors of Interest

The outcomes of interest were the systolic (force of blood flowing out of the heart) and diastolic (the pressure in the arteries when the heart is at rest between beats) blood pressures measured in mmHg which determine hypertension (a chronic condition that occurs when the force of blood against your artery walls is consistently too high) (Biino et al, 2013).

3.6.3 Potential Confounders

Socioeconomic status (SES), sex, age, educational level, household characteristics, length of time spent in the community were all potential confounders.(Laumbach & Kipen, 2012)

3.7 Field Data Collection

Four (4) stages comprised the field data collection process:

(i) field workers' training (ii) stakeholder meetings, screening, and mapping (iii) recruiting households, and (iv) data gathering

(i) Training of Field workers

Four (4) research assistants, including two (2) nurses, were trained in how to use instruments for data collection by experts. The training began at the Environmental Quality Department of the Environmental Protection Agency's (EPA) head office, Accra. The training was conducted for three (3) days.

On the first day, the team discussed procedures and steps in conducting field work and the ethos of research work. Research assistants were taking through the various sections of the questionnaire and how to fill it thoroughly. They were educated about the ethical issues relating to participants and the need to allocate time for participants to get the relevant information needed for analysis.

On the second day, there was hands-on training on air quality monitoring and personal exposure monitoring. Procedures in appropriate site identification for ambient monitoring and where to place personal monitors on participants were discussed. The team was taken through the calibration/zeroing processes of PATS+ and lascar CO monitors. Subsequently the downloading and analyzing data process from monitors were demonstrated.

On the third day, the use of the Omron blood pressure monitor was also demonstrated, and the Standard Operation Procedure of the instrument was followed to check for precision and reliability. The team was educated about the need to give ample time to participants when taking the blood pressure and make sure that participants are not under stress or duress when taking the measurement. The team was also educated on the interpretation of the results.

Figure 3: Picture of training of field officers at the EPA Head Office laboratory Accra.

(ii) A stakeholder meeting, mapping and selection of participants

To inform the Kpong communities' stakeholders on the study, the research team met with them. A brief presentation and an introduction of the team, including research assistants who resided in the community during the period of the study were shown to the stakeholders.

The main objective of the project was discussed including timelines, participant recruitment, data collection process, instrumentation to be used and consent of participants. A fisherman who resides in the community with good knowledge about the study area was chosen to lead the team

during the mapping process. The fisherman spoke Ga adangbe which was the language predominantly among the people of Kpong.

Subsequently, a questionnaire was filled in by the stakeholder to inform the team about some statistics in the study area. The stakeholders included members from the municipal assembly who gave information about the number of households in the study area and the names of the heads of the households.

(iii) Participants recruitment

The eligibility of participants was carried out by asking questions on the questionnaire and ascertaining whether the individual meets the inclusion criteria. When an individual meets the criteria, the objectives of the study are explained. In the same way, those who did not meet the criteria were informed and an explanation for the reasons why they were not chosen was given. Both the research team and the participants agreed on the date and time for the field data collection for those that were selected for the study. One hundred and ten participants were chosen from the following communities Bartokoge (20), Anlokoge (14), Ahodwzo (15), Weapong (10), Kpong quarters (10), Abesakope (10), Ayikpala (12) and the Kpong lorry Park/ Market (19).

Figure 4: Picture of participants wearing personal PM2.5, CO monitors and blood pressure measurements

3.8 Data Collection

Questionnaire

A printed questionnaire was administered to participants to get information about their personal information, vital statistics, household characteristics, socioeconomic characteristics, smoking status and health outcomes.

Personal Particulate Matter (PM2.5)

Personal particulate matter ($PM_{2.5}$) was sampled using a PATS+ sampler. The PATS+ is a small, portable data logging device that measures real-time particle concentrations. It has a lower particulate matter detection limit of 10 to 20 $\mu g/m^3$ and Upper particulate matter detection limit 30,000 to 50,000 $\mu g/m^3$. It is also a mobile device that measures temperature and humidity. The PATS+ was calibrated in a zero-particle environment (clean area, safe from direct sunlight) for 10 minutes before sampling. i.e. The PATS+ was placed in an airtight box with an intake hole connected with a clean filter. 100 squeezes of air were pumped through the intake hole using the squeeze pump. After 10 minutes, the PATS+ sampling mode was activated when the lights flashed green. The monitors were placed in fabricated vests on the participants for 24hrs. The participants were followed and their activities during the day were recorded. The zeroing process ended after the 24hr sampling to stop the PATS+ (the PATS+ lights were flashing red). The PATS+ was connected to a computer and the results were downloaded.

Particulate Matter (PM10)

Clarity node sensors were used to measure indoor particulate matter (PM_{10}). The clarity nodes were collocated with the EPA reference monitor at the university of Ghana Legon to ensure accuracy of particulate matter levels. The sensors were placed at a height above 5 meters to avoid the sampling of dust made airborne by gusty winds. Indoor PM_{10} was measured for 3 months during the period of the study.

Carbon monoxide (CO)

A Lascar U500 data recorder with a measurement range of 0-1000 ppm and a resolution of 0.5 ppm was used to measure the personal CO levels over a 24-hour period. Each participant wore a specially designed apron, and the personal monitors were held tight in the pockets of the apron. Sampling was done for a 24-hr period. Before deployment, the monitors were charged to attain full battery status. The instrument was then connected to a laptop to download the data.

Systolic and Diastolic Blood Pressure

An Omron blood pressure monitor was used to measure the participants' systolic and diastolic blood pressure. The monitor's batteries were completely charged. Participants were educated on the procedures of taking accurate measurements. They were made to sit comfortably for at least 5 minutes before taking the measurement. They were made to relax and avoid talking during the measurement. They sat with their backs supported, feet flat on the floor, and arms at heart level, resting on a flat surface. The cuff of the monitor was wrapped around the upper arm, 1-2 cm above the elbow not too tight. There was enough room to slip one finger between the cuff and the arm. The cuff was positioned on the bare skin. The "Start" button on the Omron BP monitor was pressed and the cuff inflated automatically and then gradually deflated. The measurement of the blood pressure displayed on the screens and recordings were recorded. To ensure consistency multiple readings are taken after allowing participants to wait at least 1-2 minutes before taking another measurement to allow the arm to return to its normal state.

3.9 Quality Control

To guarantee uniformity and completeness, the field staff and main investigator carefully reviewed and cross-checked the completed questionnaires at the conclusion of each day. Results

obtained for personal PM2.5 and CO, indoor PM10, systolic and diastolic blood pressure were downloaded after measurement and thoroughly cross checked.

3.10 Potential Risks

The lead investigator, research assistants, and participants were not in danger during the data gathering process.

3.11 Data Analyses

To find any missing values, the acquired data was examined and cross-checked. As a result, there were fewer errors in the data entry and analysis. STATA Version 16 was used to analyze the data that was gathered using the modified questionnaire. The study's results were evaluated using a 95% confidence level and a p-value of less than 0.05. Frequency tables and charts were used to display the data. To find correlations between blood pressures, personal CO and PM2.5, indoor PM10 concentrations, logistic regression was used.

3.12 Ethical Consideration

The study's ethical permission was acquired from the Ghana Health Service's Ethics Review Committee through the University of Ghana's School of Public Health and Kpong Township's community leaders. Before any responders were included as study participants, their signed agreement was obtained. Ethics clearance has been granted for this investigation (GHS-ERC:015/03/21).

3.13 Informed Consent

Participants were asked for their informed permission. With the assistance of a translator, the participants were informed of the study's goal and methodology in the language they could understand the best. Any questions that came up during the informed consent procedure were carefully answered.

CHAPTER FOUR

RESULTS

4.0 Introduction

This section provides the study's findings; the first portion highlights the information gathered from the questionnaire that was given out, while the second section details the study participants' levels of particulate matter (PM2.5, PM10) and CO

4.1 Characteristics of study population

For this study, 110 participant's data were analyzed. All participants were older than eighteen. Most research participants (33.64%) were in the 35–44 age range, while the smallest percentage (17.27%) were in the 18–24 age range. 52.73% had basic education. While 12.73% of the study population was unemployed during the study period, more than 60% of the population worked during the period of the study. 19.09% were habitual smokers. 33.64% were hypertensive during the period of the study.67.57% in the 35-44 age range were hypertensive.

Table 1: Characteristics of the study population at kpong

Age Group	**Frequency**	**Percentage**
18-24	19	17.27
25-34	32	29.09
35-44	37	33.64
>45	22	20.00
Education Level		
Basic	58	52.73
Secondary	29	26.36
Tertiary	23	20.91
Occupation		
Formal	29	20.36
Informal	67	60.91
Unemployed	14	12.73

Household fuel type		
Biomass	33	30.00
Clean fuel	48	43.64
Both biomass and clean fuel	29	26.36
Smoking?		
No	89	80.91
Yes	21	19.09

Note: Clean fuels are fuels that are cleaner burning, pollute less and reduce greenhouse gas emissions.

4.2 Particulate matter ($PM_{2.5}$ and PM_{10}) concentration.

The 24-hour personal PM2.5 levels measured ranged between (35.98 – 76.64) ug/m3 with mean and standard deviation of (55.90 ± 9.26). The PM10 levels measured indoors ranged between (40.71 – 113.07) ug/m3 with mean and standard deviation of (73.10 ± 13.84).

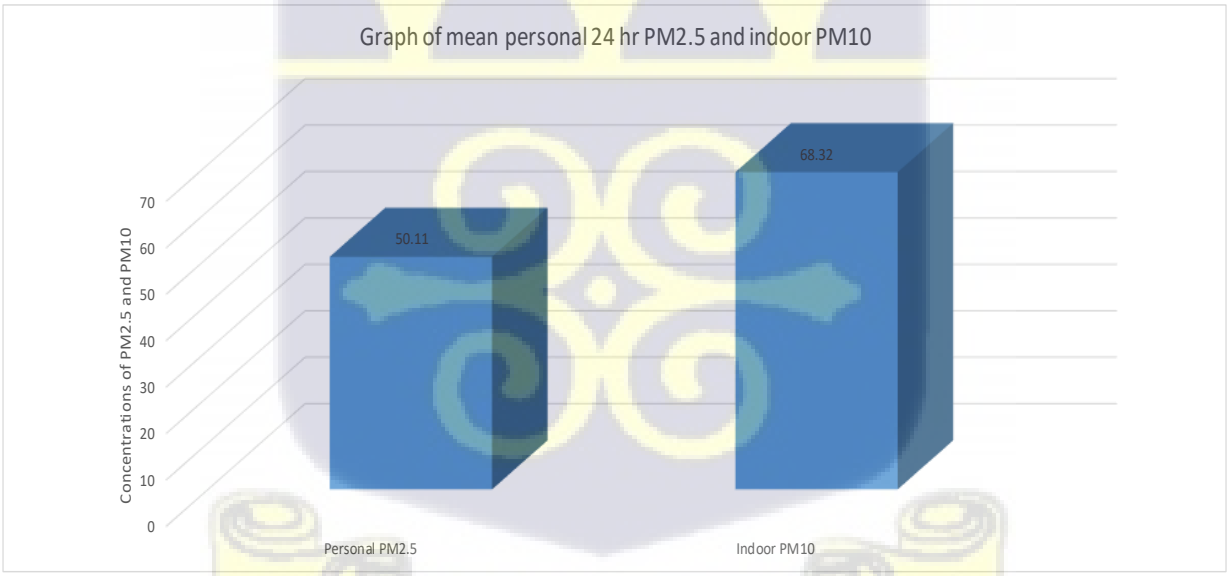


Figure 5. Graph of mean 24-hour personal PM2.5 and indoor PM10 measured.

4.3 Personal carbon monoxide (CO) concentration measured

The personal 24 - hour carbon monoxide concentrations measured ranged between (0.98 – 17.70) ppm with mean and standard deviation of (4.59 ±2.84). The concentration of mean CO exposure for non – smokers and smokers were 3.6 and 8.57 ppm respectively.

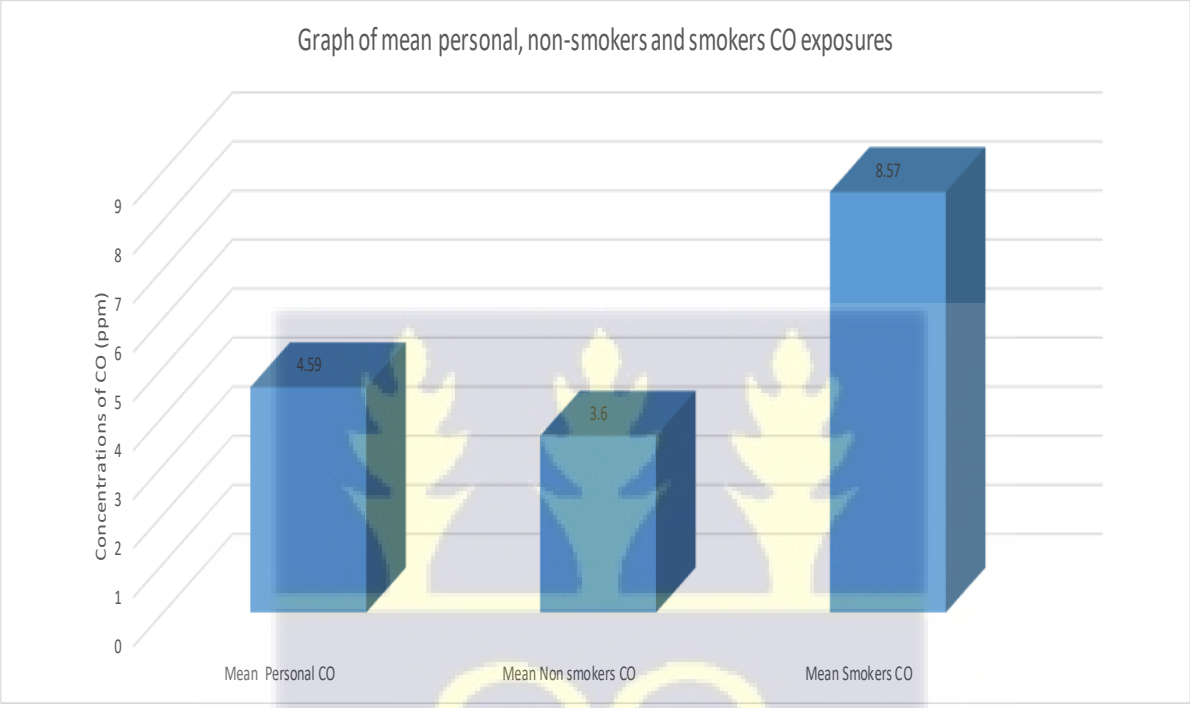
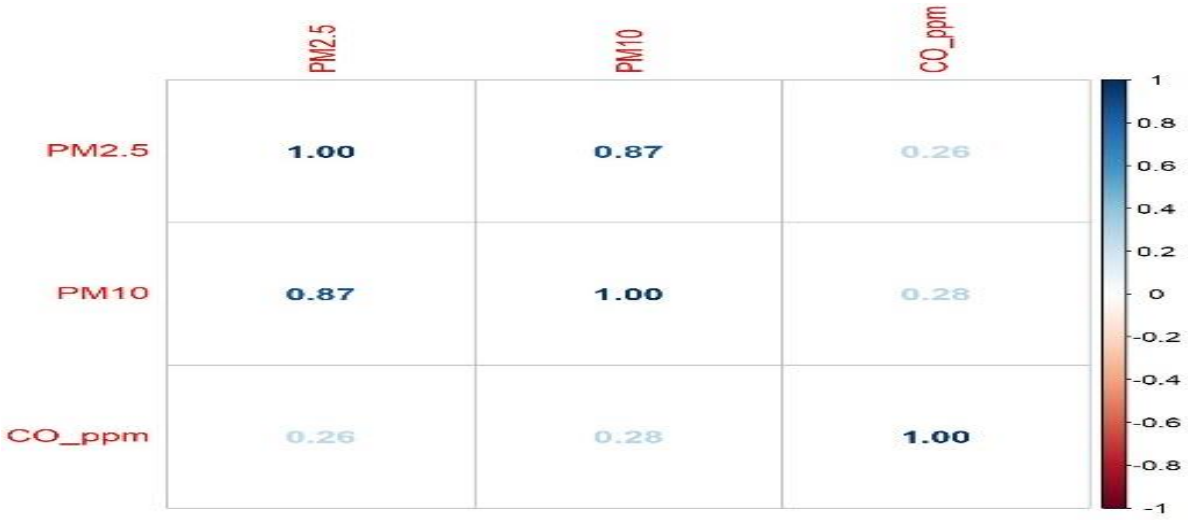


Figure 6. Graph of mean 24-hours personal CO, non – smokers and smokers CO exposure.

4.4 The correlation analysis between independent variables (PM2.5, PM10 and CO)

The correlation matrix revealed a strong rela PM2.5 and PM10 (0.87), suggesting that these two pollutants may originate from similar sources. In contrast, the correlation between carbon monoxide (CO) exposure and particulate matter was weak (0.28 for PM2.5 and 0.26 for PM10), indicating that other sources likely influence CO levels.

Table 2. Correlation table



4.4 Distribution of PM2.5 (A), PM10 (B) levels and occupation and smoking status

The assessment of Particulate matter (PM2.5 and PM10) exposure levels by occupation was conducted to determine how different occupations influence the level of Particulate matter exposure within the participants. The results of the one-way ANOVA indicated significant differences in PM exposure levels across various occupations [F = 3.20, p-value = 0.03]. Subsequent Bonferroni post hoc analysis identified that the significant difference was specifically between formal and informal workers. Unemployed participants showed slightly different exposure levels, suggesting that PM exposure levels are relatively similar across the occupations. This can also be inferred on the plot for smokers and non – smokers.

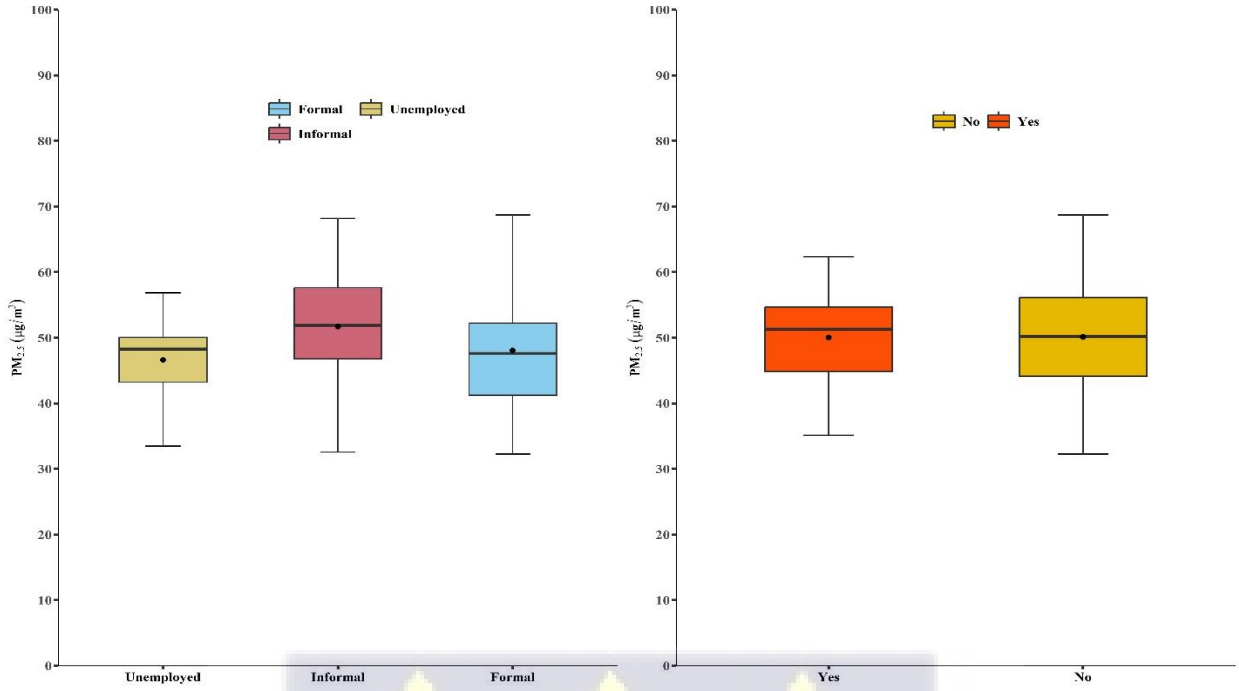


Figure 7. (A) Graph of distribution of personal PM2.5 levels, occupation and smoking status.

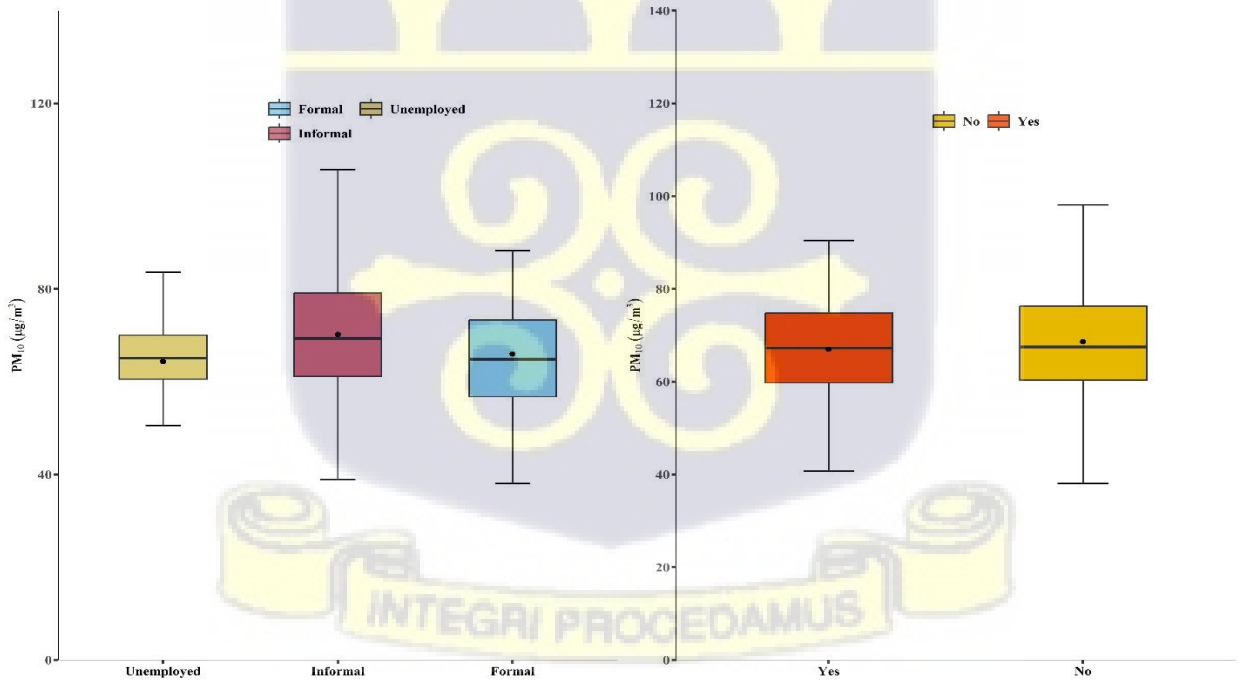


Figure 8. (B) Graph of distribution of indoor PM10 levels, occupation and smoking status.

4.5 Distribution of personal CO concentrations, occupation and smoking status

The exposure levels of carbon monoxide based on smoking status was assessed. The analysis (independent t-test) revealed that the levels of CO (ppm) exposure differ significantly between smokers and non – smokers [t=-4.27 p-value=0.0003]. This implies that smokers within the study area are likely to be exposed to higher levels of CO levels as compared to non-smokers.

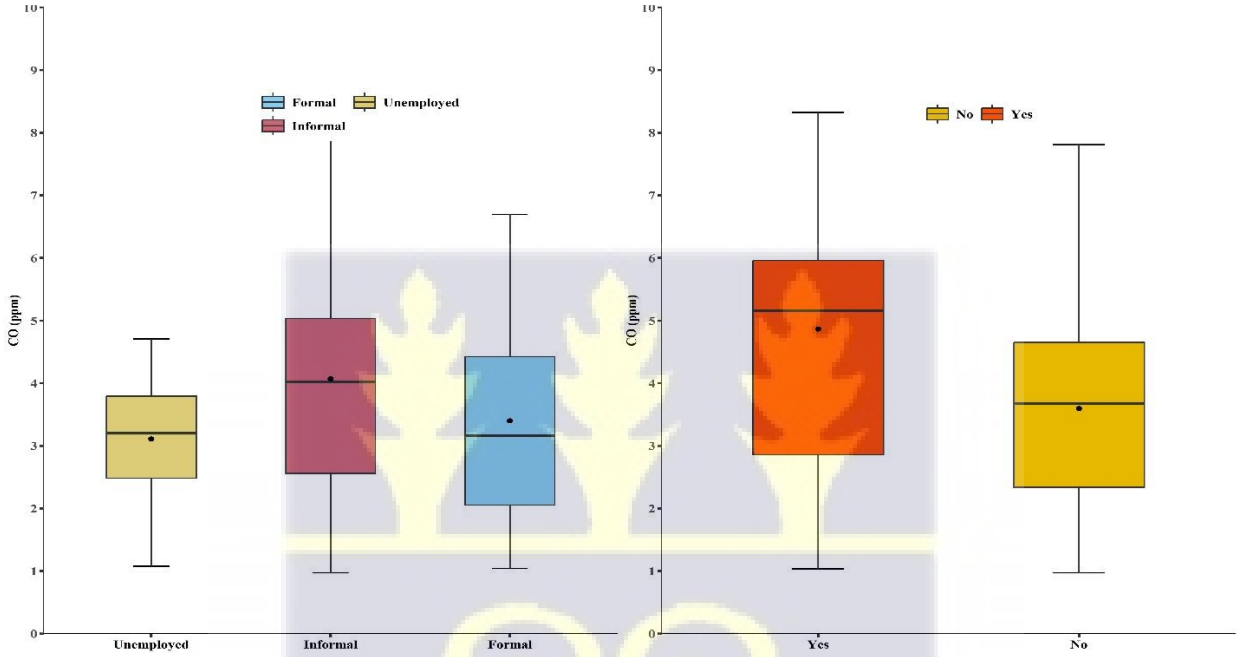


Figure 8. Plot of personal CO concentrations, occupation and smoking status.

4.7 Diastolic and systolic blood pressure

The diastolic blood pressure of the participants ranged between (61 – 99) mmHg with mean and standard deviation (79 ±12) mmHg. Similarly, the systolic blood pressure of the participants ranged between (102 – 151) mmHg with mean and standard deviation (121 ±12) mmHg.

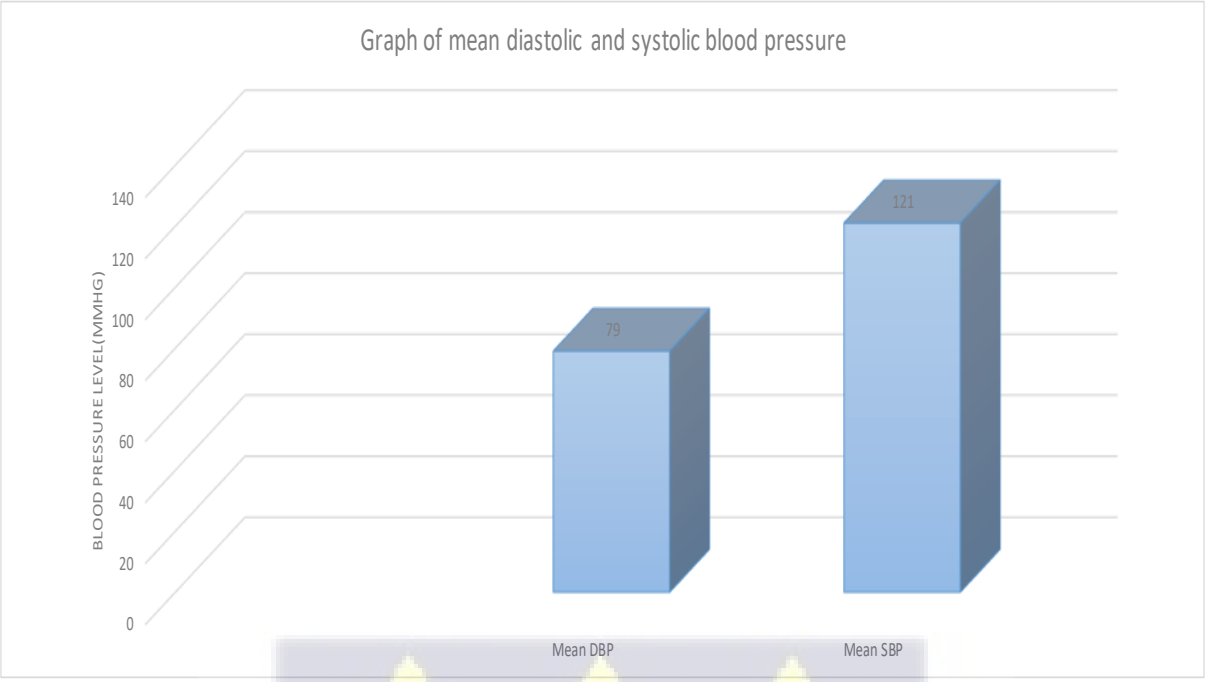


Figure 9. Graph of mean diastolic and systolic blood pressure of participants.

4.7 Diastolic and systolic blood pressure of non – smokers and smokers

The diastolic blood pressure of the non – smoking participants ranged between (62 – 91) mmHg with mean and standard deviation (78 ±11) mmHg. Also, the systolic blood pressure ranged between (102 – 145) mmHg with mean and standard deviation (118 ±11) mmHg. For smokers, the diastolic blood pressure ranged between (65 – 99) with mean and standard deviation (85 ±14) mmHg. The systolic blood pressure ranged between (102 – 149) mmHg with mean and standard deviation (130 ±14) mmHg.

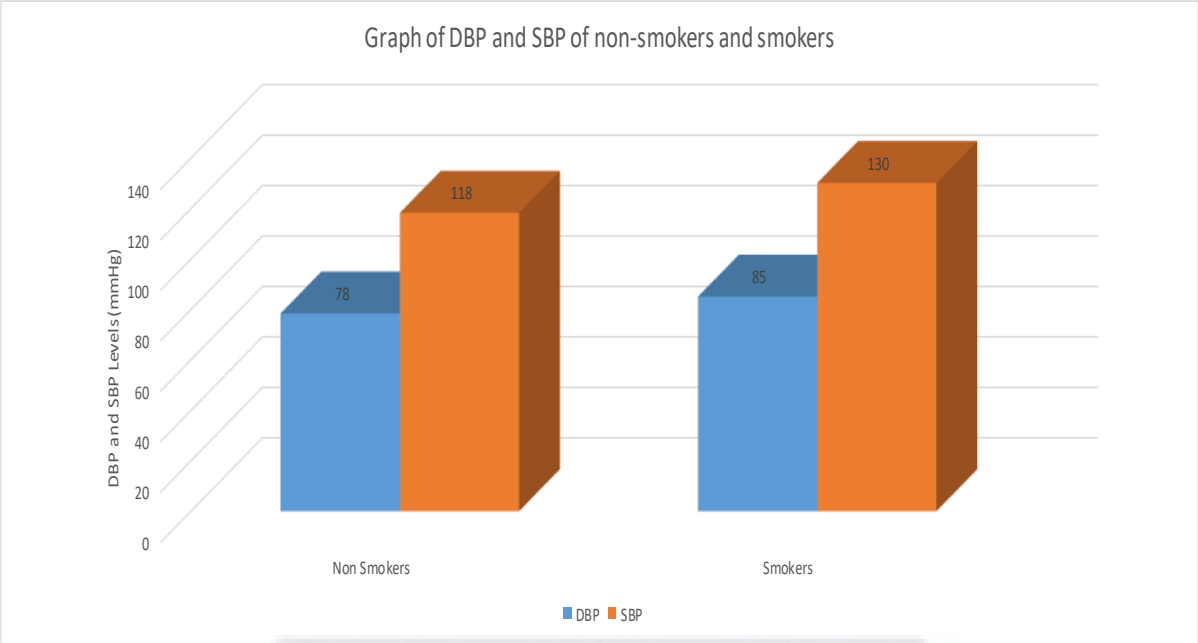


Figure 10. Graph of mean diastolic and systolic blood pressure of non – smokers and smokers.

4.8 Prevalence of Hypertension among participants

37 participants out of a total of 110 were hypertensive during the period of the study. The prevalence of hypertension by age has also been illustrated in the graphs below (B).

Figure 11. Graph of hypertensive and non – hypertensive participants.

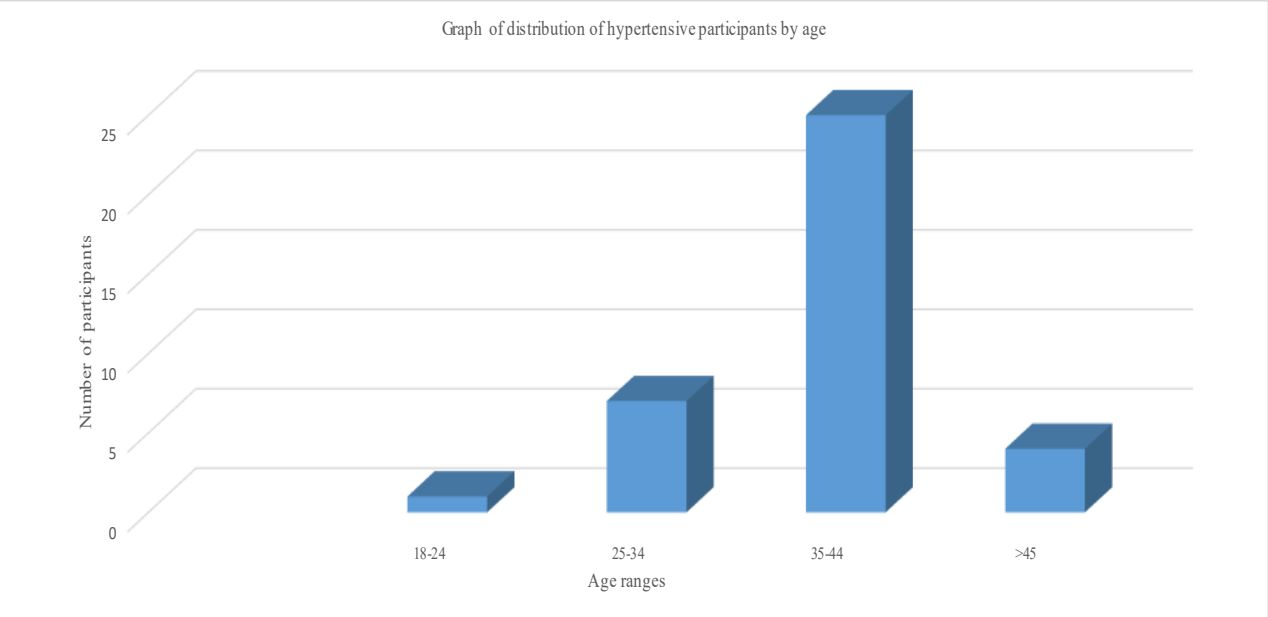


Figure 12. Graph of the prevalence of hypertension by age ranges.

4.9 Association between personal 24-hour PM2.5 levels, CO, indoor PM10, hypertension, diastolic and systolic blood pressure

Carbon Monoxide (CO) shows significant associations with both hypertension and systolic blood pressure in the unadjusted models, and the relationship remains borderline significant for systolic blood pressure after adjusting. This suggests that CO could have an important role in these outcomes. For hypertension, after adjusting for other factors, CO's association strengthens, with an adjusted OR of 2.27 and a p-value of 0.04, indicating a statistically significant relationship. PM2.5 and PM10 have weaker or non-significant associations with all three outcomes in both unadjusted and adjusted models, with PM10 showing a borderline trend toward significance for hypertension (adjusted OR = 0.74, p-value = 0.08). Diastolic blood pressure and systolic blood pressure both show borderline associations with air pollution in some cases (e.g., CO for DBP and PM10 for DBP), but none of the relationships are significant after adjustment. PM2.5 has a very weak or negligible relationship with systolic blood pressure, with a very low adjusted OR of 0.91 and a p-value of 0.35.

Table 3: Table of association between air quality indicators and hypertension, systolic and diastolic blood pressures.

*Adjusted models include confounders such as smoking habits, occupation, level of education and household fuel type.

	Unadjusted		Adjusted	
	Odds Ratio [95% CI]	**p-value**	**Odds Ratio [95% CI]**	**p-value**
Outcome Variable: Hypertension				
PM2.5	0.97[0.92 – 1.02]	0.25	0.91[0.80 – 1.04]	0.17
PM10	0.93[0.85 – 1.01]	0.19	0.74[0.69 – 1.15]	0.08
CO	1.53[0.03 – 4.67]	0.01	2.27[1.36 – 3.78]	0.04
Outcome Variable: Diastolic Blood Pressure				
PM2.5	0.11[0.06 – 0.37]	0.40	0.02[0.01 – 0.52]	0.29
PM10	0.08[0.05 – 0.31]	0.15	0.28[0.47 – 1.10]	0.09
CO	0.82[0.16 – 1.48]	0.02	1.34[1.21 – 3.56]	0.06
Outcome Variable: Systolic Blood Pressure				
PM2.5	0.03[-0.23 – 0.28]	0.84	0.18[0.80 – 1.04]	0.35
PM10	0.13[0.05 – 1.13]	0.18	0.43[0.29 – 1.05]	0.13
CO	1.51[0.87 – 2.19]	0.01	1.69[1.48 – 3.85]	0.09

CHAPTER FIVE

DISCUSSION

5.1 Main findings

The prevalence of hypertension among the adult male in this study was 33.64%. The mean levels of diastolic and systolic blood pressures were 79 and 121mmHg respectively. The correlation between carbon monoxide (CO) exposure and particulate matter was weak ($r < 0.30$). PM2.5 and PM10 exposure levels are relatively similar and there were no significant differences across the occupations. $PM_{2.5}$ levels might not have a significant relation to hypertension within males in the study area.

On the contrast, CO exposure exhibited a significant positive correlation with diastolic and systolic blood pressure. On average, each 1 ppm increase in CO exposure was linked to a rise of 1.34 mmHg in DBP and 1.69 mmHg in systolic blood pressure (SBP).

Additionally, compared to non-smokers, smokers in the study area were exposed to higher levels of CO. It was shown that CO significantly affects blood pressure, both diastolic and systolic, and increases the risk of hypertension. It is worth noting that smoking already contributes to a higher cardiovascular risk due to the toxic substances in cigarette smoke (like nicotine and other chemicals), which can damage the heart and blood vessels. The added effect of CO exposure from smoking further exacerbates this risk, creating a synergistic effect that accelerates the development of hypertension and cardiovascular diseases.

5.2 Methodological Validity

The strength of this study is in the fact that several standard operation procedures were followed before the commencement of the study. The study was carefully planned with the mapping and screening process of the household where the male participants were selected from.

A modified questionnaire was drafted and reviewed to ensure accuracy and the capturing of important information from the male participants. To minimize selection bias, the screening procedure used to identify the participants for this study was followed by random sampling of the high-participation respondents and proportionate sample selection throughout the communities.

Research assistants were properly trained before been deployed to the field to conduct the study. The equipment used for the study was well calibrated and measurements were repeated to ensure precision.

Consent was sort from community leaders from the onset, and they lead and supported the team by rallying male participants to be selected. The effects of not evaluating possible confounders were minimized because the study population had similar features.

Nevertheless, the study had limitations as well in the fact that measuring equipment was not acquired on time thereby delaying the process of data collection. Also, some of the participants were reluctant to wear the personal monitors for the required 24-hour monitoring period. This required strict surveillance, supervision and recalibration of equipment at participants' homes especially.

5.2 Comparison with previous studies

In the current study group, 33.64% of the male participants had hypertension. The findings of this study are comparable to those of a study conducted by Fedelis Atibila and colleagues (2021) in Ghana titled prevalence of hypertension in Ghanaian society, a systematic review, meta- analysis, and GRADE assessment where 45,470 subjects (n= 22,866 males and 22,604 females) were enrolled. The prevalence of hypertension in males was 34.00%.

In a study by Ruqayya Nasir Sani in 2022, on rural – urban difference in the prevalence of hypertension in West Africa: a systematic review and meta – analysis. The prevalence of hypertension was high in both rural and urban areas. The rural areas had a pooled prevalence of 27.4%; and that of urban areas was 33.9% respectively. The pooled prevalence of hypertension was 32.6% in males. This result is quite similar with the prevalence of 34.00% obtained in the study in Kpong.

The results obtained for this current study on the correlation between PM2.5 and PM10 ($r < 0.5$) is similarly to that of S. A Sarpong and associates in 2021 in the Tema Metropolitan Area on the exposure to PM2.5, PM10, TSP. The study revealed a significant correlation ($r<0.5$) between PM2.5 and PM10).(Asomaning Sarpong et al., 2021).

Each 1 ppm increase in CO exposure was linked to a rise of 0.82 mmHg in DBP and 0.11 mmHg in SBP, according to this current study. There was a significant positive association between CO exposure and DBP. This is comparable to a study by Quinn among pregnant women in rural Ghana that found a 0.43 mmHg increase in DBP for every 1 ppm increase in CO exposure.(Quinn et al., 2016).

A study by Huang on neurological consequences in patients with carbon monoxide poisoning were predicted by exposure duration and history of hypertension revealed smokers are likely to be exposed to higher levels of CO levels as compared to non-smokers (Huang et al., 2019) which is similarly to the findings in this study.

This study revealed that carbon monoxide (CO) significantly influences both systolic and diastolic blood pressure and the risk of hypertension. Numerous studies have highlighted the increased exposure to carbon monoxide (CO) in smokers. Additionally, these studies have noted

a higher risk of hypertension in smokers compared to non-smokers (Peng et al., 2023)(Quinn et al., 2016).

The result of the odds ratio of hypertension in males when exposed to household air pollutants was 2.34 in this study. This is different from the odds ratio of 1.9 for males in the urban setting obtained by Charles Agyeman in 2006 on a study on rural and urban differences in blood pressure and hypertension in Ghana, West Africa.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Mean $PM_{2.5}$ exposure levels and CO recorded during the period of the study exceeded the 24-hour recommended levels for the concentrations of these pollutants prescribed in the local (35 ug/m3) and international (15 ug/m3) regulatory limits. $PM_{2.5}$ levels might not have a significant relation to hypertension within study participants; however, it was revealed that CO has significant impact on systolic and diastolic blood pressure as well as the risk of developing hypertension irrespective of adult male occupation, educational level and socio – economic status.

6.2 Recommendations

1. The Health Directorate in Kpong should periodically perform health screening to check the blood pressure especially among the male populace within the fishing community because of their exposure to CO through the processing of fish.
2. The Environmental Protection Authority in collaboration with other stakeholders should advocate for clean air initiatives and promote use of alternative fuels that reduce levels of CO. This would help reduce the exposure of populace to harmful pollutants and mitigate the health impacts associated with air pollution.
3. The planning unit of the municipality should make sure they demarcate plots of land with enough spaces for the houses to be able to be built with adequate ventilation.
4. The Academia and Environmental Protection Authority Ghana should source for funding regarding research and advocate for policies that will bring targeted interventions into HAP sources.

References

Abdul-Wakeel Karakara, A., & Dasmani, I. (2019). An econometric analysis of domestic fuel consumption in Ghana: Implications for poverty reduction. *Cogent Social Sciences*, *5*(1). https://doi.org/10.1080/23311886.2019.1697499

Abdullahi, L. K. (2016). *CHARACTERISATION OF PARTICULATE MATTER*.

Aboagye, B., Gyamfi, S., Ofosu, E. A., & Djordjevic, S. (2021). Status of renewable energy resources for electricity supply in Ghana. *Scientific African*, *11*, e00660. https://doi.org/10.1016/J.SCIAF.2020.E00660

Adekoya, A., Tyagi, S. K., Duru, C. N., Satia, I., Paudyal, V., & Kurmi, O. P. (2022). Effects of household air pollution (HAP) on cardiovascular diseases in low-and middle-income countries (LMICs): a systematic review and meta-analysis. *International Journal of Environmental Research and Public Health*, *19*(15), 9298.

Adusah-Poku, F., Kwame Adjei-Mantey, |, & Kwakwa, P. A. (2021). *Are energy-poor households also poor? Evidence from Ghana*. https://doi.org/10.1002/pop4.301

Agyei Paul Kwakwa, Edward Debrah Wiafe, & Hamdiyah Alhassan. (2013). *(PDF) Households Energy Choice in Ghana*. https://www.researchgate.net/publication/270452842_Households_Energy_Choice_in_Ghana

Agyekum, K., Ayarkwa, J., Koranteng, C., & Adinyira, E. (2013). *An Overview of the Symptoms Associated with Dampness in Walls of Residential Buildings in Major Towns in Ghana*. 1–10.

Ahmad, R., Nabila Ilyas, H., Li, B., Sultan, M., Amjad, M., Aleem, M., Abbas, A., Imran, M. A., Riaz, F., Kumar, S., Kshirsagar, M., Vincent, S., & Hu, J. (2022). *Current challenges and future prospect of biomass cooking and heating stoves in Asian Countries REVIEWED BY*. https://doi.org/10.3389/fenrg.2022.880064

Ahmed, H. (2019). *Exposure to Household Air Pollution from Wood Combustion and Association with Respiratory Symptoms and Lung Function in Nonsmoking Women_ Results from the RESPIRE Trial, Guatemala*.

Argyropoulos, C., Pana, Z. D., Tawiah, T., Shupler, M., Gyaase, S., Anderson De Cuevas, R., Saah, J., Nix, E., Twumasi, M., Quansah, R., Puzzolo, E., Pope, D., & Asante, K. P. (2022). *The Association between Household Air Pollution and Blood Pressure in Obuasi Municipality, Ghana*. https://doi.org/10.3390/atmos13122033

Ashmore, M. (2024). Air Pollution. *Encyclopedia of Biodiversity, Third Edition: Volume 1-7*, *August*, V4-331-V4-342. https://doi.org/10.1016/B978-0-12-822562-2.00180-8

Asomaning Sarpong, S., Fosu Donkoh, R., Kan-saambayelle Konnuba, J., Ohene-Agyei, C., & Lee, Y. (2021). *Analysis of PM 2.5 , PM 10 , and Total Suspended Particle Exposure in the Tema Metropolitan Area of Ghana*. https://doi.org/10.3390/atmos12060700

Atkinson, J., Chartier, Y., Pessoa-silva, C. L., Jensen, P., & Li, Y. (n.d.). *Natural Ventilation for*

Infection Control in Health-Care Settings Edited by :

Bawakyillenuo, S., Crentsil, A. O., Innocent, K., Danquah, S., Boakye-, E. B., & Menyeh, B. O. (2021). *The landscape of energy for cooking in Ghana : A review Submitted By*. *June*.

Bruce, N., Pope, D., Rehfuess, E., Balakrishnan, K., Adair-rohani, H., & Dora, C. (2015). WHO indoor air quality guidelines on household fuel combustion : Strategy implications of new evidence on interventions and exposure e risk functions. *Atmospheric Environment*, *106*, 451–457. https://doi.org/10.1016/j.atmosenv.2014.08.064

Carter, E., Norris, C., Dionisio, K. L., Balakrishnan, K., Checkley, W., Clark, M. L., Ghosh, S., Jack, D. W., Kinney, P. L., Marshall, J. D., Naeher, L. P., Peel, J. L., Sambandam, S., Schauer, J. J., Smith, K. R., Wylie, B. J., & Baumgartner, J. (2017). Assessing exposure to household air pollution: A systematic review and pooled analysis of carbon monoxide as a surrogate measure of particulate matter. *Environmental Health Perspectives*, *125*(7). https://doi.org/10.1289/EHP767

Ceballos, D. M., Broadwater, K., Page, E., Croteau, G., & La, M. J. (2022). *of Pit Foam with PBDE-Free Foams*. 1–9. https://doi.org/10.1016/j.envint.2018.03.035.Occupational

Clark, M. L., Peel, J. L., Balakrishnan, K., Breysse, P. N., Chillrud, S. N., Naeher, L. P., Rodes, C. E., Vette, A. F., & Balbus, J. M. (2020). *Health and Household Air Pollution from Solid Fuel Use : The Need for Improved Exposure Assessment*. *1120*(10), 1120–1128.

Eljarrat, E., Li, F., Jahangir Alam, M., Stavropoulou, E., Manisalidis, I., Stavropoulos, A., & Bezirtzoglou, E. (2020). Environmental and Health Impacts of Air Pollution: A Review. *Frontiers in Public Health | Www.Frontiersin.Org*, *8*, 14. https://doi.org/10.3389/fpubh.2020.00014

Gan, H., Cheng, L., Zhai, Y., Wang, Y., Hu, H., Zhu, Z., Sun, B., Zhang, Q., Rajput, P., & Han, C. (2022). *(No Title)*. https://doi.org/10.3389/fenvs.2022.945870

Giordano, M. R., & Jaramillo, P. (2021). AfriqAir's mission towards cleaner air for Africa and a call to action. *Clean Air Journal*, *31*(1), 1-3.

Giorgini, P., Di Giosia, P., Grassi, D., Rubenfire, M., D. Brook, R., & Ferri, C. (2015). Air Pollution Exposure and Blood Pressure: An Updated Review of the Literature. In *Current Pharmaceutical Design* (Vol. 22, Issue 1, pp. 28–51). https://doi.org/10.2174/1381612822666151109111712

Holm, S. M., Balmes, J., Gillette, D., Hartin, K., Seto, E., Lindeman, D., ... & Fong, E. (2018). Cooking behaviors are related to household particulate matter exposure in children with asthma in the urban East Bay Area of Northern California. *PLoS One*, *13*(6), e0197199.

Home | Clean Air Africa. (n.d.). Retrieved April 8, 2022, from https://cleanairafrica.com/

Honda, T., Pun, V. C., Manjourides, J., Suh, H., Author, C., Honda, T. J., & Res Author manuscript, E. (2018). Associations of long-term fine particulate matter exposure with prevalent hypertension and increased blood pressure in older Americans HHS Public Access Author manuscript. *Environ Res*, *164*, 1–8. https://doi.org/10.1016/j.envres.2018.02.008

Huang, C. C., Lee, J. C., Lin, K. C., Lin, H. J., Su, S. Bin, Hsu, C. C., & Guo, H. R. (2019).

Exposure Duration and History of Hypertension Predicted Neurological Sequelae in Patients with Carbon Monoxide Poisoning. *Epidemiology*, *30*(July), S76–S81. https://doi.org/10.1097/EDE.0000000000001000

Hussain, Anwar, Huggins, R. (2021). *home and industry*.

Jebet, A., Kibet, J. K., Kinyanjui, T., & Nyamori, V. O. (2018). Environmental inhalants from tobacco burning : Tar and particulate emissions. *Scientific African*, *1*, e00004. https://doi.org/10.1016/j.sciaf.2018.e00004

Jha, P., Chaloupka, F. J., Corrao, M., & Jacob, B. (2006). Reducing the burden of smoking world-wide: Effectiveness of interventions and their coverage. *Drug and Alcohol Review*, *25*(6), 597–609. https://doi.org/10.1080/09595230600944511

Jilla, A. (2017). *ScholarWorks @ UNO University of New Orleans Theses and Particulate Matter and Carbon Monoxide Emission Factors from Incense Burning A Thesis Submitted to the Graduate Faculty of the University of New Orleans requirements for the degree of Master of Scien*.

Johnson, M. B., Kingston, R., Utell, M. J., Wells, J. R., Singal, M., Troy, W. R., Horenziak, S., Dalton, P., Ahmed, F. K., Herz, R. S., Osimitz, T. G., Prawer, S., & Yin, S. (2019). Exploring the science, safety, and benefits of air care products: perspectives from the inaugural air care summit. *Inhalation Toxicology*, *31*(1), 12–24. https://doi.org/10.1080/08958378.2019.1597221

Kansiime, W. K., Mugambe, R. K., Atusingwize, E., Wafula, S. T., Nsereko, V., Ssekamatte, T., Nalugya, A., Coker, E. S., Ssempebwa, J. C., & Isunju, J. B. (2022). Use of biomass fuels predicts indoor particulate matter and carbon monoxide concentrations ; evidence from an informal urban settlement in Fort Portal city , Uganda. *BMC Public Health*, 1–12. https://doi.org/10.1186/s12889-022-14015-w

Karpinska, L., & Śmiech, S. (2022). Shadow of single-family homes: Analysis of the determinants of Polish households' energy-related CO2 emissions. *Energy and Buildings*, *277*, 112550. https://doi.org/10.1016/J.ENBUILD.2022.112550

Katsoyiannis, A., Leva, P., Barrero-Moreno, J., & Kotzias, D. (2012). Building materials. VOC emissions, diffusion behaviour and implications from their use. *Environmental Pollution*, *169*, 230–234. https://doi.org/10.1016/J.ENVPOL.2012.04.030

Kelly, F. J., & Fussell, J. C. (2017). Role of oxidative stress in cardiovascular disease outcomes following exposure to ambient air pollution. *Free Radical Biology and Medicine*, *110*, 345-367.

Khan, M. N., Nurs, C. Z. B., Islam, M. M., Islam, M. R., & Rahman, M. M. (2017). Household air pollution from cooking and risk of adverse health and birth outcomes in Bangladesh: A nationwide population-based study. *Environmental Health: A Global Access Science*

Source, *16*(1). https://doi.org/10.1186/S12940-017-0272-Y

Konlan, K. D., Lee, H., Lee, M., Kim, Y., Lee, H., & Abdulai, J. A. (2023). Risk factors associated with the incidence and prevalence of hypertension in Ghana: an integrated review (2016-2021). *International Journal of Environmental Health Research*, *33*(11),

1132-1147.

Kuamoah, C. (2020). Renewable Energy Deployment in Ghana: The Hype, Hope and Reality. *Insight on Africa*, *12*(1), 45–64. https://doi.org/10.1177/0975087819898581/ASSET/IMAGES/LARGE/10.1177_0975087819898581-FIG1.JPEG

Kumar, P., Singh, A. B., Arora, T., Singh, S., & Singh, R. (2023). Critical review on emerging health effects associated with the indoor air quality and its sustainable management. *Science of The Total Environment*, *872*, 162163.

Laumbach, R. J., & Kipen, H. M. (2012). Respiratory health effects of air pollution: update on biomass smoke and traffic pollution. *The Journal of Allergy and Clinical Immunology*, *129*(1), 3–11. https://doi.org/10.1016/J.JACI.2011.11.021

Lee, K. K., Bing, R., Kiang, J., Bashir, S., Spath, N., Stelzle, D., Mortimer, K., Bularga, A., Doudesis, D., Joshi, S. S., Strachan, F., Gumy, S., Adair-Rohani, H., Attia, E. F., Chung, M. H., Miller, M. R., Newby, D. E., Mills, N. L., McAllister, D. A., & Shah, A. S. V. (2020). Adverse health effects associated with household air pollution: a systematic review, meta-analysis, and burden estimation study. *The Lancet Global Health*, *8*(11), e1427–e1434. https://doi.org/10.1016/S2214-109X(20)30343-0

Li, L., Bai, Y., Wang, B., Ren, Y., Dai, W., Tan, J., Yang, W., Wu, Z., & Hu, Y. (2022). Cooking fuel and the risk of pregnancy-induced hypertension in Lanzhou, China: A birth cohort study. *Food Science and Technology (Brazil)*, *42*, 1–8. https://doi.org/10.1590/fst.38320

Lin, L. Z., Gao, M., Xiao, X., Knibbs, L. D., Morawska, L., Dharmage, S. C., Heinrich, J., Jalaludin, B., Lin, S., Guo, Y., Xu, S. L., Wu, Q. Z., Chen, G., Yang, B. Y., Zeng, X. W., Yu, Y., Hu, L. W., & Dong, G. H. (2021). Ultrafine particles, blood pressure and adult hypertension: a population-based survey in Northeast China. *Environmental Research Letters*, *16*(9), 094041. https://doi.org/10.1088/1748-9326/AC1C28

Livshits, Z., Lugassy, D. M., Shawn, L. K., & Hoffman, R. S. (2012). Falsely Low Carboxyhemoglobin Level after Hydroxocobalamin Therapy. *New England Journal of Medicine*, *367*(13), 1270–1271. https://doi.org/10.1056/NEJMC1114820

Mallett, S. (2024). *Understanding Home: A Critical Review of the Literature - Shelley Mallett, 2004*.

Mihalis, L. (2010). *Indoor Air Pollution _ SpringerLink*.

Mullié, C., Burt, F. J., Chala, B., & Hamde, F. (2021). Emerging and Re-emerging Vector-Borne Infectious Diseases and the Challenges for Control: A Review. *Frontiers in Public Health | Www.Frontiersin.Org*, *9*. https://doi.org/10.3389/fpubh.2021.715759

Muthu, M., Gopal, J., Kim, D.-H., & Sivanesan, I. (2021). *sustainability Reviewing the Impact of Vehicular Pollution on Road-Side Plants-Future Perspectives*. https://doi.org/10.3390/su13095114

On, M., & Engineering, E. (2019). *2018 / 2019 AIRBORNE PARTICLES IN RESIDENTIAL ENVIRONMENTS : LEVELS , EXPOSURE DOSE AND DEPOSITION IN RESPIRATORY*

SYSTEM. *July*.

Peng, H., Sreedharan, J., Xu, K., Liu, T., Gao, N., Wang, Y., Chen, M., Yu, L., & Fu, C. (2023). OPEN ACCESS EDITED BY Assessing the association between smoking and hypertension: Smoking status, type of tobacco products, and interaction with alcohol consumption. *Front. Cardiovasc. Med*, *10*, 1027988. https://doi.org/10.3389/fcvm.2023.1027988

Perrett, T. *Energy Access and Urban Livelihoods: the impact of clean energy access on the livelihoods of low-income, urban enterprises in Accra, Ghana* (Doctoral dissertation, Loughborough University).

Prabhakaran, D., Mandal, S., Krishna, B., Magsumbol, M., Singh, K., Tandon, N., Venkat Narayan, K. M., Shivashankar, R., Kondal, D., Ali, M. K., Srinath Reddy, K., & Schwartz, J. D. (2020). Exposure to Particulate Matter Is Associated With Elevated Blood Pressure and Incident Hypertension in Urban India. *Hypertension*, *76*(4), 1289–1298. https://doi.org/10.1161/HYPERTENSIONAHA.120.15373

Quinn, A. K., Ae-ngibise, K. A., Jack, D. W., Abrafi, E., Enuameh, Y., Nuhu, M., Chillrud, S. N., Wylie, B. J., Owusu-agyei, S., & Kinney, P. L. (2016). International Journal of Hygiene and Association of Carbon Monoxide exposure with blood pressure among pregnant women in rural Ghana : Evidence from GRAPHS. *International Journal of Hygiene and Environmental Health*, *219*(2), 176–183. https://doi.org/10.1016/j.ijheh.2015.10.004

Raju, S., Siddharthan, T., & McCormack, M. C. (n.d.). *Indoor Air Pollution and Respiratory Health Synopsis*. https://doi.org/10.1016/j.ccm.2020.08.014

Rani, P., & Dhok, A. (n.d.). *Effects of Pollution on Pregnancy and Infants*. https://doi.org/10.7759/cureus.33906

Rohra, H., & Taneja, A. (2016). Indoor air quality scenario in India—An outline of household fuel combustion. *Atmospheric Environment*, *129*, 243–255. https://doi.org/10.1016/J.ATMOSENV.2016.01.038

Salvi, S., & Apte, K. (2016). Household air pollution and its effects on health. *F1000Research*, *5*. https://doi.org/10.12688/F1000RESEARCH.7552.1

Sani, R. N., Connelly, P. J., Toft, M., Rowa-Dewar, N., Delles, C., Gasevic, D., & Karaye, K. M. (2024). Rural-urban difference in the prevalence of hypertension in West Africa: a systematic review and meta-analysis. *Journal of human hypertension*, *38*(4), 352-364.

Senewa, A., Pertet, A. M., & Otieno-Odawa, C. (2018). Cooking fuel as a risk factor for adenoid hypertrophy in children aged less than five living in an informal settlement, Nairobi County, Kenya. *International Journal of Contemporary Pediatrics*, *5*(4), 1168. https://doi.org/10.18203/2349-3291.ijcp20182531

Simkovich, S. M., Goodman, D., Roa, C., Crocker, M. E., Gianella, G. E., Kirenga, B. J., ... & Checkley, W. (2019). The health and social implications of household air pollution and respiratory diseases. *NPJ primary care respiratory medicine*, *29*(1), 12.

Smith, K. R., & Pillarisetti, A. (2018). Household air pollution from solid cookfuels and its

effects on health.

Sokoty, L., Kermani, M., Janani, L., Dowlat, M., Hassanlouei, B., & Rimaz, S. (n.d.). Estimation of cardiovascular and respiratory diseases attributed to PM10 using AirQ model in Urmia during 2011-2017. *Med J Islam Repub Iran*, *2020*. https://doi.org/10.34171/mjiri.34.60

Stec, D. E., Drummond, H. A., & Vera, T. (2008). *Role of Carbon Monoxide in Blood Pressure Regulation*. https://doi.org/10.1161/HYPERTENSIONAHA.107.097154

Sykes, O. T., & Walker, E. (2016). The neurotoxicology of carbon monoxide - Historical perspective and review. In *Cortex* (Vol. 74, pp. 440–448). https://doi.org/10.1016/j.cortex.2015.07.033

Taghian, G., Fisher, S., Chiles, T. C., Binagwaho, A., & Landrigan, P. J. (2024). The Burden of Cardiovascular Disease from Air Pollution in Rwanda. *Annals of Global Health*, *90*(1), 1–9. https://doi.org/10.5334/aogh.4322

Tawiah, T., Shupler, M., Gyaase, S., Anderson de Cuevas, R., Saah, J., Nix, E., ... & Asante, K. P. (2022). The association between household air pollution and blood pressure in Obuasi municipality, Ghana. *Atmosphere*, *13*(12), 2033.

Tewari, S., Brousse, V., Piel, F. B., Menzel, S., & Rees, D. C. (2015). Environmental determinants of severity in sickle cell disease. *Haematologica*, *100*(9), 1108–1116. https://doi.org/10.3324/haematol.2014.120030

Toqeer Ahmed, Muhammad Usman, M. S. (2018). *Toqeer Ahmed, Muhammad Usman, Miklas Scholz, 2018*.

Udoudoh, F., & Bassey, L. E. (2021). *Traditional Building Materials in Housing Construction : Usage and*. *X*(Iv), 1–20.

Vardoulakis, S., Giagloglou, E., Steinle, S., Davis, A., Sleeuwenhoek, A., Galea, K. S., Dixon, K., & Crawford, J. O. (2020). Indoor Exposure to Selected Air Pollutants in the Home Environment: A Systematic Review. *Int. J. Environ. Res. Public Health*, *17*, 8972. https://doi.org/10.3390/ijerph17238972

Vicente, E. D., Vicente, A., Evtyugina, M., Carvalho, R., Tarelho, L. A. C., Oduber, F. I., & Alves, C. (2018). Particulate and gaseous emissions from charcoal combustion in barbecue grills. *Fuel Processing Technology*, *176*, 296–306. https://doi.org/10.1016/J.FUPROC.2018.03.004

Wang, L., Xiang, Z., Stevanovic, S., Ristovski, Z., Salimi, F., Gao, J., ... & Li, L. (2017). Role of Chinese cooking emissions on ambient air quality and human health. *Science of the total environment*, *589*, 173-181.

Wathore, R., & Patel, A. (2024). Household Air Pollution. *Textbook of Children's Environmental Health*, 332.

Wen, C., Liu, S., Yao, X., Peng, L., Li, X., Hu, Y., & Chi, T. (2019). A novel spatiotemporal convolutional long short-term neural network for air pollution prediction. *Science of the total environment*, *654*, 1091-1099.

World Health Organization. (2025). WHO report on the global tobacco epidemic, 2025: warning about the dangers of tobacco.

Wilbur, S., Williams, M., Williams, R., Scinicariello, F., Klotzbach, J. M., Diamond, G. L., & Citra, M. (2012). *HEALTH EFFECTS*. https://www.ncbi.nlm.nih.gov/books/NBK153687/

DEFINITIONS

Adult male - Males above the age of 18years

Household - A " household" is a collective of individuals who dwell under the same roof and compose a family

Formal employment – employment that offers employees a formal working agreement. This can include either written contracts or verbal agreements. Examples: teachers, doctors, office workers etc

Informal employment- Casual, temporary, and seasonal workers who lack social protection coverage or other employment benefits, or who fall short of full legal status,

Unemployed Participants - Participants without a paid job

APPENDIX 1: CONSENT FORM FOR ADULT MALE STUDY PARTICIPANTS IN KPONG, EASTERN REGION.

STUDY TITLE: Household air pollution and hypertension among adult male population within a riparian community of lower volta lake.

PARTICIPANTS' STATEMENT

1. I acknowledge that I have read or have had the purpose and contents of the Participants' Information Sheet read and all questions have been satisfactorily explained to me in a language I understand (Ga [ ] 2. Adangbe [ ] 3. Krobo [ ] 4.Ewe [ ] 5. Akan [ ])

I fully understand the contents and any potential implications as well as my right to change my mind (ie withdraw from the research) even after I have signed this form.

I voluntarily agree to be part of this research.

Name or Initials of Participant…… ID Code……..

Participants' Signature …….

Date: …….

INTERPRETERS' STATEMENT

2. I interpreted the purpose and contents of the Participants' Information Sheet to the above named participant to the best of my ability in the (Ga [ ] 2. Adangbe [ ] 3. Krobo [ ] 4.Ewe [ ] 5. Akan [ ]) language to his proper understanding. All questions, appropriate clarifications sort by the participant and answers were also duly interpreted to his/her satisfaction.

Name of Interpreter…… Signature of Interpreter……..

Date: ……

Contact Details

STATEMENT OF WITNESS

3. I was present when the purpose and contents of the Participant Information Sheet was read and explained satisfactorily to the participant in the language, he/she understood (Ga [ ] 2. Adangbe [ ] 3. Krobo [ ] 4.Ewe [ ] 5. Akan [ ])

   I confirm that he/she was given the opportunity to ask questions/seek clarifications and same were duly answered to his/her satisfaction before voluntarily agreeing to be part of the research.

Name:…… Signature……

Date: …….

INVESTIGATOR STATEMENT AND SIGNATURE

I certify that the participant has been given ample time to read and learn about the study. All questions and clarifications raised by the participant have been addressed.

Researcher's name……. Signature …….

Date…….

APPENDIX 2: QUESTIONNAIRE.

QUESTIONAIRE FOR ADULT MALE PARTICIPANTS ON EXPOSURE TO HOUSEHOLD AIR POLLUTANTS

A. **General Information**

Name of Participant ……

Contact of Participant …….

Name of interviewer ……

Date of interview …….

Place of interview …… Height ……Weight …….

GPS of household Longitude……. Latitude……. Elevation …….

A. Demographic Characteristics

4. Age in years ……

5. Sex 1. Male [ ]

6. Educational level

1. Never attended [ ] 2. Pre-primary/Primary/JHS/SSS [ ] 3. Technical professional certificate/diploma [ ]
4. Bachelor/Postgraduate [ ]123

7. Ethnicity 1. Ga [ ] 2. Adangbe [ ] 3. Krobo [ ] 4.Ewe [ ] 5. Akan [ ]

6. Others……

8. Marital Status 1. Married [ ] 2. Single [ ] 3. Divorce [ ] 4. Cohabiting [ ] 5.widow

[ ] 6. Others …….

9. How many years have you stayed in the community? 1.<1 year [ ] 2. 1-2years [ ] 3. 3-5 [ ] 4. >5years [ ]

10. What material is used to construct the house 1. Blocks [ ] 2. Brick [ ] 3.Mud [ ]

11. What type of paint is used in painting your house and room 1. Emulsion [ ] 2. Oil [ ]

12. Is there mold in your rooms Yes[ ] No[ ]

13. How many people are in your household 1. <4 [ ] 2. 4-6 [ ] 3. 6-8 [ ] 4. >8 [ ] 5.<8 [ ]

14. How many rooms are in your house 1. 1 [ ] 2. 2 [ ] 3. 3 [ ] 4. 4 [ ] 5. >5 [ ] 6. [ ]

15. How much time in hours do you spend at home 1. 4-8 [ ] 2. 8-12 [ ] 3. More than 12 [ ]

16. Which section of the home do you spend most time 1. living room [ ] 2. Lounge [ ] 3. Kitchen [ ] 4. Bedroom [ ] 5. Open Compound [ ]

17. Occupation 1. Unemployed/pensioner/student [ ] 2. Manager/professional [ ] 3. Service /sales worker [ ] 4. Farmer [ ] 5. Driver [ ] others ……

18. Are you exposed to air pollution at your workplace 1. Yes [ ] 2. No [ ]

19. No. of Dependents 1. None [ ] 2. 1-5 [ ] 3. 6-10 [ ] 4. 11 and above [ ]

20. Income level 1. Sufficient [ ] 2. Insufficient [ ]

21. Do you have any chronic diseases? 1. Yes [ ] 2. No [ ]

22. If yes, indicate the disease ……

B. Exposure to Smoke from Biofuels, Garbage Burning, Cigarette Smoking / Second-Hand Smoking.

Please tick the following where applicable

23. Do you use biomass fuel? 1. Yes [ ] 2. No [ ]

24. What type of fuel do you use? 1. Wood [ ] 2. Saw dust [ ] 3. Charcoal [ ] 4. LPG [ ]

    5. Electricity [ ]

25. How often do you use the fuel in a day? 1. Once [ ] 2. Twice [ ] 3. Thrice [ ]

20. What do you do with garbage? 1. Burn [ ] 2. Throw away [ ] 3. Bury [ ] 4. Waste collectors come to pick them [ ]
21. Are you exposed to neighborhood smoke 1. Yes [ ] 2. No [ ]

22. How often are you exposed to smoke from neighborhood?. 1. Almost daily [ ] 2. 1-3 days /week 3. > once a month
23. Do you have exposure to smoke from cigarette smoking (active or passive)?

    1. Yes [ ] 2. No [ ]

24. Do you smoke cigarette? 1. Yes [ ] No [ ]

25. If yes, how many number of cigarettes do you smoke a day? 1. < 5 sticks of cigarette(s) [ ]

    2. 5-10 sticks of cigarettes [ ] 3. > 10 sticks of cigarettes [ ]

26. Are you exposed to second hand smoke? 1. Yes [ ] 2. No [ ]

27. Have you or any household members experienced respiratory issues (e.g., asthma, chronic cough)? 1. Yes [ ] 2. No [ ]

28. Have you noticed any correlation between indoor air quality and your health symptoms? 1. Yes [ ] 2. No [ ]

29. Do you have any pre-existing health conditions that might be affected by air quality? 1. Yes [ ] 2. No [ ]

30. Have you been diagnosed with hypertension? 1. Yes [ ] 2. No [ ]

31. If yes, how long have you been diagnosed with hypertension?

32. How concerned are you about indoor air pollution in your home? (Not concerned/Somewhat concerned/Very concerned)

33. Are you aware of the health risks associated with household air pollution? 1. Yes [ ] 2. No [ ]

34. What measures, if any, have you taken to improve indoor air quality?

35. How often do you monitor your blood pressure? (Daily/Weekly/Monthly/Never)

36. Have you noticed any changes in your blood pressure readings in relation to indoor air quality? 1. Yes [ ] 2. No [ ]

Thank you for participating in this very important study

APPENDIX 3: ACTIVITY DIARY

OBSERVATION GUIDE FOR MALE PARTICIPANTS ON EXPOSURE TO HOUSEHOLD AIR POLLUTANTS

Observer's ID : OB1
Participant Name: KAD Participant ID: PA1
Date Monitors were worn: 28/08/ 2023 Participant Occupation : Driver
Monitoring start time: 09.30am
Monitoring end time : 09.39am

Activity/Time	03:00	04:00	05:00	06:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
Wake up time		X																			
Brushing teeth outside		X																			
Boiling water for bathing		X																			
Bathing (self)		X																			
Travelling to school and workplace by vehicle (car, motor, pragia, train, etc)			X																		
Travelling to school or workplace by walking																					
Loiter around lorry station				X																	
Going to the office																					

Going to the farm																				
Going to the water body (river or stream to fish)																				
Going to the shop																				
Converge with friends to play games (ie checkers, card games)												X			X					
Taking nap/rest in the compound																X				
Travel to villages for market																				
Picking children from school																				
Eating dinner																				
Bathing																				
Watching TV and chatting																	X			
Go to bed																			X	