AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

TRANSMISSION DYNAMICS OF TYPHOID FEVER IN THE EJURA/SEKYEDUMASE MUNICIPALITY OF THE ASHANTI REGION, GHANA: A TEN-YEAR RETROSPECTIVE TREND ANALYSIS

APPIAH STEPHEN

2025

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BY

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A thesis submitted to the Department of Public Health Education of the Faculty of Environment and Health Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in partial fulfilment of the requirements for the award of a Master of Philosophy degree in Public Health

SEPTEMBER, 2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis, except for quotations and references contained in published works which have been duly acknowledged and cited, is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: Appiah Stephen

Signature: …… **Date: ……**

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Principal Supervisor's Name: Rev. Dr. Denis Dekugmen Yar

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ABSTRACT

This study examined the transmission dynamics and temporal trends of typhoid fever in Ejura/Sekyedumase over ten years (2013–2023), with specific objectives to (1) determine the prevalence and trends of typhoid fever; (2) analyze socio-demographic patterns across age and gender; and (3) evaluate the influence of seasonality and climate on disease incidence using predictive time-series models. A retrospective design was employed, utilizing secondary health data from the Ejura/Sekyedumase Municipal Health Directorate. Monthly reported typhoid cases were aggregated, cleaned, and analyzed using R (version 4.3.2). Time-series modelling involved Seasonal-Trend decomposition (STL) and Auto-Regressive Integrated Moving Average (ARIMA) modelling, with further validation using Error-Trend-Seasonal (ETS) and Prophet forecasting techniques. The findings revealed a persistent endemic trend with recurrent seasonal peaks, particularly during the rainy months (May–August). Young adults aged 20 years and above (≥ 20) exhibited the highest burden, accounting for over two-thirds of reported cases, followed by adolescents (15-19 years old). A gender analysis revealed a slightly higher incidence among females, reflecting gendered exposure patterns associated with water collection, domestic food preparation, and childcare. The Augmented Dickey–Fuller (ADF) and KPSS tests confirmed non-stationarity in the original series (ADF $p = 0.207$; KPSS $p = 0.039$), leading to first differencing before modelling. The ARIMA (1,1,1)(1,1,1)[12] model provided the best fit (AIC = 1451.72, RMSE = 95.51), capturing both short-term fluctuations and strong annual seasonality. The study concludes that typhoid fever in Ejura/Sekyedumase is driven by a combination of seasonal climatic variability, poor sanitation, and socio-cultural practices that facilitate faecal–oral transmission.

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May the Almighty God shower His immeasurable blessings on you all, Amen.

DEDICATION

I dedicate this work to my mother, Stella Appiah, and my father, Emmanuel Gyebi, for their unwavering support, advice, and encouragement throughout my educational and research journey. I also dedicate this work to all loved ones who contributed to its successful completion.

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LIST OF ACRONYMS (ABBREVIATIONS)

ADF	-	Augmented Dickey - Fuller
ARIMA	-	Auto-Regressive Integrated Moving Average
CDC	-	Centers for Disease Control and Prevention
DHIMS	-	District Health Information Management System
ETS	-	Error-Trend and Seasonality
GBD	-	Global Burden of Disease
KPSS	-	Kwiatkowski-Phillips-Schmidt-Shin
LMICs	-	Low-Middle Income Countries
MENA	-	Middle East and North Africa
NTS	-	Non-typhoidal Salmonellae
STL	-	Seasonal-Trend decomposition using Loess
WASH	-	Water, Sanitation, and Hygiene
WHO	-	World Health Organization

ETHICAL APPROVAL

The study received approval from the Committee for Human Research and Ethics of the University of Energy and Natural Resources, Sunyani, with approval number CHRE/AP/368/025

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

The global estimate of typhoid fever caused by *Salmonella enterica serovar typhi* (*S. typhi*) was estimated to be 26.9 million cases, with 217,000 deaths recorded (Akinyemi et al., 2018). Worldwide, there are 9 million cases of typhoid fever annually, resulting in about 110,000 deaths per year as of 2019 estimates (WHO, 2023). Salmonella infection significantly contributes to the worldwide prevalence of illness and death, particularly in low- and middle-income countries (LMICs) (Marks et al., 2017). In the majority of regions where the disease is prevalent, nearly 90% of enteric fever cases can be attributed to typhoid. The extent of Salmonella infection in various regions of sub-Saharan Africa remains undisclosed primarily. The paucity of diagnostic facilities is commonly associated with fatal cases of Salmonella, which are frequently attributed to malaria (Rufai et al., 2023).

Previous research conducted over 15 years (1975-1990) in four African nations (Zambia, Tanzania, Ghana, and Kenya) revealed that Ghana had the highest national incidence rate of one in a thousand among the examined countries (Balogun, 2022; Carey et al., 2022). However, data are scarce in Sub-Saharan Africa, particularly Ghana, regarding the case-fatality rates of typhoid fever (Fusheini & Gyawu, 2020).

The clinically identical syndrome known as paratyphoid fever is caused by *Salmonella enterica serovars paratyphi* A, B, and C. Salmonella is divided into two major categories: invasive and non-invasive. The invasive Salmonella, also known as typhoidal Salmonellae, causes enteric fevers (Stanley et al., 2023). Typhoidal Salmonellae include *Salmonella*

typhi and *paratyphi*. Non-invasive Salmonella are known as non-typhoidal Salmonellae (NTS) and consist of Salmonella species that typically cause gastroenteritis (Stanley et al., 2023). Typhoid and paratyphoid fever continue to pose a significant global public health burden; however, annual prevalence estimates vary, and similar disparities exist within countries, underscoring a severe health concern (Fusheini & Gyawu, 2020). Serovars of *S. enterica* are classified into two groups based on their disease outcomes in humans: typhoidal and nontyphoidal salmonellosis (Adesegun et al., 2020). *S. typhi* and *S. paratyphi* are typhoidal Salmonellae that cause life-threatening systemic infections (Adesegun et al., 2020; Marchello et al., 2019).

Typhoid fever is primarily transmitted through the ingestion of food or water contaminated with faecal matter. Poor sanitation, inadequate access to clean water, and improper hygiene practices facilitate its spread. *Salmonella typhi* is transmitted through two primary patterns: short-cycle transmission, which occurs when contaminated food and water are contaminated with faecal matter, and long-cycle transmission, which involves the ingestion of contaminated food or water. A significant determinant of the likelihood of contracting typhoid fever is the absence of or limited availability of uncontaminated and secure water sources (Faiz et al., 2023). Poor hygiene and sanitation practices in the local surroundings primarily contribute to the spread of the disease.

Previous research in Ghana has consistently reported the prevalence and consequences of typhoid fever. However, the most recent documented instances of typhoid fever in Ghana continue to exhibit a concerning pattern, posing a significant public health issue. According to records from 2015, 2016, and 2017, there were 337,120, 384,704, and 365,148 cases of

typhoid fever, respectively (Agyen et al., 2024). These cases ranked in the top twenty causes of outpatient morbidity, accounting for 1.3%, 1.7%, and 1.2% of hospital admissions, respectively (Agyen et al., 2024). In Ghana, Typhoid fever, caused by *Salmonella enterica serovar typhi*, remains a significant public health concern.

In the Ejura/Sekyedumase Municipality of the Ashanti Region, typhoid fever continues to pose a significant health challenge, necessitating a comprehensive epidemiological study to understand its transmission dynamics, risk factors, and public awareness. Quantifying the burden of enteric fever is important for understanding the extent of health loss and the widespread dissemination of the disease. However, there is a lack of data on the prevalence of typhoid fever, especially in Ejura/Sekyedumase Municipality. Therefore, this study seeks to investigate the transmission dynamics of typhoid fever in the Ejura/Sekyedumase Municipality of the Ashanti Region, Ghana.

1.2 Problem Statement

The Ejura/Sekyedumase Municipality is a rapidly developing municipality with numerous slum areas characterized by poor sanitation practices, including open defecation, inadequate food handling, and a low-quality water supply. Moreover, the Ejura market is a prominent hub for maize production, drawing traders from neighbouring West African nations (Akowuah et al., 2015). Rapid urbanization, population growth, climate change, and seasonal variability exacerbate the typhoid fever situation, posing significant challenges for prevention and control. There is a widespread occurrence of typhoid fever in the municipality, although up-to-date empirical data on disease transmission trends over the last decade are not available. However, the 2023 annual report from the District Health

Information Management System (DHIMS 2) recorded 3,880 cases of typhoid fever in the municipality. Several studies have been conducted on typhoid fever in the region (Boakye et al., 2025; Marks et al., 2024; Kungu et al., 2025). However, there is a paucity of data on annual transmission trends, which serve as a measure of the effectiveness of prevention and control efforts over the period in the municipality. This is pivotal for a multi-sectoral approach that integrates improved sanitation, access to safe water, health education, and other relevant measures to effectively reduce the disease burden. Consequently, typhoid fever remains prevalent in the municipality, with recurring outbreaks that pose a threat to the health and livelihoods of residents. Thus, it has become imperative to assess the transmission dynamics and trends of typhoid fever over the past decade in the Ejura/Sekyedumase municipality. The outcome of this study has the potential to provide detailed insights into the trends and prevalence of typhoid fever in the municipality, facilitating evidence-based health interventions and informed policy formulation.

1.3 Research Question

1. Which demographics are most affected by typhoid fever in Ejura/Sekyedumase?
2. What is the influence of climatic variables on the distribution of typhoid fever cases in the municipality?
3. Which statistical model provides the most accurate forecasts of typhoid incidence and can be integrated into municipal surveillance systems to support early-warning interventions?

1.4 Main Objective

The primary objective of this study was to assess the prevalence trends and transmission dynamics of typhoid fever in the Ejura/Sekyedumase municipality in the Ashanti Region of Ghana.

1.4.1 Specific Objectives

Specifically, the study sought to:

1. Examine the socio-demographic patterns of typhoid fever incidence with respect to age and gender in the study area.
2. Assess the influence of seasonal climatic variations on the incidence of typhoid fever in Ejura/Sekyedumase Municipality.
3. Evaluate the utility of statistical forecasting models (ARIMA, ETS, Prophet) in predicting typhoid fever trends for public health planning.

1.5 Justification of the Study

Typhoid fever remains a major public health challenge in many low- and middle-income countries, including Ghana, where sanitation and water safety issues persist (WHO, 2023). The disease is primarily transmitted through the faecal-oral route, often due to contaminated food, water, and inadequate sanitation practices (Parry et al., 2021). The Ejura/Sekyedumase Municipality, situated in Ghana's Ashanti Region, has experienced recurrent typhoid outbreaks; however, limited empirical data exist on its transmission dynamics, seasonal patterns, and sociocultural risk factors.

Understanding the prevalence and risk factors of typhoid fever in this region is critical for designing effective interventions. This study would contribute to public health planning by

providing localized epidemiological data to support evidence-based interventions, such as improved sanitation infrastructure, targeted vaccination campaigns, and health education programmes. Moreover, given the climatic variability in Ghana, this study would explore how seasonal factors influence typhoid fever incidence, a research gap identified in previous studies (Kariuki & Dougan, 2022).

Additionally, limited studies have examined community knowledge and awareness of typhoid fever in Ghanaian rural and peri-urban communities. This study would assess the population's level of understanding of preventive measures, symptoms, and treatment-seeking behaviours, which are essential for promoting community-led interventions (Crump & Mintz, 2020). Findings from this study will support local health authorities and policymakers in designing targeted interventions to reduce typhoid morbidity and mortality in the municipality.

1.6 Significance of the Study

This study will provide critical insights into the transmission dynamics of typhoid fever, helping public health officials and policymakers design targeted interventions. By understanding the epidemiological trends, risk factors, and community perceptions, this research will contribute to the formulation of more effective prevention and control strategies, ultimately reducing the burden of typhoid fever in Ejura/Sekyedumase and similar settings.

Typhoid fever persists as a significant public health concern in the municipality. The results of this research will provide valuable information for health authorities and service providers to educate the public about the disease, in order to tackle the challenge

effectively. This research aims to enhance knowledge by addressing the existing gap in the literature regarding the determination of typhoid fever prevalence in Ghana. Subsequently, this could lead to the implementation of effective public health policies and programs aimed at addressing the issue. Understanding the extent of the problem can also be utilized by other regions in Ghana and other sub-Saharan African nations in formulating policies and initiatives targeted at enhancing and advocating for the health and overall welfare of the population.

1.7 Limitations of the Study

This study has some limitations. First, the reliance on retrospective hospital records over the past ten years may introduce information bias due to incomplete or missing data. The study is geographically confined to Ejura/Sekyedumase Municipality, which limits the generalizability of the results to other regions. Another limitation is the reliance on clinical diagnoses rather than laboratory confirmation of typhoid fever cases, which may lead to misclassification errors. Furthermore, the study's attempt to analyze the seasonality of typhoid fever may be constrained by the availability and accuracy of meteorological data, which could affect the strength of correlations drawn between climate factors and disease incidence.

1.8 Delimitations of the Study

To maintain focus and feasibility, the study is delimited in several ways. It is conducted exclusively in Ejura/Sekyedumase Municipality due to its high burden of typhoid fever and diverse population. The study covers a ten-year period (2013–2023) to assess long-term trends and seasonal variations. Data collection includes hospital records for prevalence analysis and climate records to evaluate seasonal trends; however, it does not involve

laboratory testing of blood samples. The study specifically focuses on socio-cultural and environmental determinants of typhoid transmission, excluding genetic predispositions and individual immune responses. Moreover, the survey excludes children under five years of age and individuals who have not resided in the municipality for at least one year, to ensure that responses accurately reflect local risk factors and experiences.

1.9 Organization of the Study

The study is organized into six chapters. Chapter One introduces the research by providing background information, stating the problem, defining objectives, and outlining the significance, scope, and justification of the study. Chapter Two reviews relevant literature, covering conceptual definitions, theoretical perspectives, and empirical studies on typhoid fever transmission while identifying research gaps. Chapter Three details the research methodology, including the study design, data collection methods, analytical techniques, and ethical considerations. Chapter Four presents and discusses the findings on prevalence, risk factors, seasonal trends, and sociocultural influences. Chapter Five discusses and interprets the study findings, relating them to existing literature and theoretical framework, and it critically examines the results, discussing implications for practice and future research. Finally, Chapter Six summarizes the key findings, draws conclusions, and provides recommendations for public health interventions and future research.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

Typhoid fever, caused by the bacterium *Salmonella enterica serovar typhi*, is still a significant public health concern, particularly in developing countries (Kim et al., 2022). The disease is basically transmitted through the ingestion of contaminated food or water, often due to inadequate sanitation and hygiene practices (Marchello et al., 2019). In Ghana, typhoid fever remains a significant health challenge, with regions such as the Kadjebi District reporting an alarming increase in cases, from 298 in 2021 to 672 in 2023 (Latsu, 2024).

Understanding the transmission dynamics of typhoid fever is important for developing effective prevention and control strategies. Transmission dynamics include the patterns and factors influencing the spread of the disease within a population, considering environmental, behavioural, and sociocultural determinants (Adesegun et al., 2020; Kim et al., 2019). In the context of the Ejura/Sekyedumase Municipality in Ghana's Ashanti Region, a comprehensive analysis of these dynamics over the past decade (2013–2023) can provide valuable insights into the prevalence trends and risk factors associated with typhoid fever.

This literature review, therefore, aims to explore existing research on typhoid fever, focusing on its conceptual framework, theoretical underpinnings, and empirical findings, by examining the interplay between the bacterium, host factors, and environmental conditions, as well as reviewing models of transmission and control measures (Asamoah

et al., 2024). This also seeks to identify knowledge gaps and inform future public health interventions tailored to the specific context of the Ejura/Sekyedumase Municipality.

2.2 Conceptual Review

2.2.1 Definition of Key Concepts

In the context of this study on the transmission dynamics of typhoid fever in the Ejura/Sekyedumase Municipality, it is essential to define the following key concepts:

Typhoid Fever: A life-threatening systemic infection caused by the bacterium. It is primarily transmitted through the ingestion of contaminated food or water. It is characterized by symptoms such as prolonged high fever, fatigue, headache, nausea, abdominal pain, and either constipation or diarrhoea. In severe cases, it can lead to serious complications or death (Adesegun et al., 2020).

Paratyphoid Fever: A condition similar to typhoid fever but caused by different bacteria, namely *Salmonella enterica serovars paratyphi* A, B, or C. It shares many clinical features with typhoid fever, including high fever, gastrointestinal disturbances, and malaise, but is generally considered to have a slightly lower mortality rate (Adesegun et al., 2020).

Transmission Dynamics: This refers to the patterns and mechanisms through which a disease spreads within a population. Understanding transmission dynamics involves studying factors such as the rate of infection, modes of transmission, contact patterns among individuals, and environmental influences that facilitate or hinder the spread of the disease (Aweke, 2019).

Prevalence: The total number of cases of a particular disease present in a population at a specific point in time. Prevalence provides a snapshot of how widespread the disease is and is crucial for public health planning and resource allocation (Kim et al., 2019).

Incidence: The number of new cases of a disease that develop in a specific population during a defined time period. Incidence rates help in understanding the risk of contracting the disease and are vital for evaluating the effectiveness of control measures(Adesegun et al., 2020; Marchello et al., 2019).

Risk Factors: Attributes, characteristics, or exposures that increase the likelihood of an individual developing a disease. For typhoid fever, common risk factors include consuming contaminated food or water, poor sanitation, lack of access to clean drinking water, and inadequate personal hygiene practices (Kim et al., 2019).

Sociocultural Determinants: The social and cultural factors that influence an individual's or community's health behaviours and outcomes. These determinants encompass beliefs, traditions, social norms, and practices that can affect disease transmission and prevention efforts. In the case of typhoid fever, sociocultural determinants might include communal eating habits, traditional food preparation methods, and community perceptions about sanitation and hygiene (Kim et al., 2022).

2.2.2 Epidemiological Triad and Typhoid Fever

The epidemiological triad is one of the foundational conceptual models in infectious disease epidemiology. It explains the occurrence and distribution of diseases through the dynamic interaction of three essential components, the agent, host, and environment (Sanders et al., 2008). This tripartite model offers a systematic framework for understanding how infectious diseases, such as typhoid fever, emerge, persist, and spread within populations. The balance and interdependence among these elements determine not only the likelihood of disease transmission but also the scale and pattern of outbreaks (Aweke, 2019).

The Agent Component: *Salmonella enterica serovar typhi*

The causative agent of typhoid fever, *Salmonella enterica serovar typhi* (*S. typhi*), is a Gram-negative, facultatively anaerobic bacterium that is highly adapted to humans as its exclusive reservoir (Adesegun et al., 2020). Unlike many other enteric pathogens that infect both humans and animals, *S. typhi* is human-specific, a feature that shapes its transmission dynamics and epidemiological profile. Infection typically occurs through ingestion of food or water contaminated with faeces or urine from an infected person or asymptomatic carrier (Kim et al., 2019).

Once ingested, *S. typhi* penetrates the intestinal mucosa, invades the bloodstream, and disseminates systemically, producing clinical manifestations such as prolonged fever, abdominal discomfort, headache, malaise, and hepatosplenomegaly. In the absence of timely treatment, complications such as intestinal perforation, haemorrhage, and septicemia may occur (Marchello et al., 2019). The bacterium's ability to survive in harsh environmental conditions and its resistance to multiple antibiotics further complicate disease control (Kariuki & Dougan, 2022). The presence of chronic carriers, notably exemplified by the historical case of *"Typhoid Mary"* in the early 1900s, remains a critical public health concern, as such individuals silently sustain community transmission even in the absence of symptoms.

The Host Component: Human Susceptibility and Immunity

Humans are the sole natural host for *S. typhi*, and host susceptibility varies by age, immunity, nutritional status, and prior exposure (Marchello et al., 2019). Epidemiological evidence indicates that school-aged children and young adults are the most affected demographic, primarily due to higher exposure to contaminated food and water, weaker

acquired immunity, and risk behaviours such as consuming food from street vendors (Baker et al., 2021). Moreover, individuals with compromised immune systems, such as those affected by HIV/AIDS or malnutrition, are at greater risk of severe infection (Akinyemi et al., 2021).

An important host-related phenomenon is asymptomatic carriage, where individuals recover from the acute phase of the illness but continue to harbour and excrete *S. typhi* bacteria, particularly through the biliary tract. These carriers, often unaware of their infectious status, play a crucial role in sustaining endemic transmission, particularly in communities with inadequate sanitation. The host dimension thus captures both biological and behavioural determinants of infection, linking human practices (e.g., food handling and hygiene) with biological susceptibility.

The Environmental Component: The Facilitating Context of Transmission

The environmental component of the epidemiological triad encompasses all external factors that influence the agent-host interaction, including water quality, sanitation infrastructure, climate, and sociocultural practices. The environment not only facilitates the persistence and transmission of *S. typhi* but also dictates the spatial and temporal patterns of typhoid fever (Kim et al., 2022).

Environmental contamination remains the primary driver of typhoid transmission in endemic regions. Poor sewage disposal systems, open defecation, and inadequate waste management contribute to the contamination of water bodies, particularly during rainy seasons (Adesegun et al., 2020). Historical accounts, such as the 1937 typhoid outbreak in Croydon, England, traced to a polluted municipal water supply, underscore the role of environmental contamination in facilitating widespread transmission (Kim et al., 2019). In

sub-Saharan Africa, similar conditions persist: unprotected wells and streams remain the primary sources of domestic water, while poor drainage systems exacerbate contamination during floods (Rahman et al., 2022).

Seasonal variations further modulate typhoid dynamics. Increased rainfall often overwhelms drainage and sanitation systems, allowing sewage overflow into water sources. Conversely, in dry seasons, water scarcity leads communities to rely on unsafe sources such as ponds and shallow wells. Studies across Ghana, Kenya, and Bangladesh confirm that typhoid incidence peaks during the rainy season, when waterborne contamination is most prevalent (Owusu-Ansah et al., 2023; Kariuki & Dougan, 2022; Aweke, 2019).

In the Ejura/Sekyedumase Municipality, environmental and sociocultural factors converge to create a conducive setting for transmission. The predominance of farming and open markets, coupled with seasonal labour migration, leads to periodic overcrowding and inadequate sanitation in farming settlements. Communal eating during harvest festivals, poor food storage practices, and the use of untreated surface water amplify exposure risks. Thus, the environment in the epidemiological triad extends beyond the physical ecosystem to include social and cultural behaviours that influence disease ecology (Mensah et al., 2023; Aweke, 2019).

Interconnectedness of the Triad in Typhoid Epidemiology

The strength of the epidemiological triad lies in its holistic perspective, which emphasizes that disease occurrence results not from a single factor but from the synergistic interaction of the agent, host, and environment. For typhoid fever, these relationships are dynamic and cyclical. Poor environmental conditions facilitate the survival of *S. typhi* (the agent), which

then infects susceptible humans (the host), who in turn shed the pathogen back into the environment, sustaining the cycle of transmission. This interrelationship explains why improvements in sanitation and hygiene, targeting the environmental component, can yield significant reductions in disease incidence, even without changes in host or agent characteristics (Amoako & Nyarko, 2021).

2.2.3 Waterborne Disease Transmission and Typhoid Fever

Typhoid fever is a classic example of a waterborne infectious disease transmitted primarily through the faecal–oral route, where *Salmonella enterica serovar typhi* is ingested via contaminated food or water. This transmission pathway is closely associated with inadequate sanitation, poor hygiene, and unsafe water sources, conditions that remain prevalent in many low- and middle-income countries (LMICs). Waterborne transmission plays a particularly significant role in typhoid epidemiology, especially in rural and peri-urban communities where the integrity of water and sanitation systems is compromised (Kim et al., 2022; Aweke, 2019).

According to the World Health Organization (WHO, 2023), an estimated 11–20 million people are infected with typhoid fever annually, resulting in approximately 150,000–200,000 deaths, most of which occur in areas where access to clean water and sanitation is limited. In such environments, untreated wastewater, open defecation, and informal waste disposal contribute to the contamination of surface and groundwater sources. Pathogens, including *S. typhi*, can persist in these environments for extended periods, maintaining a reservoir for continuous transmission (Rahman et al., 2022).

Contaminated Water Sources

One of the major contributors to typhoid transmission is the contamination of drinking water supplies through inadequate sewage management and unsafe disposal of human waste. In regions without proper sewage systems, effluents often mix with water bodies used for domestic purposes such as drinking, cooking, or washing (Adesegun et al., 2020). Open defecation and the use of pit latrines near wells and streams further increase the risk of faecal contamination. Studies conducted in sub-Saharan Africa indicate that over 70% of rural households rely on unimproved water sources, including streams and hand-dug wells, many of which are contaminated by surface runoff and human activities (Mensah et al., 2023; Kariuki & Dougan, 2022).

In Ghana, similar challenges persist in rural municipalities such as Ejura/Sekyedumase, where agriculture is the dominant occupation and water for domestic use is often drawn from streams, boreholes, or shallow wells. During the rainy season, heavy runoff frequently carries faecal matter from open fields into these water sources. The presence of *S. typhi* in such environments has been confirmed by environmental surveillance studies, demonstrating that even low-level contamination can sustain transmission within communities (Amoako & Nyarko, 2021).

Poor Sanitation and Hygiene Practices

Beyond environmental contamination, inadequate sanitation infrastructure and poor personal hygiene practices are key determinants in the spread of typhoid fever. The lack of adequate toilet facilities, combined with low hygiene literacy, often results in behaviours that facilitate pathogen transmission. Failing to wash hands after defecation or before food preparation introduces faecal bacteria into food and water, perpetuating the faecal–oral

cycle (Kim et al., 2022). In densely populated urban settlements, shared toilet facilities and improper waste disposal create further exposure risks.

Empirical studies have demonstrated a strong association between poor sanitation and an increased incidence of typhoid. For instance, a study in Nairobi's informal settlements revealed that households without access to improved toilets were 2.5 times more likely to experience typhoid infections than those with adequate sanitation (Amin et al., 2021). Similarly, in Kumasi, Ghana, poor food hygiene among street vendors was identified as a significant contributor to typhoid transmission, particularly in low-income neighbourhoods (Owusu-Dabo et al., 2020). These findings demonstrate that both household-level practices and broader environmental conditions collectively determine disease risk.

Linking Water, Sanitation, and Hygiene (WASH) to Typhoid Dynamics

The WASH framework provides a conceptual basis for understanding how improvements in water, sanitation, and hygiene can disrupt the transmission cycle of typhoid fever. According to the WHO-UNICEF Joint Monitoring Programme (2022), interventions that ensure access to safely managed drinking water, improved sanitation, and consistent handwashing with soap could reduce the global burden of typhoid and other enteric infections by more than 50%. The framework emphasizes that the benefits of water and sanitation interventions are maximized when combined with behavioural change strategies and public health education.

In Ejura/Sekyedumase Municipality, the dynamics of waterborne transmission are influenced by a combination of seasonal flooding, poor drainage infrastructure, and high population mobility. During rainy seasons, floodwaters often mix with open refuse dumps

and latrine waste, contaminating wells and surface water sources. These conditions create temporal spikes in typhoid incidence, as observed in similar Ghanaian municipalities (Owusu-Ansah et al., 2023). Addressing this requires integrated WASH interventions that not only improve infrastructure but also strengthen public health education and community participation in sanitation maintenance.

2.3 Theoretical Review

The theoretical review provides the conceptual frameworks that underpin the study of typhoid fever transmission dynamics. Several theories and models are relevant to understanding the factors influencing the spread of the disease, its control, and prevention strategies (Naserrudin et. al. 2022). This section will explore three key theoretical perspectives: the Germ Theory of Disease, the Waterborne Disease Theory, and the Health Belief Model (HBM).

2.3.1 Germ Theory of Disease

The Germ Theory of Disease, proposed by Louis Pasteur and Robert Koch in the 19th century, states that microorganisms are the causative agents of infectious diseases. This theory revolutionized medicine and public health by shifting the understanding of disease transmission from miasma (bad air) to specific pathogens.

In the context of typhoid fever, the Germ Theory explains how *Salmonella enterica serovar typhi* infects individuals via the faecal-oral route. Contaminated food and water act as vectors for bacterial transmission, leading to infection when ingested. The identification of *S. typhi* as the etiological agent of typhoid fever has led to the development of vaccines, antibiotic treatments, and public health interventions focused on improving hygiene and sanitation.

2.3.2 Waterborne Disease Theory

The Waterborne Disease Theory highlights the role of contaminated water sources in the spread of infectious diseases. First emphasized in the work of John Snow during the 1854 cholera outbreak in London, this theory remains relevant in explaining the transmission of typhoid, especially in regions with inadequate sanitation infrastructure.

Typhoid fever is a quintessential example of a waterborne disease, as outbreaks often correlate with the consumption of untreated water from contaminated sources. In Ghana, several studies have linked typhoid fever outbreaks to poor water quality and inadequate sanitation facilities. This theory underscores the significance of water treatment, proper sewage disposal, and hygiene education in preventing the transmission of diseases.

2.3.3 Health Belief Model (HBM)

The Health Belief Model, developed in the 1950s by social psychologists at the U.S. Public Health Service, is a psychological framework used to explain health-related behaviours. Applying the HBM to typhoid fever in Ejura/Sekyedumase Municipality can help design effective health interventions by addressing knowledge gaps and behavioural factors influencing disease prevention (Green et al., 2020). The model suggests that individuals' decisions regarding health interventions are influenced by: Perceived Susceptibility, which refers to the belief about the likelihood of contracting a specific disease or condition. Individuals who perceive themselves at high risk (e.g., those living in unsanitary conditions) are more likely to adopt preventive measures. Perceived Severity: The belief about the seriousness of typhoid fever and its consequences. Understanding the potential complications of untreated typhoid, such as intestinal perforation, increases the likelihood of seeking medical intervention. Perceived Benefits: The belief that actions such as

vaccination, boiling drinking water, and practising good hygiene can prevent typhoid infection. Perceived Barriers: The obstacles individuals face in adopting preventive measures, such as the cost of water treatment or limited access to healthcare. Cues to Action: External prompts, such as public health campaigns and community awareness programs, that motivate individuals to adopt preventive behaviours. Self-Efficacy: The confidence in one's ability to practice disease prevention, such as consistently maintaining hygiene and seeking medical care when needed (Green et al., 2020).

2.4 Empirical Review

The empirical review plays a critical role in understanding the epidemiology, transmission patterns, and control of typhoid fever across different contexts. It provides evidence-based insights into the biological, environmental, and socio-behavioural determinants that sustain the disease, particularly in low- and middle-income countries. This section critically reviews recent empirical studies that examine global and regional trends, prevalence and incidence patterns, risk factors, knowledge and awareness levels, seasonal variations, socio-cultural and behavioural determinants, interventions and control strategies, and the emerging challenge of multidrug-resistant typhoid fever (MDR-TF). Together, these studies provide a comprehensive understanding of the transmission dynamics of typhoid fever, offering a foundation for designing context-specific public health interventions.

Globally, empirical studies indicate that typhoid fever continues to impose a substantial burden on public health systems, particularly in parts of Asia and sub-Saharan Africa, where inadequate sanitation, unsafe water, and population growth intersect to create favourable conditions for disease persistence (Marks et al., 2023; Kariuki & Dougan, 2022). Although global initiatives, such as improved WASH (Water, Sanitation, and

Hygiene) interventions and the introduction of typhoid conjugate vaccines, have reduced the incidence in some areas, the disease remains endemic in many low-resource settings. In Ghana and comparable regions, empirical evidence indicates that despite advances in healthcare delivery, periodic outbreaks and seasonal surges persist, underscoring the ongoing structural and behavioural challenges (Adjei et al., 2021; Akinyemi et al., 2021).

Several studies have quantified the prevalence and incidence of typhoid fever using retrospective health records, cross-sectional surveys, and data analysis from surveillance systems. These investigations reveal marked spatial and temporal variations, often associated with urban overcrowding, inadequate waste management, and contaminated food sources. Others have identified key risk factors, such as unsafe water consumption, poor sanitation practices, and unhygienic street food vending, as major drivers of transmission (Rahman et al., 2022; Amankwah et al., 2020). At the household level, knowledge and awareness studies have demonstrated that misconceptions about typhoid transmission, overlapping symptoms with malaria, and reliance on self-medication contribute to delayed diagnosis and underreporting (Mensah et al., 2023).

Empirical analyses also highlight seasonal variations in disease incidence, particularly the correlation between rainfall patterns and an increase in typhoid cases during the wet season. Rain-induced flooding, contamination of water sources, and breakdown of sanitation systems facilitate the spread of *Salmonella typhi*, a finding consistently observed in Ghana, Kenya, and Bangladesh (Owusu-Ansah et al., 2023; Baker et al., 2021). These seasonal dynamics are intertwined with socio-cultural and behavioural factors, including traditional food preparation practices, communal eating during festivals, and gendered roles in water

collection and caregiving, all of which enhance exposure risk (Adongo et al., 2022; Dery et al., 2021).

In response, empirical studies have examined intervention and control strategies, ranging from community-based WASH initiatives and vaccination campaigns to predictive modelling and early-warning systems. Evidence shows that integrated approaches combining vaccination, improved sanitation, and behavioural change communication yield the most sustainable results (Marks et al., 2023; Kariuki &Dougan, 2022).
However, these gains are increasingly threatened by the emergence of multidrug-resistant (MDR) strains of *S. typhi*, which complicate treatment and heighten disease persistence (Stanaway et al., 2019).

Within this broader context, the current study situates itself by focusing on the transmission dynamics, demographic distribution, and seasonal trends of typhoid fever in Ejura/Sekyedumase Municipality, Ghana. By applying retrospective trend analysis and time-series forecasting models, the study contributes empirical evidence on how environmental, demographic, and temporal factors interact to influence typhoid transmission in an agrarian and rapidly urbanizing setting. This synthesis not only fills a research gap in localized epidemiological modelling but also informs policy and public health programming aimed at typhoid control in similar endemic areas.

2.4.1 Global and Regional Trends in Typhoid Fever

Typhoid fever remains a significant global public health concern, particularly in low- and middle-income countries (LMICs). *Salmonella enterica serovar typhi* causes the disease and is primarily transmitted through the ingestion of contaminated food or water.

Despite substantial advances in public health infrastructure, the burden of typhoid fever remains high, with millions of cases and thousands of deaths reported annually (Adesegun et al., 2020).This section provides a detailed overview of the global prevalence of typhoid fever, highlighting regional disparities, risk factors, and recent epidemiological trends.

According to the Global Burden of Disease (GBD) Study, an estimated 9 to 15 million cases of typhoid fever occur annually, resulting in approximately 110,000 to 160,000 deaths each year (WHO, 2021; GBD, 2019). The burden is disproportionately high in sub-Saharan Africa, South Asia, and parts of Southeast Asia, where inadequate sanitation, poor hygiene, and limited access to clean drinking water contribute to sustained transmission (Kim et al., 2022).

The World Health Organization (WHO) classifies typhoid fever as a primary enteric infection and has recommended widespread vaccination campaigns and improved water and sanitation as critical intervention strategies (Saha et al., 2019). WHO has also emphasized that multidrug-resistant (MDR) strains of *Salmonella typhi* pose a growing threat, particularly in endemic regions (Park, 2015).

South Asia: The Epicentre of Typhoid Fever

South Asia bears the highest burden of typhoid fever, accounting for approximately 70% of global cases. Countries such as India, Pakistan, Bangladesh, and Nepal report high incidence rates due to factors such as rapid urbanization with poor sanitation infrastructure, high population density, contaminated water supplies, and limited healthcare access in rural areas (Marchello et al., 2019).

A recent study estimated that India alone records over 6 million cases annually (GBD 2019). Pakistan, on the other hand, has faced multiple outbreaks of extensively drug-resistant (XDR) typhoid fever, particularly in Sindh Province, posing serious treatment challenges (Klemm et al., 2018).

Sub-Saharan Africa: Rising Incidence Rates

Typhoid fever is a growing concern in sub-Saharan Africa, particularly in densely populated urban areas with inadequate sanitation. Countries such as Nigeria, Ghana, Kenya, and the Democratic Republic of the Congo (DRC) report thousands of cases annually (Kim et al., 2022). A multi-country study conducted by the Typhoid Surveillance in Africa Program (TSAP) estimated that the incidence of typhoid fever in sub-Saharan Africa ranges from 100 to 500 cases per 100,000 population per year (Marks et al., 2017). Ghana, for instance, has seen an increase in cases, with hotspots in Accra, Kumasi, and Tamale, primarily attributed to contaminated water sources and poor waste disposal.

Southeast Asia: A Persistent Public Health Challenge

Countries such as Indonesia, the Philippines, Myanmar, and Vietnam continue to struggle with typhoid fever, though sustained vaccination efforts have led to some decline in cases (Kim et al., 2022). A study in Jakarta, Indonesia, estimated an incidence rate of 350 cases per 100,000 per year (Saha et al., 2019). Vietnam has implemented school-based vaccination programs, leading to a 50% reduction in cases over the past decade (WHO, 2021).

Latin America and the Caribbean: Declining but Still Present

Latin American countries have seen a significant decline in typhoid fever cases due to improved sanitation and widespread vaccination. However, Bolivia, Peru, Haiti, and Venezuela continue to experience outbreaks. The Andean region continues to report incidence rates of 30–60 cases per 100,000 people (GBD 2019).

The Middle East and North Africa (MENA): Moderate Prevalence with Periodic Outbreaks

Countries such as Egypt, Yemen, and Iraq report sporadic outbreaks of typhoid fever. Yemen, currently facing a severe humanitarian crisis, has seen a resurgence of typhoid and other waterborne diseases due to damaged sanitation infrastructure and limited healthcare services (WHO, 2022).

High-Income Countries: Rare but Possible

In developed nations such as the United States, Canada, the United Kingdom, and Australia, typhoid fever is rare and primarily affects travellers returning from endemic regions. The U.S. Centres for Disease Control and Prevention (CDC) reports approximately 300–500 cases annually, with 75% linked to international travel, particularly to South Asia (CDC, 2023).

2.4.2 Studies on Prevalence and Incidence of Typhoid Fever

Typhoid fever continues to pose a serious public health challenge in many low- and middle-income countries, including Ghana, where persistent environmental, infrastructural, and behavioural factors sustain transmission. Globally, it is estimated that between 9 and 15 million cases occur annually, resulting in approximately 110,000 to 160,000 deaths, with

the highest burden concentrated in South and Southeast Asia, sub-Saharan Africa, and parts of Latin America (WHO, 2023; Stanaway et al., 2019). These global figures mask substantial regional variations, with incidence rates in sub-Saharan Africa often exceeding 300 cases per 100,000 population due to inadequate water, sanitation, and hygiene (WASH) infrastructure and rapid urbanization (Kariuki & Dougan, 2022).

Empirical data from African surveillance systems demonstrate that typhoid fever remains endemic, exhibiting cyclical and seasonal fluctuations. A multi-country study by Marks et al. (2017) found that typhoid incidence was significantly higher during the rainy season, when contamination of water and food sources was at its peak. The authors emphasized that climate variability and unplanned urban settlements exacerbate the risk of infection, reinforcing the need for seasonally adaptive public health interventions.

In Ghana, the epidemiological landscape of typhoid fever mirrors these broader regional patterns. A retrospective analysis conducted in the Hohoe Municipality of the Volta Region between 2012 and 2016 reported 6,282 confirmed cases, with prevalence rising from 148 per 100,000 in 2012 to 943 per 100,000 by 2015 (Marks et al., 2017). The study revealed notable gender disparities; females accounted for 66.9% of all reported cases, and identified the 25–29-year age group as the most affected. The observed seasonal trend, with higher incidence during the wet months, highlighted the role of rainfall, flooding, and water contamination in disease propagation.

Similarly, a recent surveillance report from the Kadjebi District in the Oti Region indicated a continuous rise in typhoid fever cases over three years: 298 cases in 2021, 370 in 2022, and 672 in 2023, with the surge in 2023 partly linked to improved diagnostic testing and

health information reporting (Nielsen et al., 2012). This upward trajectory underscores both the persistent transmission of typhoid fever and the positive impact of enhanced disease surveillance on case detection.

At the national level, the Global Burden of Disease (GBD) Study estimated that Ghana recorded approximately 65,856 cases of typhoid fever and 1,150 related deaths in 2019, corresponding to an incidence rate of approximately 208 cases per 100,000 population (Marchello et al., 2019). These findings demonstrate that despite ongoing public health efforts, typhoid fever remains a primary endemic disease in Ghana, contributing significantly to morbidity and mortality, particularly among children and young adults.

The persistence of typhoid fever in Ghana can be attributed to structural and environmental vulnerabilities, including limited access to potable water, poor waste management, and the proliferation of informal food markets. Studies from other regions of the country reinforce these observations. For example, Adjei et al. (2021) found that typhoid cases were prevalent across both urban and rural districts, with urban slums exhibiting a higher incidence due to overcrowding and inadequate drainage systems. Similarly, Osei et al. (2022) identified hotspots in peri-urban farming communities, where irrigation with contaminated water sources contributed to recurrent outbreaks.

In the context of Ejura/Sekyedumase Municipality, the prevalence and incidence of typhoid fever are likely influenced by similar factors. The area's mixed urban-agricultural setting, characterized by periodic population inflows during farming seasons and limited sanitation infrastructure, creates conditions conducive to faecal–oral disease transmission.

Understanding the local prevalence trends through retrospective analysis is therefore crucial to guiding municipal public health planning and intervention.

2.4.3 Risk Factors Associated with Typhoid Fever

Typhoid fever is a waterborne and foodborne disease strongly linked to poor sanitation, contaminated water sources, and inadequate hygiene practices. Numerous studies have established the correlation between these factors and typhoid transmission, particularly in low- and middle-income countries (LMICs) where access to clean water and proper sanitation is limited (Kim et al., 2022; Marchello et al., 2019).

Water Contamination and Typhoid Fever

Contaminated drinking water is a primary mode of transmission for *Salmonella typhi*, the causative agent of typhoid fever. Studies have shown that populations relying on untreated or poorly treated water sources, such as rivers, wells, and open reservoirs, have higher infection rates (Ahmed et al., 2019). A study in Bangladesh found that households using piped water without chlorination had a 2.5 times higher risk of typhoid fever than those using properly treated water (Saha et al., 2019). Similarly, research in Kenya and Nigeria identified seasonal flooding as a major contributor to waterborne typhoid outbreaks (Marks et al., 2017).

Sanitation and Typhoid Prevalence

Poor sanitation, including open defecation, poorly managed sewage systems, and inadequate waste disposal, facilitates the spread of *S. typhi* in communities. Studies in India and Pakistan have demonstrated that areas with limited access to improved latrines have significantly higher typhoid incidence rates (Qamar et al., 2020). In Ghana, a study by

Agyei-Mensah and Aikins (2021) found that high-density urban slums with inadequate sanitation infrastructure recorded higher typhoid prevalence compared to well-planned residential areas.

Hygiene Practices and Disease Transmission

Hand hygiene plays a critical role in preventing typhoid fever. A study in Nepal found that individuals who did not wash their hands after using the toilet were three times more likely to contract typhoid than those who practised regular handwashing with soap (Baker et al., 2018). Similarly, research in sub-Saharan Africa has confirmed that poor food handling practices, such as consuming raw vegetables washed in contaminated water and eating street food prepared under unhygienic conditions, significantly contribute to typhoid outbreaks (Peters et al., 2021).

2.4.4 Knowledge and Awareness Levels

Knowledge and awareness of typhoid fever play a pivotal role in determining individual and community-level preventive practices, timely health-seeking behaviour, and overall disease control. Public understanding of the causes, symptoms, modes of transmission, and preventive measures directly influences adherence to hygiene practices and the utilization of healthcare services (Kim et al., 2022). Low awareness levels often translate into delayed diagnosis, self-medication, and continued environmental contamination, which perpetuate transmission cycles in endemic settings (Adesegun et al., 2020).

In Ghana, community awareness studies indicate similar trends. A study by Adjei et al. (2021), revealed that while most respondents had heard of typhoid fever, fewer than 40% could correctly identify its transmission pathways, and only 28% associated it with poor

sanitation or contaminated food. Misconceptions such as attributing typhoid to excessive sun exposure or fatigue were also prevalent. These knowledge gaps were more pronounced in rural areas, where literacy levels are lower and access to formal health education is limited.

Health education interventions have been undertaken in several districts to address these deficiencies. In the Kadjebi District of the Oti Region, public health officials-initiated community-based education campaigns between 2020 and 2023, emphasizing recognition of typhoid symptoms such as loss of appetite, abdominal pain, joint pain, diarrhoea, headaches, and rashes. These programs encouraged early reporting and diagnosis to reduce complications and mortality (Kim et al., 2022; Adesegun et al., 2020). Community information sessions, conducted through local radio broadcasts, durbars, and health outreach programs, have been reported to improve awareness and reporting rates, although sustainability and coverage remain uneven.

The level of community knowledge has implications for self-treatment and the misuse of antimicrobials. Studies in urban Ghana have reported that individuals who misidentify typhoid symptoms frequently resort to self-medication using antibiotics without proper laboratory confirmation, contributing to the growing threat of antimicrobial resistance (Kariuki & Dougan, 2022; Osei et al., 2022). Hence, public health education must not only raise awareness about the disease but also correct misconceptions about antibiotic use and encourage laboratory-based diagnosis.

2.4.5 Seasonal Variations and Prevalence of the Disease

The occurrence and intensity of typhoid fever exhibit distinct seasonal patterns, primarily driven by variations in climatic and environmental factors, including rainfall, temperature, and humidity. Several studies across endemic regions have consistently reported an increase in typhoid incidence during the rainy or monsoon seasons, when flooding and inadequate sanitation systems promote faecal contamination of water sources (Marchello et al., 2019; Zhang et al., 2016). These seasonal dynamics have significant implications for disease surveillance, forecasting, and control strategies, particularly in regions where waterborne transmission remains the dominant route of infection.

Global Evidence of Typhoid Seasonality

Globally, seasonality is a defining feature of typhoid epidemiology. In South Asia, where typhoid remains hyperendemic, several longitudinal and modelling studies have documented clear seasonal peaks coinciding with the monsoon period. For example, Dewan et al. (2013) observed that typhoid incidence in Dhaka, Bangladesh, rose sharply during the pre-monsoon and monsoon seasons (June–September), attributed to sewage infiltration into water supplies following heavy rainfall. Similarly, in India, Saha et al. (2019), found that typhoid cases peaked between June and September, corresponding to increased surface water contamination and the breakdown of urban drainage systems. In Nepal, the annual cycle of disease was closely linked to the onset of the monsoon, with flooding in the Kathmandu Valley often associated with the widespread contamination of shallow wells used for domestic consumption (Bahl et al., 2019). These studies collectively affirm that increased rainfall and high humidity create ecological conditions favorable for

the persistence and transmission of *S. typhi* in densely populated and poorly drained urban environments.

In Latin America, similar seasonal patterns have been documented. Galindo et al. (2020) reported that typhoid incidence in Peru and Bolivia surged during the wet season (December–March), coinciding with flooding that overwhelmed sanitation systems. In these regions, water storage in open containers during periods of intermittent supply provided additional breeding grounds for *S. typhi* and related enteric pathogens. The study further emphasized that water management behaviours, such as storing untreated water, significantly amplified the risk of household-level transmission.

Seasonal Dynamics in Sub-Saharan Africa

In Sub-Saharan Africa, where environmental sanitation challenges persist, rainfall and flooding have been identified as strong predictors of typhoid outbreaks. Research in Ghana, Nigeria, and Kenya demonstrates that peak typhoid incidence typically occurs during the rainy season (May–October) (Kariuki & Dougan, 2022; Marks et al., 2017). In Ghana, for example, Addo et al. (2020), found that typhoid fever cases in the Ashanti and Northern regions increased by more than 45% during periods of heavy rainfall, which corresponded with contamination of drinking water sources due to surface runoff and open defecation. In Kenya, Kariuki et al. (2021), reported similar findings, showing that rainfall intensity was positively correlated with typhoid incidence, particularly in peri-urban settlements lacking adequate drainage infrastructure.

In Nigeria, Nwakanma et al. (2022), observed that typhoid cases rose significantly during the wet months, with the highest incidence recorded between July and September. Their study highlighted the role of agricultural runoff, clogged drains, and the use of contaminated surface water in perpetuating transmission during this period. These findings underscore the ecological vulnerability of African municipalities, where rainfall not only exacerbates environmental contamination but also disrupts access to clean water, increasing dependence on unsafe sources.

Modelling and Predictive Evidence

A multi-country modelling study by Pitzer et al. (2014), provided quantitative evidence linking climatic variability to typhoid transmission dynamics. Using time-series data from 16 endemic regions, the study found that fluctuations in rainfall, temperature, and water storage practices explained a substantial proportion of the seasonal variability in typhoid incidence. Importantly, higher ambient temperatures were shown to prolong the environmental survival of *S. typhi*, while humidity favoured bacterial persistence in water and soil. The model also predicted that urban areas with intermittent water supply systems were particularly susceptible to seasonal spikes, reinforcing the role of infrastructure in modulating disease risk.

More recent applications of ARIMA and Seasonal-Trend Decomposition (STL) models in Africa and Asia have further validated these patterns. For instance, Rahman et al. (2022), demonstrated that rainfall, relative humidity, and temperature significantly predicted monthly typhoid case counts in Bangladesh. In contrast, Adebayo et al. (2023) applied ARIMA models to Nigerian surveillance data and found predictable seasonal peaks aligned

with the rainy season. These statistical models underscore the value of predictive analytics in public health planning, enabling early warnings and targeted interventions during high-risk periods.

Contextual Relevance to Ejura/Sekyedumase Municipality

In the context of Ejura/Sekyedumase Municipality, the pattern of seasonal typhoid prevalence closely mirrors observations from other tropical regions. The municipality experiences a bimodal rainfall pattern, with significant rains between April and July and minor rains between September and November. During these periods, flooding of open drains and contamination of wells and surface water are common, increasing exposure to *S. typhi*. Moreover, farming and food processing activities that dominate the local economy often intensify during the rainy season, heightening contact with contaminated water. These conditions contribute to periodic peaks in typhoid cases, as confirmed in retrospective data analyses from similar agro-ecological zones in Ghana (Owusu-Ansah et al., 2023).

Socio-cultural behaviours further compound this risk. Communal events, such as harvest celebrations, often involve the preparation of large quantities of food under poor hygienic conditions. Meanwhile, seasonal labour migration introduces temporary overcrowding in settlements with inadequate sanitation facilities. Thus, in Ejura/Sekyedumase, both environmental seasonality and human activity cycles act synergistically to sustain typhoid transmission.

2.4.6 Socio-Cultural and Behavioural Factors and Their Role in the Disease Spread

Socio-cultural factors significantly influence the transmission dynamics of typhoid fever, affecting behaviours, beliefs, and practices related to hygiene, sanitation, and healthcare-

seeking behaviour. These factors vary across communities and can either contribute to the persistence of typhoid fever or aid in its control. Understanding these elements is essential for developing targeted interventions that align with the cultural context of affected populations. Socio-cultural factors play a crucial role in the transmission dynamics of typhoid fever. Traditional beliefs, communal food practices, water use habits, migration patterns, gender norms, and health-seeking behaviours all contribute to the persistence of typhoid in specific communities. Understanding and addressing these factors through culturally appropriate interventions is essential for effective typhoid control and prevention strategies.

Sociocultural practices have a significant impact on typhoid transmission dynamics, particularly in regions with traditional beliefs and limited access to healthcare. Empirical studies confirm that seasonality plays a significant role in the prevalence of typhoid fever, with peaks during rainy seasons due to increased water contamination. Additionally, cultural and behavioural factors, such as food handling practices, religious gatherings, and the use of traditional medicine, contribute to the persistent transmission of typhoid in endemic areas. Listed are some of these factors and habits:

Traditional Beliefs and Perceptions of Disease Causation

In many communities, typhoid fever is often misattributed to supernatural causes, spiritual punishment, or curses rather than a bacterial infection caused by *Salmonella typhi*. This perception leads to reliance on traditional healers and herbal remedies rather than modern medical treatment, delaying proper diagnosis and increasing disease spread. In many communities, self-medication with herbal remedies delays appropriate treatment,

increasing the risk of severe infections and further transmission (Agyei-Mensah & Aikins, 2021).

In parts of West Africa, some individuals believe that typhoid fever results from "dirty blood," leading them to seek traditional herbal treatments instead of antibiotics, prolonging infection duration and enhancing community transmission (Akwah et al., 2021). A study in Ghana and Nigeria reported that some individuals avoid hospital treatment due to mistrust in Western medicine, which contributes to underreporting and the continued spread of disease (Osei et al., 2022).

Religious and Festive Gatherings:

Large religious gatherings, such as the Kumbh Mela in India and pilgrimages in Mecca, have been linked to typhoid outbreaks due to crowding, inadequate sanitation, and the sharing of food/water sources (Chiao et al., 2021). In many African and South Asian cultures, street food and communal eating practices increase the risk of exposure to contaminated food and water. A study in Pakistan found that unregulated street vendors and poor hygiene among food handlers contributed to persistent typhoid outbreaks (Qamar et al., 2020).

Similarly, in Ghana, shared eating habits as part of the religious festivities (E.g. Ramadan and Eid celebrations), coupled with poor food hygiene, contribute significantly to typhoid transmission. In many cultures, meals are prepared in large communal pots, and people eat with bare hands, often without washing them properly. If one infected individual handles food without proper hygiene, the bacteria can easily spread to others. Moreover, at social gatherings like funerals and festivals, food is often prepared in bulk and served to large

groups of people. If food handlers do not observe proper hygiene, there is an increased risk of foodborne transmission of typhoid fever (Tack et al., 2020).

Water Use and Sanitation Practices

In many communities, traditional practices influence water use, which can either mitigate or exacerbate the transmission of typhoid fever. The use of unprotected water sources, such as rivers and communal wells, increases the risk of contamination with *Salmonella typhi* (Chiao et al., 2021). In rural areas of Ghana, some communities believe that rainwater is "naturally pure" and use it for drinking without proper treatment. If rainwater is collected from contaminated surfaces or stored improperly, it can serve as a medium for typhoid infection (Ampofo et al., 2022).

Other cultural attitudes toward personal hygiene and handwashing vary across communities. In some areas, handwashing is not prioritized, or the practice is performed only on specific occasions, such as before prayer, but not necessarily before eating. Studies in northern Ghana have found that while handwashing is commonly practised before prayer in Islamic communities, it is not always done after using the toilet, which increases the risk of faecal-oral transmission of typhoid (Ali et al., 2021).

Seasonal Migration and Urbanization

Seasonal migration and urbanization have increasingly been recognized as important socio-environmental determinants influencing the transmission dynamics of typhoid fever. Migration patterns, particularly temporary or cyclical movements for agricultural or economic activities, create conditions conducive to disease transmission through population mobility, overcrowding, and inadequate sanitation infrastructure. According to

Kim et al. (2022), seasonal migrants often move from rural or peri-urban areas with limited access to clean water and healthcare services into urban centres where environmental sanitation challenges, overcrowding, and poor waste management exacerbate enteric infections, including typhoid fever.

Urbanization, when not accompanied by corresponding improvements in water and sanitation infrastructure, further amplifies the risk of enteric disease outbreaks. Rapid population growth in small and medium-sized towns in sub-Saharan Africa has strained water supply systems, resulting in intermittent access to potable water and a reliance on unsafe sources (Rahman et al., 2022; Aweke, 2019). Informal settlements, characterized by poor drainage and limited sanitation facilities, serve as hotspots for faecal contamination of food and water, sustaining endemic transmission. These challenges are compounded by seasonal migration for agricultural work, which results in temporary spikes in local population density during the planting and harvest seasons.

In the context of Ejura/Sekyedumase Municipality, seasonal agricultural migration is a defining socio-demographic feature. The municipality's fertile lands attract large numbers of temporary labourers during peak farming periods. These workers often reside in overcrowded, poorly serviced settlements lacking proper waste disposal and access to safe drinking water. Such conditions facilitate faecal–oral transmission of *Salmonella enterica serovar typhi*, especially where hygiene practices are inadequate, and food is prepared communally (Owusu-Ansah et al., 2023). Moreover, the transient nature of these populations limits access to health education, vaccination, and disease surveillance, resulting in delayed case detection and heightened transmission potential.

Empirical studies across Ghana and other African settings corroborate these findings. For instance, Abubakar et al. (2021) observed that rural–urban migration for farming and trade activities significantly increased exposure to typhoid infection in northern Nigeria, while Amankwah et al. (2020) linked agricultural labour migration in Ghana's forest–savannah transitional zone to seasonal enteric disease outbreaks. These findings highlight the interplay between population mobility, environmental sanitation, and access to the health system in sustaining endemic typhoid fever.

Overall, the phenomenon of seasonal migration and rapid urbanization in Ejura/Sekyedumase contributes to the spatiotemporal clustering of typhoid fever cases, particularly during rainy and harvest seasons. Addressing these structural drivers requires integrated interventions that link agricultural planning, urban governance, and public health systems - ensuring that mobile and informal populations have equitable access to safe water, sanitation, and health services.

Gender Roles and Health-Seeking Behaviour

Gender roles and health-seeking behaviour are key socio-cultural determinants influencing the transmission and management of typhoid fever, particularly in low- and middle-income settings where traditional gender norms persist. These roles shape both the risk of exposure to infection and the likelihood of timely diagnosis and treatment. According to Baker et al. (2018), gendered divisions of labour often position women at the frontline of domestic and caregiving responsibilities, such as water collection, food preparation, and child care, activities that increase their contact with potentially contaminated sources of water and

food. Consequently, women are disproportionately exposed to faecal–oral pathogens like *Salmonella enterica serovar typhi.*

However, exposure risk is compounded by limited autonomy in decision-making. In many African societies, including Ghana, women's health-seeking behaviour is mediated by male control over household resources and medical decisions (Dery et al., 2021). This patriarchal structure means that even when women recognize illness symptoms, including fever and gastrointestinal distress consistent with typhoid, they may require permission or financial support from their husbands before seeking medical care. Such gender-based dependency often delays healthcare access, increasing disease severity and the potential for intra-household transmission (Mensah et al., 2023).

Conversely, men, who typically control household finances, face their own behavioural barriers to health-seeking. Cultural expectations of male strength and stoicism may discourage men from seeking timely medical attention for themselves or their dependents, especially when symptoms appear mild (Adongo et al., 2022). Additionally, the economic pressures faced by male breadwinners can lead to the prioritization of income-generating activities over healthcare expenditures, resulting in delayed diagnosis and treatment (Ali et al., 2021). This dynamic not only prolongs individual illness but also sustains community transmission, particularly in settings where untreated or partially treated cases contribute to environmental contamination through poor sanitation.

In the Ghanaian context, these gendered disparities are particularly evident in rural and peri-urban areas such as Ejura/Sekyedumase Municipality, where household labour is strongly gendered. Women are primarily responsible for managing domestic chores,

preparing food, and collecting water from wells, boreholes, or streams, activities that heighten their risk of exposure to *S. typhi* in the absence of adequate sanitation infrastructure. Men, on the other hand, are engaged in farming and market trade, which also exposes them to unsafe water used for irrigation or food washing. However, women's limited autonomy in healthcare decision-making often means that illnesses in children or themselves progress to severe stages before care is sought.

Empirical evidence supports this pattern. A study by Amponsah and Dako-Gyeke (2020), found that among rural Ghanaian women, socio-cultural barriers, including financial dependency and limited mobility, significantly delayed health-seeking for febrile illnesses. Similarly, Akumiah et al. (2021) observed that in the Ashanti Region, male-dominated household structures and income constraints were associated with delayed presentation of typhoid cases at health facilities. These findings emphasize that gender is not only a biological category but a social determinant of health, shaping exposure, vulnerability, and access to care.

Addressing gendered disparities in health-seeking behaviour requires integrating gender-sensitive approaches into public health planning. Community-based health education campaigns should target both men and women, promoting shared responsibility for household sanitation and prompt medical consultation. Moreover, empowering women through education, income-generating opportunities, and access to micro-health insurance can reduce their dependency and improve health outcomes. In the context of typhoid fever control, such interventions are critical for breaking the cycle of delayed treatment and environmental contamination.

2.4.7 Interventions and Control Strategies of Typhoid Fever

A multi-pronged approach combining sanitation improvements, hygiene promotion, vaccination, and community engagement has been essential for controlling typhoid fever (Saha et al., 2019). While vaccination campaigns have proven highly effective over the years, limited access to sanitation facilities and behaviour change challenges continue to hinder the effectiveness of WASH programs, particularly in low-income and high-density urban settings (Kim et al., 2019). This will demand a long-term investment in water and sanitation infrastructure, which remains a critical achievement to sustain disease reduction in endemic regions.

Effectiveness of Sanitation and Hygiene Programmes

Improving sanitation, water quality, and hygiene (WASH) practices is a crucial strategy for controlling and preventing typhoid fever. Numerous studies have demonstrated that access to clean drinking water, improved sanitation infrastructure, and hygiene education significantly reduce the incidence of typhoid. In water treatment and supply: Chlorination, filtration, and the provision of safe piped water have been linked to a 30–60% reduction in typhoid cases in endemic regions (Marks et al., 2017). Sanitation Infrastructure, as part of the WASH program, contributes to the elimination of open defecation. The construction of improved latrines has also contributed to a decline in typhoid transmission in countries like India and Bangladesh (Baker et al., 2018). Regarding handwashing and sanitation, studies in Nepal and Kenya have found that handwashing with soap after using the toilet reduces the risk of typhoid by 35–50% (Pitzer et al., 2014).

Impact of Vaccination Campaigns and Community-Based Interventions

Typhoid conjugate vaccines (TCVs) have emerged as a highly effective tool for preventing typhoid fever, particularly in endemic regions. Studies show that mass vaccination campaigns, combined with community-based interventions, significantly lower the disease burden(Saha et al., 2019).

Effectiveness of Vaccination:

WHO recommends TCVs for routine immunization in typhoid-endemic areas, as they provide long-term immunity (WHO, 2021). A large-scale study in Pakistan found that TCVs reduced typhoid cases by 82% over a two-year period (Qamar et al., 2020). In Malawi, school-based TCV campaigns led to a substantial decline in pediatric typhoid cases (Meiring et al., 2022).

Community-Based Interventions:

Health education programs that promote safe food handling, proper waste disposal, and early medical care have been successful in reducing typhoid outbreaks (Dewan et al., 2013). Integrated approaches that combine vaccination with WASH initiatives are more cost-effective and sustainable in endemic regions (Antillón et al., 2017).

2.4.8 Multidrug-Resistant Typhoid: A Growing Global Threat

One of the significant challenges in managing typhoid fever is the emergence of multidrug-resistant (MDR) and extensively drug-resistant (XDR) strains of *Salmonella typhi*. MDR Typhoid (resistant to first-line antibiotics such as ampicillin, chloramphenicol, and trimethoprim-sulfamethoxazole) has been widely reported in South Asia and parts of Africa(Park, 2015). XDR Typhoid (resistant to multiple classes of antibiotics, including fluoroquinolones and third-generation cephalosporins) has been identified in Pakistan,

leading to large-scale outbreaks (Klemm et al., 2018).The emergence of drug-resistant typhoid underscores the urgent need for new treatment strategies and expanded vaccination programs in endemic regions(Park, 2015).

Efforts to Control Typhoid Fever Worldwide

The fight against typhoid fever involves multiple strategies, including vaccination programs. The WHO recommends typhoid conjugate vaccines (TCVs), which provide long-term immunity and are being rolled out in high-burden countries. Water, Sanitation, and Hygiene (WASH) Interventions – Improving access to clean drinking water and sanitation infrastructure is crucial. Surveillance and Early Diagnosis – Strengthening disease monitoring systems to detect and contain outbreaks early. Antimicrobial Stewardship – Restricting the overuse of antibiotics to prevent the development of further resistance (Saha et al., 2019; Park, 2015).

2.5 Summary of Literature Review

Despite extensive research on typhoid fever transmission, prevalence, and control strategies, several gaps remain:

Limited Localized Studies: While global and regional studies exist, there is a lack of comprehensive data on typhoid fever specific to the Ejura/Sekyedumase Municipality, particularly regarding seasonality, sociocultural factors, and risk determinants.

Sociocultural Influences Underexplored: Most studies focus on biomedical and environmental factors, with insufficient exploration of sociocultural practices, such as the use of traditional medicine, food handling behaviours, and hygiene perceptions, which may influence disease spread.

Gaps in Awareness and Prevention Strategies: The existing literature indicates low levels of public awareness about typhoid prevention in endemic areas; however, there are limited evaluations of knowledge gaps and their implications for community-based interventions.

Limited Studies on Long-Term Trends: Although seasonal variations are acknowledged, few retrospective analyses have examined long-term incidence trends, making it challenging to assess the changing patterns of transmission and the effectiveness of interventions over time.

Given these gaps, this study is justified in expanding the existing body of knowledge on typhoid fever by providing empirical data on long-term trends of typhoid prevalence in Ejura/Sekyedumase, which can be compared with national and global patterns. This will also help in bridging the gap between epidemiological data and intervention strategies, facilitating community engagement, policy development, and targeted public health campaigns. Moreover, this will also lead to enhancing future research directions by identifying critical areas for further study, such as the effects of climate change, antibiotic resistance patterns, and the effectiveness of integrated intervention programs.

2.6 Conceptual Framework

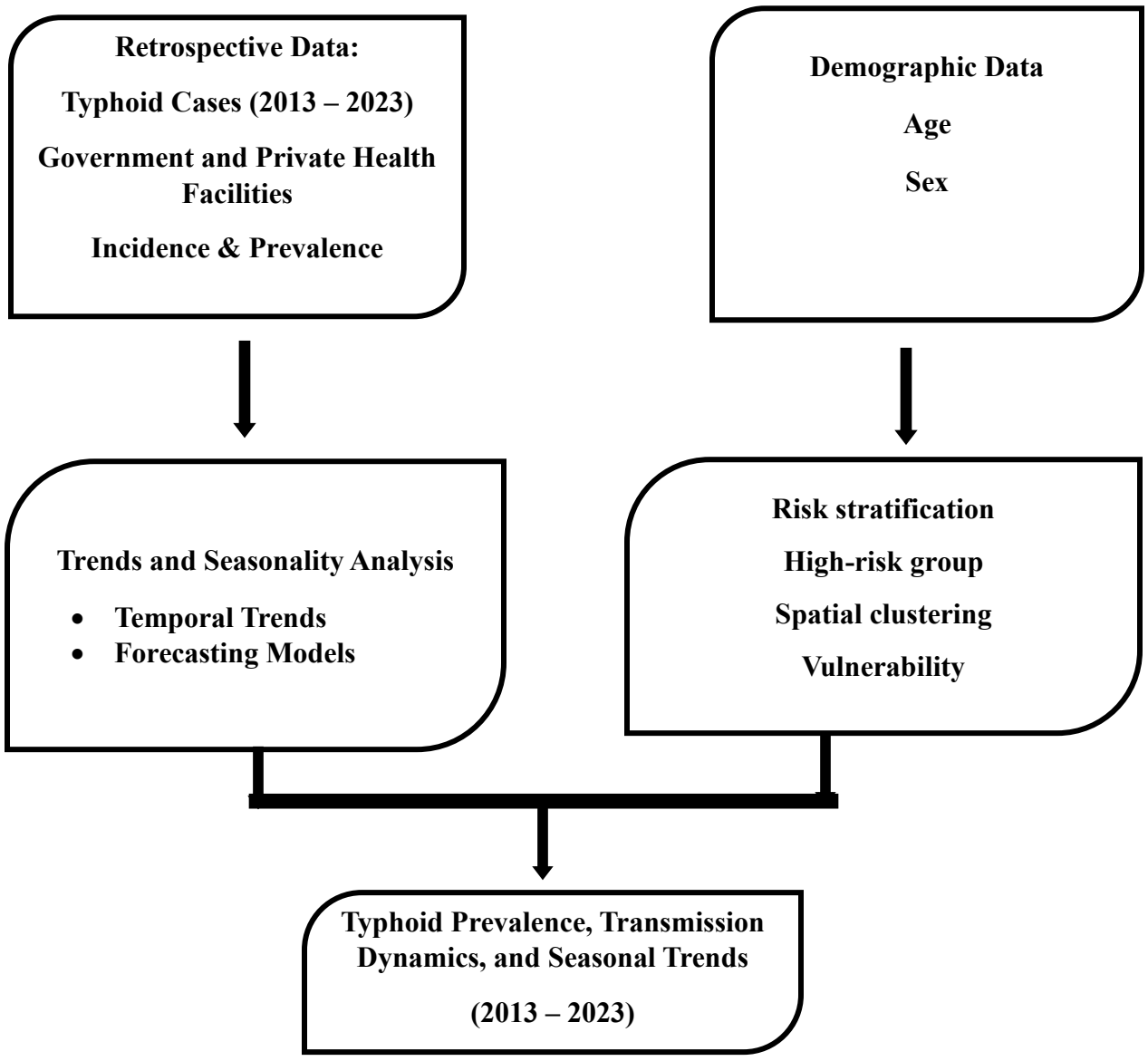

Figure 2.1 Author's construct: a conceptual framework based on the germ theory, the waterborne disease theory, and the health belief model.

CHAPTER THREE

METHODOLOGY

3.1 Study Design

This study employed a cross-sectional design to analyze trends and risk factors regarding typhoid fever in Ejura/Sekyedumase Municipality over a decade (2013–2023).

3.2 Study Area

The Ejura/Sekyedumase Municipality is situated in the northern part of Ghana's Ashanti Region, covering an area of approximately 1,252 square kilometres. Established in 1988 and elevated to municipal status in 2012, it shares borders with the Atebubu-Amantin District to the northwest, Mampong Municipality to the east, Sekyere South District to the south, and Offinso Municipal Assembly to the west. The municipal capital, Ejura, is located about 106 kilometres from Kumasi, the regional capital. The Ejura/Sekyedumase Municipality's demographic profile, economic activities, and socio-cultural dynamics present a unique environment for investigating the prevalence and transmission of typhoid fever.

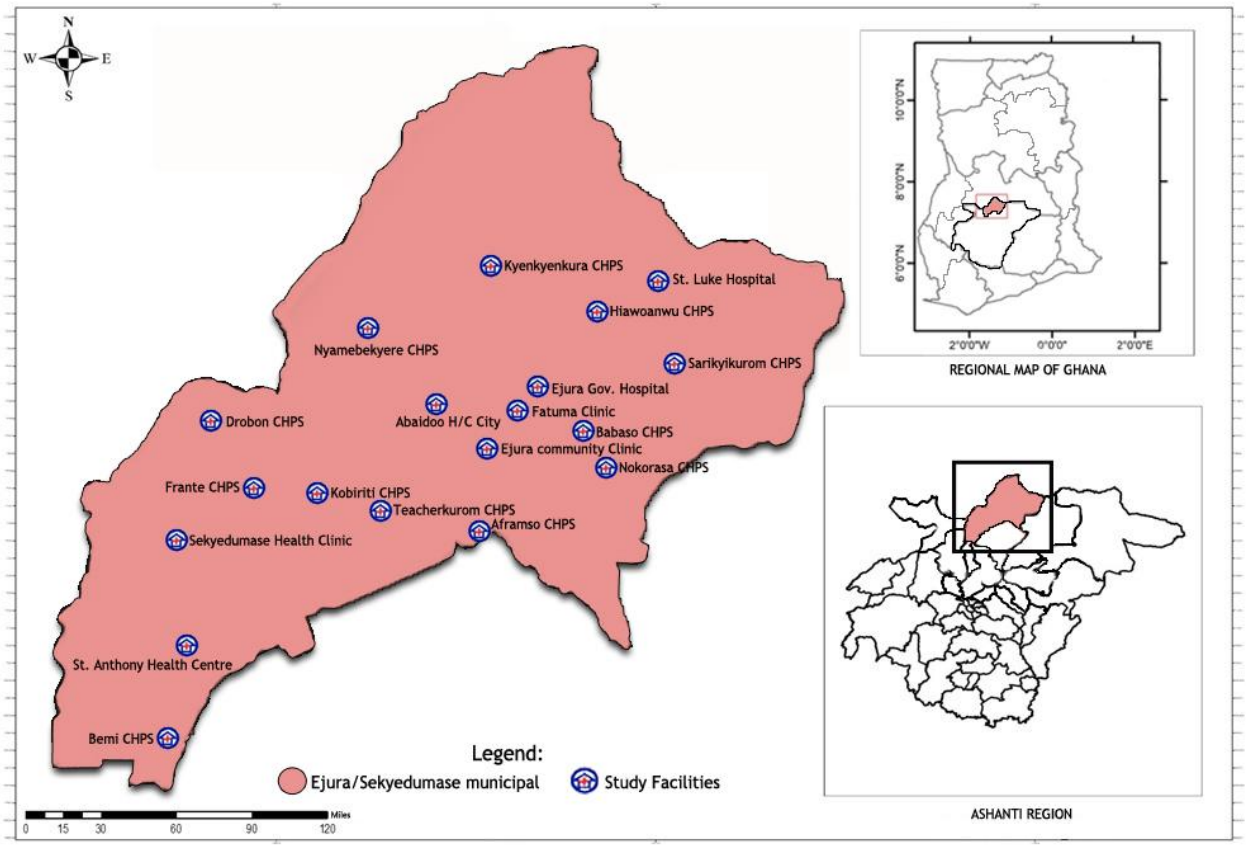

Figure 3.1. An area map of the Ejura-Sekyedumase Municipality showing the study area.

3.2.1 Demographics and Economy

As of the 2021 census, the municipality has a population of approximately 137,672 residents. The area is predominantly agrarian, earning the moniker "Food Basket of the Ashanti Region." It is renowned as the largest maize-producing district in the region, with agriculture serving as the primary source of livelihood for the majority of its inhabitants. Key agricultural activities include the cultivation of maize, yams, and other staple crops, supported by initiatives such as the "Planting for Food and Jobs Programme."

3.2.2 Agricultural Practices

The reliance on agriculture involves extensive interaction with water sources for irrigation and domestic use. Inadequate water management and sanitation facilities can lead to contamination, thereby increasing the risk of waterborne diseases, such as typhoid fever.

3.2.3 Population Density and Mobility

The municipality's significant population, coupled with its role as a hub for agricultural trade, results in high human mobility. This movement can facilitate the spread of infectious diseases, including typhoid fever, especially in areas with limited healthcare infrastructure.

3.2.4 Socio-cultural Factors

Traditional and religious practices, such as communal eating during festivals like the Sekyerene yam celebration, Christmas, and Ramadan observance, may influence hygiene behaviours. Understanding these socio-cultural practices is crucial for designing effective public health interventions that are tailored to the community's specific context.

3.2.5 Healthcare Infrastructure

Assessing the existing healthcare facilities and their capacity to diagnose and manage typhoid cases is crucial. Identifying gaps in healthcare delivery can inform strategies to enhance disease surveillance and treatment.

3.3 Study Population

The study population consisted of individuals diagnosed with typhoid fever during the study period, as recorded in health facility databases. A stratified sampling technique was used to ensure diverse demographic representation. Additionally, a representative sample of residents was surveyed to assess risk factors and knowledge levels.

3.4 Data Source and Processing

Retrospective Data: Health facility records from hospitals, clinics, and public health offices were reviewed to determine trends in prevalence.

3.5 Inclusion and Exclusion Criteria

The study encompassed all individuals from the government hospital in the municipality who had either *Salmonella typhi* or *Salmonella paratyphi* isolated from their blood or stool samples, spanning from January 2013 to December 2023. Individuals who did not visit the local government hospital within the specified period, or visited but did not receive treatment for typhoid or paratyphoid fever, were not included in the study. Individuals who were suspected of having typhoid fever but did not receive laboratory confirmation were also excluded.

3.6 Data Analysis

The study analyzed secondary data from patients who reported to the local government hospital within the specified period, specifically within the Ejura/Sekyedumase Municipality, for care during the study period (January 2013 to December 2023). By applying a mix of descriptive, inferential, and time series analyses, this study assessed the prevalence, risk factors, knowledge levels, and seasonal variations in typhoid fever incidence.

The analytical approach for this study was structured to align with the specific objectives and research questions. Both descriptive and inferential statistical methods were applied to secondary surveillance data, supported by time-series modelling to capture seasonal patterns and forecast future incidence. The methodological steps for each objective are outlined below.

3.6.1 For specific objective 1

To determine the socio-demographic patterns of typhoid fever incidence in relation to age and gender.

Hospital morbidity and surveillance data were disaggregated by age group (children under 10 years, adolescents 10–19 years, and adults ≥20 years) and gender. The data were cleaned to remove duplicates and incomplete demographic records. Descriptive analyses were performed to summarize the frequency and proportion of cases within each demographic group. Age-specific incidence rates per 1,000 population were calculated using denominators from the Ghana Statistical Service population estimates for the Ejura/Sekyedumase Municipality. Chi-square tests were applied to determine statistically significant differences in case distribution between gender groups, while patterns across age categories were interpreted in the context of exposure risks.

3.6.2 For specific objective 2

To assess the influence of seasonal climatic variations on the incidence of typhoid fever.

Monthly typhoid fever case data from 2013 to 2023 were retrieved from the Ejura/Sekyedumase Municipal Health Directorate. Corresponding rainfall and climatic data were obtained from the Ghana Meteorological Agency. To establish whether the time-series data were stationary, the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test were applied. Since the raw data were non-stationary (ADF p-value> 0.05; KPSS p-value< 0.05), first-order differencing was performed.

The Seasonal-Trend decomposition using Loess (STL) method was employed to separate the long-term trend, seasonal patterns, and residual fluctuations in the incidence of typhoid fever. Seasonal ARIMA models were then fitted to the differenced series to identify the contribution of seasonality to disease transmission. Finally, correlations between monthly rainfall patterns and typhoid incidence were examined to establish the extent to which seasonal climatic variations influenced disease occurrence.

3.6.3 For specific objective 3

To evaluate the utility of statistical forecasting models (ARIMA, ETS, Prophet) in predicting typhoid fever trends.

Monthly typhoid case data were modelled using three approaches: Autoregressive Integrated Moving Average (ARIMA), Error-Trend-Seasonal (ETS) models, and Prophet forecasting. For ARIMA, model selection was guided by the auto. The arima() function in R optimizes the autoregressive, differencing, and moving average parameters, including seasonal components. ETS models were fitted to account for exponential trends and error smoothing, while Prophet was used to capture multiple seasonalities and nonlinear variations in incidence.

Model diagnostics included residual analysis using the Ljung–Box Q test to confirm the absence of autocorrelation, as well as a comparison of Akaike Information Criterion (AIC), corrected AIC (AICc), and Bayesian Information Criterion (BIC) values to assess model fit. Forecast accuracy was evaluated using Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE). Out-of-sample forecasts were generated for 2024–2027, and the models were compared to determine the most parsimonious and reliable predictor of typhoid fever incidence.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the results of the study on the transmission dynamics of typhoid fever in the Ejura/Sekyedumase Municipality of the Ashanti Region, based on retrospective health records and time-series analyses from 2013 to 2023. The findings are organized in line with the study objectives, focusing on the prevalence patterns, demographic distributions, risk factors, and temporal dynamics of typhoid fever within the municipality.

The results reveal that a complex interaction of demographic, environmental, and socio-cultural factors influence the transmission of typhoid fever in Ejura/Sekyedumase. Variations by age and gender highlight specific vulnerability groups, while spatial and seasonal trends underscore the influence of rainfall patterns, sanitation infrastructure, and community practices on disease prevalence. The analysis also confirms that seasonality plays a central role, with distinct peaks corresponding to the major rainy seasons, a pattern typical of waterborne and faecal-oral diseases. Using time-series modelling techniques such as Seasonal-Trend Decomposition (STL) and Autoregressive Integrated Moving Average (ARIMA), the study further explores the temporal behaviour of typhoid incidence over the 10 years. These projections provide valuable evidence for integrating data-driven predictive surveillance into local health planning and response strategies. The subsequent sections present the detailed findings, beginning with the demographic characteristics of reported cases, followed by analyses of temporal trends, seasonal effects, and model forecasts, all aimed at deepening understanding of typhoid transmission dynamics in the Ejura/Sekyedumase Municipality.

4.1 Distribution of Typhoid Cases by Age and Sex Groups (2013–2023)

The results indicate variations in typhoid incidence across age and sex groups in the Ejura/Sekyedumase Municipality.

Table 4.1: Distribution of Typhoid Fever Cases by Sex, Ejura/Sekyedumase Municipality (2013–2023)

Sex	Total Cases (n)	Percentage (%)
Female	18,335	56.7
Male	13,941	43.1
Unknown	49	0.2%
Total	**32,276***	**99.8**

Chi-square Statistic (χ^2): 598.19 **df:** 1 **p-value:**< 0.001

Source: Field Data, 2024

Note: 49 cases (0.2%) with unspecified sex were excluded from the statistical test.

The gender distribution of typhoid fever cases shows a statistically significant difference ($p < 0.001$), with females (56.7%) being more affected than males (43.1%).

Table 4.2: Distribution of Typhoid Fever Cases by Age Group, Ejura/Sekyedumase Municipality (2013–2023).

Age Group	Total Cases	Percentage (%)
5–9	2,183	6.8%
10–14	1,959	6.1%
15–19	2,630	8.1%
20+	25,553	79.1%
Total	32,325	100.0

Chi-square Statistic (χ^2): 50,394.37 **df:** 3 **p-value:**< 0.001

Source: Field Data, 2024

The age group distribution differs significantly from what would be expected under a uniform pattern ($p < 0.001$). Adults aged 20 years and above accounted for nearly four-fifths of all typhoid fever cases, showing a strong age-related concentration of disease burden.

4.3 Monthly Typhoid Fever Cases (2013–2023)

Figure 4.1illustrates the monthly case distribution, which exhibits recurrent peaks associated with a seasonal pattern. Case spikes coincided with rainy seasons, which are linked to flooding and water contamination, and these factors significantly drive enteric infections.

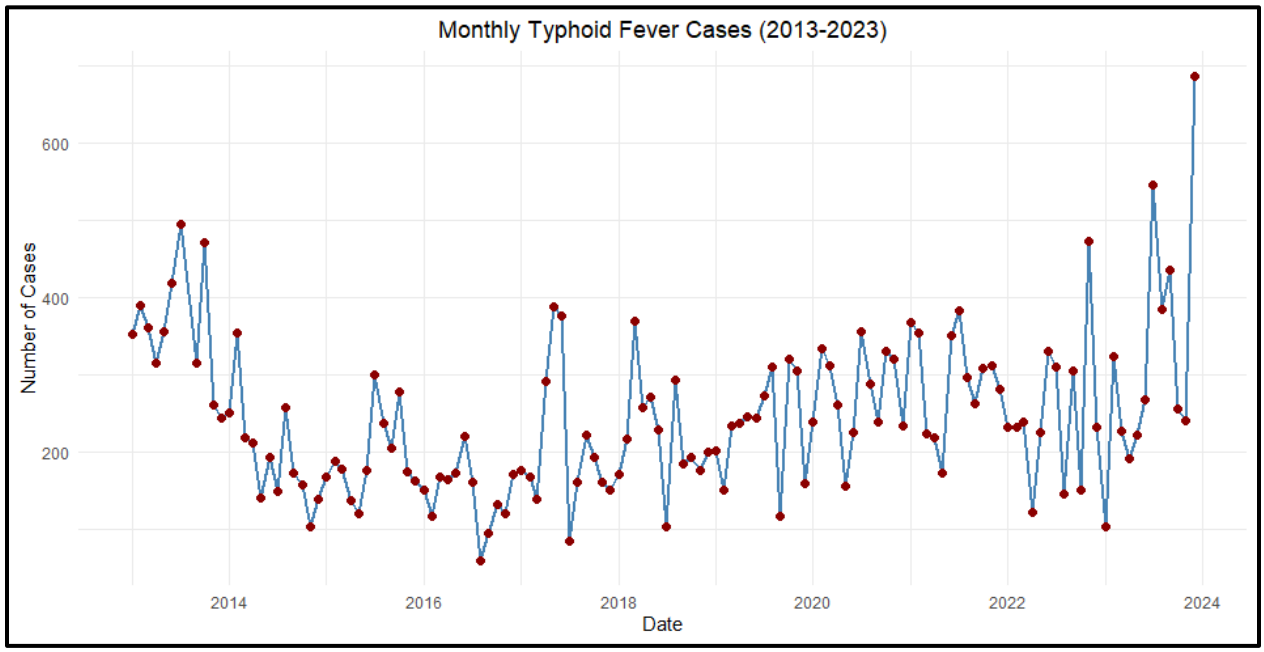

Figure 4.1: Monthly typhoid fever cases (2013-2023)

Source: Field Data, 2024

4.4 Total Typhoid Cases by Year

The annual trend showed that reported typhoid fever cases varied across years, with certain years experiencing sharp increases, suggesting possible outbreak periods. These peaks may correlate with periods of poor water supply, sanitation challenges, or outbreaks linked to food contamination. The fluctuations further suggest that typhoid remains endemic, with periodic intensification influenced by both environmental and infrastructural vulnerabilities.

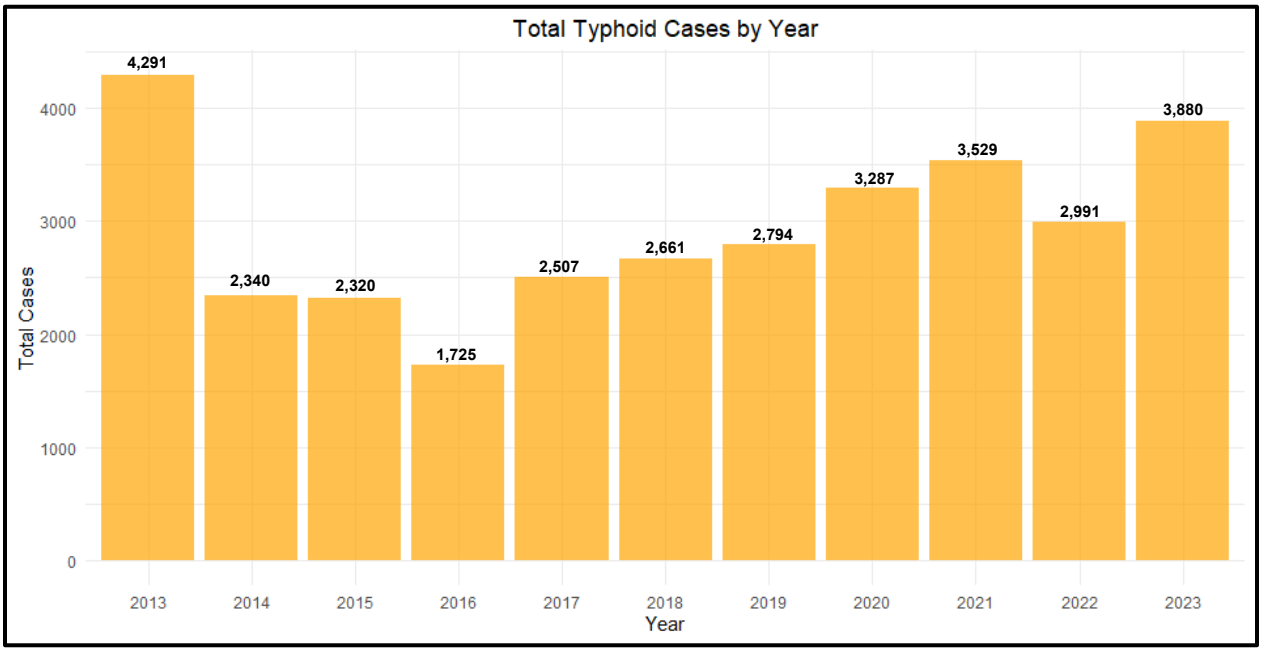

Figure 4.2: Total typhoid cases by year

Source: Field Data, 2024

4.5 Seasonal Distribution of Typhoid Cases

A seasonal effect was observed in the distribution of typhoid fever cases. Figure 4.3 shows that July and June recorded the highest average typhoid cases, with 9.76% and 9.37%, respectively. However, there was a sharp decline in January and April, representing 7.45% and 7.43%, respectively. These seasonal variations confirmed a strong seasonal influence on typhoid incidence. Higher case counts during rainy seasons may result from

contamination of water supplies and reduced access to safe sanitation. The rainy season consistently recorded a higher incidence compared to the dry season.

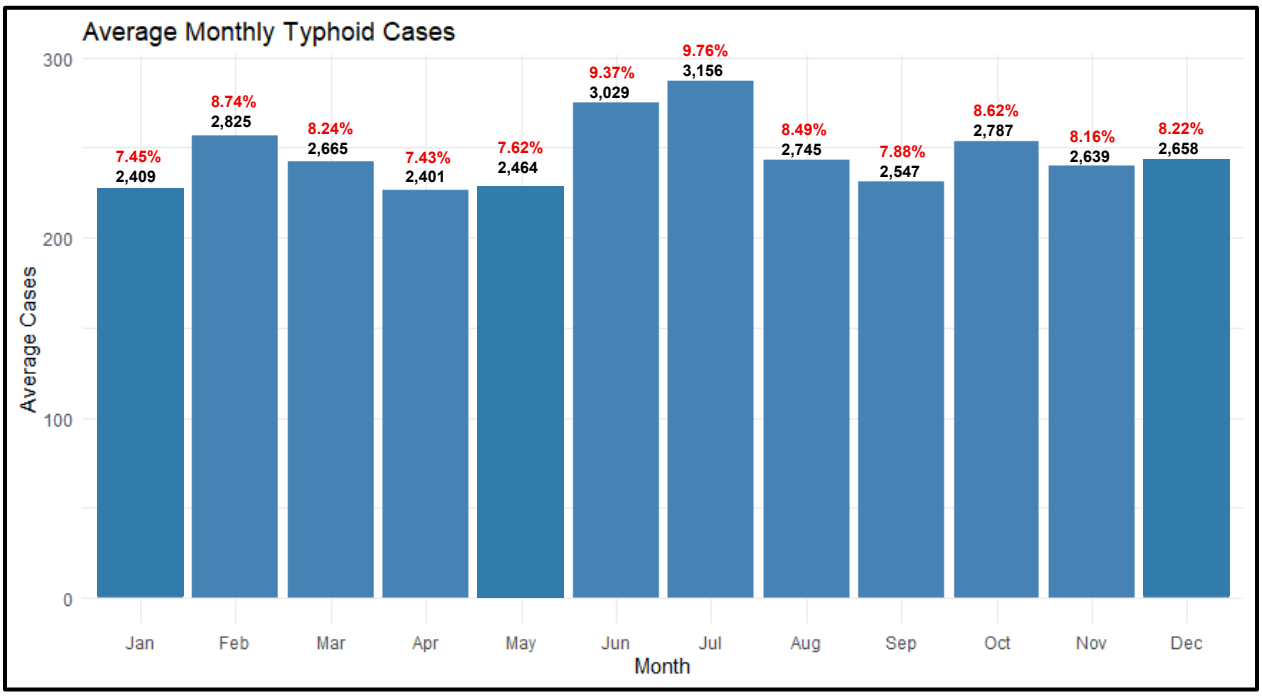

Figure 4.3: Average monthly typhoid cases

Source: Field Data, 2024

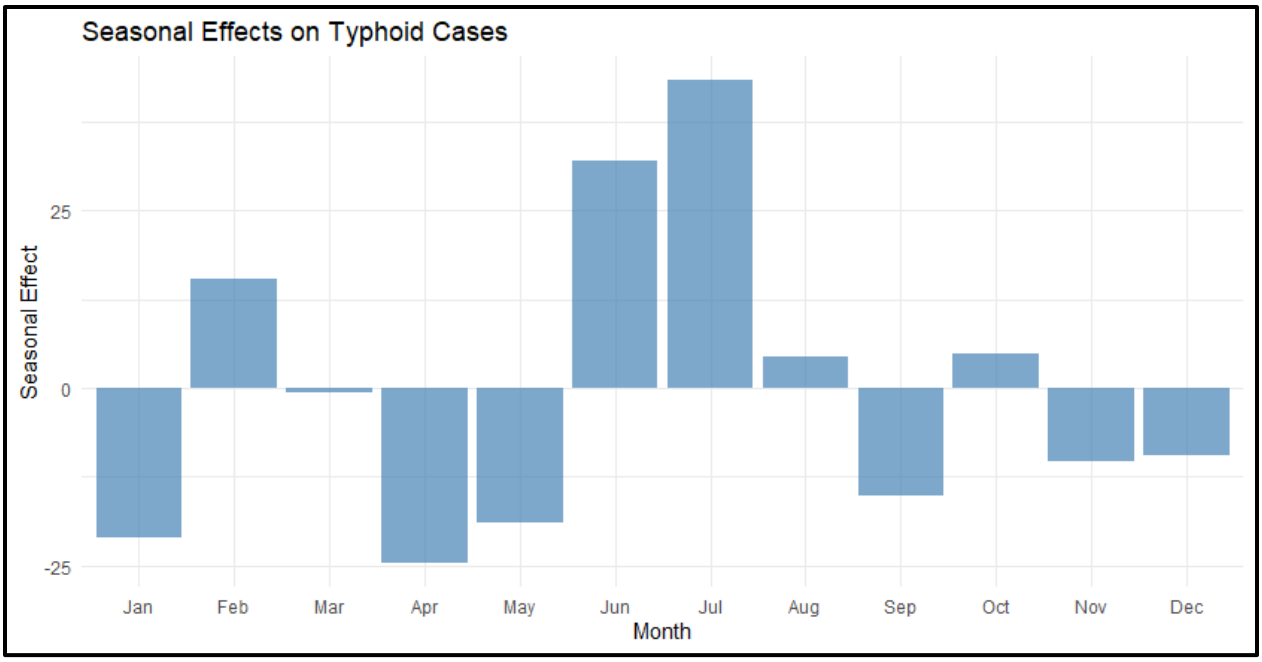

Figure 4.4: Seasonal effects on typhoid cases

Source: Field Data, 2024

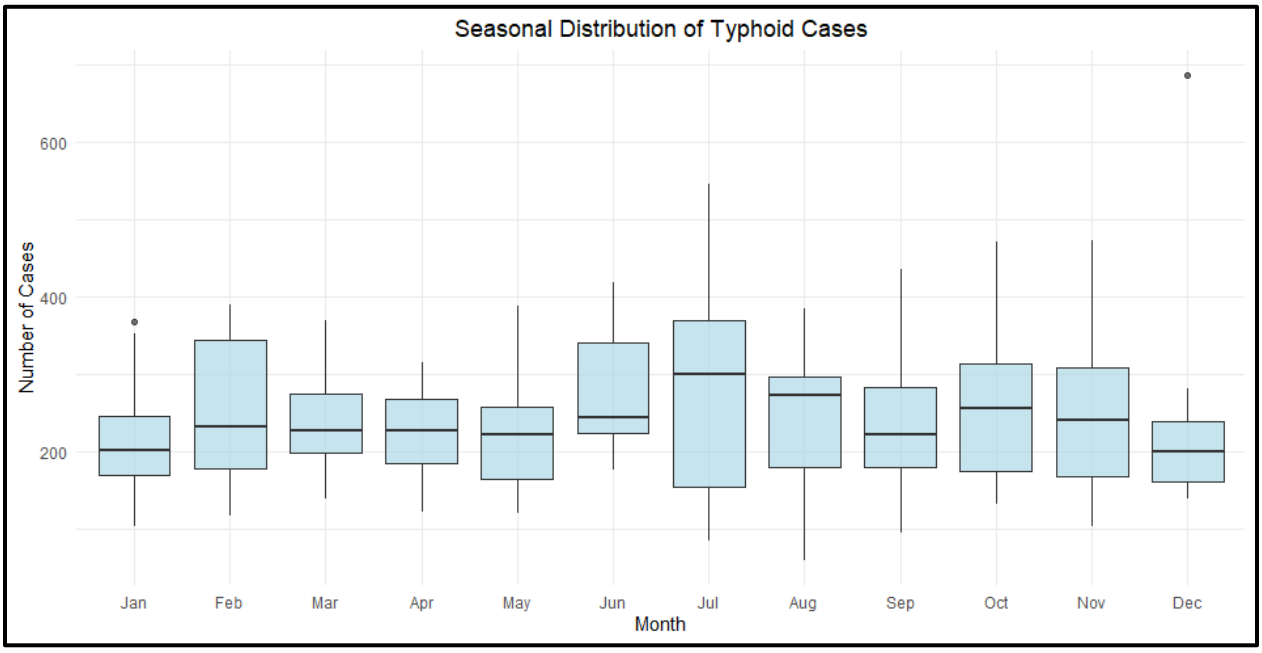

Figure 4.5: Seasonal distribution of typhoid cases

Source: Field Data, 2024

4.6 Time-Series Stationarity and Model Fitting

To assess the suitability of the time-series data for ARIMA modelling, both the Augmented Dickey-Fuller (ADF) test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test were conducted. The ADF test yielded a p-value of 0.207, failing to reject the null hypothesis of a unit root. In contrast, the KPSS test produced a p-value of 0.039, rejecting the null hypothesis of stationarity. Together, these results indicated that the series was non-stationary, necessitating first differencing before further analysis.

Two seasonal ARIMA models were then fitted to the differenced series:

1. **ARIMA (0,1,1)(1,0,0)[12]**
    - Coefficients: MA(1) = -0.82 (SE = 0.07), SAR(1) = 0.18 (SE = 0.11)
    - Model fit: log-likelihood = -779.13, AIC = 1564.26, BIC = 1572.89
    - Residual diagnostics: Ljung–Box Q(24) = 19.16, p = 0.635, indicating no significant autocorrelation in the residuals.
    - Forecast accuracy: RMSE = 91.77, MAE = 69.34, MAPE = 31.4%.

2. **ARIMA (1,1,1)(1,1,1)[12]**
    - Coefficients: AR(1) = 0.08 (SE = 0.12), MA(1) = -0.85 (SE = 0.07), SAR(1) = 0.12 (SE = 0.20), SMA(1) = -0.67 (SE = 0.19)
    - Model fit: log-likelihood = -720.86, AIC = 1451.72, BIC = 1465.62
    - Forecast accuracy: RMSE = 95.51, MAE = 69.07, MAPE = 32.2%.

Comparatively, the ARIMA (1,1,1)(1,1,1)[12] model provided a better fit than the simpler ARIMA (0,1,1)(1,0,0)[12], as indicated by its lower AIC (1451.72 vs. 1564.26) despite slightly higher RMSE values. Residual diagnostics for both models showed no significant autocorrelation, confirming that the models adequately captured the data structure.

The analysis suggests that typhoid fever incidence in Ejura/Sekyedumase exhibits both short-term dependencies (autoregressive and moving average components) and strong seasonal patterns. The ARIMA (1,1,1)(1,1,1)[12] model, which accounts for both seasonal autoregression and moving averages, was retained as the most parsimonious and statistically adequate model for forecasting.

4.7 STL Decomposition of Typhoid Data

The decomposition of the time-series data revealed three distinct components: a trend indicating gradual long-term changes, a seasonal component showing recurrent peaks, and residual fluctuations accounting for irregular variations. STL decomposition isolated the trend, seasonality, and residuals, confirming the seasonal pattern of typhoid. The ARIMA (0,1,1)(1,0,0)[12] model showed a good fit (AIC = 1564.26; $p > 0.63$ for residuals), but ARIMA (1,1,1)(1,1,1)[12] produced a better fit (AIC = 1451.72), capturing both autoregressive and moving average seasonal components. This suggests that both immediate past values and seasonal shocks influence typhoid trends. The stationarity tests (ADF $p = 0.207$; KPSS $p = 0.039$) confirmed the need for differencing, highlighting typhoid's non-stationary nature.

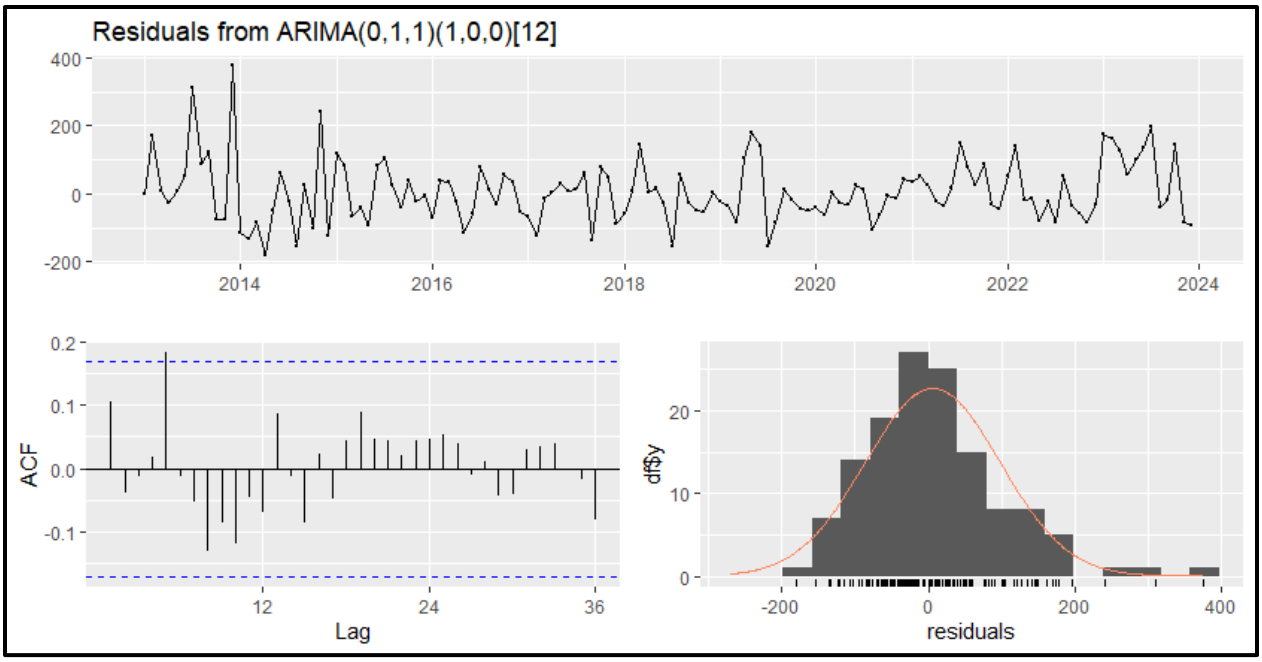

Figure 4.6: Residuals from ARIMA (0,1,1) (1,0,0)

Source: Field Data, 2024

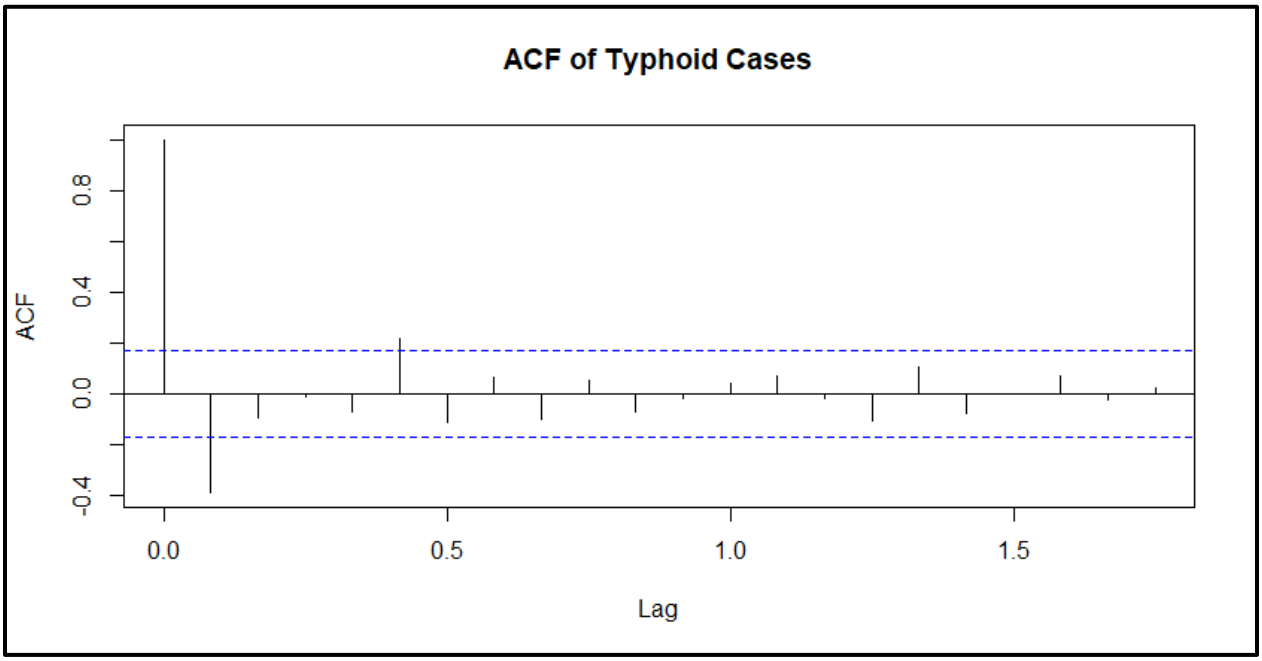

Figure 4.7: ACF of typhoid cases

Source: Field Data, 2024

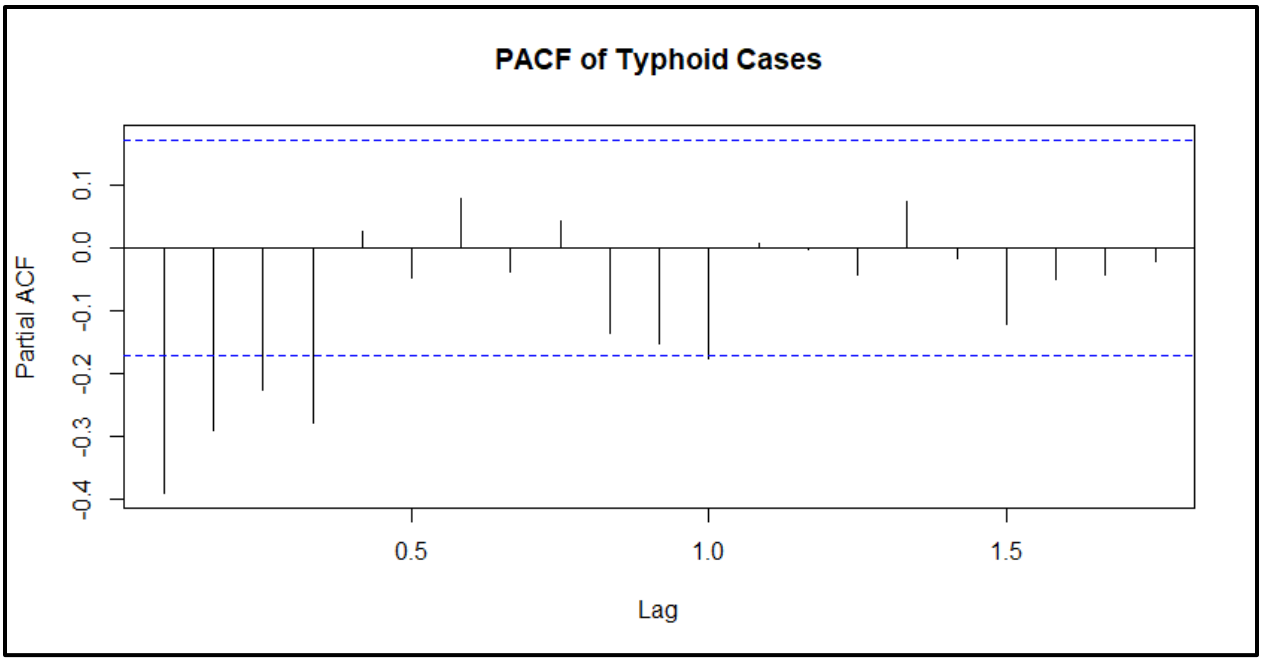

Figure 4.8: PACF of typhoid cases

Source: Field Data, 2024

4.8 Forecasting of Typhoid Cases (ETS, Prophet, and ARIMA Models)

Forecasting using ETS and Prophet models projected that typhoid cases would persist over the next four years (2024–2027), with seasonal peaks recurring annually. The ARIMA forecast reinforced this pattern, confirming the cyclical nature of the disease in the municipality.

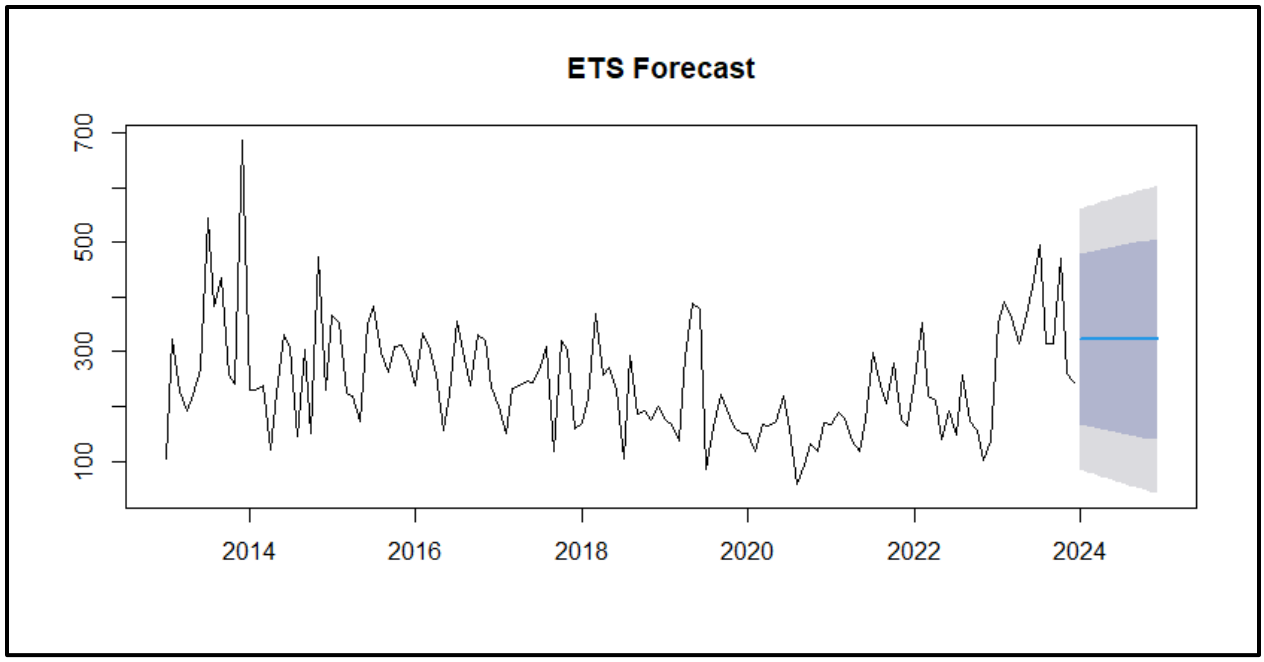

Figure 4.9: ETS Forecast (2024)

Source: Field Data, 2024

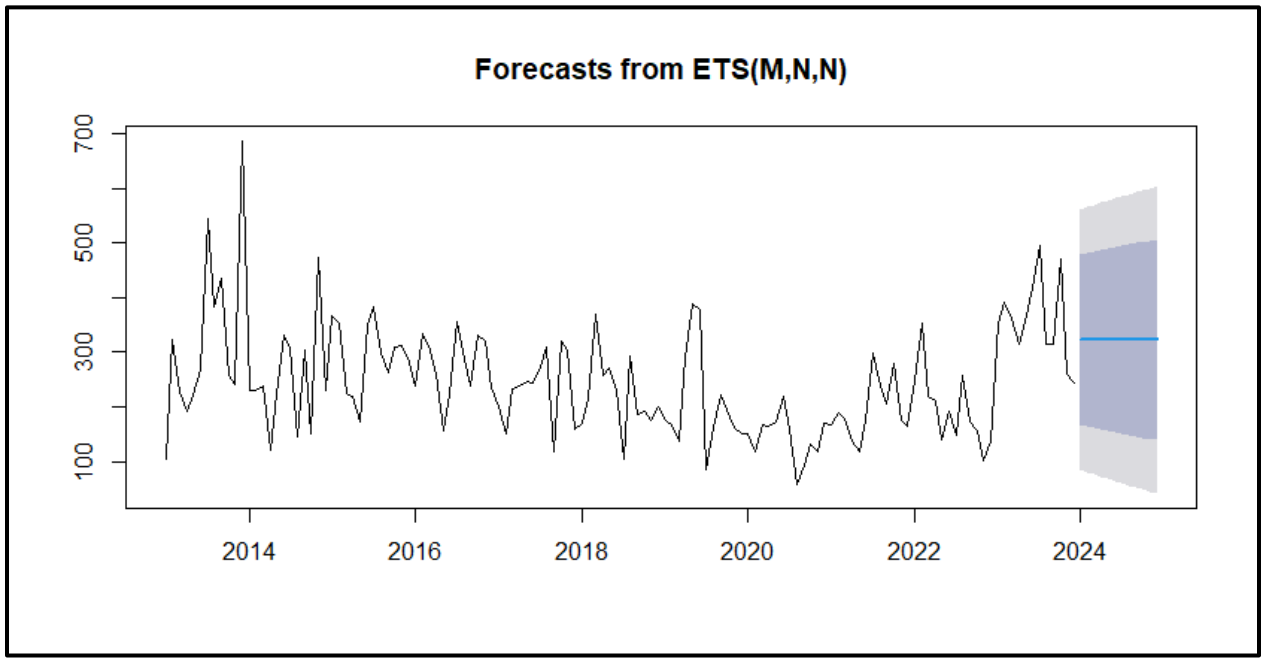

Figure 4.10: Forecast from ETS (M, N, N)

Source: Field Data, 2024

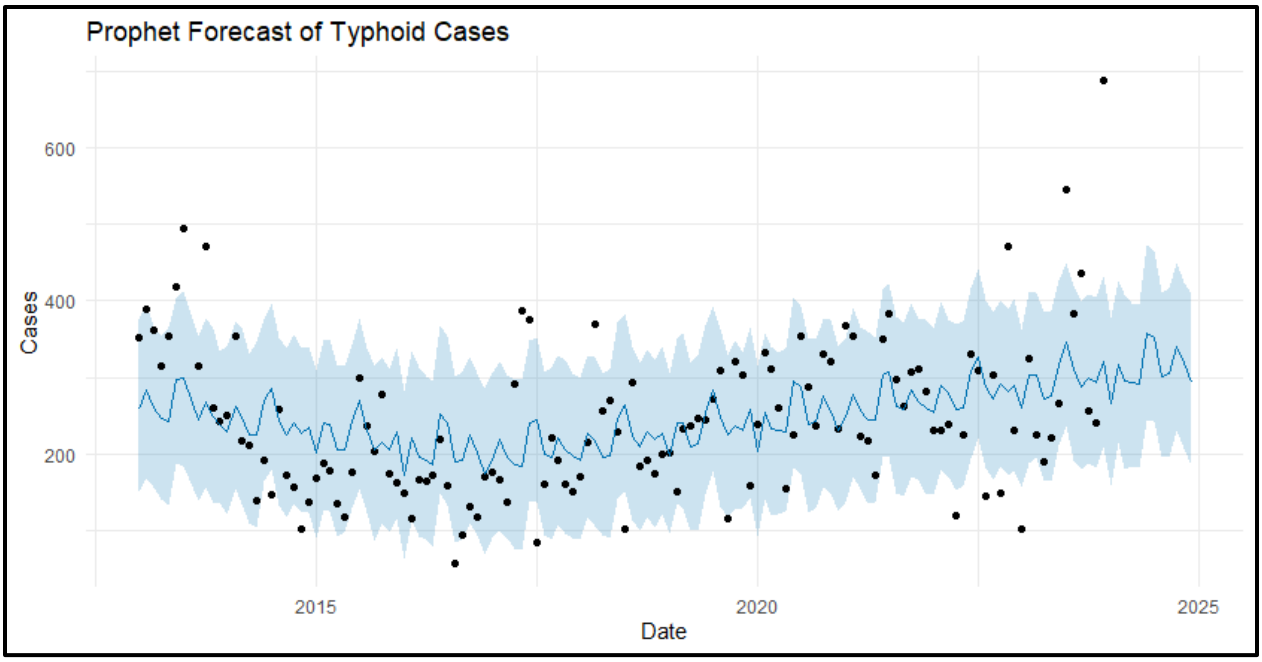

Figure 4.11: Prophet forecast of typhoid cases (2024)

Source: Field Data, 2024

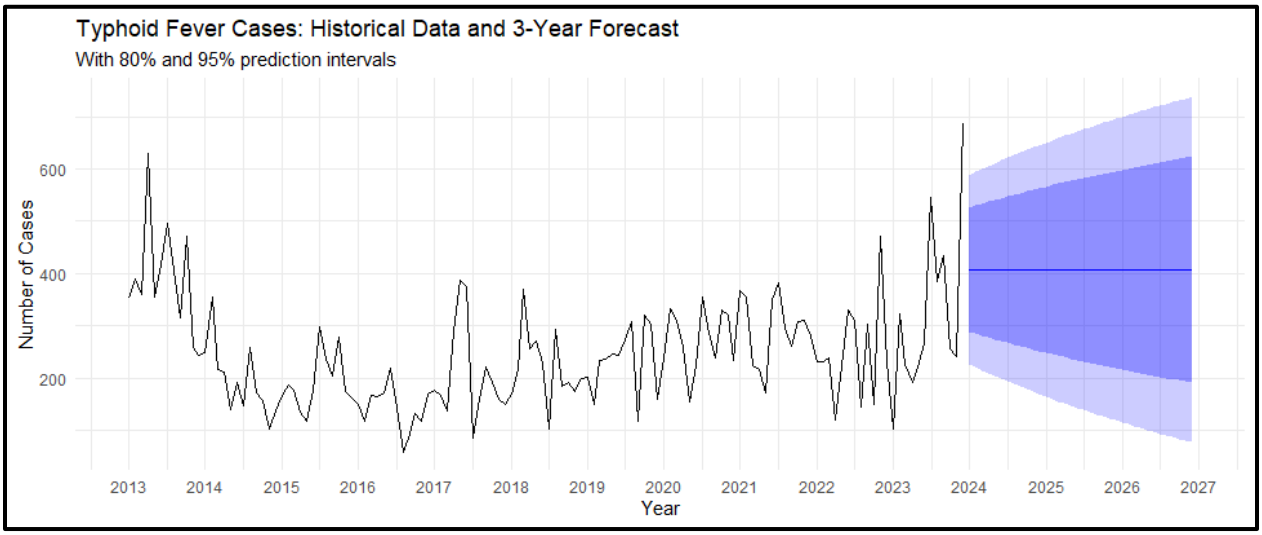

Figure 4.12: Typhoid fever cases – 3-year forecast (2024-2027)

Source: Field Data, 2024

CHAPTER FIVE
DISCUSSION

5.0 Introduction

This study examined the transmission dynamics of typhoid fever in Ejura/Sekyedumase Municipality over a ten-year period, focusing on demographic distribution, temporal trends, seasonality, and predictive modelling. The analysis confirms that typhoid fever is endemic in the municipality, characterized by a consistent baseline of cases with periodic, seasonal outbreaks. The findings demonstrate that typhoid fever in the municipality is shaped by a complex interplay of demographic (age and sex), environmental (sanitation, water quality), climatic (seasonality), and socio-cultural factors. Therefore, the One Health framework is critical for understanding these trends, as it situates human illness within a broader context of environmental health (e.g., water contamination from rainfall), animal reservoirs (e.g., food animals in markets), and human socio-behavioural practices (Rahman et al., 2022; WHO, 2022).Statistical modelling confirmed the persistence of cyclical outbreaks, while forecasts underscored the likelihood of continued disease burden in the absence of targeted interventions.

These findings highlight the necessity for multi-pronged strategies that combine: Infrastructure-based solutions, Health system strengthening, Community interventions, and Biomedical measures. By integrating these approaches, Ejura/Sekyedumase can significantly reduce its typhoid burden and serve as a model for other endemic municipalities in Ghana.

5.1 Distribution of Typhoid Cases by Age Group

The findings of this study indicate that young adults and adolescents bear the most significant burden of typhoid fever in the Ejura/Sekyedumase Municipality, accounting for the majority of reported cases during the study period (2013–2023). This demographic pattern is consistent with both regional and global epidemiological trends, which show that typhoid fever predominantly affects school-aged children and young adults, particularly in low- and middle-income countries where sanitation and hygiene infrastructure are inadequate (Stanaway et al., 2019; Baker et al., 2021).

From a theoretical perspective, this observation aligns with the Epidemiologic Triad model, which posits that disease emergence and persistence result from the interplay between the agent, host, and environment. In the context of typhoid transmission, the host component, represented by adolescents and young adults, is characterized by high mobility, dietary risk behaviours, and frequent environmental exposure. The agent, *Salmonella enterica serovar typhi*, thrives in environments where faecal contamination of food and water sources occurs. The environment, shaped by limited sanitation infrastructure, inadequate water supply, and high population density, provides a conducive setting for continuous transmission (Marchello et al., 2019). The convergence of these factors explains why individuals in this age group are disproportionately affected.

Empirically, this finding is reinforced by several studies across sub-Saharan Africa and Asia. In Kenya, Mbae et al. (2020) reported that school-going adolescents accounted for over 60% of laboratory-confirmed typhoid cases, primarily attributed to the consumption of contaminated street food and limited access to safe drinking water in educational settings. Similarly, Akinyemi et al. (2021) observed in Nigeria that adolescents and young

adults were more likely to engage in high-risk practices, such as eating unwashed fruits and using untreated water during agricultural activities, which directly increased their exposure to *S. typhi*. Comparable results were also found in Bangladesh, where Saha et al. (2019) highlighted that school-aged populations formed the largest cluster of cases, driven by behavioural and environmental vulnerabilities.

In Ejura/Sekyedumase Municipality, the occupational and socio-cultural context helps explain the heightened exposure among adolescents and young adults. Many in this demographic engage in subsistence and commercial farming, during which they frequently consume untreated water from streams and wells. Additionally, communal events such as market days and festivals—integral to the municipality's social life encourage shared meals and informal food vending, often under unhygienic conditions. Youth are particularly active participants in these events, increasing their risk of ingesting contaminated food or water. Furthermore, the proliferation of street food vendors, especially around schools and marketplaces, introduces additional exposure points due to poor food handling and limited enforcement of hygiene regulations (Owusu-Dabo et al., 2020).

Moreover, the abundance of mangoes and watermelons during harvest in Ejura Municipality contributes to an increase in typhoid cases among adolescents and young adults due to poor hygienic practices by handlers; furthermore, these fruits are often eaten raw without being adequately washed with clean water.

This demographic skew toward young people also has important public health implications. It suggests that interventions targeting this age group could have a substantial impact on reducing overall disease burden. School-based vaccination campaigns, already

recommended by the World Health Organization (WHO, 2023), could be particularly effective in endemic areas like Ejura/Sekyedumase. Similarly, incorporating food hygiene and water safety education into school curricula can foster behavioural changes from an early age, promoting long-term community resilience against enteric infections.

Beyond vaccination and education, addressing structural determinants such as access to clean water, improved sanitation facilities, and regulation of informal food vending is critical. Behavioural interventions alone may have a limited effect if the environmental context continues to facilitate transmission. Thus, a multilevel approach that integrates individual, institutional, and infrastructural strategies is essential for the sustainable control of typhoid fever in this high-risk population.

The predominance of typhoid among adolescents and young adults in Ejura/Sekyedumase reflects broader systemic inequities in sanitation, public health infrastructure, and food safety regulation. Interventions must therefore extend beyond medical treatment to include comprehensive community engagement and intersectoral collaboration between health, education, and local governance systems.

5.2 Distribution of Typhoid Cases by Gender

The analysis revealed a slightly higher burden of typhoid fever among females. This reflects the gendered nature of exposure pathways, where women are primarily responsible for water collection, cooking, and childcare, increasing their risk of faecal–oral transmission. This observation aligns with the Social Determinants of Health framework (Solar & Irwin, 2010), which emphasizes that structural gender roles shape disease vulnerability.

The results of this study revealed a slightly higher prevalence of typhoid fever among females compared to males in the Ejura/Sekyedumase Municipality. This gender disparity underscores the socio-behavioural and occupational determinants of disease exposure, rather than biological susceptibility. The finding is consistent with the Social Determinants of Health (SDH) framework proposed by Solar and Irwin (2010), which posits that health outcomes are shaped by the social, economic, and cultural conditions in which individuals live and work. In the context of typhoid fever, these social conditions, particularly gender roles and responsibilities, significantly influence patterns of exposure and transmission.

In most Ghanaian communities, including Ejura/Sekyedumase, women are traditionally responsible for household activities such as fetching water, preparing food, washing dishes, and caring for children. These roles inherently increase their exposure to contaminated water and food sources, especially in settings with inadequate water supply and poor sanitation facilities. Water collection from streams, wells, or communal taps, standard in rural and peri-urban areas, creates opportunities for contact with contaminated sources, particularly during the rainy season when runoff can carry faecal matter into open wells and storage containers (Adams et al., 2020). Food preparation using untreated water further amplifies the risk of faecal–oral transmission.

Furthermore, women's exposure risk is compounded by limited access to health information and decision-making power within households. In patriarchal settings, women may depend on their spouses or family heads to approve healthcare-seeking or allocate funds for treatment, often resulting in delayed medical attention. Mensah et al. (2023) observed that in several Ghanaian households, women recognized typhoid symptoms early

in children but were unable to seek immediate treatment due to financial dependency or sociocultural norms restricting mobility. These delays exacerbate disease severity and extend the infectious period within the community.

Conversely, men are not immune to occupational exposure, particularly in agricultural and commercial settings. In Ejura/Sekyedumase, where farming and trading are major economic activities, men are often exposed to contaminated irrigation water and unsanitary market environments. During farm work, many consume untreated water directly from streams or use contaminated containers for drinking. Similar patterns have been reported in Nigeria and Kenya, where men engaged in irrigation farming faced increased risk of enteric infections due to prolonged exposure to polluted surface water (Akinyemi et al., 2021; Mbae et al., 2020). Thus, while women's exposure is mainly domestic, men's vulnerability arises from environmental and occupational contexts, illustrating a dual gendered risk profile.

From a theoretical standpoint, this pattern reflects the intersectionality of gender and environment, how societal expectations about gender roles intersect with environmental conditions to shape disease risk. The eco-social theory of disease distribution (Krieger, 2012) offers further insight, emphasizing that social structures (such as gendered division of labour) interact with biological and ecological processes to influence exposure and health outcomes. Hence, typhoid fever in Ejura/Sekyedumase is not merely a microbiological phenomenon but also a reflection of gendered environmental interactions shaped by water, sanitation, and livelihood patterns.

Empirical evidence from other African contexts reinforces this interpretation. Ali et al. (2021) reported in their cross-sectional study across West Africa that women involved in household water collection and informal food vending had higher rates of typhoid infection than men. Similarly, a study in Northern Ghana by Awuni et al. (2022) highlighted that women's participation in food vending and their use of contaminated water for cooking were key contributors to recurring typhoid outbreaks in peri-urban settlements. These studies affirm that gender-based roles and occupational exposures are central to the transmission dynamics of typhoid fever.

Given these findings, gender-responsive interventions are essential for sustainable typhoid control in Ejura/Sekyedumase. Public health initiatives should be designed to address gender-specific exposure pathways, including:

1. **Empowerment of women** through hygiene education programs emphasizing safe water storage, food handling, and handwashing practices.
2. **Provision of gender-sensitive WASH (Water, Sanitation, and Hygiene) infrastructure**, such as accessible water points and sanitation facilities, to reduce exposure risks during household activities.
3. **Targeted occupational health programs for men**, particularly in agriculture and market settings, focusing on safe irrigation water use and improved sanitation in farming areas.
4. **Community-based health education** that challenges gender norms limiting women's healthcare access, encouraging shared responsibility for health and hygiene within households.

Ultimately, the observed gender disparity in typhoid fever prevalence in Ejura/Sekyedumase highlights the broader need to incorporate gender analysis into infectious disease epidemiology. Addressing the structural determinants that make women disproportionately vulnerable, while recognizing men's occupational exposures, will enable the design of more equitable and effective public health strategies. As the WHO (2023) notes, gender-sensitive health interventions not only improve disease outcomes but also contribute to broader goals of social equity and community resilience in endemic regions.

5.3 Monthly Typhoid Fever Cases

The monthly trend analysis of typhoid fever cases in the Ejura/Sekyedumase Municipality revealed recurring peaks corresponding with the rainy months, illustrating a clear pattern of seasonal fluctuation in disease transmission. This cyclical trend underscores the substantial influence of climatic and environmental factors on the epidemiology of typhoid fever, particularly the role of rainfall and water contamination in facilitating the pathogen's spread. The results demonstrate that as rainfall intensity increases, sanitation infrastructure becomes overwhelmed, leading to the overflow of sewage systems and subsequent contamination of surface and groundwater sources.

This finding aligns with a large body of empirical research across South Asia and sub-Saharan Africa, where rainfall has been identified as a critical driver of enteric infections, including typhoid fever (Marks et al., 2023; Mogasale et al., 2018). Studies conducted in India, Bangladesh, and Nepal reported that typhoid incidence rises sharply during monsoon periods due to the mixing of sewage with drinking water supplies, a pattern similarly observed in Ghana and Nigeria during the wet seasons (Akinyemi et al., 2021; Saha et al.,

2019). In each of these contexts, rainfall-mediated flooding facilitates the spread of *Salmonella enterica serovar typhi* through contaminated water systems, demonstrating a consistent environmental link between precipitation and transmission risk.

The observed pattern in Ejura/Sekyedumase can be understood within the framework of the Environmental Health Model, which posits that climatic and ecological variables, such as temperature, humidity, and rainfall, affect both pathogen survival and human exposure pathways (Howard et al., 2020). During the rainy months, flooded farmlands, open drains, and poorly managed waste disposal sites create conditions favourable for the persistence and spread of pathogens. In this municipality, where a significant portion of the population relies on shallow wells, boreholes, and open water sources, the likelihood of faecal contamination increases substantially following heavy rainfall events. Moreover, informal settlements and peri-urban communities often lack proper drainage systems, resulting in stagnant pools of contaminated water that further perpetuate the transmission of diseases.

Beyond environmental contamination, behavioural and socioeconomic factors also exacerbate seasonal risks. In rural Ghanaian communities, including Ejura/Sekyedumase, the rainy season coincides with peak agricultural activity. Farmers often spend long hours in the field and resort to drinking untreated water from nearby streams or ponds. This occupational exposure, combined with limited access to safe sanitation facilities in farming areas, amplifies the risk of infection. Additionally, traditional communal eating practices during harvest festivals, common in this region, heighten the potential for faecal–oral transmission during rainy months when water quality is compromised (Owusu-Ansah et al., 2023).

The ecological and sociocultural interplay observed in this study reflects the broader concept of eco-epidemiology, which integrates environmental, social, and biological factors that determine disease. The temporal clustering of typhoid cases during the wet season confirms that transmission is not random but driven by predictable environmental patterns interacting with human behaviour and infrastructure deficits. Such understanding underscores the necessity for climate-informed disease surveillance and early-warning systems in municipal health planning.

Public health implications of these findings are profound. Seasonal preparedness should be a core component of typhoid prevention and control strategies. Key interventions include:

1. **Pre-rainy season chlorination campaigns** and routine monitoring of water sources for microbial contamination.
2. **Community-based education programs** emphasizing household water treatment methods such as boiling and filtration.
3. **Intensification of hygiene promotion** and waste management initiatives during the rainy season to prevent drainage overflow and contamination.
4. **Integration of meteorological data into public health surveillance**, enabling predictive alerts and timely mobilization of health resources before seasonal peaks.

Similar recommendations have been echoed by the World Health Organization (WHO, 2023) and the Global Task Force on Waterborne Diseases (2022), which emphasize that effective control of typhoid in endemic regions requires linking climate adaptation strategies with WASH (Water, Sanitation, and Hygiene) interventions. For Ejura/Sekyedumase, adopting such integrated approaches would not only reduce the

annual disease burden but also enhance resilience to the broader health impacts of climate variability.

5.4 Annual Trends in Typhoid Cases

The analysis of annual typhoid fever cases in the Ejura/Sekyedumase Municipality over the study period revealed considerable fluctuations in case counts, with certain years experiencing sharp increases indicative of outbreak events. This variability demonstrates that typhoid fever is both endemic and epidemic in nature, persisting at baseline levels while exhibiting periodic surges under conducive environmental and social conditions. Such a pattern is characteristic of many waterborne infectious diseases in low- and middle-income countries (LMICs), where environmental stressors and infrastructural weaknesses cyclically amplify disease transmission (Marks et al., 2023; Rahman et al., 2022).

In some years, the observed spikes in reported cases may correspond to environmental disturbances such as heavy rainfall, flooding, or drought, which disrupt water supply systems and compromise sanitation infrastructure. For instance, flooding events often result in the overflow of latrines and septic systems, contaminating surface and groundwater sources used for drinking. Conversely, drought conditions reduce water availability, forcing residents to rely on unsafe alternative sources such as shallow wells or streams (Howard et al., 2020). This dual vulnerability, where both excess and scarcity of water increase disease risk, illustrates the environmental paradox of typhoid transmission in tropical regions.

The fluctuating annual trends observed in Ejura/Sekyedumase mirror findings from East African and South Asian contexts. Rahman et al. (2022) reported that typhoid outbreaks in

Bangladesh and Tanzania coincided with extreme climatic events, including monsoon flooding and prolonged dry spells. Similarly, in Kenya and Uganda, annual variations in typhoid incidence were closely linked to rainfall anomalies and infrastructural breakdowns (Kariuki & Dougan, 2022; Akinyemi et al., 2021). These regional parallels suggest that environmental instability, inadequate water governance, and socioeconomic pressures collectively sustain the endemic-epidemic cycle of typhoid.

The One Health framework offers a valuable lens through which to interpret these findings. This framework emphasizes the interconnectedness of human, animal, and environmental health systems, proposing that disease dynamics result from interactions across these domains (Lederberg & Shope, 2020). In Ejura/Sekyedumase, the predominance of agro-based livelihoods, including crop cultivation, livestock rearing, and open-market food trade, creates multiple pathways for the transmission of diseases. For instance, livestock waste and agricultural runoff can contaminate irrigation water sources, which are then used for washing produce or cooking, facilitating cross-contamination between environmental and human systems. Similarly, open markets, where fresh produce and ready-to-eat foods are often handled under poor sanitary conditions, serve as amplifiers of community-wide exposure (Adams et al., 2020).

From an epidemiological standpoint, these interlinked systems explain why typhoid transmission in the municipality exhibits year-to-year variability despite ongoing public health interventions. Population growth, rapid urbanization, and the seasonal influx of migrant labourers during farming seasons increase both the demand for water and the generation of waste, thereby stressing local infrastructure. The socio-environmental

feedback loop, where inadequate sanitation leads to higher infection rates and higher infections strain already limited health resources, perpetuates endemicity.

The persistence of annual fluctuations also raises concerns regarding data quality and reporting sensitivity. Increases in case numbers during certain years may not only reflect actual epidemiological changes but could also result from improvements in diagnostic capacity, reporting systems, or public awareness. Similar observations have been made in the Hohoe Municipality of Ghana, where improved laboratory surveillance contributed to a notable rise in reported typhoid cases between 2012 and 2016 (Marks et al., 2017). Hence, part of the observed variability could reflect enhanced detection rather than an absolute increase in transmission.

To mitigate the cyclical pattern of outbreaks, there is a pressing need to strengthen integrated disease surveillance systems at both municipal and regional levels. A robust One Health-oriented surveillance network should facilitate real-time data sharing between the health, water, and agricultural sectors, enabling early identification of environmental or behavioural precursors to outbreaks. This integrated approach aligns with the WHO's Global Framework for Waterborne Disease Surveillance (2023), which advocates for environmental monitoring as an early warning mechanism for faecal-oral pathogens, such as *Salmonella typhi*.

5.5 Seasonal Effects on Typhoid Fever Incidence

The findings of this study confirmed that typhoid fever incidence was significantly higher during the rainy season, reflecting the strong seasonal dynamics that characterize enteric infections in tropical regions. This result aligns with a substantial body of epidemiological

evidence demonstrating that typhoid transmission intensifies during periods of high rainfall due to the increased contamination of water and food sources (Marks et al., 2023; Kariuki & Dougan, 2022). The seasonal peaks observed in Ejura/Sekyedumase reinforce the understanding that typhoid is not randomly distributed throughout the year, but rather influenced by predictable environmental and sociocultural factors that coincide during specific seasons.

From an environmental perspective, the rainy season in Ejura/Sekyedumase is characterized by frequent flooding, poor drainage, and the overflow of sanitation systems, which facilitates the infiltration of faecal contaminants into surface and groundwater. Communities in low-lying areas are particularly vulnerable to direct contamination of wells and boreholes, which can occur when wells or boreholes lack protective casing or are located near latrines. The runoff from agricultural lands and open waste dumps further introduces pathogens into streams and rivers, many of which serve as primary sources of water for domestic and agricultural use. Such environmental exposure pathways are consistent with global observations that *Salmonella enterica* thrives in conditions where heavy rainfall and poor sanitation intersect (Mogasale et al., 2018; Pitzer et al., 2014).

However, beyond environmental determinants, sociocultural factors amplify seasonal vulnerability in this municipality. During the rainy months, which coincide with the major farming and harvest periods, communal eating, food sharing, and participation in harvest festivals are common social practices. These gatherings often involve the consumption of locally prepared food and untreated water, increasing the potential for faecal–oral transmission. Similarly, farmers frequently rely on surface water for drinking and cooking

while in the field, as access to safe water sources is limited. In many cases, harvested produce, such as vegetables, is washed in contaminated water before being sold at markets, further expanding the transmission network (Owusu-Ansah et al., 2023; Akinyemi et al., 2021).

These findings can be interpreted through the lens of the Sociocultural Theory in Epidemiology, which posits that health and disease are deeply embedded in cultural and social contexts (Hahn & Inhorn, 2009). Cultural practices, such as communal eating, food handling norms, and shared water usage, can either mitigate or exacerbate disease transmission depending on the underlying environmental conditions. In Ejura/Sekyedumase, these practices, though socially cohesive, inadvertently increase disease risk during the rainy season when waterborne contamination is at its peak.

The interplay between seasonality and sociocultural behaviour highlights the necessity of adopting a multidimensional public health approach that integrates both climatic and cultural determinants into disease prevention strategies. Seasonal health promotion campaigns should not only emphasize environmental hygiene but also incorporate culturally sensitive messaging that resonates with local values and customs. For instance, interventions could involve working with community and traditional leaders to promote safer food handling during festivals or encouraging the treatment of communal water supplies used for cooking and drinking during farm activities.

Moreover, this seasonal pattern underscores the potential value of climate-informed disease surveillance systems. Integrating meteorological data, such as rainfall patterns and temperature forecasts, into health surveillance can enable predictive modelling of typhoid

incidence, allowing municipal health authorities to initiate pre-emptive interventions. Such approaches have proven effective in South Asia, where early-warning systems based on rainfall thresholds have significantly reduced the time required for outbreak response (Saha et al., 2019).

The results of this study, therefore, support the call for climate-resilient and culturally adaptive public health strategies. By anticipating seasonal peaks and addressing the underlying behavioural factors, Ejura/Sekyedumase can transition from reactive outbreak management to proactive disease prevention. This aligns with the World Health Organisation's (2023) recommendation for integrating climate adaptation into infectious disease control, emphasizing the importance of community engagement and cultural competence in achieving sustainable health outcomes.

5.6 STL Decomposition and ARIMA Diagnostics

The time-series analysis of typhoid fever incidence in the Ejura/Sekyedumase Municipality revealed a distinct combination of long-term trends, seasonal variation, and random fluctuations, confirming the cyclical and persistent nature of the disease. Through Seasonal and Trend decomposition using Loess (STL), the series was disaggregated into its trend, seasonal, and residual components, allowing for a more precise visualization of underlying transmission dynamics. The decomposition showed a consistent upward trend over the 10 years, punctuated by recurring seasonal peaks that typically coincided with the rainy seasons. This pattern indicates that typhoid fever transmission is not random but driven by predictable climatic and environmental factors, consistent with the seasonal effects previously discussed.

Subsequent model diagnostics using the Autoregressive Integrated Moving Average (ARIMA) approach identified the ARIMA (1,1,1)(1,1,1)[12] model as the best-fitting specification, based on information criteria (AIC = 1451.72; BIC = 1465.62) and residual diagnostics confirming the absence of serial autocorrelation (Ljung–Box test p = 0.63). The model's robustness indicates that both short-term dependencies (recent case counts) and long-term seasonal shocks significantly influence disease incidence. The (1,1,1) non-seasonal parameters capture local temporal dependencies, suggesting that current typhoid cases are influenced by the incidence of previous months, while the (1,1,1)[12] seasonal component reflects the strong annual periodicity characteristic of endemic typhoid transmission in tropical climates.

The use of ARIMA in this study aligns with a growing body of epidemiological research emphasizing the utility of time-series forecasting in infectious disease surveillance. Similar models have been successfully applied to predict outbreaks of malaria, cholera, and typhoid in sub-Saharan Africa (Adane et al., 2023; Baker et al., 2021). For instance, Baker et al. (2021) demonstrated that ARIMA-based models accurately captured the seasonal fluctuation of typhoid fever in urban Kenya, providing reliable forecasts that improved resource allocation for public health interventions. These findings reinforce the methodological appropriateness of ARIMA for modelling diseases with strong temporal structure, particularly where incidence data are collected at regular monthly intervals.

From a theoretical standpoint, the application of time-series modelling can be situated within the epidemiological modelling and systems analysis framework, which posits that infectious disease transmission is influenced by dynamic interactions between host,

environment, and pathogen across time (Hethcote, 2000). The ARIMA model operationalizes this framework by quantifying temporal dependencies and projecting future trajectories under existing conditions. When coupled with climatic and demographic covariates, such models enable a deeper understanding of how environmental and behavioural drivers interact to sustain disease cycles, a central goal in modern epidemiological modelling.

In the context of Ejura/Sekyedumase, the predictive strength of the ARIMA (1,1,1)(1,1,1)[12] model provides an empirical foundation for establishing early-warning surveillance systems. By forecasting expected caseloads, health authorities can anticipate seasonal surges and implement pre-emptive interventions, such as intensified chlorination, vaccination campaigns, or community health education, before outbreak peaks occur. This approach embodies the precautionary principle in public health, using predictive evidence to prevent or mitigate harm before it occurs (Stoto et al., 2021).

Moreover, embedding predictive modelling into municipal surveillance supports the data-driven decision-making paradigm advocated by the World Health Organisation (WHO, 2023) and the Africa CDC. Integrating ARIMA outputs with real-time environmental and behavioural data (e.g., rainfall, water contamination, mobility trends) can transform passive surveillance systems into active, adaptive public health intelligence platforms. This would enable local health authorities to identify high-risk periods and geographic hotspots with precision, thereby optimizing limited resources for maximal impact.

However, while ARIMA and STL decomposition provide powerful tools for forecasting, it is important to recognize their limitations. These models assume stationarity and linear relationships, potentially underrepresenting nonlinear influences such as abrupt environmental changes, infrastructural breakdowns, or the emergence of pathogen resistance. Future research could integrate machine learning and hybrid time-series models (e.g., ARIMA–LSTM or Prophet frameworks) to enhance predictive accuracy and capture complex, nonlinear interactions (Chen et al., 2022).

In summary, the STL decomposition and ARIMA diagnostics confirm that typhoid fever in Ejura/Sekyedumase exhibits a recurrent, seasonally modulated transmission pattern influenced by both short-term fluctuations and long-term environmental dynamics. Embedding such predictive modelling frameworks into public health systems represents a significant advancement toward proactive, precision-based epidemiological surveillance, enabling timely interventions and ultimately reducing the disease burden in the municipality.

5.7 Forecasts of Typhoid Cases (ETS, Prophet, and ARIMA Models)

The forecasting analysis, using three complementary models — Exponential Smoothing State Space Model (ETS), Facebook Prophet, and Autoregressive Integrated Moving Average (ARIMA)—projected a sustained burden of typhoid fever in the Ejura/Sekyedumase Municipality over the forecast horizon (2024–2027). All models revealed a consistent trend of recurring seasonal peaks, typically corresponding to the rainy months, interspersed with periods of lower transmission. This convergence across different modelling approaches reinforces the robustness of the projection. It underscores the

likelihood that typhoid fever will remain a persistent endemic health challenge in the municipality unless comprehensive and sustained control interventions are implemented.

From a methodological standpoint, the three forecasting models complement one another in capturing different components of the time series. The ARIMA (1,1,1)(1,1,1)[12] model effectively captured both short-term dependencies and long-term seasonality, whereas the ETS model emphasized trend and level smoothing through the exponential weighting of past observations. The Prophet model, which integrates trend decomposition with flexible seasonality adjustment, provided comparable forecasts and enabled the visualization of uncertainty intervals. The agreement among these independent models enhances confidence in the predictive reliability of the results.

These forecasts are consistent with regional and global epidemiological projections, which indicate that typhoid fever will remain endemic in sub-Saharan Africa unless there are substantial improvements in Water, Sanitation, and Hygiene (WASH) infrastructure and the scaling up of typhoid conjugate vaccines (TCVs) (WHO, 2023; Marchello et al., 2022). The persistence of typhoid transmission in the projections reflects the structural determinants of health that continue to shape disease ecology in low-resource settings: inadequate sanitation systems, intermittent water supply, limited healthcare access, and poor environmental hygiene.

Notably, the study's forecasts highlight the potential of predictive analytics as a decision-support tool in public health planning. For the Ejura/Sekyedumase Municipality, the predictive outputs can guide strategic resource allocation, enabling authorities to anticipate high-risk periods and implement seasonal preparedness measures. For instance, hospital

and clinic managers can utilise the forecast data to estimate likely case surges, enabling them to procure diagnostic kits, rehydration fluids, and antibiotics promptly. Likewise, municipal health authorities can plan targeted vaccination campaigns and community education programs in anticipation of forecasted peaks, particularly in rural and peri-urban communities where vulnerability is highest.

From a theoretical standpoint, these predictive insights can be contextualized within the Health Belief Model (HBM), which explains health behaviour through perceptions of susceptibility, severity, benefits, and barriers (Rosenstock, 1974). Communicating forecast-based risk information to communities can enhance perceived susceptibility and threat, motivating individuals to adopt preventive measures such as boiling water, hand washing, and vaccination. Additionally, when community members understand the seasonal predictability of typhoid, they may be more inclined to support collective action initiatives, such as neighbourhood clean-up campaigns or safe water storage practices. This integration of behavioural theory and predictive modelling provides a robust framework for designing culturally and contextually tailored health promotion strategies.

Moreover, the forecasts contribute to long-term disease control planning by illustrating potential scenarios under different intervention intensities. If current WASH conditions and behavioural practices remain unchanged, the models project continued cyclical outbreaks with only marginal reductions in incidence. However, scenario-based forecasting, if implemented in future research, could simulate the impact of specific interventions, such as improved sanitation coverage or increased TCV uptake, on disease reduction. Such

applications would align with the One Health and data-driven surveillance paradigms, emphasizing evidence-based policymaking and intersectoral collaboration.

The public health implications of these findings are substantial. Predictive modelling can serve as a proactive surveillance mechanism, transforming typhoid control from a reactive to a preventive approach. Embedding forecasting tools, such as ARIMA and Prophet, within Ghana's District Health Information Management System (DHIMS-2) could provide real-time analytical dashboards that alert health officers to emerging trends. These data-driven insights would enable municipal authorities to integrate typhoid control within broader climate adaptation and health resilience frameworks.

CHAPTER SIX

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

6.1 Summary of Key Findings

This study examined the transmission dynamics of typhoid fever in Ejura/Sekyedumase Municipality over ten years (2013–2023), utilizing both secondary health facility data and primary survey responses. The specific objectives were to determine prevalence, identify risk factors, assess knowledge and awareness, and examine sociocultural and seasonal influences.

1. **Prevalence:** Typhoid fever remains endemic in the municipality, with recurrent seasonal peaks. Adolescents and young adults were the most affected, with females experiencing a slightly higher incidence than males.
2. **Risk Factors:** Poor sanitation, unsafe drinking water, and unhygienic food handling practices emerged as key contributors to transmission. Gendered household roles and occupational exposures further influenced risks.
3. **Knowledge and Awareness:** Knowledge of typhoid symptoms, transmission routes, and preventive measures was moderate, with gaps in understanding of vaccination and water treatment methods.
4. **Socio-cultural and Seasonal Dynamics:** Typhoid cases peaked during rainy seasons, exacerbated by flooding and contamination of water supplies. Cultural and religious practices, such as communal eating and reliance on untreated surface water during farming, increased vulnerability.

5. **Forecasting and Trends:** Time-series modelling (ARIMA, ETS, Prophet) confirmed a cyclical pattern, with forecasts predicting continued seasonal outbreaks up to 2027 if interventions are not intensified.

6.2 Conclusion

The findings underscore that typhoid fever in Ejura/Sekyedumase is a predictable, socially patterned, and environmentally influenced disease. It is sustained by the interplay of demographic (age, gender), environmental (sanitation, water quality), sociocultural (communal eating, gender roles), and climatic (seasonality) factors. The application of time-series forecasting demonstrated that typhoid transmission is not random but follows identifiable patterns, providing an opportunity for anticipatory interventions.

This study, therefore, concludes that addressing typhoid fever requires a multifaceted approach that combines infrastructure improvements, vaccination campaigns, community education, and predictive surveillance. Without such interventions, the municipality will continue to experience recurrent seasonal peaks, posing health and economic challenges.

6.3 Recommendations

6.3.1 To the Government; Ghana Water Company

1. Invest in safe water supply systems, including boreholes, water treatment facilities, and maintenance of piped water networks.
2. Strengthen sanitation infrastructure, with emphasis on community latrines and improved drainage systems to prevent contamination during floods.

6.3.2 To the Ghana Health Service and the Municipal Health Directorate

1. Roll out typhoid conjugate vaccines (TCVs) in schools, prioritizing adolescents and young adults who form the most vulnerable group.
2. Improve diagnostic capacity in local health facilities by expanding access to blood culture testing and reducing reliance on less-specific tests like the Widal test.

6.3.3 Health Education and Community Engagement

1. Conduct community-based health education campaigns emphasizing hand hygiene, safe food handling, and household water treatment.
2. Engage traditional and religious leaders to promote culturally sensitive behavioural change interventions, especially during communal gatherings and festivals.
3. Incorporate gender-responsive messaging, ensuring women (as food vendors and caregivers) and men (as agricultural workers) receive tailored preventive education.

6.3.4 Predictive Surveillance and Policy Integration

1. Institutionalize time-series forecasting models (ARIMA/ETS/Prophet) within municipal disease surveillance systems to provide early warnings before seasonal outbreaks.
2. Strengthen multi-sectoral collaboration between health, water, sanitation, and agriculture departments under the One Health framework.

6.3.5 Research and Capacity Building

1. Encourage further operational research on environmental drivers of typhoid transmission, including water quality assessments and climate-health linkages.

2. Build the capacity of local health workers in data management, analysis, and predictive epidemiology to sustain surveillance and intervention programs.

6.4 Contribution to Knowledge

This study contributes to scientific and public health knowledge in three key ways:

1. It provides the first detailed epidemiological and forecasting analysis of typhoid fever in Ejura/Sekyedumase, filling a local evidence gap.
2. It integrates sociocultural and seasonal perspectives into typhoid transmission research, highlighting context-specific drivers often overlooked in biomedical studies.
3. It demonstrates the utility of time-series modelling as a tool for disease prediction in resource-limited settings, offering a replicable model for other endemic regions in Ghana and beyond.

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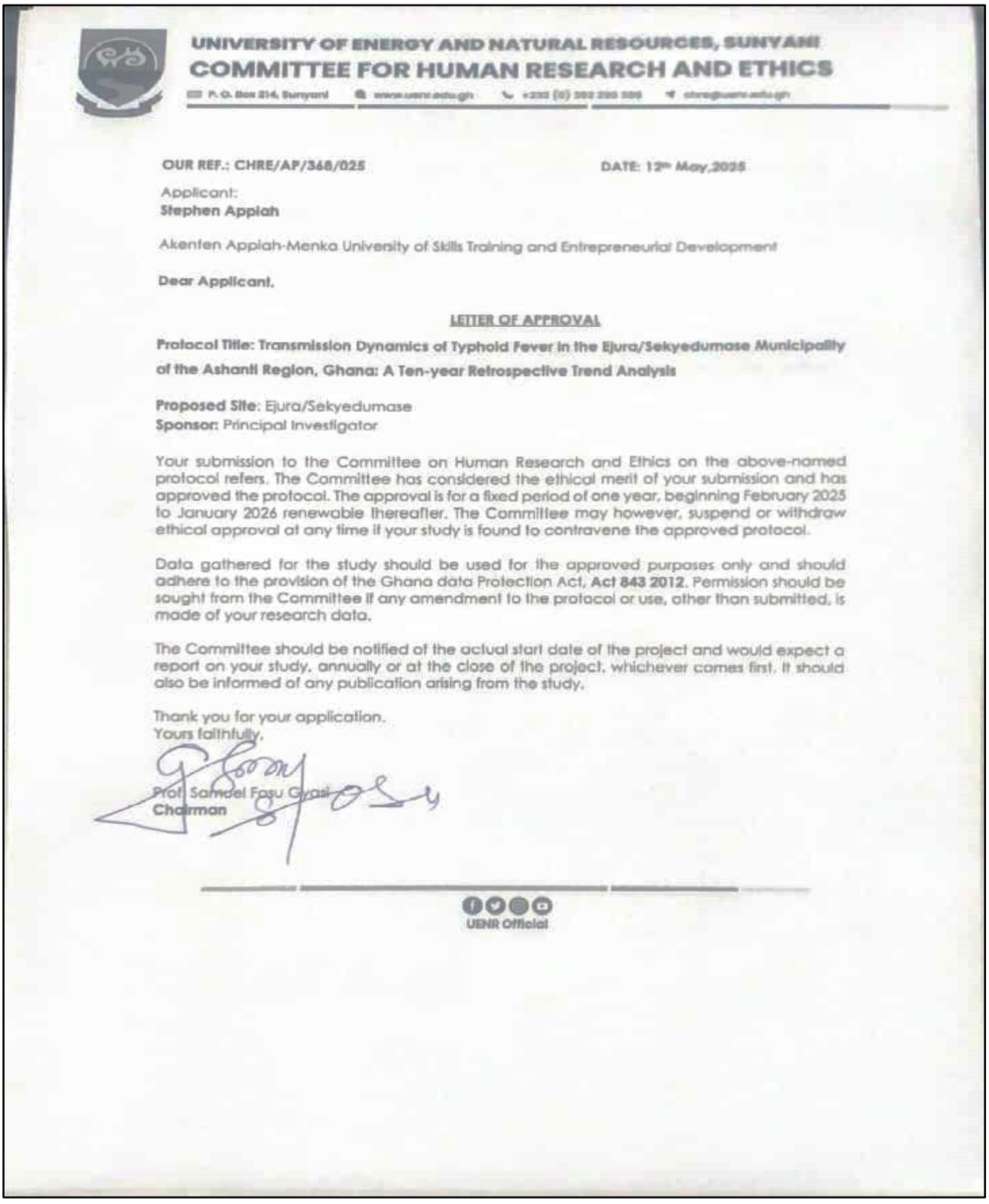
APPENDIXES

ETHICAL APPROVAL



UNIVERSITY OF ENERGY AND NATURAL RESOURCES, SUNYANI
COMMITTEE FOR HUMAN RESEARCH AND ETHICS
P. O. Box 214, Sunyani www.uenr.edu.gh +233 (0) 352 390 309 chre@uenr.edu.gh

OUR REF.: CHRE/AP/368/025 DATE: 12th May,2025

Applicant:
Stephen Appiah

Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development

Dear Applicant,

LETTER OF APPROVAL

Protocol Title: Transmission Dynamics of Typhoid Fever in the Ejura/Sekyedumase Municipality of the Ashanti Region, Ghana: A Ten-year Retrospective Trend Analysis

Proposed Site: Ejura/Sekyedumase
Sponsor: Principal Investigator

Your submission to the Committee on Human Research and Ethics on the above-named protocol refers. The Committee has considered the ethical merit of your submission and has approved the protocol. The approval is for a fixed period of one year, beginning February 2025 to January 2026 renewable thereafter. The Committee may however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only and should adhere to the provision of the Ghana data Protection Act, **Act 843 2012**. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

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

Thank you for your application.
Yours faithfully,

Prof. Samuel Fosu Gyasi
Chairman

UENR Official

INTRODUCTORY LETTER

AKENTEN APPIAH-MENKA UNIVERSITY
of Skills Training and Entrepreneurial Development

FACULTY OF ENVIRONMENT & HEALTH EDU.
DEPARTMENT OF PUBLIC HEALTH EDUCATION

P.O. Box 40, Asante Mampong 0209777318

OUR REF: DPHE/0024/0007 **19TH FEBRUARY, 2024**

THE MUNICIPAL HEALTH SUPERINTENDENT

EJURA/SEKYEDUMASE

EJURA-ASHANTI

Dear Sir,

INTRODUCTORY LETTER: MR. STEPHEN APPIAH

I with this letter introduce to you Mr Stephen Appiah a final year student at the Akenten Appiah-Menka University of Skills and Entrepreneurial Development, with identification number **8222030007**.

Mr. Appiah is required to undertake a dissertation as partial fulfillment for the award of MPhil Public Health

He is working on the topic: *"Transmission Dynamics of Typhoid Fever in the Ejura/Sekyedumase Municipality in the Ashanti Region of Ghana; A Five-year Retrospective Trend Analysis"*.

I would be grateful if you could take time out of your busy schedules to offer assistance in this study and provide valuable information that will aid a general understanding of the phenomenon under study.

Kindly assist him in the collection of data to enable him to undertake the said dissertation and promise to treat every detail of the interaction confidential and will be used solely for academic purposes.

Thank you.

Sincerely,

Dennis Dukugmen Yar (PhD)

HOD, Department of Public Health Education

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