EVALUATING HUMAN EXCRETA MANAGEMENT AND SANITATION SERVICES USING A SHIT FLOW DIAGRAM AT ITEN MUNICIPALITY, ELGEYO MARAKWET COUNTY, KENYA

CYNTHIA JELAGAT KIPROP

A Thesis Submitted in Partial Fulfilment of Requirements for Conferment of the Degree of Master of Science in Sanitation of Meru University of Science and Technology

2025

DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other institution.

EG407/201418/21

Signed……………………………. Date…………………………..

Cynthia Jelagat Kiprop

DECLARATION BY SUPERVISORS

This thesis has been presented with our approval as University Supervisors.

Signed……………………………. Date…………………………..

Dr. Jane Jemeli Rutto, Ph.D

Meru University of Science and Technology, Kenya

Signed……………………………. Date…………………………..

Dr. Dorothy Kagendo Kithinji, Ph.D

Chuka University, Kenya

DEDICATION

I dedicate this research to my parents, Mr. William Kiprop and Mrs. Rose Kiprop, my children, Annabelle Chebet and AxelGrey Berur, and my partner, Hillary Rotich, who have been a constant source of inspiration, guidance, and support throughout my academic and professional journey. Their unwavering belief in my abilities, coupled with their encouragement and motivation, has been instrumental in shaping me into the person I am today. Their guidance and advice have helped me navigate the most challenging times, and their unwavering support has given me the strength to pursue my goals and aspirations.

ACKNOWLEDGMENT

First and foremost, I thank God for granting me the strength, wisdom, and perseverance to complete this research project. Without His blessings and guidance, this achievement would not have been possible. Additionally, I would like to sincerely thank my supervisors, Dr. Jane Rutto and Dr. Dorothy Kagendo, for their guidance, support, and invaluable feedback throughout the research period. Their insights, expertise, and constructivism have been instrumental in shaping my research. I would also like to thank the Meru University Sanitation Research Institute team, including Dr. Joy Riungu, Dr. Lilan Mworia, Mr. Domenic Kiogora, and my classmates, for their tireless effort, dedication, and teamwork. Their small or big contribution has been integral to the research's success. Finally, I would also like to thank my family and friends for their unwavering support, encouragement, and love throughout the research period. Their patience, understanding, and belief in me have motivated and inspired me. Thank you all for your contributions and support in making this research successful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS, SYMBOLS, AND ACRONYMS

BOD	Biochemical Oxygen Demand
CDC	Centers for Disease Control
CHVs	Community Health Volunteers
COD	Chemical Oxygen Demand
FSM	Faecal Sludge Management
ITWASCO	Iten Tambach Water and Sewerage Company
JMP	Joint Monitoring Programme
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
KPHC	Kenya Population and Housing Census
MLIC	Middle- and Low-Income Countries
NEMA	National Environmental Management Authority
OSS	Onsite Sanitation Systems
SDA	Sanitation Delivery Assessment
SDG	Sustainable Development Goal
SFD	Shit Flow Diagram
SFD-P1	Shit Flow Diagram Promotion Initiative
SPSS	Statistical Package for the Social Sciences
SSWM	Sustainable Sanitation and Water Management
UN	United Nations
UNCHCR	The United Nations High Commissioner for Refugees
UNICEF	The United Nations Children's Fund

WHO	World Health Organization
WSP	Water Service Providers

DEFINITION OF TERMS

Basic Sanitation	Refers to the essential infrastructure, facilities, and services for safe and hygienic human waste management.
Excreta Management	Refers to the systematic process of handling human waste (urine and faeces) from the point of generation to its safe disposal or reuse. Effective excreta management is crucial for maintaining public health, protecting the environment, and ensuring sustainable sanitation practices.
Evaluation	Involves analyzing various aspects of sanitation infrastructure and practices to determine their effectiveness and efficiency.
Faecal Sludge Management (FSM)	Refers to collecting, transporting, treating, and safely disposing or reusing faecal sludge, including solid and liquid waste, from onsite sanitation systems such as pit latrines, septic tanks, and simplified sewer systems.
Grey Water	Wastewater from non-toilet household uses such as bathing, laundry, and dishwashing. It does not contain human excreta and has lower levels of contamination than toilet waste (black water).
Household Head	Refers to the individual within a household who holds primary responsibility for making decisions related to sanitation practices and facilities. The head can be male or female. This person typically oversees the management of household resources, including water and waste disposal, and plays a key

	role in determining sanitation behaviors within the household.
Household	Refers to a group of people living together in a residential unit, typically sharing common facilities and resources, such as a dwelling, sanitation facilities, and water supply.
Human Excreta	Is waste material expelled from the body, consisting of urine and faeces.
Improved sanitation	Refers to providing adequate and hygienic sanitation facilities that effectively separate human excreta from human contact and the environment.
Mortgaged House	Refers to a property purchased with a loan (mortgage) from a financial institution. The buyer makes monthly payments to repay the loan over a specified period.
Rent-free housing	Refers to a living arrangement where an individual or family resides in a property without paying rent.
Pests	Refer to unwanted animals or insects that inhabit or access sanitation facilities. Common examples include cockroaches, flies, mosquitoes, rodents, and worms, which are often attracted by poor hygiene, stagnant water, or improperly sealed pits and tanks.
Sanitation Services	Encompasses all the activities and facilities involved in safely collecting, treating, and disposing of human excreta.
Sanitation Service Chain (SCC)	Refers to the sequence of stages and activities involved in managing human excreta, from its generation to its final

	treatment and disposal. The chain typically includes containment, collection, transport, treatment, and safe disposal or reuse. The sanitation service chain comprises various actors, technologies, and processes that are involved in ensuring the safe and sustainable management of human waste.
Semi-Detached House	A residential building that shares one common wall with another house.
Shit Flow Diagram Graphic Generator	A tool or software designed to create visual representations of the flow and management of human excreta across different stages, from containment through treatment and final disposal or reuse in urban or rural settings.
Shit Flow Diagram Matrix	Is a structured framework used to categorize and analyze the flow of human excreta through different stages of sanitation management in a given context, such as a city or rural area. The matrix helps in systematically identifying where excreta are safely managed and where they are not.
Shit Flow Diagram (SFD)	Also referred to as an excreta flow diagram, is a visual representation or diagram that depicts the flow of human excreta along the sanitation service chain. It provides a comprehensive overview of the different stages of excreta management, including containment, storage, transport, treatment, and disposal.
Townhouse	This is a type of multi-story residential property that shares one

	or more walls with adjacent properties but has its own entrance.
Unimproved sanitation	Refers to the lack of access to basic sanitation facilities that effectively separate human excreta from human contact and the environment.

ABSTRACT

In low- and middle-income countries such as Kenya, access to safe sanitation is a significant challenge contributing to public health issues and economic burdens. Various sanitation interventions have been implemented to address these challenges. However, the effectiveness of these interventions in managing human excreta along the sanitation service chain remains unclear. Therefore, the primary objective of the research was to evaluate human excreta management and sanitation services in Iten Municipality, using the Shit Flow Diagram (SFD), to identify existing gaps and challenges. The study's specific objectives included determining the main onsite sanitation technologies used, evaluating their performance, generating SFD, and identifying potential health risks associated with the current sanitation service chain. A mixed-methods approach was employed, involving quantitative and qualitative data collection. A sample size of 388 household heads was determined using the Yamane formula and selected through a cluster random proportionate sampling technique. Qualitative data were obtained via purposely selected key informants and observations, using a checklist and a transect walk guide. Quantitative data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26 for descriptive statistics and chi-square tests of association. Findings were presented in tables and charts. Qualitative data were transcribed and manually analyzed into themes, and the results were presented in a narrative format. Results indicated that major onsite sanitation technologies include pit latrines (69.1%), septic tanks (22.9%), and Anaerobic digesters (2.9%). The study also established that 69% of the waste was adequately managed, while 31% was not safely managed, and 3% still practice open defecation. Pests (42%), odour (41.8%), malfunctions, and blockages (64.6%) were common issues with these onsite technologies. The results revealed that 28% of the population had experienced sanitation-related health issues in the past year, with 12.9% reporting diseases such as amoebiasis, dysentery, and diarrhoea. Additionally, 19.1% of respondents acknowledge local water source contamination, exacerbating health risks, as indicated by laboratory findings of high levels of E. coli and Total coliforms in various water sources. These findings underscore the need for enhanced sanitation infrastructure, standardized maintenance protocols, and community education to improve waste management and public health outcomes in Iten Municipality.

CHAPTER ONE: INTRODUCTION

1.0 Introduction

This chapter lays the foundation for the research by discussing the background information on human excreta management and sanitation services, the problem statement, research questions, research objectives, the significance of the study, limitations, and delimitations.

1.1 Background of Human Excreta Management and Sanitation Services

Access to safe water and sanitation is a fundamental human right (United Nations [UN], 2021). However, more than 3.6 billion people globally lack access to safely managed sanitation. Of this population, 1.9 million have only basic sanitation services in their homes, and 494 million people still practice open defecation (United Nations Children's Fund [UNICEF] & World Health Organization [WHO], 2020). In South Asia and Sub-Saharan Africa, the situation is particularly dire. Over 70% of the global population practicing open defecation resides in these two regions, with countries like India, Nigeria, and Ethiopia leading in prevalence (Saleem *et al.,* 2019; Girmay *et al.,* 2023). In Sub-Saharan Africa alone, approximately 31% of the rural population continues to defecate in the open due to limited infrastructure, social norms, and poverty (Apanga *et al.,* 2020; MacLeod *et al.,* 2025). In Kenya, the scenario is similar, with a significant portion of the population lacking access to improved sanitation facilities. According to a report by the Joint Monitoring Programme for Water Supply, Sanitation, and Hygiene, approximately 23 million Kenyans lack access to basic sanitation services (Joint Monitoring Programme [JMP], 2021). This indicates that approximately half of Kenya's population lacks access to essential sanitation amenities, such as toilets (Hall *et al.,* 2021). Improving access to basic sanitation services is crucial for achieving sustainable development and improving the well-being of people in Kenya.

Goal 6 of the Sustainable Development Goals (SDGs) advocates for universal access to safe drinking water and sanitation. According to Berendes *et al*. (2017), achieving this goal requires delivering faecal sludge management (FSM) services to over 1.8 million people in low and middle-income countries, where millions of toilets linked to onsite sanitation systems (OSS) have been built to curb open defecation.

The first efforts of the United Nations towards advocating for safe water, sanitation, and hygiene are outlined in the Millennium Development Goals (MDGs). Target 7c of the MDGs aimed to halve the number of people without access to sanitation and increase the attention of key decision-makers to the need for investment in sanitation (Bartam *et al*., 2018). The MDGs partially achieved their goals because more than 1.9 million people gained access to improved sanitation by 2015 (JMP, 2020). While the MDGs were successful in many areas, there were limitations in their scope and focus. Hence, the SDGs were developed as a successor framework to the MDGs, adopted by the UN in 2015 (Westrate *et al*., 2019). The SDGs build upon the environmental dimensions of the MDGs and integrate them into a comprehensive framework to tackle social, economic, and ecological issues.

However, some challenges facing the achievement of the SDG goals for water and sanitation for all include the limited availability of accurate and up-to-date data on sanitation coverage, insufficient financial resources allocated to sanitation initiatives, and inadequate sanitation infrastructure (Herrera, 2019). Improved sanitation facilities, including toilets and effective wastewater management systems, can help curb disease transmission, promote better hygiene practices, and enhance the overall quality of life for individuals and communities (Lam *et al*., 2015; Zhang *et al*., 2022).

By 2020, only 34% of the global population had access to safely managed sanitation through sewer connections, which were predominantly found in urban areas and higher-income countries (Alam *et al*., 2025). In South Asia, over 60% of sanitation relies on non-sewered technologies, with urban slums and peri-urban areas facing significant risks of feacal sludge mismanagement (Zaghloul *et al*., 2024). For instance, in Dhaka, the capital of Bangladesh, only 20% of the total population is connected to a sewer, mostly from high-income communities (Alam *et al*., 2020). Similarly, in Sub-Saharan Africa (SSA), approximately 70% of urban populations use onsite sanitation systems, often with minimal regulation or waste treatment (Twinomucunguzi *et al*., 2020; Ravina *et al*., 2023; Lerebours *et al*., 2022). In Kenya specifically, *only* 16% of the population has access to centralized sewage systems, with the majority depending on onsite sanitation technologies (UNICEF & WHO, 2020). Therefore, there is a need to assess the strengths and weaknesses of sanitation technologies along the service chain. The MDG goals prioritized the construction of latrines and other onsite sanitation technologies to reduce open defecation, hoping that people would eventually move up the sanitation ladder to networked sanitation. However, as the period progressed, it was clear that the hope of networked sanitation was unrealistic, and the planners shifted their focus to feacal sludge management (FSM) (Westrate *et al*., 2019). Faecal sludge from onsite sanitation is managed through a series of steps to ensure safe management. The steps are collectively referred to as the sanitation service chain (Peal *et al*., 2020) (Figure 1.1).

Figure 1.1:

The Sanitation Service Chain

Source: Peal et al., (2020)

The global urban population is expected to grow from 4.2 billion in 2018 to approximately 6.7 billion by 2050, with most of this increase concentrated in low-and middle-income countries (Gambrill *et al*., 2020). This rapid urbanization necessitates more sustainable approaches to urban planning, particularly in managing human excreta across the sanitation service chain. Understanding the movement of faecal matter from containment to its ultimate use or disposal is essential for ensuring public health and environmental protection. Tools such as the Shit Flow Diagram (SFD) have proven vital in facilitating this understanding and promoting citywide inclusive sanitation planning (Furlong *et al*., 2023; Bateganya *et al*., 2023).

The shit flow diagram is an innovative tool used to visualize the movement of human excreta, including faeces and urine, through a sanitation system from the point of generation to the point of disposal or reuse (SFD-PI, 2018b). The diagram often identifies and addresses gaps in the sanitation chain, promoting sustainable and safe sanitation practices. The SFD can help determine the sanitation technologies used in urban areas, their performance, and their associated challenges. Using the SFD, various stakeholders' multisectoral and combined efforts can be mobilized to promote safe and sustainable human excreta management practices. This includes promoting the adoption of suitable sanitation technologies in urban areas and developing policies and regulations that facilitate the safe management of faecal sludge.

The Shit Flow Diagram (SFD) is a tool that can contribute to achieving the SDG 6.2 goal by promoting safe and sustainable faecal sludge management practices. The SFD can help identify gaps in sanitation services, particularly in urban areas, and assist decision-makers in prioritizing investments in appropriate sanitation technologies (Peal *et al*., 2019). Additionally, the SFD can help decision-makers monitor progress toward achieving SDG 6, as regularly updating the SFD enables them to track changes in the sanitation system and measure the impact of interventions (Blackett *et al*., 2014). This can help ensure that investments in sanitation are being used effectively and efficiently and that progress toward achieving SDG 6 is being made.

On-site sanitation systems vary widely regarding the standards to which they have been constructed and the extent to which they prevent hazardous exposure of excreta into the environment through open drains and groundwater. The most common onsite sanitation technologies include septic tanks, pour-flush systems, and unlined or lined pit latrines dug into the earth (Vidal *et al*., 2019). Effective faecal sludge management (FSM) prevents health threats such as diarrhoea, cholera, and typhoid, particularly as sludge accumulates in these containment systems (Baltazar *et al*., 2021). A comprehensive understanding of the current sanitation service chain is critical for urban and peri-urban areas to enhance safe excreta management. However, gathering reliable data on existing systems is often hindered by informal service provision, inadequate regulatory oversight, and insufficient monitoring metrics (Ward *et al*., 2022; Maqbool *et al*., 2022; Scott *et al*., 2019). Tools such as the Service Delivery Assessment (SDA) and Shit Flow Diagrams (SFDs) have been instrumental in enabling municipalities to visualize and assess sanitation flows, offering standardized diagnostics to inform planning and policy (Aboutaleb, 2022; Panesar *et al*., 2022).

The study by Peal *et al*. (2014) describes the methodology adopted to assess the delivery of urban sanitation services through the service delivery assessment (SDA) and the shit flow diagram (SFD). The World Bank's World Sanitation Program (WSP) created these two evaluation tools in 2012 and 2013 to assess excreta management along the sanitation service delivery chain (Spuhler *et al*., 2020). The shit Flow Diagram (SFD) has been adopted in more than 118 countries as a planning and advocacy tool to inform the critical sanitation stakeholders of the state of faecal sludge management across the sanitation service chain. Furthermore, Panesar *et al*. (2022) highlight how SFD describes the structure of the entire service chain in a single graphic that is easily understandable for specialists and the general population.

The shit flow diagram has been used in various countries for sanitation planning and monitoring (Peal *et al*., 2020). For example, in Indonesia, the SFD was utilized to evaluate its progress toward achieving its sanitation targets and pinpoint areas where improvements were necessary (Daniel *et al*., 2021; *Trinanda, 2018*). In Nepal, the SFD was utilized to identify sources of faecal contamination in the environment and contributed to developing interventions to prevent contamination (Strande *et al.,* 2021). In Luzaka, Zambia, the SFD was used to identify gaps in the sanitation chain and develop strategies to address these gaps (Kapulu, 2021). The SFD tool has also been used in Kenya to identify gaps in the sanitation chain and to develop strategies to address these gaps (Hall *et al*., 2021). For instance, in 2016, the Kenyan government launched the "Kenya Sanitation and Hygiene Improvement

Programme" (K-SHIP), a national sanitation campaign aimed at improving access to safe and sustainable sanitation for all Kenyans (Ouma & Jackson, 2017). As part of the K-SHIP program, the shit flow diagram (SFD) was used to map the movement of faecal matter in various towns and cities across Kenya. One such example is the city of Kisumu, located in western Kenya. In Kisumu, the shit flow diagram was used to identify the primary sources of faecal contamination and to develop strategies to improve sanitation. The diagram revealed that a significant amount of faecal matter was being dumped into Lake Victoria, a primary source of drinking water for the city (Furlong *et al*., 2015). To address this issue, the city developed a plan to construct new sanitation facilities and upgrade the existing ones, focusing on promoting the safe disposal of faecal matter.

Another town in Kenya where the shit flow diagram has been used is Nakuru, located in the Rift Valley region. The diagram was used to identify the primary sources of faecal contamination and to develop strategies to improve sanitation (Simiyu, 2017). In Nakuru, the diagram revealed that a significant amount of faecal matter was being discharged into the town's rivers and streams, which serve as the primary sources of drinking water for the town (SFD-P1, 2018a). To address this issue, the town developed a plan to construct new sanitation facilities and upgrade the existing ones, focusing on promoting the safe disposal of faecal matter. By mapping the movement of faecal matter, the diagram has helped local authorities to understand the complex sanitation challenges facing their communities and to develop targeted solutions to address these challenges. The primary advantage of the SFD tool is that it can be applied to any geographical entity, regardless of its size or population.

The adoption of SFD in evaluating faecal sludge management across the sanitation service chain classifies the services as poor, improved, or good (SFD-PI, 2018a). A collaborative effort of a joint monitoring program (JMP) for water supply and sanitation, aimed at understanding the missing link in sanitation services, adopted the SFD tool in 12 cities worldwide. The study found that 64% of the population relied on onsite sanitation technologies; therefore, faecal sludge management services are crucial (Blackett *et al*., 2014). A population-weighted average generated from faecal waste flow matrices of the 12 cities revealed that only 22% of households with onsite sanitation technologies manage their waste safely. The study also revealed that Palu city in Indonesia and Dumaguete city in the Philippines lack sewerage connections, with 50% of the faecal sludge being safely managed (Blackett *et al*., 2014).

In 2014, the SFD promotion initiative funded by the Bill and Melinda Gates Foundation (BMGF), a group of institutions focused on the safe management of excreta, came together to prepare the second phase of the SFD tool framework (JMP, 2020). The SFD tools used for collecting and planning faecal management services have undergone improvements through sharing and promotions with potential users (Peal *et al*., 2020). Countries that fail to emphasize safe sanitation services usually incur substantial economic impacts.

According to the World Bank, 165 million children under five are in poverty areas with low substandard sanitary conditions, increasing their risks of developing sanitation-related illnesses and deaths (UNICEF & WHO, 2019). According to Sangsanont *et al*. (2022), the recent COVID-19 pandemic has highlighted the importance of accessing safely managed sanitation services, as faecal excreta can harbour COVID-19 Ribonucleic acid (RNA) that can be transmitted from one individual to another when these services are poorly managed. Untreated faecal sludge poses a significant threat to the health of the surrounding community and the environment, as it spreads infectious diseases and contaminates water quality.

The rapid growth of urbanization and the disparity between the poor and the rich in urban areas continue to exacerbate sanitation problems in middle- and low-income countries (MLIC); thus, there is a need to address and pinpoint these sanitation challenges. Additionally, in most low- and middle-income countries, utility companies operate sewers that serve a specific privileged population. According to Furlong *et al*. (2016), the SFD tool for Lusaka revealed that 75% of the excreta produced in the city is not safely managed. Communicating the Lusaka sanitation problem through the SFD tool led to transformative changes in sanitation after the city adopted a city-wide inclusive sanitation model.

Most East African countries lack safe sanitation systems, resulting in significant public health and environmental issues. Low sanitation coverage and waterborne diseases are two of the most pressing public health issues in East Africa, primarily due to inadequate sanitation (Herrera, 2019). Millions lack access to improved sanitation and are exposed to dangerous bacteria and diseases such as cholera, diarrheal illnesses, and typhoid fever (Rombo *et al*., 2017). These waterborne illnesses can devastate vulnerable populations, especially children and the elderly, who are at risk of severe dehydration and malnutrition. Approximately 70% (340 million) of the population in Eastern and Southern Africa lack access to basic sanitation services (Rombo *et al*., 2017).

The sanitation issues in many urban areas of East African countries are primarily due to fast population growth and the migration of people from rural to urban areas. The lack of a conceptual framework, policy planning, and financing further complicates the sanitation situation in East Africa (Jiménez *et al*., 2019). However, it is crucial to understand that factors such as inadequate sanitation technologies and a lack of prioritization of sanitation also exacerbate sanitation challenges in East Africa. The Kenya Sanitation and Hygiene policy aims to achieve and sustain 100% access to improved sanitation by 2030 and to increase public investment in sanitation from 0.2% to at least 0.5% of the Gross Domestic Product (GDP) by 2020 and to 0.9% of the GDP by 2030 (World Bank, 2019). However, without learning about the grim reality of the sanitation situation, which can be perfectly illustrated by an excreta flow diagram in many parts of the country, these goals will be unrealistic for the country.

1.2 Statement of the Problem

Safe and adequate sanitation is essential for public health, environmental sustainability, and is recognized as a fundamental human right. However, many cities and towns in middle and low-income countries face the pressure to expand their sewerage systems but cannot ensure adequate collection and treatment (Ward *et al*., 2022; Panesar *et al*., 2022; Berendes *et al*., 2017) Approximately 829,00 people in middle and low-income countries die as a result of scarce water, sanitation, and hygiene each year, and this is equivalent to 60% of the total diarrheal rates (JMP, 2020) hence, it is crucial to take immediate steps to prevent such demise. The first step is to develop an SFD to understand the challenges along the sanitation service chain and ensure adequate management of human excreta.

Iten Municipality, located in the Rift Valley region of Kenya, is no exception, as a significant portion of its population lacks access to safe sanitation facilities (Omonei, 2019). As a result, human excreta are not adequately managed, leading to environmental pollution and public health hazards. To address the lack of access to safe sanitation facilities in Iten Municipality, the local government and other stakeholders have implemented various sanitation interventions, including the construction of public toilets, septic tanks, and pit latrines. However, the effectiveness of these interventions in managing human excreta along the SSC remains unclear. Without a clear understanding of the flow of human excreta, it is challenging to identify gaps in the sanitation service chain and design targeted interventions to improve sanitation outcomes.

Despite the government's and other stakeholders' efforts to address the lack of sanitation, a comprehensive understanding of the flow of human excreta along the sanitation service chain in Iten Municipality remains necessary. Iten is experiencing rapid growth, and a lack of information on the sanitation technologies being used, their performance, and the associated challenges can hinder the development of effective interventions to promote safe and sustainable faecal sludge management practices. Therefore, there is a need for an assessment of the flow of human excreta along the sanitation service chain using the SFD to identify areas where the faecal sludge management system may be weak and develop targeted interventions to improve the entire sanitation service chain, from containment to end-use or disposal.

Therefore, the primary objective of this research was to evaluate human excreta management and sanitation services in Iten Municipality, using SFD analysis to identify existing gaps and challenges. The study aimed to provide policymakers and sanitation practitioners with valuable insights for designing and implementing effective sanitation interventions that can improve the overall health and well-being of the population in Iten Municipality.

1.3 Justification of the Study

Effective planning and monitoring of sanitation services in low- and middle-income countries (LMICs) requires tools that can assess access to toilets and the safe management of human excreta across the entire sanitation service chain. Traditionally, frameworks such as the Sanitation Safety Planning (SSP) developed by the World Health Organization, the Service Delivery Assessment (SDA) by the World Bank, and the Joint Monitoring Programme (JMP) by UNICEF/WHO have been widely used. However, these tools often focus on institutional performance, risk control at treatment sites, or access-level metrics, which do not provide detailed insight into where and how faecal sludge is actually being lost or safely managed along the chain (World Bank, 2014; UNICEF & WHO, 2021).

The Shit Flow Diagram (SFD) approach fills this critical gap by offering a simple, visual representation of the proportion of excreta that is safely managed versus that which is not, tracing its flow from toilet use to final disposal or reuse. Unlike other tools, the SFD combines quantitative data with stakeholder knowledge to generate an intuitive graphic easily understood by local governments, planners, and the community (Peal *et al.,* 2020). For example, SSP requires microbiological risk assessments and extensive data on infrastructure, which are often unavailable in smaller municipalities like Iten. Similarly, SDA tools assess financial and institutional bottlenecks but overlook operational weaknesses in the sanitation chain (Kennedy-Walker *et al.,* 2015). In contrast, SFDs have been successfully used in over 150 cities globally to identify key points of faecal contamination, assess informal and onsite systems, and facilitate low-cost sanitation planning in areas without sewers (Peal *et al.,* 2020). They have been adopted in Kenyan urban centres, such as Kisumu and Nakuru; however, smaller towns, like Iten Municipality, remain underrepresented in both national data and the research literature. This study addresses that gap by applying the SFD method in Iten for the first time, offering a locally grounded diagnostic of how faecal sludge is handled in a peri-urban environment with mixed sanitation technologies.

1.4 Research Questions

i. What are the main onsite sanitation technologies being used in Iten Municipality?
ii. How is the performance of the different sanitation technologies along the sanitation service chain at Iten Municipality?
iii. What are the potential health risks associated with the current sanitation service chain in Iten Municipality?
iv. How can a shit flow diagram be generated to visualize the flow of human excreta within Iten Municipality?

1.5 Research Objectives

1.5.1 General objective

To investigate human excreta management and sanitation services using a Shit Flow Diagram at Iten Municipality, Elgeyo Marakwet County, Kenya.

1.5.2 Specific objectives

i. To determine the main onsite sanitation technologies being used at Iten Municipality
ii. To assess the performance of the different sanitation technologies along the sanitation service chain at Iten Municipality
iii. To determine potential health risks associated with the current sanitation service chain in Iten Municipality.

iv. To generate a shit flow diagram to visualize the flow of human excreta within Iten Municipality.

1.6 Significance of the Study

The significance of the study findings lies in their ability to inform decision-making and enable targeted interventions that improve sanitation systems and public health outcomes. By identifying the primary sanitation technologies in Iten municipality, the study provides a clear understanding of the existing infrastructure, enabling local authorities, policymakers, and sanitation practitioners to pinpoint critical gaps and design targeted solutions. This knowledge allows decision-makers to prioritize improvements across the sanitation service chain by evaluating each technology's strengths and weaknesses.

Additionally, by assessing the performance of various sanitation technologies along the Sanitation Service Chain (SSC), the study enables stakeholders to identify areas where inefficiencies or failures occur, such as collection, transportation, treatment, and disposal of human excreta. Identifying these performance gaps allows for more effective allocation of resources and targeted interventions to address weaknesses, thereby enhancing sanitation systems' overall functionality and reliability.

The findings also provide a deeper understanding of the potential health risks associated with inadequate sanitation practices. By identifying specific health risks within Iten municipality, such as the spread of waterborne diseases like diarrhoea, cholera, and typhoid fever, the study enables the design of targeted public health interventions to reduce disease burden and improve the community's well-being.

Furthermore, the use of the Shit Flow Diagram (SFD) as a tool for analyzing the sanitation service chain allows for evidence-based decision-making in sanitation planning.

Stakeholders can rely on the SFD to communicate complex sanitation issues clearly, engage in informed dialogue, and make decisions leading to sustainable sanitation system improvements. Overall, these findings enable the development of a framework that can be applied in similar contexts, inspiring further research and the broader adoption of the SFD methodology in addressing sanitation challenges across diverse communities.

1.7 Limitations

The study relied heavily on self-reported data obtained through household surveys and interviews, which may be influenced by recall bias, misinterpretation of questions, or socially desirable responses. These factors can compromise the accuracy and reliability of data on sanitation behaviors, facility use, and health symptoms. To reduce this limitation, the study incorporated multiple strategies. Enumerators were trained to explain questions clearly and probe for accurate responses where necessary. Additionally, triangulation was applied by cross-verifying survey data with direct observations during transect walks and site visits, as well as comparing key informant narratives to household-level responses. This approach enhanced data credibility and helped validate self-reported claims with observed sanitation conditions.

The laboratory testing conducted in this study was limited in scope due to logistical constraints. Only a small number of water samples were analyzed, and the tests focused on basic microbiological indicators (e.g., *E. coli* and Total Coliforms). To address this constraint, water samples were strategically selected from a variety of commonly used sources (e.g., rivers, boreholes, piped water) to maximize representativeness despite the limited sample size. Additionally, analysis was performed at an ISO-certified laboratory (ELDOWAS) using standardized and validated testing protocols to ensure reliability and accuracy. While the scope of parameters tested was minimal, the chosen microbial indicators are internationally recognized as proxies for faecal contamination and are relevant to assessing sanitation-related health risks.

1.8 Delimitations

This study was geographically delimited to Iten Municipality within Elgeyo Marakwet County, Kenya. The focus was intentionally restricted to this locality to allow for an in-depth assessment of human excreta management and sanitation services in a rapidly urbanizing, peri-urban context. While this geographical focus limits broader applicability, it enabled a detailed analysis of localized sanitation technologies, service chain dynamics, and health risks. The findings are therefore most relevant to Iten and similar municipalities with comparable demographic, environmental, and infrastructural characteristics.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter presents a comprehensive literature review on the flow of human excreta along the sanitation service chain using a Shit Flow Diagram (SFD) at Iten Municipality, Elgeyo Marakwet County. The chapter aims to provide a solid theoretical foundation and contextual understanding of the research topic, highlighting key concepts, theories, and empirical studies related to sanitation technologies, performance evaluation, and health risks associated with the current sanitation service chain.

2.1 Main Sanitation Technologies

The flow of human excreta along the sanitation service chain is a critical aspect of public health and environmental sustainability (Borowy *et al.,* 2021; Okaali *et al.,* 2022). Proper human waste management is crucial in preventing the spread of waterborne diseases, protecting water resources, and promoting overall community well-being. Understanding excreta flow is fundamental in designing and implementing effective sanitation interventions and policies, as it identifies critical failure points and guides evidence-based decision-making for sustainable urban sanitation systems (Cookey *et al.,* 2020; Ejigu & Yeshitela, 2024). Many onsite and offsite sanitation technologies have been developed and implemented worldwide; the most common is the pit latrine (Brands *et al.,* 2022; Chandana & Rao, 2022). Pit latrines are a common low-cost sanitation option, particularly in rural and peri-urban areas. While they are inexpensive and relatively easy to construct, they present several challenges, including odour control, vector attraction, and risks to groundwater if not properly lined or maintained (Mamera *et al.,* 2021).

Regular maintenance and safe pit emptying are crucial in mitigating health risks, particularly those associated with faecal contamination. An improved version, the pour-flush toilet, features a water-sealed bowl that enhances hygiene by reducing odours and preventing fly infestations. These systems are often preferred in urban contexts due to their improved user experience. However, similar to pit latrines, they also demand regular desludging and effective faecal sludge management systems (Odjegba *et al.,* 2024; Sisay *et al.,* 2024). Furthermore, both technologies must be integrated into a comprehensive sanitation value chain to avoid environmental and public health hazards (Kanda *et al.,* 2021).

Furthermore, septic tanks are a common form of excreta management in rural areas and small towns, typically made of concrete or fiberglass and buried underground (Cookey *et al.,* 2022; Li *et al.,* 2023). The waste from the toilet flows into the septic tank, where bacteria partially break down the waste. The partially treated waste is then released into a drain field, where the soil further treats it. Septic tanks require less maintenance than pit latrines or pour-flush toilets but still require periodic pumping and cleaning (Anand & Apul, 2014; Tasnim *et al.,* 2023). Additionally, sewer systems are the most advanced form of excreta management and are typically found in urban areas.

They consist of a network of pipes that carry waste to a central treatment plant, where it is treated and released into the environment (Chirgwin *et al*., 2021).

Sewer systems require significant infrastructure and investment but provide the most comprehensive and hygienic form of excreta management. Composting toilets are a sustainable and environmentally friendly form of excreta management. They work by separating urine and faeces and using natural processes to break down the waste into compost. Composting toilets are odourless and do not require water or electricity (Berger, 2010). They are commonly used in remote or off-grid locations and can benefit environmentally conscious individuals or communities.

The other less common form of the excreta management system is the excreta Container-based management system, which is an innovative approach to safely managing human waste in areas where traditional sewer systems or pit latrines are not feasible or desirable (Russel *et al*., 2019; Oishi *et al.,* 2023; Bidira *et al.,* 2024). These Container-based management systems use sealed containers to store and transport human waste, which can be safely disposed of or treated later (Tiley *et al*., 2014; Orner & Mihelcic, 2018). There are several types of container-based excreta management systems, each with its advantages and limitations. One common approach is the use of urine-diverting dry toilets (UDDTs), which separate urine and faeces into separate containers. Container-based excreta management systems can be periodically emptied and transported to a treatment facility or composted as fertilizer (Tiley *et al*., 2014). The urine container can be used directly as fertilizer or treated separately in agriculture.

Another container-based approach is the use of prefabricated sanitation systems, essentially pre-made containers that can be quickly deployed in areas without access to traditional sanitation infrastructure. These containers can be fitted with various features, such as solar-powered fans for odour control, and can be easily transported to a central treatment facility for safe disposal (Russel *et al*., 2019). Container-based excreta management systems have several advantages over traditional pit latrines or sewer systems. They are more hygienic, as the sealed containers prevent odours and the spread of disease (Tilmans *et al*., 2015). They also reduce the risk of groundwater contamination, a significant concern in areas with high water tables or poor soil conditions (Chambers *et al*., 2022). Container-based systems are also more flexible and adaptable than traditional systems, as they can be easily moved or modified to suit changing needs or conditions.

However, there are also some challenges associated with container-based excreta management systems. They require regular maintenance and cleaning, and the containers must be disposed of or treated appropriately to prevent environmental contamination (Russell *et al*., 2019). There may also be cultural barriers to using container-based systems, as they may be perceived as less desirable or dignified than traditional sanitation infrastructure (Berger, 2010; Tiley *et al*., 2014; Tilmans *et al*., 2015; VanRiper *et al.,* 2022). Despite these challenges, container-based excreta management systems have the potential to significantly improve sanitation and public health in areas where traditional systems are not feasible or appropriate. They are particularly well-suited for emergency response situations, refugee camps, or other areas where rapid deployment and flexibility are essential (Tilamnas *et al*., 2015). With proper planning and investment, container-based excreta management systems can provide a safe, hygienic, and sustainable solution for managing human waste in various settings.

Integrating toilet systems with anaerobic digesters is another sanitation technology that offers a promising solution to sanitation challenges by effectively treating human waste while generating biogas, a renewable energy source (Colon *et al*., 2015; Forbis-Stokes *et al*., 2016; Orner & Mihelcic, 2018; Almansa *et al.,* 2023). According to Forbis-Stokes *et al*. (2016), this system not only treats waste locally but also reduces the reliance on centralized sewage treatment facilities, which often require significant energy and infrastructure. Additionally, Colon *et al*. (2015) highlight the energy recovery potential of such systems, particularly in off-grid areas or regions with limited infrastructure, by converting organic matter from human waste into biogas that can be used for cooking, heating, or electricity generation. Lansing et al. (2017) discussed that technologies such as vacuum toilets or low-flush systems significantly reduce water usage compared to traditional flush systems, which are particularly crucial in water-scarce areas where conservation is a priority.

However, the efficiency of anaerobic digesters depends highly on the balance of water usage and waste consistency. High water usage in conventional flush systems can dilute the waste, reducing the efficiency of methane production, while using less water can lead to operational challenges in waste conveyance. Laramee et al. (2018) noted that these technological and operational hurdles require continuous maintenance and a certain level of technical expertise, which might pose challenges in developing regions due to the lack of trained personnel and funding for regular upkeep. Furthermore, cultural acceptance and adaptation are significant barriers, as Bautista *et al*. (2018) mentioned, where educational campaigns and community engagement are crucial for successfully implementing new technologies.

As suggested by Colon *et al*. (2015), future research directions in this field should focus on optimizing digester designs to handle varying loads and types of waste more efficiently. Policy and incentive structures, as proposed by Alamansa *et al*. (2023), could encourage the adoption of integrated waste treatment solutions by offering subsidies or incentives to households for installing and maintaining these systems. Engaging local communities in the design, operation, and maintenance of anaerobic digesters, as demonstrated in several pilot projects worldwide, can increase the acceptance and sustainability of these systems, making them a viable pathway toward sustainable sanitation and energy recovery. Enhanced cooperation among engineers, policymakers, and the community is crucial to fully harness the potential of these systems in improving global sanitation infrastructure.

2.2 Performance Assessment of Sanitation Technologies along the Sanitation Service Chain

Evaluating sanitation technologies is essential for assessing their effectiveness, sustainability, and suitability. The evaluation encompasses various factors, including cost-effectiveness, functionality, cultural acceptance, waste treatment efficiency, odour control, and maintenance requirements(ref). Understanding the strengths and limitations of various sanitation technologies along the SSC could provide valuable insights for improving the sanitation service chain and promoting sustainable human waste management practices.

The cost-effectiveness of sanitation technologies is crucial for their successful implementation and long-term viability (Malima *et al*., 2022). Several studies have examined the financial implications of various sanitation technologies. A study by Mills *et al. (*2020) in South Asia analyzed various sanitation systems, including pit latrines, septic tanks, and anaerobic baffled reactors (ABRs), with a focus on implementation costs, climate resilience, and contamination risks. The study found that while septic tanks and ABRs had higher capital investment, they provided better containment and reuse potential, offering long-term economic benefits in densely populated areas. The authors noted that poor maintenance of pit latrines often led to high sludge removal costs, making them less sustainable in urban settings. Similarly, Daudey (2018) conducted a comparative cost review of urban sanitation systems globally, concluding that pour-flush systems were more cost-effective over time due to their adaptability and lower per capita costs of sludge management. However, Daudey (2018) emphasized that economic viability also depends on access to infrastructure and the quality of governance.

A scoping review by Tomoi *et al.* (2024) examined the willingness to pay for FSM services across low- and middle-income countries, revealing that perceived unaffordability remains the most frequently cited constraint to service uptake, even among households aware of the risks associated with delayed emptying. Interestingly, the author also highlighted a growing mistrust in service value, noting that some communities question whether high prices truly reflect better service quality. Supporting the evidence on economic perceptions as a barrier to sanitation access, Cameron *et al.* (2019) conducted a randomized field experiment in rural Bangladesh to evaluate household willingness-to-pay (WTP) for various sanitation service delivery models. The quantitative study revealed that uptake of safe sanitation was 50% higher when households were offered flexible payment options, such as installment-based microfinance schemes. The authors concluded that affordability is not merely a function of total cost but is also shaped by how payment is structured, with flexible models significantly enhancing access. Despite this, few studies have explored perceptions of affordability in mid-sized municipalities like Iten, highlighting a contextual gap in the empirical literature on the economic feasibility of sanitation technologies.

Empirical research underscores the pivotal role of cultural acceptance in the adoption and sustainability of sanitation technologies (Simiyu, 2017; VanRiper, 2021; Dube *et al*., 2023) A qualitative study by Simiyu (2017) in Kisumu, Kenya found that in the informal settlements of Kisumu, Kenya, cultural beliefs and social perceptions about hygiene and odour significantly influenced the preference for pit latrines over septic tanks, often regardless of technical efficiency. Similarly, VanRiper *et al.* (2021) examined the uptake of

Container-Based Sanitation (CBS) in Haiti. They noted that technologies lacking cultural embedding or user trust experienced poor adoption, regardless of their benefits. The authors argued that "technical design must be informed by social logic." In contrast, Dube *et al.* (2023) investigating CBS in South Africa's Khayelitsha township, highlighted that neglecting community participation and socio-cultural dynamics led to resistance, despite the system's technical viability. In a broader evaluation, Russel *et al.* (2019) emphasized that scaling CBS globally requires tailoring implementation to community values, with social cohesion, local governance support, and user dignity being central pillars of acceptance. Together, these studies reveal that cultural fit is not a secondary concern but a foundational criterion for the successful deployment of sanitation. Failure to engage with cultural factors risks undermining infrastructure investments, while participatory, culturally grounded approaches enhance system uptake and long-term sustainability.

These cultural considerations underscore the need for context-specific approaches when implementing sanitation interventions. Furthermore, a similar study by Nakagiri *et al*. (2015) emphasized the importance of community engagement and participation in decision-making processes. Involving community members in the planning and design of sanitation facilities increases their ownership and acceptance of the technologies. It was found that when sanitation interventions aligned with local cultural practices and preferences, they were more likely to be embraced by the community and effectively utilized. The research by Nakagiri *et al*. (2015) and Simiyu (2017) highlights the importance of cultural acceptance in the successful implementation of sanitation technologies in the Iten municipality.

Past studies have consistently highlighted the centrality of privacy and dignity in shaping sanitation preferences, especially in marginalized settings (Thye *et al*., 2011; Jenkins *et al*., 2014; Sclar *et al.,* 2018). Sclar *et al*. (2018) conducted a systematic review linking inadequate sanitation to adverse psychosocial outcomes such as anxiety, embarrassment, and social withdrawal. The Study findings reveal that the mere presence of facilities is insufficient; users require spaces that afford privacy, gender separation, and personal control to protect their dignity. Ross *et al.* (2021), through qualitative research in Maputo, Mozambique, reinforce this notion, illustrating that residents valued sanitation solutions not primarily for health outcomes but for their contributions to autonomy, safety, and everyday quality of life. The authors found that poor design undermined the perceived dignity of individuals, particularly women and vulnerable groups. Similarly, Schmitt *et al.* (2018) examined the implications of gender-insensitive sanitation infrastructure in diverse low-income settings. Their findings stressed that women often encounter heightened risks in public or communal sanitation environments, including sexual harassment, embarrassment, and restricted menstrual hygiene management. The authors advocated for the adoption of "female-friendly" toilets, which provide privacy, safety, and accessibility characteristics strongly associated with dignity and empowerment. The absence of such considerations not only affects health outcomes but also restricts mobility and reinforces gender inequities.

The ability of sanitation technologies to effectively treat human waste and control odours is critical for maintaining a hygienic environment. Studies have examined the performance of different technologies in terms of waste treatment efficiency and odour control. For instance, Zewde *et al.* (2021) evaluated multiple faecal sludge treatment methods in pit latrines and septic systems across low-income settings. Their research highlighted the efficacy of composting and resource recovery techniques, showing improved pathogen inactivation, including *E. coli,* while reducing odours. These findings reinforce the importance of coupling sanitation hardware with biological or thermal treatment solutions. In a user-centered study, Ganesan (2017) explored household perceptions of septic tanks in rural India, where residents preferred septic systems over pit latrines due to their lower odour levels and reduced insect presence. However, poor sludge management infrastructure continued to be a challenge. Collectively, these studies confirm that both traditional and enhanced sanitation technologies can be effective; however, their success hinges on the local context, maintenance, and innovation.

Maintenance requirements are crucial to ensuring the sustainable operation and longevity of sanitation technologies. Understanding the maintenance practices and challenges associated with different technologies provides valuable insights for improving maintenance procedures and addressing potential issues (Vidal *et al.,* 2019; Varma *et al.,* 2023). Various studies have examined the maintenance practices of specific sanitation technologies, shedding light on common challenges and identifying strategies for improvement. A research study by Hussain *et al*. (2017) focused on the maintenance practices of pour-flush toilets. The study aimed to identify common maintenance issues and explore strategies to enhance the upkeep of these facilities. Through surveys, interviews, and site visits, the researchers gathered data on maintenance practices and challenges faced by users and service providers. The study revealed several common maintenance issues associated with pour-flush toilets. One of the primary challenges identified was blockages in the drainage system, often caused by the improper disposal of solid waste or the accumulation of debris (Hussain *et al*., 2017). This issue not only affected the functionality of the toilets but also resulted in unpleasant odours and hygiene concerns.

In addition, issues related to water supply, such as insufficient water pressure or water scarcity, were reported as maintenance challenges (Tiley *et al*.,2014). This concern is echoed by Welling *et al.* (2020), who showed that pour-flush systems rely heavily on consistent water input, and fluctuations in water supply compromise their functionality, especially in urban low-income contexts. Moreover, user behavior and awareness are critical to sustainable latrine maintenance. Still and Louton (2012) observed that improper disposal habits, such as flushing solid waste or excessive water use, often cause blockages or overflows in pour-flush toilets in South African settlements. Similarly, Duku and Mdee (2020) reported in Ghana that many users lacked basic training in hygienic toilet use, which contributed to frequent maintenance problems, such as seal damage and odour issues.

Behavioral components were also highlighted in studies such as Hussain *et al.* (2017), where a lack of knowledge among users regarding the importance of regular cleaning contributed to latrine deterioration. In Kumasi, Ghana, Antwi-Agyei *et al.* (2020) noted that communal toilet misuse, conflicts over shared responsibilities, and the absence of user guidelines further exacerbated maintenance neglect. The evaluation of sanitation technologies provides valuable insights into their cost-effectiveness, resource availability, cultural acceptance, environmental considerations, and waste treatment efficiency. However, while these studies offer valuable insights, they are primarily drawn from urban slums and peri-urban areas in countries such as Ghana, South Africa, and Bangladesh. Their findings may not be directly transferable to semi-rural, highland municipalities such as Iten in Kenya, where environmental conditions, cultural norms, and service delivery mechanisms differ significantly.

2.3 Potential Health Risks Associated with the Sanitation Service Chain

The potential health risks associated with the sanitation service chain have been widely documented in the literature. The lack of basic sanitation facilities is a major global challenge, particularly in low-income countries. Without access to adequate sanitation facilities, people are forced to defecate in the open, which can contaminate water sources and the environment with faecal matter, leading to the spread of waterborne diseases such as diarrhea, cholera, and typhoid fever (CDC, 2020). Additionally, open defecation can attract disease vectors, such as flies and mosquitoes, which can further spread diseases like malaria. The WHO (2020) estimates that inadequate sanitation is responsible for approximately 432,000 diarrheal deaths globally annually, and that improving sanitation can reduce the global burden of disease by up to 10%.

One of the main contributors to health risks associated with the sanitation service chain is the inadequate collection and transport of human waste (Hyun *et al*., 2019). In many low-income countries, there is a lack of infrastructure and resources for safe and efficient collection and transport of human waste. This often results in human waste being collected manually and transported in open containers or on carts, which can be unsanitary and unsafe. Manual collection of human waste can expose workers to harmful pathogens and diseases, particularly if they lack access to appropriate protective gear, such as gloves or masks, which can lead to the spread of diseases like hepatitis A, cholera, and typhoid fever (Giusti, 2009). Additionally, open containers or carts used to transport human waste can spill or leak, thereby increasing the risk of disease transmission.

Furthermore, inadequate collection and transport of human waste can also result in environmental pollution and contamination of water sources, which can further exacerbate health risks (Lam *et al*., 2015). When human waste is not collected or disposed of properly, it can contaminate soil and water sources with harmful pathogens and bacteria, spreading waterborne diseases and other illnesses (Hutton & Chase, 2022). The treatment and disposal of human waste are critical to mitigating health risks associated with the sanitation service chain. Inadequate treatment of human waste can release harmful pathogens and pollutants into the environment, leading to water and soil contamination and the spread of diseases (Grimes *et al*., 2015). Human waste must be appropriately treated and disposed of to prevent environmental pollution and safeguard public health. Effective treatment of human waste can significantly reduce the concentration of harmful pathogens, making the waste safe for disposal or reuse. Various treatment methods are available for human waste, including biological, chemical, and thermal methods.

Several studies have highlighted the potential health risks of the sanitation service chain. For instance, a study conducted by Behora *et al*. (2021) in India found that inadequate sanitation facilities significantly contributed to diarrheal disease in children under the age of five. Diarrheal disease is a significant cause of mortality and morbidity in children under five, particularly in low-income countries with limited access to adequate sanitation facilities. The study found that children living in households without access to sanitation facilities were at a higher risk of contracting diarrheal diseases than those living in households with access to basic sanitation facilities. According to the WHO (2020), better water, sanitation, and hygiene could prevent the deaths of 297,000 children under five years of age each year worldwide.

Another similar study conducted in Ghana found that the spread of cholera was linked to poor sanitation practices, including the inadequate collection and treatment of human waste

(Zhang *et al*., 2022). The study found that poor sanitation practices, including the disposal of human waste in open areas and inadequate wastewater treatment, contributed to the proliferation of cholera (Muoghalu *et al*., 2023). Other studies have highlighted the link between poor sanitation and the spread of diseases such as typhoid, hepatitis A, Rotavirus, shigella, and polio (Bischel *et al*., 2019; Geng *et al*., 2009). Inadequate sanitation facilities and improper disposal of human waste can also lead to the contamination of water sources and food crops, facilitating the transmission of these diseases (Lam *et al.,* 2015).

Water contamination is one of the major health risks associated with the sanitation service chain due to its significant implications for public health. The World Health Organization (WHO) reports that approximately 2 billion people worldwide lack access to safely managed drinking water sources, and nearly 4.5 billion people lack access to safely managed sanitation services (WHO, 2020). The lack of access to safe water and sanitation contributes to waterborne diseases, resulting in an estimated 485,000 global deaths annually (UNICEF/WHO, 2020). Water contamination is particularly prevalent in Africa, where access to clean water and adequate sanitation remains a significant challenge. According to the United Nations Children's Fund (UNICEF), in sub-Saharan Africa, only 24% of the population has access to basic sanitation facilities (UNICEF/WHO, 2020). The lack of sanitation infrastructure and inadequate waste management practices in Africa contribute to water contamination and the spread of waterborne diseases.

In East Africa, water contamination poses a significant threat to public health. The region faces challenges, including limited access to safe drinking water sources, inadequate sanitation facilities, and ineffective wastewater management systems. According to an East African Community (EAC) report, diarrheal diseases caused by waterborne pathogens are responsible for a significant burden of illness and mortality in the region, particularly among children under five (WHO, 2020). Within Kenya, water contamination is a pressing issue with adverse implications for public health. According to the Kenya Integrated Household Budget Survey (KIHBS), approximately 41% of households in Kenya rely on unimproved water sources, such as rivers, lakes, and ponds, which are prone to contamination (Hall *et al*., 2021). Poor sanitation practices and inadequate wastewater treatment systems also contribute to water pollution, especially in densely populated areas and informal settlements. Water contamination resulting from human excreta contamination can lead to the transmission of waterborne diseases, including cholera, typhoid fever, and hepatitis A (WHO 2020; Bischel *et al*., 2019; Zhang *et al*., 2022). These diseases significantly burden public health, particularly in areas with limited access to clean water and proper sanitation facilities. The consequences of water contamination extend beyond immediate health impacts, affecting productivity, economic development, and overall well-being within communities. Water contamination can occur at various stages of the sanitation service chain, from the collection and containment of human excreta to the treatment and distribution of water.

The first stage involves collecting and containing human excreta, where improper construction, maintenance, or use of sanitation facilities can lead to direct contamination of water sources. If pit latrines are located too close to wells or open bodies of water, pathogens and contaminants can seep into groundwater or surface water. Faecal water contamination can also occur directly when the community practices open defecation due to a lack of containment sanitation technologies. When individuals defecate in open areas, the faeces are left exposed to the environment without any containment or proper disposal.

Rainwater or surface runoff can carry faecal matter into nearby water sources such as rivers, lakes, or ponds. This direct contact between faeces and water results in contamination, as the water becomes infused with harmful pathogens present in the faecal matter.

During the transportation and conveyance stage, there is a risk of contamination if human excreta is not adequately transported and contained. Leakage or spillage can occur, contaminating surrounding soil and water sources (Bischel *et al*., 2019). Additionally, if vehicles or containers used for transportation are not adequately cleaned and disinfected, they can become reservoirs for pathogens and contribute to contamination during subsequent trips. The treatment and disposal stage is crucial for reducing health risks, but inadequate treatment or improper disposal methods can lead to water contamination. Poorly designed, operated, or maintained wastewater treatment plants or septic systems may not effectively remove pathogens and pollutants, allowing them to enter water bodies (Scott *et al*., 2019). Similarly, if treated wastewater or sludge is not appropriately managed and disposed of, it can contaminate surface water or infiltrate groundwater sources.

Inadequate management of wastewater and stormwater can also contribute to water contamination. Improperly designed or maintained drainage systems can mix wastewater and stormwater, causing sewage overflows or backflows. These incidents introduce faecal matter and contaminants into water sources, particularly during heavy rainfall events (Bischel *et al*., 2019).

Even after wastewater treatment, there is a risk of contamination during water treatment and distribution. If water treatment plants are not functioning optimally or do not adequately remove pathogens, the treated water may still contain harmful microorganisms. Issues with the distribution system, such as leaks or cross-connections with contaminated water sources, can further contaminate the treated water before it reaches the consumer. It is essential to address contamination risks at every stage of the sanitation service chain, as failure to do so can have a cascading effect on subsequent stages of the process. A holistic approach is necessary to prevent water contamination, including the implementation of proper sanitation infrastructure, regular maintenance and monitoring, public education on safe hygiene practices, and the integration of appropriate treatment and disposal technologies. By implementing these measures, water contamination risks can be minimized, ensuring the provision of safe and clean water to communities.

2.4 Visualization of Human Excreta Flow through the Shit Flow Diagram

The Shit flow diagrams (SFDs) are effective tools for visualizing and comprehending the movement of excreta through a city or town, from defecation to disposal or end-use. They were initially introduced by the Water and Sanitation Program (WSP) of the World Bank in 2012-2013 to assess the context and outcomes related to faecal matter flow within cities (SuSanA, 2020). The concept was further refined by a consortium of institutions involved in excreta management, including the Sustainable Sanitation Alliance (SuSanA), the Global Sector Program on Sustainable Sanitation of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ GmbH), and the Department of Water and Sanitation in Developing Countries (SANDEC) at the Swiss Federal Institute of Aquatic Science and Technology (EAWAG).

The development of SFDs has been driven by the need for a comprehensive tool that simplifies complex sanitation data. Conceptualized initially to aid urban sanitation planning, SFDs have evolved to incorporate detailed data on each stage of the sanitation chain, from containment to disposal or reuse (Parkinson *et al*., 2020). Their importance lies in their ability to provide a snapshot of sanitation performance, which is crucial for making informed decisions and prioritizing investments. The methodology for creating SFDs involves extensive data collection and analysis. Data is gathered on various aspects of the sanitation chain, including containment, emptying, transport, treatment, and final disposal or reuse. This information is then used to map the flow of excreta, illustrating the proportion that is safely managed versus that which is not. Recent studies have refined this methodology to improve accuracy and reliability (Peal *et al*., 2020).

Many countries have utilized SFDs to identify faecal contamination and sanitation planning. A comparative study by Peal *et al*. (2020) assessed sanitation service delivery in 39 cities across Africa, Asia, and Latin America using Shit Flow Diagrams (SFDs). With a combined urban population of 72 million, the analysis revealed that only 42% of excreta was safely managed, while the remaining 58% entered the environment untreated. The study identified five critical failure modes, including uncontained excreta (14%), untreated sludge not delivered to treatment facilities (18%), and treatment inefficiencies (6%). The findings underscore the systemic weaknesses in urban sanitation, particularly in cities that heavily rely on onsite systems without adequate infrastructure for emptying or treatment.

Additionally, for instance, the SFD Maor Dhaka, Bangladesh, revealed that a significant portion of excreta was being improperly disposed of, leading to targeted efforts to improve waste treatment facilities (Mills *et al*., 2019). By highlighting areas where sanitation services are lacking, SFDs enable more efficient allocation of resources. In a study conducted in Lusaka, Zambia, the SFD showed that a large proportion of excreta was being inadequately managed due to insufficient treatment capacity (Chanda *et al*., 2021). This information led to investments in new treatment plants and the upgrading of existing facilities.

In agreement, a study by Endris *et al*. (2024) mapped faecal sludge flows in Kombolcha Town, Ethiopia, using the SFD method. The research found that although 56% of faecal sludge was considered safely managed, only 17% was effectively treated at the municipal facility. A further 39% of the sludge remained onsite and unemptied, while 16% was fully uncontained, leaking directly into the environment. Most households used unlined or semi-lined pits that were emptied infrequently, often by informal actors. The SFD revealed severe system inefficiencies in containment, transport, and treatment infrastructure, placing residents at risk of environmental and health hazards.

A recent application of SFDs in Nairobi, Kenya, revealed significant gaps in the city's sanitation infrastructure. The study found that only 31% of excreta was safely managed, with 69% being inadequately treated and disposed of (Van-Welie *et al*., 2019). This prompted the development of targeted interventions such as the construction of new treatment facilities and the implementation of network waste transport systems. A study by Gituma *et al*. (2022) investigated the sanitation service chain in Nkubu Town, Meru County, Kenya, using an SFD. The findings revealed that only 28% of excreta was safely managed, while 72% remained unsafely managed due to gaps in containment, ineffective sludge emptying, and inadequate treatment facilities.

The town lacked a local treatment plant, requiring sludge to be transported 17 km away to Meru, a burden handled by private operators with limited capacity. Alarmingly, only 40% of the sludge reaching the treatment site was processed, and significant groundwater contamination was reported, confirmed by the presence of coliforms and Escherichia coli. The study highlighted how high emptying fees, informal services, and fragmented governance structures hinder the delivery of safe sanitation. These challenges reinforce the importance of SFDs in identifying critical gaps and guiding local authorities toward achieving SDG 6.2 targets.

Despite their benefits, there are challenges associated with the use of SFDs. One major challenge is the availability and reliability of data. Accurate data collection can be challenging in many settings, particularly in informal settlements where sanitation services are often inadequate (Panesar *et al*., 2019). For instance, in a study conducted in Kampala, Uganda, researchers found it difficult to obtain reliable data on the emptying and transport stages due to the prevalence of informal service providers (Nakagiri *et al*., 2015). Additionally, the creation and interpretation of SFDs require specialized knowledge and skills (Peal *et al*., 2020). In many settings, there is a shortage of trained personnel capable of conducting the necessary analyses and producing accurate diagrams, which can limit the effectiveness of SFDs as a tool for sanitation planning and monitoring.

In summary, the shit flow diagrams are a valuable tool for visualizing and managing the flow of human excreta in sanitation systems. They offer significant benefits in terms of communication, decision-making, and resource allocation. However, challenges related to data collection and technical expertise must be addressed to fully realize their potential. As the field of sanitation continues to evolve, the development and application of SFDs will play a critical role in achieving improved sanitation outcomes globally.

2.4 Potential Health Risks Associated with Sanitation Service Chain

The potential health risks associated with the sanitation service chain have been widely documented in the literature. The lack of basic sanitation facilities is a major global challenge, particularly in low-income countries. Without access to adequate sanitation facilities, people are forced to defecate in the open, which can contaminate water sources and the environment with faecal matter, leading to the spread of waterborne diseases such as diarrhea, cholera, and typhoid fever (CDC, 2020). Additionally, open defecation can attract disease vectors, such as flies and mosquitoes, which can further spread diseases like malaria. The WHO (2020) estimates that inadequate sanitation is responsible for approximately 432,000 diarrheal deaths globally annually, and that improving sanitation can reduce the global burden of disease by up to 10%.

One of the main contributors to health risks associated with the sanitation service chain is the inadequate collection and transport of human waste (Hyun *et al*., 2019). In many low-income countries, there is a lack of infrastructure and resources for safe and efficient collection and transport of human waste. This often results in human waste being collected manually and transported in open containers or on carts, which can be unsanitary and unsafe. Manual collection of human waste can expose workers to harmful pathogens and diseases, particularly if they lack access to appropriate protective gear, such as gloves or masks, which can lead to the spread of diseases like hepatitis A, cholera, and typhoid fever (Giusti, 2009). Additionally, open containers or carts used to transport human waste can spill or leak, thereby increasing the risk of disease transmission.

Furthermore, inadequate collection and transport of human waste can also result in environmental pollution and contamination of water sources, which can further exacerbate health risks (Lam *et al*., 2015). When human waste is not collected or disposed of properly, it can contaminate soil and water sources with harmful pathogens and bacteria, spreading waterborne diseases and other illnesses (Hutton & Chase, 2022). The treatment and disposal of human waste are critical to mitigating health risks associated with the sanitation service chain. Inadequate treatment of human waste can release harmful pathogens and pollutants into the environment, leading to water and soil contamination and the spread of diseases (Grimes *et al*., 2015). Human waste must be treated and disposed of properly to prevent environmental pollution and protect public health. Effective treatment of human waste can significantly reduce the concentration of harmful pathogens, making the waste safe for disposal or reuse. Various treatment methods are available for human waste, including biological, chemical, and thermal methods.

Several studies have highlighted the potential health risks of the sanitation service chain. For instance, a study conducted by Behora *et al*. (2021) in India found that inadequate sanitation facilities significantly contributed to diarrheal disease in children under the age of five. Diarrheal disease is a significant cause of mortality and morbidity in children under five, particularly in low-income countries with limited access to adequate sanitation facilities. The study found that children living in households without access to sanitation facilities were at a higher risk of contracting diarrheal diseases than those living in households with access to basic sanitation facilities. According to the WHO (2020), better water, sanitation, and hygiene could prevent the deaths of 297,000 children under five years of age each year worldwide.

Another similar study conducted in Ghana found that the spread of cholera was linked to poor sanitation practices, including the inadequate collection and treatment of human waste (Zhang *et al*., 2022). The study found that poor sanitation practices, including the disposal of human waste in open areas and inadequate wastewater treatment, contributed to the proliferation of cholera (Muoghalu *et al*., 2023). Other studies have highlighted the link between poor sanitation and the spread of diseases such as typhoid, hepatitis A, Rotavirus, shigella, and polio (Bischel *et al*., 2019; Geng *et al*., 2009). Inadequate sanitation facilities and improper disposal of human waste can also lead to the contamination of water sources and food crops, facilitating the transmission of these diseases (Lam *et al*., 2015).

Water contamination is one of the major health risks associated with the sanitation service chain due to its significant implications for public health. The World Health Organization (WHO) reports that approximately 2 billion people worldwide lack access to safely managed drinking water sources, and nearly 4.5 billion people lack access to safely managed sanitation services (WHO, 2020). The lack of access to safe water and sanitation contributes to waterborne diseases, resulting in an estimated 485,000 global deaths annually (UNICEF/WHO, 2020). Water contamination is particularly prevalent in Africa, where access to clean water and adequate sanitation remains a significant challenge. According to the United Nations Children's Fund (UNICEF), in sub-Saharan Africa, only 24% of the population has access to basic sanitation facilities (UNICEF/WHO, 2020). The lack of sanitation infrastructure and inadequate waste management practices in Africa contribute to water contamination and the spread of waterborne diseases.

In East Africa, water contamination poses a significant threat to public health. The region faces challenges, including limited access to safe drinking water sources, inadequate sanitation facilities, and ineffective wastewater management systems. According to an East African Community (EAC) report, diarrheal diseases caused by waterborne pathogens are responsible for a significant burden of illness and mortality in the region, particularly among children under five (WHO, 2020). Within Kenya, water contamination is a pressing issue with adverse implications for public health. According to the Kenya Integrated Household Budget Survey (KIHBS), approximately 41% of households in Kenya rely on unimproved water sources, such as rivers, lakes, and ponds, which are prone to contamination (Hall *et al*., 2021). Poor sanitation practices and inadequate wastewater treatment systems also contribute to water pollution, especially in densely populated areas and informal settlements. Water contamination resulting from human excreta contamination can lead to the transmission of waterborne diseases, including cholera, typhoid fever, and hepatitis A (WHO 2020; Bischel *et al*., 2019; Zhang *et al*., 2022). These diseases significantly burden public health, particularly in areas with limited access to clean water and proper sanitation facilities. The consequences of water contamination extend beyond immediate health impacts, affecting productivity, economic development, and overall well-being within communities. Water contamination can occur at various stages of the sanitation service chain, from the collection and containment of human excreta to the treatment and distribution of water. The first stage involves collecting and containing human excreta, where improper construction, maintenance, or use of sanitation facilities can lead to direct contamination of water sources.

If pit latrines are located too close to wells or open bodies of water, pathogens and contaminants can seep into groundwater or surface water. Faecal water contamination can also occur directly when the community practices open defecation due to a lack of containment sanitation technologies. When individuals defecate in open areas, the faeces are left exposed to the environment without any containment or proper disposal. Rainwater or surface runoff can carry faecal matter into nearby water sources such as rivers, lakes, or ponds. This direct contact between faeces and water results in contamination, as the water becomes infused with harmful pathogens present in the faecal matter.

During the transportation and conveyance stage, there is a risk of contamination if human excreta is not adequately transported and contained. Leakage or spillage can occur, contaminating surrounding soil and water sources (Bischel *et al*., 2019). Additionally, if vehicles or containers used for transportation are not adequately cleaned and disinfected, they can become reservoirs for pathogens and contribute to contamination during subsequent trips. The treatment and disposal stage is crucial for reducing health risks, but inadequate treatment or improper disposal methods can lead to water contamination. Poorly designed, operated, or maintained wastewater treatment plants or septic systems may not effectively remove pathogens and pollutants, allowing them to enter water bodies (Scott *et al*., 2019). Similarly, if treated wastewater or sludge is not appropriately managed and disposed of, it can contaminate surface water or infiltrate groundwater sources.

Inadequate management of wastewater and stormwater can also contribute to water contamination. Improperly designed or maintained drainage systems can mix wastewater and stormwater, causing sewage overflows or backflows. These incidents introduce faecal matter and contaminants into water sources, particularly during heavy rainfall events (Bischel *et al*., 2019). Even after wastewater treatment, there is a risk of contamination during water treatment and distribution.

If water treatment plants are not functioning optimally or do not adequately remove pathogens, the treated water may still contain harmful microorganisms. Issues with the distribution system, such as leaks or cross-connections with contaminated water sources, can further contaminate the treated water before it reaches the consumer. It is essential to address contamination risks at each stage of the sanitation service chain, as failure to do so can have cascading effects on subsequent stages. A holistic approach is necessary to prevent water contamination, which includes implementing proper sanitation infrastructure, regular maintenance and monitoring, public education on safe hygiene practices, and integrating appropriate treatment and disposal technologies. By implementing these measures, water contamination risks can be minimized, ensuring the provision of safe and clean water to communities.

2.5 Theoretical Framework

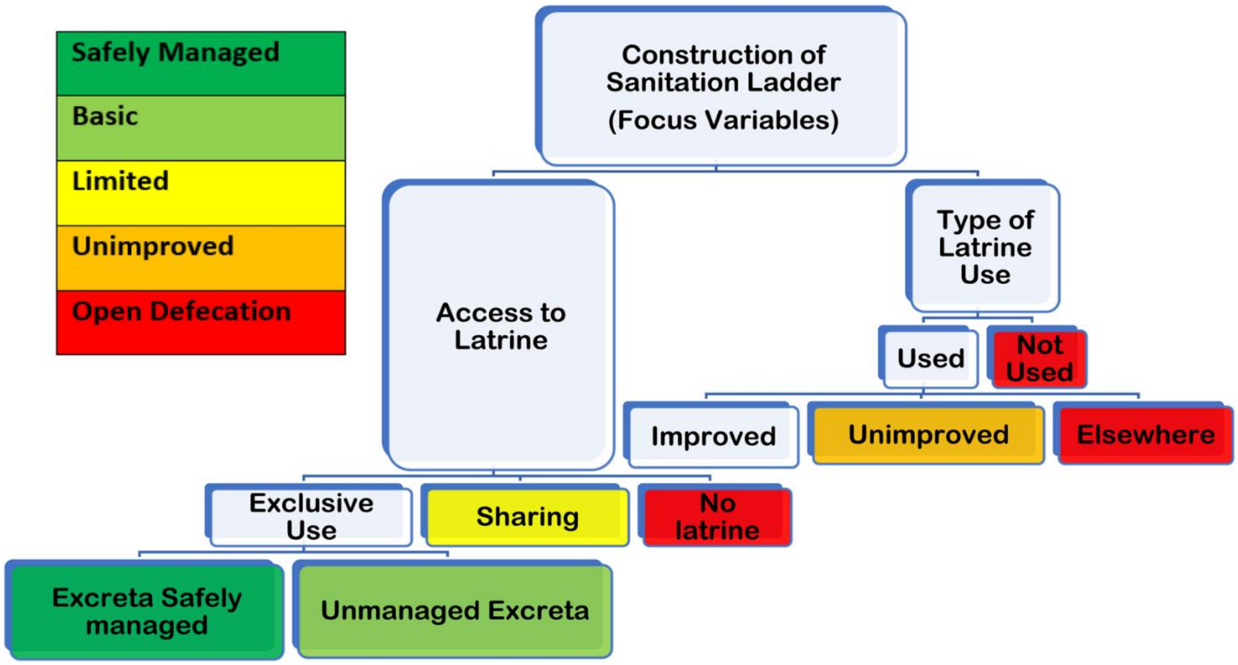
The shit flow diagram (SFD) has emerged as an analytical tool for assessing the flow of human excreta along the sanitation service chain. SFD aims to track the five critical steps of the flow process: usage, collection, treatment, reuse/disposal, and end use. The underlying theoretical framework for the SFD approach is the 'sanitation ladder, a widely accepted measure of sanitation development. The sanitation ladder defines a hierarchy of sanitation facility types and practices, ranging from the least safe to the most desirable, as shown in Figure 2.1. The five main levels, or "rungs," of the ladder are: open defecation (lowest), unimproved facilities, limited services (shared facilities), basic services (private, improved facilities), and safely managed services (highest. The World Health Organization (WHO) and UNICEF Joint Monitoring Programme (JMP) use this ladder to track progress towards the Sustainable Development Goal (SDG) for sanitation, which aims for universal access to safely managed services (Kempster & Hueso, 2018; Prakash *et al*., 2022).

The framework evolved from a simpler binary "Improved"/ "Unimproved" metric used during the MDG era to a more nuanced, multi-level ladder for the SDGs, which emphasizes the entire sanitation service chain (Zimmerman *et al*., 2022). Each successive rung of the ladder signifies a preferable and safer sanitation option. At the lowest rung, individuals dispose of human faeces in open spaces, such as fields, forests, bushes, or open bodies of water, or mix it with solid waste.

This practice poses the most significant and direct health risks (Kouassi *et al.,* 2023). Next are unimproved facilities, defined as facilities that do not hygienically separate human excreta from human contact. Examples include pit latrines without a slab or platform, hanging latrines, and bucket latrines (Prakash *et al*., 2022). The use of improved sanitation facilities that are shared between two or more households. While technically "improved," shared use increases risks related to cleanliness and maintenance, placing this level below basic services (Zimmerman *et al.,* 2022). The use of improved sanitation facilities that are not shared with other households. "Improved" facilities are designed to separate excreta and include flush/pour-flush toilets, hygienically ventilated improved pit (VIP) latrines, pit latrines with slabs, and composting toilets (Prakash *et al.,* 2022; World Health Organization & United Nations Children's Fund, 2023). The highest level and the international gold standard are defined as the use of a basic facility where excreta are either safely treated and disposed of in situ (on-site) or transported and treated off-site. It also includes access to a handwashing facility with soap and water (World Health Organization & United Nations Children's Fund, 2023). Studies leveraging this framework reveal significant disparities. For instance, an analysis in India using 2018 data showed that while 52% of households had access to at least basic services, there was a stark rural-urban divide, with open defecation far more prevalent in rural areas (28.7%) than in urban areas (3.8%) (Prakash *et al.,* 2022).

Figure 2.1:

Sanitation Ladder



Source: Bose & Dutta, (2024)

The Shit Flow Diagram (SFD) is an analytical tool that integrates with and builds upon the sanitation ladder. While the ladder classifies the type of toilet a household uses, the SFD traces the entire journey of the human excreta from that toilet through containment, transport, and treatment to its final disposal or reuse. By visually representing these flows, SFDs reveal where the sanitation service chain breaks down and excreta is unsafely released into the environment, even from "basic" or "improved" facilities (Bose & Dutta, 2024; Peal *et al.,* 2020). This integration provided a comprehensive assessment of sanitation effectiveness, moving beyond mere access to facilities to evaluate whether waste is truly managed safely, thus offering a crucial evidence base for policy decisions, investment planning, and targeted interventions to improve public health and environmental quality.

The sanitation ladder helps in understanding the existing sanitation situation by categorizing different sanitation practices and infrastructure. It allows policymakers, researchers, and practitioners to identify the current level of sanitation coverage and prioritize interventions accordingly. By promoting the use of improved sanitation facilities, the sanitation ladder aims to enhance public health, environmental sustainability, and overall well-being. The theoretical framework for assessing the flow of human excreta along the sanitation service chain in Iten municipality draws on several relevant theories and concepts, including the Sanitation Service Delivery (SSD) approach, the Sustainable Sanitation and Water Management (SSWM) framework, and the Shit Flow Diagram (SFD).

The sanitation Service Delivery (SSD) approach is a comprehensive framework for analyzing and improving sanitation services in low- and middle-income countries (Blackett *et al*., 2016). It focuses on the entire sanitation service chain, from containment and transport to treatment and disposal. The SSD approach acknowledges that effective sanitation service delivery necessitates a multifaceted approach, encompassing technical, institutional, financial, and social factors, and emphasizes the importance of collaboration and partnership among stakeholders (Blackett *et al*., 2016). By adopting the SSD approach, this research could provide a holistic understanding of the flow of human excreta along the sanitation service chain in Iten municipality.

The Sustainable Sanitation and Water Management (SSWM) framework is a practical tool for designing, planning, and implementing sustainable sanitation and water management systems. The framework includes six key elements: institutional framework, technology, operation and maintenance, financial sustainability, social acceptance, and environmental and public health (Blackett *et al*., 2014). The SSWM framework was employed in this research to identify the strengths and weaknesses of the existing sanitation service chain in

Iten and to inform the development of recommendations for enhancing the system's sustainability.

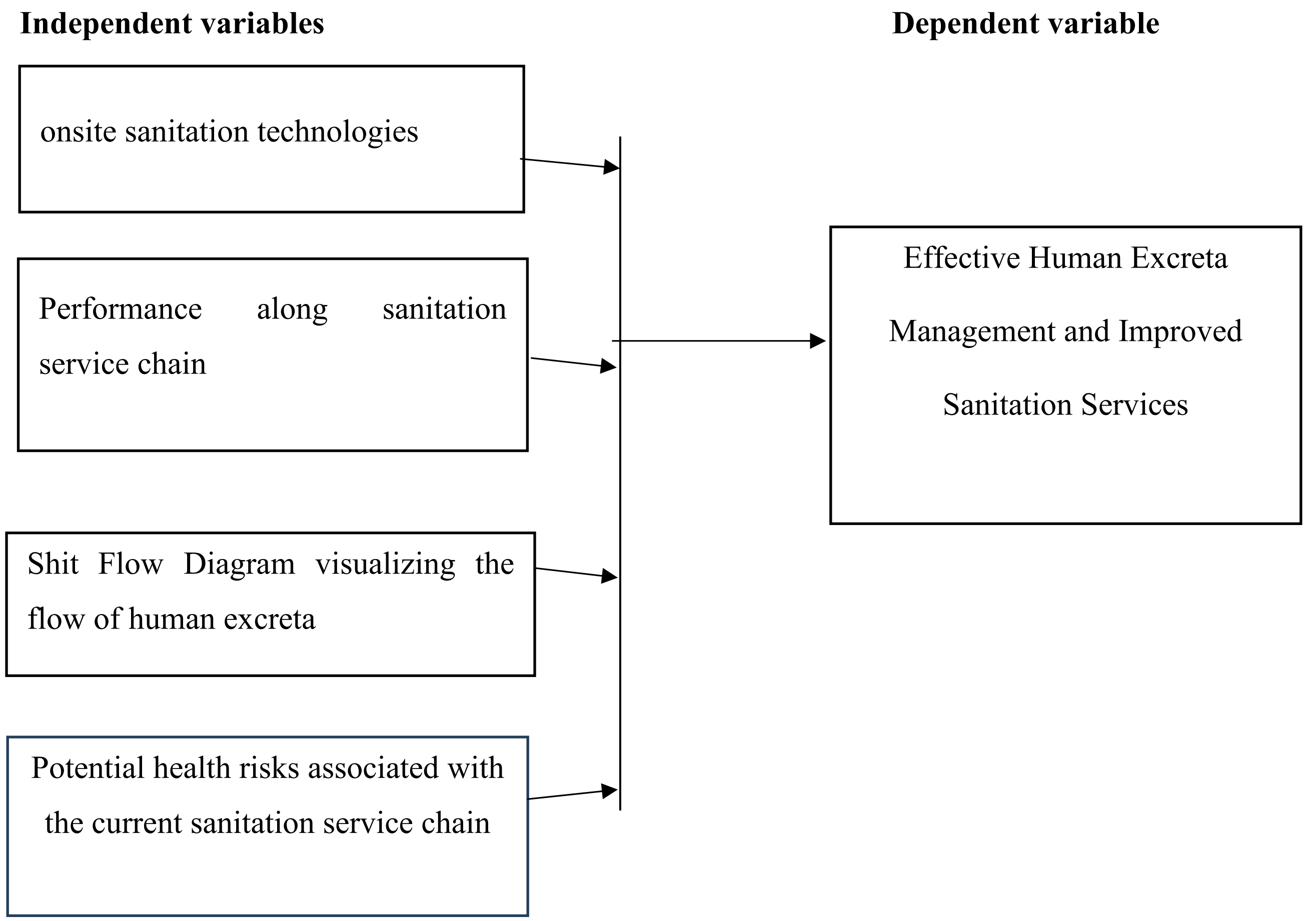
The SFD is a tool for visualizing and analyzing the flow of human excreta along the sanitation service chain. It provides a clear picture of the sources of human excreta, the types of facilities used for containment and disposal, and the pathways of transport and treatment. The SFD was the primary tool used in this research to assess the flow of human excreta in Iten Municipality and to identify the challenges and gaps in the sanitation service chain. By integrating these various theories and concepts, the research can provide a comprehensive and multidimensional understanding of the flow of human excreta along the sanitation service chain in Iten municipality, offering insights for improving the sustainability and effectiveness of the system.

2.6 Conceptual Framework

The conceptual framework aims to examine the relationship between the dependent variable, which is the evaluation of human excreta management and sanitation services, and the independent variables, including the types of onsite sanitation technologies, the performance of these technologies, shit flow diagram visualizing the flow of human excreta, and the potential health risks associated with the current sanitation service chain in Iten municipality, Elgeyo Marakwet County (Fig. 2.2). The study explored the various types of sanitation technologies employed in Iten municipality, such as pour-flush toilets, pit latrines, septic tanks, and others. These technologies were evaluated based on their functionality, maintenance requirements, waste treatment efficiency, odour control capabilities, and cost-effectiveness. The performance of these technologies plays a crucial role in determining the flow of human excreta and the overall effectiveness of the sanitation service chain.

Figure 2.2 :

Conceptual Framework



Source: Literature review,(2024)

Furthermore, the study examined the potential health risks associated with the current sanitation service chain in Iten Municipality. This includes investigating the prevalence of waterborne diseases, assessing exposure to pathogens, and analyzing the contamination of water sources. Understanding these health risks is crucial for assessing the impact of inadequate sanitation practices and pinpointing areas for improvement in the sanitation service chain. By considering these variables within the conceptual framework, the research could provide a comprehensive understanding of the flow of human excreta, the performance of sanitation technologies, and the potential health risks associated with the current sanitation service chain in Iten Municipality.

CHAPTER THREE: RESEARCH METHODOLOGY

3.0 Introduction

This chapter outlines the research methodology employed in this research to evaluate human excreta management and sanitation services within Iten Municipality. The chapter describes the study area, sampling techniques, data collection methods, and data analysis procedures, while also discussing ethical considerations and the measures taken to ensure the validity and reliability of the research.

3.1 Study Area

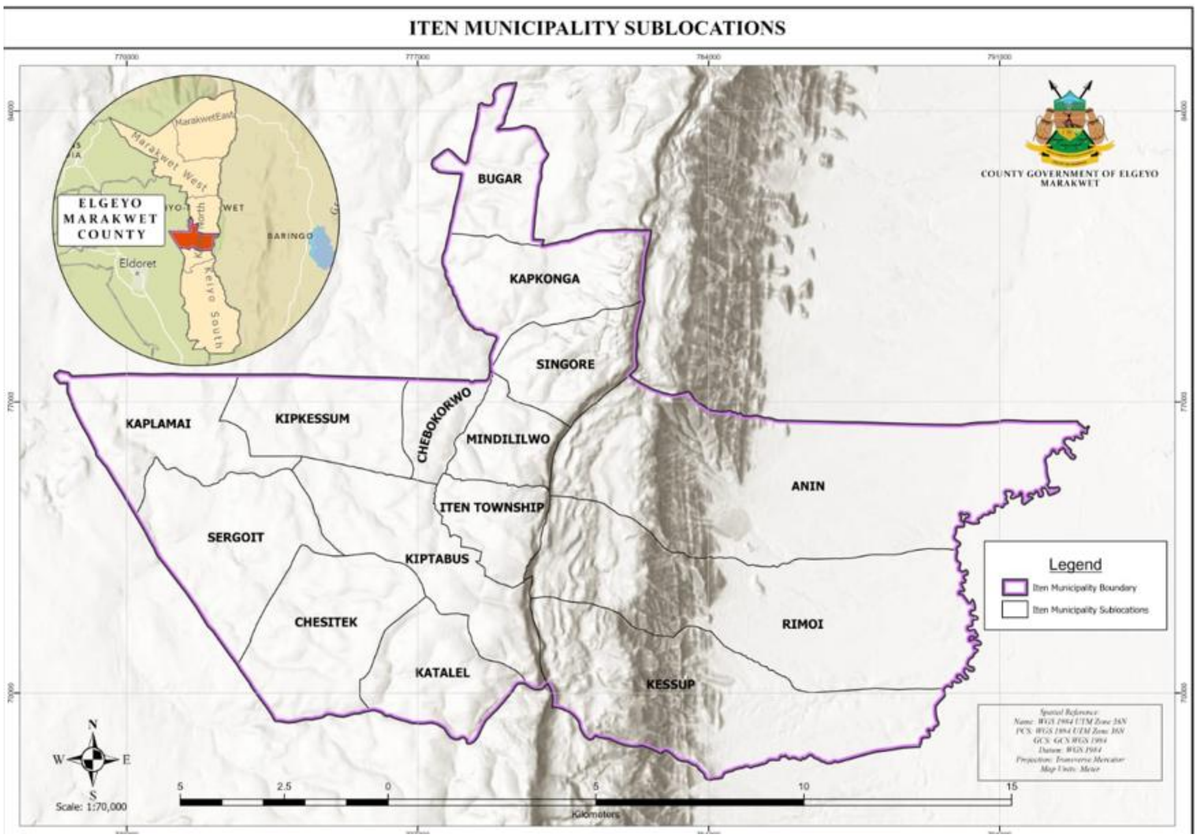
The study was conducted in Iten Municipality, located in Elgeyo Marakwet County, 35 km east of Eldoret within the North Rift region in western Kenya. This municipality, which serves as the county headquarters, is situated at an elevation of 2400 meters (7900 feet) (Omonei, 2019). Iten Municipality spans an area of over 184 square kilometres and features rugged terrain that becomes less pronounced as one moves west. The area receives annual rainfall ranging from 120 mm to 1,500 mm, and temperatures vary between 15°C and 24°C, with an average of 19°C (Omonei, 2019). The high altitude significantly impacts the municipality's temperature and rainfall patterns.

The municipality encompasses 15 sub-locations within the Kamariny, Kapchemutwa, and Tambach wards of Keiyo North sub-county, as shown in Figure 3.1. The 2019 Kenya Population and Housing Census (KPHC) reports the total population of Iten Municipality as 60,685, with an equal ratio of males to females, and the majority of the ethnic group being Kalenjin, accounting for 80% of the population (KNBS, 2019). The total number of household units in Iten Municipality was estimated to be 13,821, according to the 2019 KPHC. The study area is urban and peri-urban, with an estimated population density of 82 to

2040 persons per square kilometer (KPHC, 2019). The local economy is diverse, with activities such as running, crop farming, and small-scale trading. Although predominantly Christian, the population comprises followers of other religions, such as Islam. The Iten-Tambach Water and Sanitation Company (ITWASCO) is the sole licensed water service provider for Iten Municipality and surrounding areas (Omonei, 2019).

Figure 3.1:

Map of Iten Municipality



Source: County Government of Elgeyo-Marakwet, (2024)

3.2 Research Design

The study adopted a convergent parallel mixed-methods design, integrating qualitative and quantitative approaches to explore the complex issues surrounding human excreta management and sanitation services in Iten Municipality, Elgeyo Marakwet County. The rationale for using this design was to enable the simultaneous collection and analysis of both data types, thereby ensuring a comprehensive understanding of sanitation challenges and solutions (Creswell & Clark, 2023). This design supports triangulation, enhances validity, and facilitates a nuanced interpretation of results from different epistemological angles.

The quantitative component of the research involved collecting numerical data and employing structured household surveys, observations, and water sampling analysis to gather empirical evidence. The primary objective was to provide statistically quantifiable information on various aspects of sanitation services, such as the prevalence of different sanitation technologies, usage patterns, and the performance of these technologies.

The qualitative component of the research focused on capturing non-numerical data and involved Key Informant Interviews. The primary aim was to gain a deeper understanding of stakeholders' attitudes, behaviors, and perceptions, as well as the context and public health risks associated with sanitation services. Both data sets were collected independently, analyzed separately, and merged at the interpretation phase, consistent with the convergent model (Younas *et al.,* 2023). This dual approach strengthens the reliability of the findings. It aligns with global Water, Sanitation, and Hygiene (WASH) research trends, where mixed methods have become increasingly central to understanding behavioral change, policy efficacy, and infrastructure equity (Lantagne *et al.,* 2021).

3.3 Variables

Variables are critical elements in a research study that are measured, observed, or manipulated to provide information and insights into the research topic. Several variables were considered in the study evaluating human excreta management and sanitation services using a Shit Flow Diagram (SFD) analysis at Iten Municipality, Elgeyo Marakwet County. These variables were categorized as either dependent or independent variables. The study's dependent variable was the evaluation of human excreta management and sanitation services. The independent variables in the study included the different types of sanitation technologies used in Iten Municipality, assessing the performance of various sanitation technologies along the sanitation service chain. This evaluation utilized multiple indicators, such as functionality, maintenance requirements, waste treatment efficiency, odour control, and cost-effectiveness. The performance of sanitation technologies directly influences the flow of human excreta and determines the effectiveness of the sanitation service chain. The other third independent variable in the study was the potential health risks associated with the current sanitation service chain in Iten Municipality. It comprised factors such as the prevalence of waterborne diseases, exposure to pathogens, contamination of water sources, and the overall public health impact of inadequate sanitation practices. Understanding the potential health risks was crucial for identifying areas of improvement in the sanitation service chain.

3.4 Target Population

The target population is the entire group of individuals who share specific characteristics relevant to the research objectives (Willie, 2023). In this study, the primary focus was on male and female household heads residing within Iten Municipality, which comprises approximately 13,821 households, according to the most recent data from the Kenya National Bureau of Statistics (KNBS, 2019). Household heads were deliberately chosen because they are typically the primary decision-makers regarding sanitation practices, water usage, facility maintenance, and the adoption of health and hygiene interventions within the home. Their perspectives are crucial for understanding how sanitation technologies are used, perceived, and maintained at the household level, particularly in peri-urban and rapidly urbanizing areas, such as Iten.

Beyond households, the study also included a select group of key informants involved in sanitation service delivery and regulation. These included vacuum truck operators, public health officers, technical personnel from the Iten Tambach Water and Sanitation Company (ITWASCO), and professionals from the Eldoret Water and Sanitation Company (ELDOWAS). These individuals were selected due to their specialized roles in the sanitation service chain, encompassing human waste collection, transportation, treatment, and regulation. Their insights could help capture operational realities, infrastructure constraints, and institutional gaps that household respondents might not be aware of. This aligns with Peal *et al*. (2020), who emphasize that faecal sludge management assessments should involve both user and provider perspectives to ensure accuracy and actionability of tools such as the Shit Flow Diagram (SFD).

3.4.1 Inclusion criteria

Eligible participants were household heads aged 18 years and above who had resided in Iten Municipality for at least six months. This duration allowed for adequate familiarity with local sanitation practices, access patterns, and household-level decision-making on excreta management. Furthermore, all participants were required to provide written informed consent, consistent with established ethical research protocols.

3.4.2 Exclusion criteria

Participants were excluded from the study if they lacked sufficient residency duration, specifically those who had lived in Iten Municipality for less than six months, as limited exposure to the local sanitation environment could compromise the validity of their input. Similarly, individuals who were not household heads or primary sanitation decision-makers, including minors and transient visitors, were not eligible for participation in the households. Additionally, persons who were medically unfit or visibly ill at the time of data collection were excluded to avoid placing an undue burden on vulnerable individuals and to reduce the risk of data distortion due to physical discomfort or health-related stress.

3.5 Sample Size Determination

The sample size was determined using the Yamane (1967) formula, a simplified and widely adopted statistical technique that is especially suitable when the total population (N) is known. Several recent studies across environmental health, WASH (Water, Sanitation, and Hygiene), and social sciences have used this formula for sampling in population-based research (Singh *et al.,* 2022; Chaokromthong & Sintao, 2021).

The procedure was as follows;

$$n = \frac{N}{1+N(e^2)} \qquad (3.1)$$

Where: n = sample size, N = Total number of household units (13821), and e = level of precision (0.05 for a 95% confidence level).

$$n = \frac{13,821}{1+13821(0.05^2)}$$

n = 388

Therefore, the total household sample size of 388 was distributed over the determined clusters.

3.6 Sampling Techniques

The study employed both probability and non-probability sampling techniques to ensure comprehensive representation and targeted insights.

3.6.1 Purposive sampling

Purposive sampling was applied in selecting the study area and key informants. First, Iten Municipality was selected purposively due to its rapid urban growth, mixed sanitation infrastructure (both onsite and offsite), and recurring challenges in human excreta management. The municipality represents a peri-urban context typical of many emerging towns in Sub-Saharan Africa, where sanitation services are often under-regulated, fragmented, and insufficiently studied (Simiyu *et al*., 2019; Hernandez & Kim, 2022). This specific context made Iten an ideal case for evaluating sanitation systems using a Shit Flow Diagram (SFD) approach.

Second, purposive sampling was used to select key informants with expert knowledge and operational roles in the sanitation service chain. These participants were chosen based on their direct responsibilities, specialized knowledge, and ability to provide critical insights on aspects such as containment, emptying, transport, treatment, and disposal of human excreta (Palinkas *et al*., 2016). This approach is consistent with recommendations for qualitative public health and sanitation inquiry, where information-rich cases are sought to illuminate system-level dynamics (Etikan, 2019).

3.6.2 Cluster sampling

Cluster sampling was employed to select households across the study area. In this approach, the entire Iten Municipality was divided into natural clusters based on administrative boundaries, specifically the 15 sub-locations that make up the municipality (KNBS, 2019). These sub-locations were treated as primary sampling units (PSUs) because they align with existing governmental divisions and demographic data collected during national censuses. Using administrative boundaries to define clusters enhances both logistical efficiency and representativeness in household-based sanitation studies, particularly in resource-constrained settings (Gazi *et al*., 2020; Malhotra *et al*., 2022).

To ensure that each cluster was proportionately represented in the overall sample of 388 households, proportional allocation was applied based on the number of households per sub-location, as derived from the 2019 Kenya National Bureau of Statistics (KNBS) data, as shown in Table 3.1. The number of households selected from each sub-location (s_i) was determined using the formula as shown in equation 3.2.

$$s_i = \frac{N_i}{N} \times n \qquad (3.2)$$

Where s_i = sample size for the i^{th} sub-location, N_i is the total number of households in the sub-location, N is the total number of households in Iten Municipality (13,821), and n is the total required sample size (388). This proportional allocation approach ensures that larger sub-locations contribute a greater number of respondents to the sample, while smaller ones are not underrepresented. It increases precision and minimizes sampling bias in cluster-based household studies (Kothari, 2021; Etikan & Bala, 2019).

Within each sub-location, simple random sampling was applied to select the specific households to be interviewed. This technique ensured that each household had an equal and independent probability of being selected, which preserves internal validity and guards against selection bias. Moreover, simple random sampling is well-suited to field studies where accurate household listings are available through local government or community health volunteers (CHVs) (Creswell & Creswell, 2018; Bolarinwa, 2021).

Table 3.1:

Specific sample size for household survey in each sub-location (n=388)

Sub-Location	Total Households	Households Surveyed	Percentage (%)
Anin	753	21	2.79
Bugar	640	18	2.81
Chebokokwo	336	9	2.68
Chesitek	703	20	2.84
Iten Township	2960	83	2.80
Kapkessum	391	11	2.81
Kapkonga	421	12	2.85
Katalel	1095	31	2.83
Kessup	814	23	2.83
Kiplamai	563	16	2.84
Kiptabus	1490	42	2.82
Mindililiwo	976	27	2.77
Rimoi	572	16	2.80
Sergoit	1871	52	2.78
Singore	236	7	2.97
Total	**13,821**	**388**	—

Source: Researcher, (2024)

3.6.3 Water sampling procedure

The first step in water sampling analysis was to determine the sampling locations. The locations within Iten Municipality were strategically chosen to capture the variability in water sources, such as taps, wells, rivers, and boreholes. The water sources were sampled from both upstream and downstream locations to assess any potential sources of contamination and the impact on water quality. Purposive sampling was used to sample water from Kipsinende River, Iten Tambach Water and Sewerage Company (ITWASCO) tap water from the Iten County Hospital, Borehole in Singore, and Rorget Spring in Anin. Approximately 500 mL of samples for routine examination from each source were collected using clean glass bottles (Winchester Overt bottles) and transported to a nearby Eldoret Water and Sanitation Company (ELDOWAS) laboratory, which is ISO-certified for analysis. In the detection of Total coliforms and *E. coli*, the Colilert-18 test procedure was used.

3.6.4 Procedure for the water test

The procedure for water testing involved several steps: adding the contents of one pack to a 100 mL room temperature water sample in a sterile water container, capping the container, and shaking it until the contents are dissolved, pouring the sample/reagent mixture into a tray/2000, and sealing it in a quanti tray container. Then, the sealed tray was placed in a 37 °C ± 5 °C incubator for 22 hours to incubate faecal coliforms. After incubation, the results were read according to the interpretation table attached as Appendix (G), and the number of positive wells was counted. Finally, the count was referred to the MPN table to obtain the most probable number.

To determine water contamination, the indicator organisms analysed were *E. coli* and coliforms, expressed as colony-forming units (CFUs) per 100 mL of water, as they are naturally present in the intestines of warm-blooded animals, including humans. *E. coli* is a normal inhabitant of the intestinal tract and is not generally found in fresh water. Therefore, if it is detected in water, it is assumed that the water has been contaminated with faeces (Motlagh & Yang, 2019), according to WASREB. (2008), a Coliform count of 0 per 100 mL is considered excellent, a range between 1 - 3 is Satisfactory, 4 - 10 is Unsatisfactory, and coliforms above 10 counts per 100 mL are considered suspicious.

3.7 Data Collection Instruments

The study employed both primary and secondary data sources to comprehensively assess human excreta management and sanitation services in Iten Municipality. Secondary data included demographic data from KNBS (2019), technical documentation from ITWASCO, and existing reports from previous studies. Primary data were obtained through structured household questionnaires, key informant interviews, site observations, transect walks, and water sampling.

3.7.1 Structured questionnaire

The structured questionnaire (Appendix C) was the primary instrument for collecting household quantitative data. The questionnaire was structured into several thematic sections, aligned with the study's specific objectives. These included demographic information, facility type and usage patterns, functionality and user satisfaction, faecal sludge management practices, water source protection, hygiene behavior, and exposure to potential health risks. The method employed for this instrument was the household survey, which is widely recognized for its ability to collect standardized data across diverse populations and enable comparative analysis (Kamau *et al*., 2021).

3.7.2 Key informant interview guide

To complement and contextualize household data, a key informant interview (KII) guide (Appendix D) was developed to obtain expert insights into sanitation service provision's technical, institutional, and policy dimensions. The interview guide consisted of semi-structured prompts organized around five main domains: sanitation infrastructure and coverage, faecal sludge emptying and transport practices, treatment and disposal methods, challenges in regulatory enforcement, and perceived environmental and public health impacts. This structure provided consistency across interviews, allowing for in-depth probing based on respondent expertise. The guide ensured that data from technical actors could be triangulated with community-level findings to produce a more holistic analysis. The method applied was the expert interview, a qualitative approach that explores complex institutional dynamics and sector-specific challenges not observable through household-level tools (Van Welie *et al*., 2019).

3.7.3 Observational checklist

An observational checklist facilitated structured field observations during site visits (Appendix E) and transect walks (Appendix F). The tool was designed to document the physical condition, spatial arrangement, and environmental risks associated with sanitation infrastructure. The checklist captured key parameters, including the structural integrity of pit latrines and septic tanks, evidence of overflow or open defecation, the proximity of sanitation facilities to water sources, and visible signs of poor maintenance or pest presence. The method employed was direct observation, a non-intrusive approach widely used in environmental health research to verify and complement self-reported data (Endris *et al*., 2024).

3.7.4 Water sampling and laboratory analysis tool

A water sampling protocol and corresponding laboratory test sheet were used as an environmental data collection instrument to assess faecal contamination levels in commonly used water sources within the study area. The method applied was environmental testing, specifically microbiological water quality analysis using laboratory-based assays. This tool was critical in linking sanitation infrastructure with water safety outcomes, particularly in areas where pit latrines and septic tanks are located near shallow groundwater or surface water sources.

Water samples were collected from key sources, including boreholes, rivers, springs, and piped municipal taps. Samples were drawn using sterile 500 mL bottles, following the World Health Organization (WHO) guidelines for water sampling, and immediately preserved in ice boxes before being delivered to the Eldoret Water and Sanitation Company (ELDOWAS) laboratory. The laboratory analysis focused on the enumeration of *Escherichia coli* and total coliforms using the Colilert-18 method, which is widely recognized for its rapid and reliable quantification of faecal indicator bacteria in resource-constrained settings (Motlagh & Yang, 2019). This tool was vital in empirically verifying whether the prevailing sanitation practices had resulted in contamination of water sources, especially in areas where water and sanitation infrastructures are closely situated. The results provided objective evidence for risk exposure and supported triangulation of findings from the household survey and observational assessments.

3.7.5 Shit flow diagram development tool

To visualize the flow of faecal waste from containment to final disposal or reuse, the study employed the Shit Flow Diagram (SFD) Graphic Generator Tool provided by the Sustainable Sanitation Alliance (SuSanA). The method applied through this tool was sanitation service chain mapping, which involves quantifying and categorizing excreta flows across various stages, namely containment, emptying, transport, treatment, and final disposal or reuse. This approach is internationally recognized for guiding city-wide inclusive sanitation planning in low-resource and rapidly urbanizing contexts (Peal *et al*., 2020; Furlong *et al*., 2023).

The study utilized the Intermediate Level SFD, which is recommended when city-wide data are limited but reasonably reliable data can be derived from primary fieldwork (e.g., household surveys, KIIs, and structured observations). This level strikes a balance between feasibility and technical rigor by incorporating estimated proportions of the population served by various containment and treatment systems, based on observed infrastructure types, reported practices, and expert assessments. The SFD model output clearly distinguishes between safely managed and unsafely managed excreta flows across the entire sanitation chain. By integrating data from multiple instruments into the SFD matrix, the tool enabled the study to provide a systems-level diagnostic of the sanitation situation in Iten Municipality. The resulting diagram offered visual clarity on service gaps, institutional bottlenecks, and environmental risks, thereby serving as both a research output and a policy communication instrument.

3.8 Pretest of Questionnaires

The pretesting of questionnaires is a crucial step in survey methodology, ensuring the clarity, relevance, and effectiveness of the questions. Before the actual study, pretesting was conducted in Iten Township, and the process was carried out meticulously on 10% of the sample size (388) to refine the questionnaire and ensure it met the research objectives efficiently. The individuals who were involved in the pretesting of the questionnaires did not participate in the finalized tool. Pre-testing of questions ensured that the questionnaires used in the interviews could be completed within the stipulated time and were not too lengthy for the respondents to handle. The research revealed that the questions effectively assessed the intended metrics and were clearly comprehended and accurately interpreted by the participants. The duration required for each respondent to finish the questionnaire was tracked, revealing that, on average, respondents needed approximately 30 minutes to respond to all questions, which was deemed acceptable.

3.8.1 Reliability of the study

Reliability pertains to the consistency of a measurement, indicating whether the measurement produces consistent results when applied using the same methods and conditions (Heale & Twycross, 2015). The test-retest method was employed with participants during pretesting to assess the reliability of the research instrument using questionnaires. The researcher administered the same trials to the same participants on two separate occasions to determine if the scores from one test closely matched those from the previous test. A reliability analysis using Cronbach’s alpha was conducted to confirm the dataset's suitability for analysis. The results showed a Cronbach’s alpha of 0.772, indicating acceptable reliability (Heale & Twycross, 2015).

3.8.2 Validity of the study

Validity is concerned with whether the measurement technique yields accurate information about the true construct (Heale & Twycross, 2015). In this study, content validity was employed; the instrument was presented to experts for their input to facilitate any necessary adjustments. The supervisors assigned to me from the Meru University of Science and Technology's Sanitation Department verified the instrument before we proceeded with the data collection tools.

3.9 Data Collection Procedure

Before initiating fieldwork, all necessary ethical and administrative approvals were obtained to ensure compliance with national research regulations and institutional protocols. To facilitate household-level data collection, the study recruited three enumerators, each with at least a diploma in Public Health and prior experience in community-based field research. These enumerators underwent a two-day intensive training session before being deployed in the field.

The training curriculum included modules on research ethics, proper procedures for obtaining informed consent, structured questionnaire administration, and use of mobile data collection tools, specifically the KoboCollect application on Android devices. Enumerators were also instructed on neutral, respectful engagement techniques and how to respond if a household declined participation. In such cases, non-response was recorded anonymously, and a replacement household was randomly selected from the existing sampling frame within the same stratum. This ensured the study retained its statistical integrity and avoided sampling bias (Creswell & Creswell, 2018; Tashakkori & Teddlie, 2021).

Quantitative data were collected through face-to-face interviews using a structured questionnaire embedded in KoboCollect. Interviews were conducted in either English or Swahili, depending on respondent preference, to enhance understanding and inclusivity. Households were selected through simple random sampling within each of the 15 sub-locations in Iten Municipality. The first household in each sub-location was chosen using a computer-generated random number. Immediately following each household interview, an observational checklist was administered through Kobo Collect to document the physical condition of the sanitation infrastructure.

For qualitative data, the principal researcher conducted all Key Informant Interviews (KIIs) using a semi-structured guide. Interviews were conducted in quiet, neutral locations and held in both English and Kiswahili. All KIIs were audio-recorded with participant consent and supplemented by detailed field notes that captured non-verbal cues and environmental context. This combination of verbatim and contextual documentation enhanced the depth and authenticity of qualitative insights (Tashakkori & Teddlie, 2021). The study also involved water quality assessment through microbial sampling. Four water sources were sampled: Kipsinende River, a borehole in Singore, piped tap water at Iten County Hospital, and Rorget Spring in Anin.

3.10 Data Processing, Analysis, and Presentation

Quantitative data were cleaned, coded, and entered into the Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, including means, standard deviations, frequencies, and percentages, were used to summarize respondents' demographic information, the types of sanitation technologies in use, water access, waste disposal behaviors, and exposure to sanitation-related illnesses. The results were presented in the form of tables, pie charts, and bar graphs.

To assess relationships between categorical variables, the Pearson Chi-square test was applied at a 95% confidence interval (CI). A p-value of ≤ 0.05 was considered statistically significant, indicating a strong likelihood that the observed association was not due to chance. For instance, Chi-square tests were used to explore the associations between sanitation technology types and waste management adequacy, as well as household exposure to health risks. The assumptions for this test, including independence of observations and adequate expected cell frequencies, were verified before application.

In addition, Pearson's Product-Moment Correlation analysis was conducted to examine the strength and direction of linear relationships between key continuous variables, such as health outcomes and the adequacy of sanitation services. This test also adhered to a 95% confidence level, and relationships were interpreted based on both the correlation coefficient (r) and p-values. A positive or negative correlation was deemed statistically significant if $p \leq 0.05$. Assumptions of linearity, normality, and interval-level measurement were assessed and confirmed prior to running the correlation tests.

For the qualitative component, data collected from key informant interviews, site observations, and transect walks were transcribed, manually coded, and presented in narratives. These narratives provided deeper insights into the lived realities behind the performance of sanitation infrastructure. This qualitative layer complemented the statistical findings by explaining the "how" and "why" behind observed quantitative trends, particularly concerning user satisfaction, informal waste management practices, and local-level enforcement issues.

Microbiological analysis of water samples was conducted to assess faecal contamination using the Colilert-18 method, with results recorded as the Most Probable Number (MPN) per 100 mL. Samples from boreholes, springs, rivers, and piped taps were tested for Escherichia coli and Total coliforms. Results were analyzed descriptively and compared against WHO and WASREB drinking water standards. Contaminated sources were flagged as health risks. The findings were summarized in tables that showed microbial load by source. Laboratory data were triangulated with household survey responses and field observations for cross-validation.

The Shit Flow Diagram (SFD) for Iten Municipality was developed using the SFD Graphic Generator Tool, available at http://sfd.susana.org/data-to-graphic. An intermediate-level SFD was constructed appropriately in cases where citywide data may be limited but supported by reliable field-level information.

The process drew on primary data collected through household surveys, key informant interviews, and field observations, ensuring the inputs reflected actual sanitation practices on the ground. The tool required inputting general municipal information, selecting the dominant sanitation systems (e.g., pit latrines, septic tanks, and open defecation), and assigning quantitative estimates for each system's contribution to containment, emptying, transport, treatment, and final disposal or reuse. A default internal flow value of 100% was assumed for each sanitation type to maintain consistency within the SFD matrix. These data were then synthesized into a color-coded diagram, clearly illustrating the proportions of human excreta that were safely versus unsafely managed throughout the sanitation service chain in Iten.

3.11 Ethical Consideration

Ethical integrity was a central pillar throughout this research process. Every step was conducted with a strong commitment to safeguarding the dignity, privacy, and autonomy of participants. Prior to commencing data collection, all necessary approvals were obtained from relevant authorities. An introductory letter was obtained from the School of Engineering and Architecture, Department of Civil and Environmental Engineering, Meru University of Science and Technology, dated 24th August 2023 (Appendix H), which supported the application for a research permit from the National Commission for Science, Technology, and Innovation (NACOSTI) under License No. NACOSTI/P/24/31512 (Appendix I). Additional administrative approvals were secured from the County Commissioner (Appendix J) and the County Governor through the County Secretary (Appendix K) to ensure compliance with local governance protocols.

Informed consent was obtained from all participants before their involvement in the study (Appendix B). The purpose of the research, the nature of their participation, and their right to withdraw at any time without penalty were clearly explained to them. Participation was entirely voluntary, and all respondents were assured of anonymity and confidentiality. To ensure secure handling of data, both digital and physical materials were stored with strict safeguards. Electronic data, including survey responses, interview notes, and transcripts, was saved on password-protected computers and backed up on an encrypted external drive. Only the principal researcher and approved supervisors had access to the data. Hard copy documents, such as consent forms, were kept in a locked cabinet. All data could be retained for the duration required by institutional policy and then responsibly destroyed to maintain participant confidentiality.

CHAPTER FOUR: RESEARCH RESULTS

4.0 Introduction

This chapter presents findings from a study conducted in Iten Municipality, Elgeyo-Marakwet, regarding the types of onsite sanitation technologies in use, their performance, and the potential health risks associated with the sanitation service chain. The analysis integrates the responses from the questionnaires, observations, and the applied Shit Flow Diagram (SFD), providing a structured overview of the current sanitation landscape in the municipality.

4.1 Response Rate

The study aimed to gather responses from household heads in Iten Municipality, targeting a total of 388 households, which yielded a high overall response rate of 90% (n = 350), as shown in Table 4.1. This response rate is considered adequate for robust data analysis and interpretation, particularly in household survey research, where rates above 70% are generally deemed sufficient for minimizing non-response bias (Babbie, 2021).

This strong participation reflects a commendable level of community engagement, enhancing the reliability and credibility of the collected data. A small proportion of responses were either incomplete or not returned, accounting for a combined non-response and partial response rate of 10%. The highest number of valid responses was recorded in Iten Township (19.3%), consistent with its relatively large population size. In contrast, Singore (1.5%) and Chebokokwo (2.3%) had the lowest response rates. The use of a proportional allocation method ensured equitable representation across all 15 sub-locations based on household distribution. Overall, the consistently high response rates across most sub-locations support the validity of the findings and suggest that the results are reflective of the broader sanitation and excreta management conditions within Iten Municipality.

Table 4.1:

Survey response rate by sub-location (n = 350)

Sub-Location	**Total Households**	**Targeted (n)**	**Non-Response**	**Partial Response**	**Responded**	**Percent (%)**
Anin	753	21	2	0	19	4.9
Bugar	640	18	2	0	16	4.1
Chebokokwo	336	9	0	0	9	2.3
Chesitek	703	20	1	0	19	4.9
Iten Township	2960	83	6	2	75	19.3
Kapkessum	391	11	1	0	10	2.6
Kapkonga	421	12	1	0	11	2.8
Katalel	1095	31	2	1	28	7.2
Kessup	814	23	2	1	20	5.1
Kiplamai	563	16	1	1	14	3.6
Kiptabus	1490	42	3	1	38	9.8
Mindililiwo	976	27	1	1	25	6.4
Rimoi	572	16	1	1	14	3.6
Sergoit	1871	52	4	2	46	11.9
Singore	236	7	0	1	6	1.5
Total	**13821**	**388**	**27**	**11**	**350**	**90%**

Source: Researcher, (2024)

4.2 Demographic Information

A total of 350 household heads participated in the study across Iten Municipality. As shown in Table 4.2, the majority of respondents were female (60.6%), with males constituting 39.4%. The age distribution revealed that 44.3% were between 18 and 35 years, followed by 39.7% aged 36 to 50 years, and 16.0% aged 51 years and above. This indicates a predominantly youthful respondent population.

Regarding housing typology, 85.4% of participants resided in single-family houses, while smaller proportions lived in semi-detached houses (6.6%), apartments (3.1%), and townhouses (2.0%). Ownership status showed that most respondents were homeowners (74.0%), with 21.1% residing in rental units, 4.0% in rent-free arrangements, and less than 1% occupying mortgaged properties. The average household size was 4.96 members (SD = ±1.55), with the smallest household comprising one individual and the largest consisting of nine members. This reflects moderately sized households typical of peri-urban Kenyan settings and provides essential context for interpreting sanitation infrastructure demand.

Table 4.2:

Demographic characteristics of respondents (n = 350)

Variable	**Frequency**	**Percent (100%)**
Gender		
Female	212	60.6
Male	138	39.4
Age bracket in years		
18-35	155	44.3
36-50	139	39.7
51 and above	56	16.0
Type of housing		

Apartment	11	3.1
Semi-detached house	23	6.6
Single family house	299	85.4
Town house	7	2.0
Others	10	2.9
Ownership Status		
Mortgaged	3	.9
Owned	259	74.0
Rent free	14	4.0
Rented	74	21.1
Household Size	Mean = 4.96 members (SD±1.55), Minimum= 1, Maximum=9	

Source: Researcher, (2024)

4.3 On-site Sanitation Technologies

This section presents findings on the types, functionality, and quality of on-site sanitation technologies used in Iten Municipality. The study assessed the type of technology, maintenance frequency, pest and odour issues, user satisfaction, and methods for disposing of excreta.

4.3.1 Type and quality of sanitation technologies

The study examined the types and quality of sanitation technologies employed by households in Iten Municipality. As shown in Table 4.3, the majority of respondents (69.1%) reported using pit latrines. A smaller portion (22.9%) relied on flush toilets that drained into septic tanks, while 2.9% used systems connected to anaerobic digesters. A further 5.1% reported using other sanitation arrangements, which included open defecation or container-based systems. In terms of facility maintenance, Figure 4.1 illustrates the frequency of servicing sanitation systems among the 69.1% respondents who answered this item. Most households (40.9%) reported conducting maintenance on a weekly basis or in response to specific events, such as extreme weather conditions. Another 36.9% performed annual maintenance, while 12.7% did so every few months. Only 9.5% reported monthly maintenance. Field observations confirmed the presence of open defecation in certain areas. This was further corroborated by a key informant (WASH Coordinator), who estimated that approximately 3% of the population still engaged in open defecation practices. Additionally, pest and odour control around sanitation facilities was assessed. More than half of the respondents (58.0%) reported no presence of pests. However, 30.6% observed occasional pest activity and 11.4% reported frequent pest issues. Regarding odour control, 58.3% indicated that their facilities had no unpleasant smells, while 30.9% experienced occasional odours and 10.9% reported frequent odour issues.

Table 4.3:

Sanitation technologies and facility conditions in iten municipality (n = 350)

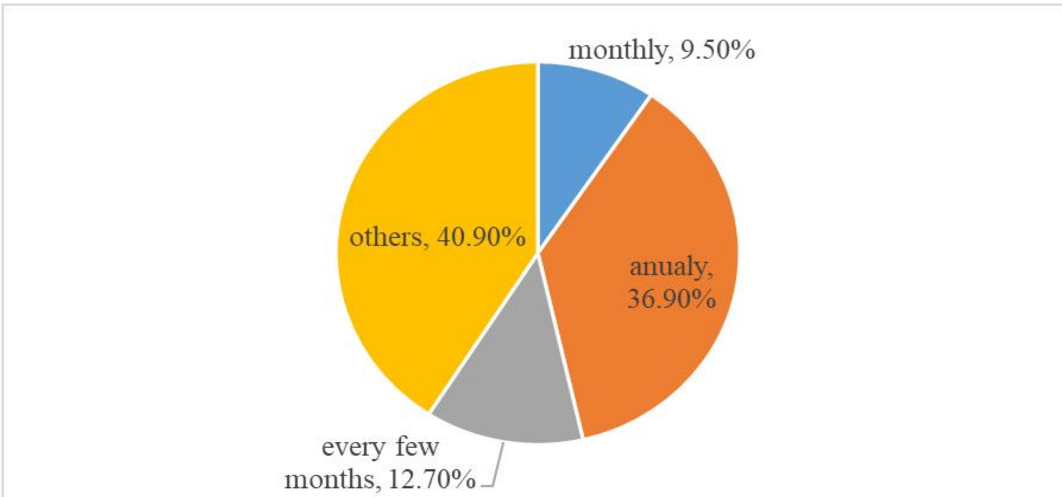
Variables	Frequency	Percentage (%)
Sanitation Facilities		
Flush toilets connected to anaerobic digesters	10	2.9
Flush toilet draining into a septic tank	80	22.9
Pit latrine	242	69.1
Others	18	5.1
Presence of pest		
No	203	58.0
Yes frequently	40	11.4
Yes occasionally	107	30.6
Presence of Odours		
No	204	58.3

Yes frequently	38	10.8
Yes occasionally	108	30.9

Source: Researcher, (2024)

Figure 4.1:

Frequency of Maintaining Sanitation Technologies



Source: Researcher, (2024)

When asked about the presence of pests or insects around sanitation facilities, the majority of respondents (58%) reported no presence of pests or insects around their sanitation facilities. However, 11% reported frequent sightings of pests, while 31% observed them occasionally, as depicted in Table 4.4. Regarding odour, 58% reported no unpleasant smells, while 31% experienced them occasionally, and 11% reported them frequently.

The level of cleanliness of the facilities, safety, and dignity of the users were assessed, and findings are presented in Table 4.4. Nearly half of the respondents (48%) reported that their sanitation facilities were somewhat clean and hygienic, while 38% described them as unclean. An additional 11% noted the facilities were not very clean, and only 3% regarded them as very clean and hygienic. The results indicate widespread concerns related to hygiene standards, as depicted in Plate 4.1. Regarding the control of odours, most participants (61.1%) posited that odours are prevalent; however, a small proportion (28.6%) and a moderate proportion (10.3%) reported that facilities control odours completely and to some extent, respectively.

Plate 4.1:

Condition of a Pit latrine used in a Rental Houses within Iten Municipality

Source: Researcher, (2024)

The level of satisfaction with privacy was investigated, and it was found that more than half (73.4%) were satisfied with the privacy of their sanitation facilities. Only 13.7%% and 4.6% were reported to be very dissatisfied and dissatisfied, respectively, as shown in Table 4.4. The study noted that 59.4% of the participants felt that the technologies adequately protect the dignity and safety of users to some extent, 34.3% completely, and only 6.3% reported that they do not at all. The study further examined the disposal of excreta from children under three years old in the Iten Municipality. As shown in Figure 4.3, the majority, 46.0%, of respondents indicated that they used others (disposable diapers as their method). A small proportion, 16% of respondents, had no children under 3 years. Additionally, 12.6% mentioned throwing waste into the garbage, 7.1% reported rinsing children's tools into drains or ditches, and only 2.3% stated that children use the toilet.

Table 4.4:

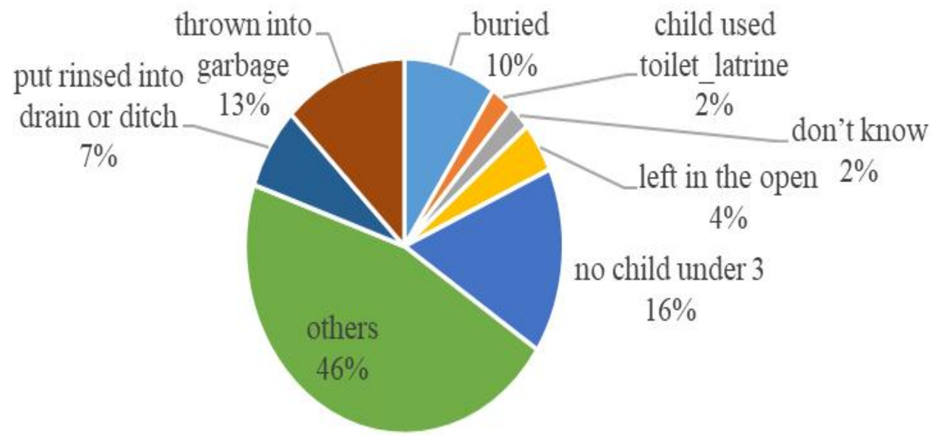
Performance of sanitation technologies (n=350)

Variables	Frequency	Percentage
Level of cleanliness		
Somewhat clean and hygienic	169	48.3
Very clean and hygienic	10	2.9
Unclean and unhygienic	133	38.0
Not very clean and unhygienic	38	10.9
Control of Odours		
No, not at all	214	61.1
Yes, completely	100	28.6
Yes, to some extent	36	10.3
Privacy of the facility		
Very dissatisfied	48	13.7
Dissatisfied	16	4.6
Neutral	22	6.3
Satisfied	257	73.4
Very satisfied	7	2.0
Dignity and safety for the users		
No, not at all	22	6.3
Yes, completely	120	34.3
Yes, to some extent	208	59.4

Source: Researcher, (2024)

Figure 4.2:

Disposal Methods of Stools for Children Under 3



Source: Researcher, (2024)

The study examined household practices related to greywater disposal from sources such as kitchens, bathrooms, and laundry areas. The findings, as shown in Table 4.5, revealed that a significant proportion of households (24%) discharged greywater directly into open drains or roadside ditches, while 23% disposed of it on open ground. Approximately 20% reported using pits with unlined bottoms or sides, which pose potential environmental and public health risks through groundwater contamination and serve as breeding grounds for disease vectors. A smaller segment of households (11%) indicated the use of lined septic tanks with soak-away systems, while 6% utilized fully lined septic tanks. Other methods, including direct discharge into rivers or lakes and unspecified techniques, were reported by 6% of respondents. Only 4% of households used partially lined septic tanks, and no respondents indicated the use of a centralized sewer system, underscoring the municipality's reliance on decentralized greywater disposal solutions.

Table 4.5:

Greywater disposal methods(n=350)

Greywater Disposal Method	**Frequency**	**Percentage**
Directly to open the drain ditch	85	24.3
Directly to the lake or river	20	5.7
Fully lined septic tank	21	6.0
Lined septic tank with soak-away	38	10.9
Open ground	80	22.9
Partially lined septic tank	15	4.3
Others	20	5.7
Pit with unlined bottom or sides	71	20.3
Sewer system	0	0
Total	**350**	**100.0**

Source: Researcher, (2024)

4.3.2 Water access

The study assessed household access to water and the proximity of sanitation infrastructure to water sources in Iten Municipality. As presented in Table 4.6, the majority of respondents (88.9%) reported access to a reliable water source. In comparison, 10.6% indicated they lacked access, and a small fraction (0.6%) were uncertain about their water access status. Regarding sources of water, the most common was boreholes, reported by 79.7% of respondents. A significant proportion (58.5%) accessed piped municipal water. Rainwater harvesting was utilized by 27.3% of households, followed by other sources, such as vendors or community points (22.8%), and wells (10.9%). These figures highlight a significant reliance on both formal and informal sources of groundwater, which are often susceptible to contamination.

Concerning the proximity of latrines to water points, 24.6% of respondents reported having a latrine located within 15 meters of a well or handpump. Among these, 25.6% stated that the latrine was situated on higher ground than the handpump, posing a potential risk for vertical contamination. Furthermore, 33.7% of respondents observed the presence of animal excreta or solid waste within the same proximity to their water sources. Additionally, 33.7% reported that animal faeces or solid waste were present within 15 meters of their water source, further exacerbating risks of microbial pollution. The study findings suggest that, although access to water is generally high, a significant proportion of households in Iten Municipality are at risk of water source contamination due to poor spatial planning and inadequate waste disposal practices.

Table 4.6:

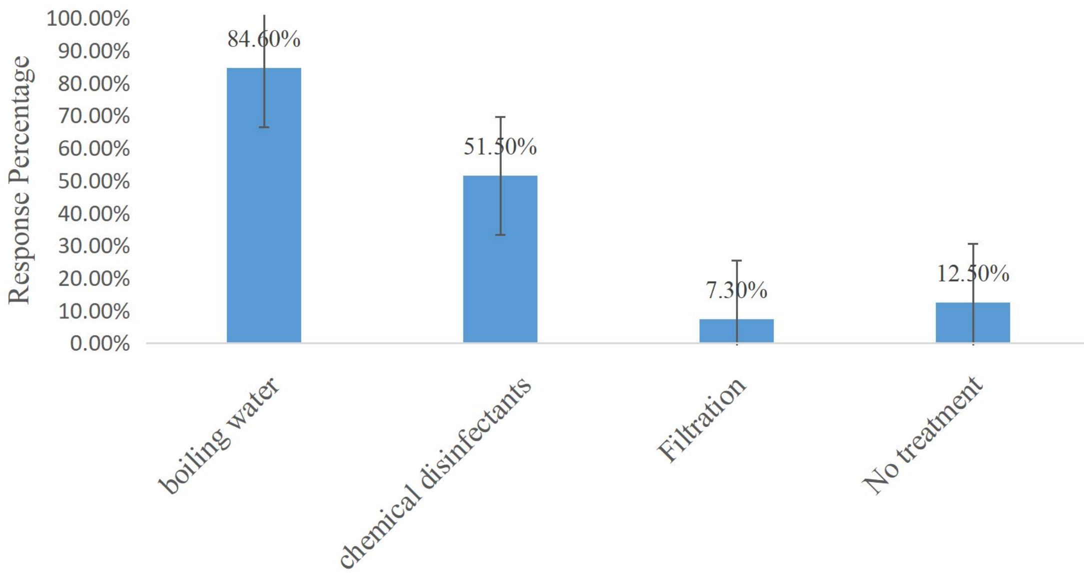
Water access and sanitation proximity in iten municipality (n = 350)

Variable	Frequency	Percentage (%)
Water Access		
Yes	311	88.9
No	37	10.6
Not sure	2	.6
Total	**350**	**100.0**
Water Sources		
Piped water municipality supply	182	58.5%
Borehole	248	79.7%
Well	34	10.9%
Rain harvesting	85	27.3%
Others	71	22.8%
Latrine within 15m of the well and handpump		
No	264	75.4%
Yes	86	24.6%
Latrine on higher ground than the handpump (n=86)		
No	64	74.4%
Yes	22	25.6%
Animal excreta or rubbish within 15m of the handpump (n=86)		
No	57	66.3%
Yes	29	33.7%

Source: Researcher, (2024)

The study examined household practices for treating drinking water before consumption. As illustrated in Figure 4.4, boiling was the most commonly reported treatment method, used by 84.6% of respondents. The use of chemical disinfectants, such as chlorine-based products, was also prevalent, with 51.5% of households employing this method. A smaller portion of respondents (7.3%) employed filtration methods, while 12.5% indicated that they did not treat their water before consumption. These findings demonstrate a generally high awareness of water safety among residents of Iten Municipality. However, the proportion of households that fail to treat their water suggests a need for enhanced public health education and increased access to affordable treatment options.

Figure 4.3:
Water Treatment Methods Used by Households in Iten Municipality



Source: Researcher, (2024)

4.4 Sanitation Service Chain of Iten Municipality

The study further assessed the sanitation technology chain, including emptying, transportation, treatment, and disposal methods, in Iten Municipality. The study also evaluated the performance of the technologies along the service chain.

4.4.1 Emptying, transport, treatment, and disposal/reuse of excreta

The study assessed the functionality and maintenance of onsite sanitation technologies used by households in Iten Municipality. As shown in Table 4.7, among the 92% (n = 322) respondents using onsite technologies such as pit latrines and septic tanks, the majority (77.0%) reported that their sanitation facilities had not yet filled up. In comparison, 12.7% had experienced full pits or tanks, and 10.2% were unsure of their status. Regarding toilet overflow incidents, 76.9% of all respondents stated that they had not experienced any overflow events, 12.3% had encountered such incidents, and 10.9% were uncertain about their own experience.

Among those who reported overflow, the leading causes included surface or stormwater flooding (30.2%) and the unavailability of pit-emptying services when needed (30.2%). Additional contributing factors were flooding from rising groundwater (20.9%), blockages within the facility (18.6%), and lack of financial means to conduct emptying (11.6%). A small proportion (7.0%) did not know the cause of the overflow. The findings indicate the need for interventions to enhance the management of sanitation infrastructure in the municipality. Improvements should focus on reliable and affordable pit emptying services, proper drainage systems to prevent stormwater intrusion, and public sensitization on regular sanitation maintenance and early detection of overflow risks.

Table 4.7*:*

Pit Emptying practices and toilet overflow in iten municipality (n=350)

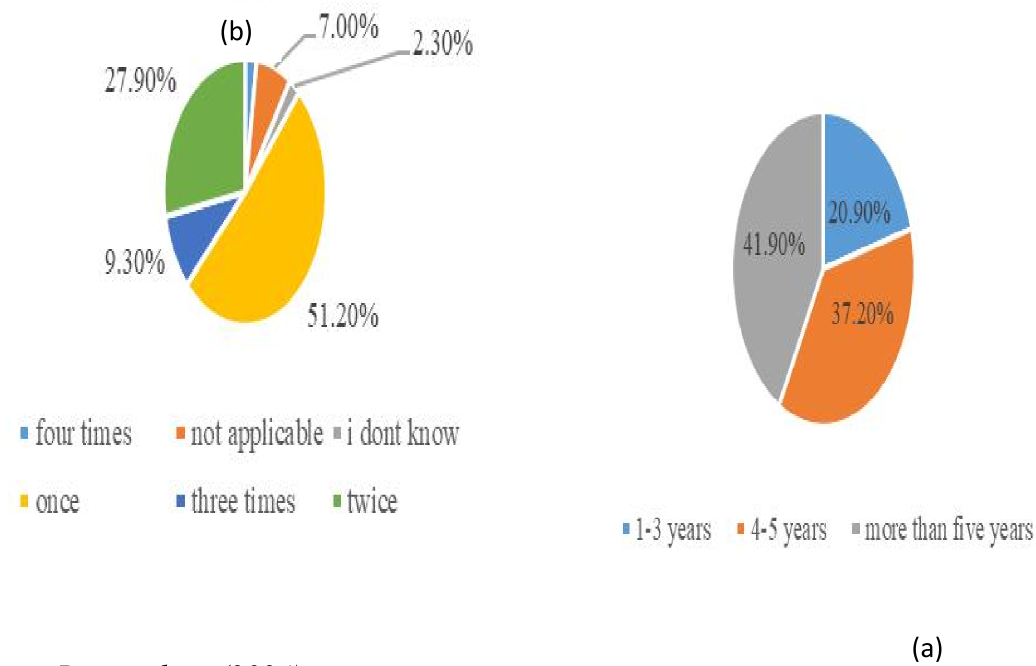
Variables	Frequencies	Percent
Toilet filled up		
Don't know	33	10.2
No	248	77.0
Yes	41	12.7
Total	**322**	**100.0**
Has the toilet overflowed		
Yes	43	12.3
No	269	76.9
I Don't Know	38	10.9
Total	**350**	**100.0**
If yes, what was the reason(n=43)		
Blocked	8	18.6%
Flooded with rising water table (from below ground)	9	20.9%
Flooded by surface water/storm water (from above ground)	13	30.2%
No money to empty	5	11.6%
The emptier is not available when needed	13	30.2%
Don't know	3	7.0%

Source: Researcher, (2024)

Among the 12.7% (n = 41) respondents who had previously emptied septic tanks or pit latrines, the study examined how frequently their sanitation facilities had filled up over the past five years. As presented in Figure 4.4(a), the majority (51.2%) indicated that their toilet had filled only once during this period, while 27.9% reported experiencing two fill-ups. These findings suggest a relatively low frequency of fill-ups among households with onsite sanitation systems. In examining the duration of use following emptying, Figure 4.5(b) shows that 41.9% of respondents continued to use their sanitation facilities for more than five years before requiring another emptying. Additionally, 37.2% reported a reuse duration of between four and five years, while 20.9% stated that their toilets were full again within three years of being emptied.

Figure 4.4:

Maintenance/Emptying Frequency in the Last Five Years



Source: Researcher, (2024)

The study explored how households managed filled sanitation facilities and how pit emptying was conducted, focusing on the actors involved, the methods used, and the ultimate disposal locations for faecal sludge. As shown in Table 4.8, among the 12.7% of respondents with filled pits or septic tanks, 53.5% reported emptying and reusing the same pit, 34.9% covered the full pit and started using a new one, and 11.6% abandoned the pit without sealing it. In terms of future intentions, the majority of the (92%) households using onsite sanitation systems intended to have their pits emptied by a private individual or company (55.0%). Additionally, 27.6% planned to cover and seal the pits, while 14.9% expected to abandon the toilets without covering. Only a small proportion (2.5%) intended to empty the pits themselves.

Table 4.8:

Emptying practices in Iten municipality(n=350)

Emptying practices of the filled pits	Frequency	Percent (%)
Abandoned pit/tank unsealed	6	14.0
abandoned with a sealed cover on the pit tank	8	18.6
Covered and used an alternative pit	8	18.6
Emptied and reused pit/tank	21	48.8
Total	**43**	**100.0**
Intended Emptying Practices.		
Abandon toilet without covering/seal	48	14.9
Cover and seal the pit	89	27.6
Empty by a member of the household	8	2.5
Empty by a private individual or company	177	55.0
Total	**322**	**100.0**
Who emptied		
Informal provider (individual)	15	71.4
Formal provider (utility)	4	19.0
Formal provider (NGO/Company)	1	4.8
Member of the household	1	4.8
Total	**21**	**100.0**
How was emptied		
By hand, using buckets	0	0
By hand, using a manual pump	1	4.8
Mechanically, using a small machine	3	14.3
Mechanically, using a tanker truck	17	81.0
Total	**21**	**100.0**
Where was emptied into		
Directly into a drum or open container	1	4.8
Into a pit on the compound that is then covered	1	4.8
Directly into a machine tanker	19	90.5
Total	**21**	**100.0**

Source: Researcher, (2024)

Among respondents who had previously emptied their pits (48.8%), as presented in Table 4.8, the majority (71.4%) indicated that the task was carried out by informal providers (individuals), while 19.0% used formal utility providers. A small portion reported services from an NGO or private company (4.8%) or a household member (4.8%). Most of the emptying was performed mechanically; 81.0% of respondents reported using a tanker truck, and 14.3% used small machines. Manual emptying using hand-operated pumps was reported by 4.8% of respondents. Regarding disposal sites, 90.5% of the discharged sludge was disposed of in a tanker, while the remainder was disposed of in covered pits within the compound (4.8%) or open containers (4.8%). Most of the emptying was performed mechanically; 81.0% of respondents reported using a tanker truck, and 14.3% used small machines. Manual emptying using hand-operated pumps was reported by 4.8% of respondents. Regarding disposal sites, 90.5% of the discharged sludge was disposed of in a tanker, while the remainder was disposed of in covered pits within the compound (4.8%) or open containers (4.8%).

The study examined how households that had emptied pit latrines or septic tanks financed these services. As summarized in Table 4.9, the vast majority of respondents (95.2%) indicated that they paid for emptying services, while only a small fraction (4.8%) did not. Among those who paid for the service, payment was most commonly calculated either based on the volume removed (45.0%) or through a flat rate system (45.0%). A minority (10.0%) were unsure of how the cost was determined. Regarding payment methods, 80.0% of respondents reported paying the full amount upfront. Others paid in two installments (15.0%) or three installments (5.0%). Regarding perceptions of cost, 55.0% of households considered the price fair, while 45.0% viewed it as too high. These findings suggest that while payment for pit emptying is a nearly universal practice, affordability and transparency in pricing remain concerns for a significant portion of households.

Table 4.9*:*
Household payment practices for pit emptying services (n = 21)

Variable	Frequency	Percent
Payment for emptying		
Yes	20	95.2
No	1	4.8
Total	**21**	**100.0**
If yes, how is payment calculated		
Cost per volume removed	9	45.0
Flat rate	9	45.0
Don't know	2	10.0
Total	**20**	**100.0**
Did you pay installments?		
No, paid in the full amount	16	80.0
Yes, in two installments	3	15.0
three installments	1	5.0
Total	**20**	**100.0**
Was the price fair		
Too high	9	45.0
About fair	11	55.0
Total	**20**	**100.0**

Source: Researcher, (2024)

The study further examined the operational difficulties encountered by pit emptiers during the delivery of sanitation services. As summarized in Table 4.10, 61.9% of respondents reported that pit emptiers faced challenges during emptying operations, while 38.1% indicated that they did not. Among those who acknowledged the presence of challenges, the most frequently reported issues were unstable soil conditions (69.2%) and a lack of space at the sanitation site (61.5%). Poor road access was cited by 23.1% of respondents, with additional operational constraints including nighttime working (15.4%) and high-water table levels (15.4%). Other unspecified difficulties were mentioned by 7.7% of respondents. Observational data collected during transect walks further confirmed that topographical factors, particularly the hilly terrain of Iten Municipality, exacerbate these challenges. The steep and uneven landscape complicates the maneuvering of vacuum trucks and other emptying equipment, while also raising safety concerns during excavation and stabilization.

Table 4.10*:*

Challenges encountered by pit emptiers (n = 21)

Variable	Frequency	Percentage (%)
Did Emptier face difficulties		
No	8	38.1
Yes	13	61.9
Total	21	100.0
Challenges faced by emptier		
Lack of space	8	61.5%
Poor road conditions	3	23.1%
Night-time working	2	15.4%
Unstable soil condition	9	69.2%
High water table	2	15.4%
Others	1	7.7%

Source: Researcher, (2024)

Regarding transport and treatment, the study found from interviews that motorized emptying of sludge was commonly done by private providers and transported using Motorized Vacuum exhausters, commonly referred to as 'Honeysuckers', to the Kipkenyo Sewerage central treatment plant in Eldoret, near Uasin-Gishu County, where waste stabilization ponds systems were used. During transportation, there are sometimes small leakages on the road due to acid burns on the vacuum, but they try as much as possible to avoid them because of the penalty from NEMA. When asked about how often people typically have their on-site sanitation technologies emptied, the interview revealed that the frequency depends mainly on the type of on-site sanitation technology. For instance, pit latrines require emptying approximately every 2-3 years, while those with septic tanks require emptying only once a year. The typical volume of faecal sludge emptied each time ranges from approximately 6,000 liters to 10,000 liters, depending on whether it is a pit latrine or a septic tank. At the treatment site, the sludge settles in the primary ponds, which are often desludged after 5 years. After desludging, they are placed at sludge drying beds and sold as fertilizers. The treated effluent is typically discharged to the nearby River Sossiani.

"*Emptying here is mostly done using motorized technology(mechanically), by informal (private) providers…. into tankers, and it's transported by private exhausters(suckers) to central sewerage treatment in Eldoret Uasin Gishu County…*", [WASH Coordinator]

When informants were asked, the proportion that was safely treated was estimated to be approximately 50%, and treated waste was disposed of at designated treatment disposal sites.

"*About 50% of collected sludge is adequately treated… Once treated, they are deposited in disposal sites of the treatment plant in Uasin-Gishu county."* [Environmental Officer]

"*The raw sewage we receive is 99% liquid, which settles in the primary ponds, so we can say the treatment is 90% efficient since indicators like COD and BOD are reduced from 1200 and 600mg/l to 50 and 26mg/l, respectively."* (Technical Operator at Eldoret Sewerage Treatment Plant).

4.4.2 Performances of the technologies

The study assessed user satisfaction with the overall performance of sanitation technologies in Iten Municipality, including perceptions of functionality, reliability, issue resolution, and training on use and maintenance.

Respondents were asked to rate their satisfaction with the performance of sanitation technologies using a five-point Likert scale, where 1 represented "very dissatisfied" and 5 indicated "very satisfied." As shown in Table 4.11, a majority of respondents (77.4%) reported being satisfied with the performance of the sanitation technologies. An additional 7.1% indicated that they were very satisfied. Conversely, 6.0% expressed dissatisfaction, while 1.4% were very dissatisfied. A neutral stance was taken by 8.0% of participants. The mean satisfaction score was 3.85 with a standard deviation of 0.794, indicating generally positive user perceptions. These findings suggest that the majority of residents perceive the technologies as reliable and functional, although a small segment reported dissatisfaction, highlighting the need for continuous monitoring and support services.

Table 4.11*:*

User satisfaction with performance of sanitation technologies (n = 350)

Users Satisfaction	**Frequency**	**Percentage (%)**
Very Dissatisfied	5	1.4
Dissatisfied	21	6.0
Neutral	28	8.0
Satisfied	271	77.4
very satisfied	25	7.1

Source: (Researcher, 2024)

Respondents were asked to report how often their current sanitation technologies, such as pit latrines and septic tanks, experienced operational issues, including blockages and mechanical malfunctions. As shown in Table 4.12, the majority (64.6%) reported that such issues occurred occasionally, while 33.2% indicated that they occurred frequently. A small number of respondents stated that problems arose either very frequently (1.1%) or rarely (1.1%). Regarding the timeline for resolving these issues, 55.1% of respondents indicated that resolution typically took longer than one week. In contrast, 24.0% reported that issues were addressed immediately, while others noted that problems were resolved within a few days (8.0%) or within a week (4.0%). Notably, 8.9% of respondents reported that issues were not resolved at all. These findings suggest that although operational challenges are common, there are considerable delays in response and repair for many households.

Table 4.12:

Reported operational issues and resolution timelines for sanitation technologies (n = 350)

Variables	Frequency	Percentage (%)
Frequency of sanitation technology experiencing issues		
Very frequently	4	1.1
Frequently	116	33.2
Occasionally	226	64.6
Rarely	4	1.1
Total	350	100.0
Frequency of resolving issues		
Longer than a week	193	55.1
Immediately	84	24.0
Issues are not resolved	31	8.9
Within a few days	28	8.0
Within a week	14	4.0

Source: Researcher, (2024)

The study assessed user perceptions regarding the reliability, maintenance capabilities, frequency of maintenance, and training on sanitation technologies. As shown in Table 4.13, when asked to rate the reliability of their sanitation technologies, 58.9% of respondents reported that their systems were somewhat reliable. A quarter (25.1%) found them to be highly reliable, while 11.7% and 4.3% indicated that the systems were not very reliable and unreliable, respectively. Regarding the ability to maintain and repair the technologies, the majority (53.1%) of respondents indicated that they required assistance from others for maintenance. Additionally, 17.1% reported that they were unable to maintain or repair the systems at all. On the other hand, 17.4% of participants stated they could maintain the systems easily, while 12.3% were able to do so with some difficulty.

The frequency of maintenance and repairs varied among respondents. As shown in Table 4.13, 44.0% of respondents reported performing maintenance regularly, such as monthly or more often. In contrast, 26.9% performed maintenance rarely (once a year or less), and 24.9% did so occasionally (every few months). Only 4.3% of respondents reported never performing maintenance on their sanitation technologies. Regarding training, 28.0% of respondents had received training on the use and maintenance of their sanitation technologies, while a significant proportion (72.0%) had not received any formal guidance or instruction. These findings underscore the need for targeted training programs to enable users to effectively maintain and repair their sanitation systems, thereby enhancing their longevity and reliability.

Table 4.13*:*

Reliability, maintenance ability, frequency of maintenance, and training on sanitation technologies (n = 350)

Variable	Frequency(n)	Percentage (%)
Reliability of sanitation technologies		
Unreliable	15	4.3
Highly reliable	88	25.1
Not very reliable	41	11.7
Somewhat reliable	206	58.9
Ability to maintained		
No, need assistance from others	186	53.1
No, unable to maintain or repair	60	17.1
Yes, easily	61	17.4
Yes, with some difficulty	43	12.3
Frequency of Maintenance		
Never	15	4.3
Occasionally (e.g., every few months)	87	24.9
Rarely (e.g., once a year or less)	94	26.9
Regularly (e.g., monthly or more often	154	44.0
Received training		
No	252	72.0
Yes	98	28.0

Source: Researcher, (2024)

4.5 Potential Health Risks Associated with the Current Sanitation Service Chain

The study examined the potential health risks associated with the sanitation service chain in Iten Municipality, with a specific focus on waterborne diseases, exposure to pathogens, and contamination of water sources. As shown in Table 4.14, 28.0% of respondents reported that sanitation-related illnesses had affected household members, while the majority (72.0%) indicated that no such occurrences had occurred. When asked about the prevalence of water-related diseases such as amoebiasis, typhoid, and diarrhea, 12.9% of respondents acknowledged the presence of these diseases in the area, while 82.6% reported no prevalence. A small proportion (4.6%) were uncertain about the presence of such diseases.

Handwashing practices were also investigated, as proper hygiene can significantly mitigate health risks. The study found that 62.3% of respondents always washed their hands with soap and water, while 33.1% washed their hands most of the time. Only a small fraction reported occasional (3.4%) or rare (0.6%) handwashing, and a minimal 0.6% admitted to never washing their hands with soap and water. These findings suggest that while many households engage in consistent handwashing, there are still gaps in hygiene practices that may contribute to the transmission of waterborne diseases.

Table 4.14:

Sanitation-related issues in Iten municipality(n=350)

Variable	Frequency	Percent
Household member experiences sanitation illness.		
No	252	72.0
Yes	98	28.0
Total	350	100.0
Are there water-related diseases prevalent in the study area		
No	289	82.6
Not sure	16	4.6
Yes	45	12.9
Total	350	100.0
Handwashing with soap and water		
Never	2	0.6
Always	218	62.3
Most of the time	116	33.1
Occasionally	12	3.4
Rarely	2	.6
Total	**350**	**100.0**

Source: Research Data, (2024)

The study examined various health-related factors, including respondents' perceptions of the relationship between sanitation and disease transmission, their training in proper sanitation practices, the frequency of seeking medical attention, the contamination of water sources, and the adequacy of waste management infrastructure. The findings are presented in Table 4.15.

As shown in Table 4.15, the majority of respondents (89.7%) strongly believed that there is a direct link between sanitation and the spread of diseases related to sanitation. Only 1.4% of respondents did not believe in this connection, while 6.9% somewhat believed and 2.0% were unsure. Regarding training on proper sanitation practices, only 30.9% of respondents reported having received any form of education, while the majority (69.1%) had not received any training on this topic. The study also found that more than half of the respondents (59.7%) had never sought medical treatment for sanitation-related health issues, while 27.7% reported seeking medical help rarely, 10.9% occasionally, and 1.7% regularly.

Table 4.15:

Health predictors on the adequacy of waste management (n=350)

Variable	Frequency	Percentage (%)
Link of Sanitation and the spread of diseases		
No, don't believe	5	1.4
Not sure	7	2.0
Yes, somewhat believe	24	6.9
Yes, strongly believe	314	89.7
Contamination of water sources		
No	260	74.3
Not sure	23	6.6
Yes	67	19.1
Trained on proper sanitation practices		
No	242	69.1
Yes	108	30.9
Medical treatment		
Never	209	59.7
Occasionally	38	10.9
Rarely	97	27.7
Regularly	6	1.7
Need to improve the Sanitation infrastructure		
Not sure	4	1.1
No, do not believe	24	6.9
Yes, somewhat believe	10	2.9
Yes, strongly believe	312	89.1
Adequate waste management and disposal		
No	22	6.3
Not sure	11	3.1
Yes	317	90.6

Source: Researcher, (2024)

When asked about the need to improve sanitation infrastructure in Iten Municipality, as shown in Table 4.15, (89.1%) of respondents strongly believed that improvements were necessary. On the adequacy of current waste management and disposal practices, 90.6% agreed that the system was sufficient, while 6.3% disagreed, and 3.1% were unsure. The study revealed that 73.4% of respondents were unaware of the contamination of water sources due to improper sanitation practices, indicating a significant gap in public awareness and education regarding the broader environmental impacts of inadequate sanitation.

4.5.1 Pearson Chi-Square Test: health risk predictors and adequacy of waste management

The study further conducted Pearson Chi-Square tests at a 95% confidence interval to establish health risk predictors associated with users' technologies (adequacy of waste management), with findings summarized in Table 4.16. The study revealed a significant association between sanitation illness and the adequacy of waste management ($\chi^2 = 26.350$, $df = 1$, $p = 0.000$). This association underscores the importance of effective waste management in preventing health-related issues in the community. The prevalence of water-related diseases, including amoebiasis, typhoid, and diarrhea, also showed a significant relationship with waste management adequacy ($\chi^2 = 48.800$, $df = 2$, $p < 0.001$). This suggests that inadequate waste management is associated with an increase in waterborne diseases, underscoring the need for improved sanitation infrastructure.

The Chi-Square analysis revealed a significant association between handwashing practices and waste management ($\chi^2 = 48.20$, $df = 4$, $p < 0.001$). The findings suggest that households with better handwashing habits tend to have more effective waste management systems, highlighting the importance of hygiene in sanitation and health. A significant association was found between the contamination of water sources and the adequacy of waste management ($\chi^2 = 37.173$, df = 2, p = 0.000). Respondents who reported water contamination had less adequate waste management practices, indicating a direct link between sanitation and environmental health risks.

The frequency of seeking medical treatment for sanitation-related illnesses was significantly associated with the adequacy of waste management ($\chi^2 = 16.940$, df = 3, p = 0.000). This finding further supports the need for proper waste management to prevent health issues and reduce the burden on medical services. The study found a significant association between receiving training on sanitation practices and the adequacy of waste management ($\chi^2 = 2.285$, df = 1, p = 0.000). Only 30.9% of respondents had received training, suggesting that a lack of education on proper sanitation may contribute to inadequate waste management practices.

Table 4.16:

Test of association health predictors and adequacy of waste management (n=350)

Independent Variable	Categories	Adequacy of waste management Good 92(26.3%)	Poor 258(73.7%	Statistical significance
Sanitation illness	Yes	7(2.0%)	40(11.4%)	X^2= 26.350
	No	85(24.3%)	218(62.3%)	df= 1
				p=0.000
Handwashing	Always	61(17.4%)	157(44.9%)	X^2= 48.20
	Most of the time	29(8.3%)	87(24.9%)	df= 4
				p=0.000
	Never	0(0.0%)	2(0.6%)	
	Occasionally	2(0.6%)	10(2.9%)	
	Rarely	0(0%)	2(0.6%)	
Water-related diseases	No	84(24%)	205(58.6%)	X^2= 48.808
	Not sure	2(0.6%)	14(4.0%)	df= 2
	Yes	6(1.7%)	39(15.1%)	p=0.000
Link of Sanitation and the spread of diseases	Not sure	2(0.6%)	5(1.4%)	X^2= 26.950
	Yes somewhat	10(2.9%)	14(4.0%)	df= 2
	Yes strongly	80(22.9%)	239(68.3%)	p=0.000
Presence of odour	No	67(19.1%)	137(39.1%)	X^2= 26.950
	Yes frequently	10(2.9%)	28(68.0)	df= 3
	Yes occasionally	15(4.3%)	93(26.6%)	p=0.000
Presence of pest	No	69(19.7%)	134(38.3%)	X^2= 38.273
	Yes, frequently	8(2.3%)	32(9.1%)	df= 2
	Yes occasionally	15(4.3%)	92(26.3%)	p=0.000
Contamination of water sources	No	75(21.4%)	185(52.9%)	X^2= 37.173
	Not sure	9(2.6%)	14(4.0%)	df= 2
	Yes	8(2.3%)	59(16.9%)	p=0.000
Training	No	65(18.6%)	177(50.6%)	X^2= 2.285
	Yes	27(7.7%)	81(23.1%)	df= 1
				p=0.000
Medical treatment	Never	132(37.7%)	77(22%)	X^2= 16.940
	Occasionally	35(10.0%)	3(0.9%)	df= 3
	Rarely	86(24.6%)	11(3.1%)	p=0.000
	Regularly	5(14%)	1(0.3%)	

Source: Researcher, (2024)

4.5.2 Pearson Correlation Analysis: health indicators and adequacy of waste management

To explore the relationship between health indicators and the adequacy of waste management, Pearson's Product-Moment Correlation was conducted at a 95% Confidence Interval. The results of the analysis, summarized in Table 4.17, indicate significant correlations between various health outcomes and the perceived effectiveness of waste management systems.

The analysis revealed a negative correlation between the adequacy of waste management and several health indicators, indicating that inadequate waste management systems are associated with poorer health outcomes.

For example, the study found a weak negative correlation between sanitation-related illnesses and waste management ($r = -0.102$, $p = 0.057$), indicating that inadequate sanitation is associated with higher rates of illness in the community. Similarly, water-related diseases exhibited a moderate negative correlation ($r = -0.131$, $p = 0.014$), further highlighting that improper waste management contributes to the prevalence of diseases such as typhoid and diarrhea. In addition, the presence of odour ($r = -0.207$, $p = 0.000$), presence of pests ($r = -0.192$, $p = 0.000$), and contamination of water sources ($r = -0.133$, $p = 0.013$) all demonstrated negative correlations with waste management adequacy, suggesting that inadequate sanitation increases the risk of environmental contamination and pest infestation, which can, in turn, affect public health.

The correlation between handwashing practices and sanitation-related health outcomes revealed a positive correlation with sanitation illness ($r = 0.298$, $p = 0.000$) and water-related diseases ($r = 0.242$, $p = 0.000$). This suggests that improved handwashing practices are associated with a decrease in health issues, underscoring the importance of hygiene in preventing sanitation-related illnesses and waterborne diseases. The presence of pests and contamination of water sources were also positively correlated ($r = 0.331$, $p < 0.001$), indicating that areas with higher pest populations tend to experience higher levels of water contamination.

This further suggests the need for comprehensive sanitation solutions that address both the physical infrastructure and public health education. The findings demonstrate the significant role that waste management plays in influencing the health outcomes of a community. Poor waste management not only contributes to higher rates of sanitation illnesses and environmental contamination but also exacerbates the spread of waterborne diseases. Conversely, promoting handwashing and improving waste management infrastructure can significantly reduce the prevalence of these health issues, thereby improving long-term public health outcomes.

Table 4.17*:*

Correlation matrix of health predictors and waste management(n=350)

		Adequacy of waste management	Sanitation illness	Handwashing	Water related diseases	Sanitation, and diseases	Presence of odour	Presence of pest	Contamination of water sources
Adequacy of waste management	Pearson Correlation	1							
	Sig. (2-tailed)								
Sanitation illness	Pearson Correlation	-.102	1						
	Sig. (2-tailed)	.057							
Handwashing	Pearson Correlation	-.072	.298**	1					
	Sig. (2-tailed)	.179	.000						
Water related diseases	Pearson Correlation	-.131*	.499**	.242**					
	Sig. (2-tailed)	.014	.000	.000					
Link of Sanitation, and the spread of the diseases	Pearson Correlation	-.070	-.179**	-.319**	-.118*	1			
	Sig. (2-tailed)	.189	.001	.000	.027				
Presence of odour	Pearson Correlation	-.207**	.222**	.282**	.274**	-.064	1		
	Sig. (2-tailed)	.000	.000	.000	.000	.235			
Presence of pest	Pearson Correlation	-.192**	.222**	.238**	.315**	-.046	.603**	1	
	Sig. (2-tailed)	.000	.000	.000	.000	.387	.000		
Contamination of water sources	Pearson Correlation	-.133*	.221**	.160**	.371**	-.029	.304**	.331**	1
	Sig. (2-tailed)	.013	.000	.003	.000	.592	.000	.000	

**Correlation is significant at the 0.05 level (2-tailed), ** Correlation is significant at the 0.001 level (2-tailed).*

Source: Researcher, (2024)

4.5.3 Water quality testing and contamination levels

The study further conducted laboratory tests to assess the levels of *E. coli* and Total Coliforms in various water sources within Iten Municipality. The results, as presented in Table 4.18, revealed that all tested water sources failed to meet the drinking water quality standards for both Total Coliforms and E. coli, indicating a serious public health concern. The laboratory analysis revealed that water from boreholes, springs, and rivers all showed Total Coliforms Too Numerous to Count (TNTC), with E. coli counts of 22, 30, and 40 CFU/100 mL, respectively.

These values significantly exceed the safe levels established by the World Health Organization (WHO), which mandates that water for human consumption should contain zero E. coli and Total Coliforms per 100 mL. The tap water from ITWASCO, while showing lower contamination levels of 100 CFU/100 mL for Total Coliforms and 3 CFU/100 mL for E. coli, still failed to meet the acceptable standards. The presence of *E. coli* and Total Coliforms in these water sources is a clear indicator of faecal contamination, which poses a substantial health risk to the residents of Iten Municipality. The findings underscore the urgent need for improved water treatment and sanitation measures to safeguard public health and ensure access to safe drinking water.

Table 4.18:

Laboratory results for the water test

Water source	Test Results		
	Total Coliforms (CFU/100ml)	***E. coli* (CFU/100ml)**	**Remarks**
Borehole water (Iten Municipality)	TNTC	22	Fail
Spring (Rorget)	TNTC	30	Fail
Tap water (ITWASCO)	100	3	Fail
River (Kipsinende)	TNTC	40	Fail

TNTC-Too Numerous to Count.

Source: Researcher, (2024)

4.6 Shit Flow Diagram of Iten Municipality

The Shit Flow Diagram (SFD) matrix for Iten Municipality provides a comprehensive analysis of the various sanitation systems in use, the proportion of the population relying on each system, and the management of faecal sludge (FS) throughout different stages of the sanitation service chain. As illustrated in Figure 4.6, the matrix categorizes different sanitation systems, their characteristics, and the corresponding faecal sludge management (FSM) practices. This detailed examination highlights the challenges and inefficiencies of the current sanitation infrastructure, as well as the effectiveness of faecal sludge management in the region.

The matrix categorizes sanitation systems under different labels and descriptions. The system labeled T1A2C5 represents septic tanks connected to soak pits, used by 22% of the population. These systems have a high proportion of FS management efficiency, with 80% of FS being emptied, 50% of which is delivered to treatment plants, and 90% of the delivered FS being treated. Another category, T2A2C5, involves similar septic tank systems but poses a significant risk of groundwater pollution. These systems are used by 6% of the population and show the same proportions of FS management as the T1A2C5 systems, with 80% of FS being emptied, 50% delivered to treatment plants, and 90% treated.

A significant portion of the population, 55%, uses pit latrines labeled as T1B7C10. These pit latrines are emptied when full. Similarly, the T2B7C10 systems, which account for 14% of the population, involve pit latrines that are never emptied and abandoned when full, but also carry a significant risk of groundwater pollution. These types of systems highlight a critical area for intervention as they do not involve any emptying or treatment processes. Furthermore, the matrix indicates that 3% of the population practices open defecation, categorized under T1B11 C7 to C9. Open defecation presents severe health risks and environmental hazards, emphasizing the need for urgent sanitation solutions for this segment of the population.

Figure 4.5:

Shit Flow Diagram Matrix

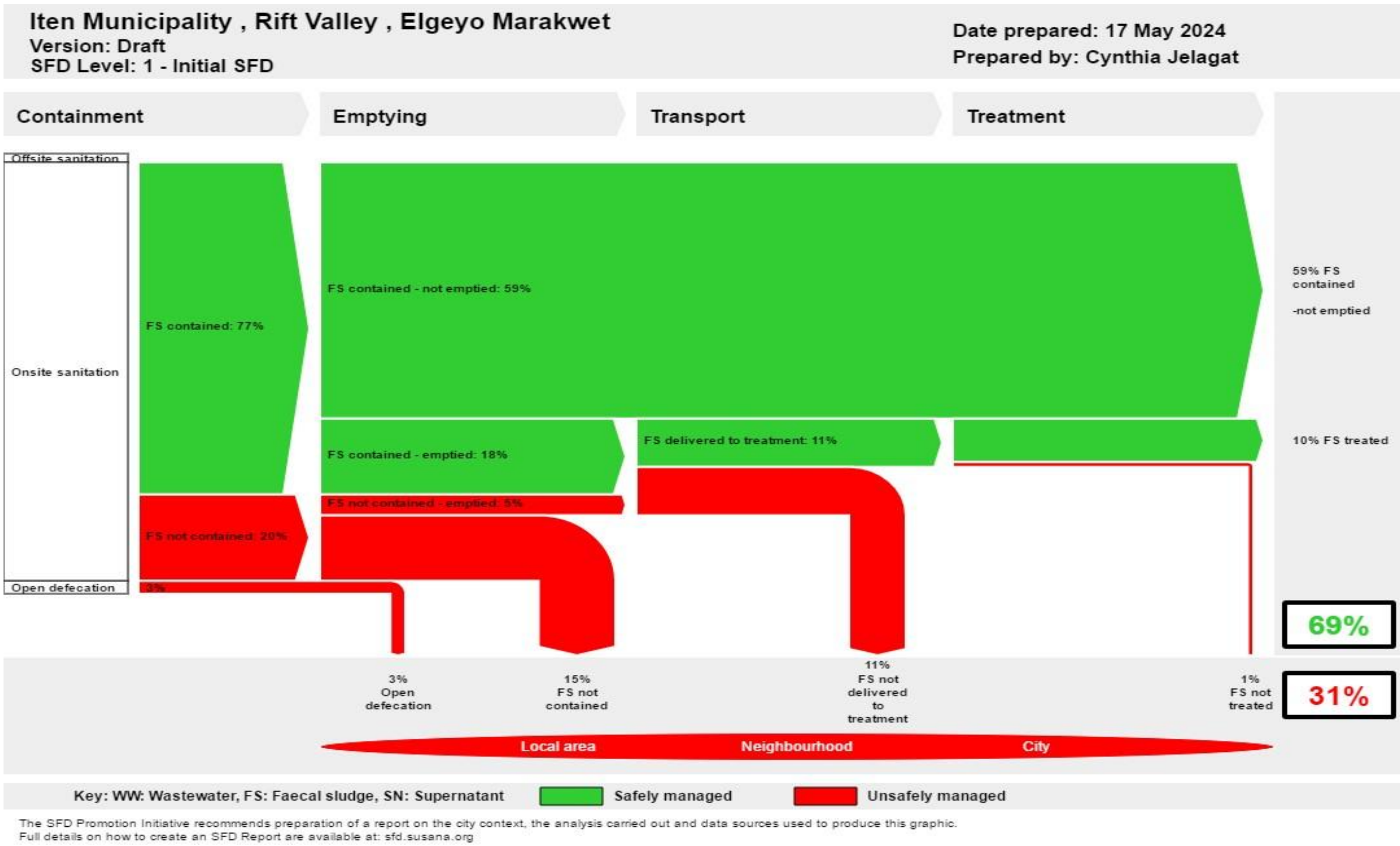
System Label	System descriptions	Pop	F3	F4	F5
		Proportion of the population using this system	The proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	Proportion of faecal sludge delivered to the treatment plant which is treated
T1A2C5	Septic tank connected to soak pits	22	80	50	90
T2A2C5	Septic tank connected to soak pit, where there is a 'significant risk' of groundwater pollution	6	80	50	90
T1B7C10	Pit (all types, never emptied but abandoned when full and covered with soil, no outlet or overflow	55			
T2B7C10	Pit (all types, never emptied but abandoned when full and covered with soil, no outlet or overflow, where there is a 'significant risk' of groundwater pollution	14			
T1B11C7 T0C9	Open defecation	3			

Source: Researcher, (2024)

The Shit Flow Diagram Graphic (Figure 4.6) was generated to visualize the Flow of Human Excreta along the sanitation service chain in Iten Municipality.

Figure 4.6:

The Shit Flow Diagram of Iten Municipality



Source: sfd.susana.org, (2024)

The visual representation of the Shit Flow Diagram (SFD) for Iten Municipality, as shown in Figure 4.6, provides both quantitative and qualitative analysis of human excreta management systems in the area. The diagram uses green arrows to represent flows likely to result in a safe outcome and red arrows to denote unsafely managed flows, highlighting the effectiveness and risks associated with different sanitation practices. The most commonly used sanitation system in Iten Municipality is pit latrines, which are used by approximately 69.1% of the population. Of these, 14% are associated with a significant risk of groundwater contamination, while the remaining 55% are not at risk. These latrines are typically abandoned when full and covered with soil, which can contribute to potential long-term environmental contamination if not properly managed and disposed of. Septic tanks connected to soak pits, used by 22.9% of the population, present a similar situation, where 6% of the systems pose a significant risk of groundwater contamination.

Although 80% of the faecal sludge from septic tanks is emptied, only 50% of this sludge is delivered to the Kipkenyo Sewerage Central Treatment Plant in Eldoret, with the treatment plant itself operating at 90% efficiency. Issues such as road leakages caused by acid burns on vacuum trucks limit the effectiveness of sludge delivery and treatment, indicating a gap in the transportation and treatment process. Flush toilets connected to anaerobic digesters, used by 2.9% of the population, offer a more modern and technically advanced solution but require optimal maintenance and expertise. Additionally, open defecation, practiced by 3% of the population, remains a critical public health risk, directly contributing to environmental contamination and disease transmission. Approximately 69% of the population is covered by safely managed sanitation systems, primarily those utilizing well-maintained septic tanks and pit latrines that pose minimal risks to groundwater contamination. However, approximately 31% of the population relies on unsafely managed sanitation systems, including those that pose significant risks to groundwater contamination and involve open defecation practices.

CHAPTER FIVE: DISCUSSIONS

5.0 Introduction

This chapter discussed the findings' relation to existing sanitation technologies, their performance along the sanitation service chain, and the health risks associated with inadequate excreta management.

5.1 Main Sanitation Technologies Used in Iten Municipality

The study found that most (61%) households in Iten Municipality use pit latrines, a prevalent sanitation solution in low-income areas due to their relatively low construction costs and simplicity in design. The reliance on pit latrines reflects their cost-effectiveness and simplicity in construction and operation, making them an accessible sanitation solution for low-income households in the study area. The results support findings from previous studies, which have documented the prevalence of pit latrines in low-income and peri-urban settings due to their cost-effectiveness and low maintenance requirements. Brands *et al.* (2022) and Cookey *et al.* (2020) similarly observed that pit latrines are commonly used in regions with limited access to more advanced sanitation infrastructure.

The study revealed that a portion of households experience significant maintenance challenges and health risks, which were identified in the study. Pit latrines require regular maintenance, including emptying to prevent overflow, which can be particularly challenging in areas with inadequate waste management infrastructure and where informal sanitation services are often relied upon. These challenges are consistent with global research highlighting the risks associated with pit latrines when they are not properly maintained, particularly regarding groundwater contamination and the spread of waterborne diseases (Peal *et al.,* 2019; Chandana & Rao, 2022).

The next most common sanitation technology identified in the study was flush toilets connected to septic tanks, used by 22.9% of respondents. The adoption of septic tanks can be attributed to their perceived improved hygiene and convenience compared to pit latrines, offering more comfort and privacy, which is appealing in urbanizing areas like Iten. Septic tanks provide better waste containment and require less frequent emptying than pit latrines, making them more sustainable in the long term. However, the relatively low adoption rate of 22.9% reflects several barriers. High initial costs for installation and the need for more space for septic tanks are significant limitations, particularly in densely populated peri-urban settings. Additionally, septic tanks still require regular maintenance and periodic emptying, which may not be easily accessible in Iten, leading to issues like overflow.

The next most common sanitation technology identified in the study area was flush toilets connected to septic tanks, used by 22.9% of respondents. The adoption of septic tanks can be attributed to their perceived improved hygiene and convenience compared to pit latrines, offering more comfort and privacy, which is appealing in urbanizing areas like Iten. Septic tanks provide better waste containment and require less frequent emptying than pit latrines, making them more sustainable in the long term. However, the relatively low adoption rate of 22.9% reflects several barriers. High initial costs for installation and the need for more space for septic tanks are significant limitations, particularly in densely populated peri-urban settings.

Additionally, septic tanks still require regular maintenance and periodic emptying, which may not be easily accessible in Iten, leading to issues like overflow. While septic tanks offer better sanitation, their higher financial cost and maintenance requirements make them less accessible to the majority of the population. This limits their broader adoption and suggests the need for affordable financing options, improved waste management infrastructure, and community awareness programs to promote sustainable practices. These findings align with other studies that have examined the adoption and maintenance of septic systems. For example, Mamera *et al.* (2021) found that while septic tanks are more hygienic than pit latrines, their adoption is often limited by the higher costs associated with installation and the lack of awareness about proper maintenance. Similarly, Kanda *et al.* (2021) found that despite the advantages of septic tanks in providing more hygienic sanitation solutions, many households in peri-urban areas were reluctant to adopt them due to the high initial investment and the complexity of maintenance. Moreover, research by Peal *et al.* (2019) suggests that even where septic systems are used, improper maintenance is a significant issue, leading to overflow and contamination if systems are not emptied regularly.

A smaller proportion of respondents in Iten Municipality, approximately 2.9%, reported using flush toilets connected to anaerobic digesters. The limited adoption of this technology can be attributed to several factors, including high initial installation and maintenance costs, as well as the technical expertise required for operation. In peri-urban areas like Iten, where financial constraints and limited access to specialized services are common, these factors significantly hinder the widespread adoption of anaerobic digesters. Additionally, the benefits of anaerobic digesters, such as biogas production and water conservation, may not be immediately apparent to households, especially when basic sanitation needs remain unmet. According to research by Chambers *et al*. (2022), advanced systems, such as biogas digesters, not only provide effective waste treatment but also contribute to renewable energy production, presenting a dual benefit that is absent in traditional systems. Studies from other regions support these findings. Colon *et al.* (2015) and Forbis-Stokes *et al.* (2016) argue that while anaerobic digesters offer significant environmental benefits, their adoption is often limited by high initial costs, lack of technical expertise, and inadequate maintenance infrastructure. In off-grid areas or regions with limited resources, the complexity and high maintenance requirements of anaerobic digesters can be significant barriers to adoption. Similarly, Alamansa *et al.* (2023) emphasize that policy incentives, subsidies, and financial support mechanisms are crucial to encouraging the widespread adoption of such technologies. Furthermore, the cultural acceptance of such technologies can be a significant barrier to their adoption. According to Bautista *et al.* (2018), the successful implementation of anaerobic digesters in new communities often depends on educational campaigns and community engagement to foster understanding and acceptance.

The study found that a significant proportion, 5.1% were using alternative sanitation arrangements, which included open defecation or container-based systems. The adoption of these non-traditional sanitation solutions can be attributed to the lack of access to formal sanitation infrastructure. The low adoption of container-based systems could be due to the associated stigma, which may hinder their adoption, even if they offer a more hygienic alternative to open defecation. These systems require regular maintenance and the safe disposal or treatment of waste, which can become a logistical and financial burden if not properly managed (Russel *et al.,* 2019). Studies by Tiley *et al.* (2014) and Orner and Mihelcic (2018) emphasize that, while hygienic and flexible, container-based systems require careful management to prevent environmental contamination and ensure that waste is safely treated or disposed of. Furthermore, the cultural acceptance of such systems is a significant factor, as noted by VanRiper *et al*. (2021) and Dube *et al*. (2023), who point out that user preferences and perceptions play a crucial role in determining the success of sanitation interventions.

Interestingly, the study highlighted a complete absence of respondents connected to municipal sewer systems, which are usually prevalent in more urbanized environments. The utility provider, Iten Tambach Water and Sewerage Company (ITWASCO), only deals with water supply in the areas. The lack of a sewerage treatment plant indicates a significant gap in the sanitation infrastructure within Iten Municipality, as sewer systems are typically considered the most advanced and hygienic form of waste management for a large population, such as that of the municipality. They involve a network of pipes that transport waste to a centralized treatment facility where it is processed and treated before being safely discharged into the environment (Chirgwin *et al*., 2021).

The study revealed a heavy reliance on formal and informal water sources in Iten Municipality, with significant use of boreholes and piped water, rainwater harvesting, and vendors' use. This reliance on informal water sources, combined with the proximity of sanitation infrastructure to these sources, can lead to groundwater contamination, especially if pit latrines are not properly maintained or are located too close to wells. The reasons for this reliance likely stem from economic constraints and limited municipal water infrastructure, which is common in peri-urban areas. The effects are serious, as contamination of water sources can lead to the spread of waterborne diseases. Previous studies, such as those by Hutton and Chase (2022) and Peal *et al*. (2019), highlight that poor spatial planning between sanitation facilities and water sources increases the risk of groundwater contamination. Lam *et al.* (2015) further stress the importance of proper infrastructure planning to safeguard water quality in urbanizing regions.

5.2 Evaluation of the Performance of the Different Sanitation Technologies in Iten Municipality

The performance of various sanitation technologies in Iten Municipality was evaluated based on several key indicators, including functionality, maintenance requirements, waste treatment efficiency, odour control, cost-effectiveness, and user satisfaction. Each of these indicators provides insight into the effectiveness of the sanitation service chain and helps identify areas for improvement.

The study revealed inconsistency in pit latrine maintenance frequency, with many respondents reporting unspecified intervals, highlighting a significant issue. This lack of standardized maintenance can compromise the efficiency of sanitation systems, leading to reduced functionality and increased health risks. Regular and well-managed maintenance schedules are essential to ensure these facilities' proper operation and prevent overflow or contamination. Research supports the need for more reliable and frequent maintenance. Hussain *et al*. (2017) emphasize that regular maintenance is crucial to avoid blockages and system overflows, which can lead to environmental and public health hazards. The irregular maintenance intervals reported suggest a need for standardization and increased community education on the importance of maintaining regular sanitation.

The disposal practices for human excreta and greywater in Iten Municipality reveal concerning trends. The majority of human waste is disposed of in pits (49.4%) or septic tanks (23.1%), reflecting a reliance on traditional systems that often lack proper maintenance or design to ensure effective waste treatment. The low adoption of sustainable technologies, such as composting (3.1%), suggests a gap in awareness or infrastructure for alternative waste management methods. Additionally, a significant portion of greywater is discharged onto open ground (22.9%) or into open drains (24.3%), pointing to inadequate wastewater treatment infrastructure. These disposal practices contribute to environmental contamination, posing a soil and water pollution risk and increasing the likelihood of waterborne diseases. Similar patterns have been observed in other low-income regions, where reliance on outdated sanitation systems and inadequate waste management infrastructure exacerbates public health issues (Burlingame *et al.,* 2020; Junaid *et al.,* 2020). These findings underscore the pressing need for sustainable sanitation solutions to mitigate health risks and safeguard the environment.

The discharge of greywater directly onto open ground or into open drains is a primary concern, as it can contribute to the contamination of water sources and increase the risk of vector-borne diseases. This practice is well-documented in studies by Grimes *et al*. (2015) and Lam *et al*. (2015), which emphasize the health risks associated with the improper disposal of greywater, including the potential for contamination of local water sources. Similar practices have been observed in other parts of Sub-Saharan Africa, where inadequate drainage systems and poor sanitation infrastructure exacerbate the risk of waterborne diseases (Sisay *et al.,* 2024).

A notable challenge identified in this study relates to the issue of odour control in the sanitation facilities used in Iten Municipality. About 41.7% of respondents reported experiencing Oduors either frequently or occasionally around their sanitation facilities, which may reflect the inadequate design or maintenance of the sanitation technologies. Oduor often results from inefficient waste decomposition processes in pit latrines or septic systems, where proper aeration or frequent desludging is lacking (Mamera *et al.,* 2021). The findings align with previous research by Ganesan (2017), who found that households using septic tanks in rural India reported odour issues less frequently than those using pit latrines. Similarly, Chandana & Rao (2022) observed that while pour-flush toilets provide better odour control compared to pit latrines, they still require consistent maintenance and management to mitigate unpleasant smells.

The study found that 45% of respondents perceive sanitation services as expensive, particularly concerning the costs of emptying pit latrines and septic tanks. The primary reason behind this perception is the high direct costs incurred by households for the periodic emptying of onsite sanitation systems, such as pit latrines and septic tanks. In many cases, these services are provided informally, which often leads to higher costs and irregular service delivery. Moreover, the lack of regulatory oversight in informal service provision means that households may face price variations and reduced service quality, further exacerbating the financial burden on users, as was noted in interviews. Without affordable options for emptying and maintaining these systems, households may resort to using them until they become full, exacerbating sanitation-related health issues and environmental contamination. Previous studies align with the findings of this research, showing that high maintenance costs represent a significant barrier to improving sanitation in low- and middle-income settings. For example, research by Tomoi *et al.* (2024) and Cameron *et al*. (2019) demonstrated that affordability is a significant barrier to the uptake of improved sanitation technologies. Similarly, the study by Malima *et al.* (2022) in Tanzania found that the high cost of maintaining sanitation facilities, especially pit latrines and septic tanks, significantly hindered the frequency of maintenance. Furthermore, studies such as those by Daudey (2018) and Mills *et al.* (2020) emphasized the importance of introducing flexible payment schemes or financing options to enhance the accessibility of sanitation services.

They showed a significant proportion of respondents (77.4%) reported satisfaction with the performance of their sanitation facilities (Table 4.11). This high satisfaction rate is likely attributed to factors such as consistent functionality, privacy, and perceived user safety, all of which were rated positively across multiple indicators. The sustained use of familiar onsite technologies, such as pit latrines and septic tanks, may have also reinforced user confidence and perceived control over maintenance routines. As observed in Simiyu (2017), familiarity and perceived control often contribute to higher satisfaction in sanitation service delivery. Similarly, Sclar *et al.* (2018) found that sanitation dignity, especially in terms of privacy and security, has a significant psychosocial impact on user satisfaction, often outweighing technical concerns. The implication here is that in peri-urban contexts, enhancing privacy and safety may yield more community buy-in than focusing solely on infrastructure upgrades. This aligns with Ross *et al.* (2021), who argue that perceived autonomy and security strongly shape sanitation acceptability, especially among women. The findings reinforce the necessity of integrating both technical and socio-cultural factors in the design, implementation, and maintenance of sanitation systems, particularly in rapidly urbanizing settings such as Iten Municipality.

The study highlights the challenges respondents face in maintaining and repairing their sanitation systems. A significant proportion of users reported needing external assistance for maintenance, and many had not received any formal training on how to care for their sanitation technologies. This suggests that a lack of user knowledge and reliance on external support may compromise the sustainability and effectiveness of sanitation systems over time.

Systems are prone to deterioration without adequate knowledge, resulting in higher repair costs, longer service downtimes, and potential health risks. This is consistent with previous studies, which have noted that inadequate maintenance and user training are significant barriers to the proper functioning of sanitation systems. For example, Hussain *et al*. (2017) observed that the lack of technical expertise among users led to frequent malfunctions, while Welling *et al*. (2020) highlighted the importance of ongoing education for ensuring effective maintenance. Additionally, Still and Louton (2012) found that behavioral issues, such as improper usage, exacerbated the need for regular maintenance, further emphasizing the importance of user-centered training and support.

5.4 Potential Health Risks Associated with the Sanitation Service Chain

Evaluating potential health risks within the Iten Municipality sanitation service chain has revealed key insights into the interactions between sanitation practices and health outcomes. The findings showed that 28% of the population in Iten Municipality experienced sanitation-related health issues within the past year, highlighting a significant public health concern. These issues, often preventable with better sanitation practices and infrastructure, contribute to a substantial disease burden. Additionally, 12.9% of respondents reported the prevalence of waterborne diseases. A statistical analysis revealed a significant association between sanitation-related illness and the adequacy of waste management. This suggests that inadequate sanitation systems are closely linked to higher rates of illness within the community. The weak negative correlation found between sanitation-related illness and waste management further supports the notion that poor waste management is a key driver of health issues. The correlation between inadequate sanitation and disease prevalence is well-documented in the literature, with studies highlighting that poor sanitation facilities are significant contributors to the spread of sanitation-related and waterborne diseases, which have a substantial impact on global morbidity and mortality (CDC, 2020; WHO, 2020). Previous research in Kisumu, Kenya, and Kampala, Uganda, has also shown a similar trend, where inadequate sanitation systems have been strongly correlated with higher rates of waterborne diseases (Simiyu, 2017; Nakagiri *et al*., 2015). These studies further emphasize the urgent need for improved sanitation infrastructure and practices to reduce health risks.

The study found a significant association between handwashing practices and waste management ($p < 0.001$), with 62.3% of respondents consistently practicing handwashing with soap and water. This positive behavior can be attributed to growing awareness of hygiene's role in disease prevention and the impact of public health campaigns promoting sanitation. Additionally, consistent handwashing may stem from a cultural shift toward improved hygiene practices, especially as sanitation-related health issues are increasingly recognized. This aligns with the positive correlation between handwashing practices and sanitation-related health outcomes observed in the study ($r = 0.298$, $p < 0.000$), suggesting that regular handwashing with soap can significantly reduce the transmission of pathogens and prevent sanitation-related illnesses. However, while a majority of respondents in this study practiced handwashing, a notable proportion (33.1%) reported inconsistent handwashing habits, which may indicate gaps in knowledge or infrastructure that hinder consistent hygiene practices. This observation aligns with the findings of the WHO (2020), which revealed that social norms, infrastructure, and access to soap and water can significantly influence handwashing behavior. As such, despite the positive correlation observed, the study highlights the need for improved public health campaigns and infrastructure to encourage regular and consistent handwashing practices across all segments of the population.

The significant association between receiving training on sanitation practices and waste management adequacy underscores the importance of education in improving sanitation outcomes. The low percentage of respondents (30.9%) who received training suggests a gap in sanitation education, potentially due to limited access to or prioritization of training programs. This lack of education may contribute to improper waste management practices, including inadequate waste containment, infrequent maintenance, and improper disposal of waste. Such practices increase the risk of environmental contamination and waterborne diseases, as seen in similar studies by Peal *et al.* (2020), emphasizing that inadequate knowledge leads to poor sanitation outcomes. Effective training and education on sanitation are crucial for enhancing public health outcomes and are recommended by various studies as effective interventions to improve hygiene practices and reduce the spread of disease (Giusti, 2009; Hyun *et al*., 2019).

The study revealed a significant association between water source contamination and inadequate waste management practices ($p < 0.000$). Respondents who reported contamination of local water sources tended to exhibit poorer waste management practices, highlighting a direct link between sanitation issues and environmental health risks. This direct connection highlights the importance of effective waste management for sanitation and the protection of public health and the environment. The 19.1% of respondents who acknowledged contamination in local water sources further emphasize the gravity of the situation, as improper waste management systems directly contribute to the pollution of water bodies, thereby increasing the risk of waterborne diseases. These findings are consistent with studies from other regions that have identified a strong relationship between inadequate sanitation and the contamination of water sources. For instance, Furlong *et al*. (2023) highlighted how unsafely managed excreta in urban and peri-urban areas often find their way into local water supplies, leading to widespread public health risks.

The study's laboratory findings, which show high levels of E. coli and Total Coliforms in various water sources within the municipality, further substantiate these concerns. These microbial indicators are widely recognized as proxies for faecal contamination, and their presence in drinking water clearly indicates the public health risks associated with inadequate sanitation systems. According to the World Health Organization (WHO, 2020), the presence of E. coli and total coliforms in drinking water is a key indicator of faecal contamination. Specifically, the WHO guidelines for drinking water quality stipulate that E. coli should be absent from any 100 mL potable water sample. The detection of E. coli and high levels of total coliforms in these water sources suggests significant contamination, which poses a direct public health risk, as these bacteria can cause waterborne diseases such as cholera, typhoid, and dysentery. Previous studies have linked inadequate waste management and sanitation infrastructure to the contamination of water sources, emphasizing the need for comprehensive waste management systems to mitigate these risks (Lam *et al*., 2015; Grimes *et al*., 2015).

The study's data further indicate that 24.6% of latrines are located within 15 meters of a well or hand pump. This proximity poses a significant risk of water source contamination, especially during rainy seasons or flooding, when pathogens from human waste can easily infiltrate water sources. The presence of latrines near water points is a recognized risk factor for groundwater contamination with nitrates, pathogens (such as E. coli), and other biological pollutants, which can lead to waterborne diseases like cholera, dysentery, and typhoid (WHO, 2020). This risk is exacerbated if the latrines are not well-constructed or properly maintained, which is often the case in resource-limited settings. Moreover, only 25.6% of these latrines are located on higher ground relative to handpumps. This configuration is preferable because it minimizes the risk of wastewater flowing downhill into the water source. However, the majority (74.4%) are not positioned on higher ground, increasing the risk of water source contamination through subsurface flow paths, especially in areas with porous soil. This directly impacts the potential health risks associated with the sanitation service chain by increasing the likelihood of disease transmission through contaminated water sources.

The high level of belief (89.1%) in the need for improved sanitation infrastructure points towards a recognized need for enhancement in the sanitation service chain. Effective waste management and disposal are crucial, as indicated by 90.6% of participants believing their current systems are adequate. However, this perception may not fully align with the observed contamination levels in water sources. The Pearson Chi-Square Tests highlight significant associations between sanitation-related illnesses, water-related disease prevalence, and the adequacy of waste management (Table 4.19). These statistical relationships underscore the critical need for robust sanitation systems to effectively manage waste to prevent disease. Evidence of open defecation still practiced with a small proportion of the population (approximately 3%) also poses a significant health risk since it leads to the contamination of water sources, soil, and food with faecal matter, which can harbor pathogens such as bacteria, viruses, and parasites (Zhang *et al*., 2022; Grimes *et al*., 2015). These pathogens are responsible for various diseases, including diarrhea, cholera, dysentery, and intestinal worm infections, which are particularly harmful to children and can result in malnutrition, stunted growth, and even death (Hutton & Chase, 2022; Behara *et al*., 2021).

5.5 Shit Flow Diagram of Iten Municipality

The study revealed critical gaps in the Sanitation Service Chain (SSC) in Iten Municipality, highlighting both strengths and areas for improvement in local sanitation systems. The majority of the population, approximately 69.1%, uses pit latrines, with 55% of these systems being safely managed. However, 14% of pit latrines pose a significant risk of groundwater contamination, primarily due to improper abandonment practices, where latrines are sealed and left unused once they are full. This finding is consistent with global research, such as Peal *et al.* (2020), which highlights the environmental risks associated with the abandonment of pit latrines in peri-urban areas. While 69% of the population benefits from safely managed sanitation systems, the remaining 31% rely on unsafely managed systems, including those prone to contamination and open defecation. This gap underscores the urgent need for improved waste management practices and enhanced infrastructure to mitigate the risks associated with unsanitary sanitation systems.

Septic tanks, which are used by 22.9% of the population, present a similar situation. Although 80% of faecal sludge is emptied from these tanks, only 50% of the sludge is transported to the Kipkenyo Sewerage Treatment Plant. Additionally, transportation inefficiencies, such as leaks from vacuum trucks due to acid burns, limit the effectiveness of sludge delivery and treatment. This points to significant weaknesses in the sludge transport infrastructure, which compromises the overall treatment process and exposes the environment to untreated waste. These findings align with studies conducted in other African cities, such as Lusaka, Zambia, where similar gaps in sludge management led to calls for better infrastructure and capacity building (Chanda *et al*., 2021). The treatment plant itself operates at 90% efficiency; however, inefficiencies in sludge transportation and treatment are critical challenges that need to be addressed to ensure safe waste management practices.

The application of the Shit Flow Diagram (SFD) has proven valuable in visualizing the flow of human excreta and identifying gaps in sanitation services. This tool, initially developed by the Water and Sanitation Program (WSP) of the World Bank, allows for a clear representation of safe and unsafe sanitation flows, facilitating informed decision-making in sanitation planning. The SFD for Iten Municipality revealed that while 69% of excreta is safely managed, 31% remains unsafely managed, with a significant portion of waste entering the environment untreated. This finding is consistent with studies on SFD in cities such as Nairobi, Kenya, and Kombolcha, Ethiopia, where inadequate treatment and poor management systems remain widespread (Van-Welie *et al.,* 2019; Endris *et al.,* 2024). Similarly, in Nkubu Town, Meru County, a 2022 study reported that the SFD illustrates that 35–45% of excreta bypass safe management routes entirely, primarily due to informal housing and insufficient enforcement of sanitation regulations (Gituma *et al.,* 2022). The findings from this study underscore the need for targeted investments in sludge treatment infrastructure, community education, and improved waste management systems to mitigate public health risks and environmental contamination.

CHAPTER SIX: CONCLUSION, RECOMMENDATIONS, AND PUBLICATIONS

6.0 Introduction

This chapter presents a summary of the research findings and further discusses the conclusions drawn from data analysis, highlighting the critical insights gained. Based on the findings, practical recommendations are proposed to address the identified issues and improve waste management practices. Additionally, suggestions for further studies are provided along with topics for publications.

6.1 Summary of Findings

The study in Iten Municipality identified three primary sanitation technologies utilized by the local population: pit latrines, flush toilets connected to septic tanks, and flush toilets connected to anaerobic digesters. Pit latrines are the most common, used by approximately 69.1% of respondents, reflecting their low cost and simplicity. However, they require significant maintenance and pose health risks if not managed properly. Flush toilets with septic tanks, used by 22.9% of respondents, offer a more controlled waste management environment, but still require regular maintenance to prevent system failures and environmental contamination. The least common, used by 2.9% of the population, are flush toilets connected to biogas digesters, which treat waste and generate energy, but face challenges such as maintenance complexity and the need for community acceptance.

Performance assessment of these technologies revealed a concerning lack of standardized maintenance practices. Only 36.9% of pit latrine users perform annual maintenance, while others do not follow a consistent schedule, leading to potential overflows and increased health risks. Odour control and pest issues are significant factors that affect these sanitation technologies. Disposal methods for human waste and greywater predominantly involve direct discharge into pits or open grounds, reflecting inadequate waste management infrastructure. This practice poses severe risks of environmental contamination. Despite these challenges, a significant majority of residents (77.4%) expressed satisfaction with their sanitation facilities, indicating a potential disconnect between perceived adequacy and actual safety standards of these sanitation systems.

Regarding potential health risks, 28% of respondents experienced sanitation-related health issues within the last year, indicating significant public health challenges. Diseases linked to water and sanitation, such as typhoid, amoebiasis, and diarrhea, were reported by 12.9% of the population. A majority practised handwashing, which helps mitigate the spread of disease; yet, a substantial number lack proper sanitation training, highlighting a gap in education and behaviour change initiatives. Water source contamination remains a critical issue, with nearly 20% of respondents confirming it, compounded by the presence of E. coli and coliforms in local water sources, which signals a severe risk of waterborne diseases.

The Shit Flow Diagram (SFD) for Iten Municipality reveals significant gaps in sanitation management. While 69.1% of households use pit latrines, 14% are at risk of groundwater contamination, and 22.9% use septic tanks, with 6% facing similar risks. Only 50% of septic sludge reaches treatment facilities. 3% of the population practices open defecation, exacerbating public health risks. Overall, 31% of the population relies on unsafely managed sanitation systems.

6.2 Conclusion

The primary findings in this study indicate a predominant reliance on basic sanitation facilities, notably pit latrines, which are extensively used due to their low cost and simplicity, but pose significant maintenance and health challenges. More advanced systems, such as septic tanks and anaerobic digesters, although utilized by a smaller fraction of the population, offer better waste management but require regular and knowledgeable maintenance to prevent environmental and health risks.

The performance evaluation of these technologies revealed that the absence of regular and standardized maintenance leads to inefficiencies and health hazards, indicating a gap in community education and local governance in sanitation management. Notably, issues such as odour control, pests, and irregular maintenance schedules underscore the need for structured community engagement and standardized practices.

The study also highlighted significant health risks associated with inadequate sanitation practices. A considerable number of respondents reported diseases related to poor sanitation, with a notable prevalence of waterborne illnesses. The water quality tests confirmed the presence of harmful pathogens such as *E. coli* and total coliforms in local water sources.

The Shit Flow Diagram (SFD) for Iten Municipality provides a clear representation of the current sanitation management system, revealing areas where improvements are needed. While sanitation technologies serve a significant portion of the population, considerable challenges remain regarding the safety and effectiveness of these systems. The gaps in sludge management, the risks of groundwater contamination, and the persistence of open defecation underscore the complexity of achieving safe and sustainable sanitation for all, highlighting the critical public health implications of inadequate waste management.

6.3 Recommendations

To address the sanitation challenges identified in the study, several comprehensive recommendations are proposed:

Enhance Sanitation Infrastructure: It is crucial to develop and implement a comprehensive infrastructure plan that focuses on constructing advanced sanitation systems, such as biogas digesters and modern septic tanks. These systems not only provide safer and more efficient waste treatment but also contribute to energy production. Additionally, the introduction of municipal sewer systems in densely populated areas would mitigate the reliance on individual septic systems and pit latrines, ultimately reducing environmental contamination and improving public health.

Standardize Maintenance Protocols: Implement regular and standardized maintenance schedules for all types of sanitation facilities to ensure proper functioning and prevent system overflows and failures. Establishing a municipal authority or enhancing the capacity of existing ones to oversee sanitation system maintenance will ensure adherence to health and environmental standards. This authority could also facilitate community education on the importance of regular sanitation maintenance and proper waste disposal practices.

Promote Sustainable Waste Disposal Practices: The community should be encouraged to adopt eco-friendly technologies for waste treatment, such as composting toilets, which not only reduce the environmental impact but also provide valuable byproducts like compost. The implementation of community-based waste management programs that incorporate waste material recycling and reuse would significantly mitigate the environmental impacts associated with traditional waste disposal methods.

Launch Community Education and Awareness Campaigns: Targeted campaigns, such as Community-Led Total Sanitation (CLTS), should be launched to inform residents about the importance of proper sanitation, the dangers of open defecation, and the benefits of maintaining hygiene practices. Training should focus on proper handwashing techniques, the risks associated with open defecation, and the community benefits of improved sanitation systems.

Enhance Public Health Monitoring and Support Systems: Strengthening local health services to manage and mitigate health issues arising from poor sanitation will enhance the community's ability to prevent and respond to outbreaks of waterborne diseases. Regular health education programs focusing on the prevention and effective management of sanitation-related diseases will equip the community with the knowledge to maintain a healthy environment.

Implement Legislative and Policy Interventions: Stricter regulations concerning the construction and maintenance of sanitation facilities should be advocated to ensure they meet required health and environmental standards. Policies that provide incentives for households and businesses to upgrade their sanitation facilities to more sustainable and environmentally friendly systems should be encouraged.

6.4 Recommendation for Further Studies

The study recommends that further research should focus on conducting longitudinal studies to monitor and evaluate the long-term effectiveness and sustainability of different sanitation technologies implemented in Iten Municipality. This will provide insights into the durability, maintenance requirements, and overall performance of various systems over time.

Additionally, research exploring user satisfaction and cultural acceptance of various sanitation technologies will provide valuable insights into community preference and potential barriers to adopting more sustainable sanitation technologies, such as Anaerobic digesters. Understanding these factors can help tailor sanitation solutions to local contexts and increase their uptake. Also, further studies could explore the effectiveness of existing policy and governance frameworks in managing sanitation services within the municipality to ensure adequate emptying and transportation of faecal sludge to the treatment plant, thereby avoiding environmental and groundwater pollution.

6.5 Publication

Kiprop, C. J., Rutto, J. J., Kithinji, D. K., & Kipngeno, A. (2025). Assessment of health risk associated with sanitation system: A case study of Iten Municipality, Elgeiyo-Marakwet, Kenya. *International Journal of Innovative Science and Research Technology, 10*(7), 405–414.

REFERENCES

Abdirasheed, A. M. (2024). Faecal Sludge Management Situational Assessment: The Case of Jigjiga City, Somali Regional State of Ethiopia (Doctoral dissertation).

Aboutaleb, M. H. H. (2022). A Systematic Literature Review on the Influence Civil Society Stakeholders Exert on Shaping Managerial Decisions Taken in Water, Wastewater, and Sludge Treatment Facilities. https://www.politesi.polimi.it/retrieve/40b54a6e-0d56-4b15-be7b-f8887f72d98e/2023_12_Aboutaleb.pdf

Alam, M. U., Rahat, M. A., Nawaz, S., Neeher, N., Tabassum, K. F., Upoma, T. A., ... & Hutchings, P. (2025). Behaviour Change Interventions to Promote Household Connectivity to Sewer: A Scoping Review. Global Health Action, 18(1), 2476335. https://doi.org/10.1080/16549716.2025.2476335

Alam, M. U., Sharior, F., Ferdous, S., Ahsan, A., Ahmed, T., Afrin, A., & Tidwell, J. B. (2020). Strategies To Connect Low-Income Communities with the Proposed Sewerage Network of the Dhaka Sanitation Improvement Project, Bangladesh: A Qualitative Assessment of The Perspectives of Stakeholders. *International Journal of Environmental Research and Public Health*, 17(19), 7201.

Almansa, X. F., Starostka, R., Raskin, L., Zeeman, G., De Los Reyes III, F., Waechter, J.,. & Radu, T. (2023). Anaerobic Digestion as a Core Technology in Addressing the Global Sanitation Crisis: Challenges and Opportunities. Environmental Science & Technology, 57(48), 19078-19087. https://doi.org/10.1021/acs.est.3c05291

Anand, C. K., & Apul, D. S. (2014). Composting toilets as a sustainable alternative to urban sanitation–A review. *Waste management*, *34*(2), 329-343.

Antwi-Agyei, P., Dwumfour-Asare, B., Amaning Adjei, K., Kweyu, R., & Simiyu, S. (2020). Understanding the barriers and opportunities for effective management of shared sanitation in low-income settlements—the case of Kumasi, Ghana. International Journal of Environmental Research and Public Health, 17(12), 4528.

Apanga, P. A., Garn, J. V., Sakas, Z., & Freeman, M. C. (2020). Assessing the impact and equity of an integrated rural sanitation approach: a longitudinal evaluation in 11 sub-Saharan Africa and Asian countries. International Journal of Environmental Research and Public Health, 17(5), 1808. https://www.mdpi.com/1660-4601/17/5/1808

Baltazar, D. E., Harada, H., Fujii, S., Tan, M. F., & Akib, S. (2021). A comparative analysis of septage management in five cities in the Philippines. Eng, 2(1), 12-26

Bartram, J., Brocklehurst, C., Bradley, D., Muller, M., & Evans, B. (2018). Policy review of the means of implementation targets and indicators for the Sustainable Development Goal for water and sanitation. *NPJ Clean Water*, *1*(1), 3.

Bateganya, N. L., Beardsley, R., Lebu, S., Atim, J., Lilian, K. S., Lahai, F., & Manga, M. (2023). Shifting from traditional infrastructure planning to a collaborative approach: lessons from the Freetown sanitation master plan. Journal of Water, Sanitation and Hygiene for Development, 13(12), 974–985.

Bautista Angeli, J. R., Morales, A., LeFloc'h, T., Lakel, A., & Andres, Y. (2018). Anaerobic digestion and integration at urban scale: Feedback and comparative case study. Energy, Sustainability and Society, 8(1), 1-23. https://doi.org/10.1186/s13705-018-0170-3

Behera, M. R., Pradhan, H. S., Behera, D., Jena, D., & Satpathy, S. K. (2021). Achievements and challenges of India's sanitation campaign under Clean India mission: A commentary. *Journal of education and health promotion*, *10*, 350.

Berendes, D., Kirby, A., Clennon, J. A., Raj, S., Yakubu, H., Leon, J., Robb, K., Kartikeyan, A., Hemavathy, P., Gunasekaran, A., Ghale, B., Kumar, J.S., Mohan, V. R., Kang, G., & Moe, C. (2017). The Influence of Household- and Community-Level Sanitation and Faecal Sludge Management on Urban Faecal Contamination in Households. https://doi.org/10.4269/ajtmh.16-0170

Bidira, F., Yesuf, M. B., Schaefer, N., Friedle, M., & Alemayehu, E. (2024). Review on dry toilet and management: Brown water (faeces) characteristics, composition, and management. Environmental Health Engineering and Management Journal, 11(3), 371–384.

Bischel, H. N., Caduff, L., Schindelholz, S., Kohn, T., & Julian, T. R. (2019). Health risks for

sanitation service workers along a container-based urine collection system and resource recovery value chain. Environmental science & technology, 53(12), 7055–7067. https://doi.org/10.1021/acs.est.9b01092

Blackett, I., Hawkins, P., & Heymans, C. (2014). Targeting the urban poor and improving services in small towns. The missing link in sanitation service delivery: A review of faecal sludge management in 12 cities. Water and Sanitation Program Research Brief.

Blackett, I., Hawkins, P., & Smith, M. (2016). Faecal sludge management services diagnostic and decision-support tools: an overview. Work. Pap., Water Sanit. Progr., World Bank Gr., Washington, DC.

https://www.fsmtoolbox.com/assets/pdf/204.20.WSP-Faecal-Sludge-Management-Overview-Conference-Edition.pdf

Borowy, I. (2021). Human Excreta: Hazardous Waste or Valuable Resource? Shifting Views of Modernity. *Journal of World History*, *32*(3), 517–545.

Bose, D., & Dutta, A. (2024). Sanitation ladder in rural and urban India: can subsidy from the Swachh Bharat Mission ensure transition to safely managed toilets?. *Journal of Water, Sanitation and Hygiene for Development*, *14*(11), 1096–1112.

Brands, J., Rhodes-Dicker, L., Mwalugongo, W., Rosenberg, R., Stradley, L., & Auerbach, D. (2022). Improving management of manually emptied pit latrine waste in Nairobi's urban informal settlements. Waterlines, 41(1).

Cameron, L., Olivia, S., & Shah, M. (2019). Scaling up sanitation: evidence from an RCT in Indonesia. *Journal of Development Economics*, *138*, 1-16.

Centers for Disease Control (CDC), (2020). Disease Threats and Global WASH Killers: Cholera, Typhoid, and Other Waterborne Infections.

Chambers, K. G., Sheridan, P. M., & Cook, S. M. (2022). Sanitation criteria: a comprehensive review of existing sustainability and resilience evaluation criteria for sanitation systems. Environmental Science & Technology Letters, 9(7), 583-591.

Chanda, K. M., *et al*. (2021). Assessment of faecal sludge management in Lusaka, Zambia. Journal of Water, Sanitation and Hygiene for Development, 11(2), 312-321. https://doi.org/10.2166/washdev.2021.038

Chandana, N., & Rao, B. (2022). A critical review on sludge management from onsite sanitation systems: a knowledge to be revised in the current situation. Environmental Research, 203, 111812.

Chaokromthong, K., & Sintao, N. (2021). Sample size estimation using Yamane, Cochran, Krejcie and Morgan, and green formulas, and Cohen statistical power analysis by G* Power and comparisons. Apheit International Journal, 10(2), 76-86.

Chirgwin, H., Cairncross, S., Zehra, D., & Sharma Waddington, H. (2021). Interventions promoting uptake of water, sanitation and hygiene (wash) technologies in low-and middle-income countries: an evidence and gap map of effectiveness studies. *Campbell Systematic Reviews*, *17*(4), e1194. https://onlinelibrary.wiley.com/journal/18911803

Colón, J., Forbis-Stokes, A. A., & Deshusses, M. A. (2015). Anaerobic digestion of undiluted simulant human excreta for sanitation and energy recovery in less-developed countries. Energy for Sustainable Development, 29, 57–64.

Cookey, P. E., Koottatep, T., & Polprasert, C. (2022). Product/equipment manufacturing. Integrated Functional Sanitation Value Chain, 37.

Cookey, P. E., Kugedera, Z., & Alamgir, M. (2020). Perception management of non-sewered sanitation systems towards scheduled faecal sludge emptying behaviour change intervention. Humanities and Social Sciences Communications, 7(1).

Creswell, J. W., & Plano Clark, V. L. (2023). Revisiting mixed methods research designs twenty years later. Handbook of mixed methods research designs, 1(1), 21–36.

Daniel, D., Djohan, D., & Nastiti, A. (2021). Interaction of factors influencing the sustainability of water, sanitation, and hygiene (WASH) services in rural Indonesia: evidence from small surveys of WASH-related stakeholders in Indonesia. Water, 13(3), 314.

Daudey, L. (2018). The cost of urban sanitation solutions: A literature review. Journal of Water, Sanitation and Hygiene for Development, 8(2), 176–192.

DeCoster, J., & Claypool, H. (2004). Data analysis in SPSS.

Dube, M., Anciano, F., & Mdee, A. (2023). The illusion of the container-based sanitation solution: Lessons from Khayelitsha, South Africa. Water Alternatives, 16(3).

Duku, G. A., Appiah-Effah, E., Nyarko, K. B., & Dwumfour-Asare, B. (2020). Early live-prototype testing of a low-cost latrine technology for rural and peri-urban communities: The case of a modified pour-flush latrine. Scientific African, 8, e00338. https://www.sciencedirect.com/science/article/pii/S2468227620300764

Ejigu, A. K., & Yeshitela, K. (2024). Envisioning sustainable sanitation planning: A unified approach of diffusion of innovation and theory of planned behavior in predicting ecosan toilet adoption in Arba Minch, Ethiopia. Frontiers in Environmental Science, 12, 1371659. https://www.frontiersin.org/articles/10.3389/fenvs.2024.1371659/full

Endris, S., Kebede, A., Assefa, E., Ali, A., & Desale, T. (2024). Excreta flow mapping along the sanitation service chain: A case of Kombolcha town, Ethiopia. Scientific Reports, 14, 3690. https://doi.org/10.1038/s41598-024-53724-7

Etikan, I. (2019). Sampling and sampling methods. Biometrics & Biostatistics International Journal, 5(6), 00149. https://doi.org/10.15406/bbij.2019.05.00149

Forbis-Stokes, A. A., O'Meara, P. F., Mugo, W., Simiyu, G. M., & Deshusses, M. A. (2016). On-site faecal sludge treatment with the anaerobic digestion pasteurization latrine. Environmental engineering science, 33(11), 898–906.

Furlong, C. (2015). Shit Flow Diagram Report for Kisumu, Kenya. SFD Promotion Initiative and the Water, Engineering and Development Centre (WEDC), Kisumu, Kenya.

Furlong, C., Mensah, A., Donkor, E., & Scott, R. E. (2016). Learnings from implementing the excreta flow diagram (SFD) process in Kumasi.

Furlong, C., Mugendi, A., & Brdjanovic, D. (2023). Exploring the usage and impact of urban sanitation tools targeting low-and middle-income countries. Frontiers in Environmental Science, 11, 1109306. https://doi.org/10.3389/fenvs.2023.1109306

Gambrill, M., Gilsdorf, R. J., & Kotwal, N. (2020). Citywide inclusive sanitation—business as unusual: shifting the paradigm by shifting minds. Frontiers in Environmental Science, 7, 201. https://doi.org/10.3389/fenvs.2019.00201

Geng, Y., Zhu, Q., Doberstein, B., & Fujita, T. (2009). Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China. Waste Management, 29(2), 996–1002. https://doi.org/10.1016/j.wasman.2008.06.036

Girmay, A. M., Weldetinsae, A., Mengesha, S. D., Adugna, E. A., Alemu, Z. A., Wagari, B., ... & Tollera, G. (2023). Associations of WHO/UNICEF Joint Monitoring Program (JMP) Water, Sanitation and Hygiene (WASH) Service Ladder service levels and sociodemographic factors with diarrhoeal disease among children under 5 years in Bishoftu town, Ethiopia: a cross-sectional study. BMJ open, 13(7), e071296. https://bmjopen.bmj.com/content/13/7/e071296

Gituma, K. K., Gachoka, K., & Gakii, G. (2022). Tracking the Flow of Excreta Across the Sanitation Service Chain in Nkubu Town, Meru County, Kenya Using a Shit Flow Diagram. International Journal of Current Science, 12(2), 686–689.

Giusti, L. (2009). A review of waste management practices and their impact on human health. Waste management, 29(8), 2227–2239.

Grimes, J. E., Croll, D., Harrison, W. E., Utzinger, J., Freeman, M. C., & Templeton, M. R. (2015). The roles of water, sanitation, and hygiene in reducing schistosomiasis: a review. Parasites & vectors, 8(1), 1–16. https://doi.org/10.1186/s13071-015-0766-9

Hall, C., Crookston, B., West, J., Linehan, M., McGahey, C., Wendo, D., & Abdi, A. (2021). Systems Thinking and Water, Sanitation, and Hygiene: Examples from Kenya's Afya Jijini Program. Health, 13(7), 694–704. https://doi.org/10.4236/health.2021.137053

Heale, R., & Twycross, A. (2015). Validity and reliability in quantitative studies. Evidence-based nursing, 18(3), 66–67. http://dx.doi.org/10.1136/eb-2015-102129

Herrera, V. (2019). Reconciling global aspirations and local realities: Challenges facing the Sustainable Development Goals for water and sanitation. World Development, 118, 106–117. https://doi.org/10.1016/j.worlddev.2019.02.009

Hussain, F., Clasen, T., Akter, S., Bawel, V., Luby, S. P., Leontsini, E., ... & Winch, P. J. (2017). Advantages and limitations for users of double pit pour-flush latrines: a qualitative study in rural Bangladesh. BMC public health, 17(1), 1-9. https://doi.org/10.1186/s12889-017-4412-7

Hutton, G., & Chase, C. (2017). Water supply, sanitation, and hygiene. Injury Prevention and Environmental Health. 3rd edition.

Hyun, C., Burt, Z., Crider, Y., Nelson, K. L., Prasad, C. S., Rayasam, S. D., ... & Ray, I. (2019). Sanitation for low-income regions: a cross-disciplinary review. Annual Review of Environment and Resources, 44, 287–318.

Jenkins, M. W., Cumming, O., & Cairncross, S. (2014). Pit latrine emptying behavior and demand for sanitation services in Dar es Salaam, Tanzania. International Journal of Environmental Research and Public Health, 11(7), 6965–6981.

Jiménez, A., LeDeunff, H., Giné, R., Sjödin, J., Cronk, R., Murad, S., ... & Bartram, J. (2019). The enabling environment for participation in water and sanitation: A conceptual framework. Water, 11(2), 308. https://doi.org/10.3390/w11020308

JMP. (2020). Regional analysis | JMP. https://washdata.org/how-we-work/country-and-regional-engagement/regional-analysis-2021

Joint Monitoring Programme (JMP). (2021). *Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs*. World Health Organization (WHO) and United Nations Children's Fund (UNICEF). https://washdata.org/reports

Kanda, A., Ncube, E. J., & Voyi, K. (2021). Effect of sanitation interventions on health outcomes: A systematic review of cluster-randomized controlled trials in rural communities of low- and middle-income countries. International Journal of Environmental Research and Public Health, 18(16), 8313. https://www.mdpi.com/1660-4601/18/16/8313

Kapulu, M. H. (2021). Approach for scaling up citywide safely managed sanitation access and services: A study of Lusaka, Zambia—University of Leeds.

Kempster, S., & Hueso, A. (2018). Moving Up the Ladder: Assessing Sanitation Progress through a Total Service Gap, Water, doi:10.3390/w10121735.

Kenya National Bureau of Statistics (KNBS) (2019). Kenya Population and Housing Census

Kone, D., *et al*. (2022). Faecal sludge management in Dakar, Senegal: A case study. Environmental and Urbanization, 34(1), 200–217.

Kouassi, H.A.A., Andrianisa, H.A., Traoré, M.B., Sossou, S.K., Nguematio, R.M., Ymélé, S.S.S., Ahossouhe, M.S., (2023). Review of the slippage factors from open defecation-free (ODF) status towards open defecation (OD) after the Community-Led Total Sanitation (CLTS) approach implementation, International Journal of Hygiene and Environmental Health, doi: 10.1016/j.ijheh.2023.114160.

Lam, S., Nguyen-Viet, H., Tuyet-Hanh, T. T., Nguyen-Mai, H., & Harper, S. (2015). Evidence for public health risks of wastewater and excreta management practices in Southeast Asia: a scoping review. International Journal of Environmental Research and Public Health, 12(10), 12863–12885. https://doi.org/10.3390/ijerph121012863

Lansing, S., Maile-Moskowitz, A., & Eaton, A. (2017). Waste treatment and energy production from small-scale wastewater digesters. Bioresource technology, 245, 801–809. https://doi.org/10.1016/j.biortech.2017.08.215

Lantagne, D., Lehmann, L., Yates, T., Gallandat, K., Sikder, M., Domini, M., & String, G. (2021). Lessons learned from conducting six multi-country mixed-methods effectiveness research studies on water, sanitation, and hygiene (WASH) interventions in humanitarian response. BMC Public Health, 21(1), 560.

Laramee, J., Tilmans, S., & Davis, J. (2018). Costs and benefits of biogas recovery from communal anaerobic digesters treating domestic wastewater: Evidence from peri-urban Zambia. Journal of Environmental Management, 210, 23-35. https://doi.org/10.1016/j.jenvman.2017.12.064

Lerebours, A., Scott, R., Sansom, K., & Kayaga, S. (2022). Barriers and enablers to the regulation of sanitation services: a framework for emptying and transport services in Sub-Saharan African Cities. Frontiers in Environmental Science, 10, 869403.v

Li, W., Li, Y., Zhang, J., Wang, F., & Wang, B. (2023). Overview of Rural Domestic Sewage Treatment Technology. In Integrated Treatment Technology of Rural Domestic Sewage: Ten Cases of Integrated Sewage Treatment in Rural Area of China (pp. 11-49). Singapore: Springer Nature Singapore.

Malima, G., Mshida, H., Machunda, R., Moyo, F., Banzi, J., Gautam, O. P., ... & Njau, K. N. (2022). What influences individuals to invest in improved sanitation services and hygiene behaviours in a small town? A formative research study in Babati, Tanzania. PloS one, 17(7), e0270688. https://doi.org/10.1371/journal.pone.0270688

Mamera, M., van Tol, J. J., & Aghoghovwia, M. P. (2021). Potential use of biochar in pit latrines as a faecal sludge management strategy to reduce water resource contaminations: A review. Applied Sciences, 11(24), 11772.

Maqbool, N., Shahid, M. A., & Khan, S. J. (2023). Situational assessment for faecal sludge management in major cities of Pakistan. Environmental Science and Pollution Research, 30(44), 98869–98880.

Marphatia, A., Simiyu, S., Flint-O'Kane, M., Bukachi, S., Caruso, B. A., Khurana, I., ... & Ross, I. (2025). Gender equality, quality of life, and sanitation: An overview of reviews. VeriXiv, 2(82), 82. https://verixiv.org/articles/2-82

Mills, F., *et al*. (2019). Evaluating the sanitation chain in Dhaka, Bangladesh: Insights from a Shit Flow Diagram. Water and Sanitation Program.

Mills, F., Willetts, J., Evans, B., Carrard, N., & Kohlitz, J. (2020). Costs, climate and contamination: three drivers for citywide sanitation investment decisions. Frontiers in Environmental Science, 8, 130.

Motlagh, A. M., & Yang, Z. (2019). Detection and occurrence of indicator organisms and pathogens. Water environment research: a research publication of the Water Environment Federation, 91(10), 1402–1408. https://doi.org/10.1002/wer.1238

Muoghalu, C., Semiyaga, S., & Manga, M. (2023). Faecal sludge emptying in Sub-Saharan Africa, South and Southeast Asia: A systematic review of emptying technology choices, challenges, and improvement initiatives. Frontiers in Environmental Science, 11. https://doi.org/10.17615/cz3m-q728

Nakagiri, A., *et al*. (2020). Challenges in faecal sludge management in Kampala, Uganda: Insights from a Shit Flow Diagram. Water, 12(5), 1401.

Nakagiri, A., Niwagaba, C. B., Nyenje, P. M., Kulabako, R. N., Tumuhairwe, J. B., & Kansiime, F. (2015). Are pit latrines in urban areas of Sub-Saharan Africa performing? A review of usage, filling, insects, and odour nuisances. BMC Public Health, 16, 1-16. https://doi.org/10.1186/s12889-016-2772-z

Nelson, K. L., & Murray, A. (2008). Sanitation for unserved populations: technologies, implementation challenges, and opportunities. Annual Review of Environment and Resources, 33, 119–151. https://doi.org/10.1146/annurev.environ.33.022007.145142

Odjegba, E. E., Bankole, A. O., Sadiq, A., & Layi-Adigun, B. O. (2024). Water, sanitation and hygiene (WASH) index for primary healthcare facilities: Towards achieving WASH security. Heliyon, 10(5), e26470.

Oishi, W., Vinnerås, B., & Sano, D. (2023). Resource recovery technologies as microbial risk barriers: towards safe use of excreta in agriculture based on hazard analysis and critical control point. Environmental Science: Water Research & Technology, 9(4), 1008-1029.

Okaali, D. A., Bateganya, N. L., Evans, B., Ssazi, J. G., Moe, C. L., Mugambe, R. K., & Hofstra, N. (2022). Tools for a comprehensive assessment of public health risks associated with limited sanitation services provision. Environment and Planning B: Urban Analytics and City Science, 49(8), 2091-2111.

Omonei, R.K. (2019). Iten Municipality Integrated Development Plan.

Orner, K. D., & Mihelcic, J. R. (2018). A review of sanitation technologies to achieve multiple sustainable development goals that promote resource recovery. Environmental Science: Water Research & Technology, 4(1), 16–32.

Ouma, V. M.; Jackson, Muhuri (2017). Scaling-up sanitation and hygiene promotion through grant-making. Loughborough University. Conference contribution.

Palinkas, L. A., *et al*. (2016). Purposeful sampling for qualitative data collection and analysis in mixed-method implementation research. Administration and Policy in Mental Health and Mental Health Services Research, 42(5), 533–544.

Panesar, A., Walther, D., Kauter-Eby, T., Bieker, S., Rohilla, S., Dube, R., ... & Schertenleib, R. (2022). The SuSanA platform and the shit flow diagram: tools to achieve more sustainable sanitation for all. A Better World, 2018(3), 40.

Parkinson, J., *et al*. (2020). Evolution of Shit Flow Diagrams: Addressing sanitation challenges in urban areas. Waterlines, 39(1), 21–35. https://doi.org/10.3362/1756-3488.19-00001

Peal, A., Evans, B., Blackett, I., Hawkins, P., & Heymans, C. (2019). *Faecal sludge management: A comparative analysis of 12 cities*. Journal of Water, Sanitation and Hygiene for Development, 4(4), 563–575. https://doi.org/10.2166/washdev.2014.026

Peal, A., Evans, B., Ahilan, S., Ban, R., Blackett, I., Hawkins, P., ... & Veses, O. (2020). Estimating Safely Managed Sanitation in Urban Areas: Lessons Learned from A Global Implementation of Excreta-Flow Diagrams. Frontiers in Environmental Science, 8, 1. https://doi.org/10.3389/fenvs.2020.00001

Peal, A., Evans, B., Blackett, I., Hawkins, P., & Heymans, C. (2020). Estimating safely managed sanitation in urban areas: Lessons from Shit Flow Diagrams. Frontiers in Environmental Science, 8, 1. https://doi.org/10.3389/fenvs.2020.00001

Peal, A., Evans, B., Blackett, I., Hawkins, P., & Heymans, C. (2014). Faecal sludge management (FSM): analytical tools for assessing FSM in cities. Journal of Water, Sanitation and Hygiene for Development, 4(3), 371–383.

Prakash, S., Kumar, P., Dhillon, P., Unisa, S. (2022). Correlates of access to sanitation facilities and benefits received from the Swachh Bharat Mission in India: analysis of cross-sectional data from the 2018 National Sample Survey, BMJ Open, doi:10.1136/bmjopen-2021-060118.

Rombo, D. O., Lutomia, A. N., & Malinga, T. (2017). Water and Sanitation in East Africa: Perspectives from Africana Feminism. Journal of Pan African Studies, 10(5), 190–204. https://www.jpanafrican.org/docs/vol10no5/10.5-11-Rombo.pdf

Russel, K. C., Hughes, K., Roach, M., Auerbach, D., & Peletz, R. (2019). Taking container-based sanitation to scale: Opportunities and challenges. Frontiers in Environmental Science, 7, 190. https://doi.org/10.3389/fenvs.2019.00190

Russel, K. C., Hughes, K., Roach, M., Auerbach, D., Foote, A., Kramer, S., & Briceño, R. (2019). Taking container-based sanitation to scale: opportunities and challenges. Frontiers in Environmental Science, 7, 190.

Sakas, Z., Uwah, E. A., Bhattrai, R. K., Garn, J. V., Gc, K. H., Mutta, A., ... & Freeman, M. C. (2022). Assessing sustainability factors for rural household sanitation coverage in Bhutan, Kenya, Nepal, and Zambia: a qualitative analysis. Global Health: Science and Practice, 10(6).https://www.ghspjournal.org/content/10/6/e2100724

Saleem, M., Burdett, T., & Heaslip, V. (2019). Health and social impacts of open defecation on women: a systematic review. BMC Public Health, 19(1), 158.

Sangsanont, J., Rattanakul, S., Kongprajug, A., Chyerochana, N., Sresung, M., Sriporatana, N., ... & Sirikanchana, K. (2022). SARS-CoV-2 RNA surveillance in large to small centralized wastewater treatment plants preceding the third COVID-19 resurgence in Bangkok, Thailand. Science of the Total Environment, 809, 151169.

Scott, P., Cotton, A.P., 2020, The Sanitation Cityscape –Toward a Conceptual Framework for Integrated and Citywide Urban Sanitation, Frontiers in Environmental Science, doi:10.3389/fenvs. 2020.00070.

Scott, R. E., Ross, I., Hawkins, P., Blackett, I., & Smith, M. D. (2019). Diagnostics for assessing city-wide sanitation services. Journal of Water, Sanitation and Hygiene for Development, 9(1), 111–118.

Scott, R. E., Ross, I., Hawkins, P., Blackett, I., & Smith, M. D. (2019). Diagnostics for assessing city-wide sanitation services. Journal of Water, Sanitation and Hygiene for Development, 9(1), 111–118. https://doi.org/10.2166/washdev.2018.113

SFD-PI (2018a). SFD Manual, Volumes 1 and 2, Version 2.0. Available online

SFD-PI. (2018b). SFD Manual -Volume 1 and 2.

SFD-PI. (2018c). SFD Manual Volume 1 and 2. https://sfd.susana.org/news-events/news/96-sfd-manual-volume-1-and-2-version-2-0

Simiyu, S. (2017). Preference for and characteristics of an appropriate sanitation technology for the slums of Kisumu, Kenya. International Journal of Urban Sustainable Development, 9(1), 1–15. https://doi.org/10.1080/19463138.2017.1325366

Simiyu, S. (2017). Preference for and characteristics of an appropriate sanitation technology for the slums of Kisumu, Kenya. International journal of urban sustainable development, 9(3), 300-312. https://doi.org/10.1080/19463138.2017.1325366

Simiyu, S., Swilling, M., Cairncross, S., & Rheingans, R. (2019). Determinants of quality of shared sanitation facilities in informal settlements: Case study of Kisumu, Kenya. BMC Public Health, 19, 424. https://doi.org/10.1186/s12889-019-6754-3

Singh, S., Ibrahim, M. A., Pawar, S., & Brdjanovic, D. (2022). Public perceptions of reuse of faecal sludge co-compost in Bhubaneswar, India. Sustainability, 14(8), 4489.

Sisay, S. F., Gari, S. R., & Ambelu, A. (2024). Faecal sludge management and sanitation safety: An assessment in Addis Ababa, Ethiopia. Environmental Health Insights. https://doi.org/10.1177/11786302241267187

Spuhler, D., Germann, V., Kassa, K., Ketema, A. A., Sherpa, A. M., Sherpa, M. G., ... & Langergraber, G. (2020). Developing sanitation planning options: A tool for systematic consideration of novel technologies and systems. Journal of Environmental Management, 271, 111004. https://doi.org/10.1016/j.jenvman.2020.111004

Still, D., & Louton, B. (2012). Piloting and Testing the Pour-flush Latrine Technology for Its Applicability in South Africa. WRC Report.

Strande, L., Englund, M., & Andriessen, N. (2021). Estimating quantities and qualities (Q&Q) of faecal sludge at community to citywide scales. In Methods for Faecal Sludge Management (Ch. 5). EAWAG.

Sustainable Sanitation Alliance (SuSanA). (2020). Shit Flow Diagram - Improving Understanding of Urban Sanitation - SFD.

Tasnim, G., Khan, M. D., Farooqi, I. H., & Basheer, F. (2023). Sources, Characteristics, Treatment Technologies and Disposal Methods for Faecal Sludge. In Management of Wastewater and Sludge (pp. 297–337). CRC Press.

Thye, Y. P., Templeton, M. R., & Ali, M. (2011). A critical review of technologies for pit latrine emptying in developing countries. Critical reviews in environmental science and technology, 41(20), 1793-1819. https://doi.org/10.1080/10643389.2010.481593

Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrügg, C. (2014). Compendium of sanitation systems and technologies.

Tilmans, S., Russel, K., Sklar, R., Page, L., Kramer, S., & Davis, J. (2015). Container-based sanitation: assessing costs and effectiveness of excreta management in Cap Haitien, Haiti. Environment and urbanization, 27(1), 89-104.

Tomoi, S., Ito, N., & Chigusa, H. (2024). Determinants of Willingness to Pay for Faecal Sludge Management Services and Knowledge Gaps: A Scoping Review. Environmental Science & Technology. https://doi.org/10.1021/acs.est.3c06628

Trinanda, N. G. (2018). The Shit Flow Diagram in Indonesia – Cities' Instrument Toward Universal Access to Sanitation. SuSanA.

Twinomucunguzi, F. R., Nyenje, P. M., Kulabako, R. N., Semiyaga, S., Foppen, J. W., & Kansiime, F. (2020). Reducing groundwater contamination from on-site sanitation in peri-urban Sub-Saharan Africa: Reviewing transition management attributes towards implementation of water safety plans. Sustainability, 12(10), 4210.

United Nations (UN). (2021). *Resolution adopted by the General Assembly on the human rights to safe drinking water and sanitation* (A/RES/75/212). United Nations. https://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/75/212
Accessed on August 23, 2024.

United Nations High Commissioner for Refugees (UNHCR). (2018). *UNHCR WASH Manual – Raised Pit Latrines*. UNHCR. https://www.unhcr.org/washer-manual/raised-pit-latrines
Accessed on August 23, 2024.

UNICEF & World Health Organization (WHO). (2020). *Billions of people will lack access to safe water, sanitation, and hygiene in 2030 unless progress quadruples – warn WHO and UNICEF*. World Health Organization. https://www.who.int/news/item/01-07-2021-billions-of-people-will-lack-access-to-safe-water-sanitation-and-hygiene-in-2030-unless-progress-quadruples-warn-who-unicef
Accessed on August 23, 2024.

UNICEF. (2019). *Sanitation | UNICEF*. UNICEF. https://www.unicef.org/wash/sanitation
Accessed on August 23, 2024.

UNICEF, & World Health Organization (WHO). (2020). *Progress on Household Drinking Water, Sanitation and Hygiene 2000–2020*. UNICEF/WHO. https://washdata.org
Accessed on August 23, 2024.

United Nations (UN). (2021). *Summary progress update 2021: SDG 6 – Water and sanitation for all*. United Nations. https://www.unwater.org/publications/summary-progress-update-2021-sdg-6-water-and-sanitation-all
Accessed on August 23, 2024.

United Nations Children's Fund [UNICEF] & World Health Organization [WHO]. (2020). Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs. https://washdata.org

Van Welie, M. J., Truffer, B., & Yap, X. S. (2019). Towards sustainable urban basic services in low-income countries: A Technological Innovation System analysis of sanitation value chains in Nairobi. Environmental Innovation and Societal Transitions, 33, 196–214. https://doi.org/10.1016/j.eist.2019.06.002

VanRiper, F. R. (2021). The viability of container-based sanitation as a tool for sanitation coverage in urban Haiti (Master's thesis, Oregon State University). Oregon State University Libraries.

VanRiper, F., Russel, K. C., Tillias, D., Tilt, J., & Laporte, J. (2022). Container-based sanitation in urban Haiti: how can it improve human rights as a component of citywide inclusive sanitation?. H2Open Journal, 5(1), 135–152.

Varma, V. C., Rathinam, R., Suresh, V., Naveen, S., Satishkumar, P., Abdulrahman, I. S., ... & Kumar, J. A. (2023). Urban waste water management paradigm evolution: Decentralization, resource recovery, and water reclamation and reuse. Environmental Quality Management. https://doi.org/10.1002/tqem.22109

Vidal, B., Hedström, A., Barraud, S., Kärrman, E., & Herrmann, I. (2019). Assessing the sustainability of on-site sanitation systems using multi-criteria analysis. Environmental Science: Water Research & Technology, 5(9), 1599-1615.

Ward, B. J. (2022). Settling and Dewatering of Faecal Sludge: Building Fundamental Knowledge for Improved Global Sanitation (Doctoral dissertation, ETH Zurich).

Ward, B. J., Andriessen, N., Tembo, J. M., Kabika, J., Grau, M., Scheidegger, A., ... & Strande, L. (2021). Predictive models using "cheap and easy" field measurements: Can they fill a gap in planning, monitoring, and implementing faecal sludge management solutions? Water Research, 196, 116997.

WASREB (2008) Guidelines on Drinking Water Quality & Effluent Monitoring. Water Services Regulatory Board, Nairobi.

Welling, C. M., Varigala, S., Krishnaswamy, S., Raj, A., Lynch, B., Piascik, J. R., ... & Grego, S. (2020). Resolving the relative contributions of cistern and pour flushing to toilet water usage: Measurements from urban test sites in India. Science of the Total Environment, 730, 138957.

Weststrate, J., Dijkstra, G., Eshuis, J., Gianoli, A., & Rusca, M. (2019). The sustainable development goal on water and sanitation: learning from the millennium development goals. Social Indicators Research, 143, 795-810. https://doi.org/10.1007/s11205-018-1965-5

WHO (1997) Guidelines for Drinking-Water Quality Volume 3 Surveillance and Control of Community Supplies. Guidelines for Drinking-Water Quality II WHO Library Cataloguing in Publication Data. 2nd Edition, World Health Organization, Geneva, 1-250.

World Health Organization (WHO). (2020). *Sanitation key facts*. World Health Organization.https://www.who.int/news-room/fact-sheets/detail/sanitation Accessed on August 23, 2024.

Willie, M. M. (2023). Distinguishing between population and target population: A mini review. Article in surgery journal, 7.

World Bank. (2019). Providing Sustainable Sanitation and Water services to Low-income Communities in Nairobi. https://www.worldbank.org/

World Health Organization/United Nations Children's Fund, 2023, Integrated Functional Sanitation Value Chain, IWA Publishing eBooks, doi:10.2166/9781789061840

Younas, A., Fàbregues, S., & Creswell, J. W. (2023). Generating metainferences in mixed methods research: A worked example in convergent mixed methods designs. Methodological Innovations, 16(3), 276–291.

Zaghloul, M. S., Hamze, A., Kakar, F. L., Hamza, R. A., & Elbeshbishy, E. (2024; pp. 195–210). Decentralized sanitation implementation in different countries. In Decentralized Sanitation and Water Treatment (pp. 190–202). CRC Press.

Zhang, Z., Malik, M. Z., Khan, A., Ali, N., Malik, S., & Bilal, M. (2022). Environmental impacts of hazardous waste, and management strategies to reconcile circular economy and eco-sustainability. Science of The Total Environment, 807, 150856. https://doi.org/10.1016/j.scitotenv.2021.150856

Zimmerman, J., Sheridan, C., Cumming, O., Elliott, M., 2022, Every rung counts–A retrospective analysis of global sanitation progress across the servicelevel ladder under the MDGs, PLOS Water, doi: 10.1371/journal.pwat.0000002.

APPENDICES

Appendix A : Publication

Volume 10, Issue 7, July – 2025 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/25jul043

Assessment of Health Risk Associated with Sanitation System: A case Study of Iten Municipality, Elgeiyo-Marakwet, Kenya

Cynthia Jelagat Kiprop[1*]; Dr. Jane Jemeli Rutto[2];
Dr. Dorothy Kagendo Kithinji[3]; Aron Kipngeno[4]

[1]Meru University of Science and Technology,
Department of Civil and Environmental Engineering, P.O. BOX 972-60200 Meru, Kenya.
[2,4]Meru University of Science and Technology,
Department of Public Health P.O. BOX 972-60200 Meru, Kenya
[3]Chuka University,
Department of Nursing and Public Health, P.O. Box 109 - 60400, Chuka, Kenya

Corresponding Author: Cynthia Jelagat Kiprop[1*]

Publication Date: 2025/07/11

Abstract: Sustainable Development Goal (SDGS) advocates for access to adequate sanitation and safe water, which are essential for public health. However, deficiencies in sanitation infrastructure remain a significant concern in many urban areas. The study examined the health risks associated with the existing sanitation service chain in Iten Municipality, Elgeiyo-Marakwet County, Kenya. A mixed-methods research design was employed to obtain quantitative data using structured questionnaires, water sampling forms, and qualitative data using interview guides. Purposive, Cluster, and proportionate simple random sampling were employed to identify 388 household heads, four community water points, and informants. Quantitative data was analyzed using Statistical Package for Social Sciences (SPSS) version 27 using descriptive statistics techniques and Pearson's R correlation, while qualitative data was analyzed through categorization into various themes. The findings revealed that only 69% of excreta was safely managed. Significant correlations were identified between inadequate waste management and sanitation-related illnesses ($r = 0.30$, $p = 0.03$), waterborne diseases ($r = 0.33$, $p = 0.014$), and contamination of water sources ($r = -0.13$, $p < 0.003$). Water quality testing showed that all sampled sources were contaminated with coliforms and *E. coli*. surpassing the World Health Organization (WHO) safety limits of zero *E. coli* and total coliforms per 100 mL. Qualitative data highlighted that inadequate waste collection and unsafe disposal practices were key drivers of disease spread. Informants pointed out that pest infestations, such as rodents and flies, and persistent odors from poorly maintained sanitation facilities, significantly exacerbated health risks. In conclusion, the study underscores the urgent need for improved sanitation infrastructure and management, as deficiencies contribute to significant public health risks, including sanitation-related illnesses, water contamination, and environmental hazards.The study recommends that sanitation stakeholders, such as the county government, improve sanitation infrastructure, implement routine water quality testing, and strengthen behaviour change communication campaigns on handwashing and sanitation.

Keywords: *Health Risk, Sanitation System, Sustainable Development Goals, Public Health.*

How to Cite: Cynthia Jelagat Kiprop; Dr. Jane Jemeli Rutto; Dr. Dorothy Kagendo Kithinji; Aron Kipngeno (2025) Assessment of Health Risk Associated with Sanitation System: A case Study of Iten Municipality, Elgeiyo-Marakwet, Kenya. *International Journal of Innovative Science and Research Technology*, 10(7), 405-414. https://doi.org/10.38124/ijisrt/25jul043

I. INTRODUCTION

Sanitation is globally recognized as a fundamental human right and a critical pillar for ensuring public health, environmental sustainability, and socio-economic advancement (World Health Organization [WHO], 2020; United Nations [UN], 2015). Access to safely managed sanitation facilities reduces exposure to fecal pathogens and prevents the transmission of numerous infectious diseases, which remain a leading cause of morbidity and mortality worldwide (UNICEF & WHO, 2021). Despite international progress, substantial sanitation challenges persist, particularly in urban areas of low- and middle-income countries (LMICs), driven by rapid urbanization, inadequate

Appendix B : Informed Consent

INFORMED CONSENT FORM FOR PARTICIPATION IN RESEARCH

Study Title: Evaluating Human Excreta Management and Sanitation Services Using a Shit Flow Diagram at Iten Municipality, Elgeyo Marakwet

Investigator: Cynthia J. Kiprop, 0724073885/cynthiakip99@gmail.com

Introduction: You are being invited to participate in a research study about sanitation services in Iten Municipality. Before deciding whether to participate, it is essential to understand the purpose of the research and what it entails. Please take the time to read the following information carefully.

Purpose of the Study: This study aims to assess the current practices and challenges related to human excreta management and to evaluate the effectiveness of existing sanitation infrastructure using a Shit Flow Diagram Analysis. The results will help in planning and implementing more effective sanitation services in the community.

What Will Happen: If you agree to participate in this study, you will be asked to complete a questionnaire about your sanitation practices, the types of facilities you use, and possible health risks associated with sanitations service chain. The questionnaire will take approximately 30 minutes to complete.

Voluntary Participation: Your participation in this study is entirely voluntary. It is up to you to decide whether or not to take part in this study. If you decide to take part, you are free to withdraw at any time without giving a reason and without any consequences.

Confidentiality: Your responses will be confidential. Data will be summarized and reported in aggregates. Personal information that could identify you will not be used in any reports or publications.

Benefits and Risks: There are no direct benefits or significant risks to you participating in this study. However, your responses may help improve local sanitation services and contribute to better public health outcomes in the community.

Consent: By completing and returning the questionnaire, you are consenting to the use of your responses in the study. If you have any inquiries regarding the research study, please do not hesitate to ask now or contact the investigator using the contact details provided earlier.

Do you agree to participate in this survey

Sign ………………. or oral consent (yes).

Appendix C : Household Survey

Tick in the box or fill in where appropriate.

SECTION A: HOUSEHOLD INFORMATION

1. Household Location:
2. Gender of the Respondent
   a) Male
   b) Female
3. This housing unit is in which sub-location?

a) Bugar…………
b) Singore……….
c) Kapkonga…………
d) Mindililiwo………….
e) Iten Township……………….
f) Chebokokwo ………………….
g) Kapkessum………………….
h) Sergoit……………………….
i) Kiplamai…………………….
j) Kiptabus………………….
k) Katalel………………….
l) Chesitek………………
m) Rimoi………………….
n) Anin………………….
o) KESSUP………………….

4. Total number of household members:

a) How many individuals are less than 1-year-old?.................
b) How many individuals are between 1-5 years old?................
c) How many individuals are between 6-15 years old?...............
d) How many individuals are between 16-50 years old?.............
e) How many individuals are above 50 years old?................

5. Type of housing:
   a) Single-family house ………………….

b) Apartment ……………………

c) Semi-detached house………………

d) Townhouse ……….

e) Other (please specify): __________

6. Is this house/residence owned, rented, rent-free, or mortgaged by a household member?

a) Owned……………….

b) Rented……………….

c) Rent Free…………….

d) Mortgaged…………………

e) Others, Specify………………….

7. Duration of residence in Iten Municipality (in Years): -------------------

SECTION B: UTILIZATION OF SANITATION AND WATER STRUCTURES

8. Does your household have access to a reliable and safe water source?

a) Yes………….

b) No………….

c) Not sure………….

If yes, please specify the type of water source:

a) Piped water (municipal supply) …………….

b) Borehole ………………….

c) Well……………….

d) Rainwater harvesting………………

e) Other (please specify): __________

9. Do you treat the water before consuming it?

a) Yes, through boiling ……….

b) Yes, through filtration………….

c) Yes, through chemical disinfection……………….

d) No, we consume it without treatment…………………

e) Not applicable (no access to water) ……………….

10. Type of sanitation technology used in your household (select all that apply):

a) Flush toilet connected to a sewer system………….

b) Flush toilet connected to a septic tank…………….
c) Pit latrine…………….
d) Flush toilet connected to Anaerobic Digesters……………….
e) Other (specify): __________

11. How frequently is your sanitation facility emptied or maintained?

a) Weekly………………
b) Monthly……………….
c) Every few months………….
d) Annually……………….
e) Other (please specify): __________

12. How are the stools of children less than three years usually disposed of?

a) Child used toilet/latrine………………….
b) Put/rinsed into toilet or latrine…………….
c) Put/rinsed into drain or ditch……………….
d) Thrown into garbage………………
e) Buried……………….
f) Left in the open……………….
g) Others, Specify……………….
h) No child under 3………….
i) Don't know……………….

13.Is there latrine within 15m of the well and handpump?

a) Yes……………….

b) No………………

14. Is there a latrine on higher ground than the handpump?

a) Yes ……………

b) No……………...

15. Are there any animal excreta or rubbish within 15m of the handpump?

a) Yes…………………

b) No………………...

SECTION C: EMPTYING

16. If the toilet empties to a pit or septic tank, has it ever filled up? a.

   a) Yes………….
   b) No ………….
   c) Don't know……………

17. In the last 5 years, how many times has it filled up?

a) Once………….
b) Twice……………
c) Three times…………
d) Four times………….
e) Five times……………
f) More than five times………….
g) Never filled up……………
h) Not applicable - my household does not use a septic tank…………
i) I don't know/unsure…………….

18. Has the toilet ever overflowed?

   a) Yes………….
   b) No…………
   c) Don't know…………

19. If yes, what was the reason for this? (Tick all that apply)

   a) Blocked……….
   b) Flooded with rising water table (from below ground) ………….
   c) Flooded by surface water/storm water (from above ground) ……………
   d) No money to empty…………….
   e) Emptier not available when needed………….
   f) Don't know……………
   g) Other (Please Specify) ……………

20. What did you do when the pit or septic tank filled up last time?

   a) Emptied and reused pit/tank………….
   b) Abandoned and pit/tank unsealed ……………
   c) Abandoned with a sealed cover on pit/tank………….

d) Covered and used an alternative pit…………

21. On average, how many years does it take for an emptied pit latrine/septic to be full again?
    a) 1-3 years………….
    b) 4-5 years………….
    c) More than five years………….
    d) Not applicable - my household does not use a toilet with a tank………….
    e) Don't know/Unsure………………
22. Next time the toilet fills up, what do you intend to do?
    a) Empty by a member of the household…………
    b) Empty by a private individual or company………….
    c) Cover and seal pit…………
    d) Abandon toilet without covering/seal……………….
23. Last time it was emptied, who did the emptying?
    a) Member of the household………….
    b) Neighbor…………
    c) Informal provider (individual)………….
    d) Formal provider (company / NGO) …………….
    e) Formal provider (utility)……………….

24. How was it emptied?
    a) By hand, using buckets or similar……….
    b) By hand, using a manual pump…………...
    c) Mechanically, using a small machine………….
    d) Mechanically, using a tanker truck…………
25. What was it emptied into?
    a) Directly into a drain/water body/field…………
    b) Into a pit on the compound that is then covered………….
    c) Into a pit on the compound that is then left open …………….
    d) Directly into a drum/open container…………….

e) Directly into a machine/tanker………….

26. Did you pay for the pit to be emptied?

a) Yes……………

b) No………….

c) Don't know………….

27. How was the payment calculated?

a) Flat rate……….

b) Cost per volume removed………….

c) Don't know……….

28. Did you pay in installments?

a) No, paid in the full amount………….

b) Yes, two…………

c) Yes, three………….

d) Yes, more than three………….

29. Was this a fair price?

a) Too high……….

b) About fair……….

c) Quite cheap……….

30. Did the emptier face difficulties in getting their equipment to your toilet

a) Yes……….

b) No………….

c) Don't know…………

31. What difficulties did they face? (Tick all that apply)

a) Lack of space………….

b) Poor road conditions…………

c) Night-time working………….

d) Unstable soil condition………….

e) High water table…………….

f) Others (please specify): ___________

SECTION D: PERFORMANCE EVALUATION

32. How satisfied are you with the overall performance of your current sanitation technology?
    a) Very satisfied………….
    b) Satisfied………….
    c) Neutral…………….
    d) Dissatisfied……………
    e) Very dissatisfied………….
33. How often does your current sanitation technology experience issues or problems? (e.g., blockages, malfunctions, odours)
    a) Rarely………….
    b) Occasionally………….
    c) Frequently…………
    d) Very frequently………….
34. If you face issues with your sanitation technology, how quickly are they resolved?
    a) Immediately……….
    b) Within a few days……….
    c) Within a week…………
    d) Longer than a week………….
    e) Issues are not resolved…………….
35. How would you rate the reliability of your current sanitation technology?

a) Highly reliable…………….
b) Somewhat reliable………….
c) Not very reliable………….
d) Unreliable……………

36. Are you able to maintain and repair your sanitation technology on your own?

a) Yes, easily………….
b) Yes, with some difficulty………….
c) No, need assistance from others………….
d) No, unable to maintain or repair………….

37. How frequently do you perform maintenance or repairs on your sanitation technology?

a) Regularly (e.g., monthly or more often) ……….
b) Occasionally (e.g., every few months) ……….
c) Rarely (e.g., once a year or less) ……….
d) Never…………….

38. Have you received any training or guidance on using and maintaining your sanitation technology properly?
a) Yes………….
b) No…………….

39. How would you rate the cleanliness and hygiene level of your sanitation technology?
a) Very clean and hygienic…………….
b) Somewhat clean and hygienic………….
c) Not very clean and hygienic……………
d) Unclean and unhygienic………….

40. Does your current sanitation technology effectively control odours?
a) Yes, completely………….
b) Yes, to some extent…………
c) No, not at all………………

41. How satisfied are you with the privacy provided by your current sanitation technology?
a) Very satisfied……………….
b) Satisfied………………….
c) Neutral………….
d) Dissatisfied…………….
e) Very dissatisfied……………

42. Do you feel that your current sanitation technology adequately protects your dignity and ensures safety?
a) Yes, completely………….
b) Yes, to some extent………….
c) No, not at all………….

SECTION E: POTENTIAL HEALTH RISKS ASSOCIATED WITH THE CURRENT SANITATION SERVICE CHAIN

43. Have you or any household member experienced any sanitation-related health issues in the past year?
    a) Yes…………
    b) No………….

If yes, please specify the type of health issues experienced (e.g., gastrointestinal, respiratory, skin infections) ………………

44. How often do you or your household members wash hands with soap or hand sanitizer after using the toilet?
    a) Always………….
    b) Most of the time………….
    c) Occasionally……………
    d) Rarely ……………….
    e) Never………………
45. Are there any water-related diseases prevalent in your area? (e.g., cholera, amoeba dysentery)
    a) Yes………….
    b) No………….
    c) Not sure…………
46. Do you believe there is a link between poor sanitation and the spread of diseases in the area?
    a) Yes, strongly believe…………….
    b) Yes, somewhat believe ………………
    c) Not sure……………
    d) No, do not believe………….
47. Have you noticed any pests or insects around your sanitation facilities?
    a) Yes, frequently………….
    b) Yes, occasionally……………
    c) No…………….
48. Have you observed any unpleasant odours near your sanitation facilities?

a) Yes, frequently……….
b) Yes, occasionally………….
c) No………….

49. How would you rate the cleanliness of the surrounding environment near your sanitation facilities?
    a) Very clean………….
    b) Clean………….
    c) Moderately clean………….
    d) Unclean………….
    e) Very unclean…………

50. Do you feel that the current sanitation service chain adequately addresses waste management and disposal?

a) Yes, completely……….
b) Yes, to some extent…………
c) No, not at all……….

51. Are you aware of any contamination of water sources in your area due to improper sanitation practices?
    a) Yes……….
    b) No………….
    c) Not sure…………

52. Do you believe there is a need for improved sanitation infrastructure in your community?
    a) Yes, strongly believe………….
    b) Yes, somewhat believe………….
    c) Not sure………………
    d) No, do not believe………….

53. Have you received any health education or awareness programs related to proper sanitation practices?
    a) Yes…………
    b) No………….

If yes, what was it about (Specify)……………….

54. How often do you seek medical treatment for sanitation-related health issues?

a) Regularly…………

b) Occasionally………….

c) Rarely………….

d) Never…………

55. At home, where do you dispose of wastewater from kitchen, bathing, and/or laundry?

a) Piped sewer system…………

b) Fully-lined septic tank with soakaway……….

c) Fully-lined septic tank with overflow to drain/open ground/other………….

d) Partially- lined septic tank, Fully-lined pit……………

e) Pit with unlined bottom or sides…………….

f) Directly to open drain/ditch………….

g) Directly to the lake or river………….

h) Directly to open ground………….

i) Don't know…………

j) Others, Specify……………

Appendix D : Key Informant Interviews Guide

My name is Cynthia Jelagat Kiprop, and I am a master's student at Meru University of Science and Technology. I am currently researching human excreta management along the sanitation service chain in Iten Municipality, Elgeyo Marakwet County, to develop a sanitation advocacy tool referred to as the Shit Flow Diagram for the area. I would like to express my sincere gratitude for your agreeing to participate in this study as a key informant. This research aims to gain a comprehensive understanding of the sanitation practices and technologies employed in the Iten municipality and assess their performance, as well as the potential health risks associated with them. Your valuable insights and expertise will significantly contribute to achieving these objectives and generating meaningful findings.

Before we proceed with the Key informant interview, I would like to provide some important information regarding your participation in this study. First and foremost, your involvement in this research is entirely voluntary, and you have the right to withdraw at any time without facing any consequences or negative repercussions. Furthermore, all information disclosed during the interview will be kept confidential, and any data gathered will be used exclusively for academic research purposes, presented in aggregated and anonymized form. It is important to note that your participation in this study will be recorded through audio recording or note-taking, ensuring accurate documentation of the information provided. However, the recorded data will be kept strictly confidential and will only be accessible to the research team.

Lastly, I assure you that your privacy and anonymity will be respected throughout the research process. Personal identifying information will be handled with the utmost care, and your name or any other identifying details will not be disclosed in any publications or reports from this study. Once again, I am grateful for your willingness to participate in this research. Your valuable insights will contribute to advancing knowledge in the field of sanitation and ultimately aid in improving sanitation practices in Iten Municipality. If you have any questions or concerns, please don't hesitate to discuss them with me before we proceed.

Thank you for your time and cooperation.

To begin with, could you please introduce yourself? Stating your name, your title, and your organization

Emptying Services:

1. Can you provide insights into the customer base for on-site sanitation technologies in this area?
2. How often do people typically have their on-site sanitation technologies emptied?
3. What is the typical volume or percentage of faecal sludge emptying each time?

Transportation:

4. What types of vehicles are commonly used to transport faecal sludge from on-site sanitation technologies?
5. Could you provide an inventory of service providers involved in manual and motorized transportation?
6. How many vehicles are typically employed for this transportation purpose?

Treatment:

7. Can you share data on the quantities of wastewater or faecal sludge received for treatment from Iten Municipality?
8. What are the capacities, types, and conditions of the facilities used for treating wastewater and faecal sludge?
9. Are there any specific measurement tools such as pump readings, flow meters, or volume gauges used to monitor these quantities?

End-use/Reuse:

10. How much faecal sludge, wastewater, treated faecal sludge, or sewage sludge is received at each location for potential reuse?
11. Can you elaborate on the quantities of faecal sludge that are reused, including the methods and management processes involved?

Disposal:

12. What quantities of wastewater and faecal sludge are typically disposed of at final disposal site?
13. Are there specific disposal methods or locations designated for wastewater and faecal sludge disposal?
14. What percentage of the population within the municipality are practicing open defecation?

Appendix E : **Observational Checklist**

1. Collection Stage:
    a) Are the collection points easily accessible and properly maintained?
    b) Is the collection system adequately designed and functional?
    c) Is there proper segregation of different waste streams (e.g., faecal sludge, solid waste)?...................
    d) Are there any visible signs of leakage or spillage during collection?..........
    e) Are the collection vehicles in good condition and equipped for safe transportation?.............
2. Transportation Stage:
    a) Are the transportation routes well-planned and efficient?
    b) Is the transportation equipment (e.g., vacuum trucks) in good working condition?
    c) Are there any safety measures in place for the transport of human excreta?
    d) Is there any evidence of odour or spillage during transportation?
    e) Are there proper handling and containment measures to prevent environmental contamination?
3. Treatment Stage:

a) Are the treatment facilities properly operated and maintained?
b) Is the treatment technology appropriate for the type and volume of waste?
c) Are there any indicators of the treatment system's performance (e.g., treatment levels, effluent quality)?
d) Is there any evidence of regular maintenance and cleaning of treatment equipment?
e) Are there any visible signs of malfunction or inadequate treatment?

4. Disposal/Reuse Stage:

a) Is there a proper system in place for the disposal or reuse of treated or untreated waste?
b) Is the disposal site or reuse area properly managed to prevent environmental contamination?
c) Are there any guidelines or regulations followed for safe disposal or reuse?
d) Are there any potential health risks associated with the disposal or reuse practices?

e) Are there any measures taken to monitor and control the potential impacts on public health and the environment?

5. Observe any evidence of open defecation

Appendix F : Transect Walk Guide

1. Location Details:
    - Date:
    - Time:
    - Weather conditions:
    - Starting and ending points of the transect walk.
2. Sanitation Technologies:
    - Identify the main types of sanitation technologies being used in the area (e.g., flush toilets, pit latrines, composting toilets).
    - Note the distribution and density of each technology along the transect.
3. Collection and Storage:
    - Observe how human excreta is collected and stored at different stages of the sanitation service chain (e.g., household level, communal facilities, treatment plants).
    - Note the condition and cleanliness of collection and storage facilities.
4. Transportation and Disposal:
    - Document the methods of transportation and disposal of human excreta.
    - Identify the routes taken and the destination points (e.g., treatment facilities, dumping sites).
    - Note any visible signs of leakage or spillage during transportation.
5. Hygiene Practices:
    - Assess the availability and accessibility of handwashing facilities along the transect.
    - Observe the hygiene practices of individuals using sanitation facilities (e.g., handwashing, waste disposal).
6. Health Risks:
    - Identify potential health risks associated with the current sanitation system (e.g., exposure to pathogens, contamination of water sources).
    - Note any visible signs of environmental pollution or health hazards.
    - Note the proximity of sanitation systems neat water bodies
7. Environmental Factors:

- Observe the environmental impact of the sanitation system (e.g., contamination of water bodies, pollution, odour).
- Note any visible signs of vectors or pests in the vicinity of sanitation facilities.

8. Drainage and Sewerage Systems:
    - Assess the condition and functionality of drainage systems.
    - Observe if there are any signs of blockages or stagnant water.
    - Note the presence of open drains and their cleanliness.
9. Infrastructure and Maintenance:
    - Assess the physical condition and functionality of sanitation infrastructure (e.g., condition of toilets, presence of maintenance activities).
    - Note any signs of damage, poor maintenance, or lack of infrastructure.
10. Conclusion:
    - Summarize your overall observations and key findings from the transect walk.
    - Identify any immediate concerns or areas that require further investigation.

Appendix G : ELDOWAS Laboratory Results Sheets for Water Samples Analysis

F-1: Rorget Spring

TEST REPORT

P.o Box 8418-30100,
Eldoret, Kenya
Tel no. 0532063403,
Cell: 0724255538
Along Kampi Somali rd
email- info@eldowas.or.ke

ELDOWAS

ELDORET WATER AND SANITATION COMPANY

CENTRAL WATER TESTING LABORATORY

LABORATORY WATER ANALYSIS REPORT

Client : Ms. Cynthia Jelagat Kiprop			**Reference No :**1914-23/24		**Sampling date :** 03/04/2024
Site Location : Iten Municipality-Elgeyo Marakwet County			**Sample Source** : Rorget Spring-Iten Municipality		**Receipt date:** 04/04/2024
Submitted by: Ms. Cynthia Jelagat Kiprop			**Sample description:** Not *treated*		**Date of analysis :** 04/04/2024
Key:	**Pass**	**Fail**	**NS** - No Standard	**ND** - Not Detected	**TNTC** - Too Numerous to count

TEST RESULTS

Parameters	Method of Analysis	Units	Values	KS EAS:12:2018 Standard for natural drinking water	Remarks
Total Coliforms	ISO 9308-1	CFU/100 ml	TNTC	Not Detectable	
E-Coli	ISO 9308-1	CFU/100 ml	30	Not Detectable	

Comments: *The results of the tested water sample are as shown above.*

Disclaimer: *The results relate only to the sample(s) submitted. The laboratory will not be held responsible for any sampling errors.*

Prepared by : *P. Kimaiyo- QAO*		**Approved by :** *Edwin Mengich-QAM*	
SIGN:	**Date:** 05-04-2024	**SIGN:**	**Date:** 5/4/2024

ELDORET WATER & SANITATION CO. LTD
(ELDOWAS)
05 APR 2024
P. O. Box 8418, ELDORET-30100

nema

KENAS

The laboratory is registered by NEMA and is Accredited to ISO/IEC 17025:2017

- END-

F-2: KIPSENENDE RIVER

TEST REPORT

P.o Box 8418-30100,
Eldoret, Kenya
Tel no. 0532063403,
Cell: 0724255538
Along Kampi Somali rd
email- info@eldowas.or.ke

ELDOWAS

CENTRAL WATER TESTING LABORATORY

LABORATORY WATER ANALYSIS REPORT

Client : Ms. Cynthia Jelagat Kiprop	**Reference No :**1913-23/24	**Sampling date :** 03/04/2024
Site Location : Iten Municipality-Elgeyo Marakwet County	**Sample Source** : Kipsinende River-Iten Municipality	**Receipt date:** 04/04/2024
Submitted by: Ms. Cynthia Jelagat Kiprop	**Sample description:** Not *treated*	**Date of analysis :** 04/04/2024
Key: **Pass** / **Fail**	**NS** - No Standard; **ND** - Not Detected	**TNTC** - Too Numerous to count

TEST RESULTS

Parameters	Method of Analysis	Units	Values	KS EAS:12:2018 Standard for natural drinking water	Remarks
Total Coliforms	ISO 9308-1	CFU/100 ml	TNTC	Not Detectable	
E-Coli	ISO 9308-1	CFU/100 ml	40	Not Detectable	

Comments: *The results of the tested water sample are as shown above.*

Disclaimer: *The results relate only to the sample(s) submitted. The laboratory will not be held responsible for any sampling errors.*

Prepared by : *P. Kimaiyo- QAO*

Approved by : *Edwin Mengich-QAM*

SIGN: [signature] **Date:** 05-04-2024 **SIGN:** [signature] **Date:** 5/04/2024

ELDORET WATER & SANITATION CO. LTD (ELDOWAS) 05 APR 2024 P. O. Box 8418, ELDORET-30100

nema KENAS

The laboratory is registered by NEMA and is Accredited to ISO/IEC 17025:2017

-END-

F-3: TAP WATER

TEST REPORT

P.o Box 8418-30100,
Eldoret, Kenya
Tel no. 0532063403,
Cell: 0724255538
Along Kampi Somali rd
email- info@eldowas.or.ke

ELDOWAS
ELDORET WATER AND SANITATION COMPANY

CENTRAL WATER TESTING LABORATORY

LABORATORY WATER ANALYSIS REPORT

Client : Ms. Cynthia Jelagat Kiprop	**Reference No :** 1912-23/24	**Sampling date :** 03/04/2024
Site Location : Iten Municipality-Elgeyo Marakwet County	**Sample Source :** ITWASCO tap water-Iten Municipality	**Receipt date:** 04/04/2024
Submitted by: Ms. Cynthia Jelagat Kiprop	**Sample description:** *Treated*	**Date of analysis :** 04/04/2024
Key: **Pass** (green) **Fail** (red)	**NS** - No Standard **ND** - Not Detected	**TNTC** - Too Numerous to count

TEST RESULTS

Parameters	Method of Analysis	Units	Values	KS EAS:12:2018 Standard for natural drinking water	Remarks
Total Coliforms	ISO 9308-1	CFU/100 ml	100	Not Detectable	(red)
E-Coli	ISO 9308-1	CFU/100 ml	3	Not Detectable	(red)

Comments: *The results of the tested water sample are as shown above.*

Disclaimer: *The results relate only to the sample(s) submitted. The laboratory will not be held responsible for any sampling errors.*

Prepared by : *P. Kimaiyo- QAO*		**Approved by :** *Edwin Mengich-QAM*	
SIGN: [signature]	**Date:** 05-04-2024	**SIGN:** [signature]	**Date:** 5/04/2024

ELDORET WATER & SANITATION CO. LTD
(ELDOWAS)
05 APR 2024
P. O. Box 8418, ELDORET-30100

nema

KENAS

The laboratory is registered by NEMA and is Accredited to ISO/IEC 17025:2017

- END-

F-4: Borehole Water

TEST REPORT

P o Box 8418-30100,
Eldoret, Kenya
Tel no: 0532063403,
Cell: 0724255538
Along Kampi Somali rd
email- info@eldowas.or.ke

ELDOWAS

CENTRAL WATER TESTING LABORATORY

LABORATORY WATER ANALYSIS REPORT

Client : Ms. Cynthia Jelagat Kiprop	**Reference No :** 1911-23/24	**Sampling date :** 03/04/2024
Site Location : Iten Municipality- Elgeyo Marakwet County	**Sample Source** : Borehole-Iten Municipality	**Receipt date:** 04/04/2024
Submitted by: Ms. Cynthia Jelagat Kiprop	**Sample description:** *Not treated*	**Date of analysis :** 04/04/2024
Key: **Pass** **Fail**	**NS** - No Standard; **ND** - Not Detected	**TNTC** - Too Numerous to count

TEST RESULTS

Parameters	Method of Analysis	Units	Values	KS EAS:12:2018 Standard for natural drinking water	Remarks
Total Coliforms	ISO 9308-1	CFU/100 ml	TNTC	Not Detectable	
E-Coli	ISO 9308-1	CFU/100 ml	22	Not Detectable	

Comments: *The results of the tested water sample are as shown above.*

Disclaimer: *The results relate only to the sample(s) submitted. The laboratory will not be held responsible for any sampling errors.*

Prepared by : *P. Kimaiyo- QAO*

SIGN: [signature] **Date:** 05-04-2024

Approved by : *Edwin Mengich-QAM*

SIGN: [signature] **Date:** 5/4/2024

ELDORET WATER & SANITATION CO. LTD (ELDOWAS) 05 APR 2024 P. O. Box 8418, ELDORET-30100

nema

KENAS

The laboratory is registered by NEMA and is Accredited to ISO/IEC 17025:2017

- END-

TEST REPORT

Appendix H : Introductory Letter

MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

P.O. Box 972-60200 – Meru-Kenya.

Cell phone: +254 712 524293, +254 799 529958, +254 799 529959

Website: www.must.ac.ke Email: info@must.ac.ke

SCHOOL OF ENGINEERING AND ARCHITECTURE

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

TO: Whom It may concern **DATE:** 24th August, 2023

Dear Sir/Madam,

RE: INTRODUCTORY LETTER FOR CYNTHIA JELAGAT KIPROP, REG NO. EG407/201418/21

The above-named, is a student in the Department of Civil and Environmental Engineering at Meru University of Science and Technology, pursuing a Master's degree in Sanitation. She has been approved to conduct research on **"Evaluating human excreta management and sanitation services using a shit flow diagram (SFD) analysis at Iten Municipality, Elgeyo Marakwet County."** aimed at completing her studies. This is therefore, to request that you grant her any assistance needed to enable her meet the program requirements for her graduation.

Kindly contact us for any further enquiries.

Thank you

Mirara Simon W.
Chair of Department, Civil and Environmental Engineering
Meru University of Science and Technology

Email: CODcivilengineeing@must.ac.ke
Smirara@must.ac.ke

MUST IS ISO 9001:2015 CERTIFIED

Appendix I : Research Permit from NACOSTI

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **134770**

Date of Issue: **11/September/2023**

RESEARCH LICENSE

This is to Certify that Miss.. Cynthia Kiprop of Meru University of Science and Technology, has been licensed to conduct research as per the provision of the Science, Technology and Innovation Act, 2013 (Rev.2014) in Elgeyo-Marakwet on the topic: EVALUATING HUMAN EXCRETA MANAGEMENT AND SANITATION SERVICES USING A SHIT FLOW DIAGRAM (SFD) ANALYSIS AT ITEN MUNICIPALITY, ELGEYO MARAKWET COUNTY for the period ending : 11/September/2024.

License No: **NACOSTI/P/23/29278**

134770

Applicant Identification Number

Director General

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

See overleaf for conditions

Appendix J : Permit from County Commissioner

OFFICE OF THE PRESIDENT
MINISTRY OF INTERIOR AND NATIONAL ADMINISTRATION
State Department for Internal Security and National Administration

Telephone: (053) 42007
Fax: (053) 42289
E-mail: ccelgeyomarakwet@yahoo.com
ccelgeyomarakwet@gmail.com
When replying please quote

COUNTY COMMISSIONER'S OFFICE,
ELGEYO-MARAKWET COUNTY,
P.O. BOX 200-30700
ITEN

Ref. PUB.CC.24/2 VOL.III/194

27th February, 2024

TO WHOM IT MAY CONCERN

RE: RESEARCH AUTHORIZATION

MISS CYNTHIA KIPROP

This is to confirm that the above named has been authorized to carry out a research on **"EVALUATING HUMAN EXCRETA MANAGEMENT AND SANITATION SERVICES USING A SHIT FLOW DIAGRAM (SFD) ANALYSIS AT ITEN MUNICIPALITY, ELGEYO MARAKWET COUNTY"** for the period ending 11th September, 2024.

Please accord her the necessary assistance.

COUNTY COMMISSIONER
ELGEYO MARAKWET COUNTY

Julius K Maiyo HSC.
For: COUNTY COMMISSIONER
ELGEYO MARAKWET COUNTY.

Appendix K : Permit from County Governor

COUNTY GOVERNMENT OF ELGEYO MARAKWET
OFFICE OF THE COUNTY SECRETARY

All correspondence to be
Addressed to; County Secretary

P.O BOX 220 – 30700, ITEN
TEL: 05342277
countysecretary@elgeyomarakwet.go.ke

Your Ref...
Our Ref: EMC/ADM 69/III/252.

DATE: 28th February, 2024

MISS CYNTHIA KIPROP

RE: PERMISSION TO CONDUCT RESEARCH IN ELGEYO MARAKWET COUNTY.

Miss. Cynthia Kiprop is a student at Meru University of Science and Technology pursuing Masters Studies and wishes to conduct a research project on the topic **"Evaluating Human Excreta Management and Sanitation Services using a Shit Flow Diagram (SFD) Analysis at Iten Municipality, Elgeyo Marakwet County".**

She has been granted permission to go ahead with research project within Iten Municipality for the period ending 11th September, 2024.

This is therefore, to request all institutions and individuals within the County to accord her the necessary assistance.

Thank you.

PAUL CHEMMUTTUT
COUNTY SECRETARY/HEAD OF COUNTY PUBLIC SERVICE

THE COUNTY SECRETARY
ELGEYO MARAKWET COUNTY
P. O. Box 220-30700, ITEN
Email: info@elgeyomarakwet.go.ke

C.C

H.E. GOVERNOR

Appendix L : Target Population of Iten Municipality Source: (KNBS, 2019)

Sublocation	Total	Male	Female	Total Households	Sq.Km	Person Per Sq.Km
Bugar	2871	1493	1378	640	4.8	601
Singore	1176	572	604	236	5.2	224
Kapkonga	2095	1031	1064	421	9.8	213
Mindililiwo	4118	1967	2151	976	4.9	838
Iten Township	9176	4453	4723	2960	4.5	2040
Chebokokwo	2142	1016	1126	336	5.0	432
Kapkessum	2021	1040	981	391	7.9	255
Sergoit	9632	4805	4827	1871	31.1	309
Kiplamai	3149	1578	1571	563	10.9	288
Kiptabus	6070	2992	3078	1490	11.2	542
Katalel	5200	2529	2671	1095	13.1	398
Chesitek	3378	1669	1709	703	8.2	411
Rimoi	2551	1274	1277	572	26.2	97
Anin	3366	1756	1610	753	41.0	82
Kessup	3740	1870	1870	814	18.7	200
Total	**60685**	**30,045**	**30, 640**	**13, 821**	**202.5**	**6930**

Appendix M : Plagiarism Report

DrillBit

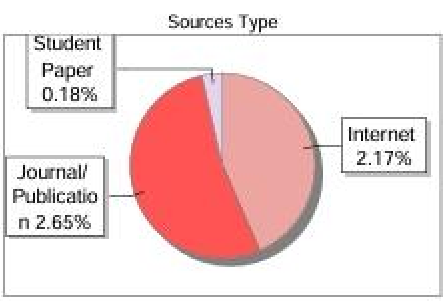
The Report is Generated by DrillBit Plagiarism Detection Software

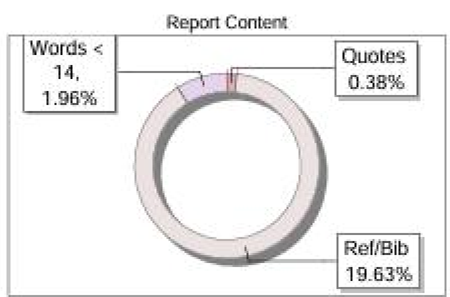
Submission Information

Author Name	CYNTHIA JELAGAT KIPROP
Title	EVALUATING HUMAN EXCRETA MANAGEMENT AND SANITATION SERVICES USING A SHIT FLOW DIAGRAM AT ITEN MUNICIPALITY, ELGEYO MARAKWET COUNTY, KENYA
Paper/Submission ID	4345194
Submitted by	mmusungu@must.ac.ke
Submission Date	2025-09-10 11:31:21
Total Pages, Total Words	196, 40216
Document type	Thesis

Result Information

Similarity **5 %**





Exclude Information

Quotes	Not Excluded
References/Bibliography	Excluded
Source: Excluded < 14 Words	Not Excluded
Excluded Source	**0 %**
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File