

**PREVALENCE OF PARASITIC CONTAMINANTS AMONG WELL WATERS
USED IN BENIN CITY,EDO STATE.**

BY:

ILENIKHIENA GLORY EBOSETA

BMS2005035



**DEPARTMENT OF MEDICAL LABORATORY SCIENCE, SCHOOL
OF BASIC MEDICAL SCIENCES,
COLLEGE OF MEDICAL SCIENCES,
UNIVERSITY OF BENIN, BENIN
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SUPERVISED BY:

DR. (MRS) Z. OMORUYI

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OF BASIC MEDICAL SCIENCES,**

COLLEGE OF MEDICAL SCIENCES,

UNIVERSITY OF BENIN, BENIN

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CERTIFICATION

This is to certify that this project is an authentic work that was carried out by ILENIKHIENA GLORY EBOSETA (MISS) with matriculation number BMS2005035 under the supervision of DR. (MRS) Z. OMORUYI in partial fulfillment of the requirement for the award of Bachelor's in Medical Laboratory Science Degree (BMLS) of the Department of Medical Laboratory Science, School of Basic Medical Science, University of Benin, Ugbowo, Benin City, Edo state.

DR. (MRS) Z. OMORUYI
(Project supervisor)

DATE

DR. (MRS) Z. OMORUYI
(Head of Department)

DATE

PROF.OMORUYI PIUS OMOSIGHO
(External Examiner)

DATE

DEDICATION

This work is dedicated to my Heavenly Father who is the source of all knowledge and wisdom and to my wonderful parents for their unwavering love and support.

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I acknowledge the all-wise, all-knowing, all-intelligent, and Almighty God from whom wisdom and knowledge come. I recognize the professional supervision given to me by my supervisor, DR. (MRS) Z. Omoruyi during this work. Special gratitude to the Head of Department, DR. (MRS) Z. Omoruyi for creating a conducive environment for learning. To all **my wonderful lecturers**, it was indeed a privilege to learn under your supervision.

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ABSTRACT

Parasitic contamination of drinking water remains a major public health challenge in developing regions, where wells serve as primary water sources. These parasites can cause debilitating infections, reduce quality of life, and contribute to high morbidity rates. This study aimed to assess the prevalence and distribution of Micro organisms in well water sources across Benin City, Edo state. A total of 195 wells were sampled and examined using standard parasitological techniques and were analyzed microscopically for the presence of parasites. The data were subjected to descriptive and inferential statistics with SPSS version 25 and chisquare tests were applied to assess associations between parasite occurrence and location, with statistical significance *set al* $p < 0.05$.. Results revealed widespread contamination, with 88.2% of wells harboring at least one parasite. *Ascaris* was the most prevalent (26.7%), followed by *Strongyloides* (16.4%) and *Entamoeba* (12.8%). *Giardia lamblia* and *Hookworm* each accounted for 9.2%, while *Schistosoma haematobium* and *Fasciola* were least prevalent at 7.2% each. Statistical analysis showed no significant differences in parasite distribution across LGAs ($p > 0.05$) except for *Schistosoma haematobium*, which was significantly associated with a location ($p = 0.019$). In conclusion, the findings highlight a high burden of parasitic contamination in well waters of Benin City, emphasizing the urgent need for improved water quality management and public health interventions.

CHAPTER ONE

1.0 Background of Study

Groundwater accessed through wells remains a critical source of drinking water for rural and peri-urban populations, particularly in low- and middle-income countries where centralized treatment systems are absent. However, recent studies confirm that the microbiological quality of groundwater is frequently compromised by fecal contamination, poor sanitary protection, and inadequate maintenance. Coliforms, especially *Escherichia coli*, continue to be widely reported in well water, underscoring risks of contamination from human and animal waste (Silva *et al.*, 2023).

Well characteristics remain strong predictors of microbial contamination. Shallow, unlined, or poorly constructed wells show significantly higher bacterial loads compared to deeper or protected ones, reinforcing long-standing findings on design-related vulnerability. Environmental drivers, including seasonal rainfall and soil permeability, also influence contamination, with recent temporal analyses showing higher detection rates of fecal indicators during rainy seasons (Olalemi *et al.*, 2023).

Indicator organisms remain central to microbial risk assessment in groundwater. While total coliforms and *Escherichia coli* are most frequently used, recent national-scale assessments suggest *Clostridium perfringens* provides a more persistent and reliable marker of fecal contamination in certain hydrogeological settings (Authors of “*Clostridium perfringens* as an Alternative Fecal Indicator Bacteria...”, 2025). Similarly, borehole surveys continue to detect enterococci and opportunistic pathogens such as *Pseudomonas aeruginosa* and *Clostridium perfringens* spores, emphasizing the need for a multiparameter approach in monitoring (Silva *et al.*, 2023).

Beyond contamination at the source, household-level storage and handling exacerbate microbial hazards. Investigations of household water samples in Nigeria revealed substantial deterioration in bacteriological quality between source and point of use, highlighting the influence of poor handling practices and storage container hygiene. Furthermore, emerging work has documented biofilm-forming and antibiotic-resistant bacteria in rural water storage systems, raising concern about secondary contamination and persistence of pathogens even after collection (Olalemi *et al.*, 2023).

Addressing these hazards requires a multipronged approach: improved well construction and sanitary protection, consistent microbial monitoring, and adoption of appropriate household treatment technologies. A recent review of innovative water treatment approaches emphasizes the promise of low-cost physical and biological methods for pathogen removal, which could be scaled in resource-limited settings. Together, these findings underscore the continuing importance of integrating environmental surveillance, community education, and infrastructure improvements to safeguard groundwater sources.

1.1 Statement of Problem

Groundwater from wells remains a vital source of domestic water supply for many residents of Edo State. However, studies in Nigeria and globally have consistently reported microbial contamination of well water due to factors such as poor sanitary construction, proximity to septic systems, and agricultural runoff. The risk is particularly pronounced in urban-periurban transition zones and rural communities where environmental management and regular monitoring are inadequate. In the absence of systematic local data on microbial load and contamination sources in these areas, the health risks posed by the consumption of untreated well water remain poorly quantified, potentially contributing to the continued burden of waterborne diseases.

1.2. Justification of Study

Well water remains a major source of domestic water supply in many parts of Edo State, where access to treated municipal water is limited. However, studies have shown that well water is often prone to microbial contamination due to poor sanitary construction, proximity to septic systems, flooding, and unsafe handling practices. Such contamination poses significant risks of waterborne diseases like diarrhea, typhoid, and cholera, which remain public health concerns in Nigeria. Evaluating the microbial quality of well waters in these LGAs is therefore crucial for identifying contamination risks, generating baseline data for health authorities, and guiding interventions that promote safe water practices.

1.3. Aim of The Study

The aim of this study is to determine the prevalence of microorganism among well waters used in benin city, Edo state.

1.4. Specific objectives of study

The specific objectives of the study were;

1. to determine the presence and concentration levels of parasitic contaminants in well water samples collected from Benin City.
2. to investigate the prevalence and spatial distribution of parasitic contaminants across different well water sources in Benin City
3. To assess the influence of well characteristics (depth, cover, distance from septic tanks/latrines, drainage systems) on parasitic contamination.

1.5. Research Questions

1. What types of parasites are present in well waters in benin city, Edo state.

2. What is the prevalence and distribution of parasitic contaminants in the sampled well waters around benin city?
3. How do well characteristics (e.g., depth, lining, presence of cover, drainage system, and distance from septic tanks/latrines) influence parasitic contamination levels?

1.6.0. Research Hypothesis

1.6.1. Null Hypothesis

There is no significant microbial contamination level of well waters around benin city, edo state.

1.6.2. Alternate Hypothesis

There is significant microbial contamination level of well waters around benin city, edo state.

CHAPTER TWO

LITERATURE REVIEW

2.1. Well Water Resources

2.1.1. Definition and Importance of Well waters

Well water refers to groundwater withdrawn from aquifers via constructed wells for domestic, agricultural, or industrial use; private wells continue to supply drinking water for millions of households worldwide and remain an important but often unregulated drinking-water source in many regions (Dotherow et al., 2024). Unlike municipally supplied water, private wells are usually unregulated, placing responsibility for maintenance and safety on individual owners (Grönwall and Danert, 2020). Stewardship studies show that owner testing, maintenance, and simple interventions can improve outcomes but are inconsistently practiced (Dotherow et al., 2024; Millner et al., 2025). However, the definition of well waters extends beyond simply being a water source—it also implies a system highly vulnerable to contamination due to factors such as inadequate construction, lack of protective casing, and proximity to pollution sources (Woolf *et al.*, 2023). Scholars highlight that well waters differ from surface water sources in that they tap into underground aquifers, which vary in depth and quality, thereby influencing the potability and sustainability of supply (Grönwall and Danert, 2020). Furthermore, well waters are increasingly recognized in public health discussions as both a vital resource and a potential health risk, emphasizing the importance of testing and stewardship practices to ensure safety (Woolf *et al.*, 2023).

Well waters remain an essential source of drinking water for millions of households worldwide, particularly in rural and peri-urban regions where municipal systems are limited or absent; recent studies from 2020 onward confirm both the high dependence on private wells and the multiple risks these unregulated supplies face (Wood et al., 2025). Their importance lies not only in providing direct access to groundwater but also in supplementing public water systems,

thereby reducing demand pressure on centralized infrastructure (Tura and Demeku, 2025). Access to well water also has critical implications for public health, as safe and sufficient water supply is directly linked to improved health outcomes, child development, and reduced disease risks (Woolf *et al.*, 2023). In many rural communities, private wells serve as the primary drinking water source, emphasizing their role in health equity and human rights to water access (Grönwall and Danert, 2020). Furthermore, well waters contribute to sustainability by enhancing local self-supply, ensuring resilience during disruptions of municipal services, and supporting agricultural activities (Tura and Demeku, 2025). However, their importance is also tied to vulnerability—without proper stewardship, wells can expose communities to contaminants such as nitrates, arsenic, and microbial pathogens, highlighting the need for monitoring and education programs (Lee and Murphy, 2020).

2.1.2. Sources of well waters in rural and urban communities

In rural areas, well waters are primarily sourced from shallow aquifers, which are accessed through privately owned and often federally unregulated wells (Lee and Murphy, 2020). These rural wells frequently tap into local groundwater reserves that are more accessible but also more vulnerable to surface contamination due to their shallow depth (Fell *et al.*, 2025). Rural communities often depend on such wells because municipal infrastructure is either absent or insufficient, making groundwater their main potable water source (Olalemi *et al.*, 2023). In contrast, urban wells typically draw from deeper and often larger aquifers to meet the high water demands of dense populations (Foster, 2022). Urban aquifers play a crucial role in ensuring water security during shortages, providing resilience against surface water variability and climate-induced stresses (Olalemi *et al.*, 2023). However, in urban contexts, groundwater availability is often constrained, necessitating both community-managed and private wells to supplement municipal systems. While both urban and rural areas rely on aquifers, the nature of the sources differs significantly: rural wells emphasize local, small-scale extraction, whereas

urban wells tend to involve larger, often regulated systems integrated into broader water supply strategies (Foster, 2022). This distinction underscores the importance of tailored groundwater governance to ensure safe and sustainable access across different geographic contexts (Lee and Murphy, 2020).

2.2. Microbiological Quality of well water

2.2.1. Concept of Water Quality and Public Health Relevance

Water quality is a multidimensional concept whose chemical, physical, and microbiological characteristics determine fitness for drinking and other uses and that a growing list of legacy and emerging contaminants (Levin *et al.*, 2024). High-quality drinking water must meet established safety standards that protect against contaminants such as heavy metals, nitrates, pesticides, and microbial pathogens, which are often linked to acute and chronic diseases (Ali and Ghareeb, 2023).

Well water quality is a critical determinant of public health, particularly in communities that depend on private wells as their primary drinking water source. Unlike municipal water systems, private wells are often unregulated, making their users more vulnerable to contaminants such as arsenic, nitrates, pesticides, and microbial pathogens (Lee and Murphy, 2020). These pollutants are associated with gastrointestinal illnesses, cancers, developmental problems, and other long-term health risks (Woolf *et al.*, 2023). The relevance of well water quality to public health is especially pronounced in rural areas, where private wells supply water to millions of households and where testing and treatment practices are inconsistent (Lee and Murphy, 2020). Poor stewardship and inadequate monitoring can increase exposure to contaminants of emerging concern, further exacerbating health disparities in underserved populations (Stokdyk *et al.*, 2025).

Moreover, safe well water contributes not only to preventing disease but also to advancing health equity, since access to uncontaminated groundwater is recognized as a basic human right (Grönwall and Danert, 2020). Sustainable management of well water resources, through regular testing, community education, and policy interventions, is therefore essential to reducing the global burden of waterborne diseases and promoting long-term public health security (Tura and Demeku, 2025).

2.2.2. Classification of Well Water Contaminants

Well water contaminants are commonly classified into three major categories: microbiological, chemical, and physical contaminants (Shah *et al.*, 2023).

Microbiological contaminants include bacteria, viruses, protozoa, and fungi that enter wells from human or animal waste, leaking septic systems, or surface runoff (Enitan-Folami *et al.*, 2020). These microorganisms, such as *Escherichia coli* and Salmonella, are linked to gastrointestinal illnesses and other infectious diseases, particularly in rural and underserved populations (Izah and Ogwu, 2025).

Chemical contaminants comprise naturally occurring substances and anthropogenic pollutants such as heavy metals (arsenic, lead), nitrates from fertilizers, pesticides, and industrial chemicals (Yahaya *et al.*, 2021). Long-term exposure to these chemicals is associated with cancers, developmental issues, and cardiovascular diseases (Olalemi *et al.*, 2023).

Physical contaminants mainly refer to suspended particles, turbidity, and changes in water color, taste, or odor, which often serve as indicators of deeper chemical or microbial pollution (Shah *et al.*, 2023). Although physical contaminants are not always directly harmful, they reduce aesthetic quality and may signal the presence of more dangerous pollutants.

A comprehensive understanding of these contaminant classes is essential for designing monitoring and intervention strategies to safeguard public health and ensure the sustainability of private well water systems (Nganje *et al.*, 2020).

2.2.3 Indicators for Microbial Contamination of Well Waters

Microbial contamination in well waters is commonly assessed through the use of indicator organisms, which act as proxies for the potential presence of pathogens (Wen *et al.*, 2020). The most widely applied indicators are total coliform bacteria, which signal general bacterial pollution and the possibility of fecal contamination (Some *et al.*, 2021). Among the coliform group, *Escherichia coli* is considered the most reliable indicator of recent fecal contamination, as its detection strongly suggests the presence of enteric pathogens (Khan, 202). *Escherichia coli* levels in well water directly correlate with health risks such as gastrointestinal illness, making it a cornerstone of water quality monitoring (Olalemi *et al.*, 2023).

Other indicators include thermotolerant coliforms (TCB), which provide additional sensitivity to fecal pollution, and aerobic endospores, which serve as non-fecal indicators that highlight the potential persistence of microbial contamination in aquifers (Petculescu *et al.*, 2022). The use of multiple microbial indicators allows for a more comprehensive evaluation of well water safety, particularly in rural and unregulated systems (Some *et al.*, 2021). Thus, the application of indicator organisms such as total coliforms, *Escherichia coli*, and thermotolerant coliforms is central to identifying microbial risks in well waters and protecting public health (Wen *et al.*, 2020).

2.2.4. Global Standard for the Consumption of Water

Global standards for the consumption of well waters are primarily guided by the World Health Organization (WHO) Guidelines for Drinking-Water Quality, which provide internationally recognized benchmarks for microbiological, chemical, and physical safety (World Health

Organization, 2022). These guidelines establish health-based values, such as zero tolerance for *Escherichia coli* in 100 mL of water and strict thresholds for contaminants including arsenic, lead, nitrates, and fluoride, to ensure safe human consumption (Rahman *et al.*, 2023).

For private wells, adherence to these standards is particularly important since they are often outside formal regulatory oversight and rely on voluntary monitoring by homeowners (Mitchell and Frisbie, 2023). The WHO's framework emphasizes a risk-based approach, encouraging proactive assessment of hazards from aquifers to point-of-use, which has been adopted by many countries to align local regulations with global benchmarks (Van Winckel *et al.*, 2021). Regional applications of WHO standards reveal both harmonization and divergence, as countries adapt guidelines to local hydrogeological conditions, infrastructure, and socioeconomic capacity. For example, chemical thresholds for arsenic or fluoride may vary slightly across jurisdictions, but the overarching principle remains to minimize health risks over a lifetime of exposure (Mitchell and Frisbie, 2023).

Thus, the global standards for well water consumption rest on WHO recommendations, which serve as the cornerstone for national policies, safeguarding public health while promoting equity in access to safe water worldwide (World Health Organization, 2024).

2.3. Types of Parasites Found in Well Waters

2.3.1 Parasites commonly Found Well Waters

Groundwater accessed through wells is often vulnerable to contamination by a variety of parasitic pathogens due to human activity and environmental factors. Research has demonstrated that parasites are frequently detected in well water, raising public health concerns about the transmission of pathogenic microorganisms among groundwater consumers (Kim *et al.*, 2022).

2.3.3. Protozoa Parasites associated with well waters

Protozoan parasites are a significant group of contaminants found in well waters, often linked to gastrointestinal diseases and waterborne outbreaks. A recent study in Cameroon demonstrated that protozoan parasites in groundwater pose substantial public health risks, particularly in areas where communities rely heavily on untreated well water for daily use (Quiggle Atud and Gideon Aghaindum, 2025).

Well water contamination with protozoan pathogens such as *Giardia* and *Cryptosporidium* has been reported globally, with untreated wells serving as reservoirs for transmission, particularly in rural and low-income settings (Stokdyk *et al.*, 2020). These pathogens are highly resistant to environmental stress and can survive for long periods in groundwater, making them particularly difficult to eliminate with conventional treatment systems. In developing regions, protozoan parasites in drinking water are closely associated with inadequate sanitation and hygiene infrastructure, contributing to waterborne disease burdens and complicating WASH related interventions (Njambi *et al.*, 2020). Moreover, rural surveys have confirmed the presence of protozoan parasites in household wells, linking them to increased risk of infection among children and immunocompromised populations (Njambi *et al.*, 2020).

Epidemiological data suggest that *Giardia* infections are often more prevalent than *Cryptosporidium* in groundwater, a pattern observed in multiple regions worldwide, including parts of Asia and Africa. This underlines the importance of routine monitoring and the adoption of advanced treatment strategies such as membrane filtration or UV disinfection, especially in communities dependent on private wells (Stokdyk *et al.*, 2020).

2.4. Sources of Parasitic Contamination in Well Waters

2.4.1. Poor Sanitation and Improper Waste Disposal

Poor sanitation and improper waste disposal are critical drivers of microbial contamination in well water, particularly in low- and middle-income regions. Inadequate sanitation infrastructure allows human and animal waste to infiltrate groundwater, directly introducing fecal pathogens into wells used for drinking water (Abanyie *et al.*, 2022). This problem is compounded in peri-urban areas where rapid population growth outpaces waste management systems, resulting in heightened microbial pollution risks. Improper solid waste disposal practices further exacerbate contamination, as leachates from poorly managed waste dumps often seep into groundwater sources. Studies in Kenya have shown that inappropriate waste collection and disposal around shallow wells significantly increases bacterial loads, making water unsafe for human consumption (Kirori *et al.*, 2022). Similar observations have been reported in healthcare and urban environments, where biomedical and municipal waste disposal failures introduce diverse microbial contaminants into water supplies (Chand *et al.*, 2020).

The persistence of these challenges underscores the connection between sanitation-related practices and waterborne disease outbreaks. Poor sanitation facilities and indiscriminate waste disposal not only degrade water quality but also sustain cycles of enteric infections, disproportionately affecting vulnerable communities. Strengthening waste management systems and enforcing sanitation standards are therefore vital to breaking the link between poor sanitation and microbial contamination of well water (Abanyie *et al.*, 2022).

2.4.2. Proximity of Wells to Septic Tanks and Pit Latrines

The proximity of wells to septic tanks and pit latrines is a well-documented source of microbial contamination, especially in rural and peri-urban communities where onsite sanitation dominates. Research in Kenya revealed that decreasing distances between septic tanks and

boreholes were strongly associated with increased bacterial contamination, emphasizing the importance of safe separation standards (Ngasala *et al.*, 2020). Similar findings in Ghana highlighted that the closeness of wells to septic systems significantly compromises groundwater quality, as pathogens and nutrients readily leach into aquifers through porous soils (Mensah, 2022). A Nigerian case study further confirmed that coliform bacteria from nearby pit latrines and septic tanks readily infiltrated shallow wells, posing direct risks to drinking water quality (Ngasala *et al.*, 2020).

Recent assessments in Nigeria demonstrated that boreholes located near pit latrines and septic tanks had significantly higher microbial loads compared to those sited further away, reinforcing the link between well siting and contamination risk (Akpan and Assian, 2023). Likewise, a 2024 review of peri-urban African settings concluded that the widespread siting of wells in close proximity to onsite sanitation facilities contributes to chronic groundwater pollution and persistent waterborne disease transmission (Otunola and Zhou, 2024).

2.4.3. Agricultural Run Offs and Animal Waste

Agricultural runoff and animal waste are among the most critical non-point sources of microbial contamination in well water. Rainfall and irrigation events mobilize manure, fertilizers, and associated pathogens from farms into groundwater, leading to the introduction of fecal coliforms, *Escherichia coli*, and other enteric pathogens into wells (Olalemi *et al.*, 2023). Such contamination risks are particularly high in intensively farmed regions where manure application is common.

Animal waste is a reservoir for bacterial and protozoan pathogens that can leach into groundwater through infiltration and percolation. A study on the environmental implications of animal waste emphasized that the microbial and nutrient loadings from poorly managed manure significantly degrade both agricultural soils and nearby well water sources (Ananna *et al.*, 2021). This aligns with global observations that agricultural discharge often coincides with

spikes in groundwater contamination, particularly during rainy seasons. Runoff carrying livestock waste not only introduces bacteria but also protozoa and viruses into groundwater, making private wells especially vulnerable. Farming-related runoff events have been consistently linked with waterborne disease outbreaks, demonstrating the epidemiological importance of agricultural pollutants in rural communities. This underlines the necessity of adopting sustainable farming practices such as buffer strips, waste management systems, and controlled manure application to protect well water quality (Olalemi *et al.*, 2023).

2.4.4. Flooding, Seasonal Variations and Environmental Factors

Flooding, seasonal variations, and environmental factors play a critical role in driving microbial contamination of well water. Flood events often transport surface contaminants, including fecal matter and agricultural runoff, into groundwater systems, significantly elevating microbial loads. For example, flooding in northern Ghana was shown to increase fecal indicator bacteria in domestic wells, making them unsafe for human consumption (Dzodzomenyo *et al.*, 2022). Seasonal variations further contribute to microbial contamination patterns, with higher contamination levels often observed during rainy seasons compared to dry periods. A study of coastal communities in Ghana confirmed that microbial contamination of groundwater fluctuated seasonally, correlating with rainfall intensity and aquifer recharge cycles (Ayeta *et al.*, 2023). Similarly, work in Thailand demonstrated that groundwater quality varied seasonally due to fecal pollution linked to fluctuating water tables and sanitation system overflows during wet periods (Ananna *et al.*, 2021). In developed countries, flood-related groundwater contamination has also been reported. A review highlighted that surface water flooding can lead to pathogen intrusion into aquifers, thereby increasing the risk of enteric disease outbreaks even in regulated water systems (Ayeta *et al.*, 2023). Likewise, studies in the U.S. revealed that flood-prone colonias experienced seasonal shifts in microbial contamination of wells, with peak risks occurring during flood events (Rowles *et al.*, 2020). These findings

illustrate how environmental conditions, particularly floods and rainfall-driven seasonal changes, directly influence groundwater vulnerability. As climate change intensifies extreme weather events, microbial contamination risks in wells are expected to rise, necessitating adaptive management strategies (Rowles *et al.*, 2020).

2.5. Prevalence of Micro-organisms in Well Water: Global and Regional Perspectives

The prevalence of microorganisms in well water remains a pressing global health concern, especially in regions with limited water, sanitation, and hygiene (WASH) infrastructure. A recent systematic analysis revealed that *Vibrio* pathogens are widespread in drinking water sources, with global and regional patterns linked to socioeconomic and WASH indices, underscoring significant disparities in microbial safety of water supplies (Ekundayo *et al.*, 2024). In sub-Saharan Africa, well water contamination is particularly acute. A meta-analysis conducted in Ethiopia found a high prevalence of fecal coliforms and *Escherichia coli*, highlighting poor water quality and the risk of waterborne diseases in both rural and urban settings (Adugna *et al.*, 2024). Similarly, a continent-wide review of *Escherichia coli* prevalence in African water sources demonstrated widespread contamination and rising antimicrobial resistance profiles, complicating public health interventions (Ramatla *et al.*, 2023). In East Africa, well water remains a reservoir of enteric pathogens. Research in Kenya showed that microbial contamination in well water was directly associated with the prevalence of diarrheal diseases, particularly in peri-urban settings where sanitation infrastructure was inadequate (Paulos *et al.*, 2024). In South Asia, microbial contamination in Bangladeshi tubewells varied by region and season, indicating that hydrological conditions play a critical role in determining the extent of contamination (Goel *et al.*, 2023).

Globally, the persistence of microbial contamination in well water continues to undermine progress toward safe water access. Although treated municipal systems offer better protection, millions remain dependent on wells, where microbial risks such as fecal coliforms, *Escherichia*

coli, and *Vibrio* spp. persistently challenge water security (Ekundayo *et al.*, 2024; Adugna *et al.*, 2024). These findings collectively emphasize the need for global monitoring frameworks, improved disinfection practices, and community-level interventions to mitigate microbial risks in well water.

2.6. Health Implications of Microorganisms in Well Waters

2.6.1. Waterborne Diseases and the Epidemiological Burden of Microorganisms in Well Waters

Waterborne diseases represent a major public health threat, particularly in communities dependent on untreated or poorly protected well water, where microorganisms infiltrate through environmental and anthropogenic activities (Sawyer *et al.*; 2025). Parasites such as *Strongyloides stercoralis*, *Ascaris lumbricoides*, and *Giardia lamblia* persist in groundwater sources, often leading to diarrheal outbreaks and long-term health complications (Shridhar, *et al.*; 2024). Epidemiological investigations consistently link contaminated well water with high disease burdens, especially during seasonal variations and extreme weather events that exacerbate microbial contamination (Noor, 2023).

The epidemiological burden of waterborne diseases extends beyond morbidity to significant healthcare costs and social disruption, particularly in low- and middle-income regions where well water serves as a primary drinking source. A recent outbreak in Albania demonstrated how contaminated well water can trigger widespread illness, highlighting the need for proactive surveillance and emergency responses (Poga, 2025). Similarly, studies in Iran revealed that waterborne outbreaks continue to affect communities due to inadequate microbial control, underscoring the persistent health risks linked to unmonitored well water (Jafari *et al.*, 2025). Furthermore, antibiotic-resistant bacteria in drinking water sources, including wells, present an emerging challenge in global public health, as resistant strains increase the severity and

duration of infections (Federigi *et al.*, 2025). Climate change is compounding these risks, with flooding and temperature shifts enhancing the survival and spread of microbial pathogens in groundwater supplies (World Health Organization, 2023). Addressing these issues requires integrated approaches, including microbial water quality monitoring, climate-adaptive strategies, and sustainable sanitation systems (Sawyer *et al.*, 2025).

2.6.2. Diarrhoeal Diseases and Childhood Mortality

Contaminated well water is a significant transmission pathway for diarrhoeal diseases in children, as it frequently harbors pathogenic bacteria such as *Escherichia coli* and coliforms (Corsita and Sinaga, 2025). Globally, diarrhoeal disease remains one of the most critical causes of childhood mortality, contributing to nearly one in nine child deaths each year, with unsafe drinking water serving as a major risk factor (Motuma *et al.*, 2025). The presence of over 40 enteric pathogens, including bacteria, viruses, and protozoa, makes children reliant on contaminated wells especially vulnerable to severe diarrhoeal episodes and death (Gebregziabher *et al.*, 2024).

Studies in rural and peri-urban settings consistently show that households dependent on untreated well water face higher diarrhoeal incidence rates, which significantly increase under-five mortality (Malebatja and Mokgatle, 2022). In South Coastal communities, for example, diarrhoeal morbidity among children has been directly correlated with microbial contamination of wells, highlighting the need for urgent water safety interventions (Corsita and Sinaga, 2025). Globally, unsafe microbial water contributes to more than 300,000 annual deaths among children under five, reinforcing the severity of the epidemiological burden in low-resource settings (Izah and Ogwu, 2025). In addition to direct health outcomes, diarrhoeal diseases from contaminated wells perpetuate cycles of malnutrition, growth stunting, and weakened immunity, which further elevate the risk of mortality (Zhao *et al.*, 2025). Furthermore, emerging evidence suggests that antibiotic-resistant microorganisms in water

sources intensify the threat by limiting treatment effectiveness and prolonging disease duration. Addressing this dual challenge requires integrated strategies involving microbial water quality monitoring, sanitation improvements, and health system strengthening (Federigi *et al.*, 2025).

2.6.3. Typhoid Fever, Cholera, and Other Enteric Infections

Microbial contamination of well water remains a significant driver of enteric infections, including typhoid fever, cholera, and dysentery, particularly in low- and middle-income countries (Hashmi *et al.*, 2025). Pathogens such as *Salmonella Typhi* and *Vibrio cholerae* are frequently isolated from unprotected groundwater sources, where inadequate sanitation and improper waste disposal allow fecal contaminants to seep into wells (Izah and Ogwu, 2025). These infections are linked to high morbidity and mortality, especially among children, due to limited access to safe water and healthcare in vulnerable populations (Ghazy *et al.*, 2025).

Typhoid fever is directly associated with the ingestion of untreated or poorly managed well water, with epidemiological data identifying unprotected groundwater as a primary risk factor for sustained transmission (Boakye and Twumasi, 2025). Similarly, cholera outbreaks have been consistently connected to microbial contamination of wells, particularly during rainy seasons and flooding events that increase the spread of *V. cholerae* (Butabayev and Yoqubov, 2025). In Pakistan and other South Asian regions, studies have demonstrated that both bacterial and viral enteric pathogens persist in community wells at levels exceeding World Health Organization safety thresholds, directly correlating with outbreaks of enteric diseases (Ashraf *et al.*, 2023). Beyond typhoid and cholera, other enteric infections such as dysentery, hepatitis A, and cryptosporidiosis are widespread in populations dependent on contaminated groundwater sources (Chowdhury *et al.*, 2025). These infections contribute significantly to the global burden of disease, with more than half of all mortality from water-associated illnesses attributed to microbial intestinal infections (Prasad and Grobelak, 2020). While vaccination campaigns and cholera elimination roadmaps are being implemented in regions such as

Zambia, contaminated groundwater continues to undermine progress, emphasizing the urgent need for safe water interventions (Mbewe *et al.*, 2024).

2.6.4. Fungal Infections and Opportunistic Pathogens

Microbial contamination of well waters is not limited to bacteria and viruses but also includes fungi and opportunistic pathogens that can cause severe infections, particularly in immunocompromised individuals (Stec, Kosikowska, and Mendrycka, 2022). Opportunistic fungi such as *Aspergillus* and *Candida* have been detected in potable and well water sources, where they may survive and proliferate within biofilms, eventually leading to invasive fungal infections (Novak Babič and Gunde-Cimerman, 2025). These pathogens pose serious risks in both community and healthcare settings, with invasive aspergillosis and candidiasis being well-documented waterborne threats (Ghodsi *et al.*, 2025). The health risks are particularly pronounced for children, the elderly, and patients with weakened immune systems, such as those in intensive care units, who are highly susceptible to opportunistic fungal infections (Klimas, Zatlōka-Mazur *et al.*, 2025). Fungal intrusion into groundwater and plumbing systems has been shown to alter microbial community structure, increasing the prevalence of opportunistic bacteria such as *Pseudomonas* in conjunction with fungi, thereby compounding public health risks (Liu *et al.*, 2025). In rural and peri-urban communities dependent on wells, untreated groundwater can serve as a reservoir for both rare and common fungi, which may resuspend during water extraction and contribute to infection risks (Nduli *et al.*, 2025).

Recent studies emphasize the growing importance of fungal and opportunistic pathogens within the broader “One Health” perspective, noting their impact not only on human health but also on environmental and animal health (Sabino *et al.*, 2025). The persistence of resistant fungal strains in well water further complicates treatment, as antifungal resistance reduces the effectiveness of standard therapies (Novak Babič and Gunde-Cimerman, 2025). Addressing these challenges requires robust microbial monitoring of well waters, coupled with improved

sanitation, disinfection practices, and awareness campaigns to mitigate risks of waterborne opportunistic infections.

2.6.5. Protozoan-Related Gastrointestinal Disorders as a Health Implication of Microorganisms in Well Waters

Protozoan parasites such as *Giardia duodenalis* and *Cryptosporidium parvum* are among the leading microbial contaminants of well waters and are strongly associated with gastrointestinal disorders in humans (El-Khadry *et al.*, 2025). These organisms are highly resistant to conventional water treatment methods, allowing them to persist in groundwater and contribute to outbreaks of diarrhoeal disease (Ogalo *et al.*, 2025). Global estimates indicate that protozoan-related gastrointestinal illnesses account for a significant burden of diarrhoea cases worldwide, especially in low-resource communities where well water serves as the primary drinking source (Suleiman and Azlan, 2025). Recent investigations reveal that protozoan contamination of well water is exacerbated by poor sanitation, livestock proximity, and fecal pollution, creating a cycle of recurrent gastrointestinal disorders in affected populations (Ogalo *et al.*, 2025). In Bangladesh, long-term studies identified protozoan oocysts as a common contaminant in water sources, highlighting their persistence in rural environments and direct links to gastrointestinal infections (Hossain *et al.*, 2025). Similarly, protozoan infections in migrant populations have shown significant associations with changes in gut microbiota, further complicating health outcomes and treatment (Marangi *et al.*, 2025).

The health impact of protozoan infections is especially severe among children, immunocompromised individuals, and populations in tropical regions, where gastrointestinal complications contribute to malnutrition and increased mortality (Ghazy *et al.*, 2025).

Evidence also suggests that environmental factors, including climate variability and air pollution, can exacerbate protozoan transmission, thereby worsening the global burden of gastrointestinal disorders (Maldonado-Barrueco and de la Calle-Prieto, 2025). Integrated One

Health approaches that address environmental, human, and animal reservoirs of protozoa are therefore essential for effective control (El-Khadry *et al.*, 2025).

2.7. Methods for Microbial Detection in Well Waters

2.7.1. Culture-Based Methods

Culture-based methods remain a cornerstone in microbial detection because they allow for the isolation and quantification of viable microorganisms. These approaches involve growing bacteria on selective or differential media to enumerate indicator organisms such as *Escherichia coli* and coliforms, which are key markers of fecal contamination in well water (McConn *et al.*, 2024). Despite their reliability, culture methods are limited by long incubation times, the inability to detect viable but non-culturable (VBNC) organisms, and challenges in identifying slow-growing pathogens (Ferone *et al.*, 2020).

2.7.2. Microscopic Identification of Fungi and Protozoa

Microscopy remains an essential diagnostic tool for identifying fungi and protozoa in well water. Techniques such as staining, fluorescence microscopy, and phase-contrast microscopy provide direct visualization of microbial morphology and motility (El-Abbassy *et al.*, 2024). For protozoa like *Giardia* and *Cryptosporidium*, microscopy combined with immunofluorescence assays increases specificity and sensitivity, although expertise is required to distinguish organisms from debris in complex water matrices (Dabban *et al.*, 2024).

2.7.3. Biochemical Characterization of Bacteria

Biochemical characterization utilizes metabolic and enzymatic profiles to differentiate bacterial species. Tests such as carbohydrate fermentation, urease activity, and catalase/oxidase reactions remain widely used for confirmatory identification following initial culture (Najjembe *et al.*, 2025). recent advances integrate biochemical assays with automated systems,

such as MALDI-TOF coupled workflows, allowing faster and more cost-effective bacterial classification in water microbiology laboratories (Ferone *et al.*, 2020).

2.7.4. Molecular Approaches

Molecular methods, including polymerase chain reaction (PCR), quantitative PCR (qPCR), and next-generation sequencing (NGS), have revolutionized microbial detection in water systems. These techniques provide high sensitivity, enable detection of unculturable organisms, and allow for species- and strain-level resolution (Ferone *et al.*, 2020). Metagenomics and other omics approaches further expand the ability to profile entire microbial communities in well water, providing insights into both pathogens and beneficial microorganisms (Dabban *et al.*, 2024).

2.7.5. Rapid Diagnostic and Field Testing Methods

Rapid diagnostic and field-based methods are increasingly vital for real-time monitoring of well water quality. Biosensors, lateral flow immunoassays, and portable microfluidic devices enable on-site detection of pathogens without requiring advanced laboratory infrastructure (Ferone *et al.*, 2020). These tools are particularly beneficial for rural and resource-limited communities, where traditional culture or sequencing approaches may be inaccessible. Current trends focus on integrating biosensing platforms with smartphone-based readouts to improve accessibility and rapid decision-making in water safety management (Najjembe *et al.*, 2025).

2.8. Preventive and Control Measures

Proper Well Construction and Design

The prevention of microbial contamination begins with the proper siting and construction of wells. Wells located too close to latrines, septic systems, or agricultural fields are at higher risk of contamination due to infiltration of surface or wastewater (Olalemi *et al.*, 2023). Protective

measures include constructing sanitary seals, using grouted casings, and ensuring sufficient wellhead elevation above ground to prevent surface runoff infiltration. Such structural interventions reduce direct pathways for microorganisms into aquifers, offering long-term microbial protection (Wells *et al.*, 2025).

Regular Maintenance and Inspection

Preventive maintenance is a critical control measure for private wells, encompassing inspection of seals, casings, and pumps to identify vulnerabilities to microbial entry. Routine wellhead maintenance reduces contamination risks, especially from structural damage and environmental wear (Olalemi *et al.*, 2023). Studies highlight that stakeholders prioritize preventive maintenance over reactive responses, as early intervention avoids costly rehabilitation and mitigates microbial risk at its source (Wells *et al.*, 2025).

Water Quality Monitoring and Testing

Regular microbial monitoring is necessary for early detection and timely response to contamination events. Periodic testing for *Escherichia coli* and coliforms serves as an indicator of fecal pollution and helps ensure compliance with drinking water guidelines. Preventive frameworks recommend that well owners test water at least annually, particularly after flooding or repair activities, as these events increase contamination likelihood (Olalemi *et al.*, 2023).

Source Protection and Land-Use Management

The land surrounding wells is a critical determinant of microbial safety. Preventing microbial intrusion involves restricting agricultural activities, livestock grazing, and septic tank installations near well recharge zones. Buffer zones and managed land-use practices help prevent microbial contaminants from infiltrating groundwater, thereby strengthening natural protection against pathogens (Olalemi *et al.*, 2023).

Disinfection Practices

Disinfection is a crucial control measure for managing microbial contamination in well water. Chlorination is widely applied due to its affordability and effectiveness, though UV disinfection is increasingly favored for its ability to inactivate chlorine-resistant protozoa such as *Cryptosporidium* (Emadian *et al.*, 2021). Preventive shock chlorination following flooding or well repairs also provides temporary microbial control while longer-term solutions are implemented (English, 2020).

Community Awareness and Risk Culture

Beyond technical measures, fostering a culture of preventive risk management significantly influences microbial safety. Community training on safe water handling, well protection practices, and recognition of contamination risks empowers users to act proactively rather than reactively (Olalemi *et al.*, 2023). Recent evidence emphasizes that communities with strong preventive risk cultures demonstrate better water quality outcomes and reduced incidence of waterborne illness (Wells *et al.*, 2025).

CHAPTER THREE

MATERIALS AND METHOD

3.1. Study Area

This study was conducted in Benin City, the capital of Edo State, located in the South-South geopolitical zone of Nigeria. **3.2 Study Design**

his study employed a **cross-sectional, descriptive-analytic design** to determine the prevalence and distribution of microorganisms in well waters used for domestic purposes in Benin City, Edo State. A cross-sectional approach is appropriate because it allows estimation of the point prevalence of microbial contamination and the examination of associations between well characteristics (exposure variables) and presence/levels of microorganisms (outcomes) at a single time point

3.3. Inclusion Criteria

Well waters located in Benin City, Edo state.

3.4. Exclusion Criteria

Well Waters located outside Benin City, Edo state.

3.5. Sample Size

The sample size for this study will be determined using the Cochran formula for estimating sample size in prevalence (proportion) studies, which is expressed as:

$$n = Z^2 \times p \times (1-p) / d^2 \text{ (Wickramaratne, 1995).}$$

Where:

□ **n** = desired sample size

□ **Z** = standard normal deviation (1.96 at 95% confidence level)

□ **p** = estimated prevalence of microbial contamination of well water

□ **q** = (1 – p)

□ **d** = margin of error (precision), *set at* 0.07

The minimum required sample size is therefore calculated as: n=

$$(1.96)^2 \times 0.50 \times (1 - 0.50) / (0.07)^2$$

$$n = 3.8416 \times 0.50 \times 0.500 / 0.0049 = 0.9604 / 0.0049 = 196$$

Therefore a minimum sample size of 196 wells will be analysed for the course of this study.

3.6. Sample Collection and Analysis

A total of about 196 water samples were collected from selected wells across Benin City, Edo State, using aseptic procedures to prevent external contamination. Sterile 500 mL polyethylene bottles were employed for collection. Prior to sampling, each bottle was rinsed three times with the well water to be sampled. For wells fitted with hand pumps, the pump was flushed for approximately 2–3 minutes before collecting the sample. For open wells, samples were obtained using a sterile bucket or sampler attached to a rope, ensuring that the bottle cap remained closed until immersion. Each sample bottle was clearly labeled with the sample ID, location, date, and time of collection. The samples were transported to the laboratory in an insulated ice chest maintained at 4 °C and analyzed within six hours of collection, in accordance with the World Health Organization guidelines for drinking-water quality (WHO, 2017).

During sample collection, field observations were recorded for each well, including depth, type (open or covered), presence of lining, proximity to potential contamination sources such as latrines, septic tanks, or refuse dumps, and the general drainage condition. The microbial

quality of the water samples was subsequently determined using standard microbiological techniques as recommended by international guidelines.

3.6.1. Centrifugation and Microscopy Method

The centrifugation method was employed to concentrate parasitic stages such as cysts, oocysts, and helminth eggs from the well water samples. Each water sample was first allowed to settle for 8 hours to reduce turbidity, after which 50 ml aliquots were transferred into sterile centrifuge tubes. The samples were then centrifuged at 3,000 revolutions per minute (rpm) for 5 minutes to facilitate sedimentation of heavier particles, including potential parasitic organisms. After centrifugation, the supernatant was carefully decanted, leaving behind a *pellet* at the bottom of the tube. The pellet was resuspended in a small volume (2–3 ml) of sterile physiological saline solution to obtain a concentrated suspension suitable for microscopic analysis.

Microscopic examination was carried out on both saline wet mounts and iodine preparations of the concentrated sediments. A drop of the suspension was placed on a clean glass slide, covered with a cover slip, and observed under the light microscope using $\times 10$ and $\times 40$ objectives. The saline wet mount aided in the detection of motile trophozoites and helminth larvae, while the iodine preparation enhanced visualization of internal structures in protozoan cysts and helminth eggs, thereby facilitating proper identification. Formalin was also used in the research for preserving the parasites in cases of delayed analysis.

3.7. Data Analysis

Data obtained from laboratory examination of well water samples were entered and analyzed using Statistical Package for the Social Sciences (SPSS) version 25. Descriptive statistics will

be employed to summarize the data, with prevalence of microorganisms expressed as proportions and percentages.

CHAPTER FOUR

4.0. RESULTS

The results presented in Table 4.1 show that parasitic contamination of well water was widespread across the sampled locations. Among the parasites detected, *Ascaris* recorded the highest prevalence, with 52 positive cases (26.7%), indicating that more than a quarter of the sampled wells harbored this parasite. This was followed by *Strongyloides*, which was found in 32 samples (16.4%), and *Entamoeba*, present in 25 samples (12.8%). A smaller proportion of wells tested positive for *Giardia lamblia* and *Hookworm*, both occurring in 18 samples each (9.2%). *Schistosoma haematobium* and *Fasciola* showed the lowest prevalence, each detected in 14 samples (7.2%). It is also notable that only 23 wells (11.8%) showed no major parasitic contamination, while the remaining 172 wells (88.2%) had at least one parasite present.

The distribution of parasites by local government area is further summarized in Table 4.2. The prevalence of *Ascaris* was consistently high across the three LGAs, with 16 cases (22.9%) in Ikpoba Okha, 17 cases (25.4%) in Oredo, and 19 cases (32.8%) in Uhunde. Similarly, *Strongyloides* was detected in all three areas, with Uhunde having the highest proportion at 22.4%. For *Giardia lamblia* and *Hookworm*, the distribution was relatively uniform across the LGAs, with prevalence values ranging between 7.1% and 12.1%. *Entamoeba* was more frequent in Ikpoba Okha (15.7%) and Oredo (14.9%) than in Uhunde (6.9%). *Fasciola* was most common in Ikpoba Okha (11.4%), while *Schistosoma haematobium* was concentrated in Ikpoba Okha (12.9%) and Oredo (7.5%) but entirely absent in Uhunde.

The statistical associations between parasite prevalence and location (χ^2 test) revealed that most parasites did not show significant variation across the three LGAs. The chi-square values for *Strongyloides* ($\chi^2 = 2.19$, $p = 0.335$), *Giardia lamblia* ($\chi^2 = 0.57$, $p = 0.753$), *Ascaris* ($\chi^2 = 1.68$, $p = 0.432$), *Hookworm* ($\chi^2 = 0.93$, $p = 0.629$), *Entamoeba* ($\chi^2 = 2.61$, $p = 0.271$), *Fasciola* ($\chi^2 =$

3.26, $p = 0.196$), and No major parasite ($\chi^2 = 0.39$, $p = 0.821$) were all statistically nonsignificant ($p > 0.05$). However, *Schistosoma haematobium* showed a statistically significant association with location ($\chi^2 = 7.88$, $p = 0.019$), suggesting that its distribution across LGAs was not uniform, with higher prevalence in Ikpoba Okha and Oredo compared to Uhunde. **Table 4.1:**

Table 4.1: Prevalence of Parasites in wells in Benin city

<u>Parasite</u>	<u>Present n (%)</u>	<u>Absent n (%)</u>
Strongyloides	32 (16.4%)	163 (83.6%)
Giardia lamblia	18 (9.2%)	177 (90.8%)
Ascaris	52 (26.7%)	143 (73.3%)
Hookworm	18 (9.2%)	177 (90.8%)
Schistosoma haematobium	14 (7.2%)	181 (92.8%)
Entamoeba	25 (12.8%)	170 (87.2%)
Fasciola	14 (7.2%)	181 (92.8%)
No Major Parasite	23 (11.8%)	172 (88.2%)

Table 4.2: Distribution and Association of Parasites by Local Government Area (LGA) in Edo state

Parasite	Ikpoba Okha n (%)	Oredo n (%)	Uhunde n (%)	χ^2 (df)	p-value
Strongyloides	10 (14.3%)	9 (13.4%)	13 (22.4%)	2.19 (2)	0.335
Giardia lamblia	5 (7.1%)	7 (10.4%)	6 (10.3%)	0.57 (2)	0.753
Ascaris	16 (22.9%)	17 (25.4%)	19 (32.8%)	1.68 (2)	0.432
Hookworm	5 (7.1%)	6 (9.0%)	7 (12.1%)	0.93 (2)	0.629
Schistosoma haematobium	9 (12.9%)	5 (7.5%)	0 (0.0%)	7.88 (2)	0.019*
Entamoeba	11 (15.7%)	10 (14.9%)	4 (6.9%)	2.61 (2)	0.271
Fasciola	8 (11.4%)	4 (6.0%)	2 (3.4%)	3.26 (2)	0.196
No Major Parasite	7 (10.0%)	9 (13.4%)	7 (12.1%)	0.39 (2)	0.821

*Significant at $p < 0.05$.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 Discussion

This study investigated the prevalence and distribution of parasitic contamination in well waters across selected local government areas in Benin City, Edo State. The results revealed a high level of contamination, with 88.2% of wells testing positive for at least one parasite, demonstrating that untreated groundwater in Benin City poses significant public health risks. This aligns with global findings that private wells in low- and middle-income countries are highly vulnerable to contamination due to poor sanitation, shallow construction, and inadequate environmental management (Grönwall and Danert, 2020).

Ascaris lumbricoides was the most frequently detected parasite (26.7%), followed by *Strongyloides* (16.4%) and *Entamoeba spp.* (12.8%). This pattern reflects fecal pollution, poor hygiene, and the proximity of wells to septic tanks or pit latrines, as emphasized in Chapter Two. Comparable studies in sub-Saharan Africa and Asia reported similar findings, identifying *Ascaris* as a dominant helminth in contaminated groundwater (Stokdyk *et al.*, 2020; Adugna *et al.*, 2024).

The detection of *Giardia lamblia* (9.2%), *Schistosoma haematobium* (7.2%), and *Fasciola spp.* (7.2%) underscores the diversity of parasites present and reflects environmental factors such as runoff from agricultural land and stagnant drainage channels (Dzodzomenyo *et al.*, 2022). Although *Schistosoma* prevalence was relatively low, its significance cannot be understated, as even minimal contamination can sustain schistosomiasis transmission in endemic areas.

Parasite distribution was generally uniform across the three LGAs, except for *Schistosoma haematobium*, which showed a statistically significant association with location ($\chi^2 = 7.88$, $p = 0.019$). Its concentration in Ikpoba Okha and Oredo, and absence in Uhunde, suggests that hydrological and environmental factors including flooding, soil permeability, and proximity to

drainage systems play a critical role in contamination risk. Similar geographic clustering has been reported in African and Asian studies (Chuah and Ziegler, 2018; Itarte *et al.*, 2024).

The relatively even distribution of *Ascaris*, *Strongyloides*, and *Giardia* across sites indicates region-wide sanitation challenges, consistent with findings from West African communities with similar socio-environmental conditions (Mensah, 2022).

The widespread detection of parasites far exceeds World Health Organization (WHO) guidelines, which set a zero-tolerance standard for pathogens in drinking water (WHO, 2022). Consuming untreated groundwater in Benin City therefore poses serious risks of diarrhoeal diseases, helminth infections, typhoid, and schistosomiasis. Vulnerable groups especially children, pregnant women, and immunocompromised individuals are at heightened risk for malnutrition, growth stunting, and chronic infections.

Contaminated well water is a significant contributor to childhood diarrhoeal mortality in subSaharan Africa (Motuma *et al.*, 2025; Corsita and Sinaga, 2025). The detection of multiple parasite species in single wells suggests potential for mixed infections, which can exacerbate morbidity and complicate treatment.

These findings are broadly consistent with studies in Ethiopia, Nigeria, and Bangladesh, confirming that contaminated wells are a widespread public health challenge (Adugna *et al.*, 2024). However, the relatively lower prevalence of *Giardia* (9.2%) compared to reports from Cameroon and Bangladesh may reflect regional differences in sanitation practices, environmental conditions, or diagnostic methods (Stokdyk *et al.*, 2020).

5.2 Conclusion

This study demonstrates that well water in Benin City is extensively contaminated with intestinal parasites and is unsafe for drinking without treatment. The prevalence of

contamination (88.2%) and the dominance of *Ascaris lumbricoides* reflect inadequate sanitation, poor waste management, and hydrogeological vulnerabilities. While most parasites were uniformly distributed, *Schistosoma haematobium* exhibited significant geographic variation, highlighting the influence of environmental factors on parasite survival.

Overall, the results indicate that parasitic contamination of well water sources is widespread across Benin City, with *Ascaris* being the most prevalent parasite. While most parasites were evenly distributed across LGAs, *Schistosoma haematobium* demonstrated significant geographic variation in occurrence.

The findings exceed WHO drinking water standards and reveal a pressing public health concern. Without urgent interventions including well protection, routine monitoring, sanitation improvements, and community education groundwater contamination will continue to drive waterborne diseases and related health burdens in Benin City.

5.3 Recommendations

To mitigate the risks identified in this study, authorities and communities in Benin City should prioritize the enforcement of proper well construction and siting standards, ensuring safe distances from septic tanks, latrines, and drainage channels. Regular monitoring of groundwater quality and community sensitization on hygiene and safe water practices are essential to reduce contamination. Households should adopt simple water treatment methods such as boiling, chlorination, or filtration before consumption, while government agencies should invest in improved sanitation infrastructure to minimize fecal pollution. Additionally, locally relevant research on seasonal variations in parasite prevalence and the effectiveness of affordable water treatment options should be encouraged to guide long-term interventions.

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APPENDIX I QUESTIONNAIRE



UNIVERSITY OF BENIN

FACULTY OF BASIC MEDICAL SCIENCES DEPARTMENT OF MEDICAL LABORATORY SCIENCES

I am a 500 level student of the University of Benin. This questionnaire is designed as part of a research project and is centered on the 'prevalence of microorganisms among well waters used in Benin city, Edo state.' All responses will be treated with confidentiality and used solely for academic research purposes.

Tick (✓) the appropriate boxes below where applicable

Section A: Socio-Demographic Information

1. Age of respondent: 10-18 19-25 26-49 50 and above
2. Sex: Male Female
3. Highest level of education: No formal education Primary Secondary Tertiary
4. Occupation: _____ 5. Household size: _____ persons

Section B: Source and Use of Well Water

6. Do you have a well in your household? Yes No
7. Type of well used: Hand-dug well Borehole Other (specify) _____
8. Approximate depth of the well (if known): _____ meters
9. Main purpose of water from this well: Drinking Cooking Washing Irrigation Other (specify) _____
10. Frequency of well use for drinking: Daily Weekly Occasionally Never
11. Do you treat your well water before use? Yes No
If Yes, how? Boiling Filtration Chlorination/Alum Others (specify) _____

Section C: Sanitary and Environmental Conditions of the Well

12. Is the well properly covered? Yes No

13. Is the well lined with concrete? Yes No
14. Is there a drainage channel around the well? Yes No
15. Approximate distance from well to nearest refuse dump: <10 m 10–30 m >30 m
16. Approximate distance from well to nearest toilet/latrine: <10 m 10–30 m >30 m
17. Do you observe flooding or surface runoff entering the well during rainfall? Yes No
18. Do you share the well with other households? Yes No

Section D: Perception and Health-Related Information

19. Do you perceive any unusual taste, odor, or color in your well water? Yes No
If Yes, specify: _____
20. Has any member of your household experienced waterborne diseases (e.g., diarrhea, typhoid, dysentery, cholera) in the last 6 months? Yes No
21. If Yes, which condition(s)? _____
22. Do you consider your well water safe for drinking? Yes No

APPENDIX II

MATERIALS USED

Field Materials:

- Sterile 1-L plastic sampling bottles (with tight-fitting screw caps)
- Permanent marker and waterproof labels for sample coding
- Cooler box with ice packs for sample preservation during transport
- GPS device (for recording sampling locations)
- Disposable gloves and protective gear (lab coats, boots)

Laboratory Consumables:

- Clean glass slides and cover slips
- Disposable Pasteur pipettes and droppers
- Centrifuge tubes (15 ml and 50 ml)
- Normal saline (0.85%)
- 10% formalin solution
- Ether reagent (for concentration technique)
- Lugol's iodine solution (for staining protozoan cysts)
- Distilled water

Equipment:

- Compound light microscope ($\times 10$ and $\times 40$ objectives)
- Centrifuge (capable of 3,000 rpm)
- pH meter (for water quality checks)
- Autoclave (for sterilization of glassware)
- Analytical balance
- Refrigerator (4 °C) for sample preservation

Personal Protective Equipment (PPE):

- Laboratory coats
- Sterile gloves
- Face masks
- Safety goggles

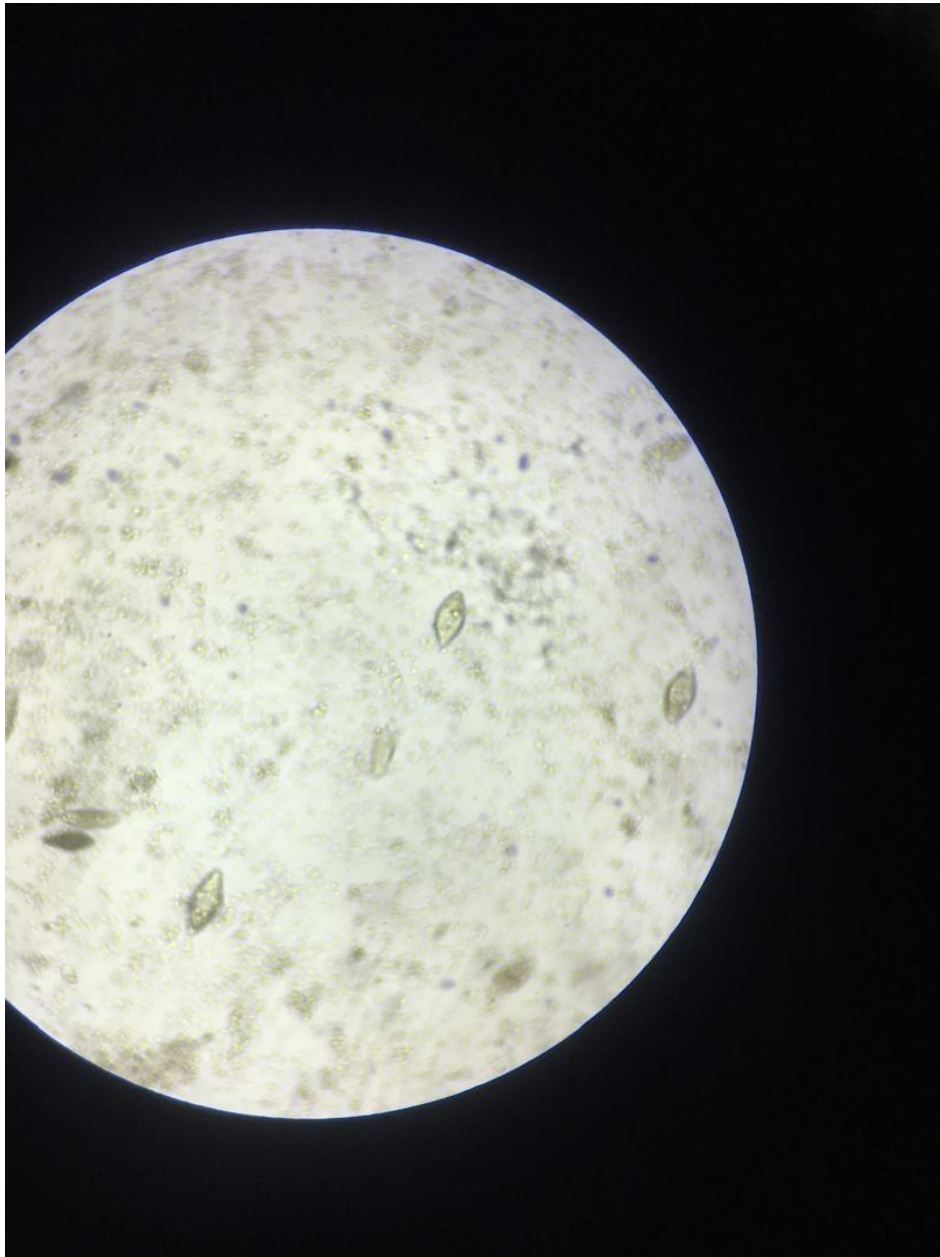


Fig 1. *Schistosoma haematobium*

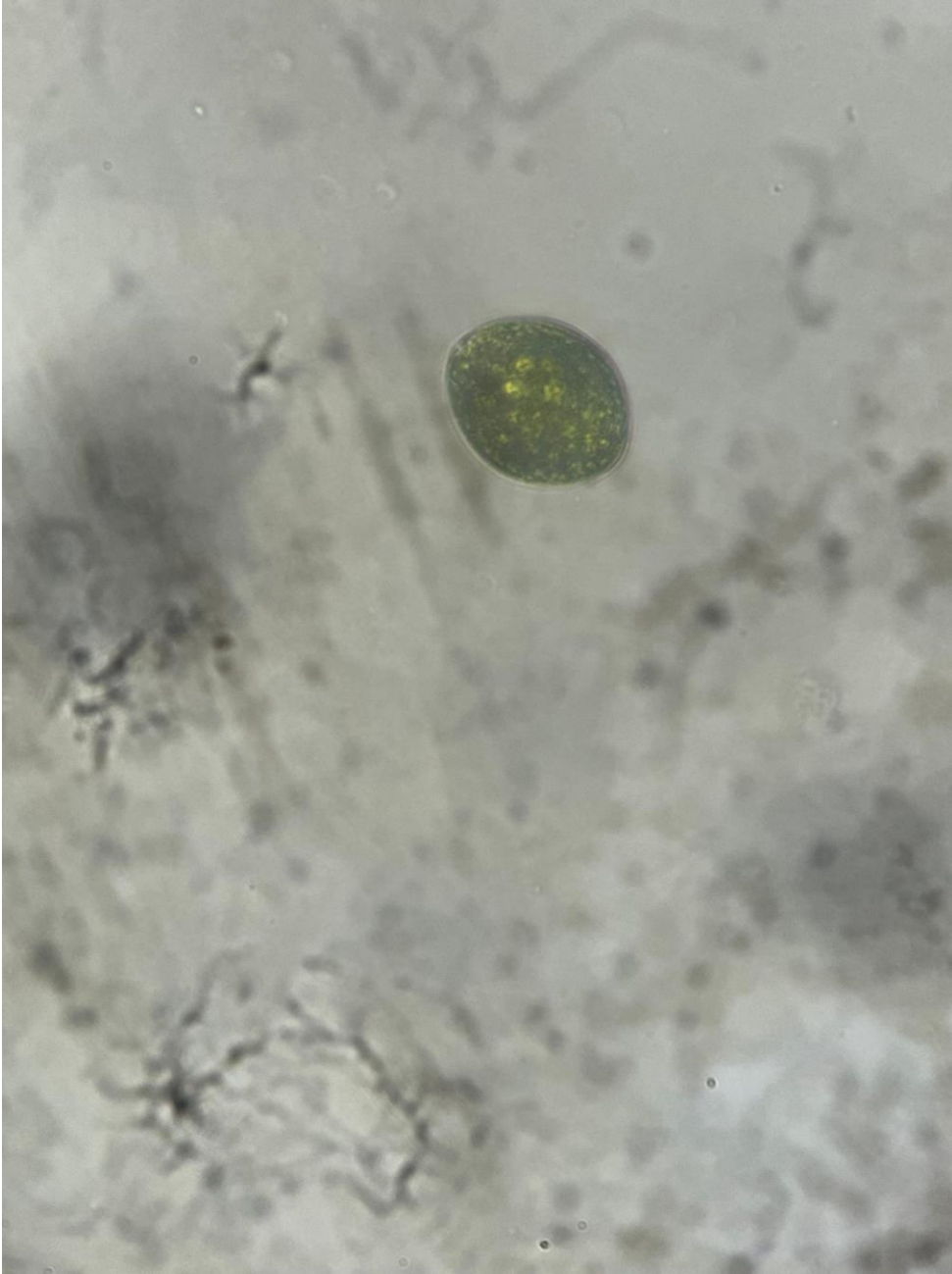


Fig 2. Ova of *Ascaris lumbricoides*



Fig 3.



Fig 4. Image of a well



Fig 5



Fig 6

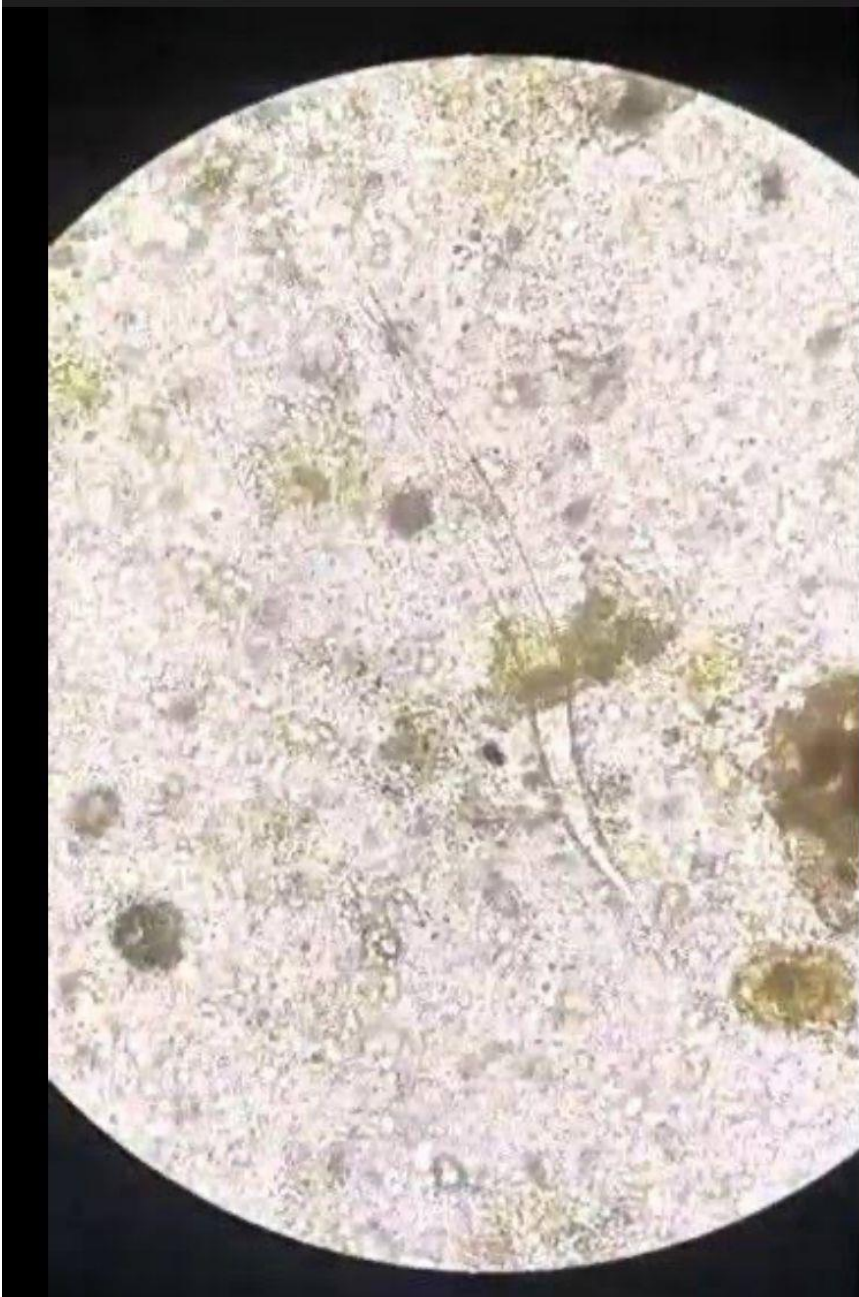


Fig 7: Larva of *Strongyloides stercoralis*



Fig 8: Rhabditiform larva of Hook worm

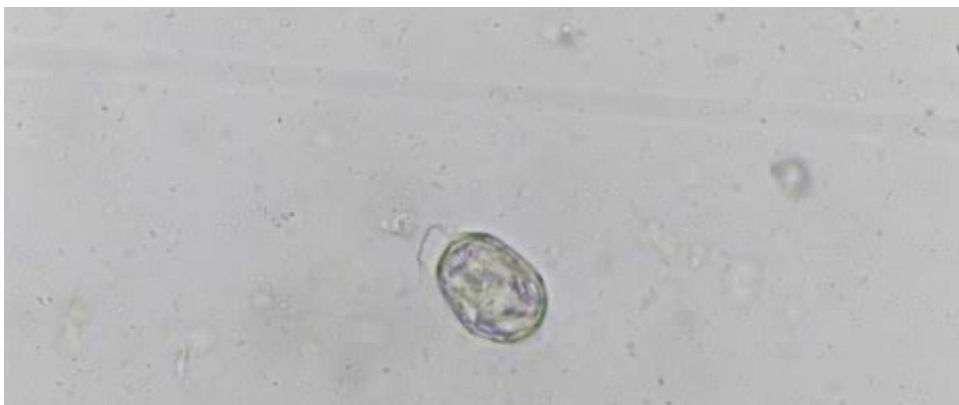


Fig 9. Image of *Giardia lamblia*



Fig 10.



Fig 11.