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ASSOCIATION OF SMOKE EXPOSURE WITH LOW BIRTHWEIGHT AMONG PREGNANT WOMEN IN THE TEMA METROPOLITAN AREA, GHANA.

BY

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A DISSERTATION SUBMITTED TO THE UNIVERSITY OF GHANA IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE MASTER OF PUBLIC HEALTH DEGREE

APRIL, 2025

DECLARATION

I hereby declare that except for reference to other people's work, which have been duly acknowledged, this piece of work is my own composition and neither in whole nor in part has this work been presented for the award of a degree in this university or elsewhere.

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DEDICATION

I dedicate this work to God Almighty, my mentor (Prof. Arku Raphael), and my mother (Mrs. Hellen Obianim).

ACKNOWLEDGEMENT

This study owes its success to a number of people. I wish to express my heartfelt gratitude to my supervisor, Dr. Quansah Reginald, for his insightful criticisms, directions and encouragement. Without his patience, this study would not have been a success. My sincere gratitude goes to the management of the Umas Chan Medical School Database for allowing me to extract data from their database for this research. Lastly, I sincerely want to thank my pastor Mr. Obed Obeng Addai and Mr. and Mrs. Rockson Longmartey for their immense support and prayers during this period.

LIST OF ABBREVIATIONS

Abbreviation	Full Meaning
AOR	Adjusted Odds Ratio
ANC	Antenatal Care
BMI	Body Mass Index
CI	Confidence Interval
CO	Carbon Monoxide
ETS	Environmental Tobacco Smoke
GA	Gestational Age
GHS	Ghana Health Service
HAP	Household Air Pollution
LBW	Low Birth Weight
LPG	Liquefied Petroleum Gas
MoH	Ministry of Health
PM	Particulate Matter
SD	Standard Deviation
SHS	Secondhand Smoke
SPSS	Statistical Package for Social Sciences
WHO	World Health Organization

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Introduction: The Impact of smoke exposure on birth weight among pregnant women is a critical public health concern with significant implications for both maternal and neonatal health. Globally, approximately 15-20% of live births are categorized as low birth weight, with the burden disproportionately affecting low- and middle-income countries (LMICs) and most of them are a results of smoke exposure. Smoking remains a common but preventable cause of adverse pregnancy outcomes worldwide but it menaces continues to be a significant health problem. In view of this, it is imperative to examine the association between smoke exposure on birth weight among pregnant women in the Tema Metropolitan Assembly.

Methods: The study adopted a retrospective cohort study with a quantitative approach for analyzing the effect of maternal cigarette smoke exposure on neonatal birth weight at a single point in time. The design is appropriate because it allows simultaneous evaluation of exposure (smoke exposure) and outcome (birth weight). Stata 18 was used for analysis and it was presented in tables, frequencies and figures. Chi-square and regression analysis was used to determine predictors of smoke exposure on pregnancy outcomes.

Results: About 8 out of every ten pregnant women were exposed to at least smoke from coil, charcoal, garbage, the method of rubbish disposal, and cigarettes, and about two-fifths (40.0%) of the pregnant women were exposed to smoke from 2-3 sources. Our study revealed that about nine percent of pregnant women exposed to smoke gave birth to low-birth-weight babies. The study found no significant determinants of smoke exposure, and a multivariable analysis revealed a significant association between exposure to smoke and low birth weight. Thus, participants who were exposed to two or more sources of exposure were almost six times more likely to give birth to babies with low birth weight as compared to those with less than two exposures

Conclusion: This study highlights that pregnant women in the population are frequently exposed to harmful smoke. About 9% of the women gave birth to low birth weight (LBW) infants, a key marker of poor neonatal health. Women exposed to two or more sources of smoke were almost six times more likely to have LBW babies compared to those with lower exposure. The findings underscore the necessity for targeted public health prevention interventions against pregnancy smoke exposure in the household and environment settings to improve birth outcomes.

CHAPTER ONE

INTRODUCTION

1.1 Background

The impact of smoke exposure on birth weight among pregnant women is a critical public health concern with significant implications for both maternal and neonatal health (Schechter et al. 2020). Smoke exposure whether from tobacco, biomass fuels, or urban air pollution, during pregnancy is widely recognized as a major determinant known to influence pregnancy outcomes adversely, often manifesting as low birth weight, preterm births, or delayed infant development (Delcroix et al., 2023). Birth weight remains one of the most important indicators of infant health, as babies born underweight face a greater likelihood of disease, early death, and ongoing developmental and chronic health complications (Browne et al., 2015). In Ghana and other numerous economically constrained and transitional nations, smoke and fine-particle emissions produced within homes through sources such as biomass burning, garbage burning, and mosquito coil use remains prevalent, contributing substantially to maternal smoke exposure continue to pose significant public-health concerns(Dockery et al., 1993; Hoek et al., 2002).

Globally, smoke exposure remains a common but preventable cause of adverse pregnancy outcomes. The World Health Organization's 2019 report estimated that about one in ten expectant mothers across the globe still engage in smoking, with prevalence notably higher among populations in economically constrained and transitional nations (WHO, 2019). In developed nations, inhalation of smoke by expectant mothers has declined in recent years due to public health interventions and awareness campaigns, yet the prevalence remains concerning. For instance, in the United States, about 7.2% of pregnant women are exposed to smoke, while in the United Kingdom, the rate is around 10% (Public Health England, 2018). In LMICs, where smoke exposure can be higher and healthcare systems may not have robust prenatal care programs, the effects of smoke exposure during pregnancy remain more pronounced (Rahman et al., 2020).

Several studies have proved that smoke originally contains over 7,000 chemicals, many of which are toxic and capable of disrupting fetal development (Kakhaki & Soleimani 2024). Nicotine, carbon monoxide, and other harmful substances in smoke reduce oxygen supply to the fetus, impair placental blood flow, and alter the growth and development of the fetus (Suter & Aagaard 2020). Exposure to nicotine during pregnancy can lead to vascular constriction, thereby restricting oxygen and nutrient delivery to the unborn child. These factors contribute to intrauterine growth restriction, leading to lower birth weights. Studies have shown that Smoke exposure is directly correlated with a higher likelihood of low birth weight, with a reduction in birth weight by an average of 1500-2000 grams for smokers compared to non-smokers (Browne et al., 2015).

Research has demonstrated a clear relationship between maternal smoke exposure and diminished neonatal weight. In the study by McCowan et al. (2016), women who inhaled smoke during pregnancy faced a higher probability of giving birth to infants weighing below 2.5 kg. Similarly, in a large cohort study in Europe, it was found that maternal smoke exposure accounted for approximately 10-20% of LBW cases (Flenady et al., 2017). In sub-Saharan Africa, where smoke exposure among women is rising, the impact of smoke on birth weight is a growing concern. A study in Nigeria revealed that expectant mothers exposed to tobacco during pregnancy were at increased risk of giving birth to underweight infants compared with non-smoking women, with the average birth weight difference being 200 grams lower in mothers exposed to smoke (Olutola et al., 2019).

The effects of smoke from biomass fuel, garbage burning, and mosquito coil usage on birth weight have long-term implications for public health. Infants born with low birth weight face a higher likelihood of experiencing developmental delays, cognitive impairments, and a greater probability of experiencing chronic health problems, such as hypertension, diabetes, and heart-related disorders in adulthood. (Browne et al., 2015). LBW is a major contributor to neonatal mortality, particularly in regions with inadequate healthcare resources. In countries with high rates of Smoke exposure, such as in parts of Eastern Europe and Latin America, the burden of smoke exposure-related birth outcomes significantly impacts healthcare systems and national economies (Salihu et al., 2011).

1.2 Problem Statement

Maternal smoke exposure through secondhand smoking, burning of polluting fuels and coil utilization during pregnancy remains a significant public health challenge worldwide, with profound consequences on neonatal health. Globally, approximately 15-20% of live births are categorized as low birth weight, while this challenge is observed to be more pronounced in countries with limited and middle-level resources (WHO, 2019). Neonatal mortality in Ghana is significantly affected by low birth weight, with approximately 27 deaths occurring per 1,000 live births, according to the Ghana Statistical Service (2021).

An estimated 15–20% of newborns worldwide are born with low birth weight, commonly associated with maternal smoke exposure, which significantly increases neonatal health risks, including morbidity and mortality (World Health Organization, 2019). The prevalence and consequences of LBW are particularly notable in low- and middle-income settings, where exposure to smoke during pregnancy further endangers maternal and infant well-being (Rahman et al., 2020).

Recent studies in Ghana provide robust evidence of these risks. Findings from the Ghana Randomized Air Pollution and Health Study (GRAPHS) indicate that maternal exposure to household air pollution during gestation specifically carbon monoxide (CO) from cooking and heating—was associated with reduced birth weight, shorter birth length, and lower gestational age at birth. Among pregnancies without placental malaria, each 1 ppm increase in maternal CO exposure was linked to a 53.4 g reduction in birth weight, as well as increased odds of LBW and small-for-gestational-age infants (Quansah et al., 2017). Research in Accra indicated that pregnant women working as street vendors, who experienced higher levels of traffic-related air pollution, delivered infants whose birth weight was, on average, 177 g lower compared to those of mothers with less exposure (Amegah & Jaakkola, 2014).

Maternal exposure to smoke considerably raised the probability of giving birth to infants with low birth weight. both moderate activity patterns and high traffic density (Basu et al., 2021). The timing of exposure is also important. Evidence from Ghana indicates that prenatal air pollution exposure during mid-gestation (15–20 weeks) is particularly associated with lower birth weight, while late-gestation exposure increases the risk of severe infant pneumonia, highlighting the need for early and sustained interventions (Wylie et al., 2014).

These findings underscore the urgent need for public health interventions to reduce smoke exposure among pregnant women in Ghana and similar settings. Even modest reductions in household air pollution could yield substantial improvements in birth outcomes and long-term child health (Quansah et al., 2017).There is a heightened severity that lies between smoke exposure and LBW. These smoke exposures reduce the oxygen and nutrient supply to the fetus, impairing fetal growth and leading to intrauterine growth restriction (Salihu & Wilson, 2011). Low birth weight significantly increases the likelihood of neonatal health issues, including breathing problems, infections, and delayed development, and is associated with persistent effects in adulthood, such as stunted growth, cognitive challenges, and chronic disease (Flenady et al., 2017).

Neonates with LBW are also at a significantly higher risk of mortality, accounting for up to 60% of neonatal deaths in LMICs (Browne et al., 2015).

The consequences of smoke exposure extend beyond the individual, affecting families, the healthcare system, and the economy. For families, the financial and emotional burden of caring for LBW infants can be overwhelming. These infants often require specialized medical attention, prolonged hospital stays, and frequent follow-ups, which strain limited resources (McCowan et al., 2016). For the healthcare system, the increased demand for neonatal intensive care and related services imposes significant operational and financial challenges, particularly in resource-constrained settings like the Tema Municipal Area. Limited availability of neonatal care facilities further exacerbates these challenges, reducing the capacity to manage complications associated with LBW effectively.

The long-term consequences of smoke exposure and LBW are substantial. Children born with LBW often experience lower educational attainment, reduced productivity, and higher healthcare costs in adulthood, contributing to economic losses at both the individual and national levels (Rahman et al., 2020). In Ghana, where the health budget is already constrained, addressing preventable causes of LBW, such as maternal smoke exposure, is critical for optimizing resource allocation and reducing the economic burden of preventable neonatal and childhood diseases.

In the Tema Municipal Area of Ghana, Urbanization and changing lifestyles have significantly increased exposure to various forms of smoke among women. These include smoke from the use of biomass fuels for cooking, garbage, and secondhand tobacco smoke within households. According to local health reports, approximately 12% of pregnant women in the area are regularly exposed to smoke, whether from household activities, occupational settings, or passive tobacco exposure (Tema Municipal Health Directorate, 2022). This level of exposure is particularly concerning given the area's limited neonatal care infrastructure and rapidly growing population. The resulting rise in low birthweight (LBW) cases contributes to a persistent cycle of poor neonatal health outcomes, increased healthcare expenditures, and long-term socioeconomic challenges for families and the broader community.

1.3 Justification and Study's Significance

The link between prenatal smoke exposure and newborn health indicators is an important public health concern due to its direct impact on neonatal health, notably increasing the risk of LBW, a condition that substantially contributes to infant morbidity and mortality and carries enduring developmental and social consequences. In Ghana, rapid urbanization, industrialization, and household practices such as the burning of refuse and the use of mosquito coils have increased smoke exposure among women of reproductive age. Reports from the Tema Municipal Health Directorate (2022) report that roughly 12% of expectant mothers experience exposure to smoke produced by biomass fuels, garbage burning, and second-hand tobacco smoke. This is alarming given the evidence that prenatal smoke exposure can reduce birth weight by approximately 150–200 grams (McCowan et al., 2016). These findings underscore the urgent need for locally generated data to better understand the magnitude and health implications of smoke exposure among pregnant women within the Tema Municipality.

Despite increasing awareness of the problem globally, evidence specific to Ghana, and particularly to the Tema Municipal Area, remains limited. While research across sub-Saharan Africa has consistently shown that maternal smoke exposure negatively affects pregnancy outcomes, many studies do not provide sufficient local context to guide policy or targeted interventions (Olutola et al., 2019). Aiming to address previous research limitations, this study evaluates the prevalence, sources, and maternal health consequences of smoke exposure among pregnant women in Tema. Insights from this work will help health authorities develop interventions that are tailored to the community's socio-cultural and environmental conditions. The study's significance lies in its potential to inform evidence-based policies and programs that protect maternal and neonatal health. Findings will support the integration of smoke exposure assessment and education into routine antenatal care, helping to strengthen existing maternal health strategies. Additionally, the results can guide public health campaigns on household air pollution and promote the adoption of cleaner cooking and waste management practices. By contributing to national health policy and aligning with the Sustainable Development Goals—particularly SDG 3 (Good Health and Well-being), SDG 5 (Gender Equality), and SDG 10 (Reduced Inequalities)—this study will generate actionable knowledge to reduce preventable causes of low birth weight and improve maternal and child health outcomes in Ghana.

1.4 General objective

The main objective of this study is to examine the association of smoke exposure with birth weight among pregnant women in the Tema Metropolitan Assembly

1.4.1 Specific Objectives

1. To determine the prevalence of smoke exposure among pregnant women in the Tema Metropolitan Assembly.
2. To establish the sources of smoke exposure among pregnant women in the Tema Metropolitan Assembly.
3. To determine the association between smoke exposure and birth weight among newborns in the Tema Metropolitan Assembly.

1.5 Research questions

1. What is the prevalence of smoke exposure among pregnant women in the Tema Metropolitan Assembly?
2. What are the sources of smoke exposure among pregnant women in the Tema Metropolitan Assembly?
3. What are the key determinants of smoke exposure among pregnant women in the Tema Metropolitan Assembly?
4. Is there an association between smoke exposure and birth weight among newborns in the Tema Metropolitan Assembly?

CHAPTER TWO

LITERATURE REVIEW

2.0 Literature review

2.1 Burden of Low Birth Weight (LBW) in Sub-Saharan Africa and Ghana

Low birth weight (LBW), defined by the World Health Organization (WHO) as a birth weight of less than 2,500 grams, remains a major public health concern, particularly in low- and middle-income countries (LMICs). Globally, LBW is a leading determinant of neonatal morbidity and mortality and is associated with long-term developmental deficits and chronic diseases in adulthood (Flenady et al., 2017). Sub-Saharan Africa (SSA) bears a disproportionate share of the burden, with prevalence rates estimated between 10% and 15% across the region (Olutola et al., 2019). In SSA, socio-economic factors, maternal nutrition, infectious diseases, and environmental exposures, including maternal smoke exposure, contribute significantly to LBW outcomes.

In Ghana, the prevalence of LBW is approximately 11–13%, with higher rates reported in urban and peri-urban areas where environmental pollution and lifestyle factors intersect (Effah et al., 2020). The Tema Metropolitan Area (TMA), as a highly urbanized and industrialized center, exhibits elevated maternal smoke exposure levels from both indoor and outdoor sources. The Tema Municipal Health Directorate (2022) reports that 12% of pregnant women in TMA are exposed to tobacco smoke, either actively or passively, making maternal smoke exposure a significant contributor to LBW in the region. These local data underscore the need for context-specific interventions to mitigate environmental and behavioral risk factors associated with poor neonatal outcomes.

2.2 Composition and Sources of Smoke

Smoke exposure during pregnancy arises from multiple sources, each containing toxic constituents that compromise maternal and fetal health.

Tobacco Smoke: Tobacco smoke, whether actively inhaled or encountered passively, contains nicotine, carbon monoxide, polycyclic aromatic hydrocarbons, and particulate matter. Nicotine constricts utero-placental blood vessels, while carbon monoxide reduces oxygen delivery to the fetus, both of which can result in intrauterine growth restriction (IUGR) and LBW (Salihu &

Wilson, 2011; Rehan et al., 2015). In LMICs, secondhand smoke exposure is particularly concerning due to social acceptance of smoking in shared spaces (Rahman et al., 2020).

Biomass Fuel Smoke: In many SSA and LMIC settings, biomass fuels such as wood, charcoal, and crop residues are widely used for cooking and heating. Combustion of these fuels produces particulate matter (PM2.5 and PM10), carbon monoxide, and other toxic chemicals that penetrate the lungs and enter systemic circulation, leading to oxidative stress, inflammation, and impaired fetal growth (Grippo et al., 2018; Liu et al., 2022). Studies in Ethiopia and Cameroon demonstrate that household biomass fuel usage is a leading contributor to maternal smoke exposure (Getahun et al., 2023; Mumuni et al., 2022).

Ambient Air Pollution: Urbanization and industrialization exacerbate ambient air pollution, introducing particulate matter and chemical pollutants from vehicle emissions, factories, and waste burning. Fine particles (PM2.5) can cross the placenta and impair fetal development, particularly when exposure occurs during critical gestational periods (Desai et al., 2017; Zhang et al., 2022,).

Occupational Exposure: Certain workplaces, including commercial kitchens, brick-making, and chemical industries, expose pregnant women to smoke and toxic fumes, further increasing the cumulative risk of adverse pregnancy outcomes (Rahman et al., 2020).

A meta-analysis by Rehan et al. (2015) the analysis indicated that maternal exposure to secondhand smoke corresponded to a 23% higher chance of having a low-birth-weight baby.. Efforts to mitigate high smoke exposures during pregnancy in high-income countries have focused on public health campaigns, air quality programs, and stringent smoke exposure regulations. These measures have contributed to a decline in maternal smoke exposure and improvements in neonatal outcomes. However, similar interventions are often absent or under-resourced in LMICs, where the burden of smoke exposure-related LBW remains high.

2.3 Smoke Exposure among Pregnant Women

The prevalence of smoke exposure among pregnant women varies globally, reflecting differences in tobacco use, cultural practices, and environmental conditions. Globally, approximately 10% of pregnant women continue to smoke, with higher prevalence in LMICs due to limited public health interventions and social norms supporting tobacco use (WHO, 2019). Secondhand smoke exposure is even more widespread, affecting women living in multi-generational households or workplaces where smoking is common.

In SSA, smoking among women is often culturally discouraged, leading to low active smoking rates of 2–5%; however, secondhand smoke exposure remains high, affecting 30–40% of pregnant women in some regions (Olutola et al., 2019). In Ghana, active smoking among pregnant women is reported at 3–5%, while secondhand exposure affects approximately 12%, particularly from male partners or household members (Effah et al., 2020; Tema Municipal Health Directorate, 2022). These data highlight that even in areas where female smoking is stigmatized, environmental and household exposures continue to pose substantial risks to maternal and neonatal health.

2.4 Adverse Health Consequences of Smoke Exposure

Smoke exposure during pregnancy has far-reaching health consequences for both the mother and the fetus. Maternal inhalation of smoke from tobacco, biomass, or ambient air pollution increases oxidative stress, systemic inflammation, and cardiovascular strain (Grippo et al., 2018). Chronic exposure is associated with respiratory illnesses, reduced pulmonary function, and increased risk of infections in mothers (Salihu & Wilson, 2011).

For the fetus, smoke exposure disrupts oxygen and nutrient supply, impairing growth and development. Nicotine constricts utero-placental vessels, carbon monoxide reduces oxygen transport, and fine particulate matter triggers systemic inflammation, collectively contributing to IUGR, preterm birth, and LBW (Zhang et al., 2022; Liu et al., 2022). The cumulative impact of these mechanisms underlines the significant public health burden of maternal smoke exposure globally and in SSA.

2.5 Smoke Exposure and Adverse Pregnancy and Birth Outcomes

Maternal smoke exposure is closely linked to multiple adverse pregnancy and birth outcomes. Both active and passive smoking increase the risk of spontaneous abortion, stillbirth, preterm delivery, IUGR, and LBW (Salihu & Wilson, 2011; Rehan et al., 2015). Globally, birth weight reductions of 150–250 grams have been documented among infants of smoke-exposed mothers, while secondhand smoke increases the risk of LBW by 20–30% (McCowan et al., 2016; Rahman et al., 2020).

In SSA, secondhand smoke exposure has been associated with a 22–25% higher likelihood of LBW (Adebiyi et al., 2017; Ndungu et al., 2019). In Ghana, particularly in TMA, maternal smoke exposure from both household and environmental sources increases the likelihood of LBW by approximately 20% (Amoako et al., 2019; Tema Municipal Health Directorate, 2022). These findings demonstrate a clear dose-response relationship, where higher cumulative exposure leads to more severe fetal growth restriction.

Beyond LBW, smoke exposure also contributes to preterm birth, neonatal respiratory distress, and long-term developmental challenges, reinforcing the need for effective mitigation strategies to safeguard maternal and child health.

2.6 Interventions for Mitigating Smoke Exposure Among Pregnant Women

Mitigating maternal smoke exposure requires a combination of policy, healthcare, community, and environmental strategies.

Policy Interventions**:** Strong enforcement of smoke-free public spaces, restrictions on tobacco sales, and environmental air quality regulations are essential. Policies promoting clean cooking fuels and technologies reduce exposure to biomass smoke and improve household air quality (WHO, 2019; Rahman et al., 2020).

Programs targeting pregnant women and their families increase knowledge about the dangers of active and secondhand smoke, promoting behavior change and reducing household exposure (Rehan et al., 2015; Salihu & Wilson, 2011).

Integrating smoke exposure screening and counseling into routine antenatal care enables early identification of at-risk women and provides tailored interventions, including cessation programs and educational resources (Amoako et al., 2019).

Improved cookstoves, better ventilation, and transition to cleaner fuels like LPG or electricity reduce exposure from biomass combustion. Urban-level interventions, including traffic regulation and emission control, complement household-level measures (Liu et al., 2022; Grippo et al., 2018).

Social support and peer education programs reinforce smoke-free norms in households and communities, particularly targeting secondhand smoke exposure from male partners and other household members (Ndungu et al., 2019).

In TMA, where multiple smoke sources converge, these integrated interventions are critical to reducing exposure and improving pregnancy outcomes, particularly LBW.

2.7 Relationship between smoke exposure and birth weight among pregnant women

Maternal smoke exposure, constituting both active and passive (secondhand) smoke exposure, is a well-established risk factor for low birthweight (LBW) globally. Birthweight is a key indicator of neonatal health, and LBW is associated with higher risks of neonatal morbidity, mortality, and long-term developmental issues. The mechanisms by which smoke exposure affects birthweight include hypoxia, reduced placental perfusion, and fetal growth restriction caused by nicotine and carbon monoxide in tobacco smoke (Salihu & Wilson, 2011).

Worldwide, the association between smoke exposure and birthweight is well-documented. Smoke exposure during pregnancy has been shown to reduce birthweight by an average of 150–250 grams compared to non-smokers (McCowan et al., 2016). Secondhand smoke exposure also significantly increases the risk of LBW, with studies indicating that pregnant women exposed to secondhand smoke are 23% more likely to deliver LBW infants (Rehan et al., 2015). These findings are consistent across diverse populations, underscoring the universal impact of smoke exposure on fetal growth.

The relationship between maternal smoke exposure and LBW has been extensively studied. In the United Kingdom, Smoke exposure during pregnancy is associated with a 200-gram reduction in birthweight on average, and various smoke exposure source accounts for approximately 7% of all LBW cases (Public Health England, 2018). Scandinavian countries, with lower smoke exposure prevalence due to robust public health policies, report similar findings, although the prevalence of LBW attributable to smoke exposure is comparatively lower (Saugstad, 2017). In Eastern Europe, where smoke exposure among pregnant women are higher, the impact on birthweight is more pronounced. For instance, a study in Romania found that maternal smoke exposure increased the risk of LBW by 45% (Flenady et al., 2017).

The effects of smoke exposure on birthweight vary by country due to differences in smoke prevalence and cultural norms. In Japan, active smoke exposure during pregnancy is associated with an average reduction of 150 grams in birthweight (Yamaguchi et al., 2017). Similarly, studies in China report that women exposed to secondhand smoke during pregnancy have a 30% higher risk of delivering LBW infants (He et al., 2019). In South Asia, where tobacco use among men is high, secondhand smoke exposure is more prevalent. In India and Bangladesh, secondhand smoke exposure increases the likelihood of LBW by approximately 20–25% (Rahman et al., 2020). These findings highlight the significant impact of both active and passive smoke exposure on fetal growth in the region.

Studies on the relationship between smoke exposure and birthweight are limited but growing in African countries. Studies found particularly in Egypt, shows that active exposure to smoke sources during pregnancy reduces birthweight by an average of 200 grams (El-Setouhy et al., 2014). In Sub-Saharan Africa, where smoke exposure among women is less prevalent, the focus is primarily on secondhand smoke exposure. Studies in Nigeria have demonstrated that secondhand smoke exposure is associated with a 25% higher risk of LBW (Adebiyi et al., 2017).

Cultural norms often discourage women from smoking, resulting in lower prevalence rates of smoke exposure among pregnant women. However, the high prevalence of secondhand smoke exposure remains a significant concern. A study in Kenya found that secondhand smoke exposure during pregnancy increased the likelihood of LBW by 22% (Ndungu et al., 2019). Similarly, in South Africa, secondhand smoke exposure is linked to a 30% increase in the risk of LBW, with the effect exacerbated by socio-economic factors such as poverty and limited access to prenatal care (Olutola et al., 2019). These studies emphasize the need for targeted interventions to reduce both active and passive smoke exposure in the region.

A systematic review of studies in LMICs found that maternal smoke exposure during pregnancy was associated with a 150–250 gram reduction in birthweight, while secondhand smoke exposure increased the risk of LBW by 20–30% (Rahman et al., 2020). In countries such as Brazil and Indonesia, where smoking is culturally acceptable, the effects on birthweight are compounded by limited access to prenatal care and nutritional deficiencies.

A study by Amoako et al. (2019) in Accra found that secondhand smoke exposure was associated with a 20% higher likelihood of LBW, even after controlling for maternal age, education, and prenatal care. The lack of public awareness about the risks of secondhand smoke and limited enforcement of smoke-free policies exacerbate the problem. These findings underscore the urgent need for public health interventions to address smoke exposure during pregnancy in Ghana. The adverse effects of smoke exposure on birthweight are primarily mediated by hypoxia and placental dysfunction. Nicotine, PM2.5 constricts uteroplacental blood vessels, reducing oxygen and nutrient supply to the fetus, while carbon monoxide binds to hemoglobin, impairing oxygen transport (Salihu & Wilson, 2011). These physiological disruptions lead to intrauterine growth restriction (IUGR), a major cause of LBW. The dose-response relationship observed in many studies suggests that even low levels of exposure can have significant effects, with greater exposure resulting in more severe outcomes (Rehan et al., 2015).

2.8 Research Gaps and Need for the Study

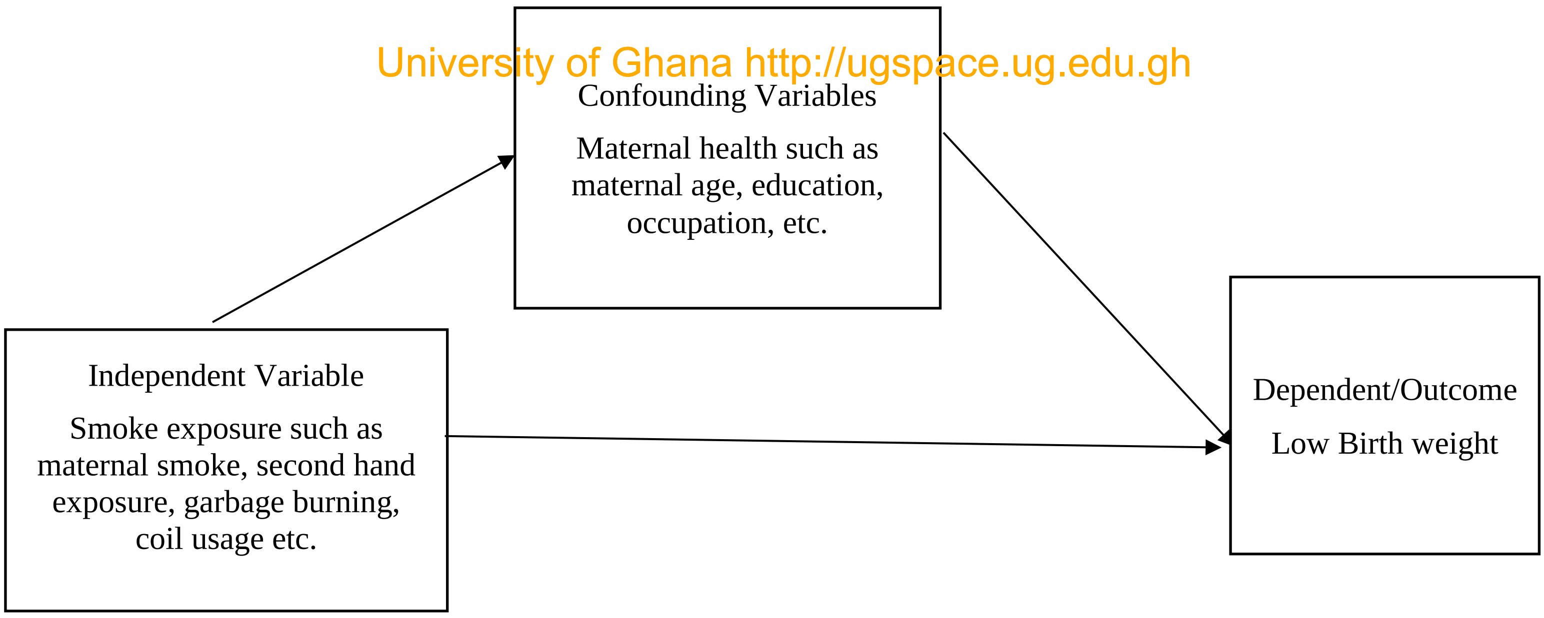
While global and regional studies provide evidence on the adverse effects of smoke exposure on birth weight, there is a lack of context-specific data for Ghana and the Tema Municipal Area. Existing research has focused primarily on high-income countries and rural areas in LMICs, leaving urban settings underexplored. Additionally, there is a limited understanding of the socio-cultural factors influencing smoke exposure among pregnant women in Ghana. Addressing these gaps through targeted research will provide valuable insights for designing effective interventions and policies to reduce smoke exposure during pregnancy and improve neonatal outcomes.

2.8 Conceptual framework

Fig 1: Conceptual framework for the association between pregnant women and pregnancy outcomes

The conceptual framework demonstrates how smoke exposure during pregnancy influences birth outcomes, particularly low birth weight. Pregnant women may be exposed to smoke through several routes such as personal smoking, inhalation of second-hand smoke from partners or household members, burning of refuse, or the use of mosquito coils and solid cooking fuels. These exposures introduce harmful substances like carbon monoxide and particulate matter into the maternal bloodstream, limiting oxygen and nutrient delivery to the developing fetus. Prolonged or frequent exposure increases the risk of intrauterine growth restriction and consequently results in low birth weight.

The framework also recognizes that the relationship between smoke exposure and pregnancy outcome may be influenced by confounding factors such as maternal age, educational level, occupation, and overall health status. These factors can determine both the extent of smoke exposure and the mother's physiological resilience to its harmful effects. For instance, women engaged in informal occupations or those living in densely populated environments may experience higher exposure levels, while lower educational attainment may reduce awareness of exposure risks. Accounting for these confounders provides a clearer understanding of the true association between maternal smoke exposure and low birth weight, guiding the design of interventions to protect pregnant women from harmful smoke exposure.


Confounding Variables
Maternal health such as maternal age, education, occupation, etc.
Independent Variable
Smoke exposure such as maternal smoke, second hand exposure, garbage burning, coil usage etc.
Dependent/Outcome
Low Birth weight

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The study was conducted in the **Tema Metropolitan Area**, a sub-region within the Greater Accra Metropolitan Area (GAMA), known for its industrial activity and vehicular congestion—key contributors to ambient air pollution. Tema is an urbanized area with a diverse population, combining industrial, residential, and informal settlements. The choice of Tema is informed by its increasing prevalence of smoke exposure, particularly among urban women of reproductive age. Additionally, the Tema Municipal Health Directorate has highlighted low birth weight (LBW) as a significant contributor to neonatal mortality in the region. Pregnant women were recruited from antenatal clinics located in selected public hospitals and polyclinics within Tema.

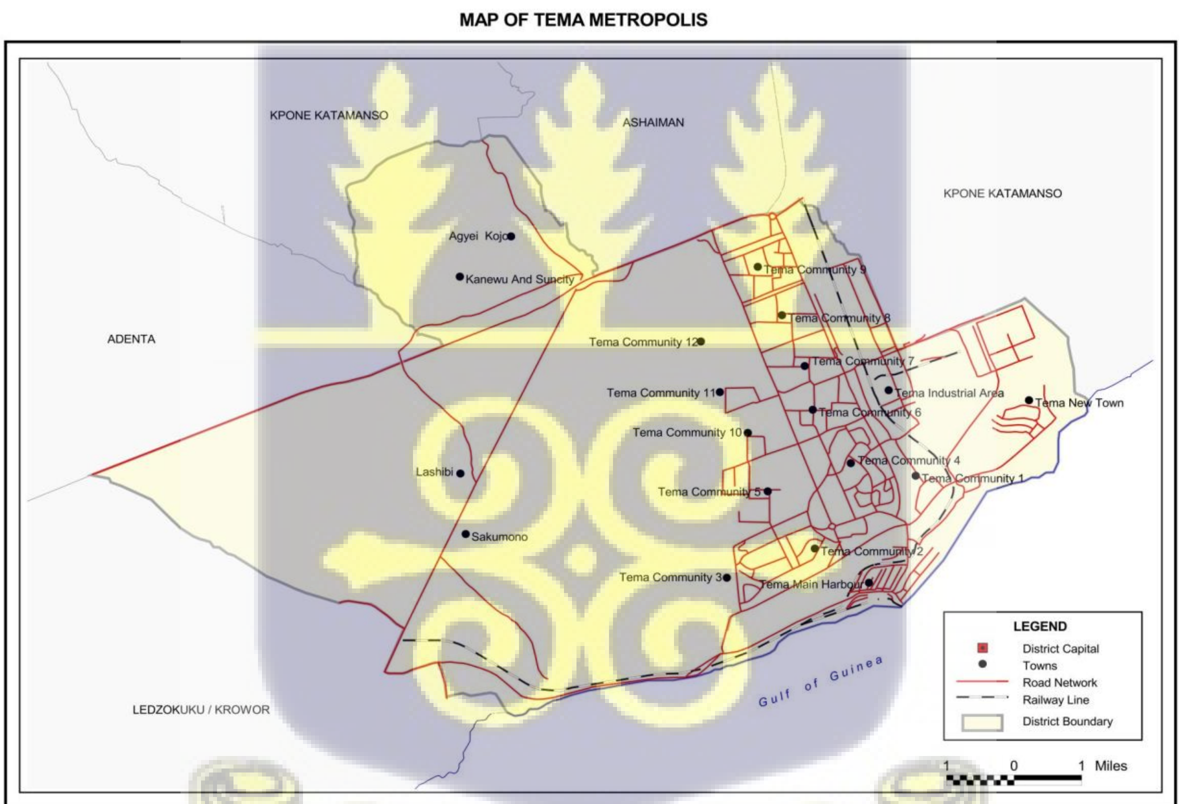


Figure 3.1: Map of Tema Metropolitan Area

3.2 Study Population

The study population comprised pregnant women in their first trimester or second trimester who were residents of Tema and its neighboring towns and met the inclusion criteria of the parent study. These participants were recruited at antenatal clinics and followed up through pregnancy until delivery.

3.3 Study Design

This study employed a cross-sectional design, nested within a larger research project titled "Urban Air Pollution in Accra: A study of prenatal exposures, birth outcomes, and lower-respiratory infections in infants," jointly conducted by the University of Ghana and the University of Massachusetts Amherst. The overarching objective of the parent study was to assess the impact of urban air and noise pollution—including household smoke, ambient pollution, and traffic-related emissions—on maternal and neonatal health outcomes in the Greater Accra Metropolitan Area (GAMA). It also aimed to compare results with findings from other large cities and developed regions. The parent study recruited 1,500 pregnant women using a stratified random sampling technique from 30 antenatal clinics in major polyclinics and hospitals across GAMA. Data collection commenced on January 19, 2023, and is expected to be completed by April 30, 2025. The current study focused on three (3) of the 30 antenatal clinics involved in the parent project, specifically those with accurate and complete birthweight records, narrowing the scope to the Tema Metropolitan Area.

3.4 Sample Size

The total number of records on pregnant women who had participated in the primary study was 1,500 (UMass Chan Medical School Database).

The sample size to be used for the study is represented below as;

Using Slovin's formula:

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

Where, n = Sample size k= constant and is (1)

N = Total records on prenatal exposure and birth outcome records of pregnant women

e = Acceptable sampling error.

Therefore, n = $\frac{1500}{1+1500\ (0.05)^2}$ = 315.7

Approximately, 320 participants' will be recruited for the study

3.5 Inclusion and Exclusion Criteria

3.5.1 Inclusion Criteria

Prenatal exposure and birth outcome records of pregnant women who were;

Resident in the Tema Metropolitan area the previous 12 months prior to the study

At least 18 years old

Were their first or second trimester

Planned to give birth at the clinic and planned to remain in Tem a Metropolitan for at least 2 years after delivery

3.5.2 Exclusion Criteria

Records that had incomplete information were excluded.

Records with known congenital anomalies or twin pregnancies

3.6 Sampling Methods

Systematic random sampling was employed in selecting data for the study. In this method, eligible records of pregnant women were arranged in a specific order, such as by date of delivery or medical record number. From this list, a random starting point was selected, and every n-th record was then be chosen to form the sample. This ensures that the sample is evenly distributed across the dataset, minimizing clustering and over-representation of specific groups or time periods.

Systematic random sampling offered several advantages for this retrospective study. It was simple to implement and ensure unbiased, representative sampling across a large dataset. By selecting records at regular intervals, the study avoids issues related to over-concentration of records from certain subgroups, making it well-suited for analyzing the impact of household air pollution on birth weights. The method streamlined data collection while ensuring that the entire population of interest is well-covered. However, care was taken to ensure that the records are not sorted in a way that could introduce bias, such as by health outcomes or socioeconomic status.

3.7 Data Collection

Data were collected through a structured questionnaire, mounted on the Redcap electronic data capture system. This questionnaire gathered information on socio-demographic factors, obstetric history, household smoke exposure (e.g., type of polluting fuel, exposure to secondhand smoke), and environmental conditions. Trained research assistants administered the questionnaire during routine antenatal visits.

Data were collected in three phases:

Baseline Interview**:** Upon enrollment (approx. 20 minutes), participants provided information on demographic details (age, education, residence), socio-economic status, housing conditions, obstetric history, and lifestyle factors including smoke exposure and occupation.

Exposure Assessment**:** Smoke exposure data were collected through self-reports on household fuel use (e.g., charcoal, firewood), passive tobacco smoke exposure, and environmental factors such as proximity to major roads or garbage burning.

Follow-Up and Outcome Measurement: Participants received bi-monthly follow-up calls (5 minutes each) from the second month until the child was 18 months old. Birthweight was recorded within 24 hours of delivery, and additional maternal and newborn health data were abstracted from medical records.

Postnatal Follow-Up: After delivery, participants were contacted via telephone twice monthly starting from the second month postpartum until the child reached 18 months of age. These brief calls (5 minutes) collected information on the child's health, including episodes of illness, hospital visits, and other developmental indicators.

3.8 Ethical Considerations

Ethical clearance for the study was obtained from the Ghana Health Service Ethical Review Committee (GHS-ERC: 008/01/23) and the Institutional Review Board of the University of Ghana. The study adhered to the principles outlined in the Declaration of Helsinki regarding research involving human subjects.

3.9 Informed Consent

Participants were fully briefed on the purpose, study procedures, potential risks, and expected benefits. Voluntary participation was emphasized, and written consent was secured prior to inclusion. As part of this process, participants consented to:

Provide information on age, education, and place of residence

Grant the study team access to their medical records, including those documented in the Maternal and Child Health Record Book

Participants were informed of their right to withdraw at any point without facing any penalty or affecting the care they receive.

3.10 Data Protection and Confidentiality

Personal identifiers were replaced with unique codes. All data were stored in password-protected databases, with access restricted to authorized personnel only. Hard copies of any records were secured in locked cabinets at the research office. Every effort was made to ensure the privacy and confidentiality of all participants throughout the duration of the study.

3.11 Data Analysis

Data was imported into STATA 18 and cleaned to remove inconsistencies and missing values. Descriptive statistics were used to determine frequencies, percentages, means, and standard deviations, and they were summarized according to socio-demographic characteristics, smoke exposure, and birth weight distributions. Inferential Statistics, such as chi-square tests to explore associations between categorical variables (e.g., smoke exposure status and LBW), Logistic regression was also used to determine the adjusted odds of LBW about smoke exposure, controlling for confounders like maternal age, education, and parity. A p-value < 0.05 was considered statistically significant.

3.12 Measurement of Smoke Exposure

Maternal exposure to harmful smoke was measured using a Smoke Exposure Index, a composite tool designed to capture overall exposure from multiple sources. The index considered household use of polluting fuels such as firewood, charcoal, or kerosene, which are major contributors to indoor air pollution; exposure to cigarette smoke, including both active smoking and secondhand smoke from family members or co-workers, which poses respiratory and cardiovascular risks; smoke from the open burning of domestic waste, particularly in settings with limited formal waste management; and indoor use of mosquito coils, which release hazardous substances such as formaldehyde and fine particulate matter.

Exposure assessment relied on participants' self-reports regarding their contact with these smoke sources over the preceding three months. Each of the four sources was treated as a binary variable, with "1" indicating the presence of exposure and "0" representing no exposure.

To quantify overall exposure, a composite score was calculated by summing the individual scores from the four sources, producing a cumulative index ranging from 0 to 4. Higher scores indicated greater cumulative exposure and a correspondingly increased potential health risk for both mother and fetus. This composite approach allowed for a more comprehensive assessment of maternal smoke exposure by accounting for the multiple, overlapping sources of environmental smoke that pregnant women may encounter in both domestic and occupational settings.

For analytical purposes, the composite index was further divided into two categories: low exposure (score ≤1), representing women with no or only one source of exposure, and high exposure (score ≥2), representing women exposed to two or more sources concurrently. This dichotomization is supported by evidence indicating that simultaneous exposure to multiple smoke sources may have synergistic effects, amplifying adverse impacts on maternal and fetal health outcomes (Salihu & Wilson, 2011; Rahman et al., 2020). The categorized index was then used as the primary exposure variable in logistic regression analyses to investigate its association with low birth weight.

3.13 Ethical Considerations

Ethical approval for the mother study was granted by the Ghana Health Service Ethical Review Committee (GHS-ERC) and the University of Massachusetts Amherst Human Research Protection Office**.** Informed consent was obtained from all participants. This sub-study used de-identified secondary data, and permission was obtained from the parent study's investigators for access and use.

CHAPTER FOUR

RESULTS

4.1 Sociodemographic characteristics of Respondents

Table 4.1 presents the sociodemographic characteristics of the respondents. The mean age of participants was 29.35 years (SD = ±5.57). More than half (58.4%) of the respondents were aged 30 years or younger, while 37.5% were between 31 and 39 years.

Regarding ethnicity, the Ewe ethnic group accounted for the highest proportion (28.4%), followed closely by Akan (27.8%), Ga-Dangbe (22.2%), and other ethnic groups (21.6%). In terms of religion, the majority (88.1%) identified as Christians, while 9.7% were Muslims.

With respect to marital status, more than half (54.6%) of the respondents were married, while 29.1% were in informal or cohabiting relationships. Employment status revealed that 80.0% of respondents were employed, whereas 20.0% were unemployed.

The type of dwelling among respondents varied, with the majority (59.7%) residing in compound houses. About one-third (33.1%) lived in separate houses [Table 4.1].

Table 4. 1: Sociodemographic characteristics of Respondents

Variable	Frequency (N=320)	Percentage (%)
Age (SD)	29.35(±5.57)	
Age		
≤ 34	259	80.9
≥ 35	61	19.1
Ethnicity		
Akan	89	27.8
Ewe	91	28.4
Ga-Dangbe	71	22.2
Other	69	21.6
Religion		
Christian	282	88.1
Islam	31	9.7
Traditionalist/None	7	2.2
Marital Status		
Single	52	16.3
Married	268	83.7
Employment Status		

Unemployed	64	20.0
Employed	256	80.0
Type of dwelling		
Compound House	191	59.7
Separate	106	33.1
Kiosk	13	4.1
Flat	10	3.1

sd=standard deviation;

4.1.1 Prevalence of smoke exposure among pregnant women

Table 4.2 depicts the patterns and sources of smoke exposure among pregnant women. Overall, 83.4% (95% CI: 78.9-87.1) of the participants were exposed to smoke from coil, charcoal, garbage, method of rubbish disposal and cigarettes.

Furthermore, about two-fifth (40.0%) of the pregnant women were exposed to smokes from 2-3 sources.

4.1.2 Sources of smoke exposure among pregnant women

Table 4.2 presents the sources of smoke exposure among pregnant women. Regarding cooking fuel, the majority (89.4%) of respondents did not use charcoal, while 10.6% reported using charcoal. Whilst 96.9% of the women reported that they did not smoke, while 3.1% indicated that they were smokers. In terms of smoke exposure, 13.4% of respondents lived with at least one smoker, while 86.6% reported no smokers in their household.

Exposure to smoke in the neighborhood was relatively common, with 60.6% of respondents indicating that they had smokes present in their surroundings. Concerning rubbish disposal methods, 79.7% of respondents did not burn rubbish, whereas 20.3% did.

Regarding the use of coils, which may contribute to smoke exposure, 45.3% of the respondents reported using them, while 54.7% did not.

Table 4. 2: Prevalence of smoke exposure among pregnant women (n=320)

Sources of Smoke Exposure	Frequency	Percentage (%)
Any exposure to smoke?		
No	53	16.6
Yes	267	83.4
Use of Polluting fuel		
No	286	89.4
Yes	34	10.6
Smoke from cigarettes		

No	273	85.3
Yes	47	14.7
Smoke from Garbage burning		
No	112	35.0
Yes	208	65.0
Coil usage		
No	175	54.7
Yes	145	45.3

*any exposure to smoke (exposed to at least=garbage, coil, charcoal and household smoke exposure)

4.1.3 Prevalence of low birth weight among pregnant women

Overall, 8.8% (95% CI = 6.10–12.40) of the pregnant women gave birth to babies with low birth weight, defined as a birth weight of less than 2,500 grams. In contrast, the remaining 91.2% of newborns had normal birth weight, indicating that the majority of births in the study population fell within the expected healthy weight range. Despite this, the observed 8.8% prevalence of low birth weight is still a significant public health concern, as low birth weight is closely linked to increased risks of neonatal morbidity and mortality, impaired immune function, developmental delays, and chronic diseases later in life. This prevalence, though relatively low compared to some national or regional averages, underscores the need for continuous monitoring and targeted interventions to address the underlying causes. It is possible that exposures such as household air pollution, maternal nutrition, infection, or socioeconomic factors may be contributing to this outcome.

Table 4.3: Determinants of smoke exposure among pregnant women

Variables	Any Smoke Exposure		Chi-Square	P-Value	cOR (95% CI), p-value
	No	Yes			
Age			0.18	0.673	
≤ 34	44(17.0)	215(83.0)			1.00
≥ 35	9(14.8)	52(85.2)			1.18(0.54-2.58),0.673
Ethnicity			3.55	0.314	
Akan	17(19.1)	72(80.9)			1
Ewe	10(11.0)	81(89.0)			1.91(0.82-4.44),0.132
Ga-Dangbe	15(21.1)	56(78.9)			0.88(0.41-1.92),0.750
Other	11(15.9)	58(84.1)			1.24(0.54-2.87),0.606
Religion				0.676*	
Christian	49(17.4)	233(82.6)			1
Islam	3(9.7)	28(90.3)			1.96(0.57-6.71),0.283
Traditionalist/None	1(14.3)	6(85.7)			1.26(0.15-10.72),0.831
Marital Status			1.13	0.287	
Single	6(11.5)	46(88.5)			1

Married	47(17.5)	221(82.5)			0.61(0.25-1.52),0.291
Employment Status			0.36	0.548	
Unemployed	9(14.1)	55(85.9)			1
Employed	44(17.2)	212(82.8)			0.79(0.36-1.71),0.548
Type of dwelling				0.584*	
Compound House	29(15.2)	162(84.8)			1
Separate	19(17.9)	87(82.1)			0.82(0.43-1.55),0.539
Kiosk	2(15.4)	11(84.6)			0.98(0.21-4.67),0.984
Flat	3(30.0)	7(70.0)			0.42(0.10-1.71),0.225

*(p-value from Fischer's exact) ;

*Compound House (a type of dwelling where multiple households share a common courtyard and facilities)

Table 4.3 presents the determinants of smoke exposure among pregnant women. The analysis revealed no statistically significant associations between smoke exposure and the sociodemographic variables examined, including age, ethnicity, religion, marital status, employment status, and type of dwelling. Although women aged 35 years and above appeared slightly more likely to be exposed to smoke compared to those aged 34 years and below (85.2% vs. 83.0%), this difference was not statistically significant (p = 0.673). Similarly, variations in smoke exposure by ethnicity, religion, and marital status were not significant, suggesting that exposure was widespread across different social groups. The findings imply that smoke exposure among pregnant women in the study area is a common environmental risk that cuts across socioeconomic and demographic lines, rather than being concentrated in specific subpopulations.

4.1.4 Association between smoke exposure and birthweight

In the multivariable logistic regression analysis, maternal exposure to multiple sources of smoke during pregnancy was strongly associated with low birth weight (LBW). Specifically, women who were exposed to two or more sources of smoke which includes household polluting fuels, cigarette smoke, domestic waste burning, and mosquito coil smoke—had a significantly higher likelihood of delivering infants with LBW compared to those exposed to fewer than two sources. The adjusted odds ratio (aOR) was 5.86 (95% confidence interval [CI]: 1.01–34.04), indicating that high cumulative smoke exposure was associated with nearly six times higher odds of low birth weight compared to lower exposure, after adjusting for maternal age, parity, socioeconomic status, and antenatal care. This suggests a dose-response effect, where multiple smoke sources compound the risk of adverse birth outcomes.

Table 4.4: Association between smoke exposure and low birth weight

Smoke Exposure indicator	Birth weight		P-Value	cOR (95% CI), p-value	aOR (95% CI), p-value
	Low birth weight 28(8.8%)	Normal birth weight 292(91.2%)			
Smoke Exposure Index			**0.023**		
≤1	11(5.8)	179(94.2)		1.00	1.00
≥2	17(13.1)	111(86.9)		2.49(1.11-5.4),0.027	**5.86(1.01-34.04),0.049**
Any exposure to Smoke			0.734		
No	4(7.6)	49(92.4)		1.00	1.00
Yes	24(9.0)	243(91.0)		1.21(0.40-3.64),0.735	1.62(0.25,10.46),0.611
Polluting fuel			0.987		
No	25(8.7)	261(91.3)		1.00	1.00
Yes	3(8.8)	31(91.2)		1.01(0.29-3.54),0.987	0.43(0.09,2.15),0.305
Smoke from Cigarette	10(8.2)	112(91.8)	**0.006**		
No	19(7.0)	254(93.0)		1.00	1.00
Yes	9(19.2)	38(80.8)		3.17(1.34-7.51),0.009	1.35(0.37,4.87),0.647

Smoke from Garbage burning	19(7.2)	246(92.8)	0.740		
No	9(8.0)	103(92.0)		1.00	1.00
Yes	19(9.1)	189(90.9)		1.15(0.50-2.63),0.740	0.41(0.09-1.85),0.245
Coil usage			0.602		
No	14(8.0)	161(92.0)		1.00	1.00
Yes	14(9.7)	131(90.3)		1.23(0.57-2.67),0.602	0.36(0.08,1.58),0.174

The analysis was adjusted for maternal age, educational level, parity, household income, marital status, gestational age at birth, antenatal care attendance, Cooking location, and sex of the baby.

CHAPTER FIVE

DISCUSION

5.1 Introduction

This chapter discusses the results generated from the collected data for this study. It includes the discussion of the prevalence of low birth weight, smoke exposure among pregnant women and its determinants and finally to assess the association between smoke exposure and birth weight.

5.2 Prevalence of smoke exposure among pregnant women

The findings of this study highlight the prevalence of smoke exposure among pregnant women, a critical public health concern given its implications for maternal and neonatal health outcomes. Our study found that about 8 out of every ten pregnant women were exposed to at least smoke from coil, charcoal, garbage, the method of rubbish disposal and cigarettes. In a consistent with this, a study conducted by (Hashimoto et al., 2023) also indicated that 96.1% of pregnant women were exposed to smoke and tobacco use. In a study of 30 low- and middle-income countries using Demographic and Health Survey data (Reece et al., 2019), the prevalence of daily secondhand smoke exposure during pregnancy ranged from 6% in Nigeria (95% CI: 5–7%) to 73% in Armenia (95% CI: 62–81%), and was higher than the prevalence of active smoking among pregnant women across all surveyed nations. Additionally, a study conducted by (Hikita, et al., 2019) to determine the prevalence of second hand smoke exposure among pregnant women self-reported smoking behavior and urinary cotinine (UC) concentrations revealed that only a small proportion of pregnant women reported daily smoking (0.8%), while 4.7% smoked occasionally, and the vast majority—approximately 88.8%—identified as non-smokers. Our study also revealed that about two-fifth (40.0%) of the pregnant women were exposed to smokes from 2-3 sources. The HAPIN study conducted a multi-country randomized trial in Guatemala, India, Peru, and Rwanda to examine how an LPG stove and fuel intervention influenced health outcomes. It was investigated that, the effects of the LPG stove and fuel intervention on stillbirth, congenital anomalies and neonatal mortality and characterized exposure-response relationships between personal exposures to fine particulate matter (PM2.5), black carbon (BC) and carbon monoxide (CO) and pregnancy outcomes. Pregnant women (18 to <35 years of age; gestation confirmed by ultrasound at 9 to <20 weeks) were randomly assigned to intervention or control arms. It was monitored that, these fetal and neonatal outcomes and personal exposure to PM2.5, BC and CO occurred three times during pregnancy. Intention-to-treat (ITT) and exposure-response (E-R) analyses were conducted to determine if the HAPIN intervention and corresponding HAP exposure were associated with the risk of fetal/neonatal outcomes. A total of 3200 women (mean age 25.4 ± 4.4 years, mean gestational age at randomization 15.4 ± 3.1 weeks) were included in this analysis. Relative risks for stillbirth, congenital anomaly and neonatal mortality were 0.99 (0.60, 1.66), 0.92 (95 % CI 0.52, 1.61), and 0.99 (0.54, 1.85), respectively, among women in the intervention arm compared to controls in an ITT analysis. Higher mean personal exposures to PM2.5, CO and BC during pregnancy were associated with a higher, but statistically non-significant, incidence of adverse outcomes. Our study shows that 44% of pregnant women were exposed to charcoal or use coil in their homes and a critical finding emerges from the examination of charcoal usage frequency from our study where pregnant women who use charcoal daily have a significantly higher odds ratio (cOR = 9.86, $p < 0.001$) for being exposed to smoke, indicating a strong association between daily charcoal use and increased exposure. Those who use charcoal occasionally also show a significant association (cOR = 4.59, $p = 0.002$), while those using charcoal a few times a week have a cOR of 2.63 ($p = 0.084$), suggesting a trend towards higher exposure but not achieving statistical significance. Hussein et al. (2020) reported elevated risks of preterm delivery among women who cooked with charcoal and firewood, showing adjusted risk estimates of 1.47 (95% CI: 1.04–2.05) and 1.18 (95% CI: 0.83–1.69), respectively, after controlling for confounding influences.

Even though the findings did not reach statistical significance, the risk of low birth weight was 1.34 times higher (95% CI: 0.45–3.97) among mothers using charcoal and 1.23 times higher (95% CI: 0.41–3.71) among those using firewood.

Likewise, babies of mothers who used charcoal and firewood for cooking exhibited comparatively reduced birth weights in relation to those of mothers employing cleaner fuel alternatives had 1.72 times (95% CI 0.52–5.65) and 1.70 times (95% CI 0.49–5.92) risk in small for gestational age after controlling for maternal BMI at first visit and anemia. Lastly, mothers who used charcoal and those who used firewood respectively had 1.87 times (95% CI 0.29–11.64) and 2.02 times (95% CI 0.31–13.04) increased risk in perinatal mortality after controlling for potential confounding variables. Our analysis revealed a significant link between maternal use of charcoal and the risk of preterm delivery. However, the associations between charcoal or firewood use and low birth weight (LBW), small-for-gestational-age (SGA) infants, and perinatal death were not significant relative to cleaner fuel users (gas or electricity). This indicates that reliance on solid fuels for cooking could negatively affect pregnancy outcomes.

King's College London researchers (2022) identified indoor air pollution as a major health concern in low- and middle-income countries, driven largely by the use of wood and charcoal for cooking and heating. Their findings linked such exposure to poor pregnancy outcomes, particularly placental hypoxia. Examining 2,690 cases of eclampsia from Ethiopia, Haiti, India, Malawi, Sierra Leone, Uganda, Zambia, and Zimbabwe, they reported a clear association between eclampsia-related deaths and indoor air pollution, with the relationship being strongest among women exposed to charcoal smoke within the home environment.

5.3 Relationship between smoke exposure and birth weight among pregnant women

Being exposed to smoke has been observed to have a direct relationship with pregnancy outcomes, including birth weight. Findings from our study revealed that about nine percent of the pregnant women gave birth to low birth weight babies. The results from our study are inconsistent with a large body of literature that consistently demonstrates the detrimental impact of both active and passive smoke exposure on birth weight. Numerous studies have reported that Smoke exposure significantly reduces birth weight, with average reductions ranging from 150 grams to 250 grams (McCowan et al., 2016; Flenady et al., 2017). For instance, a study by Rehan et al. (2015) found that Smoke exposure was associated with a 23% higher likelihood of delivering a LBW infant. This effect was even more pronounced with increased levels of smoke exposure, with heavier smokers experiencing a greater reduction in birth weight. Additionally, a study in Kenya by Ndungu et al. (2019) found that exposure to secondhand smoke during pregnancy resulted in a 22% increase in the risk of LBW, while a study in South Africa by Olutola et al. (2019) highlighted that secondhand smoke exposure during pregnancy was linked to a 30% higher likelihood of LBW. These findings are in contrast with to our study, where no statistical significance was observed. However, our study's findings align with some smaller studies, particularly in environments where smoke exposure are low or where other factors such as access to prenatal care and maternal nutrition are optimized. For example, a study conducted in rural Bangladesh by Rahman et al. (2020) showed no significant relationship between smoke exposure and birth weight, attributing this to the overall low smoke exposure and the relatively good access to maternal care in the study population.

The discrepancy between our findings and existing studies may be due to while smoke exposure was recorded among pregnant women, it is possible that the level of exposure varied significantly within the cohort. This study did not differentiate between active and passive smoke exposure, and it also did not account for the cumulative effects or intensity of smoke exposure from other significant sources such as polluting fuels, mosquito coils, and garbage burning, which may have masked the true impact of chronic exposure. Birth weight is influenced by a variety of factors, including maternal nutrition, prenatal care, socioeconomic status, and underlying health conditions such as diabetes or hypertension. These confounders could have diluted the effect of smoke exposure on birth weight in our analysis, and the retrospective nature of our study, relying on historical data from maternal health records, may have introduced recall bias or inaccuracies in reporting.

Conventionally, our results also show notable evidence of different kinds of exposure and birthweight of a child. Our study revealed that most of the pregnant women gave birth to children with birth weights of 1.95 to 2.95kg and the least was recorded to be 4 to 4.6 kg. Our results noted that most pregnant women (approximately 75%) delivered babies with birth weights ranging from 1.95 to 2.95 kg, while the highest recorded birth weight ranged from 4 to 4.6 kg. Interestingly, while the mean birth weight observed falls within the generally expected range for healthy neonates, the lack of a statistically significant association with smoke exposure is noteworthy. This suggests that, within the scope of our sample, smoke exposure did not have a direct measurable effect on the birth weight of infants. In line with this, the study by Andriani et al. (2023) demonstrated that prenatal exposure to secondhand smoke within the household was linked to lower mean birth weight. After adjustment for covariates, infants of SHS-exposed mothers weighed 71.6 g less on average ($p<0.01$), and the odds of having a low-birth-weight infant were 1.16 times higher compared to mothers not exposed to SHS (AOR=1.16; 95% CI: 1.02–1.33, $p<0.05$). Mothers experiencing daily secondhand smoke exposure gave birth to infants whose mean birth weight was 63.4 g lower than that of non-exposed mothers ($p<0.01$). Weekly and daily SHS exposure also increased the likelihood of low birth weight, with AORs of 1.33 (95% CI: 1.03–1.71, $p<0.05$) and 1.18 (95% CI: 1.01–1.38, $p<0.05$), respectively.

Due to smoking prevalence which is increasingly shifting towards low and middle-income countries in Asia, where tobacco markets have moved from high to lower-income settings, the burden of adverse outcomes such as low birth weight (LBW) may become unavoidable in these regions (Yang & Dong, 2022; ASH, 2019). Evidence from international studies—particularly those from the Netherlands, the United States, and Greece—supports the finding that secondhand smoke exposure contributes to an elevated risk of low birth weight among newborns (Di et al., 2022).

Findings from retrospective and prospective cohort investigations suggest that continuous exposure to cigarette smoke in the home during pregnancy contributes to a marked reduction in adjusted mean birth weight and roughly doubles the risk of giving birth to a smaller infant. Supporting this, Andriana et al. (2021) noted that infants in the exposed group had lower mean birth weights independent of maternal BMI. Nadhiroh et al. (2020) reported that for every additional cigarette smoked during pregnancy, birth weight decreased by approximately 12.9 g, with women exposed to smoke having about twice the likelihood of delivering low-birth-weight (LBW) infants compared with those unexposed. The biological explanation for this increased risk may involve inflammatory processes, particularly increased concentrations of inflammatory mediators such as Tumor Necrosis Factor-alpha (TNF-α) and Vascular Cell Adhesion Molecule-1 (VCAM-1) have been observed, suggesting that exposure to smoke may trigger systemic inflammation affecting placental function (Zhang et al., 2022; Lee et al., 2021; Hougaard et al., 2020) This can cross the placenta and disrupt normal fetal growth. The abundant level of inflammatory markers in pregnant women leads to the damage of the placenta, and thus nutrients and oxygen cannot be optimally delivered to the fetus, resulting in suboptimal growth and LBW (Niu et al., 2016). The study also finds a significant association between pregnant women that use charcoal was statistically significant with birth weight (aOR 0.70, CI 0.45-3.12, P-value 0.001). Constantly, a study conducted by (Linag et al., 2023) noted similar findings and recommends that coil usage, such as mosquito coil, should be avoided during pregnancy.

5.4 Determinants of smoke exposure among pregnant women

The study found no significant determinant of smoke exposure but our findings goes contrary to the body of many literatures. A study conducted by Nitcher et al., (2010) exposure to tobacco smoke during pregnancy, both through active and secondhand smoke (SHS), poses significant risks to maternal and fetal health. Understanding the determinants of smoke exposure among pregnant women is crucial for developing effective interventions. Key factors influencing this exposure include socioeconomic status, educational attainment, marital status, household environment, cultural norms, and regional smoke exposure prevalence.

Lower socioeconomic status (SES) and limited educational attainment are consistently linked to higher rates of smoke exposure during pregnancy. Studies indicate that pregnant women with lower income and education levels are more likely to smoke, potentially due to increased stressors and reduced access to cessation resources. For instance, research utilizing data from the Population Assessment of Tobacco and Health (PATH) Study found that poverty and low educational attainment were associated with Smoke exposure during pregnancy (Do et al., 2018).

Determinants such as marital status also significantly impact smoke exposure behaviors during pregnancy, as shown by a study conducted by Reece et al. (2019). Unmarried women have been identified as having higher risks for both active and SHS exposure. Additionally, having a partner who smokes increases the likelihood of Smoke exposure and SHS exposure. The presence of smokers in the household, particularly partners, correlates with increased SHS exposure among pregnant women. The differences in our results may be a result of the different methodological approaches used in our study.

5.5 Association between smoke exposure and birthweight of newborns

A multivariable analysis revealed a significant association between exposure to smoke and low birth weight. Thus, participants who were exposed to two or more sources of exposure were almost six times more likely to give birth to babies with low birth weight compared to those with fewer than two exposures. Our findings consistently align with a study conducted by Kataoka et al. (2018); compared to infants born to nonsmoking mothers, the mean birth weight was 320 g lower in newborns whose mothers smoked 6–10 cigarettes per day and 435 g lower in newborns whose mothers smoked 11–40 cigarettes per day during pregnancy. Maternal exposure to tobacco smoke, both active and passive, has been extensively linked to adverse neonatal outcomes, particularly reduced birth weight. Birth weight is a critical indicator of neonatal health, with low birth weight (LBW) associated with increased risks of infant morbidity and mortality.

Numerous studies have demonstrated a significant association between active Smoke exposure during pregnancy and reduced birth weight. A study by Bernstein et al. (2005) found that maternal cigarette consumption in the third trimester was a strong predictor of birth weight percentile, with each additional cigarette per day associated with an estimated 27-gram reduction in birth weight.

Similarly, the EDEN study conducted in Switzerland reported that infants born to mothers who smoked during pregnancy had a mean birth weight reduction of 190 grams compared to those born to non-smokers. The study also found that smoke exposure increased the odds of LBW (OR: 2.7), small-for-gestational-age (SGA) births (OR: 2.1), and preterm birth (OR: 1.4) (Zhang and Wang, 2005).

Passive exposure to tobacco smoke, or secondhand smoke (SHS), has also been implicated in reduced birth weight. A study conducted in Malaysia found that neonates born to mothers exposed to SHS during pregnancy had a significant reduction in birth weight compared to those unexposed, with a 12.9-gram decrease per cigarette smoked in the household (Abdul Razak et al., 2015). Additionally, a study by Salmasi et al. (2010) reported that maternal exposure to SHS during pregnancy was associated with a small but significant reduction in mean birth weight and an increased risk of LBW.

The mechanisms by which tobacco smoke exposure affects fetal growth are multifaceted. Nicotine and other toxic substances in tobacco smoke can constrict uterine blood vessels, reducing the flow of oxygen and nutrients to the developing fetus, thereby impairing fetal growth (Salmasi et al., 2010). Furthermore, exposure to SHS has been linked to maternal inflammation, which may disrupt placental function and nutrient transfer, contributing to LBW (Leonardi-Bee et al., 2011).

Genetic factors may also modulate the impact of tobacco smoke on birth weight. Polymorphisms in genes involved in detoxifying tobacco smoke compounds, such as CYP1A1 and GSTT1, have been associated with greater reductions in birth weight among smoke-exposed mothers (Wang et al., 2002). This suggests that genetic susceptibility can influence the degree to which tobacco smoke exposure affects fetal growth.

5.6 Study limitations

Despite its relevance and significance, the study faces several limitations that should be considered in interpreting the findings: the study adopts a cross-sectional design, and it will only provide a snapshot of the relationship between smoke exposure during pregnancy and birth weight at a particular point in time. This design limits the ability to draw conclusions about causal relationships. Longitudinal studies would be necessary to better understand the long-term effects of smoke exposure on maternal and neonatal health.

5.7 Self-Reporting of Smoke Exposure

Data on smoke exposure during pregnancy were self-reported, which introduces the possibility of underreporting or misreporting due to recall limitations and social desirability bias. This is particularly relevant for cigarette smoking and secondhand smoke, which carry stigma during pregnancy and may lead women to conceal such behaviors. However, the same bias may also affect reporting of other exposures, such as household use of polluting fuels, garbage burning, or indoor mosquito coil usage, especially if respondents perceive these practices as harmful or undesirable.

5.8 Measurement Bias

One key limitation was the lack of objective measurement or quantification of environmental pollutants, particularly particulate matter (PM2.5/PM10) and carbon dioxide (CO_2) levels in the households of the participants. This limitation restricted the study's ability to accurately assess the true extent and intensity of smoke exposure. Instead of using devices such as air quality monitors or dosimeters, the study relied on self-reported exposure, which may not accurately reflect the actual concentrations of harmful substances inhaled by the women. As a result, the strength of the association between smoke exposure and birth outcomes might have been either underestimated or overestimated.

5.9 Selection Bias

The study population consisted solely of pregnant women who delivered in health facilities, thereby excluding those who delivered at home. This introduces selection bias, as women who deliver in hospitals may differ systematically from those who deliver at home in terms of socioeconomic status, health-seeking behavior, environmental conditions, or access to clean fuels. The exclusion of home births limits the generalizability of the findings, as the sample may not fully represent the experiences of all pregnant women within the study area, particularly those in rural or underserved communities where home deliveries are more common.

5.10 Information Bias

There is potential for information bias, primarily due to the nature of data collection. While birth weight data were obtained from medical records, which enhances reliability, smoke exposure data were collected through interviewer-administered questionnaires. This reliance on participants' self-reported exposure introduces the risk of recall bias, where women may not accurately remember or report the frequency, duration, or intensity of exposure to various smoke sources. Additionally, social desirability bias may lead some participants to underreport behaviors perceived as harmful (e.g., smoking or using polluting fuels). Such biases can affect the validity and reliability of the exposure data, potentially distorting the observed associations.

5.11 Confounding Bias

Lastly, the study may be subject to confounding bias, as not all potential confounders were controlled for or measured. Factors such as maternal nutrition, pre-existing medical conditions, socioeconomic status, educational level, and access to prenatal care could independently influence both smoke exposure and birth weight outcomes. The presence of unmeasured or residual confounders could lead to spurious associations or mask true relationships, thereby weakening the causal inferences that can be drawn from the study.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

This study emphasizes the extremely high exposure of pregnant women to smoke, with as much as 80% having had exposure to smoke from sources such as cooking fuel (coil, charcoal), waste disposal (garbage burning), and tobacco smoking. Notably, two-fifths of the women had more than one source of exposure, and 2–3 accounted for overall exposure to smoke. Even though none of the determinants of exposure to smoke were statistically significant, the health implications are evident nonetheless. Approximately 9% of the women gave birth to low birth weight (LBW) infants, an important indicator of poor neonatal outcomes. Interestingly, multivariable analysis revealed that two or more smoke exposures had a substantial association with LBW, indicating that pregnant women who had been exposed to two or more sources of smoke were nearly six times more likely to have LBW infants. These findings underscore the necessity for targeted public health prevention interventions against pregnancy smoke exposure in the household and environment to improve birth outcomes.

6.2 Recommendation

Based on the findings of this study, the following recommendations are proposed to reduce smoke exposure among pregnant women and improve birth outcomes.

The Ministry of Health (MoH) in collaboration with the Ghana Health Service (GHS) should promote the use of cleaner cooking fuels such as liquefied petroleum gas (LPG), electricity, and improved cook stoves. These efforts should be integrated into maternal health education provided by public health nurses, midwives, and community health workers during antenatal care (ANC) sessions.

Additionally, the Ministry of Energy and local governments can work together to implement subsidy programs and micro-credit schemes that improve access to cleaner fuels and cookstoves, particularly for low-income households. Training programs and sensitization campaigns should also be developed to support behavioral change toward sustainable fuel adoption.

Environmental Health Units within the Metropolitan, Municipal, and District Assemblies (MMDAs) should partner with district health directorates and health facilities to develop and implement robust public awareness campaigns. These campaigns should focus on the health impacts of exposure to household and ambient smoke, especially during pregnancy. Educational content should be culturally appropriate and disseminated through community durbars, local radio programs, school visits, and ANC clinics. Messages should emphasize the association between smoke exposure and low birth weight (LBW), preterm birth, and other adverse outcomes. Involvement of traditional leaders and local influencers can further enhance the reach and acceptance of these campaigns.

To effectively reduce household smoke exposure, community health nurses and public health officers should be adequately trained and resourced to assist pregnant women in creating and maintaining smoke-free home environments. Their support should be incorporated into routine antenatal and postnatal care, as well as during community outreach activities. This support may involve counseling household members on the health risks associated with indoor smoking, open burning, and prolonged exposure to cooking smoke—particularly the dangers these pose to pregnant women and unborn babies. Nurses and officers should also promote safe cooking practices, including the use of outdoor kitchens or well-ventilated indoor cooking spaces, and encourage the installation of smoke hoods or chimney systems in enclosed areas to reduce indoor air pollution. During home visits, they can provide simple, culturally appropriate educational materials such as posters and leaflets to reinforce healthy practices. Additionally, the formation of mother-to-mother support groups within communities can foster peer learning, shared experiences, and accountability, empowering pregnant women to sustain smoke-free household behaviors throughout their pregnancies and beyond.

Local government authorities, particularly District Assemblies, should prioritize the expansion and improvement of household solid waste collection systems to reduce the common practice of backyard waste burning. The Environmental Health Department at the district level should enforce existing bylaws against indiscriminate burning and educate communities on its health risks. Community-led initiatives such as neighborhood cleanup groups or waste sorting programs could be supported to promote environmentally friendly waste disposal. Providing households with accessible waste collection points and encouraging waste segregation (e.g., organic vs. non-organic) may further reduce the need for burning.

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