AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

HELMINTHIASIS AND MALARIA CO-INFECTION AMONG SCHOOL CHILDREN IN BIBIANI-ANHWIASO-BEKWAI MUNICIPAL

ISAAC BAFFOUR AWUAH

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BY

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A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, in partial fulfilment of the requirements for the award of the Master of Philosophy degree in Public Health.

OCTOBER, 2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis, with the exception of quotations and references contained in published works which have been duly acknowledged; 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.

Isaac Baffour Awuah

Signature…………………………………. Date………………………………...

Supervisor's Declaration

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

Dr. Daniel Hayford (Principal Supervisor)

Signature…………………………………. Date………………………………...

Dr. Isaac Owusu-Mensah (Co-Supervisor)

Signature…………………………………. Date………………………………...

ABSTRACT

Helminthiasis and malaria are key parasitic diseases affecting millions of people globally, particularly in sub-Saharan Africa. These infections often coexist and significantly impact the health and well-being of individuals, particularly school children in endemic areas. This study investigated the prevalence, co-infections, and risk factors associated with malaria and helminthiasis among children in selected schools within the Bibiani-Anhwiaso-Bekwai Municipal District. A cross-sectional survey was conducted between August and September 2024 among pupils from 6 randomly selected public primary schools. Structured questionnaires were administered to collect sociodemographic, environmental, and behavioural data. Thick and thin smears were prepared using finger-prick blood samples and stained with Giemsa stain for malaria diagnosis, while stool samples were analysed for helminths using the Kato-Katz technique. Of the 333 pupils who participated in the survey, 51.4% were males and 48.6% were females. The overall prevalence rates of malaria and helminthiasis were 16.52% and 4.5%, respectively. The commonest helminths observed were *Ascaris lumbricoides* (1.5%), *Trichuris trichiura* (1.2%), and hookworm species (0.6%). The prevalence of malaria and helminth co-infection was 1.8%, with the highest co-infection rate of 0.90% observed between *Plasmodium* spp. and *A. lumbricoides*. The prevalence of malaria and helminthiasis among rural dwellers was 19.61% and 5.88%, respectively, compared to 11.63% and 2.33% in urban areas. Residence and sanitation were risk predictors of malaria. Swimming in open water bodies was associated with a significantly reduced co-infection of malaria and helminthiasis (OR = 0.04, 95% CI: 0.009–0.57, p = 0.03) compared with swimming in river waters (OR = 10.0, 95% CI: 0.83–281, p = 0.09). This study highlights the persistent burden of parasitic

infections among schoolchildren, particularly in rural areas, despite ongoing control efforts, including the distribution of insecticide-treated nets and mass deworming. This thus calls for continuous surveillance, especially in rural settings.

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My heartfelt gratitude goes to the Almighty God for giving me the strength, insight, and ability to undertake this project. I am also highly grateful to my principal supervisor, Dr. Daniel Hayford, for his constructive criticisms, guidance, and endurance, and for taking the pains to read through this work. To you, I say, may the good lord God richly bless you. Similarly, I am grateful to the co-supervisor, Dr. Isaac Owusu-Mensah, for his immense support and contribution to completing this work.

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DEDICATION

This project is dedicated to the Almighty God for his guidance and protection throughout my study, through whose grace I am alive to present this dissertation. It is also dedicated to my lovely family for their relentless spiritual and physical support during my stay on campus and towards the success of this project and the programme as a whole.

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LIST OF ABBREVIATIONS

ACTs	Artemisinin-Based Combination Therapies
DHS	Demographic and Health Survey
CDC	Centers for Disease Control
CHRPE	Committee on Human Research, Publication, and Ethics
EPG	Eggs per Gram
GHS	Ghana Health Service
GSS	Ghana Statistical Services.
ITN	Insecticide-Treated Nets
IRS	Indoor Residual Spraying
LMIC	Low and Middle-Income Country
MDA	Mass drug administration
NTDs	Neglected Tropical Diseases
OR	Odds Ratio
RDTs	Rapid Diagnostic Tests
SEM	Socio-Ecological Model
STD	Soil Transmitted Helminths
SPSS	Statistical Package for Social Sciences
WASH	Water, Sanitation and Hygiene
WHO	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Helminthiasis and malaria are key parasitic diseases affecting millions of people globally, particularly in sub-Saharan Africa (SSA) (Idris et al., 2019). These infections often coexist and significantly impact the health and well-being of individuals, particularly school children in endemic areas (Sumbele et al., 2020). Approximately one-third of the global population, predominantly those living in tropical and subtropical regions, is believed to be harbouring one or more parasitic helminths (worms) and protozoans (Harvey et al., 2020). Furthermore, children living in low and middle-income countries (LMIC) often experience the dual challenge of a substantial malaria burden along with the common presence of parasitic helminths (Eltantawy et al., 2021).

About 1.5 billion individuals are infected with helminths globally (Werkman et al., 2020). Soil-transmitted helminths, notably hookworms (*Ancylostoma duodenale* or *Necator americanus),* roundworms (*Ascaris lumbricoides),* and whipworms (*Trichuris trichiura*), impact over 800 million children in low and middle-income countries (LMIC) (Randi, 2023). Over 260 million preschool-age children, 654 million school children, 108 million adolescent girls, and 138.8 million pregnant and lactating women live in regions where these parasites are widely transmitted (WHO, 2023). These worms are grouped because of the frequent occurrence of chronic infections with all three parasites in a single individual, particularly among children living in less developed countries (Else et al., 2020).

Many of the global populations harbour infections from one or more of the soil-transmitted helminths (WHO, 2023). The impact of these infections is most pronounced in the least affluent and underserved communities that lack proper access to clean water, sanitation, and hygiene, particularly in tropical and subtropical regions. The highest prevalence is documented in sub-Saharan Africa, China, South America, and Asia (WHO, 2023). Transmission occurs through eggs in human faeces, contaminating soil in regions with inadequate sanitation (Kwong et al., 2021). The influence of soil-transmitted helminths extends across human health, economics, and culture.

Although individuals from diverse societies and locations may harbour worms at various points, the most prominent rates are observed among children living in rural areas of the tropics and subtropics (Alexander & Blackburn, 2019). The risk of soil-transmitted helminths (STHs) is most pronounced among school children, as they face increasing exposure to numerous risk factors associated with STHs as they age (Gebreyesus et al., 2020). Children's increased susceptibility to increased prevalence is attributed to their vulnerable immune systems and raised nutritional needs, which are often proving unaffordable and challenging for many (Davis et al., 2023).

Malaria remains a significant global health issue, transmitted through the bite of infected female *Anopheles* mosquitoes. Five *Plasmodium* species cause malaria in humans. They are *Plasmodium falciparum, P. vivax, P. malariae, P. ovale, and P. knowlesi* (Maniga et al., 2022). The most severe form of malaria is caused by *Plasmodium falciparum*, which is also the most common type found in sub-Saharan Africa (Tetteh et al., 2023), often leading to a high parasite load in the bloodstream and causing severe health issues in humans, including conditions like severe anaemia, weight loss, and cerebral malaria (Balaji et al., 2020). The prevalent incidence of illness and mortality in sub-Saharan Africa is primarily attributed to the prevalence of *P. falciparum* parasites, which are the leading cause of malaria (Makenga et al., 2020).

In 2021 alone, an estimated 247 million cases of malaria were recorded worldwide, and 625,000 malaria-related deaths were recorded. WHO Africa recorded 95% of the worldwide malaria cases and 96% of malaria-related deaths (WHO, 2022). The disease manifests as fatigue, weakness, headache, fever, body aches, decreased appetite, and joint pain (Kalu, 2023). Although the high prevalence of malaria is well-documented, it has only been in the past decade that an unusually high number of cases have been identified as co-infections of malaria and helminthiasis (Afolabi et al., 2022).

Plasmodium falciparum and several other helminth species in the SSA have similar geographic distributions (Mutoni et al., 2022; Adedokun & Ojurongbe, 2022). The high frequency of co-infection among individuals is addressed by the overlapping geographic distribution of parasitic illnesses in this area and the greater prevalence of these infections (Alemu et al., 2019; Lebu et al., 2023). Previous studies have indicated that approximately 25% of African schoolchildren simultaneously have hookworm and *P. falciparum* infections (Hürlimann et al., 2019). To determine the probability of coinfections and comorbidity in the population, it is essential to consider the shared distribution of different parasites (Assoum, 2019; Dejon-Agobé et al., 2021).

The age of those exposed, the degree of immunity developed, and the transmission intensity of parasite species in the area all influence the exposure risk to co-infection and comorbidity (Assoum, 2019). Schoolchildren commonly harbour schistosome species, such as *S. mansoni* and *S. haematobium*, as well as soil-transmitted helminths (STHs), including *A. lumbricoides* and *T. trichiura*. Although hookworm infections are prevalent in this age group, they peak during early adulthood (Jenkins, 2019; Ndoko, 2023). While asymptomatic infections and clinical malaria episodes are common in individuals in this age range, severe malaria is uncommon (Cheaveau et al., 2019).

Children frequently experience both malaria and helminth infections (Oboth et al., 2019). Pregnant women and school children are more vulnerable to the co-occurrence of helminth and malaria infections, as well as any potential clinical consequences, than other population groups (Sumbele et al., 2020; Otia & Bracci, 2022). Due to school children's regular exposure to these parasites, these infections have become a serious health concern in Ghana. Exposure to these substances causes stunted growth, poor cognitive development, general illness, and death (Akosah-Brempong et al., 2021). Multiple African epidemiological contexts have documented coinfection with malaria, *Schistosoma* species, and STHs (Lebu et al., 2023). Nevertheless, most of these parasite infections are usually studied separately, which leads to a paucity of information on the frequency, severity, and fatality of various parasitic diseases in Ghana (Anyan et al., 2019).

1.2 Problem Statement

Malaria and helminthiasis still constitute a critical public health burden in the whole of sub-Saharan Africa, especially among school-aged children. School-aged children are particularly vulnerable to these diseases because of their developing immune systems and the unique way they interact with the environment (G. Singh et al., 2022; Morales et al., 2023). In the Sefwi In the Bibiani area of the Bibiani/Anhwiaso/Bekwai Municipality, the problems posed by these parasitic diseases persist despite ongoing distribution of insecticide-treated bed nets and deworming activities (GHS, 2024; Yeboah, 2023).

Although helminth and malaria parasite infections are usually researched and/or reported separately, developing evidence points to the fact that co-infection is widespread and could pose a serious public health threat due to its possible synergistic impacts on health outcomes, such as anaemia, cognitive impairment, and poor performance in school (Afolabi et al., 2021; Lebu et al., 2023). Unfortunately, information on the prevalence rate, risk factors, and public health effects of helminth and malaria parasite co-infection in this municipal area is considerably limited and/or outdated (Tetteh-Quarcoo et al., 2020). Such a considerable information gap hinders the planning and implementation of integrated, setting-tailored control measures that can successfully lead to a significant reduction or elimination of the dual toll of these infections among school-age children (WHO, 2023).

Hence, the current research investigated the prevalence, risk factors, and public health costs associated with malaria and helminthiasis co-infection among schoolchildren in the Bibiani/Anhweaso/Bekwai Municipality. The results are expected to inform evidence-based approaches that enhance child health and educational outcomes in the region, augmenting the health sector's efforts in the country and sub-Saharan Africa.

1.3 Justification of the Study

Intestinal parasites affect cognition and academic performance in schoolchildren (Donkoh et al., 2022). Nevertheless, the mechanism affecting mental processes remains uncertain, characterized by an indirect nature. This study aimed to assess the rate of malaria and helminthiasis coinfection and identify potential risk factors contributing to its prevalence among schoolchildren. Understanding how helminthiasis and malaria interact is crucial for education, as it can lead to lower academic performance, increased absenteeism, and difficulty concentrating. The Western North Region of Ghana, particularly Bibiani, has high prevalence rates of malaria and helminthiasis (Boadu et al., 2020; Osarfo et al., 2023), making it an ideal location for targeted prevention strategies, including educational programs, improved sanitation measures, and promotion of personal hygiene practices among schoolchildren. This study enhances our understanding of the epidemiology of malaria and helminthiasis coinfections, with implications for future research, policy development, and the effective implementation of health interventions.

1.4 Main Objective

The current study assessed the prevalence, risk factors, and co-infection of malaria and helminthiasis among schoolchildren in the Bibiani-Anhwiaso-Bekwai Municipal area.

1.4.1 Specific Objective

Specifically, this study sought to:

i. Determine the prevalence of helminthiasis and malaria infections among school children.

ii. Determine the prevalence of helminthiasis and malaria co-infection among school children.

iii. Assess the risk factors for helminthiasis and malaria co-infections among school children.

1.4.2 Research Questions

i. What is the prevalence of helminthiasis and malaria among school children?

ii. Are there children infected with helminthiasis and malaria simultaneously?

iii. What is the prevalence of malaria and helminthiasis co-infection among the children?

iv. What significant risk factors contribute to helminthiasis and malaria co-infection?

1.5 Hypotheses of the study

1.5.1 Hypothesis 1: Malaria Prevalence

Null Hypothesis (H_0): No significant difference exists between the proportion of school children infected with malaria and those not infected.

Alternative Hypothesis (H_1): There is a significant difference between the proportion of school children infected with malaria and those who are not infected.

1.5.2 Hypothesis 2: Helminthiases Prevalence

Null Hypothesis (H_0): There is no significant difference between the proportion of school children infected with helminthiasis and those who are not infected.

Alternative Hypothesis (H_1): There is a significant difference in the proportion of school children infected with helminthiasis compared to those who are not infected.

1.6 Significance of the Study

This study examined the prevalence of malaria and helminthiasis, as well as the factors influencing coinfection, among school children, which is crucial for informing public health interventions. This study's findings would inform targeted strategies for disease prevention, early detection, and effective treatment, thereby reducing the overall morbidity and mortality associated with these infections. The findings are also expected to inform health policies and provide evidence-based recommendations for authorities to lessen the prevalence of co-infection, thus improving the health and well-being of school children in the region.

1.7 Study Scope

The scope of this study was limited to selected communities in the Bibiani, Anhwiaso, and Bekwai Areas in the Western north region of Ghana. This focus allowed for a detailed study of diseases' prevalence, risk factors, and demographic traits. Bibiani/Anhwiaso/Bekwai Municipal is known for endemic helminthiasis and malaria. This is partly due to the area's inadequate environmental conditions, sanitation, and hygiene standards. The results of this study exclusively address the prevalence of helminthiasis and malaria, as well as co-infection among the participants; other communities within the same municipality were not included.

1.8 Limitations of the Study

The study was school-based and targeted public primary school children in the Bibiani-Anhwiaso-Bekwai Municipal area. It excluded children below 5 years and above 14 years old, which could affect the generalization of findings. The slide should be read within 30 to 60 minutes after preparation; otherwise, the hookworm eggs will usually disappear. Since the researcher could not fully adhere to this rule during every survey, it is possible that some of the hookworm eggs in the current study may have disappeared and thus could not be captured. Some parents, particularly those of children in lower primary school, were unwilling to provide informed consent for their children's participation.

1.9 Organisation of the Study

This study is organized into chapters. The first chapter presents the background of the study, including the problem statement, research objectives, questions, hypotheses, justification of the study, its significance, scope, and limitations. The second chapter (chapter two) reviewed relevant literature on helminthiasis and malaria, based on the study objectives. This includes the pathophysiology of helminthiasis and malaria, epidemiology of helminthiasis and malaria, co-infection and malaria, transmission and risk factors, helminthiasis, and malaria-preventive interventions. This chapter also concludes with a theoretical and conceptual framework based on the study. The third chapter (Chapter Three) presents the methodology used in this study. It also highlights the sampling procedure, data collection technique, and data processing and management. This chapter also explains the data analysis techniques used in the study and the quality control processes implemented. The fourth chapter (chapter four) presents and describes the results of this study. The key results presented included demographic characteristics, prevalence of helminthiasis and malaria co-infection, socio-demographic predictors of malaria and helminthiasis infections and the risk factors contributing to malaria and helminthiasis co-infection. The fifth chapter (Chapter Five) discusses the results in relation to the study's objectives, existing literature, and the theoretical framework that underpins the study. Finally, the sixth chapter (Chapter Six) summarises the key findings, recommendations, and conclusions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter examines scholarly works pertinent to the research's fundamental concepts. A range of databases, including Google Scholar, PubMed, and Web of Science, were used to compile the literature. Furthermore, the study's aims were considered when assessing and evaluating previous studies on the subject, as well as official documents and grey literature. The literature search involved keywords such as helminthiasis, malaria, epidemiology, prevalence, and risk factors. The review presented relevant ideas and concepts, along with real data on risk factors, prevalence, transmission, and sociodemographic variables that indicate the likelihood of coinfection between helminthiasis and malaria. Furthermore, the assessment assessed individuals' awareness and understanding of the co-occurrence of malaria and helminthiasis. This chapter concludes with a theoretical and conceptual framework based on this study.

2.2 Conceptual Review

This section outlines the concepts used in the study, including the pathophysiology of helminthiasis and malaria co-infection, their transmission, and risk factors.

2.2.1 Pathophysiology of Helminthiasis and Malaria

2.2.1.1 Helminthiases

The helminth parasite group includes complex metazoans from various taxonomic groups, mainly Platyhelminthes and Nematoda, which cause helminthiases (Gazzinelli-Guimaraes

& Nutman, 2018). These parasites inhabit different locations in their mammalian hosts, such as blood vessels and the intestinal lumen (Frischknecht, 2024). Commonly called intestinal worms, helminths can exist outside the intestines (Karo-Atar et al., 2023).

Adult helminths do not reproduce in humans but evade the immune system, surviving for years (Abdoli & Ardakani, 2020; Ahiadorme & Morhe, 2020). The larval form is the infectious stage, migrating to specialised niches for development (Santa et al., 2021). Helminths have complex life cycles that often involve soil. Infected individuals shed eggs in their faeces, contaminating soil, primarily through open defecation. Humans can become infected by consuming contaminated food or skin contact with mature larvae in infected soil (Kurscheid, 2022); Tadege et al., 2022). Soil-transmitted helminths (STH), such as Ascaris lumbricoides, Trichuris trichiura, Necator americanus, and A. duodenale, pose significant risks (Goshu et al., 2021; M. D. Wilson et al., 2024).

STH infections do not spread directly between people and typically require time to mature in soil (Khurana et al., 2021; Lynn et al., 2021). High-risk groups include pregnant women, children, and farmers (delos Trinos, 2023). Chronic infections often show no symptoms initially but can lead to severe intestinal damage, malnutrition, and developmental issues in children (Else et al., 2020; Morales et al., 2024). Due to their dietary needs, children and pregnant women are particularly vulnerable to complications (Iqbal et al., 2020).

Ascaris lumbricoides is a common intestinal roundworm and a significant human parasite (Else et al., 2020). Related to the swine parasite, they inhabit primarily the jejunum but can be found throughout the small intestine (Brewer & Greve, 2019). Adult worms live for about a year, with some surviving up to 20 months (Else et al., 2020). Females can grow to 20-35 cm and weigh up to 9 g, while males max out at 30 cm and 3 g. They can lay 100,000–200,000 eggs daily, starting 9–11 weeks post-infection (Naim, 2012). Egg production is influenced by worm age, weight, and geographic location (Feyera et al., 2022). Fertilised eggs are spherical (45–75 µm) with a thick, rough shell, while unfertilised eggs can be larger (up to 90 µm) and have a thinner shell (Gardner et al., 2024). Depending on the temperature, eggs mature in soil into infectious second-stage larvae (L2) within two weeks to several months, with optimal maturation at 25 to 30 ºC (Bautista-Garfias et al., 2023). Eggs can survive in the soil for up to two years, but maturation stops below 15.5 °C, and viability decreases above 38 °C (Gardner et al., 2024).

2.2.2.1 Life Cycle of Ascaris Lumbricoides

These parasites have a direct life cycle, with no intermediate hosts. Adult worms live in the lumen of the small intestine. A female may produce approximately 240,000 eggs daily, passed with the faeces. Unfertilized eggs may be ingested but are not infectious. Larvae develop into infectivity within fertile eggs after 18 days to several weeks, depending on the environmental conditions (optimum: moist, warm, shaded soil). After infective eggs are ingested, the larvae hatch, invade the intestinal mucosa, and are carried via the portal vein to the lungs, where they undergo systemic circulation. The larvae mature further in the lungs (10 to 14 days), penetrate the alveolar walls, ascend the bronchial tree to the throat, and are swallowed. Upon reaching the small intestine, they develop into adult worms. Between 2 and 3 months are required from ingesting the infective eggs to oviposition by the adult female. Adult worms live for 1 to 2 years (CDC, 2019).

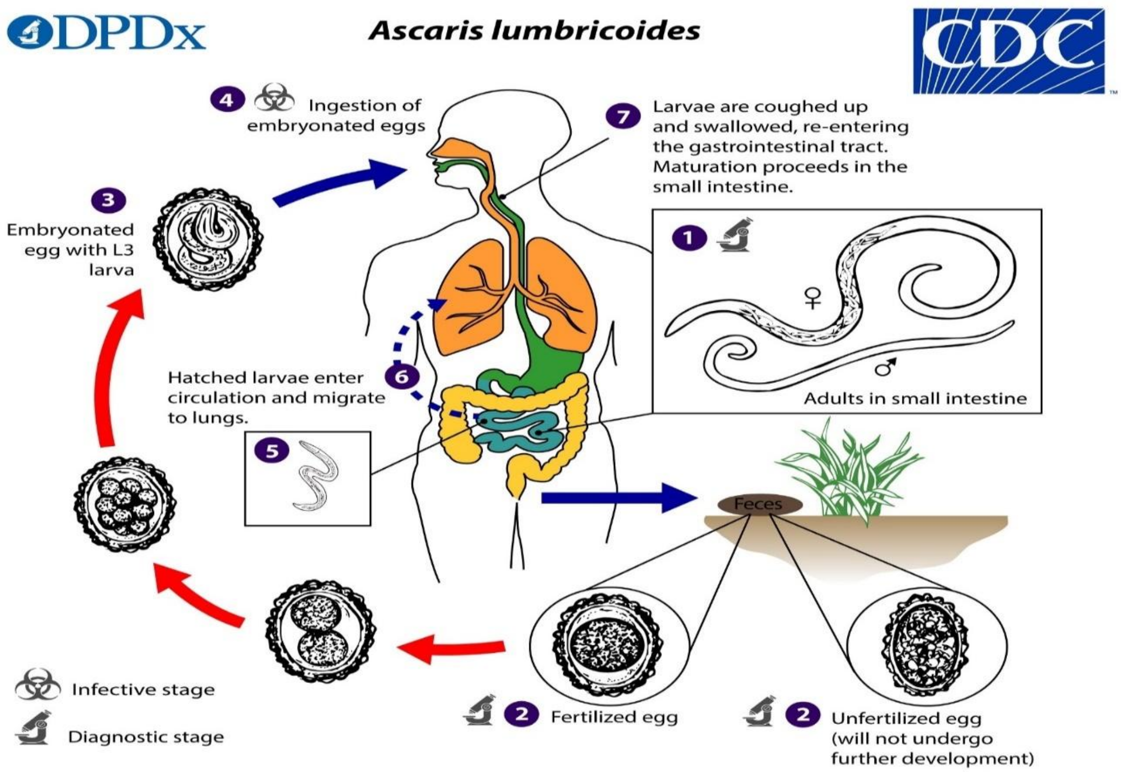

Figure 2.1: The life cycle of Ascaris lumbricoides

2.2.1.3 Trichuris trichiura

Trichuris trichiura, commonly known as the human whipworm due to its whip-like shape, is a nematode that inhabits the large gastrointestinal tract, particularly the caecum (Elsemore & Ketzis, 2021). Unlike Ascaris, whipworms adhere to the intestinal mucosa, inserting their thin anterior end into the epithelial tissue to feed on secretions (Ghoneim & Bakr, 2024). The posterior end extends into the lumen, and the worms can live between 1.5 and 2 years, with some infections lasting up to 8 years (Diakou et al., 2021).

Adult whipworms are 3-5 cm long, with females laying 3,000 to 20,000 eggs daily, about 60-70 days post-infection. The eggs are barrel-shaped with two polar plugs and are released in the host's faeces (Goulding et al., 2025). To become infective, the eggs must mature in humid soil for 2 to 4 weeks at 22 ºC, and development can take several months at varying temperatures (Boyko et al., 2025). Trichuris larvae are sensitive to temperature changes. Eggs of T. trichiura perish at -9 ºC or higher. While they cannot survive in dry conditions or direct sunlight, they can remain infectious for months or years in warm, wet soil (Abdu & Almu, 2023).

2.2.1.3.1 Life Cycle of Trichuris trichiura

The stool is excreted together with the embryonated eggs. The eggs grow into two-cell and advanced cleavage stages in the soil, after which they embryonate and become infectious within 15-30 days. Following ingestion (through hands or food contaminated with soil), the eggs hatch in the small intestine and release larvae, which then grow and mature into adults in the colon. Adult worms, approximately 4 cm long, reside in the ascending colon and caecum.

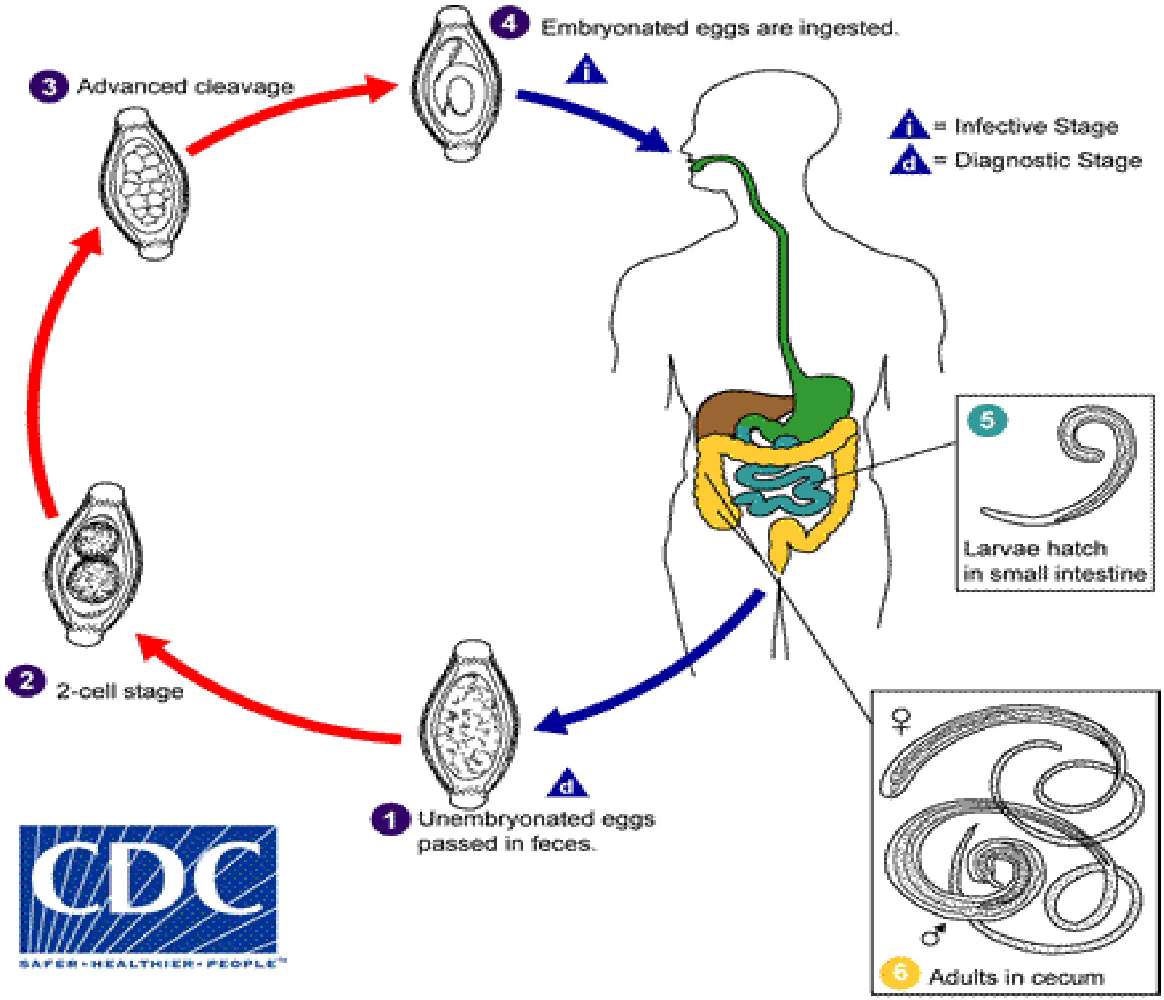

Figure 2.2: Life cycle of *T. trichiura*

2.2.1.4 Hookworms

Necator americanus, *Ancylostoma duodenale*, and *Ancylostoma ceylanicu*m are the three species that cause intestinal hookworm disease in humans (Servián et al., 2022). A. ceylanicum was once seen as primarily an animal parasite but is now recognised as an emerging threat to humans Zenebe et al., (2023). Historically, *A. duodenale and N. americanus* were considered the main global species (Clements & Alene, 2022). Both belong to the Strongyloidea superfamily and are widely distributed. *A. caninum* generally infects canids, but its larvae can cause eosinophilic enteritis in humans (M. D. Wilson et al., 2024). Their eggs are indistinguishable under a microscope. *N. americanus* primarily infects humans but can also be found in dogs. *N. americanus* and *A. duodenale* feed on their hosts' blood and tissues (Hawdon & Wise, 2021). A. duodenale typically lives for 5 to 7 years, although many die within 1 to 2 years, while *N. Americanus* can survive up to 20 years (Calder et al., 2022). Adult worms occupy the upper small intestine and use specialised oral structures to attach to the intestinal lining. *A. duodenale* females lay more eggs than *N. americanus* females, producing 10,000 to 25,000 eggs daily compared to 5,000–10,000 (Servián et al., 2022). Hookworm eggs, excreted in faeces, resemble Ascaris and Trichuris, characterised by transparent shells and embryonated stages (Montresor & Gabrielli, 2022). They develop optimally in sandy, shaded soils with high organic matter and temperatures of 23 to 33 ºC, becoming infectious L3 larvae after several growth stages (Feyera et al., 2022).

2.2.1.3.1. Life Cycle of Hookworms

The life cycle of the definitive host mirrors that of humans, involving tracheal migration to the small intestine. Certain larvae can accumulate in tissues and infect puppies through the mammary glands or placenta. Hookworm eggs hatch into larvae within one to two days, and after five to ten days and two moults, they become infectious filariform larvae, which can survive in the soil for 3 to 4 weeks. When they contact animal hosts, the larvae penetrate the skin, travel through the bloodstream to the heart and lungs, and are eventually ingested. In the small intestine, they mature into adults, attaching to the intestinal wall.

Some larvae can remain dormant in tissues and infect puppies, while filariform larvae can infect humans through skin penetration (CDC - DPDx - Zoonotic Hookworm, 2019).

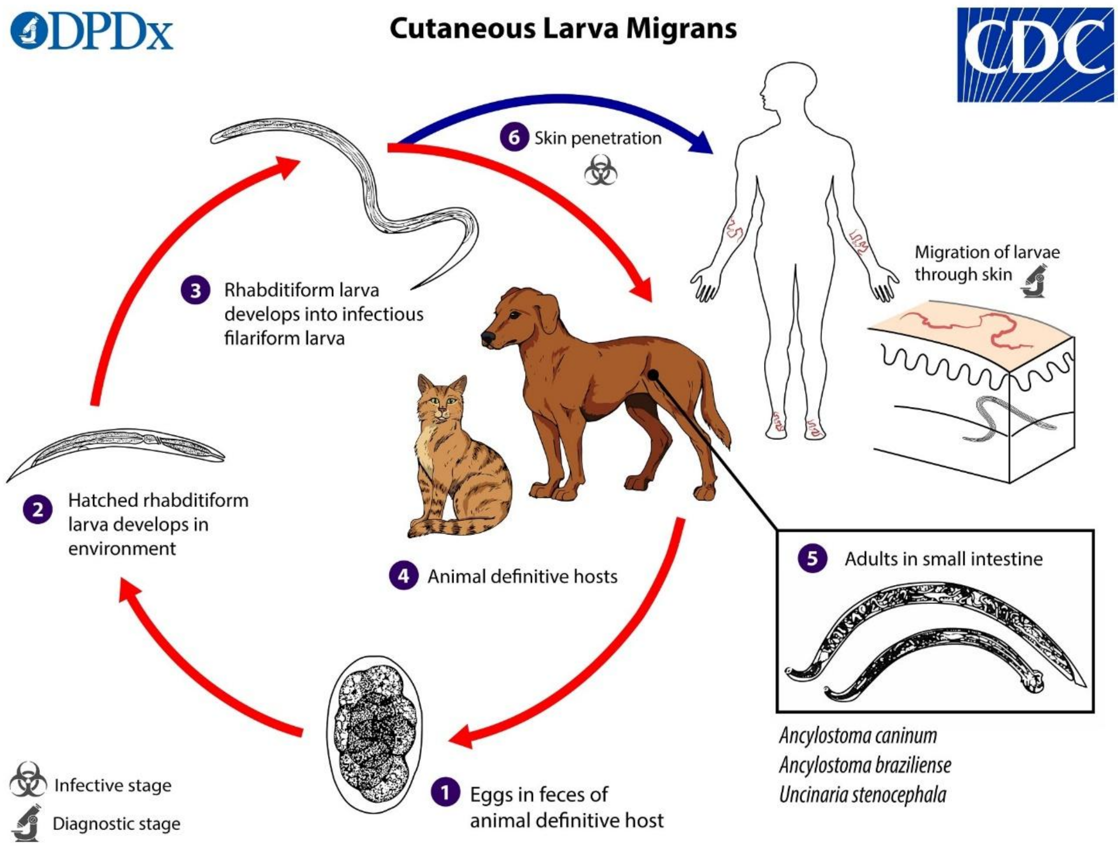

Figure 2.3: The life cycle of hookworms

2.2.1.2. Malaria

Female Anopheles mosquitoes, which carry malaria, bite humans to spread the disease (Markwalter et al. (2022). The disease is transmitted by the bite of a female Anopheles mosquito to the human host (Vantaux et al., 2021) is a blood parasite (Escalante et al., 2022). One hundred and fifty-six (156) different species of Plasmodium can infect various vertebrate animals (Gozalo et al., 2024). Five (5) species *P. falciparum, P. vivax, P. ovale,* *P. malariae,* and *P. knowlesi* are thought to be genuine human parasites as they virtually exclusively utilize people as their natural intermediate host (Vantaux et al., 2021). Nonetheless, there are infrequent cases of simian malaria parasites detected in humans; most of these studies involve *P. knowlesi* (Narapakdeesakul et al., 2023). It is unknown as of this writing whether *P. knowlesi* spontaneously spreads from person to person by mosquitoes in the absence of a natural intermediate host (Mohammad et al., 2022; Wilkerson et al., 2021).

2.2.1.2.1 Life Cycle of Malaria

The life cycle of the malaria parasite involves two hosts (Buchanan et al., 2022; Chora et al., 2023). A malaria-infected female Anopheles mosquito injects sporozoites into humans during a blood meal (Shaw et al., 2020). These sporozoites infect liver cells, grow into schizonts, and rupture to release merozoites. Notably, dormant hypnozoites can persist in the liver, potentially triggering relapses later (Gozalo, Robinson, Holdridge, Mahecha, et al., 2024). After replication in the liver (exo-erythrocytic schizogony), parasites replicate asexually in erythrocytes (erythrocytic schizogony) (Roques et al., 2023). Merozoites infect erythrocytes, transforming into ring-stage trophozoites that develop into schizonts, which in turn release more merozoites. Some transform into gametocytes (Ouologuem et al., 2023). The blood-stage parasites cause clinical symptoms (Good & Stanisic, 2020). During a blood meal, Anopheles mosquitoes ingest microgametocytes and macrogametocytes (CDC-DPDx, 2024). The process by which parasites multiply in mosquitoes is known as the sporogonic cycle. In the mosquito's stomach, microgametes penetrate the macrogametes and produce zygotes (Sekar et al., 2021). The zygotes then become motile and elongated (ookinetes), which invade the midgut wall and develop into oocysts (Ouologuem et al., 2023). The oocysts develop, burst, and release sporozoites that enter the mosquito's salivary glands (Hajkazemian et al., 2021). Inoculating sporozoites into a new human host continues the malaria life cycle (Simwela & Waters, 2022).

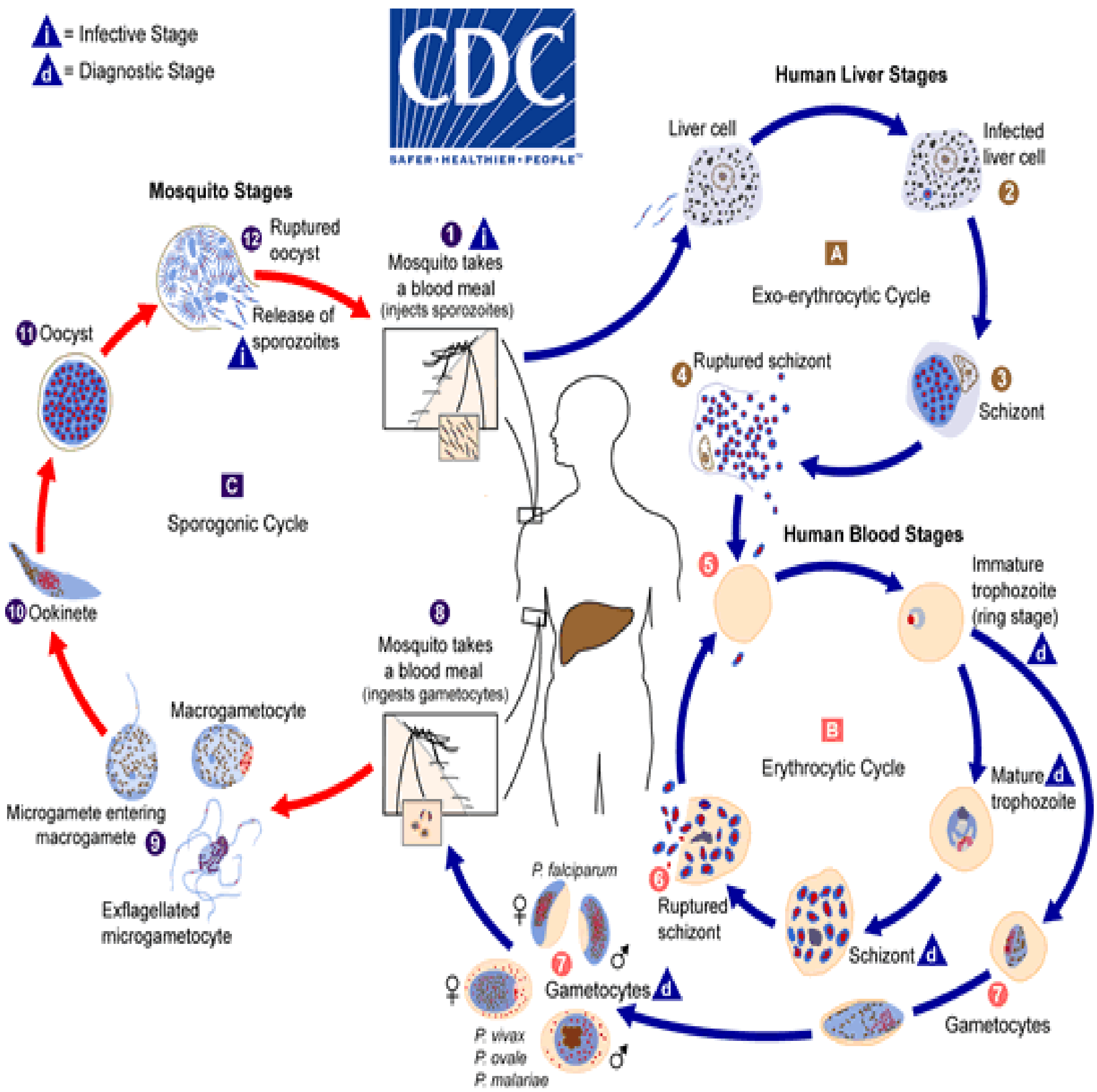

Figure 2.4: The life cycle of malaria

2.3 Empirical Review

2.3.1 Epidemiology of Helminthiasis Infection

2.3.1.1 Global Epidemiology

Soil-transmitted helminths (STH) are a group of intestinal parasites that are most commonly referred to as *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm), and the hookworm species, *Necator americanus, and Ancylostoma* (Yu & Blackburn, 2019). (including *A. duodenale* and *A. ceylanicum*). An estimated 1.5 billion individuals, or 24% of the global population, are believed to be affected by soil-transmitted helminth (STH) infections, making them among the most prevalent illnesses globally (Chen et al., 2024). Approximately 1.2 billion and 740 million persons worldwide are infected with roundworms and hookworms, respectively (Joyce, 2022). Little study has been conducted on the threadworm (*Strongyloides stercoralis*), another STH frequently linked to significant morbidity in various contexts (Neto et al., 2023). In tropical and subtropical regions, these diseases primarily affect the poorest populations; sub-Saharan Africa, China, South America, and Asia have the highest infection rates (WHO, 2024). In areas with poor human hygiene, eggs from humans contaminate the soil (Delaluna et al., 2020).

In areas where parasitic organisms are widespread, there are approximately 267 million preschool-aged children, 654 million school-aged children, 108 million teenage girls, and 138.8 million expectant and nursing mothers (WHO, 2023). These populations require treatment and prevention measures (Pasaribu et al., 2019). Around 600 million people are believed to be infected with *S. stercoralis* globally; however, due to the parasite's ability to spread in unsanitary environments, its geographic range coincides with that of another helminthiasis transmitted through soil (WHO, 2023). Children who contract infection may experience changes in their appetite, growth, physical fitness, nutrition, and cognitive function, affecting their academic performance and prolonging the poverty cycle (Fauziah, et al.,2022).

2.3.1.2 Epidemiological Patterns in African Populations

In sub-Saharan Africa, where poverty, limited access to clean water, and inadequate sanitation infrastructure continue to be prevalent, soil-transmitted helminths (STH) are still widely distributed (Franz, 2023; Owada, 2019). Children are particularly vulnerable to illnesses, causing malnutrition, anaemia, and cognitive decline (Segoviano-Lorenzo et al., 2022). Currently, millions of African children remain susceptible to infection despite control measures (Raj et al., 2022). By 2018, 2.9 million children aged 5-14 years had moderate-to-heavy STH infections, out of almost 35 million children who had at least one form of infection (Tadege et al., 2022). Most cases were found in southern Nigeria, eastern Madagascar, western-central Ethiopia, and southern Africa. Notwithstanding these obstacles, the probability of contracting an infection has dramatically decreased over the past 20 years, and 72% of endemic areas are predicted to meet the WHO 2030 target of reducing the proportion of moderate-to-heavy infections in children to 2%. The areas with the highest infection rates are still Madagascar, South Africa, Guinea, Ethiopia, Mozambique, and Central Africa (WHO, 2023).

2.3.1.3 Epidemiology Pattern in Ghana

The predominant cause of helminthiasis in Ghana is soil-transmitted helminths (STH), which is a serious public health concern, particularly in rural areas (Akosah-Brempong et al., 2021; Aribodor et al., 2023). *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworms are the 3 main helminth species (Alexander & Blackburn, 2019). Because they are spread by contaminated soil, these diseases are more common in areas with inadequate sanitation and hygiene (Abe et al., 2019). Children in rural regions are disproportionately affected because they come into frequent contact with toxic soil (Aribodor et al., 2023). According to recent studies, Ghana has reduced the prevalence of moderate-to-heavy infections through more effective public health initiatives and mass drug administration (MDA) programmes (Gebreyesus et al., 2023). Still, in certain areas where poor water supply and sanitation persist, pockets of high transmission persist. These locations are in the northern and forested regions (Chandrasena et al., 2023). Community health education and school deworming programmes are two measures used in Ghana to address helminthiasis (Ouédraogo & Addo-Lartey, 2024). The demand for more regular data collection and monitoring is increasing to follow advancements and identify high-risk regions for targeted interventions (Wong et al., 2020).

2.3.2 Epidemiology of Malaria

2.3.2.1 Global Epidemiology

An estimated 249 million malaria cases were reported in 85 endemic countries in 2022, representing a five million-case increase from 2021. In the 108 countries where malaria was endemic in 2000, the total number of cases decreased from 243 million in 2000 to 230 million in 2014, notwithstanding fluctuations in case numbers (WHO, 2023). However, malaria infections have been increasing since 2015. Between 2019 and 2020, the annual increase was 11 million cases (Li & Managi, 2022). The WHO African Region has seen the most significant increase in percentage during the last five years. The COVID-19 pandemic-related disruptions to preventative and control measures were a significant factor in the increase in cases in 2020 (Salyer et al., 2021). Similarly, malaria mortality increased by 10% in 2020 compared with 2019 but declined to 619,000 in 2021(M. P. Singh et al., 2024). Insecticide-treated bed net distribution initially decreased during the epidemic but subsequently increased due to initiatives such as home delivery (Okumu, 2020).

2.3.2.2 Epidemiological Patterns in African Populations

In 2022, the African continent accounted for 94% of global malaria cases, with an anticipated 233 million cases and 95% of malaria-related deaths (a total of 580,000. Nigeria, Ethiopia, and Uganda were the most affected countries, with increasing case counts despite disease management measures (WHO, 2023). Vulnerable groups, such as children under 5 years old and pregnant women, continue to face the highest risk of severe malaria and mortality (Palmeirim et al., 2021). Malaria transmission in Africa is primarily driven by the *Plasmodium falciparum* parasite, which is transmitted by Anopheles mosquitoes. Sub-Saharan Africa is particularly heavily affected due to the suitable environmental conditions that favour the mosquitoes (Goupeyou-Youmsi et al., 2020). Even though tremendous progress had been made in lowering the number of malaria cases and deaths before 2020, control efforts were disrupted by the COVID-19 pandemic, which led to a rise in incidence due to reduced access to anti-malarial medications and insecticide-treated nets (ITNs) (Salyer et al., 2021). Despite these obstacles, novel interventions, including the malaria vaccine and RTS, which were first used in nations like Ghana, Kenya, and Malawi, are being expanded (Adjei et al., 2024). Additional important interventions include enhanced surveillance to combat emerging threats, such as insecticide resistance and the spread of *Anopheles stephensi*, a mosquito species that is spreading throughout African cities. Seasonal malaria chemoprevention is also crucial, especially in areas with high seasonal transmission (Whittaker et al., 2023).

2.3.2.3 Epidemiological Patterns in Ghana

In Ghana, malaria is an endemic disease that accounts for 40% of all outpatient hospital visits (Bonful et al., 2019). Microscopy tests revealed that 8.6% of children in Ghana aged 6-59 months have malaria, according to the 2022 Ghana Demographic and Health Survey (DHS). The incidence rate is nearly three times higher in rural areas (12.8%) than in urban areas (4.3%). The Greater Accra region has the lowest malaria frequency (2.0%), followed by the Western North (4.4%) and the Volta (6.4%). Nonetheless, the Oti region (15.0%), Upper West (13.4%), and Upper East (12.2%) had the highest prevalence. In half of Ghana’s 16 regions, the prevalence of malaria exceeds 10% (GSS, 2023).

Various factors influence disease frequency, including the population at risk, environmental conditions, vectors, and implemented controls (A. L. Wilson et al., 2020). *Anopheles gambiae* and *Anopheles funestus* are the primary malaria vectors in Ghana; as industrialisation increases, Anopheles gambiae, the primary vector, becomes more prevalent (Zoloth, 2023). Elements such as vegetation, height, climate, and control methods influence the degree of suitability of the environment for mosquito vectors (Madzokere et al., 2020). Before becoming contagious to other people, *P. falciparum*, if transferred from an infected human to a female mosquito, undergoes a temperature-dependent extrinsic incubation stage (Kawaguchi *et a*l., 2022).

One of the high-burden nations in the African Region, Ghana, has embraced the WHO malaria treatment strategy, updating and modifying it each time it is evaluated (Patel et al., 2024). The nation has followed the same procedures for net treatment, indoor spraying, and larval source management, and all of its malaria policy documents are current and being followed (Matthews, 2011). In practical terms, the World Health Organisation's (WHO) assistance to Ghana from 2015 to 2021 has helped protect more than 12.8 million people through indoor spraying, treat 30.7 million people with artemisinin-based combination therapies (ACTs), and make it easier to obtain 36.6 million rapid diagnostic test kits and 58 million insecticidal nets delivered (WHO, 2023).

2.3.3 Helminthiasis and Malaria Co-infection

Akosah-Brempong et al. (2021) in both Southern and Northern Ghana highlighted the high prevalence of malaria and helminth co-infection among school children (Afolabi et al., 2021). The most frequent coinfections involved intestinal helminths. Globally, ≥ 3.5 billion people are believed to be infected, and 450 million clinical cases are reported annually, many of which occur in children from impoverished areas (Zenebe et al., 2023). Co-infections with *Plasmodium falciparum* and helminths were more common in children born to mothers with both infections than in those with *P. falciparum* alone (Tadesse Boltena et al., 2022). Contributing factors to these coinfections include poverty, limited access to proper diagnosis and treatment, inadequate environmental management, poor sanitation, low socioeconomic status, insufficient education, and a lack of effective malaria control measures (Goshu et al., 2021). Furthermore, humid climates promote the survival of mosquito vectors and the free-living stages of infectious helminths (Yadav & Upadhyay, 2023).

2.3.4 Risk Factors of Helminthiasis and Malaria

Malaria and helminthiasis share several risk factors and are prevalent in tropical and subtropical areas (Sumbele et al., 2020). Contaminated food, water, and soil are the main ways that poor sanitation and hygiene contribute to helminthiasis (Vaz Nery et al., 2019; Shrestha et al., 2020). Open defecation and inadequate sewage infrastructure also increase this vulnerability (Saleem et al., 2019). Exposure to mosquitoes is a risk factor for malaria, especially in areas with stagnant water and warm, humid conditions that favour *Anopheles* mosquito breeding (Liatu, 2019). Susceptibility is increased when preventative measures like insecticide-treated bed nets (ITNs) and repellents are not used (Tungu, 2024). Prevention and treatment are complex because of socioeconomic issues, such as poverty and restricted access to healthcare (McMaughan et al., 2020). Particularly vulnerable are pregnant women, children under 5 years, and visitors to endemic areas (Habimana, 2022). Weak malaria control initiatives, treatment resistance, and seasonal rainfall all contribute to the spread (Ryan et al., 2020).

2.3.5 Transmission of Helminthiasis

Soil-transmitted helminths spread through eggs present in the faeces of infected individuals. These worms lay thousands of eggs every day and live in the intestines (Abe et al., 2019). The eggs contaminate the soil in areas with inadequate sanitation, such as eating veggies that have eggs in them because they were not well cleaned or cooked, drinking contaminated water, and children placing their dirty hands in their mouths while playing in mud that contains eggs (Ruth et al., 2021). After their eggs hatch in the soil, hookworm larvae develop into a stage where they may penetrate human flesh (Servián et al., 2022). It is common to get infected by walking barefoot on contaminated soil (Zuchaliya et al., 2021). It takes around 3 weeks for the eggs to become infectious in the soil; thus, transmission does not happen directly between people or through recently passed excrement (Caldrer et al., 2022). Reinfection is only possible through contact with the infectious stages of parasites such as *A. lumbricoides*, *T. trichiura*, and hookworms in the environment; these parasites do not reproduce within the human host (Lebu et al., 2023). However, *S. stercoralis* can multiply inside its host, and unchecked growth can be lethal in people with compromised immune systems (Vasquez-Rios et al., 2019). Overwhelming rainfall and a tropical climate can contribute to the spread of these illnesses (Ellwanger et al., 2020).

2.3.6 Malaria Transmission

Malaria is transmitted through the bite of infected female *Anopheles* mosquitoes, which act as vectors for the disease (Islam et al., 2023). These mosquitoes become infective after biting a person already carrying malaria parasites (Graumans et al., 2020). malaria can also spread through blood transfusions, organ transplants, shared needles contaminated with infected blood, or congenitally from mother to child during pregnancy (Paul, 2024).

2.3.7 Malaria Preventive Interventions

Malaria is transmitted through the bite of infected female *Anopheles* mosquitoes, which act as vectors for the disease (Yu et al., 2022). Using insecticide-treated nets is a proven and effective way to protect people from mosquito bites, particularly at night when mosquitoes are most active (Nkrumah et al., 2024). Insecticides sprayed indoors also aid in lowering mosquito populations (Pryce et al., 2022). Additionally, susceptible groups such as pregnant women and travellers may receive preventive medicine (McGuinness & Steffen, 2021). Another crucial step in lowering the spread of malaria is to cut down on standing water to limit mosquito breeding grounds (Lindsay et al., 2021).

2.3.8 Helminthiasis Preventive Interventions

Intestinal parasitic worms, roundworms, hookworms, and whipworms are the cause of helminthiasis (Else et al., 2020). The primary purpose of prevention is to reduce the spread of disease by practising better sanitation and hygiene (Brown et al., 2013). Frequent mass deworming efforts, particularly in schools, aid in lowering childhood infection rates (Karutu et al., 2022). Essential actions include facilitating access to clean water, encouraging the use of restrooms, and fostering good handwashing practices(Berendes et al., 2022). Additionally, especially in unsanitary locations, wearing shoes can help reduce soil-transmitted helminth infections (Rosyidah et al., 2024).

2.4 Theoretical Review

2.4.1 Socio-Ecological Model (SEM)

The socio-ecological model (SEM) was developed in urban studies by sociologists from the Chicago School after World War I. In the 1980s, Urie Bronfenbrenner introduced the Ecological Framework for Human Development (Iorkosu et al., 2025). This model employs a systems-level approach, providing a theoretical framework for addressing several behaviour. The model posits that the individual and the environment are reciprocal; thus, the individual influences their environment and vice versa. It also postulates that the environment comprises multiple levels, including the individual, interpersonal relationships, the community and policy.

i. Interpersonal Level: Relationships with family, peers, and teachers significantly influence health behaviours. Parents' practices and the health education provided by teachers are crucial for promoting preventive measures against various diseases.

ii. Community Level: Factors within the community, such as sanitation, cultural norms, and access to healthcare, play a vital role in the prevalence of these diseases. Conditions like open defecation and stagnant water contribute to increased transmission rates.

iii. Organizational Level: Schools and healthcare facilities influence health outcomes through their policies and programs, including deworming initiatives and malaria prevention campaigns. These campaigns affect disease prevalence and the level of health knowledge in the community.

iv. Policy Level: National and regional health policies determine the availability of prevention and treatment programs. Initiatives such as mass drug administration and enhanced sanitation have a direct impact on disease prevalence and the integration of health education.

2.5 Conceptual Framework

The conceptual framework is based on the socio-ecological model. This model posits that the individual and the environment are reciprocal; thus, the individual influences their environment and vice versa. Helminthiasis and malaria infection are influenced by environmental and behavioural risk factors, including poor sanitation, cultural norms, and access to healthcare, which significantly impact the prevalence of these diseases. Conditions like open defecation and stagnant water contribute to increased transmission rates.

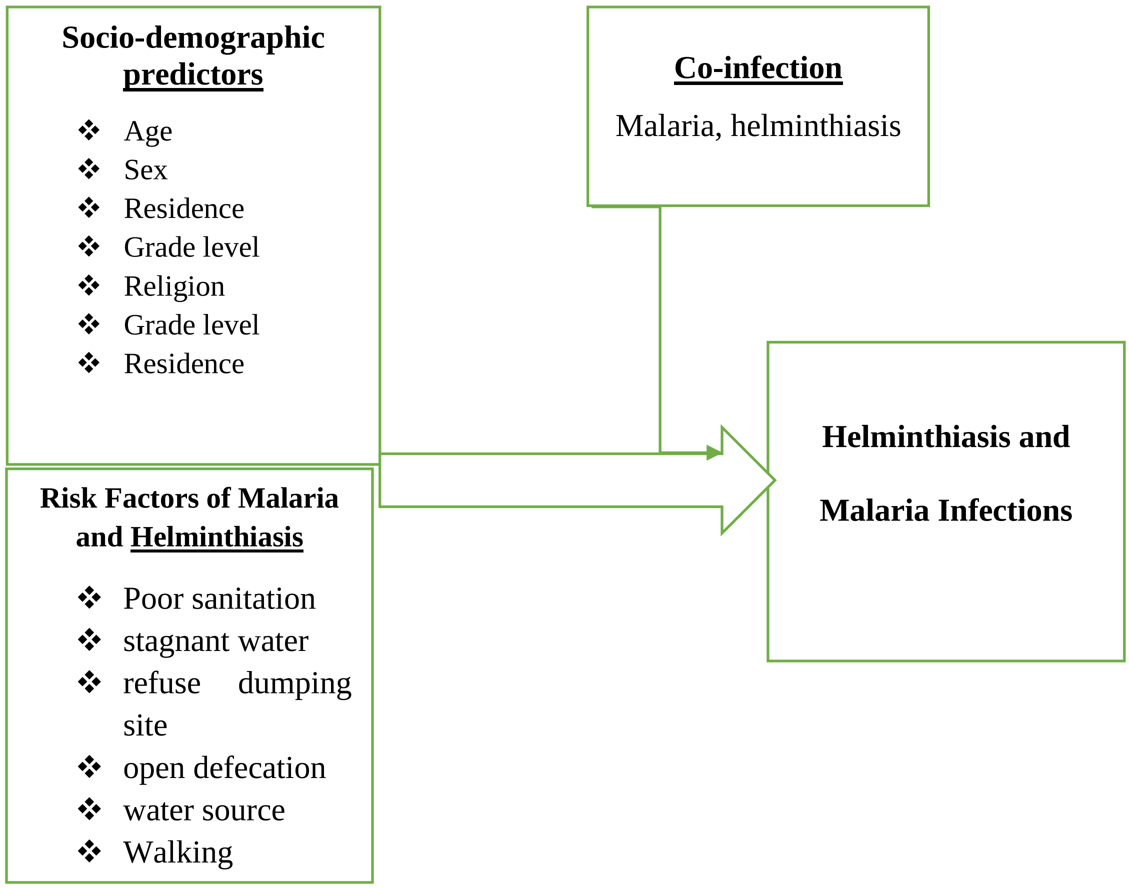

Figure 2.5: Conceptual Framework

Source: Author's construct (2024)

CHAPTER THREE

METHODOLOGY

3.1 Study Design

A school-based cross-sectional study was conducted from August to September 2024 to assess the prevalence and risk factors associated with malaria co-infection and intestinal helminthiasis among schoolchildren in Bibiani/Anhweaso/Bekwai Municipal, Western North Region, Ghana. Primary data was generated through laboratory analyses of samples collected in the field.

3.2 Study Area

The study was conducted in the Bibiani/Anhwiaso/Bekwai Municipal. The administrative capital of the municipality is Bibiani. The municipality is located in the western north region and the northeastern part of the western region. It lies between latitudes 6°N and 3°N, and longitudes 2°W and 3°W. The total land area of the municipality is 873 square kilometres. Bibiani is about 88 kilometres (km) from Kumasi in the Ashanti region and 356 km from the western capital of Sekondi. It is 218.99 meters (718.47 feet) above sea level and has a tropical wet and dry or savanna climate (Classification: Aw). The annual average temperature in the area is 32.04 °C (89.67°F). The region receives about 130.3 mm (5.13 inches) of precipitation annually, and rainy days occur on about 286.61 days annually, accounting for about 78.52% of the time. The 2021 population and housing census data revealed that the municipality has a population of 167,971, comprising 82,798 men and 85,173 women. Most people in the area speak the Sefwi language. Farming is a primary occupation for many people seeking a livelihood. Others include miners, civil servants, and traders. Some primary water sources for drinking and other domestic needs are boreholes, pipe-borne water, and public taps/Standpipes. Some residents also rely on rivers or streams as sources of water for human consumption. Poor sanitation and waste management are significant challenges in specific communities within the municipal area. Some of these challenges include the indiscriminate disposal of solid and liquid waste, as well as the lack of toilet facilities, which leads to open defecation among some people in the municipal area.

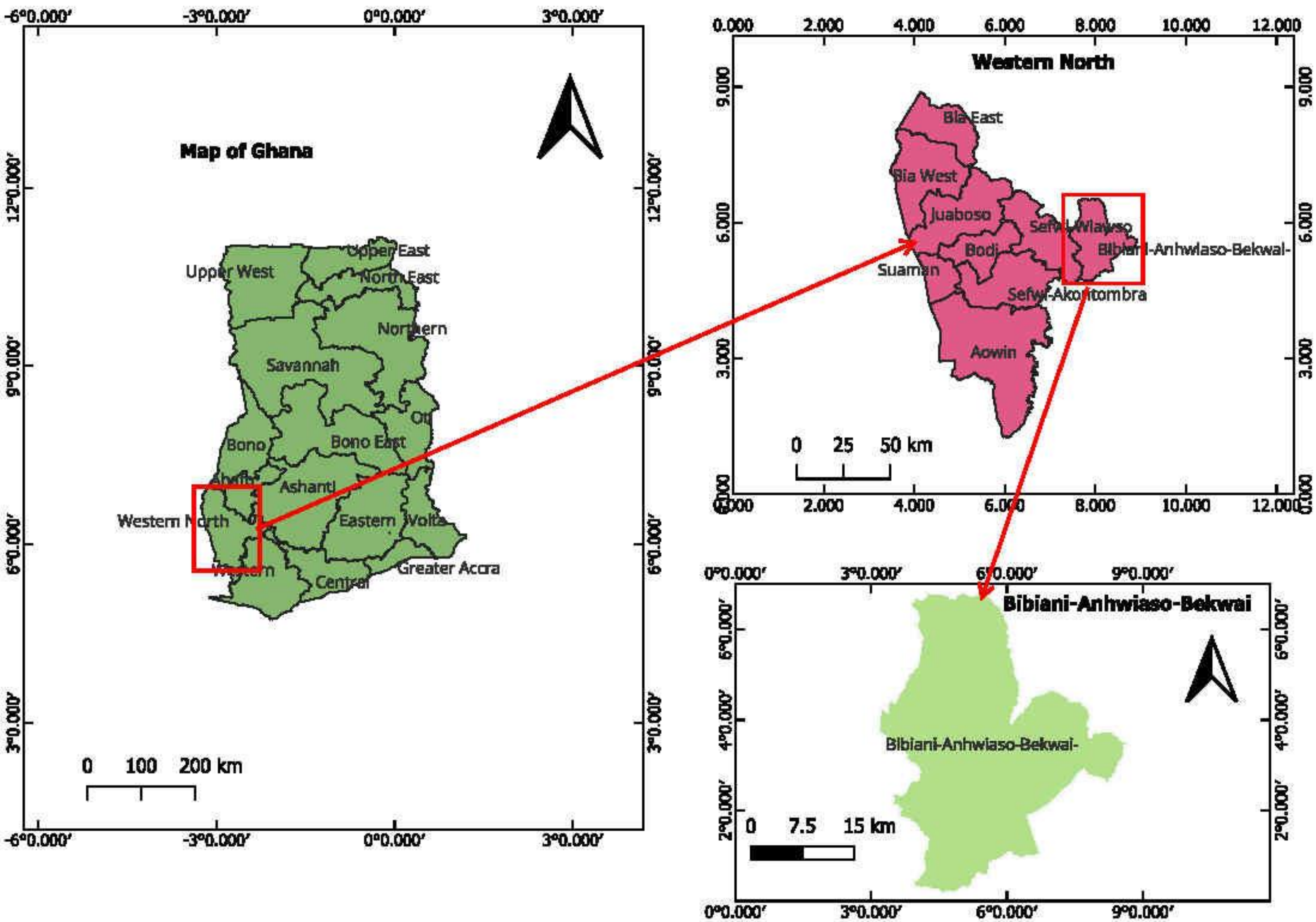

Figure 3.1: Map of Study Area.

3.3 Study Population

The study population included primary school children aged 5-14. This age group included young children aged 5-7, 8-10, and 11-14 years old. This age group consisted of early adolescents.

3.4 Eligibility Criteria

3.4.1 Inclusion Criteria

Children aged 5-14 years from pre-selected schools were considered for the study. Among children in this age group, only those whose parents, guardians, and/or teachers consented to their involvement in the study were involved in the current study. In addition, only children who had not received antihelmintic and antimalarial treatment within the previous 6 months were eligible for recruitment. Children aged 5-14 were recruited since they exhibited heightened vulnerability to helminth infections and malaria due to various factors, such as the level of their immune system development, exposure to contaminated environments, and limited access to preventive measures and healthcare services (Fauziah, Aviani, et al., 2022).

3.4.2 Exclusion Criteria

Children under 5 years and those over 14 years were excluded due to developmental differences that affect their vulnerability to co-infection. Those whose parents, guardians, or teachers refused to give informed consent and those who had received anthelmintic and antimalaria treatment within the 6 months before the study period was also excluded.

3.5 Sampling Technique

A simple random sampling technique was used to select six primary schools from a total of 97 public primary schools in the municipality. The primary schools included were Bibiani Old-Town Municipal Assembly (M/A), Hwenampori M/A, Nkatieso M/A, Anhwiaso Methodist, Aboabo M/A, and Kwamekrom M/A primary. Simple balloting was used to select participants, who were identified by small pieces of paper bearing unique numbers. The allocation of school children was proportional to the number of primary school pupils enrolled.

3.6 Sample Size Determination

The sample size consisted of 333 schoolchildren chosen from 6 public primary schools in the municipality. This is obtained using the Slovene selection formula.

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

Where n is the sample size, N is the specific population, and e is the margin of error (0.05)

$$\frac{1535}{1+1535(0.05)^2}$$

$$\approx 317$$

To compensate for non-response, an attrition rate of 5% of the calculated sample size, which is approximately 15.8, rounded to the nearest whole number, resulted in a total sample size of 333.

Table 3.1: Distribution of sample size across the study site

Primary schools	Population	Proportion (%)	Estimated Sample Size	Approximate sample size
Bibiani old-town M/A	244	15.9	52.9	53
Hwemampori M/A	263	17.1	56.9	57
Nkatieso M/A	235	15.3	50.9	51
Anhwiaso Methodist	235	15.3	50.9	51
Aboabo M/A	277	18.1	59.9	60
Kwamekrom M/A	281	18.3	60.9	61
TOTAL	**1535**	**100**	**332.5**	**333**

3.7 Data Collection Tools

A structured questionnaire was used to collect data on demographic traits and risk factors for helminthiasis and malaria infection from the participants. Microscope glass slides were used to prepare both thick and thin blood smears. A disposable blood lancet was used for finger-prick blood samples. A stool container, a metal sieve, and a template containing 41.7 mg were also used.

3.7.1 Pre-Test

The questionnaires were pre-tested. This enabled the identification of errors and unclear questions and the correction of the questions involved before field data collection.

3.7.2 Questionnaire Administration

The data were collected using printed, closed-ended, structured questionnaires that included socio-demographic characteristics and potential risk factors for co-infection with helminthiasis and malaria. The questionnaire was prepared in English and then translated into the local language (Twi) during the administration period. The questionnaire was used to collect demographic information, such as sex, age, residence, and grade level. The risk factors for malaria infections, including the use of insecticide-treated nets (ITNs), indoor residual spraying (IRS), outdoor sleeping, and environmental conditions, were surveyed. Likewise, the risk factors associated with developing soil-transmitted helminthiasis (STH) infection were studied. These include inadequate sanitary facilities, hygienic practices such as not washing hands after using the toilet, an unsafe water supply, and a low socioeconomic status.

3.7.3 Laboratory Parasitological Examinations

Thick and thin smears were prepared with finger-pricked blood to assess malaria. Stools were used to detect eggs of intestinal parasites via the wet preparation Kato-Katz method.

3.7.3.1 Blood Sample Collection

Finger-prick blood samples were collected from school children to examine for malaria parasites using a disposable blood lancet.

Plate 3.1: Collection of blood samples

3.7.3.2 Preparation of Blood Smears and Microscopy Examinations for Malaria Parasite

The participants provided capillary blood samples through a finger prick. The finger was cleansed with an alcohol-moistened swab and dried with a piece of cotton. Then it was punctured with a disposable blood lancet**.** Thick and thin blood smears were prepared and examined to detect malaria parasites. Each slide was labelled correctly to indicate the corresponding child. The smears were air-dried and fixed with 70% methanol for 30 s.

The thick smear was stained with Giemsa solution, and the thin smear was stained with 3% Giemsa for 30 min. The slide was rinsed with distilled water and allowed to air dry. Giemsa was used as the standard stain for staining blood films for malaria diagnosis, and blood film microscopy was performed, as it is a basic method and the gold standard for diagnosing malaria. Staining and blood film examinations were performed following the standard protocol of the World Health Organisation (WHO) [World Health Organisation, 2022].

Plate 3.2: Giemsa-stained preparation

The presence of malaria parasites in thick blood smears was examined using a high-power magnification objective (40x) of microscopy. Specific *Plasmodium* species, such as *P. falciparum*, *P. vivax*, or mixed malaria parasites, were identified using thin blood smears under oil immersion at 100x objective. Each child was evaluated once. Two experienced laboratory scientists individually examined the microscopic slides at the Bibiani Municipal Hospital laboratory. The discrepancy between the first and second readings was resolved by a third senior and experienced laboratory technician, whose readings were considered final in the positive check for the intensity of infection. Thick blood smears were used to detect malaria infection, whereas thin smears were used for species identification and quantification.

Plate 3.3: Microscopy examination of *Plasmodium* species

3.7.3.3 Processing of Stool Specimen for STH Identification

Each participant was given a screw-capped stool container with a unique identification code and instructions on how to collect about five grams of faeces samples. After the faeces were taken from the children, they were processed immediately. Stool samples were brought to the Parasitology Laboratory of Bibiani Municipal Hospital. Helminths in stools were identified and quantified using wet preparation and Kato-Katz methods (Katz et al., 1972).

3.7.3.4 Wet Preparation Method

An estimated 1 g of freshly collected faeces was placed on two ends of a glass slide with a drop of normal saline. The two ends were covered with coverslips and viewed under a light microscope for the presence of helminth eggs (WHO, 2023c). About 41.7 mg of each sample was examined via the Kato-Katz method. The thick smears of stools were prepared using a high-power magnification objective (40x) to identify helminth eggs (*T. Trichiura*, *A. lumbricoides,* and hookworm). Since hookworm eggs cleared quickly, microscopy was completed within one hour of collecting the sample.

The faeces were first passed through a 250-m metal sieve to remove the fibrous material. A template containing 41.7 mg of faeces was filled with stool and placed on microscope slides. To ensure sample distribution on the slide and drying of the surplus solution on blot paper, the double slides were then covered with a piece of cellophane soaked in glycerine malachite green solution and flipped upside down. After an hour, the slides were examined under a microscope to detect soil-transmitted helminths (STHs). After counting the eggs observed, the two microscopists resolved any differences in their findings. The degree of infection was assessed using parasite-specific egg counts, which were then multiplied by a factor of 24 to convert the count to eggs per gram (EPG) of faeces (WHO, 2023). The WHO's recommended thresholds were used to classify infection intensity: *A. lumbricoides*; *T. trichuriasis*, low (1-4,999), moderate (5,000-49,999), or high (>50,000) (WHO, 2023c).

Plate 3.4: Stool sample preparation and microscopy examination of helminthic eggs

3.7.4 Study Variables

3.7.4.1 Dependent Variable

The dependent variables were helminthiasis and malaria.

3.7.4.1 Independent Variables

Sex, age, place of residence, grade level, religion, indoor residual spraying (IRS) usage, outdoor sleeping or activities, bed net usage, mosquito breeding sites, environmental sanitation, and hygienic practices.

3.8 Data Analysis Process

The data were checked for completeness and then analyzed using Microsoft Excel 2016 and the R Studio software package version 2025.05.1+513. Descriptive analysis was presented using frequency tables. A comparison of the prevalence of helminthiasis and malaria co-infection between dependent and independent variables was performed using a chi-square test. Logistic regression analyses were also performed to assess the association between malaria and helminth co-infection, sociodemographic predictors, and related risk factors. Odds ratios with their 95% confidence intervals were used to identify the presence and strength of association, and statistical significance was indicated by p-value ≤ 0.05.

3.8.1 Ethical Clearance

Ethical clearance was obtained from the Committee on Human Research, Publication, and Ethics (CHRPE) at the School of Medical Sciences (SMS), College of Health Sciences, Kwame Nkrumah University of Science and Technology (KNUST), Reference: CHRPE/AP/698/24, Kumasi, Ashanti Region, Ghana. Permission from the Bibiani/Anhwiaso/Bekwai Municipal Health Directorate, Education Director and the Headmasters of the various primary schools through an introductory letter from the AAMUSTED, Department of Public Health Education. Permissions were obtained from other relevant authorities for the collection of data. Parents, guardians, and participants were fully informed about the study's objectives, rights, and the voluntary nature of their involvement. They were also assured of confidentiality throughout the study; each questionnaire was coded with serial numbers instead of the participants' names.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results of the current study and discusses them in relation to other studies. The results of this research are presented in four major categories: demographic information of participants, prevalence of malaria and helminthiasis co-infection, socio-demographic predictors of the prevalence of malaria and helminthiasis infection, and risk factors of helminthiasis and malaria among school children.

4.1 Profile of Respondents

A total of 333 study participants were recruited for the study. Out of the participants, 55.0% were males, and 45.0% were females. The majority (48.0%) of participants were between 8 and 10 years old, whereas 27.3% were between 11 and 14 years old. Rural dwellers comprised 61.3% of the population, while urban dwellers accounted for 38.7%. Pupils in Primary Three were 18.0%, and 13.5% for Primary Six. Most (73.3%) were Christians, and 0.9% were of other religions. (Table 4.1)

Table 4.1: Demographic characteristics of study participants

Variable	Frequency	Percentage (%)
Study Site		
Bibiani Old Town Primary	53	15.9
Hwenampori M/A Primary	57	17.1
Anhwiaso Methodist Primary	51	15.3
Aboabo M/A Primary	60	18.1
Nkatieso M/A Primary	51	15.3
Kwamekrom M/A Primary	61	18.3
Sex		
Male	183	55.0
Female	150	45.0
Age		
5-7	82	24.6
8-10	160	48.0
11-14	91	27.3
Residence		
Peri-urban	129	38.7
Rural	204	61.3
Class/Level		
Primary 1	56	16.8
Primary 2	58	17.4
Primary 3	60	18.0
Primary 4	56	16.8
Primary 5	58	17.4
Primary 6	45	13.5
Religion		
Christianity	244	73.3
Islam	86	25.8
Other	3	0.9

Source: Field Survey (2024)

4.2 Distribution of Malaria Prevalence among Study Participants

Distribution of malaria prevalence across demographic factors is shown in Table 4.2. Of the 333 participants tested for malaria, 55 were positive, resulting in a prevalence of 16.5%. Nkatieso M/A Primary had the highest proportion at 25.5%, while Bibiani Old Town Primary had the lowest at 9.4%. These higher rates may be related to local environmental factors that support mosquito breeding or increased exposure to vectors. Although there was variation among schools, the statistical analysis did not reveal a significant difference in malaria prevalence ($\chi^2 = 6.05$, $p = 0.301$). The prevalence among males and females was 20.2% and 12.0%, respectively, and this difference was statistically significant ($\chi^2 = 4.03$, $p = 0.04$). The 8–10-year age group had the highest prevalence at 21.9%, while the 5-7-year group had the lowest at 10.98%, with a significant difference ($\chi^2 = 6.45$, $p = 0.03$). Children living in rural areas showed the highest prevalence at 19.6%, compared to 11.6% in predominantly rural areas, which was significant ($\chi^2 = 3.65$, $p = 0.05$). The primary 3 children had the highest prevalence of 26.7%, while the Primary 6 children had the lowest at 11.6%, with an insignificant difference ($\chi^2 = 7.8$, $p = 0.16$). The prevalence among Muslims was 24.42%, compared to 13.93% among Christians, and this difference was significant ($\chi^2 = 5.67$, $p = 0.05$).

Table 4.2: Prevalence of malaria among Study Participants

Category	Total Tested	No. Negatives	No. Positives	% Positives (95%CI:)	Chi-Square	D.F.	P-value
Study Site							
Bibiani Old Town Primary	53	48	5	9.43 (3.1-20.7)			
Hwenampori M/A Primary	57	49	8	14.04 (6.3-25.7)			
Anhwiaso Methodist Primary	51	41	10	19.61 (9.8-33.1)			
Aboabo M/A Primary	60	52	8	13.33 (5.9-24.5)	6.053	5	0.30
Nkatieso M/A Primary	51	38	13	25.49 (14.3-39.6)			
Kwamekrom M/A Primary	61	50	11	18.03 (9.4-29.9)			
Total	***333***	***278***	***55***	***16.52***			
Sex							
Male	183	146	37	20.22 (14.6-26.7)	4.03	1	**0.04**
Female	150	132	18	12.00 (7.3-18.3)			
Total	***333***	***278***	***55***	***16.52***			
Age							
5-7	82	73	9	10.98 (5.1-19.8)			
8-10	160	125	35	21.88 (15.7-29.1)	6.45	2	**0.03**
11-14	91	80	11	12.09 (6.2-20.6)			
Total	***333***	***278***	***55***	***16.52***			

Table 4.2: Prevalence of malaria among Study Participants (Con't)

Category	Total Tested	No. Negatives	No. Positives	% Positives (95%CI:)	Chi-Square	D.F.	P-value
Residence							
Peri-urban	129	114	15	11.63 (6.7-18.5)	3.65	1	**0.05**
Rural	204	164	40	19.61 (14.4-25.7)			
Total	***333***	***278***	***55***	***16.52***			
Class/Level							
Primary 1	56	46	10	17.86 (8.9-30.4)			
Primary 2	58	48	10	17.24 (8.6-29.4)			
Primary 3	60	44	16	26.67 (16.1-39.6)			
Primary 4	56	50	6	10.71 (4.0-21.8)	7.8	5	0.16
Primary 5	58	49	9	15.52 (7.4-27.4)			
Primary 6	45	41	4	8.89 (2.5-212)			
Total	***333***	***278***	***55***	***16.52***			
Religion							
Christianity	244	210	34	13.93 (9.8-18.9)			
Islam	86	65	21	24.42 (15.7-34.8)	5.67	2	**0.05**
Other	3	3	0	0.00			
Total	***333***	***278***	***55***	***16.52***			

4.2.1 Association between Socio-Demographic Predictors and the Prevalence of Malaria

Compared to the age group 5-7 years (Ref:), children between the ages of 8 and 10 years were 2.7 times more likely to be infected with malaria (OR = 2.42, 95% CI: 1.28-6.48, p = 0.01). Individuals practising Islam had significantly higher odds of malaria infection (OR = 2.47, 95% CI: 1.29–4.65, p = 0.005). Residence was also a significant predictor, with children from rural areas being twice as likely to be infected with malaria compared to those from predominantly rural areas (OR = 2.13, 95% CI: 1.13–4.18, p = 0.02). Males were also twice as likely to be infected with malaria (OR = 2.14, 95% CI: 1.16–4.07, p = 0.02) (Table 4.3).

Table 4.3 Demographic predictors of the prevalence of malaria

Category	OR (95% CI)	P-Value
Sex		
Male	2.14 (1.168-4.07)	**0.02**
Female	**Ref:**	-
Age		
5-7 years	**Ref:**	-
8-10 years	2.76 (1.28-6.48)	**0.01**
11-14 years	1.13 (0.44-2.98)	0.79
Residence		
Peri-urban	**Ref:**	**-**
Rural	2.13 (1.13–4.18)	**0.02**
Religion		
Christianity	**Ref:**	-
Islam	2.47(1.29–4.65)	**0.005**

***95% CI=Confidence interval, OR= Odds ratio, P = P-value; Source: Field Survey (2024)**

4.3 Distribution of Helminthiasis Prevalence Across Demographic Factors

Out of the 333 participants tested for helminth infection, 15 were found to be positive, resulting in an overall prevalence rate of 4.5%. Anhwiaso Methodist Primary had the highest prevalence (7.84%), while Kwamekrom Primary reported the lowest at 3.28% as shown in Table 4.3. However, these differences were not statistically significant ($\chi^2 = 2.15$, $p = 0.82$). Concerning sex, males exhibited a slightly higher prevalence (4.92%) compared to females (4.00%), but this difference was also not statistically significant ($\chi^2 = 0.16$, $p = 0.68$). Among the age groups, children aged 5–7 years recorded the highest prevalence (7.32%), while those aged 11–14 years had the lowest (2.20%). These differences were not statistically significant ($\chi^2 = 2.64$, $p = 0.26$). In terms of place of residence, children from rural areas had a higher prevalence (5.88%) compared to those in peri-urban settings (2.33%), but the variation was not statistically significant ($\chi^2 = 2.32$, $p = 0.12$). Class/grade level revealed that Primary 3 pupils had the highest prevalence (10.00%), whereas no cases was recorded in Primary 6 (0.00%) ($\chi^2 = 7.60$, $p = 0.17$). Regarding religious affiliation, prevalence was slightly higher among Muslims (5.81%) compared to Christians (4.10%), though the difference was not statistically significant ($\chi^2 = 0.57$, $p = 0.74$) [Table 4.4]

Table 4.4: Prevalence of Helminthiasis among study participants

Category	Total Tested	No. Negatives	No. Positive	Positives% (95%CI:)	Chi-Square	D.F	P-value
Study Site							
Bibiani Old Town Primary	53	51	2	3.77(0.4-12.9)			
Hwenampori M/A Primary	57	55	2	3.51(0.4-12.1)			
Anhwiaso Methodist Primary	51	47	4	7.84(2.2-18.8)	2.15	5	0.82
Aboabo M/A Primary	60	58	2	3.33(0.4-11.5)			
Nkatieso M/A Primary	51	48	3	5.88(1.2-16.2)			
Kwamekrom M/A Primary	61	59	2	3.28(0.4-11.4)			
Total	***333***	***318***	***15***	***4.50***			
Sex							
Male	183	174	9	4.92(2.3-9.1)			
Female	150	144	6	4.00(1.5-8.5)	0.16	2	0.68
Total	***333***	***318***	***15***	***4.50***			
Age							
5-7	82	76	6	7.32(2.7-15.3)			
8-10	160	153	7	4.38(1.8-8.8)	2.64	2	0.26
11-14	91	89	2	2.20(0.3-7.7)			
Total	***333.00***	***318***	***15***	***4.50***			

Table 4.4: Prevalence of Helminthiasis among study participants (Con't)

Category	Total Tested	No. Negative	No. Positive	Positive% (95% CI:)	Chi-Square	D.F	P-value
Residence							
Peri-urban	129	126	3	2.33 (0.4-6.6)			
Rural	204	192	12	5.88 (3.1-10.1)	2.32	1	0.12
Total	***333***	***318***	***15***	***4.50***			
Class/Level							
Primary 1	56	53	3	5.36(1.1-14.8)			
Primary 2	58	55	3	5.17 (1.1-14.4)			
Primary 3	60	54	6	10.00 (3.7-20.5)			
Primary 4	56	55	1	1.79 (0.04-9.5)			
Primary 5	58	56	2	3.45 (0.42-11.9)	7.60	5	0.17
Primary 6	45	45	0	0.00 (0.0-7.8)			
Total	***333***	***318***	***15***	***4.50***			
Religion							
Christianity	244	234	10	4.10 (1.9-7.4)			
Islam	86	81	5	5.81(1.9-13.1)	0.57	2	0.74
Other	3	3	0	0.00			
Total	***333***	***318***	***15***	***4.50***			

4.3.1 Association between Socio-demographic Predictors and the Prevalence of Helminthiasis

A binary logistic regression analysis was conducted on the association between sociodemographic predictors and the prevalence of helminth infections. Although rural residents had higher odds of infection compared to those in predominantly rural areas (OR = 2.73, 95% CI: 0.85–12.17), this association was not statistically significant (p = 0.12). Similarly, religion was not a significant predictor, although individuals identifying with Islam had slightly higher odds of infection than Christians (OR = 1.47, 95% CI: 0.44–4.28, p = 0.49). The analysis also revealed that sex was not significantly associated with infection, with females having lower odds compared to males (OR = 0.79, 95% CI: 0.26–2.26, p = 0.67). These findings indicated that none of the assessed sociodemographic variables showed a statistically significant association with helminth infection in this model. (Table 4.5).

Table 4.5 Socio-demographic Predictors of the Prevalence of Helminthiasis

Variable	Odds Ratio (OR)	95% CI	P-Value
Sex			
Male	Ref:		
Female	0.79	(0.26-2.26)	0.67
Residence			
Peri-urban	Ref:		
Rural	2.73	(0.85-12.17)	0.12
Religion			
Christianity	Ref:		
Islam	1.47	(0.44-4.28)	0.49

*95% CI=Confidence interval, OR= Odds ratio, P = P-value; Source: Field Survey (2024)

4.4 Prevalence of Plasmodium and Helminth Co-Infection

Table 4.4 below shows the prevalence of *Plasmodium* and helminth coinfection among the study participants. Co-infections between *Plasmodium* species and soil-transmitted helminths were observed at low frequencies. Among the participants, co-infection with *Plasmodium* species and *Ascaris lumbricoides* were detected in three (0.90%) individuals. Similarly, co-infection with *Plasmodium* species and *Trichuris trichiura* was observed in two (0.60%) cases. Co-infection between *Plasmodium* species and hookworm was found in one (0.30%) person. On the whole, malaria co-infections with intestinal helminths were **1.8**%.

Table 4.6: Species composition of *Plasmodium* and helminth co-infection

Co-infection	Frequency	Percentage (95%CI)
Children with *Plasmodium* species + *Ascaris lumbricoides*	3	0.90 (0.12 - 1.00)
Children with *Plasmodium* species + *Trichuris trichiura*	2	0.60 (0.04 -0.77)
Children with *Plasmodium* species + Hookworm	1	0.30 (0.004 – 0.64)
Children without malaria and helminth co-infection	327	98.2
Total	333	100

Source: Field Survey (2024)

4.5 Socio-demographic predictors of the prevalence of Plasmodium-helminth coinfection among school children.

The distribution of co-infection across various demographic factors are shown in Table 4.5 below. Co-infection rates varied slightly by study site, with Nkatieso M/A Primary recording the highest rate (33.2%). Males and females had equal proportions of co-infection (50% each), which were not significantly different ($\chi^2 = 0.0$, $p = 1.00$). The highest co-infection rate was observed in the 8–10-year age group (50%), though the association was not statistically significant ($\chi^2 = 1.50$, $p = 0.47$). Children from rural settings had a higher co-infection rate compared to those from predominantly rural areas, with rates of 83.3% and 16.7%, respectively, which were significantly different ($\chi^2 = 3.0$, $p = 0.08$). Differences were also noted across class levels, although these were not statistically significant ($\chi^2 = 1.50$, $p = 0.08$). Regarding religion, children identifying as Christians had the highest co-infection rate (66.7%), followed by Islam (33.3%), which was not a statistically significant association with the disease ($\chi^2 = 4.0$, $p = 0.13$) (Table 4.7).

Table 4.7: Association of demographic characteristics and *Plasmodium* helminthiasis coinfection

Variable	Coinfection Positive (%)	Chi-Square	*p*-Value
Study Site			
Bibiani Old Town Primary	1 (16.7)	2.4	0.79
Hwenampori M/A Primary	0 (0.0)		
Anhwiaso Methodist Primary	1(16.7)		
Aboabo M/A Primary	1 (16.7)		
Nkatieso M/A Primary	2 (33.2)		
Kwamekrom M/A Primary	1 (16.7)		
Sex			
Male	3 (50)	0.0	1.00
Female	3(50)		
Age			
5-7	2(33.3)		
8-10	3 (50)	1.5	0.47
11-14	1 (16.7)		
Residence			
Peri-urban	1(16.7)	3.0	0.08
Rural	5(83.3)		
Class/Level			
Primary 1	0 (0.0)	9.6	0.08
Primary 2	2(33.3)		
Primary 3	3 (50.0)		
Primary 4	0 (0.0)		
Primary 5	1 (16.7)		
Primary 6	0 (0.0)		
Religion			
Christianity	4 (66.7)	4.0	0.13
Islam	2 (33.3)		
Other	0 (0.0)		

***χ^2 = chi-square, P= P=Value; Source: Field Survey (2024); Source: Field Survey (2024)**

4.6 Risk Factors for Malaria Infections

Pearson's chi-square test showed that significant associations across several risk factors among individuals tested positive for malaria. Specifically, individuals residing in households without netted or glass windows comprised 65.5% of those infected, compared to 34.5% who had netted or glass windows, which was a significant difference ($\chi^2 = 5.23$, $p = 0.02$). The infection rate was also higher among participants who owned livestock, with 70.9% testing positive, compared to 29.1% without livestock, which represented a significant difference ($\chi^2 = 9.61$, $p = 0.002$). Additionally, those not sleeping under insecticide-treated mosquito bed nets represented 72.7% of the malaria-positive group, versus 27.3% who did use these nets, which was a significant difference ($\chi^2 = 11.34$, $p = 0.001$).

Regarding mosquito control measures, 65.5% of the infected individuals did not use mosquito coils compared to them who used this vector control technique, (34.5%) and this was statistically significantly ($\chi^2 = 9.31$, $p = 0.002$). In terms of mosquito repellent use, both groups had a prevalence of 80%, ($\chi^2 = 19.8$, $p < 0.001$). Furthermore, individuals who reported a habit of swimming constituted 72.3% of the malaria-positive cohort, compared to 27.3% who did not swim and this was statistically significant ($\chi^2 = 11.34$, $p = 0.001$). Lastly, 70.9% of infected individuals lived near stagnant water, which also showed a significant association ($\chi^2 = 9.61$, $p = 0.002$) (Table 4.8).

Table 4.8: Distribution of risk factors among malaria-positive individuals (N = 55)

Variable	Frequency (%)	Chi-Square	P-value
Are the windows in your household netted?			
Yes	19 (34.5)	5.23	**0.020**
No	36 (65.5)		
Does your household own any livestock?			
Yes	16 (29.1)	9.61	**0.002**
No	39 (70.9)		
Do you sleep in an insecticide-treated mosquito net?			
Yes	15 (27.3)	11.34	**0.001**
No	40 (72.7)		
Do you use an insecticide mosquito coil?			
Yes	19 (34.5)	9.31	**0.002**
No	36 (65.5)		
Do you use mosquito repellent?			
Yes	11 (20.0)	19.8	**<0.001**
No	44 (80.0)		
Do you have a habit of swimming?			
Yes	40 (72.7)	11.34	**0.001**
No	15(27.3)		
Is your house close to stagnant water?			
Yes	39 (70.9)	9.61	**0.002**
No	16 (29.1)		

***χ^2 = chi-square, P= P=Value; Source: Field Survey (2024); Source: Field Survey (2024)**

4.6.1 Association of Risk Factors among Malaria-Positive Individuals

A binary logistic regression analysis was conducted to identify risk factors among individuals with malaria. Children having a swimming habit in open water bodies were associated with substantially increased odds of malaria (OR = 7.11, 95% CI: 3.14-16.9, p < 0.001). It was observed that, a similar situation with those who had stagnant water close to their household, which was statistically correlated with malaria infection (OR = 0.45, 95% CI: 0.143-1.24, p = 0.002). These situations were statistically significant in increasing the incidence of malaria infections. Children who did not sleep under a treated mosquito net (OR = 0.3, 95% CI: 0.07–1.01, p = 0.05) were also statistically more likely to be infected with malaria (Table 4.9).

Table 4.9: Association of Risk Factors among Malaria-Positive Individuals (N = 55)

Variable	Odds Ratio	95% CI	P-value
Are the windows in your household made of netting or glass?			
Yes (Ref.)	–	–	–
No	2.14	0.69–6.97	0.19
Does your household own any livestock?			
Yes	0.95	0.292-3.07	0.93
No (Ref.)	–	–	–
Do you sleep in an insecticide-treated net?			
Yes (Ref.)	–	–	–
No	0.3	0.07–1.01	**0.05**
Do you use an insecticide mosquito coil?			
Yes	0.82	0.25–2.54	0.74
No (Ref.)	–	–	–
Do you use mosquito repellent?			
Yes	0.68	0.16-2.61	0.58
No (Ref.)	–	–	–
Do you have a habit of swimming?			
Yes (Ref.)	7.11	3.14-16.9	**<0.001**
No	–	–	–
Is your house close to stagnant water?			
Yes	0.45	0.143–1.24	**0.002**
No (Ref.)	–	–	–

***95% CI=Confidence interval, OR= Odds ratio, P = P-value; Source: Field Survey (2024)**

4.7 Risk Factors for Helminthic Infections

The distribution of risk factors among individuals who tested positive for helminth infection are displayed in Table 4.7. Amon g the 15 infected participants, 93.3% reported of regular contact with some form of pets, while only 6.7% had no such encounters and this was, statistically significant ($\chi^2 = 19.2$, $p < 0.001$). Sources of water was also significantly associated with helminth infection, with 46.7% of the infected individuals relying on borehole water and 6.7% on river water ($\chi^2 = 10.9$, $p = 0.01$). Individuals who reported a habit of swimming constituted 72.3% compared to 27.3% who did not swim. Additionally, engagement in soil-related activities showed a significant association, as 73.3% of infected individuals had regular contact with soil compared to 26.7% who did not ($\chi^2 = 4.8$, $p = 0.02$). (Table 4.10)

Table 4.10 Distribution of risk factors among helminth-positive individuals (N = 15)

Variable	Frequency (%)	Chi-Square	P-value
Contact with any form of pets			
Yes	14 (93.3)	11.3	**<0.001**
No	1(6.7)		
Treated drinking water			
Yes	7(46.7)	0.07	0.79
No	8(53.3)		
Sources of Water source usage			
Borehole	7(46.6)	2.8	0.24
Well water	6(40)		
River	2(13.4)		
Is Open defecation in the community practiced?			
Yes	6(40)	0.6	0.44
No	9(60)		

Table 4.10 Distribution of risk factors among helminth-positive individuals (N = 15) (Con't)

Variable	Frequency (%)	Chi-Square	P-value
Was there any activities involving contact with soil			
Yes	11(73.3)	4.8	**0.03**
No	4(26.7)		
Did people walk barefooted in the community?			
Yes	8(53.3)	0.006	0.7
No	7(46.7)		
Was there any visible sign of Habit of swimming			
Yes	11(73.3)	4.8	**0.03**
No	4(26.7)		

***χ^2 = chi-square, P= P=Value; Source: Field Survey (2024); Source: Field Survey (2024)**

4.7.2 Association of Risk Factors among Helminth-Positive Individuals

A binary logistic regression analysis was conducted to assess the potential risk factors associated with helminth infections. The source of water usage among the study subjects showed significant associations. Using tap water or river water was associated with significantly lower odds of infection compared to using borehole water (OR = 0.14, 95% CI: 0.01–1.87, p = 0.01). Additionally, individuals who did not have contact with soil had significantly lower odds of infection compared to those who had contact with soil (OR = 0.31, 95% CI: 0.11–0.91, p = 0.02) (Table 4.11)

Table 4.11: Association of risk factors among helminth-positive individuals (N = 15)

Variable	Odds Ratio (OR)	95% CI	p-value
Sources of water usage			
Borehole (Ref.)	–	–	–
Well water	0.15	0.05 – 1.64	0.15
River	0.14	0.01 – 1.87	0.11
Possible Contact with soil			
Yes	7.56	1.62 –43.3	**0.01**
No (Ref.)	-	-	-
Habit of swimming			
Yes	7.56	1.62-42.3	**0.01**
No (Ref.)	–	–	–

***95% CI=Confidence interval, OR= Odds ratio, P = P-value; Source: Field Survey (2024)**

4.8 Risk Factors for Malaria-Helminthiasis Co-infections

A binary logistic regression analysis showed the association between various risk factors and malaria-helminth co-infection in children as shown in Table 4.8 below. Children residing in rural areas had higher odds of co-infection compared to those in found peri-urban areas. (Not statistically significant) (OR = 2.73, 95% CI: 0.85–12.17, p = 0.12). Religious affiliation was also not a significant predictor, as children identifying as Islam had lower odds of co-infection compared to Christian children (OR = 0.25, 95% CI: 0.02–2.51, p = 0.25). Regarding the water source, children who used river water had an increased odds of co-infection compared to those using borehole water. However, the association was not statistically significant (OR = 10.0, 95% CI: 0.83–281, p = 0.09). Particularly, children who swam in open water bodies had significantly lower odds of co-infection compared to those who did not (OR = 0.04, 95% CI: 0.009–0.57, p = 0.03) (Table 4.12).

Table 4.12: Factors Associated with Malaria-Helminth Co-infection in Children (N =6)

Variable	Odds Ratio (OR)	95% CI	P-Value
Religion			
Christianity	Ref:		
Islam	0.25	(0.017-2.51)	0.25
Residence			
Peri-urban	Ref:		
Rural	2.73	(0.85 - 12.17)	0.12
Sources of water usage			
Borehole water	Ref:		
Well water	1.0	(0.03-30.4)	1.00
River	10.0	(0.83-281)	0.09
Habit of Swimming			
Yes	0.04	(0.09-0.57)	**0.03**
No	Ref:		

***95% CI=Confidence interval, OR= Odds ratio, P = P-value; Source: Field Survey (2024)**

CHAPTER FIVE

DISCUSSION

5.1 Introduction

This chapter presents the findings of the current study in the context of previous literature. The results are organized into four main areas: prevalence and distribution of infections, co-infections, risk factors, and associations with demographic variables.

5.2 Prevalence of Helminthiasis and Malaria Infections

In this study, the prevalence of intestinal helminthic infection among schoolchildren was very low. This study showed a relatively lower prevalence of intestinal parasitic infections compared to similar studies conducted in Ghana by Abaka-Yawson et al. (2020), which reported a far higher prevalence rate of 44.08%. Recent studies conducted in Ghana by Adu-Gyasi et al. (2018) also reported a higher prevalence than the current study, with a rate of 19.3%. Other studies outside Ghana by Ohuche et al. (2020) also reported a higher prevalence of intestinal parasitic infections than the current study. The observation of a lower prevalence of intestinal parasitic infections in the current study compared to the previous studies may be due to the introduction of an effective national deworming program, which might have reduced helminthic infection among the current study participants.

Hookworm was the most frequently detected parasite, followed by *Ascaris lumbricoides* and *Trichuris trichiura*. This observation can be attributed to various ecological or environmental factors (Brooker et al., 2004), who established that hookworm infections are prevalent in tropical and subtropical regions worldwide, particularly in areas with inadequate sanitation and hygiene conditions. Regarding poor sanitation, it has been explained that hookworm eggs hatch into their larval stage in contaminated soil. The larvae then infect humans through skin contact (Hotez et al., 2004). In places like the Bibiani study, where inadequate waste product management is prevalent, the risk of hookworm transmission to humans increases. Another important anthropological or ecological factor is that playing or walking barefoot is a common practice. Playing or walking barefoot is common in some of the rural settings studied in the Bibiani area.

This situation reportedly increases the risk of hookworm infection (Bethony et al., 2006). A third ecological factor of interest in this discussion is climate. Ghana, as a whole, is located in the tropical region, and its tropical climate reportedly provides an ideal environment for hookworm larvae to survive and flourish in the soil (Allen, 2020). The occurrence of *A. lumbricoides* and *T. trichiura* alongside hookworm is similar to the results of previous studies in Ghana and comparable sites. According to Crompton & Nesheim (2002), these helminths characteristically coexist in several epidemiological settings due to their common transmission routes, including contaminated soil and poor hygiene practices.

The comparatively low prevalence of helminth infections in the current study may be attributed to generally improved sanitation, considerable access to clean water, regular deworming programmes, and ongoing public health interventions in the study area. These findings align with studies conducted in urban settings in Ghana and Nigeria, where similar infrastructural and Behavioural improvements have reduced transmission rates of intestinal parasites. For instance, a study in the Banda District, Ghana, by Donkoh et al. (2022) observed a decrease in hookworm prevalence due to enhanced hygiene practices and mass deworming initiatives by the Ghana Health Service and its partners (Allen, 2020).

However, the detection of hookworms as the most prevalent species, despite recent progress in efforts against worm infestation in the country, is consistent with their ability to persist in the environment, especially in areas where people walk barefoot, as indicated, and where soil contamination may still occur. This observation aligns with previous research that highlights the resilience of hookworms in tropical regions even amid improved public health measures (Kihumuro et al., 2024; Ofori et al., 2024). The comparative study by Ahiadorme & Morhe (2020). For example, hookworm was found to be the most persistent helminth in humid, tropical zones across West Africa, including Ghana, amid enhanced public health actions.

Studies in rural or peri-urban communities, such as one conducted in Nigeria by Amisu et al. (2023). They also often report higher prevalence rates due to poor access to clean water and inadequate sanitation, underscoring the impact of socio-environmental factors on parasite distribution even when reactive public health measures are being implemented. These findings confirm that even though urban sanitation improvements help reduce infection, persistent environmental and behavioural factors support hookworm transmission in specific contexts.

In contrast, the prevalence of malaria is relatively higher than the national malaria prevalence rate of approximately 8.6% (GSS, 2023) was a source of worry. Furthermore, the malaria prevalence observed in the current study is lower than that observed in similar studies conducted in Ghana by Asosega et al. (2025), who reported a higher malaria prevalence, 29.7%. The prevalence of such comparatively high malaria prevalence in the current study sites and some other study sites explored by Asosega et al. (2025) suggests that vector control measures, such as insecticide-treated nets and indoor residual spraying, may not be as effective or consistently and adequately implemented as key control interventions in the study area. This is particularly of concern given that malaria remains a significant public health issue in Ghana. For instance, Amoah et al. (2022) reported that malaria was endemic in multiple regions of Ghana, with prevalence rates exceeding 30% in some communities despite ongoing national control strategies. Similarly, Ahorlu et al. (2019) observed persistent malaria transmission in rural Ghana due to inconsistent use of preventive measures and gaps in community health education.

These findings are also comparable to studies in other sub-Saharan African countries, such as Nigeria and Uganda, where vector control challenges and environmental factors have led to sustained malaria parasite transmission even in areas receiving regular interventions (Musoke et al., 2024; Orok et al., 2021). Thus, the higher prevalence of malaria observed in the current study underscores the need for renewed and targeted efforts to improve malaria control, particularly through community engagement, consistent bed nets, and elimination of mosquito breeding sites.

5.3 Malaria and Helminthiasis Co-infections

Co-infection between malaria and soil-transmitted helminths (STHs) was rare, affecting only a small number of participants. This observation is comparable to findings from other regions in Ghana, such as the study by Akosah-Brempong et al. (2021), which reported a co-infection rate of 4.5%, higher than the rate observed in the current study. The low prevalence observed could be attributed to differences in the life cycles, transmission dynamics, and ecological niches of *Plasmodium* species and intestinal helminths. While *Plasmodium* transmission peaks during the rainy season due to increased mosquito breeding, STHs are more prevalent in areas and periods lacking adequate sanitation and hygiene, which may not always overlap. In addition, the scale-up of targeted control measures, such as periodic mass drug administration for helminths and the widespread distribution of insecticide-treated nets (ITNs), may have significantly reduced opportunities for co-infection.

When all forms of parasitic co-infections were assessed, the most frequent pairing was between *Plasmodium* species and *Ascaris lumbricoides,* although this pairing still occurred at a low frequency. This trend has been similarly reported in East and West African countries, including studies by Duguay et al. (2023) and (2024), where children in poor rural settings experience frequent co-infections due to overlapping risk factors such as inadequate sanitation and exposure to mosquitoes. However, the relatively low rate of such co-infections in the present study may suggest higher effectiveness of localized interventions, including school-based deworming programmes and malaria prevention campaigns. Further comparisons can be drawn with a study in southern Ghana by Adu-

Gyasi et al. (2018), which found a modest co-infection rate of 2.5% and emphasised the role of environmental sanitation and bed net usage in reducing the risk of dual infection. In contrast, some studies in more rural and under-resourced settings, such as parts of Nigeria and Tanzania, have reported co-infection rates exceeding 10%, as noted by Jackson (2023) and Duguay (2024), primarily due to gaps in healthcare delivery and infrastructural challenges.

These results suggest that co-infections may not pose a significant public health burden in the study area. Nevertheless, the need for continuous surveillance remains critical, especially among high-risk groups like children, the elderly, and immunocompromised individuals. Shifts in environmental conditions, urbanization patterns, or lapses in health interventions could potentially reverse these gains and allow the re-emergence of co-infections, as seen in some districts following flooding or disruption of health programmes.

5.4 Risk Factors of Malaria and Helminthic Infections Co-Infection

Several risk factors were found to be significantly associated with parasitic infections. Age and level of the study were notable predictors, with younger participants and those in lower academic (grade) levels being more likely to harbour infections. This finding is in line with the report of Ndoko (2023), who reported in Ghana that children and adolescents had higher parasitic burdens due to limited hygiene education, poorer sanitation facilities in schools, and frequent outdoor play. Similarly, Wami (2022) found that even first-year university students had less awareness about disease transmission and personal hygiene, increasing their vulnerability.

Religion also emerged as a significant factor, which may reflect differences in lifestyle, dietary customs, sanitation habits, or health-seeking behaviours, rather than religious doctrines per se. Perlman (2020), in Accra, Ghana, reported similar patterns, noting that varying prevalence among religious groups could be attributed to distinct community practices, such as frequency of ablution, types of communal meals, and trust in traditional remedies versus formal medical care, behavioural factors like handwashing before eating and after defecation, which were significantly associated with reduced infection rates (Wüthrich-Grossenbacher et al., 2023). Participants who practised regular hand hygiene had a lower prevalence of intestinal parasites, underlining the protective effect of these practices. This supports Shrestha et al. (2020), who demonstrated a strong inverse relationship between hand hygiene and intestinal parasitic infections in school children in southern Ghana. Additionally, a study in Ethiopia by Alemayehu et al. (2025) emphasised that poor handwashing behaviour contributed significantly to the burden of helminth infections in rural school children.

The source of drinking water also played a critical role; participants using untreated water sources, such as rivers and unprotected wells, had significantly higher rates of parasitic infections. Atemoagbo (2024) similarly found a strong correlation between protozoan infections and the consumption of untreated water in peri-urban areas of Ghana. Saxena et al. (2024) identified the water source as a significant determinant of infection in rural Nigeria, emphasising that lapses in municipal water treatment can maintain transmission even in urban settings. Moreover, co-infections between helminths and malaria were observed primarily among participants with cumulative risk factors, including a lack of access to treated drinking water, poor sanitation, and the non-use of mosquito nets. The ecological overlap of transmission routes for these infections, vector-borne and faecal-oral, creates opportunities for dual infections, particularly in marginalized communities. Studies by Gadoth-Goodman (2019) and Allen (2020) reported similar findings in Kenya and southern Ghana, respectively, noting that populations in low-resource settings with poor hygiene and limited access to preventive tools face higher risks of polyparasitism. Hence, integrated control strategies that combine deworming, vector control, water treatment, and health education are crucial for reducing the burden of co-infections.

Although co-infections were low, individuals with poor hygiene behaviours and unsafe water sources were more likely to have multiple infections. This suggests a compounding effect of multiple risk factors. Participants who did not use mosquito nets were also more prone to malaria, alone or in combination with other parasitic infections. These findings support integrated control strategies that address vector-borne and soil-transmitted infections through education, sanitation, and preventive tools such as bed nets. Similar integrated approaches have proven effective in rural Kenya and Uganda, where WASH (Water, Sanitation, and Hygiene) programmes combined with vector control measures led to significant reductions in parasitic infection rates, as reported by Kalitsilo et al. (2025).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Summary

The study assessed the prevalence, risk factors, and co-infection of malaria and helminthiasis among schoolchildren in the Bibiani-Anhwiaso-Bekwai Municipal area. The results indicate that the malaria prevalence was higher than the national malaria prevalence rate of 8.6%, and the prevalence rates of helminthiasis were very low due to ongoing mass deworming activities. Co-infection rates were low, affecting only 1.8% of participants who had both malaria parasites and at least one soil-transmitted helminth infection (*Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm), all of which also occurred at relatively low frequencies.

Co-infections between helminths and malaria were observed mainly among participants exposed to multiple risk factors. Children who swam in open water bodies had significantly lower odds of co-infection. Additionally, poor sanitation and the non-use of mosquito nets increased the children's vulnerability to both infections.

6.2 Conclusion

This study highlights the persistent burden of parasitic infections among schoolchildren, particularly in rural areas. The burden of malaria and helminthiasis among schoolchildren remains high.

Approximately two out of every 100 schoolchildren are likely to have malaria and helminth co-infection, indicating that the overall prevalence of co-infection is relatively low.

Risk factors, including age, sex, and place of residence, were significantly associated with the likelihood of malaria and helminthiasis infections. Additional factors explicitly linked to malaria mono-infection included the presence of stagnant water near homes, the habit of swimming, and the non-use of insecticide-treated nets. For helminthiasis mono-infection, poor sanitation, inadequate deworming practices, and various environmental and behavioural factors were found to increase the risk of infection. Risk factors for coinfection of malaria and helminthiasis include swimming habits that reduce the risk of co-infection with malaria and soil-transmitted helminths by promoting better hygiene and limiting exposure to contaminated soil.

6.2.1 Recommendations

Based on the findings of the study, the following recommendations were made:

I. **Ghana Health Service (GHS)**: Health authorities should prioritise malaria and helminth control interventions in rural communities, where children are at a higher risk of infection.

II. **School-based Health Programmes**: Periodic screening and treatment campaigns should be implemented in schools, especially those with high prevalence rates, such as Nkatieso M/A Primary.

III. **Health Education Campaigns**: Community-based and school-centred education programmes are recommended to improve knowledge and practices regarding personal hygiene, sanitation, and the use of mosquito protection.

IV. **Improved Sanitation and Vector Control**: Investments should be made in improving water, sanitation, and hygiene (WASH) infrastructure, as well as environmental management to reduce mosquito breeding sites.

V. **Further Research**: Longitudinal studies are needed to monitor infection trends and assess the impact of implemented interventions. Additionally, molecular characterization of parasite species could help understand transmission dynamics and resistance patterns.

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APPENDICES

APPENDIX I: ETHICAL CLEARANCE

Kwame Nkrumah University of Science and Technology, Kumasi

College of Health Sciences
SCHOOL OF MEDICINE AND DENTISTRY

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/698/24

6th August 2024

Mr. Isaac Baffour Awuah
Department of Public Health Education,
Akenten Appiah-Menka University of Skills Training
and Entrepreneurial Development.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: ***"Helminthiasis and Malaria Co-Infection among School Children in Bibiani-Anhwiaso-Bekwai Municipal, Western North Region of Ghana."***

Proposed Site: ***Bibiani Old-Town M/A Primary, Hwenampori M/A Primary, Nkatieso M/A Primary, Anhwiaso Methodist Primary, Aboabo M/A Primary, Kwamekr.***

Sponsor: ***Self-Sponsored.***

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

The Committee reviewed the following documents:

- A notification letter of 17th April 2024 from the Bibiani Municipal Health Directorate (study site) indicating approval for the conduct of the study in the municipality.
- A notification letter of 15th April 2024 from the Municipal Education Office, Western North (study site) indicating approval for the conduct of the study in the municipality.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire.

The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning **6th August 2024** to **5th August 2025** renewable thereafter. The Committee may, however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

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

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

Thank you for your application.

Yours faithfully,

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

Room 7, Block L, School of Medicine and Dentistry, KNUST, University Post Office, Kumasi, Ghana
Tel: +233 (0) 322 063 248 **Mobile:**+233 (0) 205 453 785 **Email:** chrpe.knust.kath@gmail.com / chrpe@knust.edu.gh

APPROVAL LETTER FROM THE STUDY SITE

OUR CORE VALUES

- Professionalism
- Discipline
- Teamwork
- Integrity
- Innovation and Excellence
- People-Centred Service

In case of a reply the number and the date of this letter should be quoted.

My Ref. No. GHS/WN/BAB/MHD/24

Your Ref. No..........................

GHANA HEALTH SERVICE

Your Health • Our Concern

MUNICIPAL HEALTH DIRECTORATE
GHANA HEALTH SERVICE
POST OFFICE BOX 108
BIBIANI
Tel: 0203937679
DIGITAL ADDRESS: WB-0001-0123

Email: ghsbibiani@gmail.com
bibiani.mhdwnr@ghs.gov.gh

17TH APRIL, 2024

TO WHOM IT MAY CONCERN

APPROVAL TO CONDUCT RESEARCH ON HELMINTHIASIS AND MALARIA CO-INFECTION AMONG SCHOOL CHILDREN IN BIBIANI ANHWIASO BEKWAI MUNICIPAL WESTERN NORTH REGION OF GHANA

Mr. Isaac Baffour Awuah (INDEX NO: 8222030002) an Mphil. Public Health Student of the Aketen Appiah-Menka University of skills Training and Entrepreneurial Development has required to conduct a research on the above subject in this Bibiani Anhwiaso Bekwai Municipality.

Approval is hereby given for the conduct of the research in this Municipality.

Thank you.

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OHENEBA OPPONG-DARKO
MUNICIPAL DIRECTOR OF HEALTH SERVICE
BIBIANI

APPENDIX II: Questionnaire

QUESTIONNAIRE ON THE PREVALENCE OF HELMINTHIASIS AND MALARIA COINFECTION AMONG SCHOOL CHILDREN

This study aims to evaluate the risk factors and prevalence of intestinal helminthiases and malaria co-infection in schoolchildren in the Bibiani-Anhwiaso-Bekwai Municipality in Ghana's Western North Region. Your involvement is crucial because the study is based on a chosen sample. You may be sure that whatever information you share will be kept private.

INTERVIEW INFORMATION

DATE : [ ][ ] Day [ ][ ] Month [ ][ ][ ][ ] Year

TIME STARTED: [ ][ ] Hour[ ][ ] Minutes

TIME ENDED: [ ][ ] Hour [ ][ ] Minutes

NAME OF THE SCHOOL: --

STUDENT ID CODE: --

Please tick the appropriate responses.

Section A: Demographic information.

1. Age Group

   5-7 years [ ]

   8-10 years [ ]

   11-14 years [ ]

2. Sex:

Male [ ] Female [ ]

3. Location of residence:

   Urban [ ] Rural [ ]

4. Class (grade level):

   primary 1 [ ] primary 2 [ ] primary 3 [ ] primary 4 [ ] primary 5 [ ]

   primary 6 [ ]

5. Religion:

   Christianity [ ] Islam [ ] Other (specify) [ ]

Section B: Risk factors of malaria.

6. Are windows in your household netted or glass?

   Yes [ ] No [ ]

7. Does your household own any livestock?

   Yes [ ] No [ ]

8. Do you sleep in an insecticide-treated mosquito net?

   Yes [ ] No [ ]

9. Do you use the insecticide mosquito coil?

   Yes [ ] No [ ]

10. Do you use the Insecticide Mosquito spray?

    Yes [ ] No [ ]

11. Do you use Mosquito Repellent?

    Yes [ ] No [ ]

12. Is your house close to stagnant water?

    Yes [ ] No [ ]

13. Do you have a habit of swimming?

Yes [ ] No [ ]

Section B: Risk factors of helminthiasi

14. Do you directly contact animals (e.g., livestock, pets)?

Yes [ ] No [ ]

15. Do you have access to clean, treated drinking water?

Yes [ ] No [ ]

16. Where is the water source?

Tap water [ ] Borehole water [ ] Well water [ ] River/stream [ ]

17. Are there any open defecation practices in your community?

Yes [ ] No [ ]

18. Do you have a habit of swimming?

Yes [ ] No [ ]

19. Do you wash your hands before eating or using the toilet?

Yes [ ] No [ ] Sometimes [ ]

20. Do you walk barefoot outdoors?

Yes [ ] No [ ]

21. Do you engage in activities involving contact with soil (e.g., farming or gardening)?

Yes [ ] No [ ]

APPENDIX III

Informed Consent Form for Parent/guardians

Statement of person witnessing consent (Process for Non-Literate Participants):

I ____________________(Name of Witness) certify that the information given to ____________________ (Name of Participant), in the local language, is a true reflection of what l have read from the study Participant Information Leaflet, attached. WITNESS' SIGNATURE (maintain if participant is non-literate): ____________________

FATHER/MOTHER/GUARDIANS'S SIGNATURE (maintain if participant is under 18 years):____________________________FATHER/MOTHER/GUARDIANS'NAME: ____

APPENDIX IV

Photos captured during the data collection and laboratory work

Collection of blood samples

Giemsa-stained preparation

Microscopy examination of Plasmodium species

Stool sample

Stool sample preparation and *microscopy examination of helminthic eggs*