

**EVALUATION OF EXCRETA MANAGEMENT ACROSS
SANITATION SERVICE CHAIN USING SHIT FLOW
DIAGRAM IN KERICHO TOWN, KENYA**

BERNARD KIPKEMOI KIRUI

**A Research Thesis Submitted in Partial Fulfilment of Requirements for
Conferment of the Degree of Master of Science 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.

EG407/201421/21

Signed

Date:

Bernard Kipkemoi Kirui

DECLARATION BY SUPERVISORS

This thesis has been submitted with our approval as university supervisors

Signed

Date:

Dr. Sarah Wandili, Ph.D

Meru University of Science and Technology, Kenya

Signed.....

Date:

Dr. Kennedy Gachoka, Ph.D

Meru University of Science and Technology, Kenya

DEDICATION

I dedicate this research thesis to my beloved spouse Eileen Chelangat and my son, Keenan Kemoi who have been supportive throughout this journey.

ACKNOWLEDGEMENT

I am deeply grateful to God for guiding me to this milestone in my academic journey; He has truly been my source of strength. I extend my sincere appreciation to all who contributed to the completion of this work. A special acknowledgment goes to Dr. Sarah Wandili and Dr. Kennedy Gachoka, my supervisors, whose unwavering support and expert guidance have been invaluable throughout this research endeavour. I am forever indebted to them. Gratitude is also due to Hon Rosemary Rop and Dr. Wesly Bor for their support, particularly in facilitating my research in Kericho County. I express my appreciation to the Bill and Melinda Gates Foundation (BMGF) and the Sanitation Research Institute of Meru University of Science and Technology (MUST) for enabling me to pursue my Master of Science (MSc) Degree in Sanitation. Lastly, heartfelt thanks to my wife, Eileen, and son Keenan for their unwavering emotional support and prayers. I am grateful to all my colleagues at MUST, especially MSc. Sanitation cohort of 2021 and the Ministry of Water, Sanitation, and Irrigation, for their encouragement along the way.

TABLE OF CONTENTS

DECLARATION	II
DEDICATION	III
ACKNOWLEDGEMENT	IV
LIST OF TABLES	VIII
LIST OF FIGURES	IX
LIST OF PLATES	X
LIST OF APPENDICES	XI
ABBREVIATIONS, SYMBOLS AND ACRONYMS	XII
DEFINITION OF OPERATIONAL TERMS	XV
ABSTRACT	XVII
CHAPTER ONE: INTRODUCTION	1
1.1. Introduction.....	1
1.2. Background of the Evaluation of Excreta Along the Sanitation Service Chain.....	1
1.3. Problem Statement.....	6
1.4. Justification.....	8
1.5. Research Questions.....	8
1.6. Research Objectives.....	9
1.6.1 General objective.....	9
1.6.2 Specific objectives.....	9
1.7. Significance of the Study.....	9
1.8. Limitations of the Study.....	10
1.9. Delimitation of the Study.....	12
CHAPTER TWO: LITERATURE REVIEW	13
2.1. Introduction.....	13
2.2. Sanitation Overview Along the Sanitation Service Chain.....	13
2.2.1 Urbanization and its impact on sanitation services.....	14
2.2.2 Faecal sludge management.....	16
2.2.3 Adequate sanitation access for All.....	17
2.2.4 Innovative Approaches to Address Sanitation Challenges.....	18
2.3. Sanitation Technologies.....	19
2.3.1 Onsite sanitation technologies.....	21
2.3.2 Centralized treatment.....	27
2.3.3 Gaps on sanitation technologies.....	30
2.4. Excreta Disposal Through the Sanitation Service Chain.....	31
2.4.1 Sanitation systems.....	33
2.4.2 Institutional arrangements for sanitation.....	36
2.4.3 Evaluating the city's sanitation system.....	37
2.4.4 Data on service provision and environmental sanitation situation.....	41
2.4.5 Standards for effluent discharge into the environment.....	41
2.4.6 Gaps in Sanitation Service Delivery.....	42
2.5. Description of SFD Methodology.....	44
2.5.1 SFD creation process.....	44
2.5.2 Levels of SFD reports.....	45
2.5.3 Potential uses of SFD.....	46
CHAPTER THREE: RESEARCH METHODOLOGY	48
3.1. Introduction.....	48
3.2. Study Area.....	48

3.3. Target Population	50
3.3.1 Inclusion criteria	50
3.3.2 Exclusion criteria	50
3.4. Study Design	50
3.5. Sampling Techniques	51
3.5.1 Purposive sampling	51
3.5.2 Cluster sampling	52
3.6. Sample Size Determination	52
3.7. Field Work Overview	54
3.7.1 Desk review	54
3.7.2 Key informant interviews	55
3.7.3 Household surveys	56
3.7.4 Transect walks and observations	57
3.7.5 SFD graphics development	58
3.8. Pilot Study	60
3.8.1 Validity of research instruments	60
3.8.2 Reliability of the research instruments	61
3.9. Data Analysis	61
3.10. Ethical Considerations	64
CHAPTER FOUR: RESEARCH RESULTS	65
4.1. Introduction	65
4.2. Response Rate	65
4.3. Demographic Information of the Respondents	65
4.3.1 Respondents' distribution by gender	65
4.3.2 Level of education of the respondents	66
4.3.3 Ownership status of house/residence of household	66
4.3.4 Under-Five Diarrheal Infection in Past Two Weeks	68
4.4. Sanitation Technologies	69
4.4.1 Toilet facilities (capture)	69
4.4.2 Quality of sanitations technology in Kericho town	70
4.4.5 Access To Water for Drinking and Sanitation	78
4.5. Safety of Excreta Along the Sanitation Service Chain	81
4.5.1 Containment	82
4.5.2 Faecal sludge emptying in Kericho town	85
4.5.4 Conveyance/transport	93
4.5.5 Treatment and disposal of sludge in Kericho town	94
4.6. Shit Flow Diagram	101
CHAPTER FIVE: DISCUSSION	103
5.1. Introductions	103
5.2. Discussion	103
5.2.1 Sanitation technologies in Kericho town	103
5.2.2 Safety of excreta along the sanitation service chain	107
4.2.3 Shit Flow in Kericho town	114
CHAPTER SIX: CONCLUSION, RECOMMENDATIONS, AND PUBLICATION ..	116
6.1. Introduction	116
6.2. Summary of findings	116
6.2.1 Sanitation technologies in Kericho town	116
6.2.2 Safety of excreta along the sanitation service chain	117
6.2.3 Shit flow in Kericho town Figure 6.1: SFD Graphic of Kericho Town	118

6.3. Conclusion	118
6.4. Recommendations	120
6.4.1 Sanitation technologies	120
6.4.2 Safety of excreta along the sanitation service chain	121
6.4.3 Shit flow diagram	123
6.5. Area of Further Study	123
6.6. Publication	124
REFERENCES	125
APPENDICES	146

LIST OF TABLES

Table 3- 1: Sampled households per sublocation	53
Table 3- 2: Unpublished reports	55
Table 3- 3: List of coded key informants	56
Table 3- 4: Required data for developing SFD Graphic	58
Table 3- 5: SFD Matrix	63
Table 4- 1: Respondents distribution by gender(N=409)	65
Table 4- 2: Level education of the respondents (N=409)	66
Table 4- 3: Ownership Status of the households (N=409)	67
Table 4- 4: Experienced Diarrhoea in the past week (N=409)	69
Table 4- 5: Toilet categories (N=409)	71
Table 4- 6: Toilet functionality(N=409)	72
Table 4- 7: Presence of cleanable slab (N=409)	72
Table 4- 8: Toilet Superstructure and privacy (N=409)	73
Table 4- 9: Toilet slab contamination with urine or faeces(N=409)	74
Table 4- 10: Location of the toilet in the household compound (N=409)	76
Table 4- 11: Payment to use toilet (N=409)	77
Table 4- 12: Source of water for drinking and sanitation in Kericho town (N=409)	79
Table 4- 13: Greywater Discharge (N=409)	84
Table 4- 14: Emptying practices in Kericho Town (N=409)	85
Table 4- 15: Who did the last emptying(N=38)	88
Table 4- 16: How was it emptied (N=38)	88
Table 4- 17: Where was it emptied to (N=38)	89
Table 4- 18: Payment for emptying (N=38)	90
Table 4- 19: Criteria for payment for emptying (N=31)	90
Table 4- 20: Level of satisfaction with service provider(N=38)	91
Table 4- 21: Challenges faced by emptiers in Kericho Town (N=27)	92
Table 4- 22 : Comparison of Kericho WWTP Effluent Parameters with NEMA Discharge Standards (April 2022–April 2023)	99

LIST OF FIGURES

Figure 2- 1: Sanitation Ladder SDG: (WHO/UNICEF, 2017b)	18
Figure 2- 2: MDGs vs SDGs (Hawkins, 2016)	31
Figure 2- 3 : Sanitation Service Chain (Safi et al., 2022)	33
Figure 2- 4: SFD graphic used in SFD production process (SFD-PI, 2018)	38
Figure 2- 5 : SFD Graphic for the 39 cities (Peal et al., 2020)	39
Figure 3- 1: Map of Kericho Town (KEWASCO, 2022)	49
Figure 4- 1: Monthly rental cost	67
Figure 4- 2: Experienced diarrhoea in the past week	68
Figure 4- 3: Capture/Toilet Facilities in Kericho	69
Figure 4- 4: Distribution of toilet Facilities in Kericho per sublocation	70
Figure 4- 5: Number of Household Sharing Toilet Facilities in Kericho	71
Figure 4- 6: Number of people regularly using toilet	75
Figure 4- 7: Cost of using toilet	77
Figure 4- 8: Time travel in minutes to toilet facility.	78
Figure 4- 9: Time Spent Traveling to Fetch Water	80
Figure 4- 10: Time Spent Queuing to Fetch Water	81
Figure 4- 11: Distribution of containment Facilities in Kericho Town	83
Figure 4- 12: Number of years to reach capacity	86
Figure 4- 13: Reason for toilet overflow	87
Figure 4- 14: SFD Graphic of Kericho Town	102

LIST OF PLATES

<u>Plate 4- 1: Shared Capture facilities</u>	74
<u>Plate 4-2: Shared Capture facilities showing presence of faeces and urine</u>	75
<u>Plate 4- 3: Collection tank with missing pump, downstream of sludge digesters</u>	96
<u>Plate 4-4: Untreated Supernatant into environment</u>	98

LIST OF APPENDICES

Appendix A: Concert form	146
Appendix B: Household survey questionnaire	147
Appendix C: Interview Guide	154
Appendix D: Transect Walk Observation Guide	157
Appendix E: Research License by NACOSTI	160
Appendix F: Research Authorisation by Kericho County	161
Appendix G: Target Population of Kericho Town (KNBS, 2019)	162
Appendix H: Shit Flow Diagram Selection Grid	163
Appendix I: NEMA Standards for Effluent Discharge into The Environment	164
Appendix J: Journal Article Publication	165
Appendix K: Plagiarism Report	166

ABBREVIATIONS, SYMBOLS AND ACRONYMS

BOD	Biochemical oxygen demand
CBD	Central Business District
CBO	Community Based Organisation
CGoK	County Government of Kericho
CLTS	Community-Led Total Sanitation
COD	Chemical Oxygen Demand
CSDA	City Service Delivery Assessment
CWIS	City Wide Inclusive Sanitation
DTF	Decentralised Treatment Facility
EMCA	Environment Management and Co-ordination Act
EPA	Environmental Protection Agency
FS	Faecal Sludge
FSM	Faecal Sludge Management
ICDDR, B	International Centre for Diarrhoeal Disease Research, Bangladesh
GIZ	German Corporation for International Cooperation
GPS	Global Positioning System
JMP	Joint Monitoring Programme
KESHP	The Kenya Environmental Sanitation and Hygiene Policy
KEWASCO	Kericho Water and Sanitation Company
KII	Key Informant Interviews
KNBS	Kenya National Bureau of Statistics
LMICs	Low and Middle-Income Countries
KPLC	Kenya Power and Lighting Company

KPHC	Kenya Population and Housing Census
LCC	Lusaka City Council
LWSC	Lusaka Water and Sewerage Company
LWIS	Lake-Wide Inclusive Sanitation
MDG	Millennium Development Goals
MoWSI	Ministry of Water, Sanitation and Irrigation
MUST	Meru University of Science and Technology
NACOSTI	National Commission for Science, Technology and Innovation
NEMA	National Environment Management Authority
NGO	Non-Governmental Organisation
NWP	National Water Policy
OD	Open Defaecation
ODF	Open Defaecation Free
OSS	Onsite Sanitation System
SDG	Sustainable Development Goals
SFD	Shit Flow Diagram
SFD-PI	Shit Flow Diagram- Promotion Initiative
SNV	Netherlands Development Organisation
SRI	Sanitation Research Institute
SSC	Sanitation Service Chain
SuSanA	Sustainable Sanitation Alliance
TSS	Total Suspended Solids
UNICEF	United Nations Children's Fund
VIP	Ventilated Improved Pit

VTO	Vacuum Truck Operators
WASH	Water Sanitation Hygiene
WASREB	Water Services Regulatory Board
WB	World Bank
WHO	World Health Organisation
WRA	Water Resources Authority
WSP	Water Service Providers
WWDA	Water Works Development Agency
WWTP	Waste Water Treatment Plant

DEFINITION OF OPERATIONAL TERMS

Evaluation of Excreta Management	refers to analysis of the proportion of the population whose excreta is considered safely or unsafely managed along the sanitation service chain
Excreta/Shit	comprises a combination of human urine, human faeces and any flushing water
Faecal sludge	refers to mixture human urine, human faeces and any flushing water from onsite sanitation systems such as pit latrines, septic tanks, and pit latrine with slab
Initial SFD	is also known as level 1 SFD is an easy to understand advocacy tool used for decision making support by stakeholders. It is developed when secondary data is available, and there is limited access to stakeholders due to constraints such as time, logistics, or resources
Sanitation Service Chain	for on-site sanitation systems involves excreta containment in a latrine pit or septic tank, followed by pit or tank emptying, transportation of the faecal sludge then treatment, and finally the end-use or disposal of the resulting products. For off-site sanitation systems, the Sanitation Service Chain typically includes effluent from flush toilets being transported through sewers to a wastewater treatment facility and eventual end-use or final disposal of the treated wastewater or its by-products
SFD Graphic Generator	is the instrument utilized in creating the SFD Graphic and the SFD Matrix. It includes the SFD Selection Grid
SFD Graphic	is the visual representation of the excreta flows across town/city

along the sanitation service chain from defecation to final disposal of excreta

SFD Selection Grid refers to containment technologies available in the city which serves as the basis for the SFD Matrix

Stakeholder is any group, organization, or individual that can influence or be influenced by the sanitation services being considered and who has a vested interest in the sanitation sector

The SFD Matrix is a table that refers to the methods for calculating the variables for each of the sanitation systems selected in the SFD Selection Grid

Wastewater refers to the mixture human urine, human faeces and any flushing water from flush toilets being transported through sewers to a wastewater treatment facility

ABSTRACT

Over half of the world's population lived in cities as of 2020, and it's expected that 70% of the global population will live in cities by 2050. Providing adequate sanitation services in urban and peri-urban areas is challenging especially in low- and middle-income countries where poor sanitation practices can lead to the spread of diseases with high morbidity and mortality rates. Shit Flow Diagram is an innovative tool and can be used to identify bottlenecks, areas of high risk, and opportunities for improving the safety of sanitation practices along sanitation service chain in a specific location. The study aimed to evaluate excreta management across sanitation service chain using Shit Flow Diagram (SFD) in Kericho Town, Kenya. Employing a convergent parallel mixed method, the study gathered data through diverse methods, including desk research, documented studies, County Government records, Key Informant Interviews, household surveys, and observations. A sample size of 409 households was utilized to comprehend the Faecal Sludge Management (FSM) patterns of Kericho town, employing both qualitative and quantitative data collection methods alongside the SFD data analysis tool. Thematic analysis was used to analyse qualitative data, while simple descriptive statistics were used for quantitative data analysis. The research showed that most households used onsite sanitation technologies, specifically (66.5%) pit latrines with slabs and (13.69%) pour-flush systems. Most facilities were functional and sufficiently private, but shared toilets were in poor condition structurally and required some maintenance. The study found that despite relatively high faecal sludge containment (65%), only 54% of faecal sludge and 5% of wastewater underwent effective treatment. Operational challenges included high emptying costs, poor transport infrastructure, and limited equipment availability, all of which hindered timely and safe sludge management. Furthermore, the findings revealed that the key water quality parameters (BOD₅, COD, *E. coli*, and Total Coliforms) were consistently above acceptable national effluent standards by the National Environment Management Authority (NEMA), demonstrating inefficiencies in the local treatment facilities. The study concludes that Kericho Town experiences significant sanitation service chain breakdowns, particularly at the emptying and treatment stages, resulting in 41% of excreta being unsafely managed. These challenges pose substantial risks to environmental health and hinder progress toward achieving Kenya's Vision 2030 and Sustainable Development Goal 6.2, which advocates for universal access to safely managed sanitation. The study recommended local authorities, utility and stakeholders take decisive action at infrastructure level, service delivery level, and equitable access to safe sanitation level.

CHAPTER ONE: INTRODUCTION

1.1. Introduction

This section consists of the following: background of the evaluation of excreta along the sanitation service chain, problem statement, research questions, study objectives, significance of the study, limitations, and delimitations of the study.

1.2. Background of the Evaluation of Excreta Along the Sanitation Service Chain

Urbanization is accelerating at an unprecedented pace, with the United Nations projecting that nearly 70% of the global population will reside in urban areas by 2050 (UN-Habitat, 2022). This demographic transition exerts significant pressure on urban infrastructure, especially in low- and middle-income countries (LMICs), where sanitation systems often remain underdeveloped, unregulated, or absent entirely (Bankole et al., 2023; Tay & Ocansey, 2022). In many LMICs, the expansion of basic sanitation services lags behind population growth, leading to unsafe excreta disposal, heightened disease risk, and environmental degradation (Narayan et al., 2021). These challenges are further compounded by institutional fragmentation, limited investment, and informal settlements, where basic water and sanitation services are either unreliable or non-existent (Hyun et al., 2019).

Current estimates suggest that hundreds of millions of urban dwellers still lack access to safely managed sanitation. According to recent findings, over 2 billion individuals globally remain without improved sanitation systems, disproportionately affecting urban populations in LMICs (Bankole et al., 2023; Sinharoy, Pittluck, & Clasen, 2019). Despite international efforts and Sustainable Development Goal 6.2, progress has been slow and inconsistent due to financial constraints, governance challenges, and weak policy implementation (Narayan et al., 2021; Satterthwaite, 2017). Addressing these gaps

is critical to safeguarding public health and achieving inclusive, sustainable urban development.

In many developing countries, sanitation improvements remain a neglected priority, contributing significantly to the transmission of waterborne diseases and preventable mortality due to contaminated water sources (Narayan, 2022; Schrecongost et al., 2020). While Sustainable Development Goal 6.2 emphasizes the need for adequate and equitable sanitation and hygiene for all especially vulnerable populations including women and children progress has been uneven and slow in rapidly urbanizing contexts (UN, 2015; Tang et al., 2022). Urban sanitation systems in these regions often consist of fragmented onsite and offsite technologies, provided by a mix of informal actors, private developers, and under-resourced municipal agencies (Gambrill et al., 2020; Narayan et al., 2021). However, achieving safely managed sanitation requires a shift toward integrated, inclusive, and citywide service models.

The Citywide Inclusive Sanitation (CWIS) framework promoted by global institutions such as the World Bank and Asian Development Bank advocates for equitable, resilient, and technically diverse sanitation systems that serve entire urban populations (Narayan et al., 2024; Cookey & Peter-Cookey, 2024). This approach aligns with the SDG mandate by ensuring safe sanitation from toilet capture through conveyance, treatment, and reuse or disposal. As urban populations continue to expand, CWIS offers a transformative pathway for meeting sanitation challenges in complex, informal, and underserved urban environments (Gambrill et al., 2020; Tang et al., 2022).

Kenya's Draft National Sanitation Management Policy (2022) identifies persistent barriers in the sanitation sector, including fragmented institutional leadership, underfunding, and a lack of coordinated governance frameworks that have hindered equitable service delivery across the country (MoWSI, 2022). In urban areas, fecal

sludge from pit latrines and septic tanks is frequently discharged untreated into the environment, resulting in widespread contamination of drinking water, food, and living spaces an issue strongly linked to high diarrheal disease prevalence among children under five (Tomoi et al., 2025). Poor fecal sludge management (FSM), exacerbated by unregulated effluent discharge, continues to threaten both environmental health and human well-being.

Effluent discharge whether treated or untreated has been shown to degrade aquatic ecosystems, contaminate groundwater, and expose communities to toxic pollutants. Despite global advances in effluent regulation and the formulation of water quality standards by institutions such as the World Health Organization (WHO) and national regulatory bodies, enforcement in many African countries, including Kenya, remains limited (Ayeleru et al., 2023; Obiewa, 2024).

WHO guidelines emphasize stringent criteria for effluent quality, such as limits on thermotolerant coliform bacteria (e.g., <100 CFU/100 mL for recreational water), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), and concentrations of toxic pollutants like nitrates, phosphates, and heavy metals. These parameters are crucial for safeguarding human health and preserving aquatic ecosystems in both recreational and potable water environments. However, many of Kenya's wastewater treatment systems are outdated or overloaded, failing to meet these global standards (WHO, 2019; Nyika & Dinka, 2025). Therefore, policy implementation, infrastructure upgrades, and increased investment in decentralized sanitation technologies are urgently needed to mitigate the escalating sanitation crisis.

In Kenya, it is legally prohibited for individuals or entities to discharge wastewater whether from sewage treatment plants, industrial operations, or other sources into the environment without a valid effluent discharge license issued by the National

Environment Management Authority (NEMA). The Environmental Management and Coordination (Water Quality) Regulations of 2006 outline effluent discharge parameters, including maximum limits for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), and other pollutants (NEMA, 2006). These thresholds are codified in the Third Schedule of the regulations, forming the benchmark for wastewater discharge licensing (Appendix I).

However, enforcement of these standards has remained weak, particularly in urban water bodies such as the Nairobi River, where industrial and domestic pollution persist despite regulatory mandates. For instance, recent studies show that BOD and E. coli levels in Nairobi River exceed NEMA limits during both dry and wet seasons, indicating persistent non-compliance among dischargers (Ngatia et al., 2023). Although there were initiatives in 2019 to prosecute river polluters, including threats of arrest and plant shutdowns, limited institutional capacity and inadequate follow-up have undermined regulatory outcomes (Onyango et al., 2024). This reveals a concerning gap between regulation and implementation, highlighting the urgent need for investment in monitoring systems, legal accountability, and inter-agency collaboration to restore urban river ecosystems.

To improve the rate of safe sanitation management in a city, the authorities must first understand the current state of sanitation. This task is particularly challenging in many low- and middle-income countries, where service delivery is often uncoordinated, poorly monitored, and lacks reliable data (Haque et al., 2025; Peal et al., 2020). To address this challenge, the Shit Flow Diagram (SFD) tool was introduced in 2015 as part of a global initiative to provide a standardized, easily understood visual representation of how excreta is managed along the sanitation chain (SFD-PI, 2018b). The SFD has since become a cornerstone of citywide sanitation planning. This tool has evolved into a

crucial instrument for visualizing prevalent sanitation issues in urban areas and involving political leaders, decision-makers, and civil society in discussions pertaining to sanitation. It also serves as a platform for addressing investment and management goals in cities (Karki et al., 2024; Schertenleib et al., 2021). As urban populations continue to grow, the SFD remains pivotal in guiding cities especially in underserved regions toward achieving safely managed sanitation for all.

The SFD visual simplicity supports collaboration among technical stakeholders, political leaders, and civil society actors alike. When informed by high-quality data, the SFD can be further enriched to track the volumes, mass, and even nutrient values of faecal sludge, offering opportunities for value recovery and resource optimization (Waine et al., 2025). Globally, over 290 SFDs have been created for cities across Africa, Asia, and Latin America, making it a proven instrument for mapping sanitation flows and supporting evidence-based planning (SuSanA, 2023). However, despite its wide adoption, there is a notable gap in SFD development and application for secondary and intermediary towns in Kenya such as Kericho where urban growth is accelerating but sanitation data remains sparse, fragmented, or outdated.

The SFD has been used in several cities among them; Dhaka, Bangladesh, and Kampala, Uganda, to identify high-risk areas and opportunities for improvement (Islam, 2020; Water and Sanitation for the Urban Poor 2017). Reports from aforementioned studies indicated significant challenges in the disposal of excreta and disparities in access to safe sanitation facilities. In Kenya, similar assessments in towns such as Kisumu, Nakuru, and Nkubu revealed, more than 55% of excreta generated in these areas were not properly treated and disposed of in the environment due to ineffective transportation and treatment services (Furlong, 2015; Gituma et al., 2022). These results highlight the

systemic deficiencies in fecal sludge management systems in rapid urbanizing secondary towns.

Diarrheal diseases remain a major public health concern in Kenya, closely linked to inadequate sanitation. According to report by World Health Organization and United Nations Children's Fund (WHO & UNICEF, 2021), more than 70% of Kenya's population lacks access to safely managed sanitation services, with urban areas facing mounting strain due to population growth and underdeveloped infrastructure. Although Kericho Town is expanding rapidly, it has not yet been the focus of a formal SFD study. Developing SFD for Kericho could provide valuable insights into the faecal sludge flow within the town, highlighting areas where interventions are most needed.

1.3. Problem Statement

Kericho Town, a rising urban secondary town in Kenya, is increasingly challenged by the safe management of human excreta (Kericho County Government, 2023; SNV, 2018). The sewerage system is obsolete, and is often blocked or leaking; so untreated wastewater and faecal matter often flow directly into rivers and open drains (KEWASCO, 2022). Additionally, most of households in Kericho are using on-site sanitation systems, such as pit latrines and septic tanks, but a large number of these technologies are informally emptied or not emptied at all (Kericho County Government, 2023). As a result, a high volume of excreta is managed unsafely, leading to an increased risk of diarrheal diseases and environmental contamination (Mazuze et al., 2023; Too, 2023). Therefore, it is imperative to undertake an assessment of the town's excreta management flows in a systematic way.

An effective urban sanitation system contains safe management of excreta through the entire service chain from containment and emptying to transport, treatment, and final safe disposal or reuse (WHO & UNICEF, 2017). This model supports Sustainable

Development Goal (SDG) 6.2 which encourages equitable sanitation for all, and safely managed sanitation for all. Similarly, Kenya's Vision 2030 envisages a nation where everyone has access to safe and affordable sanitation - recognizing that sustainable sanitation infrastructure is a key pillar of public health and economic development.

To achieve this Vision will require reliable data that is specific to a location, coordinated service provision, and diagnostic planning tools that highlight systemic shortcomings throughout the sanitation chain (Spuhler & Lüthi, 2020). However, the pace of progress in Kenya is slow due to inadequate infrastructure, inadequate investment in faecal sludge management, and disorganized coordination across the relevant actors (Omina et al., 2022; Bundi, 2023). Therefore, evidence-based planning, including contextual diagnostic tools, remains at the centre of achieving the sanitation-stability deficit and expediting Kenya's development objectives.

Globally, tools like the Shit Flow Diagram (SFD) have been able to fill vital data and diagnostics gaps in urban sanitation. The SFD provides a transparent visual illustrating how excreta travel from containment to final disposal or reuse and has explicitly used by cities such as Lusaka in Zambia, and Dhaka in Bangladesh to prompt and improve the Faecal Sludge Management (FSM) regime through better policy engagement and planning and programming investment (GIZ; LWSC; LCC, 2019). Even though there has been considerable uptake of the SFD in other contexts, there is limited use in Kenya's rapidly urbanizing towns where excreta mismanagement persists. More recently, studies that have examined the SFD approach in towns such as Nakuru, Kisumu and Eldoret. Findings indicated that in Nakuru and Kisumu, over 50% of generated faecal sludge is not safely treated or disposed of based on infrastructure gaps and FSM systems (Simiyu et al., 2021; Gituma, Gachoka & Gakii, 2021; Kipkoeh, 2024). For example, Simiyu et al. (2021) identified significant disparities in faecal sludge management in low-income

areas of Nakuru, while Kipkoech (2024) demonstrated the usefulness of Shit Flow Diagrams (SFDs) in visualizing sanitation flows in Eldoret and informing municipal faecal sludge management planning. However, in regard to excreta flow analysis, Kericho Town is largely undocumented by existing research, implying that decision-makers do not have an adequate basis to identify high-priority areas where intervention is to be implemented, or warranted for effective inclusive sanitation planning. This study could fill this critical gap by developing a Shit Flow Diagram (SFD) for Kericho Town.

1.4. Justification

Among available sanitation diagnostic tools, the Shit Flow Diagram (SFD) stands out due to its simplicity, accessibility, and adaptability to data-limited contexts. Compared to tools like the Sanitation Safety Planning (SSP) or FSM Plans, which often require extensive datasets and technical expertise, the SFD provides an intuitive, standardized graphic representation of excreta flows (Peal et al., 2020). It supports participatory and political engagement by translating complex sanitation information into a format digestible by stakeholders, including non-technical decision-makers (Peal et al., 2020; Narayan, 2022). The SFD has proven particularly impactful in fast-urbanizing areas in Africa, Asia, and Latin America where sanitation services are informal or unregulated. Cities like Lusaka, Nakuru, and Dhaka have used SFDs not only to reveal high-risk sanitation areas but to prompt critical investments and policy reforms in Fecal Sludge Management (FSM) (Evans et al., 2020; Kipkoech, 2024). In contrast, Kericho Town lacks such data-driven tools, creating a vacuum in strategic planning and evidence-based policymaking.

1.5. Research Questions

- i. What are the most commonly used types of sanitation technologies in Kericho Town, Kenya?

- ii. What proportions of excreta is safely and unsafely managed across the sanitation service chain in Kericho Town, Kenya.?
- iii. What does the Shit Flow Diagram (SFD) reveal about the excreta management pathways of the sanitation system in Kericho Town, Kenya?

1.6. Research Objectives

The study was guided by the following objectives;

1.6.1 General objective

To evaluate excreta management across sanitation service chain using Shit Flow Diagram (SFD) in Kericho Town, Kenya.

1.6.2 Specific objectives

- i. To identify the types of sanitation technologies currently used in Kericho Town, Kenya.
- ii. To determine the proportion of excreta that is safely and unsafely managed across the sanitation service chain in Kericho Town, Kenya.
- iii. To develop a Shit Flow Diagram (SFD showing the current excreta of the sanitation system in Kericho Town, Kenya.

1.7. Significance of the Study

The development of the Shit Flow Diagram (SFD) for Kericho Town represented a critical tool in understanding the flow and safety of excreta across the sanitation service chain. SFD could provide a detailed overview of the sanitation challenges and opportunities within the town. The findings of this study provided valuable data on the state of excreta management, highlighting areas that required urgent intervention.

This information could guide policymakers in prioritizing sanitation investments and aligning resources more effectively to improve urban sanitation. By offering a visual representation of the sanitation service chain, the SFD served as an advocacy tool to push

for the formulation of policies that promoted safe excreta disposal and enhanced Faecal Sludge Management (FSM). Policymakers could be able to use the insights from this study to ensure that future urban planning and sanitation programs were not only comprehensive but also sustainable.

Furthermore, the research informed the achievement of SDG 6.2, which aimed to eliminate open defecation and ensure that sanitation services were safely managed, even in low-resource settings like Kericho. Policymakers could leverage the findings to advocate for funding and international support for sanitation infrastructure improvements, thereby accelerating progress towards meeting global sanitation targets by 2030.

While the Shit Flow Diagram had been widely used in cities globally, the application of the tool in Kericho Town represented an important case study in the broader use of the SFD methodology. This research could add value to the academic community by exploring the adaptation of SFDs in smaller towns with limited sanitation infrastructure. The study could contribute to the development of more integrated methodologies in sanitation research. This methodological framework can be adapted for use in other regions facing similar sanitation challenges, thus enhancing the knowledge base and providing a replicable model for other towns in Kenya and beyond. Future research could benefit from the study's methods and conclusions, which could help build creative solutions to the worldwide sanitation challenge.

1.8. Limitations of the Study

The research used self-reported data from household surveys and key informant interviews. A particular limitation of using self-reported data is social desirability bias where respondents may adjust their responses to be what they believe to be socially acceptable and desirable responses. This may result in erroneous data as respondents may report inflated sanitation behaviours or suppress negative aspects to make

themselves look better. To mitigate this limitation, the study used triangulation through the use of combinations of quantitative and qualitative data-gathering techniques. Triangulation included structured questionnaires, key informant interviews, and observations. The researcher obtained multiple data points for each and was able to cross-reference responses, improving the overall reliability and validity of the results. Another advantage of using triangulation is that the respondents were assured of the privacy and confidentiality of the surveys, which may help elicit open and honest responses, and help prevent social desirability bias.

Another limitation was the possibility for respondent mis-information, especially when respondents were not certain about their sanitation system or emptying methods or the status of their sanitation facilities. When uncertainty was present it could affect the reliability of the data, especially if specific technical details were involved. To limit uncertainty, the study employed trained data collectors who understood the context and sanitation practices in Kericho Town. Their familiarity with Kericho Town increased the certainty that respondents' responses were interpreted correctly and that respondents did not misunderstand questions. For example, the use of structured interviews also assured that questions were consistently asked, and limited the miscommunication that could exist when using semi-structure interviews.

The study also had difficulty getting laboratory test results from the Wastewater Treatment Plant (WWTP) that could have provided useful information on the quality of treated wastewater and faecal sludge. In the absence of this information, the study could not effectively evaluate the treatment processes and how it impacted the environment. To overcome this gap, the study used secondary data from KEWASCO job cards, field observations, and interviews with experts to find out the operational status of the WWTP and Decentralized Treatment Facility (DTF). If nothing else, while not entirely

unwarranted in terms of laboratory test results, this provided an overall view of the treatment processes occurring in the township and contextualized the functioning of the treatment facilities in the township, along with the challenges encountered.

1.9. Delimitation of the Study

The study covered the geographical area of Kericho Town (186 km²) within Kericho County, Kenya, focusing on the sanitation practices and the flow of excreta across the sanitation service chain. This area was the urban jurisdiction of Kericho Water and Sanitation Company (KEWASCO) comprising of 17 sub locations namely: Kipchimchim, Kapsaos, Kapsoit, Kakiptui, Kapsuser, Chebocho, Chepkolon, Borborwet, Kipkoiyan, Ainapkoi, Kipsolu, Chepkosilen, Chepkurbet, Kapkugerwet, Motobo, Taiywet and Township. The results of this research study are not relevant to other geographical locations or urban environments because of differences in local context, sanitation innovations, and socio-economic conditions. Therefore, conclusions may not apply to towns or counties with different demographic, economic, and environmental factors.

The approach of the study used mixed-methods, therefore both quantitative and qualitative data collection methods were used. While mixed-method data collection may facilitate extensive data collection, it prevented a longitudinal assessment of changes or an evaluation of any interventions that may have taken place after the data collection period ended. Because of its cross-sectional assessment, this study provides estimates of the sanitation context at one point in time, but does not reflect historical changes nor could it measure long-term trends, or the impact of any changes in policies or improvements in infrastructure.

CHAPTER TWO: LITERATURE REVIEW

2.1. Introduction

This chapter provides an overview of sanitation, emphasizing urbanization and its impact on sanitation, faecal sludge management, access to adequate sanitation for all, and innovative approaches to address sanitation challenges. Additionally, the chapter illustrates various onsite and offsite sanitation technologies, as well as excreta disposal along the sanitation service chain. It also includes a description of the SFD methodology, detailing the creation process, levels of SFD reports, and potential uses.

2.2. Sanitation Overview Along the Sanitation Service Chain

Sanitation is defined by the WHO as the “access to and use of facilities and services for the safe disposal of human urine and Faeces” (World Health Organization, 2021). Kenya’s Draft National Sanitation Management Policy (2022) acknowledges the existing challenges in the country as result poor sector leadership, insufficient funding, poor coordination, and unclear arrangements which has hindered the delivery of equitable sanitation services at all levels (MoWSI, 2022).

Such governance failures undermine efforts to establish effective sanitation systems and contribute to the unsafe disposal of faecal sludge and excreta management in urban settings. While policy frameworks are established, their implementation remains fragmented particularly in smaller towns such as Kericho, where rapid urbanization outpaces the development of essential infrastructure. This gap in implementation underscores the need for research that evaluates the effectiveness of existing frameworks and the role of local governance in improving sanitation outcomes.

In Kenya’s urban areas faecal sludge from pits and septic tanks are often discharged into the environment, or transported and disposed of untreated into the environment (Okoth et al., 2017). The absence of safe faecal sludge disposal, increases the risk of contamination

to drinking water, street foods, and crops significantly and causes many diarrheal diseases especially in children under five (Simiyu, Chumo, & Mberu, 2021).

The ubiquity of contamination across different environmental compartments highlights the necessity for safe and regulated waste management systems that can alleviate the negative health effects vulnerable communities are already facing. Though faecal sludge management is an identified concern, there is a gap in the literature in terms of standard practice or practical solution for treatment (Devaraj et al., 2021). This study sought to fill this gap by investigating how Kericho Town can improve its faecal sludge management systems and sanitation infrastructure to reduce the health risks posed by unsafe excreta disposal practices.

2.2.1 Urbanization and its impact on sanitation services

Urbanization has emerged as arguably "The Defining Trend of our Era." As the world becomes increasingly urbanized, cities are expanding at an unprecedented pace, and migration towards urban zones continues. As of today, more than half of the world's population live in cities, a number projected to increase to 70% by 2050 (UN-Habitat, 2022).

The rapidly changing landscape of cities places great pressure on urban infrastructure, particularly with regard to sanitation and hygiene. As cities grow and therefore, the demand for sanitation services increases, yet without sufficient infrastructure on which to draw, there are enormous public health implications for cities across the world. In low- and middle-income countries (LMICs), the impact of urban growth on urban hygiene is even more severe compared to high-income countries, where this rapid urbanization growth occurs faster than the development of basic services (Bishoge, 2021). The World Health Organization (WHO) estimates that 2.3 billion people still do not have access to

basic sanitation services, with urban slums and informal settlements representing a disproportionate level of the sanitation crisis (WHO, 2022).

The combination of limited sanitation infrastructure in slum neighborhoods, combined with high density of overcrowding is a deadly combination that often leads to unsafe waste disposal, unsafe water sources, or uncontrolled disposal of hazardous waste, which all result in the potential widespread transmission of cholera, typhoid, hepatitis A (Soe, 2024). The effects of poor sanitation and hygiene contribute to a substantial public health burden, increasing morbidity and mortality, especially amongst vulnerable populations including children under five years of age.

Furthermore, the environmental burden of continuing urbanization makes the situation worse. The growth of an urban population leads to increased drinking and sanitation water demands, but the quantity of clean and safe water supplied frequently remains insufficient (Bishoge, 2021). Inadequate infrastructure for sanitation leads to deteriorated water bodies as riverbanks, lakes, and groundwater wells are contaminated by untreated sewage and faecal sludge (Tariq & Mushtaq, 2023).

These contaminants do not only affect drinking water but are also degrading agriculture and food production, further entrenching poverty and health inequalities in urban areas (UN-Habitat, 2022). Not only has waste produced cityscapes exploded but many urban environments especially those in LMICs are not equipped with systems to manage waste effectively. In particular, lack of proper treatment and disposal of solid and liquid waste as well as attempts to build treatment plants leaves urban populations at risk of health burdens. Without substantial action, it does not appear a systemic change will be made to urban waste management policies (Boogaard et al., 2024). The intersection of urbanization, inadequate sanitation infrastructure and environmental degradation is a call

for real investment, as emphasized by UN-Habitat (2022), in infrastructure with sound policy for public health not to precede environmental sustainability.

2.2.2 Faecal sludge management

Faecal sludge (FS) is a type of waste that is generated from sanitation systems located on the same site and not transported through a sewer (Velkushanova et al., 2021). FS is produced when excreta and blackwater are combined and stored or treated, either alone or in combination with greywater through onsite technologies such as pit latrines, unsewered public ablution blocks, septic tanks, aqua privies, and dry toilets. FS can be semisolid or slurry and raw or partially digested (Jothinathan & Singh, 2023). According to Simiyu et al. (2021) FS comprises partially decomposed human excreta along with wastewater, organic matter, and various pathogens, posing significant health risks if not managed properly.

Furthermore, Choudhury et al. (2024) and Nicholas et al. (2023) highlight that the distinct characteristics of FS such as; pH values, total suspended solids, biochemical oxygen demand, threshold odor, macro-and micronutrients, necessitate separate treatment strategies, as untreated FS can contribute to the spread of pathogens in vulnerable communities. However, faecal sludge characteristics differ based on location, climate, age of the sludge, type of sanitation technology and seasonality (Nicholas et al., 2023). Faecal Sludge Management (FSM) encompasses a series of critical processes, including the collection, transport, treatment, and safe disposal or reuse of fecal sludge Simiyu et al., 2021. The management strategies must be tailored to local contexts, particularly in resource-limited settings where informal and unregulated systems often dominate (Simiyu et al., 2021; Peletz et al., 2020). It is widely recognized that approximately 60% of fecal sludge produced in low- and middle-income countries is not

safely managed, leading to significant environmental and health hazards (Naing et al., 2019)

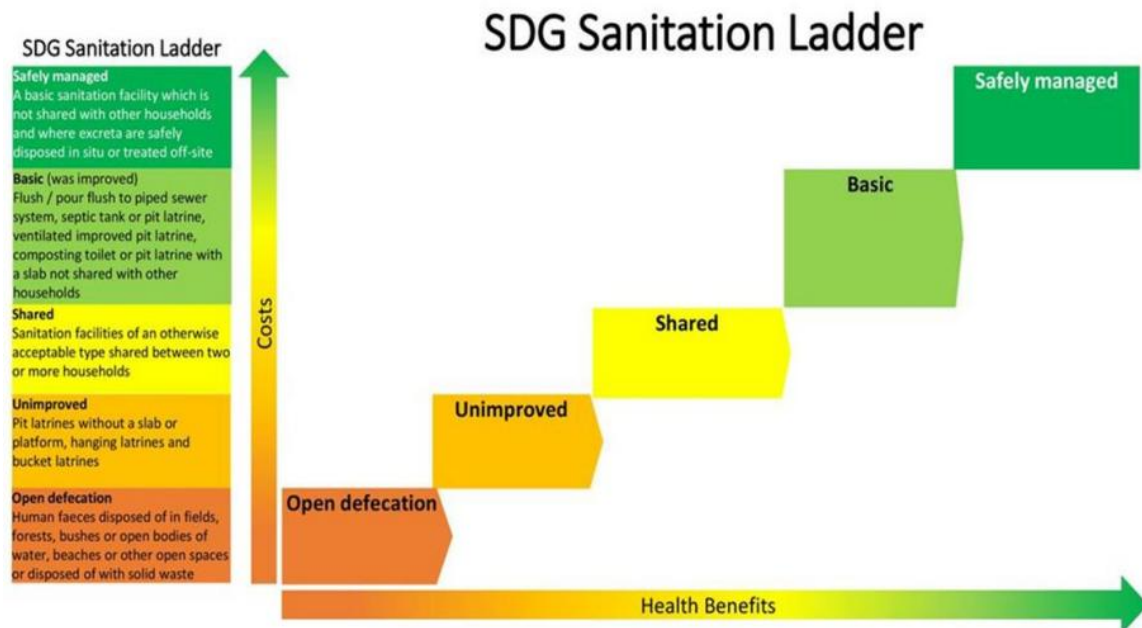
2.2.3 Adequate sanitation access for All

The SDGs framework was developed to escalate the work started by the MDGs. Goal 6 of SDG is dedicated to water and sanitation, with a specific target about sanitation: “6.2. By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation” (WHO/UNICEF, 2020). The SDG's new key indicator for sanitation is "the proportion of the population accessing safely managed sanitation services," in line with the broader viewpoint sought by institutions and experts around the world.

A basic sanitation facility (MDG "improved" indicator), one that is not shared, and one where excreta are safely disposed of on-site or transported and treated off-site make up this indicator's three key components (WHO/UNICEF, 2017b). The sanitation ladder is still being proposed as well in order to emphasise the steady development in sanitation access as shown in Figure 2.1. At a minimum, the metrics will be broken down by urban/rural, wealth, and affordability. It continues to be difficult to gather the necessary data to assess how well sanitation services are administered. The Joint Monitoring Programme (JMP) has depended on household surveys to gather data for tracking the MDGs, but this new viewpoint necessitates not just enhancing national sample surveys but also producing statistics on sanitation for each city so SDGs can truly direct policy and investment (Satterthwaite, 2016).

Figure 2.1:

Sanitation Ladder SDG:



Source:(WHO/UNICEF, 2017b)

2.2.4 Innovative Approaches to Address Sanitation Challenges

Innovative approaches to addressing sanitation problems are crucial for creating sustainable management of sanitation services, especially in rapidly urbanizing cities like Kericho Town. One such innovation is sanitation marketing, which is designed to increase the adoption of improved sanitation technologies through marketing campaigns that target populations to which they are relevant (Satterthwaite, 2017).

A more widely implemented strategy is called Community-Led Total Sanitation (CLTS), which is when communities are encouraged to take collective action for improving sanitation (Adzimah, 202). Technological approaches, including the use of mobile applications and remote sensors, can also assist in monitoring and managing sanitation systems in real time (Andres et al., 2018). Although these forms of innovation have assisted in some implementation of sanitation systems, the consistent management of fecal sludge remains un-operationalizable because there are still significant gaps in

existing sludge management in urban and peri-urban areas, which frequently remain informal and inadequate (Peal et al., 2020). Sanitation systems remain underdeveloped in some towns (like Kericho), and, generally do not have integrated operational systems, resulting in the continued contamination of water sources, and increased risks in waterborne diseases with sanitation challenges (Gituma et al., 2022).

A Shit Flow Diagram (SFD) is a tool that maps the sanitation service chain and assesses its safety. The SFD visually represents how human excreta flow through the entirety of the sanitation system, from containment and transport, to treatment and disposal. The SFD can help stakeholders identify gaps and vulnerabilities and prioritize interventions.

The SFD distills complex sanitation data into a more understandable format to enhance decision-making and reduce the risks of diseases related to poor sanitation (Panesar et al., 2022). The SFD approach has been used in several countries, including Ghana, Bangladesh, and Indonesia, to reveal significant gaps in fecal sludge management (FSM) activities and to allocate scarce budgetary resources to support areas plagued by FSM issues (Chhajed-Picha & Narayanan, 2021; Martínez, 2016; Hoque et al., 2024). Moreover, although the SFD methodology has been used in towns in Kenya, including Kisumu, Nakuru, and Eldoret (Gituma et al., 2022; Furlong, 2015), it is not documented in a town like Kericho. As a result, this gap in planning for sanitation in Kericho has neglected a comprehensive, systematic mapping the sanitation service chain for action in the town and surrounding region.

2.3. Sanitation Technologies

The term "technologies" refers to as systems and methods used to manage excreta and wastewater from collection to disposal or reuse, notably including both onsite and offsite systems (Peal et al., 2020; Tilley et al., 2014). Spuhler (2020) further refines this definition by highlighting the importance of sustainability criteria in sanitation

technologies, emphasizing environmental protection and resource recovery. Innovative approaches now integrate these criteria, aiming not only to safely manage waste but also to recover valuable resources such as water, nutrients, and energy. Recent studies by Strande et al. (2023) and Safi et al. (2022) underscore a paradigm shift in sanitation solutions. Emerging technologies increasingly focus on resource recovery, seeking to address environmental and public health challenges through integrated, eco-friendly systems.

The selection of appropriate sanitation technology is influenced by a complex interplay of user preferences and acceptability, institutional capacity and governance, technical, environmental, social-cultural, economic factors and policy and implementation arrangements (Banamwana et al., 2021; Seymour et al., 2021; Delaire et al., 2020; Donacho et al., 2022; Murray et al., 2016). For example, Murray et al. (2016) highlight that socio-economic status, local infrastructure, and available resources significantly shape the selection of sanitation systems.

In the same vein to Donacho et al. (2022) submitted that in slum areas, the most common toilet facilities are unlined pit latrines, which are often raised in response to high water tables. Other options for disposing of excreta include traditional pit latrines, the use of polythene bags (known as "flying toilets") to dispose of excreta in the surrounding environment, open defecation, and to a limited extent, ventilated improved pit latrines (VIPs) and pour flush toilets, which are used by a small number of high-income individuals.

Furthermore, a study by Seymour et al., (2021) in peri-urban South Africa found that 90% of residents preferred technologies with raised seats and water-based conveyance, highlighting the importance of comfort and familiarity.

Seymour et al. (2021) emphasize that integrating user preferences into policy and program design increases the likelihood of adoption and sustained use. Arrangement attributes such as placement, quantity, and ownership of facilities have direct implications for access and coverage. Additionally, qualitative research by Rahman et al. (2024) in Bangladesh submitted that weak institutional capacity can undermine even well-designed technologies, leading to service gaps and system failures. Effective governance, community engagement, and technical support are necessary to ensure that chosen technologies are properly managed and maintained over time.

2.3.1 Onsite sanitation technologies

Onsite sanitation refers to the collection, treatment, and disposal of human excreta at or near the point of generation, without reliance on a centralized sewerage system. It is a critical solution for regions where conventional sewerage is technically or economically unfeasible especially in rural and peri-urban areas of low- and middle-income countries (Patwa, et al., 2024).

Technologies under onsite sanitation include pit latrines, septic tanks, ventilated improved pit latrines (VIPs), composting toilets, and more recently, container-based systems. These systems are particularly relevant due to their affordability, adaptability to low-density settlements, and potential for safe waste management when properly maintained (Conaway et al., 2023; Nasim et al., 2022). In rural and peri-urban contexts, onsite sanitation serves as the backbone of public health infrastructure, helping prevent fecal-oral disease transmission, protect water resources, and ensure dignity in communities often overlooked by large-scale sanitation investments (Kabange, 2017; Appiah-Effah et al., 2014). However, challenges remain, such as poor sludge management, limited technical oversight, and environmental risks from poorly constructed or maintained systems. (Verma et al., 2020; Zaghloul et al., 2024).

Addressing these gaps through integrated fecal sludge management (FSM) strategies and context-sensitive design is essential for sustainable sanitation.

Pit latrines consist of a hole in the ground to collect and store human waste, a user-interface pan and a superstructure for privacy. Pit latrines, when constructed properly, can hygienically separate human excreta from human contact and reduce the transmission of fecal–oral-transmitted diseases (Hussain et al. 2017; Saxena & Den ,2022). Studies have reported pit latrine to be common sanitation option in rural, peri-urban areas and low-settlement (Gitonga et al., 2021; Ssemugabo et al., 2020; Tidwell et al., 2018). Tidwell et al. (2018) conducted a study in Zambia to investigate the quality of sanitation facilities by assessing 918 lavatories in Bauleni using observation checklists.

The authors reported that while 87% of the facilities were structurally improved and nearly all were shared, significant operational deficiencies remained. Most plots had toilets with solid walls (87%), solid doors (73%), and walled pits (80%), but over half lacked a sturdy roof (52%) and efficient cleaning systems (43%). Notably, only 36% could be mechanically emptied and just 29% incorporated odour-reduction technologies. The study underscore that physical infrastructure alone does not ensure sustainable or hygienic sanitation. Tidwell et al. (2018) thus established a foundational understanding of urban slum sanitation challenges. However, study findings may not be directly applicable to Kericho’s unique environmental, socio-economic, and infrastructural context. This creates a critical gap, warranting localized research in Kericho to evaluate whether similar operational shortcomings exist and to inform context-sensitive sanitation interventions.

Ssemugabo et al. (2020) conducted a study in Ethiopia, reporting that more than 90% of pit latrine had doors and roofs. However, offensive smells and flies were observed in

49.0% and 63.2% of the facilities, respectively, highlighting a significant gap between structural improvement and hygiene.

Additionally, only 22.7% of the sanitation facilities were equipped with handwashing stations, and among those, only 78% provided a jerrycan with water and soap. These findings emphasize that while basic infrastructure improvements are vital, effective sanitation hinges on operational aspects like hygiene maintenance, pest control, and handwashing provisions. Ssemugabo et al. (2020) highlighted the importance of considering these operational factors in sanitation assessments. This gap underscores the need for similar studies in Kericho to evaluate whether issues such as poor hygiene maintenance and lack of handwashing facilities are prevalent in the town's sanitation infrastructure, which could guide more comprehensive interventions.

A World Bank analysis on Lake Victoria Basin Lake-wide Inclusive Sanitation (LWIS) conducted in April 2023, covering 19 towns including Kericho, reveals that 8.8% of the town's sanitation relies on septic tanks, 13.5% on ventilated improved pit latrines (VIPs), 62% on unlined pits, 9.1% on lined pits, and 1.3% of the population has no sanitation facilities (Odeya, 2023). The high proportion of the population lacking sanitation facilities or relying on unlined pits highlights significant public health risks, particularly in terms of waterborne diseases and environmental pollution. However, study by Odeya (2023) did not investigate the quality aspects of these sanitation facilities, which are crucial for understanding their effectiveness.

While pit latrines are a common sanitation option in many areas, they do have some drawbacks. Saxena and Den (2022) reviewed recent advancements in in-situ treatment technologies for pit latrines and alluded that pit latrines are used not only for human waste but also for the disposal of solid waste. This practice increases the frequency of pit

latrine emptying, as solid waste decomposes more slowly than human waste, creating blockages.

The absence of solid waste management systems exacerbates this issue. Saxena and Den (2022) added that pit latrines impact groundwater quality that may affect human health. In the same vein, Simwambi, et al. (2023) observed that the presence of solid waste in pit latrines in peri-urban areas in Lusaka delayed the emptying process and led to public health risks. Authors argued that solid waste in sludge has made it difficult for pit-emptier's and treatment plant operators to effectively empty and treat pit latrine sludge respectively due to cumbersome tasks of separating the waste from the sludge.

Similar, challenges were submitted in, a study in Nakuru Town, Kenya by Gudda et al., (2019). The study revealed that a majority of the pit latrines were used for solid waste disposal which could lead to high filled up rate and a significant percentage of respondents had no hygiene awareness practices, which could endanger public health. The study highlights the need for further research and management strategies to address the sanitation challenges in low-income urban settlements. While findings by Gudda et al., (2019), Saxena and Den (2022), and Simwambi, et al. (2023) demonstrated challenges regarding pit latrine, findings could not be directly applicable to Kericho Town

Pit latrines are often unsuitable for regions with high water tables or in flood-prone areas. Othoo, (2021) examined the impact of climate extremes, specifically floods, on sanitation infrastructure in Kisumu, Kenya, finding that such environmental factors compromise the structural integrity of pit latrines. The study reported that flooding increased the likelihood of latrine overflows, further exacerbating the spread of diseases in flood-prone, informal settlements.

A septic tank is a rectangular watertight structure used to treat liquid waste with high settleable solids. Septic tanks serve as affordable anaerobic reactors for wastewater

treatment. A standard septic tank system comprises two main components: the septic tank and a network of field lines that are placed within an absorption field (Tabassum, 2024). Septic tanks are widely used in regions where centralized sewage systems are unavailable, often serving as a practical solution for treating domestic wastewater (Rodrigues Mesquita et al., 2021).

They are valued for their relative simplicity in construction and maintenance compared to centralized systems. However, while septic tanks are effective when properly maintained, their performance depends significantly on regular upkeep, which is often neglected, leading to adverse environmental and public health outcomes. According to US Environmental Protection Agency (2024) recommends to empty the septic tanks every 3–5 years or when biosolids exceed 25% of their volumes.

The time it takes for a septic tank to fill up depends on the size, lining type, soil type, rainfall and groundwater level (Sharada Prasad & Ray 2019). A study by Arévalo et al. (2024) in Cuenca, Ecuador to determined septic tank usage and its faecal sludge management, submitted that households using septic tanks, the majority (92.2%) do not empty their tanks but infiltrate the leachate into the soil, followed by those who report discharging it anywhere in the open (6.9%), thus endangering public health, and environmental health such as water sources. The authors recommended for urgent need improve sanitation practices and services.

In agreement a study by Flanagan et al. (2020) in coastal Florida watersheds examined the spatial distribution of septic systems and their potential impact on ground and surface water contamination. The study highlights the potential impact of septic tanks in urban areas with high runoff on surface water contamination and emphasizes the importance of data availability in addressing this issue. The findings was confirmed by Ochiba et al., (2021) study in Ongata Rongai town, Kajiado County evaluated the levels of heavy

metals groundwater samples from ten boreholes, during the dry and wet seasons and found high levels of manganese metals above the recommended levels of 0.01 mg/l by the World Health Organization and Kenya Bureau of Standards

Empirical literature on OS such as septic tanks, their maintenance, and challenges in emptying highlights several key issues, especially in low- and middle-income countries (LMICs) and rural areas. According to Taweesan et al. (2015) and Arévalo et al. (2024), a city or town should have at least one vacuum truck per 1,000 households to achieve an FS collection with more than 80% efficiency.

However, Arévalo et al. (2024) noted that Cuenca, Ecuador has two emptying trucks serving 5,636 active septic tanks, high deficiency which could lead unsafe practices such as manual emptying. A study by Mremi et al. (2025) in Tandale, Dar es Salaam to determined insights into manual emptying of onsite systems. The study found that with 70.8% of residents were using pit latrines, 27.1% using septic tanks, and the remainder utilizing eco-friendly options like Aqua privies (0.3%) and Eco-san (1.8%), commenting sanitation systems are shaped by the practical and financial realities such as ease of emptying, cost, Comfort in use, land availability and resilience to rainfall impacts. Mremi et al. (2025) reported that emptying was necessary as space is limited for digging new pits. The study noted 52.4% of households use vacuum trucks, while manual emptying remains a significant practice at 24.9%, with 5.7% of residents discharging waste directly into drains and 17.0% never emptying their latrines.

The authors argued unsafe emptying practice poses significant health risks to workers and residents, including exposure to pathogens, toxic gases and hazardous chemical. Mremi et al. (2025) alluded those geographical and topographical characteristics such as difficulty in accessing pit latrines, unplanned construction, and flooded areas, significantly hinder effective FSM. This highlights the urgent need for improved

infrastructure, equipment, and regulatory frameworks to support safer and more sustainable sanitation practice.

A systematic review by Conaway et al. (2023) examined emptying practices for pit latrines and septic tanks across various low- and middle-income countries, with a focus on Sub-Saharan Africa and South Asia. The study highlighted several barriers including financial limitations, lack of awareness, and insufficient sanitation infrastructure, which hinder the safe and efficient transportation of sludge.

The authors suggest that improving waste management technology and regulatory standards is essential for reducing health risks and improving the sustainability of sanitation systems. Similarly, a scoping review by Tomoi et al. (2023) on the willingness to pay for faecal sludge management services pointed out that while pit latrines and septic tanks are widely used, emptying services are often expensive and unaffordable for many households. In agreement a study Chumo et al. (2023) in Nairobi, Kenya to examined sanitation services for the urban poor and found that the social, technical, and financial challenges in transporting and emptying faecal sludge. The study found that poor access to formal services and inadequate infrastructure exacerbate the sanitation problems in urban slums. The research emphasized the need for improved coordination between service providers, local authorities, and communities to enhance the effectiveness of sludge management.

2.3.2 Centralized treatment

Centralized treatment involves the collection and treatment of wastewater from multiple sources in a central location. This can include technologies such as sewage treatment plants, which use physical, biological, and chemical processes to treat wastewater (Smarzewska, & Morawska, 2021).

According to a report by WaterAid, (2020) in many African countries, financial constraints, poor governance, and inadequate infrastructure limit the effectiveness and expansion of centralized wastewater treatment plants (WWTPs). For example, in Zimbabwe and Kenya, lack of funds and inefficient management have led to underperforming or non-functional centralized facilities, especially in rural or less populated areas (Omohwovo, 2024).

They may not be feasible in areas with limited resources or where the population density is too low to justify the cost of building and maintaining a centralized system. Additionally, centralized sewer systems may not be suitable for areas with poor soil conditions or where there is a high risk of flooding (Tilley et al., 2014; Muziorev et al., 2022).

Over 80 per cent of the world's wastewater and over 95 per cent in some least developed countries is released to the environment without undergoing any form of treatment (United Nations Environment Programme, 2019; Li & Yuan, 2024), which leads to severe environmental degradation such as eutrophication, loss of biodiversity, and poses significant risks to human health through the spread of waterborne diseases and contamination of food and water supplies; for example, untreated sewage caused an outbreak of skin rash at Porto Pim Beach in Faial, which was traced to a leaking underground sewage distribution box servicing the beach toilet facilities, contaminating the sand with fecal bacteria and chlorine-based irritants (Brandão et al., 2020). Similarly, in West Africa a research was carried out by Houemenou et al. (2020) to investigate the decline in the quality of groundwater in uncontrolled shallow aquifer in Cotonou linked deteriorating quality to leaking sewer systems.

Insufficient sanitation infrastructure not only pollutes the environment but also infiltrates every aspect of society, amplifying the strain on public health, resulting in diminished

economic activity and hindering overall development prospects. According to the UN, investing in sanitation yields a substantial return to society, with an estimated benefit of 5.5 USD for every USD spent (UN WWAP, 2017). Wastewater discharge standards, set nationally for centralized treatment systems in significant receiving environments, focus on the assimilative capacity of water bodies (Borah et al., 2023).

These standards can be concentration-based or load-based, with concentration-based standards being more common despite their tendency to discourage wastewater treatment due to reliance on dilution. Concentration-based standards specify the allowable levels of pollutants (e.g., mg/L) in discharged water. While widely adopted due to their simplicity, they often promote a reliance on dilution rather than actual treatment.

This can lead to unintended consequences, such as underinvestment in treatment technologies and a false sense of environmental protection when discharges are simply diluted to meet limits. In contrast, load-based standards regulate the total mass of pollutants released over time (e.g., kilograms per day), offering a more integrated approach. One notable example is the Total Maximum Daily Load (TMDL) system in the United States. TMDLs are designed by evaluating both the natural background conditions of a water body and the cumulative impact of pollutant sources, ensuring that ambient water quality standards are met.

This approach also considers local stakeholder needs and preferences, making it more adaptable and context-sensitive (Borah et al., 2023). In contrast, load-based standards, like the Total Maximum Daily Load (TMDL) in the US, consider both ambient water quality and effluent discharge, aiming to ensure compliance with water quality standards while accommodating stakeholder preferences for water use (Borah et al., 2023)

Various countries establish their wastewater standards based on different attributes of treated wastewater, with Biochemical Oxygen Demand (BOD) being nearly universally

utilized as a key metric (Schellenberg et al., 2020). In Kenya, the Biochemical Oxygen Demand (BOD), measured over 5 days at 20°C, is capped at a maximum of 30 milligrams per liter (mg/l).

The Chemical Oxygen Demand (COD) level is restricted to 50 mg/l. Additionally, the total coliform count is set at nil, as is the count for *E. coli* (NEMA,2006). Non-compliance can therefore result in environmental degradation, increased disease burden, and potential legal and regulatory penalties for responsible entities. High BOD and COD levels reduce oxygen availability in receiving water bodies, leading to aquatic ecosystem collapse and increased waterborne disease prevalence. Elevated microbial counts, particularly *E. coli*, are direct indicators of fecal contamination and pose serious pathogenic risks to surrounding communities. Thus, for the SFD to serve not only as a diagnostic but also as a policy-informing tool, it is critical to assess whether treatment facilities in Kericho Town comply with these parameters.

2.3.3 Gaps on sanitation technologies

Kericho Water and Sanitation Company (KEWASCO's) unpublished reports indicate that septic tanks and pit latrines are the predominant sanitation technologies in Kericho Town, functioning alongside a deteriorating centralized sewer system (Kericho Water and Sanitation Company, 2022). However, the safety of these systems remains largely undocumented, raising significant public health and environmental concerns.

Empirical studies have shown that poorly designed or inadequately maintained septic tanks and pit latrines can contribute to groundwater contamination, especially in areas with high water tables or dense settlements (Flanagan et al.,2020; Tomoi et al., 2024; Alam et al., 2025; Nyika & Dinka, 2025).). Similarly, a dilapidated sewer system can lead to untreated wastewater discharges into open drains and surface water bodies, exacerbating disease outbreaks and degrading urban ecosystems.

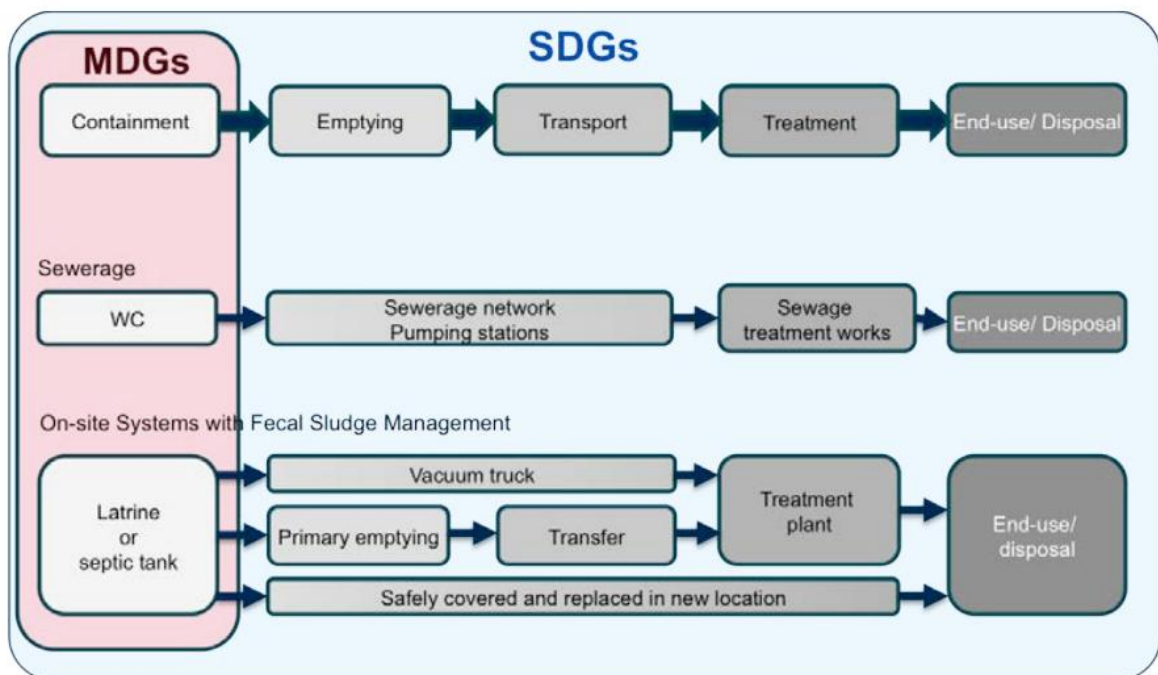
Determining the safety of these technologies is critical for designing an accurate Shit Flow Diagram (SFD), which relies on credible data about containment, emptying, treatment, and disposal practices. This diagnostic tool not only visualizes how excreta flow through the sanitation chain but also identifies where health and environmental risks emerge.

2.4. Excreta Disposal Through the Sanitation Service Chain

Hawkins (2016) and Peal et al. (2020) introduced a more comprehensive interpretation of sanitation management aligned with the Sustainable Development Goals (SDGs), building upon the narrower focus of the earlier Millennium Development Goals (MDGs) as illustrated in Figure 2.2.

Figure 2.2:

MDGs vs SDGs



Source:(Hawkins, 2016)

Van Puijenbroek (2023) and Strande et al. (2021) advanced this perspective by defining sanitation as a dynamic, multi-step continuum that includes generation, containment,

emptying, transport, treatment, and eventual disposal or reuse. Patwa et al. (2024) echoed this characterization, emphasizing that effective sanitation services rely not only on technological solutions but also on system-wide coordination.

This comprehensive outlook has facilitated the development of citywide inclusive sanitation (CWIS) approaches, which enable urban authorities to identify bottlenecks, assess system performance, and prioritize investment. Mapping sanitation as a chain of interconnected services allows for improved resilience planning in rapidly urbanizing areas (UN-Habitat, 2023). Importantly, Musaaazi (2020) argued that a break at any point such as inefficient transport or improper containment could lead to serious public health risks, including groundwater contamination, exposure to pathogens, and heightened vulnerability of marginalized populations.

Using sewers to empty and transport sewage from containments to a centralised treatment plant, off-site sanitation (also known as sewerage systems (see Figure 2,2), connects latrines to a treatment plant away from the plot where excreta and wastewater are generated (Tilley et al., 2014). Excreta and wastewater are collected, stored, or treated on the plot where they are created in onsite sanitation (also known as non-sewered sanitation (see Figure 2,2) which is an FSM service (Hawkins, 2016). The most popular remedy in emerging nations' cities is on-site sanitation.

All steps in the service chain must function properly for the sanitation service to be safely managed, which is what the SDG 6 seeks to achieve (Peal et al., 2020). Any malfunction or gap in containment, transport, or treatment stages may result in the uncontrolled release of human waste into the environment, leading to serious health consequences.

The implications extend to economic productivity and gender equity, as inadequate sanitation often disproportionately affects women and girls in terms of safety, privacy,

and educational opportunities. The World Health Organisation (2021), sanitation is described as having access to and using conveniences and amenities for disposing of human excreta safely. Besides preventing infections, safe sanitation continues to be vital for health as it also brings about one's enhanced and preserved mental and social well-being.

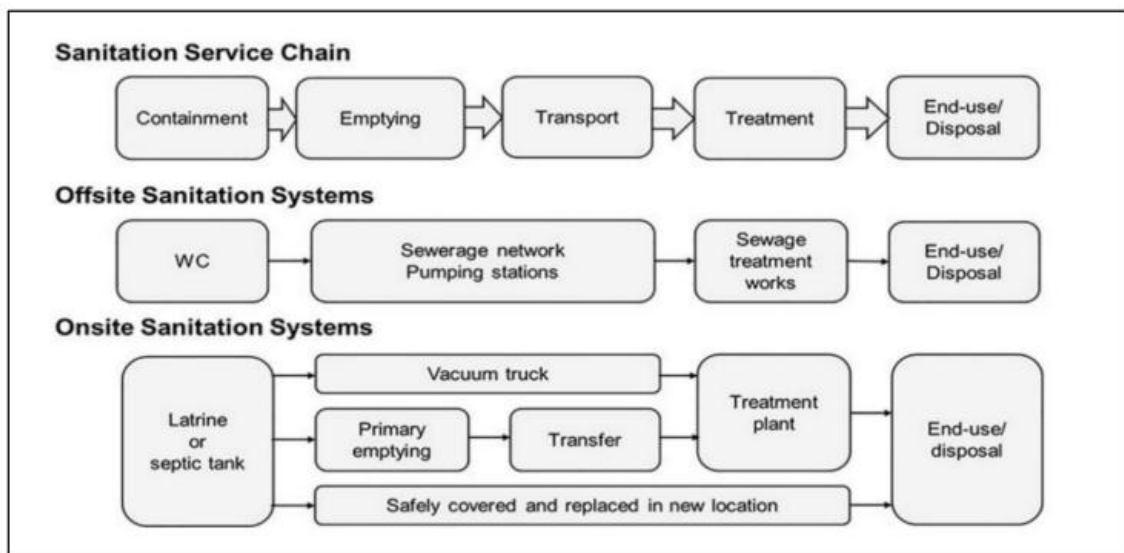
2.4.1 Sanitation systems

A safe sanitation system is defined by a collection of technologies and provisions designed to collect, contain, convey, treat and dispose of human excreta without any direct contact with humans throughout the SSC (see Figure 2.3).

) is defined as a safe sanitation system (Tilley et al., 2014). The sanitation service chain encompasses the seamless integration of collection, containment, conveyance, treatment, and disposal, ensuring a holistic and secure management of human excreta.

Figure 2.3 :

Sanitation Service Chain



Source: (Safi et al., 2022)

The two primary categories of sanitation systems are centralized and decentralized, often referred to as offsite and onsite sanitation, respectively (Sood et al., 2023). In offsite sanitation systems, the user interface is typically installed within the household and connected to a network of sewers responsible for transporting sewage (a mixture of urine, faeces, and wastewater from bathrooms and kitchens) to a treatment plant (Lehtoranta et al., 2020; Gitonga et al., 2021).

Lehtoranta et al. (2022) found that in Hiedanranta, Finland, sewer-based systems efficiently handled combined wastewater flows, offering operational advantages in dense urban settings. Similarly, Gitonga et al. (2021) observed in Kenyan cities that well-managed offsite systems ensured hygienic excreta removal and treatment, contributing to sustainable urban sanitation. These sewer-based systems, including conventional gravity sewers, simplified sewers, and solids-free sewers, consist of underground pipe networks (Lambiasi et al., 2024).

Conversely, onsite sanitation systems collect and store excreta (urine and faeces) at the point of generation. The contents, known as faecal sludge, are then discharged and transferred for treatment or burial on-site (Safi et al., 2022; Tilley et al., 2014). Various sanitation technologies, such as septic tanks, holding tanks, biodigesters, enviro loo, water potties, ventilated improved pits (VIPs), and pit latrines, are employed to collect and partially treat waste directly at the source (Lambiasi et al., 2024). Holding tanks, water potties, and enviro loo technologies are fully enclosed containers emptied once they reach capacity (Lambiasi et al., 2024). Septic tanks and biodigesters typically incorporate a soak pit or draining well to manage the supernatant (top layer liquid), with the remaining faecal sludge emptied once full (Lambiasi et al., 2024; Tilley et al., 2014). Open defecation (OD) refers to the absence of toilet facilities, leading to the use of the environment for defecation (Birasa et al., 2024). Safe sanitation systems are crucial in

providing secure sanitation with a significant impact on health. In the SSC the term "containment" encompasses both the toilet and the equipment immediately following it in the SSC (Peal et al., 2020; SFD-PI, 2018b). Transport involves the human or mechanical transfer of faecal sludge from onsite sanitation facilities and the conveyance of sewage through a pipe network (SFD-PI, 2018b). Instances such as sewer spills due to blockages, uncontrolled sewage releases into open drains, and untreated excreta are considered not safely managed (Peal et al., 2020). Treatment, as defined in the SSC, refers to any method that renders the physical, chemical, or biological composition of wastewater safe for end-use (SFD-PI, 2018b).

In the realm of citywide sanitation, the SSC provides technical insights, but effective service delivery necessitates an enabling environment (Sankara Narayan, 2022). An enabling environment comprises supportive policies, institutions, and public and private stakeholders committed to instigating necessary changes (Lüthi et al., 2010). The enabling environment consists of six critical components:

- i. Government support: Involving political buy-in and a willingness to support sanitation interventions,
- ii. Legal framework: Encompassing policies, regulations, and laws,
- iii. Institutional arrangement: Defining explicit responsibilities, roles, and mandates of various institutions,
- iv. Skills and capacities: Encompassing the necessary professions, expertise, and relevant skills,
- v. Financial arrangement: Entailing the availability of funding and related aspects,
- vi. Social-cultural acceptance: Implying contextual considerations to meet the needs of the local people.

2.4.2 Institutional arrangements for sanitation

Kenya has a complicated and disjointed institutional structure for sanitation that extends from the national level to local levels in counties, cities, utilities, and communities. The institutional framework for WASH at the national level includes a variety of ministries, departments, and organizations, such as the Ministries of Health, Water and Sanitation, and the Environment, as well as the Water Works Development Agencies (WWDAs), Water Services Regulatory Board (WASREB), and NEMA, as well as non-state actors from the private sector and development partners (USAID,2021). These entities are supported by non-state actors from the private sector and development partners, making coordination both vital and challenging.

At the county level, the institutional framework for Water Sanitation and Hygiene (WASH) includes the departments of health, the environment, water, urban development, and physical planning, education, urban authorities (City and Municipality Boards and Town Committees), water service providers (utilities), the private sector, Non-Governmental Organisations (NGOs), and Community Based Organisations (CBOs). In cooperation with the national regulatory bodies, county governments are in charge of establishing and upholding policies, laws, regulations, and standards within their respective jurisdictions (USAID,2021; Korir, 2020; Ng'ang'a & Mbataru, 2022). The county governments also have the authority to transfer control of water and sewage systems to municipalities, cities, and other lower-level entities like communities and villages.

Within licensed territories, WSPs are responsible for delivering water and sewerage services and developing county infrastructure. However, the overlapping responsibilities between national and county bodies, coupled with a lack of coordination, often result in inefficiencies and duplicative efforts (Korir, 2020; Otieno, Obosi, & Magutu, 2023). A

further institutional challenge lies in the lack of trained professionals. Kenya faces a shortage of skilled human resources in the sanitation sector, and current education and training programs are outdated and underfunded (USAID, 2021). These gaps hinder progress toward achieving the Sustainable Development Goal (SDG) target 6.2, which aims for universal access to equitable sanitation and hygiene by 2030.

2.4.3 Evaluating the city's sanitation system

Because most cities lack the capacity to provide networked sanitation for everyone and they will not be able to do so in the near future, FS is anticipated to play a significant role in managing public and environmental health as a long-term solution or, at least, for the next few years (Peal et al., 2014a). In order to discover and create efficient operations in urban sanitation, more systematic approaches to analysis and understanding the FSM and the sanitation service chain as a whole in the cities are required (Kapulu, 2021).

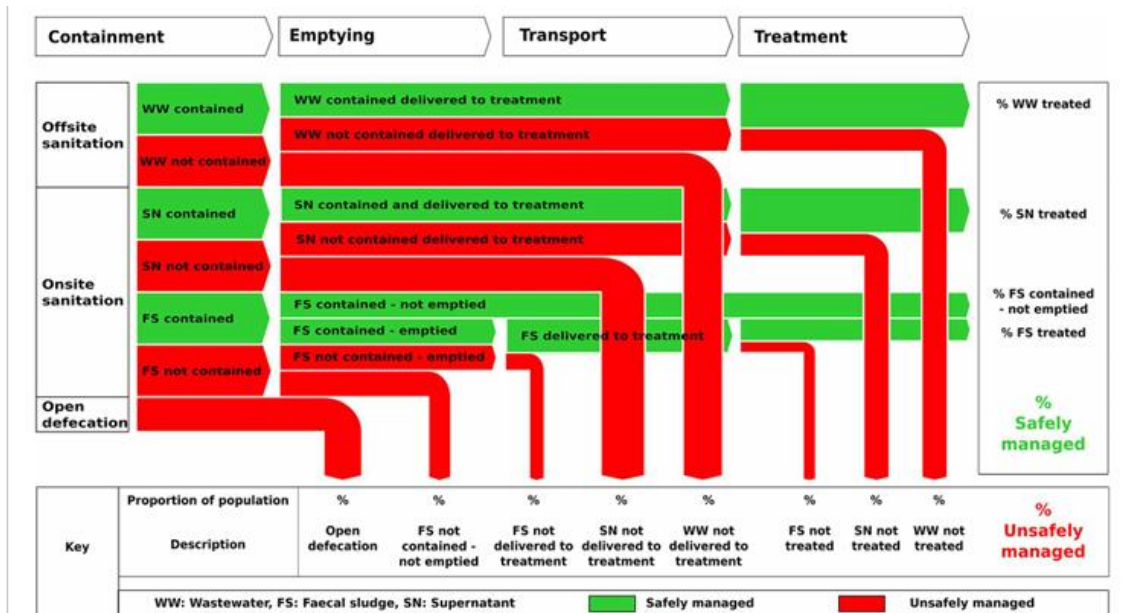
To “create analysis tools that may be used to appraise FSM at the city level and identify relevant operational action”, the World Bank, through the WSP, studied the trends in FSM using 12 cities (Musonda, 2020). This led to the creation of two tools, one of which uses a Service Delivery Assessment (SDA) Scorecard to evaluate the enabling environment.

The percentage of people whose FS is securely managed along the sanitation services chain is displayed by the other tool, known as the Shit Flow Diagram. In an SFD as shown in Figure 2.4 , green arrows represent safely managed faecal waste, while red arrows denote unsafe pathways highlighting the proportions of excreta lost to the environment due to inadequate containment, emptying, transport, or treatment (SFD-PI, 2018). Building on this study, a collection of organizations with the Bill and Melinda Gates Foundation's financial assistance created the SFD Promotion Initiative and tested

the SFDs and the service delivery context tool in 200 different cities around Africa, Asia, and Latin America (SuSanA, 2023).

Figure 2.4:

SFD graphic used in SFD production process



Source: (SFD-PI, 2018)

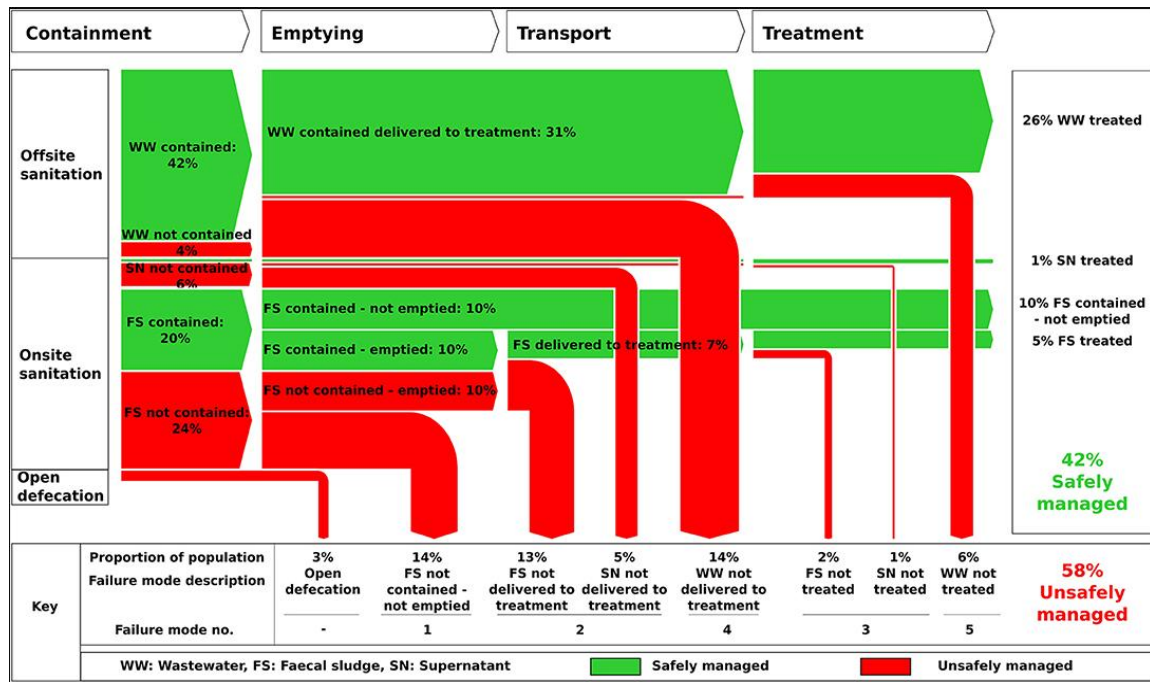
A comparative study by Peal et al. (2020) assessed sanitation service delivery in 39 cities across Africa, Asia, and Latin America using Shit Flow Diagrams (SFDs) as shown in Figure 2-5. With a combined urban population of 72 million, the analysis revealed that only 42% of excreta was safely managed, 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%). Particularly poor performance was noted in cities like Dhaka (Bangladesh), Solapur (India), and Kumasi (Ghana), where less than 10% of excreta was safely managed. The findings underscore the systemic weaknesses in urban sanitation, especially in cities heavily reliant on onsite systems without adequate infrastructure for

emptying or treatment. This global evidence reinforces the utility of SFDs in diagnosing urban sanitation failures and prioritizing interventions in line with SDG 6.2.

Figure 2.5 :

SFD Graphic for the 39 cities



Source: (Peal et al., 2020)

The Nkubu Town, SFD, represents a typical peri-urban setting with predominantly onsite sanitation systems. According to Gituma et al. (2022), 45% of residents use pit latrines, 40% use septic tanks, and only 28% of excreta is safely managed across the sanitation chain. The Shit Flow Diagram (SFD) revealed major leakages at containment and treatment stages, with only 40% of collected sludge receiving adequate treatment. Furthermore, 82% of latrines were located uphill from groundwater sources, exacerbating contamination risks.

Challenges included a high-water table, limited treatment facility access, and prohibitive service fees (Gituma et al., 2022). These conditions contribute to the release of untreated waste into the environment, evidenced by local water testing that confirmed E. coli and

coliform presence. Nkubu's case underscores the urgent need for decentralized treatment solutions, improved policy enforcement, and context-specific infrastructure planning to achieve citywide inclusive sanitation goals.

The Nakuru city SFD shows that, only 36% of excreta in Nakuru is safely managed, with the remaining 64% unsafely discharged, primarily due to untreated or improperly contained waste (Furlong 2015). The city relies heavily on onsite sanitation, with 57% of residents using basic unlined pit latrines, many of which are manually emptied and disposed of into the environment. Although Nakuru has two sewage treatment plants (Old Town and Njoro), operational inefficiencies such as leakage, underuse, and partial treatment undermine their effectiveness.

The sewer network only serves 28% of the population, and treatment quality is compromised by infrastructure deterioration. Manual emptiers operate under informal arrangements, highlighting governance gaps (Furlong 2015). While efforts like the introduction of EcoSan and sludge transfer stations offer promise, systemic improvements in FSM, regulation, and investment are needed to achieve citywide inclusive sanitation in Nakuru.

Drawing from global and regional cases such as Nakuru and Kisumu (Furlong, 2015), Nkubu (Gituma et al., 2022), and Kanyama in Lusaka (Musonda, 2020), it is evident that cities without structured assessments often underestimate the scale of fecal waste mismanagement. An SFD offers a practical, evidence-based visual tool to quantify safely and unsafely managed excreta, identify critical failure points, and support local authorities in prioritizing interventions (Peal et al., 2020). For a town like Kericho characterized by fragmented infrastructure, expanding informal settlements, and increasing pressure on water resources designing an SFD would enable a comprehensive

evaluation of existing sanitation practices, promote data-driven planning, and inform investments aligned with Sustainable Development Goal 6.2.

2.4.4 Data on service provision and environmental sanitation situation

The expansion of basic sanitation for urban poor people has been supported by the Water Sector Trust Fund through funding sanitation development projects through water utilities. The Vision 2030 Goal may not be achievable without such concentrated efforts to bridge the significant capital investment needed for the development of sewerage systems and universal access to sewerage sanitation services (WASREB, 2022).

The scope of Environmental Sanitation includes the proper management of Liquid waste such as wastewater and faecal sludge, as well as solid waste, drainage systems, public cleaning, and other related activities. In the 2017-2037 Integrated Strategic Urban Development Plan for Kericho Town reports that the current Waste Water Treatment Plant (WWTP) is not able to meet the current and future demands (CGoK, 2017). As a result, it is essential to prioritize environmental sanitation, along with other community needs, in the urban area to address this critical issue.

2.4.5 Standards for effluent discharge into the environment

Effluent discharge, the release of treated or untreated wastewater into the environment, poses significant challenges to ecosystem health and human well-being (Muruganandam et al., 2023). To mitigate the adverse effects of effluent discharge, regulatory standards have been developed globally to establish acceptable levels of pollutants in discharged wastewater. The establishment of regulatory frameworks is a crucial step in managing effluent discharge. International organizations such as the WHO and the EPA have played pivotal roles in setting global and national standards, respectively. The WHO Guidelines for Safe Recreational Water Environments provide comprehensive recommendations for managing effluent discharge to protect public health (WHO, 2019).

In Kenya, it is forbidden for individuals or entities to release wastewater from sewage treatment facilities, industrial processes, or other discharge points into the environment without holding a valid effluent discharge license issued by the NEMA (NEMA, 2006). NEMA has established water quality standards outlined in the Environmental Management and Coordination (Water Quality) Regulations of 2006 (NEMA, 2006). The third schedule specifically outlines the standards for effluent discharge into the environment including limits for parameters such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) among others. However, challenges arise in the effective enforcement of these regulations, as observed in the case of rivers such as Nairobi River, where compliance with these standards has not been consistent. Despite discussions in 2019 about prosecuting polluters of Nairobi River (NEMA, 2019), the water quality in the river has not shown significant improvement (Africanews, 2023). This raises concerns about the practical implementation and enforcement of regulatory measures, highlighting the need for more robust mechanisms to ensure compliance and address ongoing environmental degradation.

2.4.6 Gaps in Sanitation Service Delivery

Despite global progress in urban sanitation, significant gaps remain in the service delivery chain, particularly in developing countries like Kenya. These gaps manifest across both onsite and offsite sanitation systems, impairing the ability of cities to ensure safely managed sanitation for all. One of the foremost technical challenges lies in the poor operation and maintenance (O&M) of sewer networks. In many urban contexts, this results in recurrent failures at pumping stations, leakages in aging sewer pipes, and non-functional wastewater treatment plants, which operate far below capacity or are completely idle (Obradović et al., 2023). Even where infrastructure exists, O&M

negligence leads to frequent system breakdowns, exposing communities to raw sewage and exacerbating environmental pollution.

In the case of onsite sanitation, the gaps are even more severe. FSM services in informal settlements are typically unregulated, informal, and rarely monitored by public agencies (Singh et al., 2022; Chibwe, 2024). As a result, faecal sludge is often dumped illegally, buried in backyards, or discharged into open drains. Only a fraction is emptied by professional vacuum tankers, and many latrines are inaccessible due to narrow streets, unplanned layouts, or poorly designed containment systems (Juliet, 2022).

These conditions increase the risk of groundwater contamination and disease outbreaks. Moreover, stakeholder engagement and institutional coordination are critically lacking. Many cities suffer from fragmented governance, where multiple actors share overlapping responsibilities with little collaboration. Weak regulatory frameworks and insufficient public investment discourage private sector participation and innovation (Choge, 2021; Singh et al., 2022). Consequently, business models for FSM remain underdeveloped, and services are often unaffordable or absent in low-income neighborhoods

Poor coordination in responsibility sharing and business model development due to inadequate knowledge for sanitation planning and stakeholder participation at institutions and communities (Blackett et al., 2014; Medland, 2015) contributes to poor sanitation. Also lacking a stable tenure, tenants depend on landlords to provide amenities, but they typically prefer to invest in buildings that generate more income than latrines, and tenants are typically not permitted to erect permanent structures on a landlord's property (Medland, 2015).

From a planning perspective, many sanitation systems suffer due to the lack of spatially-informed designs. Latrines are often built without considering access for desludging, making future emptying impossible without damage or high cost (Mallory, 2018).

Furthermore, due to the absence of dedicated faecal sludge treatment facilities, collected sludge is often dumped at wastewater treatment plants, undermining their design and performance (Juliet, 2022).

Lastly, reuse and resource recovery from treated sludge remains marginal or absent in most cities. Without market incentives or technical support, treatment ends in disposal rather than beneficial reuse in agriculture or energy. In flood-prone zones, where containment structures overflow or collapse, the situation is even more dire resulting in the uncontrolled release of pathogens into the environment (Choge, 2021). To address these gaps, cities must conduct city-specific service chain analyses, such as through the development of Shit Flow Diagrams (SFDs). These tools help map the exact flows of faecal sludge, identify leakage points, and support data-driven planning. For Kericho town, which lacks an SFD, initiating such an analysis would provide a foundation for sustainable investment, institutional reform, and community-centered sanitation planning.

2.5. Description of SFD Methodology

The SFD is a visual tool that shows how excreta flow through the sanitation system of a city, from defecation to disposal. The SFD helps identify bottlenecks, areas of high risk, and opportunities for improving the safety of sanitation practices in a specific location. It provides a clear picture of the sanitation system, which can be used to inform policymakers and stakeholders in the sanitation sector (Andy et al., 2015; Evans et al., 2020; Kipkoech, 2024).

2.5.1 SFD creation process

The SFD-PI project, an improvement upon the approach formulated by Peal *et al.* in 2014 offers a comprehensive SFD Manual on their website that outlines the process for creating SFDs (SFD-PI, 2018b). The manual includes standard definitions, assumptions for modelling excreta flows, suggested data sources for estimates, methods for

stakeholder consultation, data collection and verification procedures, guidance questions for assessing service delivery context, and a standard report format(SFD-PI, 2018b).

The SFD creation process involves recommended steps as follows: firstly, gaining an understanding of the sanitation sector in the focus area, including physical boundaries, population, sanitation systems, topography, and the enabling environment for sanitation service delivery. Secondly, collecting relevant data. Thirdly, engaging stakeholders to ensure wider acceptance and support in preparing the SFD. Fourthly, utilizing the Graphic Generator tool available on <https://sfd.susana.org/data-to-graphic> to produce the SFD Graphic, which may require iterative discussions with stakeholders to arrive at a final version (SFD-PI, 2018a; SuSanA, 2023)

The first step in creating an SFD for Kericho involved gaining an understanding of the sanitation sector in the area. This included identifying the physical boundaries of the area, as well as the population and existing sanitation systems.

2.5.2 Levels of SFD reports

According to the SFD manual, the SFD development process is classified into four levels based on four primary criteria: the SFD's purpose, required resources, extent of data collection, stakeholder engagement, and depth of data analysis. 'Level 1' - Initial SFD is appropriate when resources such as secondary data, access to stakeholders, time, logistics, or funds are limited(SFD-PI, 2018b). This level is useful for advocacy purposes and initiating a dialogue with important stakeholders about the city's sanitation status. 'Level 2' - Intermediate SFD is applicable when extensive secondary data is available, and interviewing stakeholders is possible. This level provides a comprehensive understanding of the data and allows identifying any inconsistencies (Panesar et al., 2022).

It is useful for gaining a general understanding of the status of sanitation service delivery and can be upgraded to a Comprehensive SFD with the systematic collection of primary data(SFD-PI, 2018b). 'Level 3' - Comprehensive SFD requires the same amount of secondary data as for the Intermediate SFD, along with additional stakeholder engagement and systematic primary data collection (Panesar et al., 2022).

In-person interviews, observations, and direct measurements in the field are required to verify data accuracy at this level (SFD-PI, 2018b). It is appropriate for informing the planning of service improvement alternatives or investment decisions. The SFD Lite Report allows the creation of an SFD Graphic with minimal supporting data and linked sources (Yadava & Luthra, 2020). The data collected focuses on excreta management along the SSC to identify service outcomes without supporting service delivery background information. This report may serve as a useful starting point for developing a more comprehensive SFD Report later on (SFD-PI, 2018b).

2.5.3 Potential uses of SFD

SFDs are effective tools that visually demonstrate the different routes that faecal sludge takes within a city, enabling stakeholders and decision-makers to conduct swift assessments and identify strong and weak points along the SSC (Peal et al., 2014b; Narayan, 2022). This information is crucial in determining where future interventions should be directed towards. When reliable data is available, the SFD can be further modified to show the flow of faecal sludge volume, mass, and nutrient value through the sanitation service chain. This can help decision-makers identify areas within the SSC that have the potential for resource and value recovery (Peal et al., 2014b).

Developing SFD for Kericho could provide valuable insights into the faecal sludge flow within the town, highlighting areas where interventions are most needed. The SFD could be used to identify areas where the sanitation service chain is weak and requires

improvement, as well as areas where resource and value recovery opportunities may exist.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Introduction

This chapter describes the procedures and methodologies used to evaluate excreta management along the sanitation service chain using the Shit Flow Diagram in Kericho Town. It provides detailed information on the research design, target population, sampling methods, data collection techniques and instruments, data analysis methods, and ethical considerations considered during the study.

3.2. Study Area

The study was conducted in Kericho Town, located at coordinates -0.367632, 35.280394 in the Rift Valley Region of Western Kenya. It is approximately 260 kilometres west of Nairobi and 84 kilometres from Kisumu City. Situated near Mau Forest, East Africa's largest indigenous montane forest, Kericho Town spans about 155 square kilometres, as shown in Figure 3.1.

The town serves as the headquarters of Kericho County, following the promulgation of Kenya's 2010 Constitution. Administratively, Kericho comprises 17 sublocations and a population of approximately 166,681. Males make up 50.9% of the population, while females account for 49.1%, with 42,346 households (Kenya National Bureau of Statistics [KNBS], 2019). The population is projected to grow at a rate of 1.8% annually, as shown in Appendix G. The study area includes both urban and peri-urban regions, with population density ranging from 376 to 3,377 people per square kilometre, according to KNBS (2019), as detailed in Appendix G.

The altitude of Kericho Town ranges from 1,842 to 2,400 meters above sea level. The mean annual rainfall varies from 725.1 mm to 1,361.6 mm, while the mean annual temperature ranges from 18.7°C to 25.9°C (CGoK, 2018). Kericho Town's Population growth is estimated at 1.8% per year (KNBS, 2019).

3.3. Target Population

Target population is a subset of the broader population and possesses characteristics that are of particular interest to the research question (Willie, 2024). The study primarily focused on both a male and female households heads within 42,346 households in Kericho Town (KNBS, 2019), since they could provide key insights into the sanitation practices and waste management challenges prevalent in the area. Additionally, the study included key informants such as Vacuum Truck Operators (VTOs), KEWASCO management, DTF Operators, and sewer operators, as they are integral to the functioning of the town's waste management system. Their roles offer specialized insights into the operational challenges, resource distribution, and overall functioning of sanitation and waste management systems in Kericho Town.

3.3.1 Inclusion criteria

Household heads were required to be over 18 years of age, and to have resided in Kericho Town for at least one year. This stipulation was made to ensure that household heads had sufficient exposure to and experience with the local sanitation infrastructure, practices, and waste management challenges.

3.3.2 Exclusion criteria

Household heads under the age of 18 were excluded from the research. It was deemed that individuals in this age group may not have the requisite legal authority or sufficient cognitive maturity to make informed decisions regarding household sanitation practices.

3.4. Study Design

This study adopted convergent parallel mixed methods design to evaluate excreta management across sanitation service chain using Shit Flow Diagram (SFD) in Kericho Town, Kenya. This design enabled researchers to collect and analyse quantitative and qualitative data concurrently, allowing for a comprehensive understanding of the

research problem (Kimmons, 2022). This combination of methods ensured that both statistical trends and in-depth insights from participants' experiences were captured, enhancing the robustness and depth of the findings.

The study primarily utilized the SFD tool, developed by the Shit Flow Diagram Promotion Initiative (SFD-PI), part of a diagnostic toolkit created by the World Bank (Furlong et al., 2016). Data collection followed the SFD methodology for Faecal Sludge Management (FSM) diagnostics, as outlined by Furlong et al. (2016). This methodology was chosen because it is globally recognized as a systematic assessment tool for faecal sludge management, directly aligning with the study's focus. Using the SFD tool provided a comprehensive understanding of current faecal sludge management practices in Kericho Town.

3.5. Sampling Techniques

The study adopted the following sampling technique to identify respondents;

3.5.1 Purposive sampling

Purposive Sampling purposive sampling method was used to identify participants for the Key Informant Interviews (KIIs) according to their specialized roles in the sanitation service chain of Kericho Town. Purposive sampling ensured participants were both knowledgeable of the sanitation themes, and also uniquely positioned to provide insight into specific pieces of the excreta management process (Bazaanah et al., 2024).

For example, the Technical Manager at KEWASCO was selected because they were responsible for the water and sanitation services of the town, enabling a systems-level perspective of the infrastructure planning and policy. The Inspector at the Wastewater Treatment Plant (WWTP) was included to provide operational knowledge that detailed the process of centralized sewage treatment, its efficiency, and compliance. Furthermore, the Inspector at the Decentralized Treatment Facility (DTF) in Kapsoit was selected to

represent the non-sewered sanitation systems as they were knowledgeable about fecal sludge treatment technologies in a peri-urban context.

Furthermore, a vacuum truck operator (VTO) employed by KEWASCO was selected to understand public-sector conveyance in comparison to a VTO owner/operator in the private sector to compare their experiences, challenges, and innovation in service delivery. This purposive sampling strategy enabled this study to generate technically rich, and contextually situated data from across the sanitation service chain, from containment, conveyance, and treatment.

3.5.2 Cluster sampling

In order to achieve representativeness across the study area, a cluster sampling technique was used to divide Kericho Town into 17 clusters based on administrative boundaries (sublocations) (KNBS, 2019). The significant advantage of this technique was manageable data collection along with geographical diversity. A sample size per cluster was determined proportionately using the relative household population within each cluster. The study used a simple random sampling technique to select individual households in each cluster. The use of random sampling minimised the selection bias because it gave every household equal chance of being included in the survey (Makwana, et al., 2023).

3.6. Sample Size Determination

Sample size was calculated using the Taro Yamane formula (Lohr,2021), which is widely used for calculating sample sizes in research involving finite populations. Mugendi et al. (2023) adopted Yamane formula to obtained sample size on study investigating fecal sludge management practices. The procedure is as shown in equation (3.1)

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

Where, n = the required sample size; N is total population that is 42,346 (KNBS, 2019), and e is sampling error of 5%

$$n = \frac{42,346}{1 + 42,346(0.05 \times 0.05)} = 396$$

However, to ensure a more robust and representative sample and to also account for a potential non-responses and sampling error, the sample size was adjusted upwards by about 5% to a sample size of 416. The total households' units sample size of 416 were distributed over the determined clusters after projection to the current year (2023) based on their population size. The sample size in each cluster, actual sample (s) was calculated by multiplying sample (N=416) by cluster household size (h) and divided findings by total population (T=42,336) as shown in Table 3.1

Table 3.1:

Sampled households per sub location

Sublocation	2023 Households Projection (h)	Calculated Sample	Actual Sample Size (n)
1. Kipchimchim	1,835	17	18
2. Kapsaos	2,457	23	24
3. Kapkitony	564	5	6
4. Kapsoit	1,015	10	10
5. Kakiptui	665	6	7
6. Kapsuser	1,715	16	17
7. Chebocho	1,180	11	11
8. Chepkolon	1,946	18	19
9. Borborwet	2,327	22	23
10. Kipkoiyan	1,854	17	18
11. Ainapkoi	1,826	17	18

Sublocation	2023 Households Projection (h)	Calculated Sample	Actual Sample Size (n)
12. Kipsolu	1,662	16	16
13. Chepkurbet	1,108	10	11
14. Kapkugerwet	5,602	53	55
15. Motobo	4,588	43	45
16. Taiywet	2,666	25	26
17. Township	9,336	87	92
Total (N)	42,346	396	416

Source: (Kenya National Bureau of Statistics [KNBS], 2019)

3.7. Field Work Overview

Field work phase allowed for the collection of primary data which was used to feed into the SFD graphic software. This phase involved household surveys, key informant interviews with treatment inspectors of KEWASCO and Exhauster operators, as well as carrying out observations and transect walks. The steps followed during this phase are detailed in the following sections.

3.7.1 Desk review

A review of the literature was conducted through reading through the published works and unpublished works from key informant interviews to learn more about sanitation in Kenya and Kericho. The review aided in perspective-taking and to help to triangulate data and close gaps. Some of the unpublished data encountered during the study was a study done by World Bank as well as laboratory test reports for waste water treatment plant among others as detailed in Table 3.2.

Table 3.2:*Unpublished reports*

	Description of Unpublished Data	Source Information	of Organisation
1.	An Analysis of Sanitation in the Lake Victoria Basin in Kenya (Factsheets on nineteen Settlements- April 2023) Prepared by Lincoln Odeya of World Bank Group	Chief Executive Committee Member for Water, Energy and Environment, Natural Resources & Forests	Kericho County
2.	Laboratory test reports for the period April 2022 to April 2023	Technical Manager	KEWASCO
3.	Sewer Leakage and repair Reports	Technical Manager	KEWASCO
4.	Map of KEWASCo Service Area	Technical Manager	KEWASCO
5.	Job Cards for Sludge delivery to WWTP by exhausters from January 2023 to October 2023	Technical Manager	KEWASCO

Source: (Researcher, 2024)

3.7.2 Key informant interviews

Purposive sampling method was used to reach the key informants. KII were carried out using semi structured interviews (Appendix C). These KIIs were essential in getting information about the performance aspects of the sanitation systems as well as information about coverage of containment and stakeholder interests. Additionally, they also presented an opportunity to gather unpublished literature which all built up on the

current sanitation situation as well as the enabling environment. Four interviews were conducted as shown in the Table 3.3.

Table 3.3:

List of coded key informants

Code	Designation	Organisation	Thematic Area
1. KI-001	Technical Manger	KEWASCO	Overall Sanitation of Kericho and WWTP effluent data
2. KI-002	Wastewater Treatment Inspector	KEWASCO	Efficiency of WWTP
3. KI-003	Kapsoit Decentralised Treatment Facility Inspector	KEWASCO	Efficiency of DTF
4. KI-004	Desludging Operator- KEWASCO	KEWASCO	Desludging

Source: (Researcher, 2024)

3.7.3 Household surveys

Household surveys were conducted across the 17 sublocations in Kericho Town to assess various aspects of sanitation technologies along the service chain. Enumerators, who were local residents fluent in Kiswahili, English, and Kalenjin languages, with at least a diploma in public health and experience in community-based work, were trained on the survey questionnaire hosted on the Kobo Toolbox website. A mock test was conducted to ensure their comprehension. Each enumerator was assigned a sublocation to handle.

Data collected included GPS coordinates, sublocation, respondent gender, education level of the household head, characteristics of sanitation facilities, emptying mechanisms, and instances of open defecation, among other variables (Appendix B).

Enumerators visited 10 to 30 households daily, depending on the terrain and the distances between housing units. In each household, sanitation facilities (user interface and visible parts of containment) were georeferenced and photographed. The GPS tool automatically recorded the location, and the survey tool was programmed to ensure that valid data was entered before moving to the next question. Household surveys were conducted concurrently with structured observations of sanitation facilities.

3.7.4 Transect walks and observations

This involved making observations in different areas to gain a deeper perspective of the study area and to confirm data obtained during interviews. This process was vital to confirm the consistency of data obtained from literature as well as from the interviews so as to make it as reliable as possible. In this process, the SSC particularly the emptying process was observed from point of collection from a residence to the disposal at the treatment plant.

Furthermore, a general observation of the town including the extent of the different types of containment facilities were made during the transect walks around the municipality (Appendix D). Permission was sought as recommended by the SFD-PI (2015b) before travelling with the vacuum truck operator during an emptying exercise. One mechanical emptying process was followed from start to end due to the rareness of the activity in the town. Additionally, six transect walks were carried out over Kericho Town. A template adapted from SFD-PI was used to guide the observations (Appendix H).

3.7.5 SFD graphics development

The analysis of data through the generation of SFDs' graphics aimed to assess the safety of city sanitation management. The SFD developed was categorized as initial SFD, considering both the volume of data and the involvement of stakeholders in generating the graphic. Following the SFD manual (SFD-PI, 2018b), Table 3-4 was established where primary data was obtained through interviews with various target stakeholders across the SCC, complementing the secondary data. The SFD graphic was then created by analysing the collected data and incorporating relevant assumptions.

Table 3.4:

Required data for developing SFD Graphic

Stage of Service Chain	Data Required for SFD Development	Data Source	
Containment	Coverage of various sanitation systems used in town	Household Survey Observations Secondary Data KI-001	
	Emptying Trucks	Sanitation technologies emptied	Household Survey KI-004
		Capacity of Trucks	KI-002 KI-003
Conveyance Sewers	Average water consumption Volume of wastewater	Secondary Data KI-001	

Stage of Service Chain	Data Required for SFD	Data Source
	generated and transported	
	Status of sewer network	
	Quantity wastewater and faecal sludge received	Secondary data KI-001
	Capacity and efficiency of treatment	KI-002
Treatment	Quantity faecal sludge received	Secondary data KI-001
	Capacity and efficiency of treatment	KI-003
End-use	Quantity of treated wastewater or faecal sludge	Secondary data KI-001 KI-003
Disposal	Quantity of wastewater or faecal sludge which is disposed	Secondary data KI-001 KI-003

Source: (Researcher, 2024)

Utilizing the graphic generator (SFD-PI, 2018b) and employing procedures 3.6.1, 3.6.2, and 3.6.3 to collect data, a graphics representing SFD was generated.

3.8. Pilot Study

It is recommended that for quantitative studies, the pilot study sample should be 10% of the planned final study sample size (Mugenda & Mugenda, 2003). However, for qualitative studies, the impact of the final sample size is not expected to be significant, particularly when dealing with homogeneous groups of a small number of participants (Ismail et al., 2018).

In this study, a pilot test was conducted at Litein Town, involving a purposively selected sample size of 40 household. Litein was selected because it shares similar socio-demographic and infrastructural characteristics with Kericho Town, including urban settlement patterns, sanitation service types, and population density. The pilot test aimed to determine if the questions measured what they were intended to measure, if respondents could comprehend and interpret the questions accurately, and it was found that the estimated time to complete the questions was 10 minutes.

3.8.1 Validity of research instruments

Validity is the most crucial criterion that indicates the extent to which an instrument measures what it is intended to measure (Vu et al. 2021). In this study, content validity was utilized, where the instrument was presented to experts for their opinions to make necessary modifications.

The instrument was verified by the officer of Sanitation at the Ministry of Water, Sanitation and Irrigation (MoWSI) and supervisors from the Sanitation Research and Innovation (SRI) centre at Meru University of Science and Technology (MUST). Their expertise ensured that the items reflected operational realities, used appropriate terminology, and aligned with current sanitation frameworks. This validation step was

essential not only for enhancing conceptual accuracy but also for improving the credibility, policy relevance, and field applicability of the research tool.

3.8.2 Reliability of the research instruments

Reliability is a measure of the extent to which a research instrument produces consistent results or data after repeated trials (Sürücü & Maslakçi, 2021). In this study Cronbach's alpha was calculated by examining the correlations between all possible pairs of items within a scale and then determining the average correlation. The result was 0.711 signifying acceptable level of internal consistency.

3.9. Data Analysis

This study employed a combination of qualitative and quantitative data analysis methods. Quantitative data analysis involved processing responses gathered from questionnaires distributed to households, whereas qualitative data analysis focused on insights derived from KII, observations and published documents.

Quantitative data analysis was conducted using the Statistical Package for Social Sciences (SPSS) software, version 26, to generate descriptive statistics, including frequencies, percentages, means, and standard deviations, based on the survey responses obtained from the households. For the qualitative component, data derived from Key Informant Interviews (KIIs), field observations, and published documents were transcribed and analyzed manually. A thematic analysis approach was employed to identify key themes, which were then synthesized into narrative presentations. This allowed for an in-depth exploration of the perspectives provided by the respondents, as well as insights into the nuances of the local sanitation practices.

Following the steps stipulated in SuSanA platform and SFD Manual, The SFD Graphic Generator began by choosing an Initial SFD Level 1 and entering the general information of Kericho Town on Population. From the results of objectives one and two, the

sanitation systems in use in Kericho Town were selected as shown in Shit Flow Diagram Selection Grid (Appendix 6). From the results of objectives one and two, the sanitation systems in use in Kericho Town were selected, as shown in the Shit Flow Diagram Selection Grid (Appendix 6). The selection grid consisted of "List A," showing the list of containment technologies, and "List B," where, based on the selection of a containment technology, one could choose where the discharge from that containment goes.

The SFD matrix was created by entering the proportions of the contents of each type of onsite container, which primarily consisted of faecal sludge. The default value of "100%" was used because, in most cases, onsite containers were connected to soak pits or open ground. The entered data from each selected sanitation system is shown in Table 3-5(SFD Matrix).

Table 3.5:

SFD Matrix

System label	System description	Pop	W4a	W5a	W4c	W5c	F3	F4	F5
		Proportion of population using this type of system	Proportion of wastewater in sewer system, which is delivered to centralised treatment plants	Proportion of wastewater delivered to centralised treatment plants, which is treated	Proportion of wastewater in open sewer or storm drain system, which is delivered to treatment plants	Proportion of wastewater delivered to treatment plants, which is treated	Proportion of this type of system from which faecal sludge is emptied	Proportion of faecal sludge emptied, which is delivered to treatment plants	<i>Proportion of faecal sludge delivered to treatment plants, which is treated</i>
T1A1C2	User interface discharges directly to a centralised foul/separate sewer	25	96	20					
T1A1C6	User interface discharges directly to open drain or storm sewer	1			0	0			
T1A1C8	User interface discharges directly to open ground	1							
T1A1C9	User interface discharges directly to 'don't know where'	2							
T1A2C5	Septic tank connected to soak pit	2					100	100	20
T1A2C8	Septic tank connected to open ground	6					100	100	20
T1A5C10	Lined pit with semi-permeable walls and open bottom, no outlet or overflow	49					20	95	20
T1A6C10	Unlined pit, no outlet or overflow	14					20	95	20
T1B11 C7 TO C9	Open defecation	0							

Source: (SFD-PI, 2018b)

3.10. Ethical Considerations

Ethical considerations were addressed throughout the fieldwork process. Before initiating any research activities in Kericho Town, an introductory letter was obtained from school of engineering and architecture, Meru University of Science and Technology, which was used to obtain a research permit from National Commission for Science, Technology and Innovation (NACOSTI) license no. Nacosti/p/23/26918 (appendix E) and a permit through the county secretary (Appendix F). Prior to conducting interviews, consent was sought verbally from participants, ensuring their voluntary participation in the data collection process and willingness to respond to questions (Appendix A). It was clearly communicated that the research was conducted solely for research purposes, with no financial compensation provided or expected.

To uphold confidentiality, names of research assistants were only used to protect the anonymity of interviewees. Careful scheduling of appointments within office hours and at locations convenient to participants' workplaces was undertaken to minimize any inconvenience. Before the commencement of interviews, participants were briefed on the research topic and objectives. Permission to record the interviews was sought, and for those who agreed, photographs of their facilities were taken.

To secure the collected data, including photos, recordings, and notes, a systematic transfer was carried out from the phone to a personal computer with encryption. These ethical measures were implemented to ensure the integrity of the research process, prioritize participant confidentiality, and adhere to ethical standards.

CHAPTER FOUR: RESEARCH RESULTS

4.1. Introduction

This chapter presents the results obtained from administered household survey questionnaires, which include response rates, information on sanitation technologies, safety along the sanitation service chain, as well as findings from key informant interviews, observations, and secondary data sources.

4.2. Response Rate

The study had 98.3 % (N=409) response rate due to availability and willingness of the respondents to provide required information. The second group of respondents from interviews recorded 100% response since four resource persons were interviewed. Fourteen (14) observation checklists were recorded.

4.3. Demographic Information of the Respondents

This section outlines responses on gender distribution, level of education, household ownership and reports on under-five diarrheal infection in past two weeks.

4.3.1 Respondents' distribution by gender

Majority of the respondents, 71.9%, were female as compared to 28.1% who were male.

Table 4.1 shows results on respondent's distribution by gender.

Table 4.1:

Respondents distribution by gender(N=409)

Gender	Frequency	Percent
Male	115	28.1
Female	294	71.9
Total	409	100.0

Source: (Researcher, 2024)

4.3.2 Level of education of the respondents

The findings presented in Table 4.2 shows that the majority of respondents had attained tertiary education, accounting for 50.1% of the total sample. This was followed by 35.0% who had completed secondary education. Respondents with no formal education constituted 12.5%, while only 2.4% had achieved primary education as their highest level of schooling.

Table 4.2:

Level education of the respondents (N=409)

Level of education	Frequency	Percent
Tertiary education	205	50.1
Secondary education	143	35.0
No education	51	12.5
Primary Education	10	2.4
Total	409	100.0

Source: (Researcher, 2024)

4.3.3 Ownership status of house/residence of household

The findings presented in Table 4.3 shows that majority of the respondents 57% owned houses, 38.4% rented and 4.6% lived on rent free houses.

Table 4.3:

Ownership Status of the households (N=409)

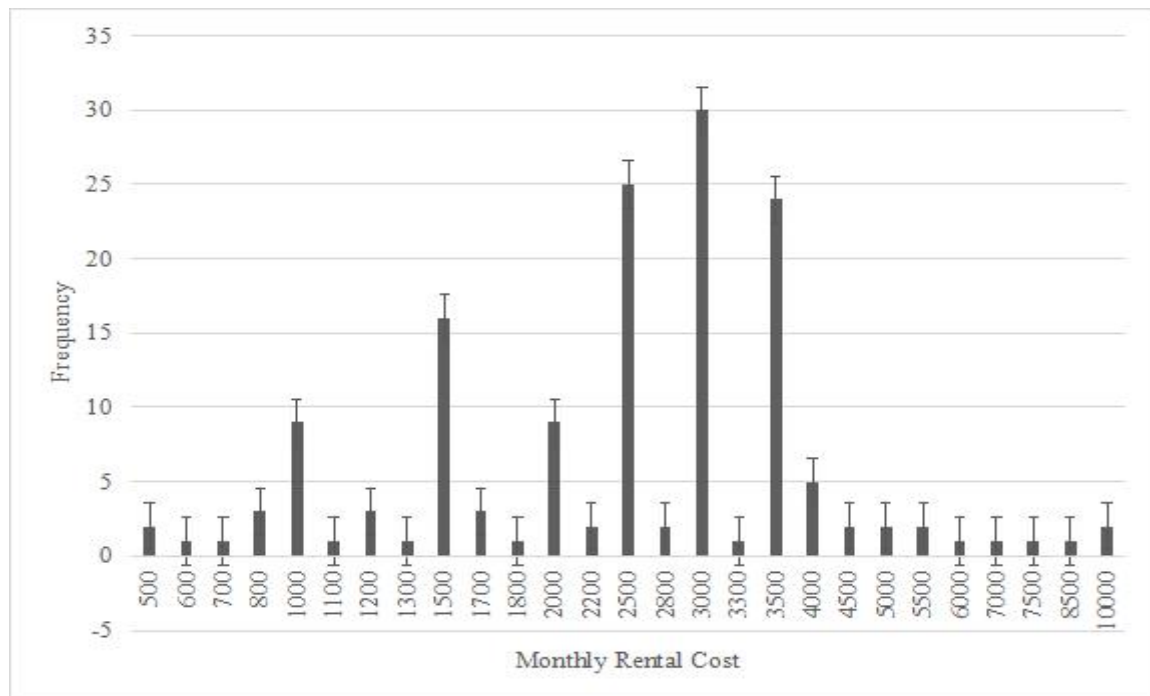
Ownership Status	Frequency	Percent
Owned	233	57.0
Rented	157	38.4
Rent free	19	4.6
Total	409	100.0

Source: (Researcher, 2024)

The respondents who reside on rental houses, were asked what was the monthly rental cost. Majority of the respondents, 30 recorded Ksh 3000, with highest Ksh.10,000 and least Ksh.500 as presented in Figure 4.1.

Figure 4.1:

Monthly rental cost



Source: (Researcher, 2024)

4.3.4 Under-Five Diarrheal Infection in Past Two Weeks

The results presented in Table 4-4 and Figure 4.2 shows that out 409 respondents, 19.1% reported cases of diarrheal infection among under-five years children within past two weeks, and majority 80.9% did not.

Table 4.4:

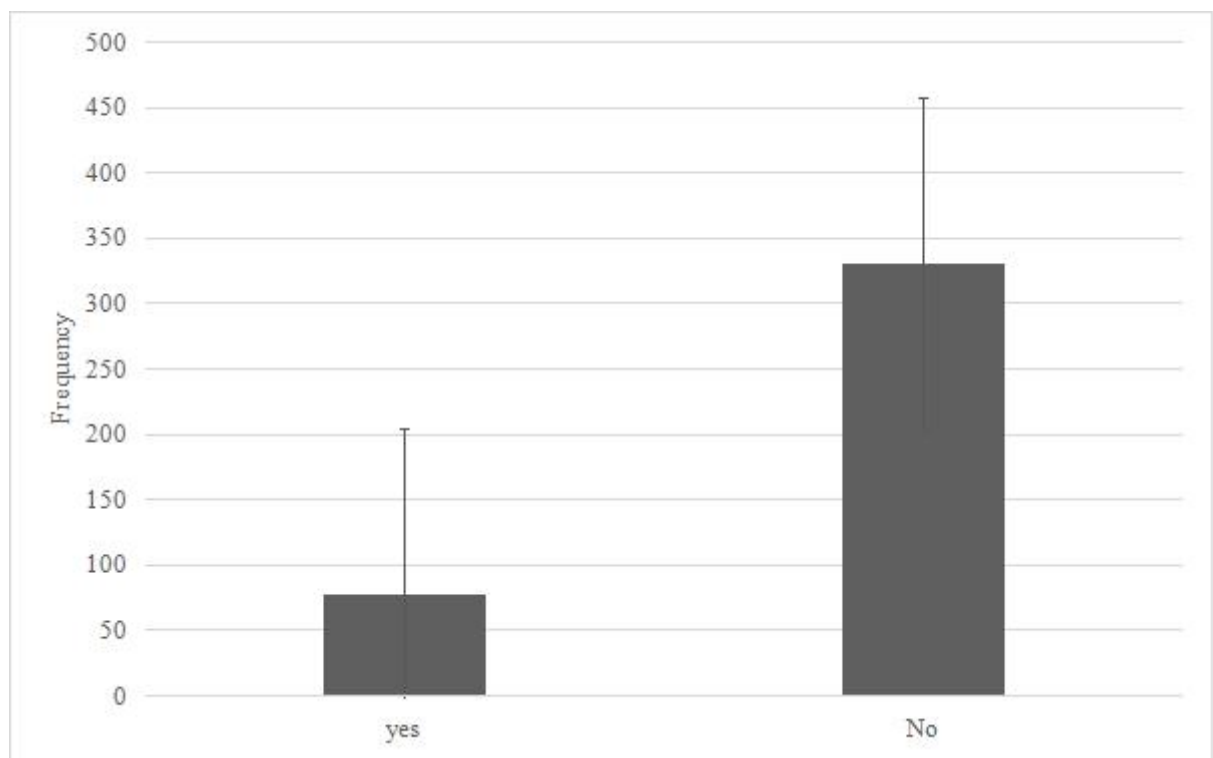
Experienced Diarrhea in the past week (N=409)

Experienced Diarrhoea in the past week	Frequency	Percent
Yes	78	19.1
No	331	80.9
Total	409	100.0

Source: (Researcher, 2024)

Figure 4.2:

Experienced diarrhea in the past week



Source: (Researcher, 2024)

4.4. Sanitation Technologies

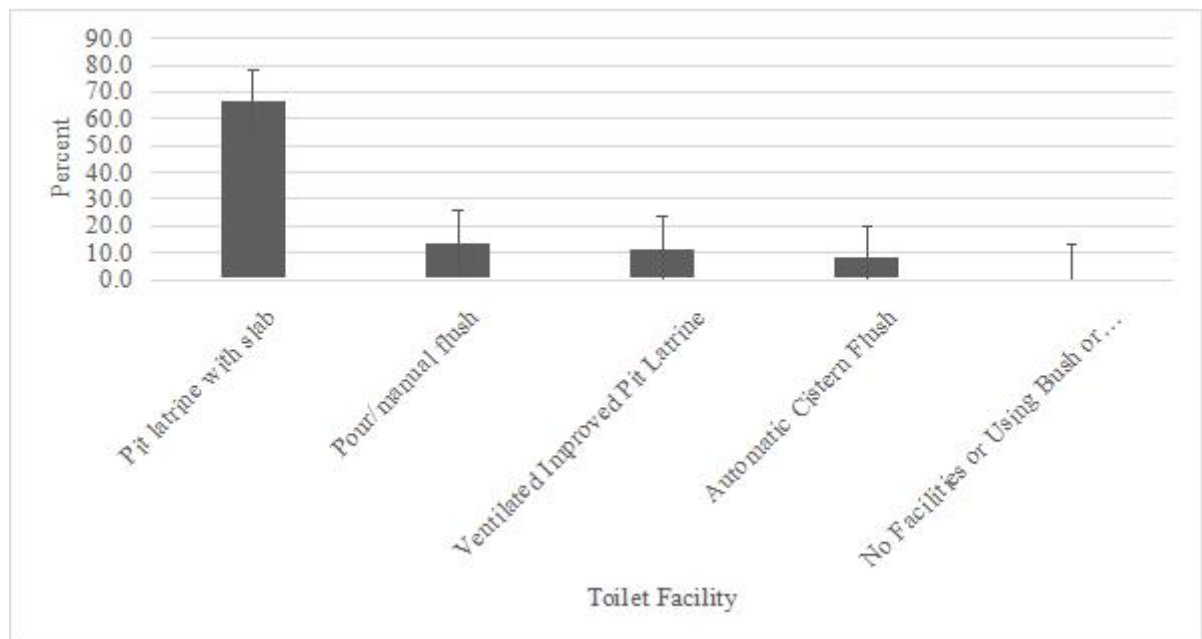
The household surveys were conducted to assess the current sanitation technologies in use in the town.

4.4.1 Toilet facilities (capture)

The study investigated sanitation technologies and overall quality in Kericho Town. The sanitation facilities (containment) in Kericho town exhibited a diverse range of types and discharge methods. Out of the total sample size (N=409), 66.5% utilized pit latrines with slabs, 13.69% relied on pour/manual flush systems, 11.49% have ventilated improved pit latrines, 8.07% used automatic cistern flush, and a minimal 0.24% practised open defaecation as shown in Figure 4.3.

Figure 4.3:

Capture/Toilet Facilities in Kericho



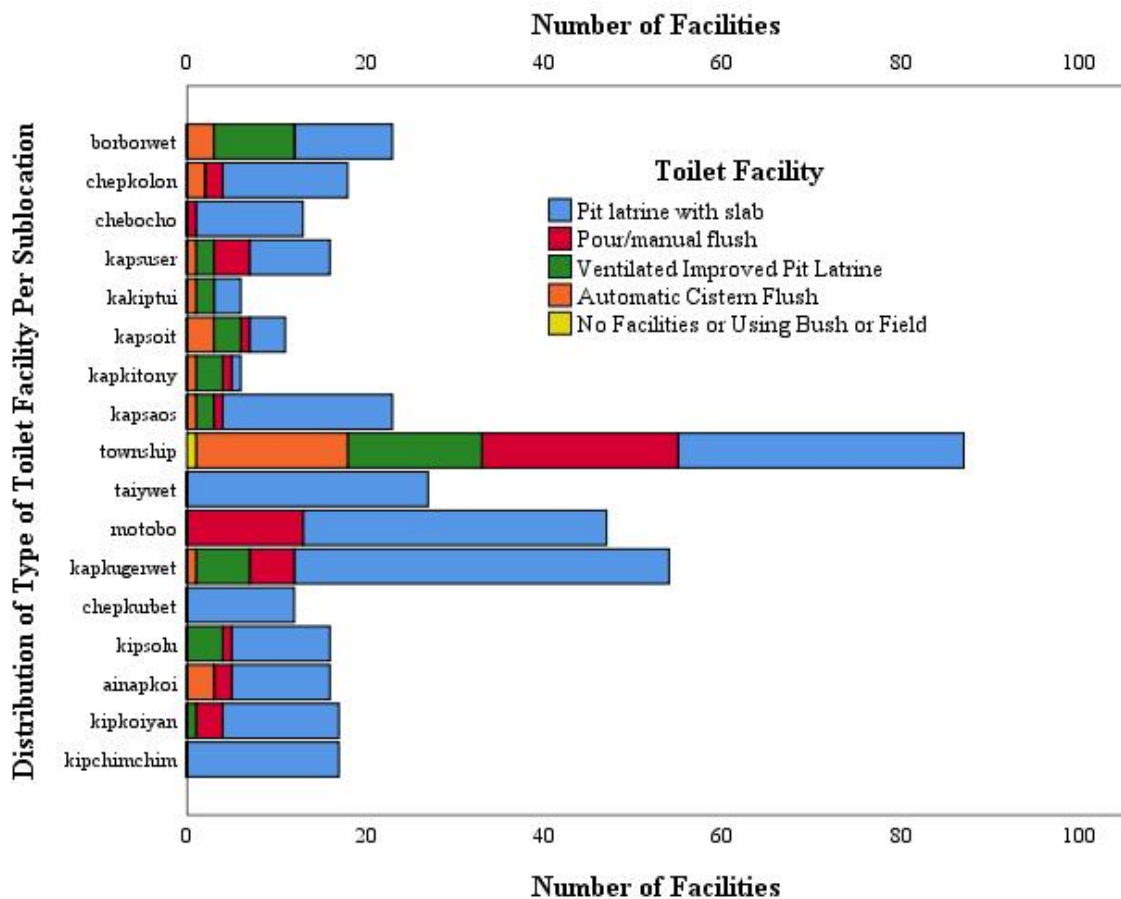
Source: (Researcher, 2024)

It is noteworthy that majority of the Kericho urban set up especially the peri urban was characterized by more less rural with majority of sublocations having pit latrine with

slabs whereas the township had the flushing toilets because of the availability of the sewerage system at the town area as shown in the composite bar graph in Figure 4.5.

Figure 4.4:

Distribution of toilet Facilities in Kericho per sublocation



Source: (Researcher, 2024)

4.4.2 Quality of sanitations technology in Kericho town.

The majority of residents (94.4%) in Kericho Town used on-plot (shared/private) facilities, whereas 4.6% used communal toilets. Out of these toilets, 32.3% were shared, while 67.7% were not shared as shown in Table 4-5.

Table 4.5:

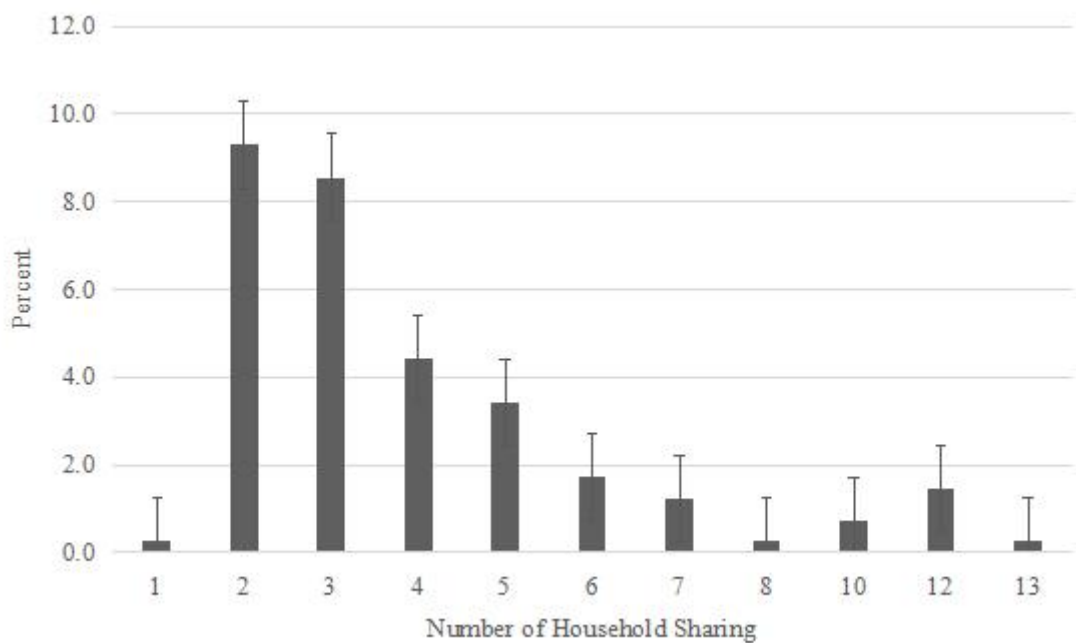
Toilet categories (N=409)

Variables	Frequency(n)	Percent (%)
Toilet category		
On plot (shared/private)	386	94.4
Off plot (communal/public)	23	4.6
Total	409	100
Sharing toilet		
Yes	137	32.3
No	277	67.7
Total	409	100

Source: (Researcher, 2024)

Figure 4.5:

Number of Household Sharing Toilet Facilities in Kericho



Source: (Researcher, 2024)

The results showed that the majority of respondents (96.3%) reported that they had toilet facilities which were operational in Kericho Town. However, 3.7% declined, as shown in

Table 4-6. Of the toilets that were not operational in Kericho Town, 47% had collapsed, and 53% were full awaiting emptying.

Table 4.6:

Toilet functionality(N=409)

Variables	Frequency(n)	Percent (%)
Toilet functionality		
Yes	394	96.3
No	15	3.7
Total	409	100
Why is not functional?		
Collapsed(fully/partial)	7	47
Full waiting for emptying	8	53
Total	15	100

Source: (Researcher, 2024)

The study noted that most respondents (88.3%) used facilities with easy to clean slabs, as presented in Table 4-7.

Table 4.7:

Presence of cleanable slab (N=409)

Variables	Frequency(n)	Percent (%)
Presence of cleanable slab		
Yes	361	88.3
No	43	10.5
No Response	5	1.2
Total	409	100

Source: (Researcher, 2024)

The study also investigated the conditions of the superstructures of toilet facilities. Of these, 68.55% had facilities with brick or other permanent wall material, 29.3% were

made of wood or semi-permanent materials, and 0.7% had no walls; 1.5% of respondents did not provide an answer, as shown in Table 4-5. Additionally, 96.1% of respondents had sanitation facilities with roofs, and 94.4% of respondents' facilities had doors, ensuring satisfactory privacy, as presented in Table 4-8.

Table 4.8:

Toilet Superstructure and privacy (N=409)

Variables	Frequency(n)	Percent (%)
Superstructure of the facility		
Brick or other permanent material	280	68.5
Wood/bamboo/cloth or other semi-permanent material	120	29.3
No superstructure	3	0.7
No response	6	1.5
Total	409	100
Presence of roof		
Yes	393	96.1
No	13	3.2
No Response	3	0.7
Total	409	100
Privacy of the facility		
Yes	386	94.4
No	19	4.6
No Response	4	1
Total	409	100

Source: (Researcher, 2024)

It was observed that the majority of respondents had facilities that were sufficiently clean. Specifically, 70.4% had slabs with no contamination of urine and faeces, 17.6% had traces of urine on the slab, and 9.8% had traces of faeces and urine on the slab, as shown in Table 4-9.

Table 4.9:

Toilet slab contamination with urine or faeces(N=409)

Variables	Frequency(n)	Percent (%)
Slab contamination with urine or faeces		
Faeces or faeces and urine	40	9.8
Urine only	72	17.6
No faeces and no urine	288	70.4
No response	9	2.2
Total	409	100

Source: (Researcher, 2024)

Most of the shared facilities observed in Kericho Town were in a deplorable state, as depicted in Plates 4-1 and 4-2.

Plate 4- 1:

Shared Capture facilities



Source: (Researcher, 2024)

Plate 4- 2:

Shared Capture facilities showing presence of faeces and urine

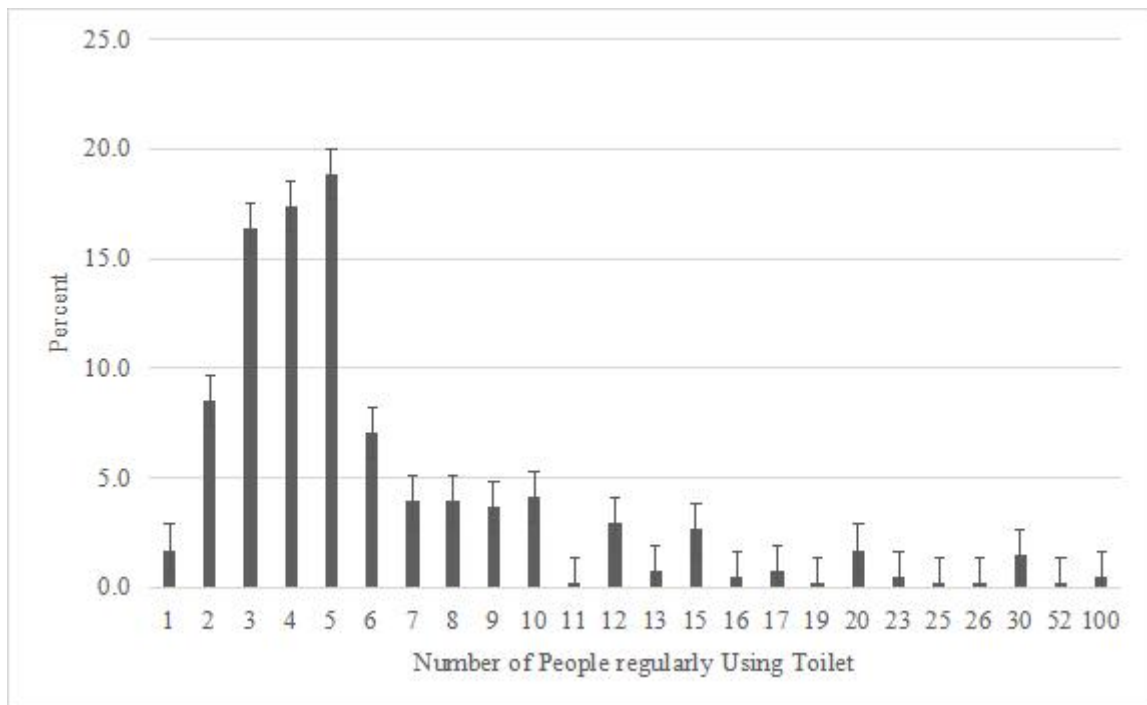


Source: (Researcher, 2024)

The findings showed that average number of people regularly using toilet was 6 with lowest being 1 and highest being 100, as presented in Figure 4.6

Figure 4.6:

Number of people regularly using toilet



Source: (Researcher, 2024)

The findings presented in Table 4-10 indicate that a significant majority of respondents (65.0%) reported having toilet facilities located outside their housing unit, while only 35.0% had toilets situated inside their homes. Regarding the use of public toilet facilities, the data show that 80.7% of respondents reported that no member of their household used public toilets, compared to 17.6% who affirmed usage. A small proportion (1.7%) did not respond to this question. The low uptake of public sanitation facilities may be attributed to factors such as cost barriers, distance, privacy concerns, or perceived hygiene standards.

Table 4.10:

Location of the toilet in the household compound (N=409)

Variables	Frequency(n)	Percent (%)
Toilet location		
Outside housing unit	266	65.0
Inside housing unit	143	35.0
Total	409	100
Can any member of household use public toilet?		
Yes	72	17.6
No	330	80.7
No Response	7	1.7
Total	409	100

Source: (Researcher, 2024)

Most of respondent 86.8%, did not pay to use toilet, 11.7% paid for use and 1.5% did not respond as shown in Table 4-11.

Table 4.11:

Payment to use toilet (N=409)

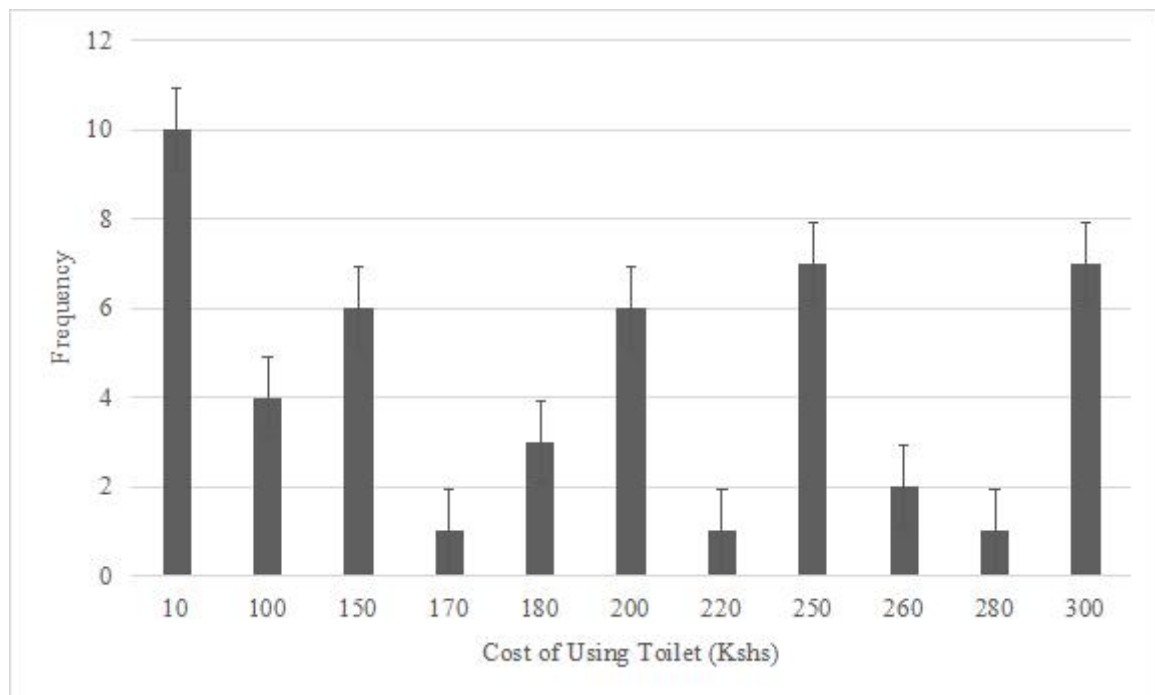
Variables	Frequency(n)	Percent (%)
Do you pay to use toilet?		
Yes	355	86.8
No	48	11.7
(Yes, per use (public)	10	2.4
Yes, monthly payment)	38	9.3
No Response	6	1.5
Total	409	100

Source: (Researcher, 2024)

For those paying they reported an average amount of KSh. 170.42, with a minimum of KSh. 10 especially for public toilets and maximum of KSh. 300 for paying monthly, as illustrated by Figure 4-7.

Figure 4.7:

Cost of using toilet

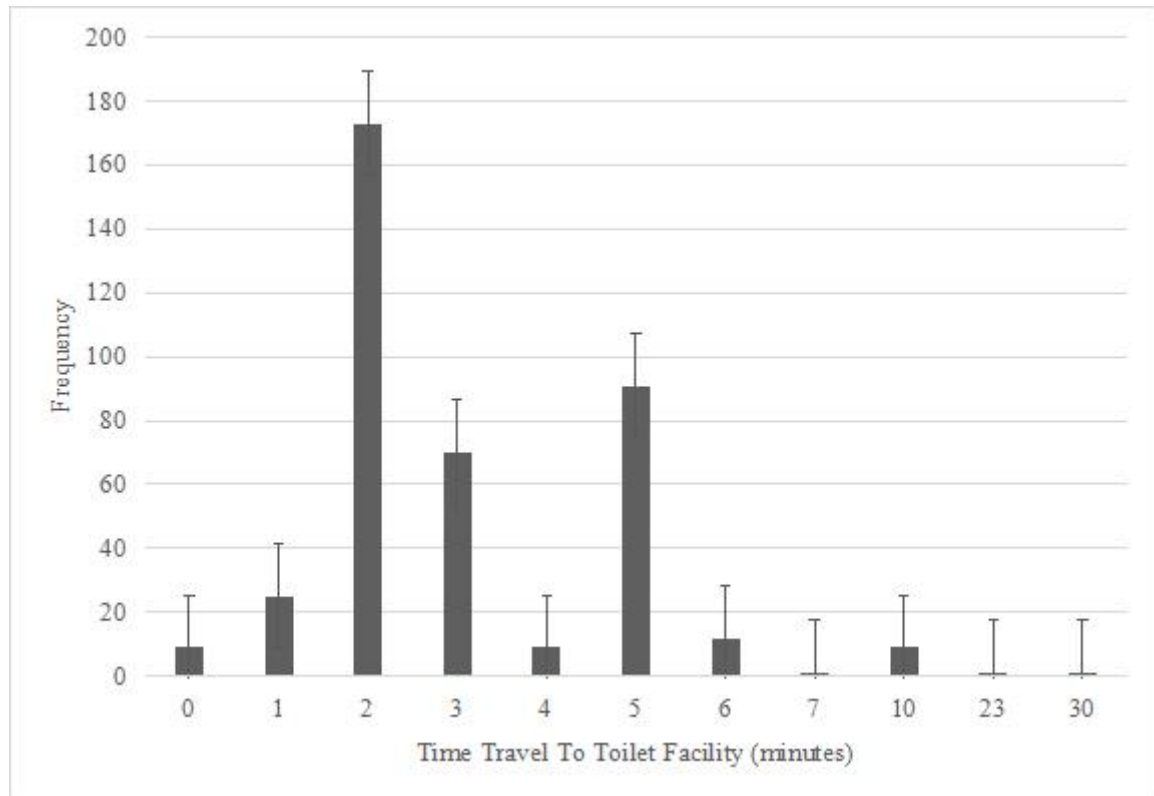


Source: (Researcher, 2024)

The average time in minutes users had to travel to a toilet facility was inquired, it was observed average time to be 3.34 minutes on average with least being 1, and most 30 minutes as shown in Figure 4.8.

Figure 4.8:

Time travel in minutes to toilet facility



Source: (Researcher, 2024)

4.4.5 Access to Water for Drinking and Sanitation

The study investigated the common sources of drinking water in Kericho Town with the findings showing that 28.1% respondents used pipe water into dwelling, 17.4% water pipe into yard or plot, 16.6% used tube well or borehole water, 16.1% used rainwater and 2.2% used water from unprotected springs as shown in Table 4.12

Table 4.12:*Source of water for drinking and sanitation in Kericho town (N=409)*

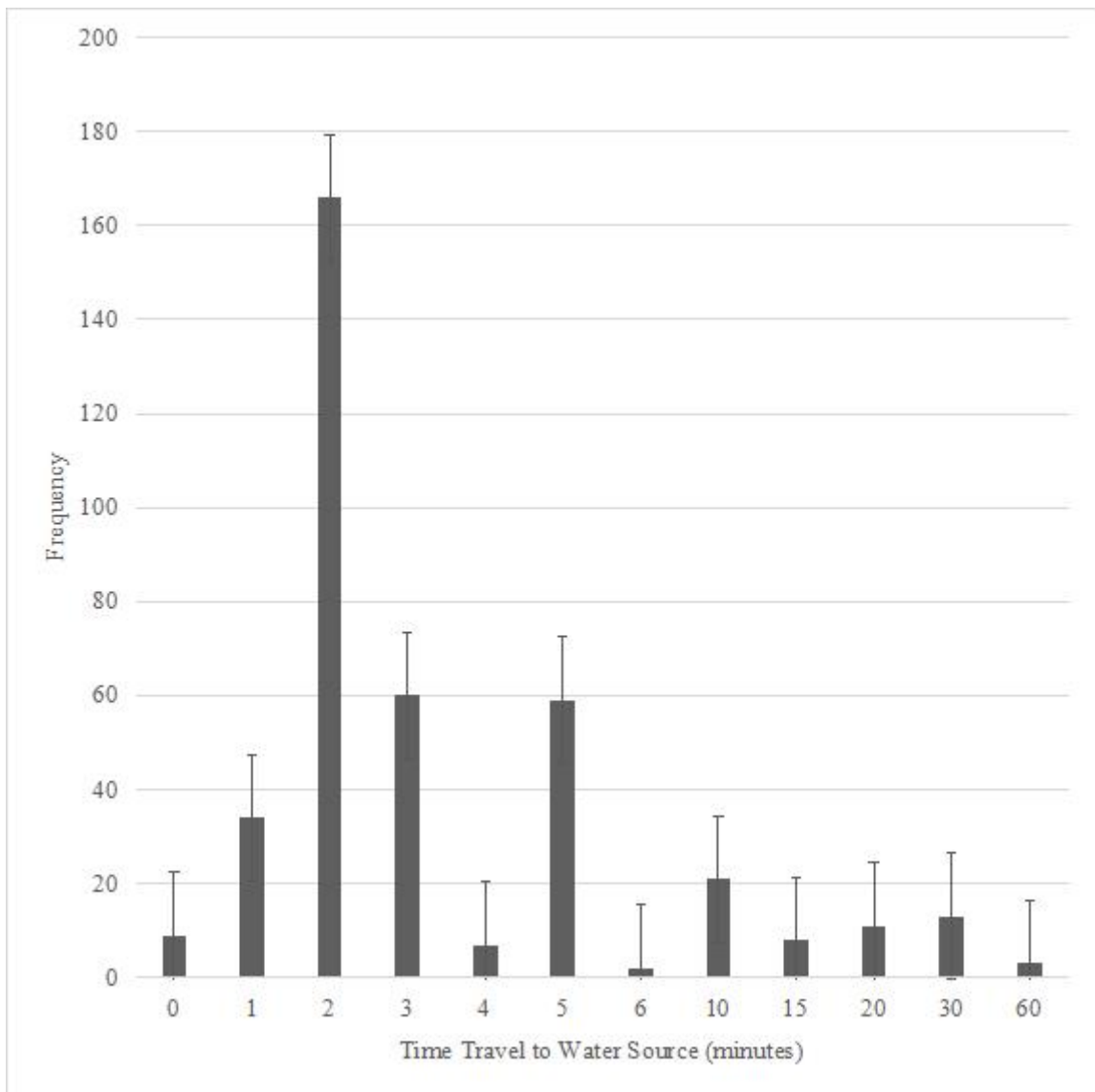
Source of drinking water	Frequency	Percent
Water piped into the dwelling	115	28.1
Unprotected spring	9	2.2
Water piped to the yard/plot	71	17.4
Tube well/borehole	68	16.6
Rainwater collection	66	16.1
Protected dug well	30	7.3
Public tap/standpipe	18	4.4
Surface water river dam lake	12	2.9
Unprotected dug well	11	2.7
Protected spring	9	2.2
Total	409	100.0

Source: (Researcher, 2024)

The average time respondents used to travel to fetch water was found to be 5.09 minutes as shown in Figure 4.9.

Figure 4.9:

Time Spent Traveling to Fetch Water

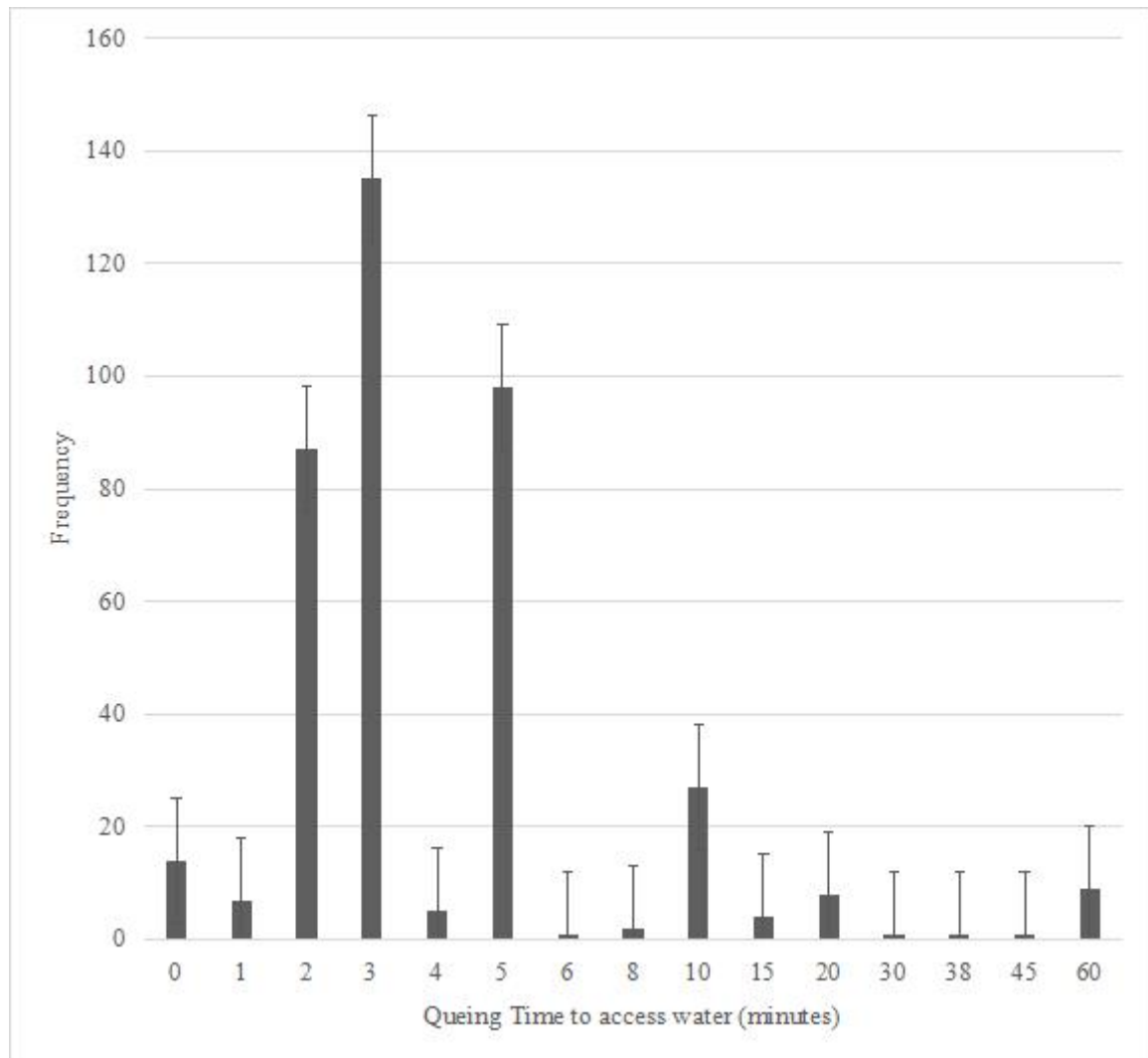


Source: (Researcher, 2024)

The average time respondents used to queue to fetch water was found to be 5.65 minutes as shown in Figure 4.10.

Figure 4.10:

Time Spent Queuing to Fetch Water



Source: (Researcher, 2024)

4.5. Safety of Excreta Along the Sanitation Service Chain

The study investigated excreta management from containment (user interface), greywater management, excreta management for under-three (3) years, emptying of the technology's practices, and challenges associated, transportation and treatment of excreta. The findings were as categorized below:

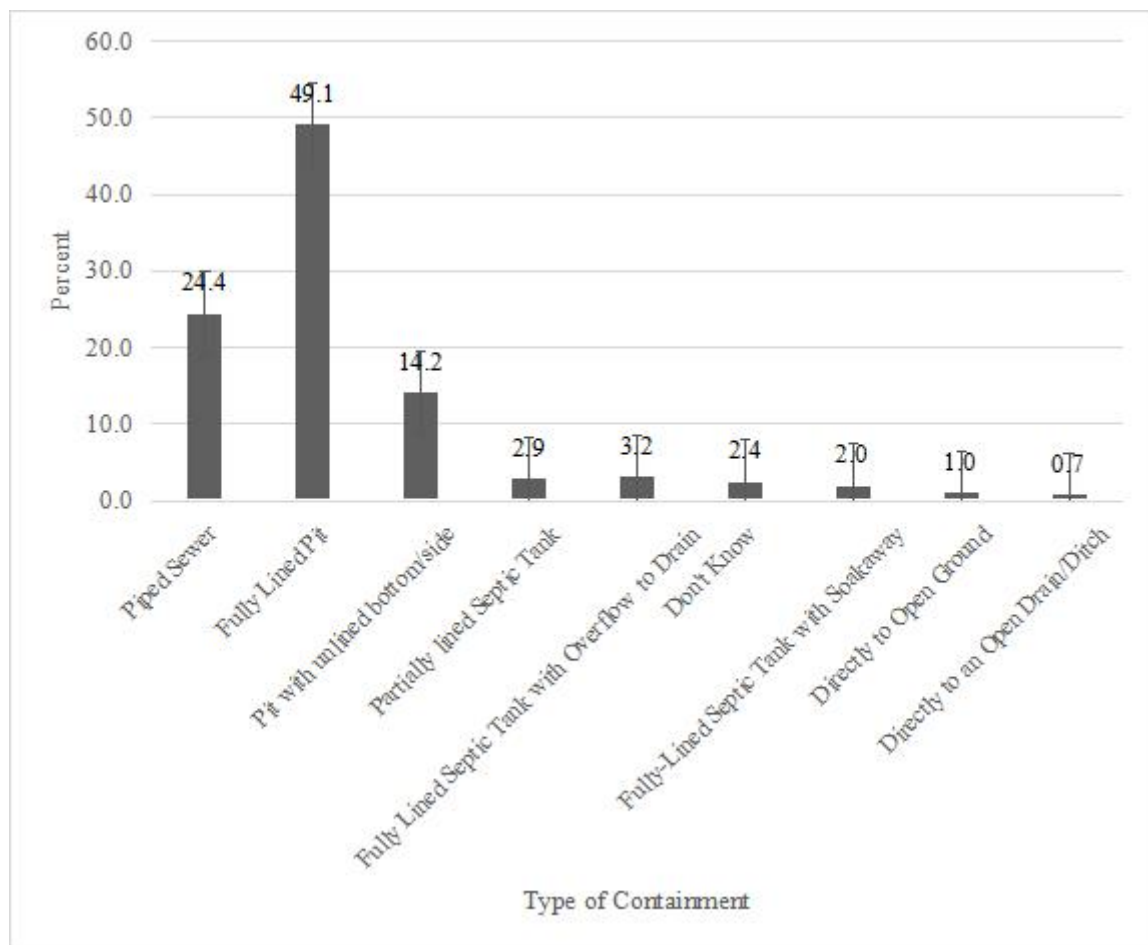
4.5.1 Containment

The study investigated safety of excreta from onsite technologies, whether lined or unlined, excreta disposal by households with children under 3 years of age in Kericho Town and greywater management. The study investigated the containment methods in Kericho Town, revealing that 49% of pit latrines were lined, while 14% were unlined. In the case of septic tanks, 3% were partially lined, 3% were fully lined with overflows to drain, and 2% were fully lined with a soakaway system.

Figure 4.11 illustrates where the discharge from the containments ended up to. Only, 24.45% (n=100) were connected to a piped sewer system, while the majority 49.945%, discharged waste into fully lined pits. Additionally, 14.18% released waste into pits with unlined bottoms or sides, 2.93% discharged into partially lined septic tanks, 3.18% released into fully lined septic tanks with overflow to drains or open ground, and 2.44% were unaware of the destination of their discharge. Furthermore, 1.96% discharged into fully lined septic tanks with soakaways, 0.098% released directly into open ground, and 0.73% discharged directly into open drains or ditches.

Figure 4.11:

Distribution of containment Facilities in Kericho Town



Source: (Researcher, 2024)

Among the 409 households surveyed, only 53 responded to the question concerning the disposal practices of child feces. Of these, the vast majority (92.5%) reported that they disposed of or rinsed the child's feces into a latrine, reflecting adherence to recommended sanitary practices. A smaller proportion (11.3%) indicated that the child independently used a sanitation facility, suggesting a degree of autonomy in hygienic behaviour. However, 1.9% (n = 1) of respondents reported that child feces were disposed of in household garbage, a practice considered unsafe due to the potential for environmental contamination and public health risks.

Additionally, greywater management practices among households in Kericho Town were assessed, with the results summarized in Table 4.13. The data reveal that the most common method of greywater disposal was direct discharge onto open ground, reported by 27.1% of respondents. This was followed by disposal via piped sewer systems at 24.9%, indicating some level of access to formal sanitation infrastructure. Other reported methods included discharge into fully-lined pit latrines (18.1%), unlined pits (9.8%), and open drains or ditches (6.8%). A smaller proportion of households reported using fully lined septic tanks with overflow mechanisms (3.2%), partially-lined septic tanks (2.9%), or fully-lined septic tanks with soakaway systems (2.9%). Additionally, 3.7% of respondents indicated that they were unsure about the greywater disposal method used in their household. Only a negligible percentage (0.5%), were discharging greywater directly into lakes or river.

Table 4.13:

Greywater Discharge (N=409)

Greywater Discharge Method	Frequency (N)	Percent (%)
Directly to open ground	111	27.1
Piped sewer system	102	24.9
Fully-lined pit latrine	74	18.1
Pit with unlined bottom or sides	40	9.8
Directly to an open drain/ditch	28	6.8
Fully lined septic tank with overflow to drain/open ground/other	13	3.2
Don't know	15	3.7
Fully-lined septic tank with soakaway	12	2.9
Partially-lined septic tank	12	2.9

Directly to the lake or river	2	0.5
Total	409	100.0

Source: (Researcher, 2024)

4.5.2 Faecal sludge emptying in Kericho town

The study assessed household experiences related to the filling and overflow of onsite sanitation systems, including pit latrines and septic tanks, in Kericho Town. As summarized in Table 4.14, the majority of respondents (56.7%) reported that their pit latrine or septic tank had never reached full capacity, indicating either regular maintenance or limited usage. In contrast, 14.2% of respondents acknowledged that their containment facilities had previously filled up, requiring attention or emptying. A substantial proportion (29.1%) indicated that they did not know whether their system had ever reached capacity suggesting a gap in user awareness or shared facility use.

Table 4.14:

Emptying practices in Kericho Town (N=409)

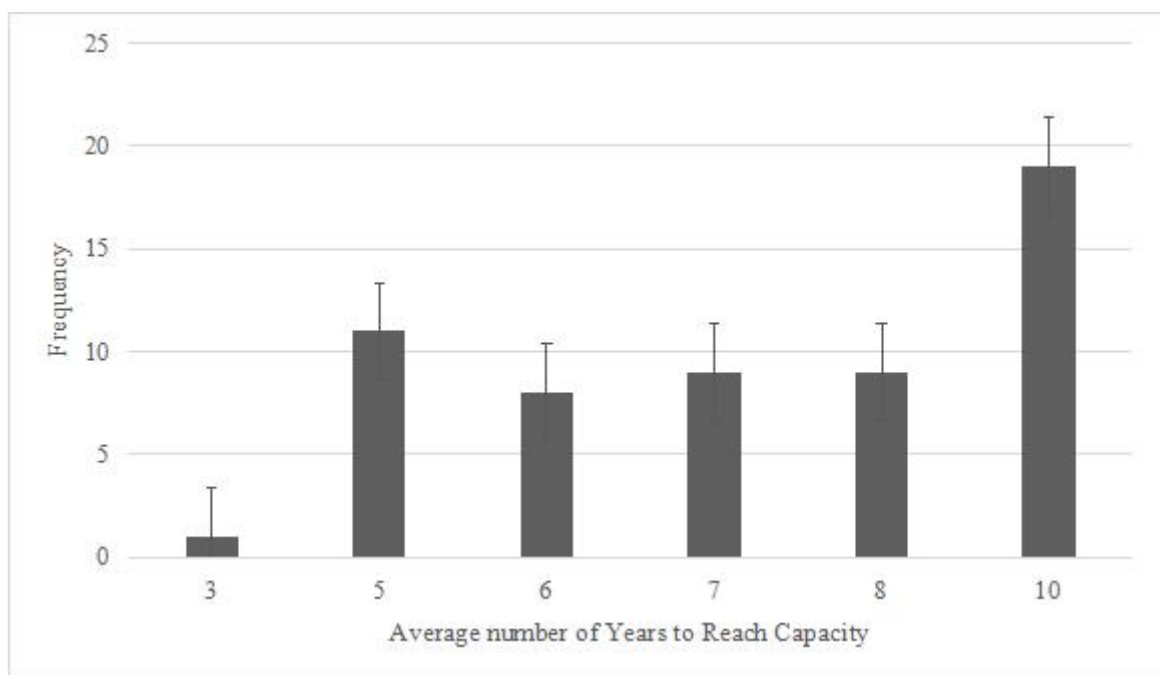
Variable	Frequency (n=409)	Percent (%)
Pit or Septic ever Reach Capacity		
Yes	58	14.2
No	232	56.7
Don't Know	119	29.1
Total	409	100
Toilet Overflow		
Yes	69	16.9
No	296	72.1
Don't Know	46	11.0
Total	409	100

Source: (Researcher, 2024)

The study found out pit filling frequency within past 5 years, out of which 58 respondents, 69% registered once, 1% twice, 0.2% thrice and 22.4% had not experience pit filling up within past 5 years. It was observed that average number of years a sanitation facility tool to reach capacity in Kericho Town was 8 years with majority 32.8% being 10 years as illustrated in Figure 4.12.

Figure 4.12:

Number of years to reach capacity

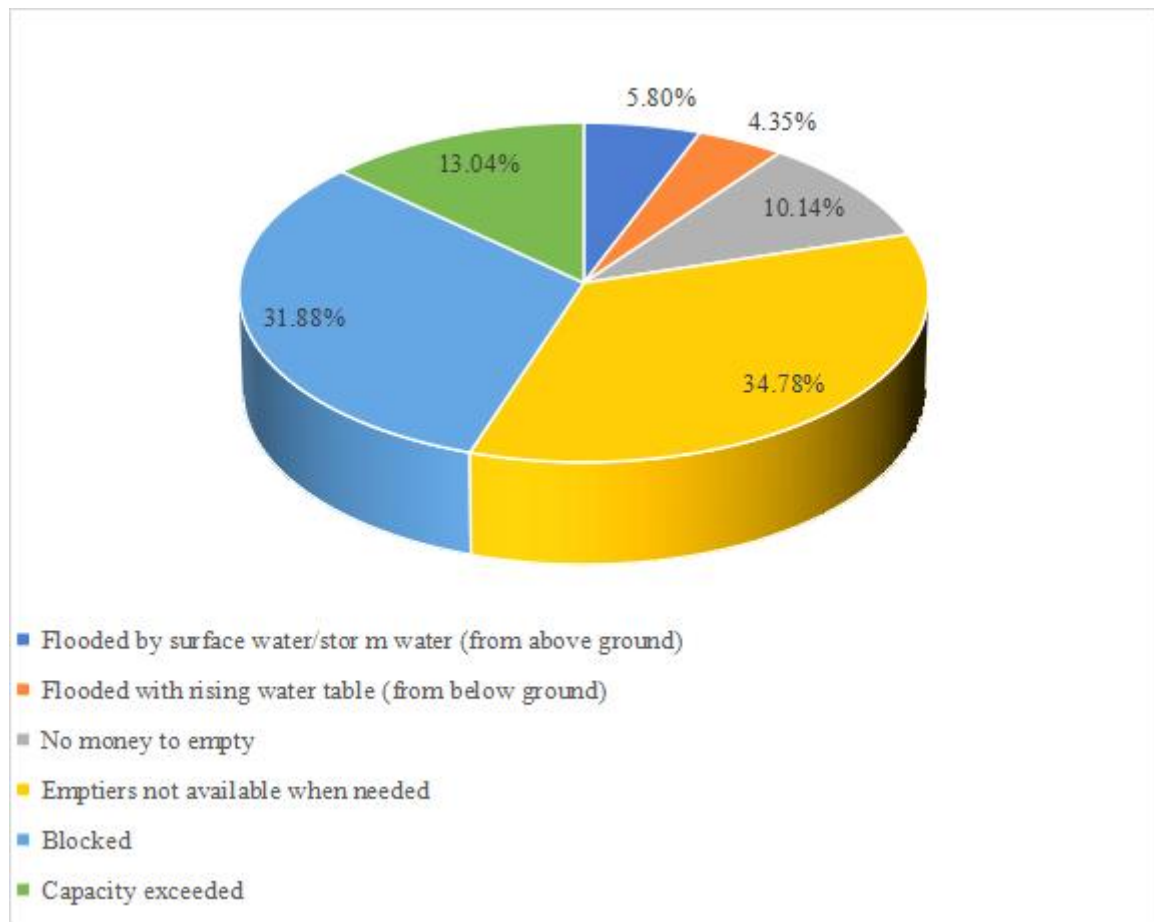


Source: (Researcher, 2024)

The study found that out 409 of respondents 16.9%, had observed toilet overflow as shown Table 4.14. The main reason for toilet overflow in Kericho Town was mainly due unavailability of emptiers as reported by 34.78% respondents, blockages of pipe/ sewer system 31.88%, overcapacity toilet 13.04%, cost related to emptying 10.14% among others as shown in pie chart Figure 4.13.

Figure 4.13:

Reason for toilet overflow



Source: (Researcher, 2024)

The study findings showed that 65.5% of household that had experienced pit filling up, they had emptied and reused it, 22.4% had covered and used alternative pit, and only 12.1% had abandoned pit latrine unsealed.

The household survey showed that emptying in Kericho Town was mainly conducted by formal utility as per 47.4% of the respondents. Others included; formal providers (company/NGOs), informal providers and member of household/neighbour at 34.2%, 7.9% and 10.5 % respectively, as shown in Table 4-15.

Table 4.15:*Who did the last emptying(N=38)*

Who did the last emptying	Frequency	Percent
Formal provider (utility)	18	47.4
Formal provider (company / NGO)	13	34.2
Informal provider (individual)	3	7.9
Member of household Neighbour	4	10.5
Total	38	100.0

Source: (Researcher, 2024)

Among the subset of households that had experienced faecal sludge emptying (n = 38), the majority (68.4%) reported that the process was carried out mechanically using a tanker truck, as shown in Table 4.16. A smaller proportion (31.6%) indicated that emptying was conducted mechanically using a small machine, likely due to accessibility limitations in densely populated or hard-to-reach areas.

Table 4.16:*How was it emptied (N=38)*

How was it emptied	Frequency	Percent
Mechanically, using tanker truck	26	68.4
Mechanically, using small machine	12	31.6
Total	38	100.0

Source: (Researcher, 2024)

The study further investigated the final disposal practices for faecal sludge emptied from household sanitation systems. As presented in Table 4.17, the majority of respondents (76.3%) reported that the sludge was emptied directly into a tanker truck for transportation to an appropriate treatment facility. Conversely, 23.7% indicated that the sludge was emptied into a pit within the household compound, which was subsequently covered.

Table 4.17:

Where was it emptied to (N=38)

Where was it emptied to	Frequency	Percent
Directly into machine/ tanker	29	76.3
Into a pit on the compound that is then covered	9	23.7
Total	38	100.0

Source: (Researcher, 2024)

According to an interview with technical operators of KEWASCO, ‘*Kericho Town, has six exhausters tasked with the removal of faecal sludge, primarily from septic tanks and occasionally from pit latrines. Among these, only two are currently operational. Two others additional VTOs belonged Finlays Company Limited and another belonged to AIC Litein Hospital*’

The study also assessed the financial aspect of faecal sludge management, focusing on whether households incurred costs for emptying services. As shown in Table 4.18, a significant majority (81.6%) of respondents whose pits or septic tanks had filled up reported paying for emptying services. A smaller proportion (13.1%) indicated that they did not pay, while 5.3% were unsure whether a payment was made possibly due to indirect arrangements or shared facility usage. The average cost of emptying services in Kericho Town was KSh. 3,532.26, with reported fees ranging from a minimum of KSh. 500 to a maximum of KSh. 7,000. This wide variation likely reflects differences in pit accessibility, service provider type (public vs. private), and distance to treatment sites.

Table 4.18:*Payment for emptying (N=38)*

Did you pay for the pit to be emptied	Frequency	Percent
Yes	31	81.6
No	5	13.1
Don't know	2	5.3
Total	38	100.0

Source: (Researcher, 2024)

Payment methods for emptying services varied among the respondents. The majority, 74.2%, reported that the cost was determined using a flat rate, while 25.8% indicated that charges were based on the volume of sludge excavated, as detailed in Table 4.19. Additionally, most respondents (88.38%) indicated that they paid the full amount upfront, in contrast to only 16.12% who opted for instalment-based payments. When asked about the perceived fairness of the pricing, a plurality (51.61%) of respondents considered the charges to be fair, while 29.03% viewed the cost as expensive.

Table 4.19:*Criteria for payment for emptying (N=31)*

How was the payment calculated	Frequency	Percent
Flat rate	23	74.2
Cost per volume removed	8	25.8
Total	31	100.0

Source: (Researcher, 2024)

The study assessed the level of satisfaction among households that had utilized emptying services, focusing on three key aspects: price, overall service quality, and ease of obtaining the service. The findings, as summarized in Table 4.20, reveal that 86.8% of respondents expressed either satisfaction or high satisfaction with the price charged. Similarly, 78.9% were satisfied with the overall quality of service, while a comparatively

lower 52.7% reported satisfaction with the ease of obtaining the service. These results suggest that while pricing and service delivery are generally well-received, accessibility and service reach remain areas for improvement in Kericho Town.

Table 4.20:

Level of satisfaction with service provider(N=38)

SATISFACTION LEVEL	PRICE (N, %)	SERVICE QUALITY (N, %)	EASE OF OBTAINING SERVICE (N, %)
Very Satisfied	17 (44.7%)	13 (34.2%)	5 (13.2%)
SATISFIED	16 (42.1%)	17 (44.7%)	15 (39.5%)
DISSATISFIED	5 (13.2%)	7 (18.4%)	15 (39.5%)
VERY DISSATISFIED	0 (0.0%)	1 (2.7%)	3 (7.8%)
TOTAL	38 (100%)	38 (100%)	38 (100%)

Source: (Researcher, 2024)

The researcher observed that, the exhausters at the point of exhaustion to disposal demonstrated a safe emptying process, with no spillage. Additionally, operators adhered to proper personal protective equipment (PPE) usage, ensuring a safe working environment during faecal sludge emptying operations. This suggested a satisfactory level of efficiency and safety in the current faecal sludge management practices in Kericho Town in terms of emptying.

The study explored the operational challenges encountered by sludge emptiers while navigating streets, accessing compounds, and reaching toilets during pit or septic tank emptying in Kericho Town. The findings, as detailed in Table 4.21, reveal that the most common difficulties in the street environment included lack of space (48.1%), narrow entrance gates (25.9%), and poor road conditions (22.2%). Similarly, within residential compounds, narrow entrances (48.1%), poor surface conditions (29.6%), and lack of

interior space for equipment (22.2%) posed significant barriers. Challenges at the toilet level were also reported, notably the inaccessibility due to distance (38.5%), small access points (34.6%), and instances where workers were forced to break slabs (11.5%) or remove latrine pans (7.7%) to reach the pit. Collapsed pits were mentioned by 7.7% of respondents as another serious operational hazard.

Table 4.21:

Challenges faced by emptiers in Kericho Town (N=27)

Variable	Frequency(N=27)	Percent (100%)
Street		
Lack of space	13	48.2
Poor Road conditions	6	22.2
Night-time working	1	3.7
Entrance gate too narrow	7	25.9
Compound		
Entrance/gate too narrow	13	48.1
Lack of space for equipment once inside	6	22.2
Poor surface conditions	8	29.6
Night-time working	0	0
Toilet		
Distance too far for equipment to reach the toilet	10	38.5
Access point too small to get equipment into the pit		
Had to break/damage the slab to gain access	9	34.6
Had to remove/ damaged latrine pans or seat		
Collapsed pit	3	11.5

Source: (Researcher, 2024)

An emptier argued that, “*At present, we are facing a significant challenge due to unexpected vehicle breakdowns. Unfortunately, four of our vehicles are currently out of*

operation, and this has had a considerable impact on our operational capacity. As a result, we're now compelled to conduct approximately 8 trips in a single day, which is quite demanding given the circumstances. In addition, it's important to note, though, that our machines have limitations. We can only pump waste from depths of up to 20 feet, so if a pit or tank is deeper than that we only exhaust 20 feet”

4.5.4 Conveyance/transport

In Kericho Town, the transportation of excreta involves conveying wastewater to treatment plants through sewer systems or by emptying from containment units, and then transporting it to these facilities by exhausters.

According to Technical service manager of KEWASCO, *“The existing sewer network in the Central Business District (CBD) of Kericho spans approximately 12 kilometres and primarily functions as a gravity system, with sewer lines ranging from Diameter- 315mm to Diameter- 160mm in diameter. The Sewerage System serve approximately 12,000 people through 2,262 piped sewer connections. The remainder of the Town’s population relies on on-site wastewater disposal methods, primarily Pit Latrines and Septic Tanks. The Kericho water and sanitation company has vacuum trucks to transport the waste from the septic tanks to the waste stabilization ponds”*

The study examined the proportion of wastewater and sludge safely transported to treatment plants, based on job cards obtained at KEWASCO from January to October 2023. On the sewer job card data, the proportion of wastewater in sewer system, which was delivered to centralised treatment plants was considered and coming up with the proportion based on the sewer data provided on leakages. The work descriptions which were handled during the months on the sewer were, unblocking, increasing pipe diameter of sewer, provision of manhole covers and replacing the leaking lines. Since the sewer delivered approximately 450 cubic metres per day (KII-02) the average blockage period

observed from KEWASCO's data was 55.57 minutes (approx. 1 hour) from the data per day. This therefore meant 55.57 minutes was the time the sewer takes to spill over per day, assuming a flow rate of 18.75 cubic per hour spills over to the environment. Hence the efficiency of sewer to transport was 95.8%. The proportion of septic tanks from which faecal sludge was emptied was reported by KEWASCO during KII as 100%, proportion of faecal sludge emptied also 100% and, which is delivered to treatment plants was 100% as there were no leakages along the way during transportation of Exhausters.

Wastewater was conveyed to treatment plants either through sewer systems or by being emptied from containment units, and it was then transported to treatment plants by exhausters. In Kericho Town, there were 9 exhausters tasked with the removal of faecal sludge, primarily from septic tanks and occasionally from pit latrines. Among these, only 2 out of 6 belonging to KEWASCO were operational, 2 trucks affiliated with Finlays Company Limited and 1 belonged to AIC Litein Hospital. It's noteworthy that within Kericho Town, there were no manual pit emptiers. This was due to licensing restrictions by KEWASCO. There was a sewer system within the Central Business District (CBD) which transported sewer to Waste Water Treatment Plant (WWTP).

4.5.5 Treatment and disposal of sludge in Kericho town

For the households with septic tanks, the emptied sludge by exhausters was treated in Kericho WWTP and DTF in Kapsoit. Wastewater inspector reported that, *“Primary treatment was done in septic tank, which are never emptied. Off-site treatment of FS is infrequent in rural areas. The limited capacity and resources of many low-income countries make it challenging to establish and sustain adequate faecal sludge treatment facilities outside major urban settlements.”*

In addition, Kericho Town has Waste Water Treatment Plant (WWTP) made up of 2 trickling filters (1 functioning) and 2 secondary clarifiers and The Decentralised Treatment Facility (DTF) at Kapsoit. According to Technical operators of KEWASCO, *“Waste Water Treatment Plant manages a daily influx of approximately 450 cubic meters of wastewater. Additionally, the facility receives an average of 66 cubic meters of faecal sludge on a daily basis from septic tanks and pit latrines within the town and from hospitals and neighbouring tea estates. The Decentralised Treatment Facility (DTF) at Kapsoit has a daily treatment capacity of 50 cubic meters, and based on the deliveries, it has not surpassed this capacity on a daily basis.”*

It was observed that the sewerage system and the collection tank, which receives supernatant from the sludge digesters, lacked installed pumps, as illustrated in Plate 4.3. The absence of pumping mechanisms at this critical junction has led to stagnation and ineffective conveyance of supernatant to subsequent treatment stages. As a result, untreated supernatant has been discharged directly into the environment, as shown in Plate 4.4. According to Key Informant KI-002, this issue has remained unaddressed since 2019. KI 002 stated: *“The supernatant has been flowing directly into the river since 2019 because the collection tank has no pump. It fills up and overflows nobody fixed it, and it’s still like that today.”*

Plate 4- 3:

Collection tank with missing pump, downstream of sludge digesters



Source: (Researcher, 2024)

This plate displays the collection tank situated after the sludge digesters, where the pump system has been physically removed. This structural gap prevents onward movement of supernatant and leads to stagnation or overflow at the site. The removal of the pump reflects systemic maintenance neglect and severely compromises process continuity.

The efficiency of the effluent from treatment plants in Kericho town could not be determined as there was no laboratory testing, and they began taking the samples to the lab at the time this research was carried out. According to KII-03 “*the effluent from DTF has never been taken to the laboratory. However, an individual conducted private tests on the DTF effluent and discovered that it exceeded water quality standards.*”

Unfortunately, efforts to obtain these test results were unsuccessful, and the technical manager assured that the results would be provided by the end of December 2023, as the facility had initiated the process of sending samples to the government chemist during the data collection period. This situation raises concerns about the effectiveness of the DTF in meeting water quality standards as it cannot be adequately established if it was effective or not.

Furthermore, the malfunctioning laboratory equipment at the Wastewater Treatment Plant (WWTP) was identified as a significant concern, as it hampered the inspector's ability to promptly identify irregularities in daily wastewater discharges or excessive toxicity of influent quantities beyond recommended water quality standards. Despite the treatment plant's efficiency in managing wastewater, there was a notable issue with the inadequate treatment of faecal supernatant. This inadequacy was primarily attributed to a non-functional pump at the collection tank, resulting in the untreated discharge of supernatant into the environment, as illustrated in Plate 4.4. Importantly, these discharges were not included among the samples submitted to the government laboratory for quality testing, thereby limiting oversight of this potential environmental hazard.

Plate 4- 4:

Untreated Supernatant into environment



Source: (Researcher, 2024)

Plate 4.4 depicts the uncontrolled discharge of untreated supernatant directly into the surrounding environment from WWTPt. Such practices not only undermine the integrity of the treatment process but also contribute to surface and groundwater contamination. This unmanaged release is indicative of infrastructural and operational gaps within the sludge management chain

The study further investigated the end and disposal practices in Kericho Town. The Kericho WWTP had 23 drying beds, which were effective for drying Sludge. As indicated by KII-02, Kericho WWTP had 23 sludge drying beds which after 6 months the public were free to come and take for reuse. Currently there was no selling of

compost. The effluent at the WWTP was released to the environment at the end of the 5th Maturation Pond and it was constantly tested for pH and temperature. The *E. coli* and BoD and CoD loading was not carried out as the KEWASCO laboratory did not have the working incubators. Therefore, the WWTP was not able to raise an alarm in case of any anomalies in the waste disposal.

Further to KEWASCO testing the samples daily, samples were also taken to the government laboratory in Kisumu City on a monthly basis. The laboratory results by the government chemist were also shared by KII-01 from April 2022 to April 2023 as summarized in the Table 4.22. The comparison was then made as per NEMA tolerance limits as per schedule provided in Appendix I.

Table 4.22 :

Comparison of Kericho WWTP Effluent Parameters with NEMA Discharge Standards (April 2022–April 2023)

Parameter	NEMA Standard	Apr-23	Mar-23	Feb-23	Jan-23	Dec-22	Nov-22	Oct-22	Sep-22	Aug-22	Jul-22	Jun-22	May-22	Apr-22	Compliance
pH	6.5–8.5	7.55	7.36	7.41	7.56	7.48	7.34	7.38	7.19	7.28	7.43	7.38	7.41	7.33	☑
Colour (Hazen Units)	<15	0.12	1.77	1.06	2.17	1.94	1.56	1.02	1.23	1.84	2.33	1.28	5.22	4.02	☑
BOD ₅ (mg/L)	<30	33.7	11.8	13.3	11.2	10.5	12.5	10.8	14.9	10.3	95	81	77	69	✗
COD (mg/L)	<50	51.4	33.9	23.1	19.9	21.2	19.2	17.6	22.2	24.8	20.2	16.1	11.8	10.2	✗
TSS (mg/L)	<30	0.72	0.72	0.72	0.88	0.91	1.01	1.11	1.04	0.33	0.22	0.10	0.11	0.03	☑
TDS (mg/L)	<120	16.5	23.5	21.7	17.3	20.1	20.3	21.1	20.1	17.0	20.5	18.4	20.2	16.4	☑
Total Nitrogen (mg/L)	<2	2.31	1.27	0.67	0.72	1.31	1.45	1.08	1.14	1.07	1.32	0.71	1.07	1.22	✗ (Apr only)
Total Phosphorus	<2	0.61	0.66	0.75	1.02	0.83	0.72	0.12	0.08	0.08	0.12	0.02	0.01	0.02	☑

(mg/L)																	
Oils, Greases, and Fats	ND	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	☑
Total Coliforms (Counts /100 mL)	<30	187	143	189	210	185	201	193	207	177	113	88	115	103			✘
<i>E. coli</i> (Counts /100 mL)	ND	11	17	14	17	12	9	47	55	43	16	11	9	12			✘

Note. ☑ = Compliant with NEMA limit; ✘ = Exceeds NEMA

limit (non-compliant); ND = Not Detectable; “<” = Below threshold.

Source: (Researcher, 2024)

It is crucial to highlight that key water quality parameters namely Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Total Coliforms, and Escherichia coli (*E. coli*) consistently failed to meet the effluent discharge standards stipulated by the National Environment Management Authority (NEMA, 2006). According to the Water Quality Regulations, the permissible limits for treated effluent are set at BOD₅ < 30 mg/L, COD < 50 mg/L, Total Coliforms < 30 counts/100 mL, and *E. coli* should not be detectable (ND) in a 100 mL sample. Persistent exceedance of these limits in effluents discharged from the Kericho Wastewater Treatment Plant underscores the potential environmental and public health risks posed by inadequately treated sewage. Such violations of regulatory thresholds suggest inefficiencies in treatment processes and call for urgent remedial actions to bring the facility into compliance.

Conversely, the treatment of faecal sludge delivered to treatment plants stood at approximately 20%. Notably, in the Kericho WWTP, only the sludge component underwent proper treatment, while the supernatant was released into the environment

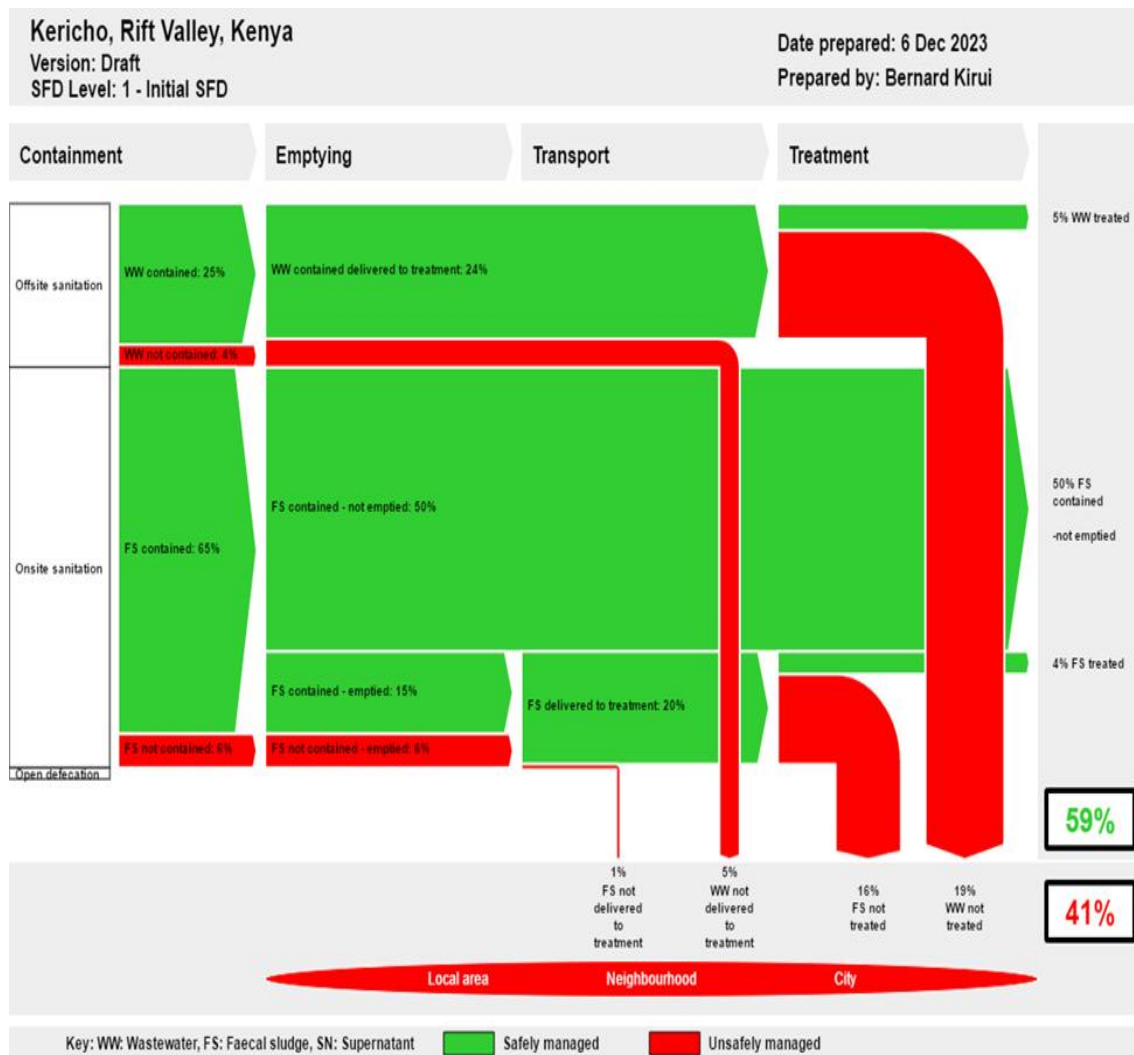
untreated as shown in Plate 4.4. This undesirable outcome was attributed to the malfunction of the pump responsible for returning the supernatant from the collection tank after separating from the sludge in the digester. Furthermore, the efficacy of the DTF remains unknown, adding another layer of concern to the overall wastewater management system.

4.6. Shit Flow Diagram

Using the SFD Graphic Generator, Figure 4.14 was developed to visually represent the management of excreta in Kericho Town. The diagram reveals 65% of households rely on onsite sanitation systems, such as pit latrines and septic tanks, for faecal sludge (FS) containment. However, despite high containment, there are critical shortcomings in the downstream stages of the sanitation service chain. Notably, only 54% of the faecal sludge undergo effective treatment, indicating significant inefficiencies in emptying, transport, and treatment processes. While 25% of households are connected to a formal offsite sewer system, a large proportion of wastewater remains untreated, with but only 5% of wastewater receives proper treatment. A concerning 1% of the population still practices open defecation. This situation contributes to 41% of all excreta being unsafely managed, primarily due to gaps in containment, emptying, and the lack of effective treatment.

Figure 4.14:

SFD Graphic of Kericho Town



Note. WW = Wastewater, FS = Faecal sludge, SN = Supernatant. Green = Safely managed; Red = Unsafely managed. Source: sfd.susana.org

Source: (sfd.susana.org, 2024)

CHAPTER FIVE: DISCUSSION

5.1. Introduction

This chapter presents a detailed discussion of the findings according to the research objectives.

5.2. Discussion

This section presents discussions of results based on study objectives.

5.2.1 Sanitation technologies in Kericho town

The majority of people in Kericho Town (66.5%) utilized pit latrines with slabs, while smaller percentages relied on pour/manual flush systems (13.69%), ventilated improved pit latrines (11.49%), and automatic cistern flush (8.07%). A minimal percentage (0.24%) resorted to no facilities. This distribution suggests that while basic forms of onsite sanitation dominate, there is a gradual shift albeit limited toward improved and water-based systems in some areas. This could be attributed to various factors such as affordability, ease of construction, and cultural norms. Pit latrines are often the most accessible and cost-effective sanitation option for many households, particularly in areas where access to piped water and sewage systems may be limited. These findings align with previous research conducted by (Lebu et al., 2023; Nasim et al., 2022; Seymour et al., 2021; Mremi et al., 2025) who also observed similar trends in sanitation preferences and practices. The relatively small proportion of households using flush systems suggests that significant infrastructural and economic barriers still limit widespread adoption of modern sanitation technologies.

The study found that 94.4% of residents in Kericho Town relied on on-plot sanitation facilities, either private or shared, while only 4.6% reported using communal toilets. Within the on-plot category, 32.3% of toilets were shared among households, while 67.7% were not shared. These findings indicate a high prevalence of household-level

sanitation access, suggesting that most residents have some form of convenient access to sanitation within their compounds. However, the proportion of shared facilities nearly one-third is significant and raises concerns regarding hygiene, privacy, and maintenance. Shared toilets often suffer from poor cleanliness and overcrowding, particularly where responsibility for cleaning is unclear or neglected.

This pattern is consistent with studies in other low and middle-income urban areas, where shared on-plot facilities are common due to land scarcity and the cost of constructing private toilets. For instance, research in urban Ethiopia by Ssemugabo et al. (2020) highlighted that while many households had structurally adequate toilets, the prevalence of sharing led to poor sanitary conditions. Similarly, Gitonga et al. (2021) found that in Kenya's informal settlements, shared toilets often lacked privacy and were in unhygienic states due to high user to toilet ratios. In Kericho, the existence of a considerable number of shared on-plot toilets implies potential risks for faecal contamination, especially where cleaning routines are not well coordinated. This underscores the need for interventions that promote improved designs of shared facilities, user agreements for maintenance, and policy incentives that encourage the construction of more private toilets within household plots.

The findings revealed a clear spatial disparity in sanitation infrastructure within Kericho Town. While the majority of sublocations relied predominantly on pit latrines with slabs (66.5%), the central township area showed a higher prevalence of flushing toilets. This contrast highlights the uneven distribution of sanitation services between the urban core and its peri-urban or rural fringes. In the township, access to infrastructure such as piped water, sewer lines, and municipal oversight likely enables the installation and maintenance of flush systems. In contrast, the peripheral sublocations face infrastructural limitations, compelling households to depend on simpler, low-cost onsite systems like pit

latrines. Previous studies have emphasized this disparity; for example, a study in Nakuru by Simiyu et al. (2021) noted that while some neighborhoods had access to sewerage, informal settlements relied almost exclusively on basic pit latrines. Similarly, Kabange (2017) identified that rapid urbanization without proportional expansion of sanitation infrastructure exacerbates such inequalities. These disparities can perpetuate health inequalities, particularly as pit latrines despite being functional are often associated with higher risks of contamination and exposure when not properly managed.

The results showed that 96.3% of respondents in Kericho Town had operational toilet facilities, while 3.7% reported non-functional toilets. Among those not in use, 47% had collapsed and 53% were full and awaiting emptying. These findings indicate relatively high access to usable sanitation, but also point to structural and service-related vulnerabilities. The collapse of some facilities suggests that construction quality or geotechnical conditions may not be optimal, especially in areas with poor drainage or unstable soils.

Meanwhile, toilets filled to capacity without prompt emptying reflect possible weaknesses in the town's faecal sludge management systems. When facilities collapse or filled up, affected households may be forced to share nearby toilets or revert to unsafe practices like open defecation, increasing the risk of disease transmission and environmental contamination. In contrast, Arévalo et al. (2024) reported that a large number of sanitation facilities across African cities remained full for extended periods due to unaffordable or unavailable desludging services. These studies emphasize that the functionality of sanitation systems depends not only on initial access but also on regular maintenance and safe waste disposal.

The study found that sanitation facilities in Kericho Town generally exhibited high structural quality. Most toilets (88.3%) had easy-to-clean slabs, 68.5% were built using

permanent materials like brick, 96.1% had roofs, and 94.4% had doors for privacy. The findings could be the availability of affordable and durable building materials such as brick in local markets likely encourages the use of permanent construction. Additionally, the relative urbanization of Kericho Town compared to more remote regions may mean better access to skilled labour and sanitation programs promoting improved designs.

The inclusion of doors and roofs in nearly all toilets' points to a user-driven emphasis on privacy and dignity, which are essential for encouraging consistent use, especially among women and children. Structurally sound toilets require less frequent repairs, and are easier to maintain in a hygienic condition. This helps reduce the risk of faecal exposure, soil and water contamination, and disease transmission especially in densely populated areas. However, the presence of faecal and urine contamination in nearly 28% of facilities indicates that structural quality alone does not guarantee hygiene. Without consistent cleaning routines and adequate user behaviour, the public health benefits of improved infrastructure may be undermined.

In agreement, Ssemugabo et al. (2020) reported that in Ethiopia, although most toilets had doors and roofs, over 60% suffered from flies and odour, and fewer than one-quarter had handwashing stations. However, Tidwell et al. (2018) in Bauleni, Zambia found that while most toilets had solid walls and doors, over 50% lacked roofs and 43% lacked effective cleaning systems conditions which discouraged regular use and increased contamination. These studies underline a common challenge: structural improvements often fail to translate into hygienic use without complementary behaviour change.

The study found moderately high level of water infrastructure coverage in Kericho, with over 45% having some form of piped connection either into their home or plot. The use of rainwater and boreholes points to adaptive strategies in areas with inconsistent piped supply or affordability limits connection to public utilities. The low use of unprotected

springs (2.2%) is a positive sign, indicating that most residents are not relying on high-risk sources. The relatively short travel of 5.09 minutes and queuing times of 5.65 minutes queuing, imply that water is physically accessible for the majority of the population, which is critical for sustaining good hygiene practices and for reducing the burden of water collection, particularly for women and children.

However, reliance on multiple water sources including rainwater and boreholes may reflect seasonal variations, cost concerns, or intermittent piped supply. This diversity in sources can lead to inconsistencies in water quality and reliability, especially when alternative sources lack treatment or regulation. The finding supports Odeya (2023), in the Lake-Wide Inclusive Sanitation (LWIS) study, noted that towns like Kericho relied heavily on non-piped water sources such as unlined pits and boreholes, often without examining the quality or reliability of those source. Water access and reliability are foundational to sanitation, hygiene, and public health; thus, these findings demonstrate the importance of integrated water supply and sanitation planning in Kericho's urban development strategy.

5.2.2 Safety of excreta along the sanitation service chain

The study examined containment methods used for human waste in Kericho Town and found that 49% of pit latrines were lined, while 14% remained unlined. Among septic tanks, 3% were partially lined, 3% were fully lined with overflows directed to drains, and 2% were fully lined with soakaway systems. These findings highlight a relatively strong effort toward containment safety, with a significant proportion of pit latrines featuring lining an essential measure for preventing pit collapse and minimizing groundwater contamination.

The presence of soakaway and drainage systems in some septic tanks indicates an attempt to manage effluent more effectively, although the small percentage reflects

limited reach of such advanced infrastructure. The high rate of lined pit latrines may be attributed to increased awareness of the structural and environmental benefits of lining, availability of local masonry skills, or guidance from public health officers during toilet construction. However, the continued use of unlined pits (14%) raises concerns, especially in areas with high water tables or porous soils where the risk of faecal contamination of groundwater is significant. Similarly, the low uptake of properly lined septic tanks with soakaway systems points to possible barriers such as construction costs, lack of technical knowledge, or inadequate regulation during installation. These findings align with Odeya (2023) in Kericho and Donacho et al. (2022) in Uganda who reported widespread use of unlined pits noting the health and environmental dangers posed by poor containment.

The study found only 24.45% of respondents were connected to a piped sewer network an indication that centralized wastewater infrastructure remains underdeveloped or inaccessible to most residents, particularly those in low-income or peri-urban areas. The dominance of fully lined pits as a disposal route reflects both a coping mechanism in the absence of sewerage and a positive shift toward safer containment practices. However, the widespread use of unlined pits and partially lined septic tanks reveals persisting structural vulnerabilities that can expose soil and groundwater to faecal contamination. Septic tanks are recommended by the Kenya Environmental Sanitation and Hygiene Policy (KESHP) as an improved sanitation facility (Ministry of Health, 2016), but they are less preferred due to a lack of awareness about proper faecal containment and cost. Notably, a small yet significant proportion of respondents were unaware of where their toilet waste was being discharged, underscoring a lack of household-level engagement with or understanding of sanitation infrastructure.

The study found that greywater management in Kericho Town remains a significant sanitation challenge, with the most common method of disposal being direct discharge onto open ground (27.1%). The high reliance on ground discharge and pits may stem from inadequate planning for greywater in both household infrastructure and urban development strategies. While 24.9% of households disposed of greywater through piped sewer systems suggesting a degree of access to formal sanitation infrastructure the majority relied on unregulated, decentralized approaches. The focus on faecal waste containment while overlooking the volume, frequency, and environmental impact of greywater could lead to waterlogging, vector breeding, and contamination of shallow groundwater or surface water, thus undermining the benefits of improved sanitation. The findings support Saxena and Den (2022) highlight that in many urban and peri-urban settlements, greywater is often mismanaged due to lack of integration in FSM policies.

The study revealed that many households in Kericho Town experience relatively infrequent filling of pit latrines or septic tanks, with some users unaware of their system's status. This reflects a mixed sanitation scenario where low pit-filling frequency may suggest durable containment or low usage per household. However, study found that significant 29.1% did not know whether their system had ever reached capacity, which could be explain by communal toilet usage, informal tenancy, or inadequate communication regarding facility maintenance. The low level of user knowledge about system capacity indicates that sanitation maintenance in Kericho is often reactive, lacking systematic monitoring or household-level responsibility.

The study found that many households, sanitation infrastructure has a relatively long service life, with the average time to reach full capacity being eight years and over 30% of respondents estimating ten years. The long intervals between fillings can mask deeper issues such as underreporting, use of soakaways that leach into the environment, or

structural failures that release contents prematurely. The findings are in line with study by Arévalo et al. (2024) found that in Cuenca, Ecuador, most septic tank users had never emptied their systems, discharging leachate into the environment instead highlighting the false sense of functionality that can accompany long intervals between emptying. However, the US Environmental Protection Agency (2024) recommends to empty the septic tanks every 3–5 years.

One of the most critical findings concerns the reasons behind toilet overflows, notably the unavailability of emptiers and blockages in sewer networks. These indicate structural and logistical weaknesses in local faecal sludge management (FSM) services. The constraints in access to emptiers mirror patterns observed in low- and middle-income urban areas, where FSM services are often informal, under-resourced, or difficult to access in unplanned settlements. For instance, Simwambi et al. (2023) in Lusaka reported that delays in emptying were largely attributed to the physical inaccessibility of vacuum trucks and the inability of residents to afford private desludging services. Similarly, Chumo et al. (2023) highlighted that in Nairobi's informal areas, lack of coordination among service providers and inadequate infrastructure created systemic emptying delays, often leading to environmental discharge or reliance on unsafe manual methods.

The study results revealed that households in Kericho Town employ a range of post-filling responses, with the majority opting to empty and reuse the existing pit. This reflects a functional familiarity with pit re-use and possibly a growing culture of periodic faecal sludge management (FSM), particularly in contexts where land scarcity or high construction costs limit the feasibility of new pit construction (Kericho county Government, 2022). However, the proportion of households abandoning pits without sealing them poses notable environmental and health concerns. Unsealed abandoned pits

can serve as breeding grounds for vectors and present contamination risks to shallow groundwater, especially in areas with high water tables. Study by Houemenou et al. (2020) in west Africa linked deteriorating water quality to poor sanitation.

The study found that pit emptying in Kericho Town is predominantly carried out by formal utility providers, which demonstrates a positive trend toward structured faecal sludge management (FSM) services. However, the town is served by only five vacuum trucks, a number that may be insufficient based on recommendations by Taweesan et al. (2015) and Arévalo et al. (2024), who argue that a city should have at least one vacuum truck per 1,000 households to achieve effective faecal sludge collection. This limited fleet likely contributes to the continued involvement of informal actors, including household members and neighbours, and highlights inconsistent access to professional services, potentially due to affordability barriers for some households.

The wide variation in emptying fees from KSh. 500 to KSh. 7,000 underscores disparities influenced by factors such as service provider type, distance from treatment facilities, and accessibility to sanitation infrastructure. These findings align with Tomoi et al. (2023) and Conaway et al. (2023), who noted that financial limitations hinder safe sanitation practices in low-income settings. Additionally, the use of small machines for emptying in areas with poor access illustrates the infrastructural barriers that prevent the widespread use of mechanized desludging.

Regarding household satisfaction with faecal sludge emptying services, lower level of satisfaction was reported with the ease of accessing these services. This highlights existing barriers to service reach and logistical availability, particularly in geographically constrained areas where vacuum trucks may have limited access. These challenges mirror observations by Chumo et al. (2023) in Nairobi, who reported that even when FSM services were available and of high quality, their reach was uneven due to

infrastructure deficits, poor road networks, and low provider density in underserved areas. In Kericho, such issues may be exacerbated by unplanned urban expansion and limited investment in decentralized sludge handling infrastructure.

The study revealed significant operational challenges faced by faecal sludge emptiers in Kericho Town, particularly related to limited access to sanitation systems. Narrow entrances, poor road conditions, and lack of space hinder the efficient movement of desludging vehicles, complicating emptying operations. At the household level, inadequate interior space and small access points further delay the process, while workers sometimes had to break slabs or remove pans to access pits, raising environmental and safety concerns. These challenges are consistent with findings by Mremi et al. (2025), Gudda et al., (2019), Saxena and Den (2022), and Simwambi, et al. (2023) that reported poor infrastructure impeded desludging efficiency.

Regarding final disposal, the majority of households reported that faecal sludge was transported offsite to treatment facilities via tanker trucks. The Kericho WWTP had 23 drying beds, which were effective for drying Sludge. This indicates a commendable level of compliance with safe FSM protocols. However, the fact that nearly a quarter of respondents disposed of sludge in household pits albeit covered raises questions about the long-term safety and environmental regulation of such practices. While this may be a temporary solution in areas lacking treatment infrastructure, it can lead to progressive soil and groundwater contamination if repeated over time without proper oversight. Studies by Rodrigues Mesquita et al. (2021) emphasize the importance of regulated disposal routes and treatment standards to avoid cumulative environmental hazards in decentralised sanitation systems.

The study identified significant deficiencies in wastewater treatment at both the Wastewater Treatment Plant (WWTP) and the Decentralized Treatment Facility (DTF)

in Kericho Town, particularly in the absence of installed pumps at the sewerage system and the collection tank receiving supernatant from sludge digesters. This lack of proper pumping infrastructure compromises the effectiveness of treatment processes and may lead to the release of untreated supernatant, posing substantial risks to public health and the environment. These issues are consistent with findings by WaterAid (2020), which highlighted that inadequate infrastructure and maintenance in wastewater treatment systems often result in the discharge of untreated waste into the environment, exacerbating pollution and health risks. Additionally, the study suggests that the poor operation and maintenance of treatment facilities may be attributed to a lack of skilled personnel and the high operational costs, a point supported by Omohwovo (2024), who noted that the shortage of trained staff and financial constraints hinder effective wastewater management in low-resource settings. These challenges underscore the need for investment in skilled human resources, proper infrastructure, and sustainable funding models to improve the reliability and safety of wastewater treatment systems in Kericho. The study also revealed that key water quality parameters, specifically Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Total Coliforms, and *Escherichia coli* (*E. coli*), consistently failed to meet the effluent discharge standards set by the National Environment Management Authority (NEMA, 2006). This indicates that the wastewater treatment processes at the WWTP and DTF are ineffective in reducing organic pollution and microbial contamination to safe levels. The failure to meet NEMA standards not only endangers public health but also undermines the environmental sustainability of water resources in Kericho. The discharge of untreated or partially treated wastewater into water bodies could lead to the contamination of local water sources, affecting both drinking water quality and agricultural irrigation. The results support United Nations Environment Programme, (2019), and Li and Yuan, (2024) who

reported that Over 80 per cent of the world's wastewater and over 95 per cent in some least developed countries is released to the environment without undergoing any form of treatment. Additionally, Houemenou et al. (2020) and Brandão et al., (2020) linked deteriorating water quality to leaking sewer systems.

4.2.3 Shit Flow in Kericho town

The study found a critical gap in the management of excreta along the sanitation service chain in Kericho Town. Despite a high proportion (65%) of households using onsite containment methods such as pit latrines and septic tanks, the subsequent stages of excreta management are not effectively addressed. The low percentage of treatment (54% for FS and 5% for WW) suggests that either the existing treatment infrastructure is insufficient or that a lack of operational capacity, such as insufficient vacuum trucks or dysfunctional treatment plants, is hindering the progress. Consequently, 41% of all excreta is unsafely managed, primarily due to inadequate containment, insufficient transportation, or total absence of treatment. The unsafely managed 41% of excreta in Kericho Town poses serious public health risks, as untreated or improperly managed faecal sludge can lead to contamination of water sources, increase the transmission of diseases such as cholera, dysentery, and typhoid, and contribute to environmental degradation.

These challenges are compounded by the growing population in urban areas like Kericho, where the demand for safe sanitation services is escalating, yet the infrastructure and resources to meet this demand remain insufficient. These findings are consistent with trends observed in other regions facing similar urbanization and sanitation challenges. For instance, Furlong (2015) and Gituma et al. (2022) found that in cities like Kisumu and Nakuru, both onsite and offsite sanitation systems struggle with infrastructure limitations that prevent effective treatment and management of faecal

sludge and wastewater. Similarly, Peal et al. (2020) reported that in rapidly growing urban centres across Africa and Asia, the failure to effectively treat wastewater and faecal sludge leads to significant health risks and environmental degradation. The low percentage of treated wastewater in Kericho aligns with global concerns about the inadequacy of wastewater treatment systems in LMICs, where lack of investment in infrastructure, outdated technology, and poor regulatory enforcement contribute to widespread pollution and public health crises (WHO, 2017).

CHAPTER SIX: CONCLUSION, RECOMMENDATIONS, AND PUBLICATION

6.1. Introduction

This chapter provided a summary of the study findings-based excreta management across sanitation service chain in the study area. The section further presents conclusions and recommendations based on the findings.

6.2. Summary of findings

Providing adequate sanitation services in urban and peri-urban areas is challenging especially in low- and middle-income countries where poor sanitation practices can lead to the spread of diseases with high morbidity and mortality rates. The study evaluates excreta management across sanitation service chain using Shit Flow Diagram (SFD) in Kericho Town, Kenya. Data was obtained from 409 households heads using structured questionnaires, informants including Vacuum Truck Operators (VTOs), KEWASCO management, DTF Operators, and sewer operators through interviews, desk review, transect walk and observations. The results on types of sanitation technologies, proportion of excreta that is safely and unsafely managed, and shit flow diagram is as follows;

6.2.1 Sanitation technologies in Kericho town

The study found that Kericho Town's sanitation system heavily relies on onsite technologies, with 66.5% of households using pit latrines with slabs and 13.69% using pour-flush systems. These technologies, though functional, face significant challenges, particularly in peri-urban areas, where regular emptying and maintenance are crucial. Ventilated improved pit latrines (VIPs) were used by 11.49%, and cistern flush toilets were less common, with 8.07% adoption. The study highlighted that most facilities are operational (96.3%), but collapsed toilets and overfilled systems remain problematic for 3.7% of respondents. Additionally, shared facilities were often in poor condition,

reflecting maintenance gaps. Water access in the town was varied, with 28.1% using piped water into their dwelling, while others relied on tube wells, rainwater, and unprotected springs.

6.2.2 Safety of excreta along the sanitation service chain

The study revealed significant safety challenges in excreta management across Kericho Town, particularly in containment, emptying, and treatment. A notable 49% of pit latrines were lined, while 14% were unlined, posing environmental and health risks. Waste disposal practices varied, with 49.95% of waste directed to lined pits, while 24.45% was connected to the piped sewer system. Greywater management was inadequate, with 27.1% of households discharging it directly onto open ground.

The majority of households with children under 3 years (92.5%) adhered to proper sanitation practices, although 1.9% disposed of child feces in household garbage, representing a potential public health concern. In terms of faecal sludge emptying, 56.7% of respondents had not experienced their systems reaching full capacity, but 16.9% reported toilet overflow. The Kericho Wastewater Treatment Plant (WWTP) and Decentralized Treatment Facility (DTF) face operational challenges, particularly with the supernatant discharge, which has been flowing directly into the environment since 2019 due to a non-functional pump.

Furthermore, the faecal sludge emptying process relies primarily on formal providers (47.4%) using tanker trucks (68.4%). The average cost for emptying services was KSh. 3,532.26, with fees ranging from KSh. 500 to KSh. 7,000. Regarding water quality, Kericho WWTP has failed to meet Kenya's NEMA water quality standards for treated effluent, particularly in terms of E. coli and BOD5 levels, highlighting the need for urgent improvements in wastewater treatment and overall sanitation infrastructure to mitigate environmental and health risks.

6.2.3 Shit flow in Kericho town Figure 6.1: SFD Graphic of Kericho Town

The study found that 65% of households were using onsite systems for faecal sludge containment, only 54% of faecal sludge undergoes effective treatment. Additionally, 25% of households are connected to a piped sewer system, but only 5% of wastewater receives proper treatment. A concerning 1% of the population still practices open defecation.

6.3. Conclusion

The study concluded that Kericho Town's sanitation system is predominantly reliant on onsite technologies, with a large proportion of the population using pit latrines with slabs and pour/manual flush systems. While most facilities are operational and provide essential privacy and functionality, issues such as collapsed toilets and the need for regular emptying remain significant challenges, particularly in peri-urban areas. The findings highlight a disparity in the quality of sanitation infrastructure, where shared facilities are often in poor condition, reflecting gaps in maintenance and accessibility. Additionally, while the majority of respondents have access to water, the dependence on both formal and informal sources such as unprotected springs and rainwater underscores the variability in service delivery across the town. Furthermore, the study revealed that most households do not pay for sanitation services, with a limited number opting for public or shared toilets, suggesting a lack of formalized sanitation payment systems.

The study concluded that excreta management in Kericho Town faces significant safety challenges, particularly in containment, emptying, and treatment practices. While 49% of pit latrines in the town were lined, ensuring some level of safety, a substantial proportion of containment systems rely on unlined or partially lined pits, posing environmental and health risks due to potential leakage or overflow. Additionally, greywater management

was inadequate, with a notable portion of households discharging greywater directly onto open ground, further contributing to environmental contamination. These findings suggest that while some households adhere to recommended disposal practices, a large portion continues to rely on suboptimal systems, which increases the risks associated with excreta management.

Moreover, the study revealed significant operational challenges in emptying and transporting faecal sludge, including limited access to emptying services and poorly maintained infrastructure. Although the formal utility and private providers are involved in sludge removal, there remains a gap in the capacity to manage the town's growing demand for emptying services. The Kericho Wastewater Treatment Plant (WWTP) and Decentralized Treatment Facility (DTF) face their own operational difficulties, including a non-functional pump system for supernatant conveyance and deficiencies in laboratory testing, which hamper effective treatment and disposal. The persistent failure to meet water quality standards for treated effluent highlights the inefficiency of the current treatment systems, calling for urgent improvements to prevent environmental pollution and safeguard public health.

The study concludes that in Kericho Town, there are significant gaps in the sanitation service chain, particularly at the stages of emptying and treatment. Despite relatively high onsite containment of faecal sludge (65%), only a small proportion of excreta undergoes effective treatment (54% of faecal sludge and 5% of wastewater). This inefficiency results in 41% of excreta being unsafely managed, highlighting critical shortcomings in both infrastructure and operational capacity. These findings suggest that without improvements in treatment capacity, transportation systems, and containment technologies, the town will continue to face substantial public health and environmental risks. Furthermore, these challenges are at odds with the objectives of Vision 2030 and

SDG 6.2, which aim to ensure access to safely managed sanitation for all. Achieving these goals will require urgent investments in sanitation infrastructure and the implementation of more efficient systems for waste treatment and management. Without addressing these gaps, Kericho Town risks falling behind on its commitments to sustainable development and the health and well-being of its residents

6.4. Recommendations

This section provides recommendations based on the study findings

6.4.1 Sanitation technologies

The local government, in collaboration with, NGOS, the Ministry of Health and the Kenya Water and Sanitation Company (KEWASCO), should prioritize the improvement of pit latrines, especially in peri-urban areas. This can be achieved through targeted subsidies or low-interest loans to encourage households to upgrade their sanitation facilities, particularly focusing on the construction of safer, more durable latrines with lined pits to prevent contamination and facilitate better waste management. Additionally, KEWASCO should establish regular maintenance and emptying services, particularly in areas with high populations using onsite containment.

This could be done through a public-private partnership to increase the availability and affordability of emptying services. Moreover, the town's municipality should focus on addressing the disparity in sanitation infrastructure by repairing or replacing collapsed toilets and improving shared facilities. A designated sanitation unit within the local government should be responsible for ensuring that all public toilets are regularly maintained and meet minimum standards of hygiene and accessibility. The unit should also work to educate residents on proper maintenance practices for shared facilities and offer financial support for communities that need to improve these facilities.

In addition, the government should facilitate the formalization of sanitation services by introducing a structured payment model that ensures households contribute to the cost of maintaining sanitation infrastructure. This could involve introducing a modest user fee for sanitation services, with options for subsidies or waivers for low-income households. KEWASCO, in partnership with local leadership, could help establish this payment system, ensuring it is transparent and equitable, while also addressing concerns about affordability. To address the variability in water access and improve sanitation outcomes, the relevant authorities, including KEWASCO and the Ministry of Water, should focus on expanding piped water access, particularly in peri-urban areas, while improving the quality of informal sources such as rainwater harvesting systems and unprotected springs. Ensuring equitable access to clean water is crucial for achieving broader sanitation and public health goals.

6.4.2 Safety of excreta along the sanitation service chain

To tackle the risks associated with unlined and partially lined pit latrines, the local government, in collaboration with KEWASCO, county government, NGOS, FBOS and the Ministry of Health, should prioritize the promotion of safe containment practices through education campaigns and technical support. This can include providing incentives or subsidies for households to upgrade to fully lined latrines, particularly in high-risk areas where pit latrines are prevalent. The Ministry of Water and Sanitation should collaborate with local authorities to develop a comprehensive strategy for improving containment infrastructure, which would include a regular inspection and certification process to ensure that all newly built facilities meet safety standards.

In addition, the management of greywater must be improved. Local authorities, in partnership with community groups, should encourage the use of sustainable and safe greywater disposal systems such as soakaways or systems that channel waste to lined

containment units. Public education campaigns should be launched to raise awareness of the environmental and health risks posed by the direct discharge of greywater into open ground. The local municipality could provide financial incentives or technical assistance for households to adopt safer greywater management practices.

Addressing the operational challenges in faecal sludge emptying and transportation is also essential. KEWASCO, with support from the Ministry of Environment, should invest in expanding the capacity of the faecal sludge emptying services by acquiring additional vacuum trucks and improving maintenance protocols for existing equipment. Private service providers could be involved in a public-private partnership to increase the availability and affordability of sludge removal services, especially in underserved peri-urban areas.

Additionally, the local government should establish a monitoring framework to ensure that emptying services are provided regularly and that containers are not left to overflow or become hazardous. Regarding the Kericho Wastewater Treatment Plant (WWTP) and Decentralized Treatment Facility (DTF), it is imperative that local authorities prioritize repairs to the non-functional pump system for supernatant conveyance and invest in improving the laboratory testing capacity to monitor effluent quality more effectively. KEWASCO, in collaboration with national agencies, should fast-track the provision of a reliable monitoring system to test water quality parameters such as BOD₅, COD, and E. coli, ensuring that the WWTP meets the water quality standards stipulated by NEMA. This can be achieved by ensuring that necessary laboratory equipment is maintained and functional.

To achieve long-term sustainability, the town must invest in expanding treatment capacity, ensuring that both WWTP and DTF systems are upgraded to handle the growing population's demands. A dedicated task force should be formed to regularly

assess and report on treatment performance, ensuring that effluent is treated to meet national and international water quality standards. These efforts would contribute significantly to reducing environmental pollution, improving public health, and supporting the achievement of SDG 6.2 for safe sanitation and water management.

6.4.3 Shit flow diagram

The significant gaps identified in Kericho Town's sanitation service chain; it is imperative that immediate and strategic interventions be implemented to address both infrastructure and operational deficiencies. The local government, in collaboration with Kericho Water and Sanitation Company (KEWASCO), Ministry of Health, Ministry of Water and Sanitation, NGOs, private entities, and environmental regulatory agencies such as NEMA, should prioritize the expansion and upgrading of the existing sanitation infrastructure, particularly focusing on increasing the capacity of faecal sludge treatment facilities and wastewater treatment plants. This includes upgrading the Kericho Wastewater Treatment Plant (WWTP) and Decentralized Treatment Facility (DTF) to ensure that they can handle the growing population's needs while meeting national and international water quality standards. These upgrades should be accompanied by regular monitoring systems to track treatment efficiency and ensure compliance with the NEMA discharge standards. KEWASCO should be tasked with spearheading these infrastructural changes, in partnership with national ministries, technical bodies, and private sector service providers.

6.5. Area of Further Study

The research findings suggest that a considerable quantity of excreta was not safely managed. Further research is needed to better understand the specific processes contributing to this improper waste management. SaniPath research would be particularly suitable for exploring this aspect within the scope of the research area.

Further studies are needed in all wastewater treatment plants in Kenya to determine the effectiveness of their treatment processes, in line with the results from Government Chemists, and to assess adherence to NEMA water quality standards in Appendix I.

Additionally, further study should also focus on illustrating how sanitation facilities in schools influence the overall sanitation services in Kericho Town including testing relationships between dependent and independent variables. Furthermore, it would be beneficial to investigate the effectiveness of a Decentralised Treatment Facility in Kericho and other parts of Kenya. This research could provide insights into how such facilities impact waste management practices in the region.

6.6. Publication

Kirui Bernard; Wandili Sarah; Gachoka Kennedy. "Evaluation of Sanitation Technologies Across Sanitation Service Chain in Kericho Town, Kenya." Volume. 9 Issue.8, August - 2024 International Journal of Innovative Science and Research Technology (IJISRT), www.ijisrt.com. ISSN - 2456-2165, PP: - 2322-2332, <https://doi.org/10.38124/ijisrt/IJISRT24AUG1375>"

REFERENCES

- Adzimah, I. (2022). Factors Affecting the Implementation of Community-Led Total Sanitation in Central Region, Ghana (Doctoral dissertation, University of Cape Coast).
- Alam, M. U., Rahat, M. A., Neeher, N., Tabassum, K. F., Nawaz, S., Evans, B., & Hutchings, P. (2025). Barriers to sewer connection in urban Dhaka: Individual and organisational challenges. *Journal of Water, Sanitation and Hygiene for Development*, 15(4), 287-304.
- Andres, L., Boateng, K., Borja-Vega, C., & Thomas, E. (2018). A review of in-situ and remote sensing technologies to monitor water and sanitation interventions. *Water*, 10(6), 756.
- Appiah-Effah, E., Nyarko, K. B., Gyasi, S. F., & Awuah, E. (2014). Faecal sludge management in low-income areas: a case study of three districts in the Ashanti region of Ghana. *Journal of water, sanitation and hygiene for development*, 4(2), 189-199.
- Arévalo, M. B., Ballari, D., & Alvarado, A. (2024). Septic tank usage and its faecal sludge management in Cuenca, Ecuador. *Journal of Water Sanitation and Hygiene for Development*. <https://doi.org/10.2166/washdev.2024.223>
- Atemoagbo, O. P. (2024). Investigating The Impact of Sanitation Infrastructure on Groundwater Quality and Human Health in Peri-Urban Areas. *International Journal of Medical Science and Clinical Invention*, 11(01), 7260-7273.
- Ayeleru, O. O., Oboirien, B., & Olubambi, P. A. (2023). Challenges of wastewater generation and management in sub-Saharan Africa: A review. *Environmental Challenges*, 13, 100727. <https://www.researchgate.net/publication/367447074>

- Bankole, A. O., James, A. O., Odjegba, E. E., & Bankole, A. R. (2023). Factors affecting sanitation coverage in three income levels and potential toward achieving SDG 6.2. *Water Policy*, 25(2), 146–160. <https://doi.org/10.2166/wp.2023.161>
- Bazaanah, P., Buthelezi, S. J., & Afua Kobe Oppong, D. (2024). Qualitative study of drinking water, sanitation, and hygiene access: perspectives from the Central Gonja District, Ghana, and Mtubatuba Municipality, South Africa. *Journal of Water, Sanitation and Hygiene for Development*, 14(11), 1043-1065.
- Birasa, D. F., Donacho, D. O., Gil, R. G., & Debele, G. R. (2024). Open Defecation Practice and Its Determinants Among Households Owned Toilet Facilities in Gambela Town, South West Ethiopia. *Environmental Health Insights*, 18, 11786302241246421.
- Bishoge, O. K. (2021). Challenges facing sustainable water supply, sanitation and hygiene achievement in urban areas in sub-Saharan Africa. *Local Environment*, 26(7), 893-907.
- Borah, D. K., Zhang, H., Zellner, M., Ahmadisharaf, E., Babbar-Sebens, M., Quinn, N., Kumar, S., Leelaruban, N., & Lott, C. (2023). Total Maximum Daily Load Implementation Modeling, Planning, and Design: A Synthesis of Resources for Watershed Stakeholders. *World Environmental and Water Resources Congress 2023*,
- Brandão, J., Albergaria, I., Albuquerque, J., José, S., Grossinho, J., Ferreira, F. C., Raposo, A., Rodrigues, R., Silva, C., Jordao, L., Sousa, M., Rebelo, M. H., Veríssimo, C., Sabino, R., Amaro, T., Cardoso, F., Patrão-Costa, M., & Solo-Gabriele, H. (2020). Untreated sewage contamination of beach sand from a leaking underground sewage system. *Science of The Total Environment*, 740, 140237. <https://doi.org/https://doi.org/10.1016/j.scitotenv.2020.140237>

- Bundi, P. K. (2023). An Investigation of the challenges in sustainable finance for water and sanitation in Kenya [Master's thesis, Strathmore University]. <https://suplus.strathmore.edu/bitstreams/6b99a1b0-0c10-44c9-aad1-a96d2a6d0249/download>
- CGoK. (2017). Intergrated Strategic Urban Development Plan (ISUDP) 2017-2037.
- CGoK. (2018). Second Generation County Integrated Development Plan 2018 -2022.
- Chhajed-Picha, P., & Narayanan, N. C. (2021). Refining the shit flow diagram using the capacity-building approach–Method and demonstration in a south Indian town. *Journal of environmental management*, 294, 112971.
- Chibwe, P. T. (2024). Factors Affecting Faecal Sludge Emptying and Transportation Entrepreneurship: A Case Study in Mzuzu, Malawi. *Sanitation*, 00028.
- Choge, C. (2021). Domestic private sector participation in faecal sludge management. Loughborough University. https://repository.lboro.ac.uk/articles/thesis/Domestic_private_sector_participation_in_faecal_sludge_management/16692394
- Chumo, I., Mberu, B., Wainaina, C., Murigi, W., Sumba, L., & Kabaria, C. (2023). Sanitation services for the urban poor: A social capital approach to sanitation challenges in informal settlements. *PLoS Water*, 2(12), e0000086.
- Conaway, K., Lebu, S., Heilferty, K., Salzberg, A. A., & Manga, M. (2023). On-site sanitation system emptying practices and influential factors in Asian low- and middle-income countries: a Systematic Review. *Hygiene and Environmental Health Advances*, 6, 100050. <https://doi.org/10.1016/j.heha.2023.100050>
- Cookey, P. E., & Peter-Cookey, M. A. (2024). Regenerative city-wide inclusive sanitation: Integration of urban development. ResearchGate. <https://www.researchgate.net/publication/382184152>

- Devaraj, R., Raman, R. K., Wankhade, K., Narayan, D., Ramasamy, N., & Malladi, T. (2021). Planning fecal sludge management systems: challenges observed in a small town in southern India. *Journal of Environmental Management*, 281, 111811.
- Donacho, D. O., Tucho, G. T., Zeine Ousman, W., Both, T. K., & Hailu, A. B. (2022). Evidence-based user interface sanitation technology selection for urban slums: a multi-criteria analysis; the case of Jimma town, Ethiopia. *Environmental Health Insights*, 16, 11786302221127270.
- Flanagan, K., Dixon, B., Rivenbark, T., & Griffin, D. (2020). An integrative GIS approach to analyzing the impacts of septic systems on the coast of Florida, USA. *Physical Geography*, 41(5), 407-432.
- Furlong, C. (2015). SFD Report, Nakuru Kenya. Susana: SFD Promotion Initiative.
- Furlong, C., Mensah, A., Donkor, E., & Scott, R. E. (2016). Learnings from implementing the excreta flow diagram (SFD) process in Kumasi. 39th WEDC International Conference: Ensuring Availability and Sustainable Management of Water and Sanitation for All,
- Gambrill, M., Gilsdorf, R. J., & Kotwal, N. (2020). Citywide inclusive sanitation—business as unusual: Shifting the paradigm by shifting minds. *Frontiers in Environmental Science*, 8, 201. <https://doi.org/10.3389/fenvs.2019.00201>
- Gitonga, F. K., Kanyepi, T., & Tanyanyiwa, V. I. (2021). Fecal sludge management for sustainable cities: Glimpses from Kenya. In *Clean Water and Sanitation* (pp. 1-13). Cham: Springer International Publishing.
- Gituma, G. M., Otieno, F. A. O., & Mwanza, D. D. (2022). Barriers to effective faecal sludge management in urban informal settlements in Nakuru County, Kenya. *Water Practice and Technology*, 17(4), 1123–1135. <https://doi.org/10.2166/wpt.2022.084>

- GIZ; Lusaka Water and Sewerage Company (LWSC); Lusaka City Council (LCC). (2019). SFD Report for Lusaka. SFD Promotion Initiative.
- GIZ;LWSC;LCC. (2019). The development and use of SFDs for better sanitation investment planning - A case story from Lusaka (Zambia). L. W. a. S. C. (LWSC). <https://www.susana.org/en/knowledge-hub/resources-and-publications/library/details/3588#>
- Gudda, F. O., Moturi, W. N., Oduor, O. S., Muchiri, E. W., & Ensink, J. (2019). Pit latrine fill-up rates: variation determinants and public health implications in informal settlements, Nakuru-Kenya. *BMC Public Health*, 19(1), 68. <https://doi.org/10.1186/s12889-019-6403-3>
- Haque, S., Amin, N., Raj, S., Green, J., Ali, S., & Wang, Y. (2025). Variation in exposure in neighborhoods of Dhaka, Bangladesh across different environmental pathways. medRxiv. <https://doi.org/10.1101/2025.02.12.25322139>
- Hoque¹, M. A., Hasan, M. A., Banik, B. K., & Kabir, M. I. (2024). Check for updates Investigating the Compatibility of Existing Sanitation Services with Sustainable Development Goal Using GIS and SFD Graphic: A Case Study on Sylhet City. In *Proceedings of the 7th International Conference on Civil Engineering for Sustainable Development (ICCESD 2024)* (Vol. 34, p. 216). Springer Nature.
- Houemenou, H., Tweed, S., Dobigny, G., Mama, D., Alassane, A., Silmer, R., Babic, M., Ruy, S., Chaigneau, A., Gauthier, P., Socohou Amadou, A., Dossou, H.-J., Badou, S., & Leblanc, M. (2020). Degradation of groundwater quality in expanding cities in West Africa. A case study of the unregulated shallow aquifer in Cotonou. *Journal of Hydrology*, 582. <https://doi.org/10.1016/j.jhydrol.2019.124438>
- Hussain, F., Clasen, T., Akter, S., Bawel, V., Luby, S. P., Luby, S. P., Leontsini, E., Unicomb, L., Barua, M. K., Thomas, B., & 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), 515. <https://doi.org/10.1186/S12889-017-4412-7>
- Hyun, C., Burt, Z., Crider, Y., & Nelson, K. L. (2019). Sanitation for low-income regions: A cross-disciplinary review. *Annual Review of Environment and Resources*, 44, 287–318. <https://doi.org/10.1146/annurev-environ-101718-033327>
- Islam, M., Sharif, S., & Chowdhury, M. (2020). Assessment of sanitation safety in low-income urban areas: The use of the Excreta Flow Diagram (SFD) approach in Dhaka, Bangladesh. *Journal of Water, Sanitation and Hygiene for Development*, 10(1), 69-78. <https://doi.org/10.2166/washdev.2019.101>.
- Ismail, N., Kinchin, G., & Edwards, J.-A. (2018). Pilot study, Does it really matter? Learning lessons from conducting a pilot study for a qualitative PhD thesis. *International Journal of Social Science Research*, 6(1), 1-17.
- Jothinathan, H., & Singh, A. P. (2023). Fecal sludge characterization, treatment, and resource recovery options: a state-of-the-art review on fecal sludge management. *Environmental Science and Pollution Research*, 30(57), 119549-119567
- Juliet, N. (2022). An Assessment of The Health and Safety Practices in Faecal Sludge Management in The Urban and Slum Areas of Kampala (Doctoral dissertation, Institute of Petroleum Studies-Kampala). <https://dspace.ipsk.ac.ug/handle/123456789/95>
- Kapulu, M. (2021). Approach for scaling up citywide safely managed sanitation access and services: A study of Lusaka, Zambia [Doctoral thesis, University of Sheffield]. <https://etheses.whiterose.ac.uk/30232/>

- Karki, B. K., Baniya, S., Kharel, H. L., & Angove, M. J. (2024). Urban wastewater management in Nepal: generation, treatment, engineering and policy perspectives. *H2Open Journal*. <https://doi.org/10.2166/h2oj.2024.105>
- Kericho County - Report of research findings.
- Kericho County Government. (2023). Kericho County Integrated Development Plan (CIDP) 2023–2027. Council of Governors – Maarifa Centre. <https://www.maarifa.cog.go.ke/sites/default/files/2024-06/KERICHO%20%20CIDP%20%202023-2027.pdf>
- Kericho Water and Sanitation Company, K. (2022).
- KEWASCO. (2022). Kericho Water and Sanitation Company Limited Service Area.
- Kimmons, R. (2022). Mixed methods. *Education Research*, 63(5), 631-641.
- Kipkoech, O. M. (2024). Parametric analysis of sanitation technologies for sustainable fecal sludge management: A case of Eldoret Municipality, Uasin Gishu County, Kenya. Meru University Repository. <https://repository.must.ac.ke>
- KNBS. (2019). Distribution of Population by Administrative Units.
- Korir, B. (2020). An Analysis of Kenya's water sector institutional and regulatory framework from 2002-2017 (Doctoral dissertation, Strathmore University).
- Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.
- Lambiasi, L., Ddiba, D., Andersson, K., Parvage, M., & Dickin, S. (2024). Greenhouse gas emissions from sanitation and wastewater management systems: a review. *Journal of Water and Climate Change*, 15(4), 1797-1819.
- Lehtoranta, S., Malila, R., Särkilahti, M., & Viskari, E. L. (2022). To separate or not? A comparison of wastewater management systems for the new city district of Hiedanranta, Finland. *Environmental Research*, 208, 112764.

- Li, Z., & Yuan, D. (2024). Global performance and trends of research on emerging contaminants in sewage sludge: A Bibliometric Analysis from 1990 to 2023. *Ecotoxicology and Environmental Safety*, 281, 116597.
- Liu, L., Stroulia, E., Nikolaidis, I., Miguel-Cruz, A., & Rios Rincon, A. (2016). Smart homes and home health monitoring technologies for older adults: A systematic review. *Int J Med Inform*, 91, 44-59. <https://doi.org/10.1016/j.ijmedinf.2016.04.007>
- Lohr, S. L. (2021). *Sampling: design and analysis*. Chapman and Hall/CRC. <https://www.taylorfrancis.com/books/mono/10.1201/9780429298899/sampling-sharon-lohr>
- Lüthi, C., Willetts, J., & Hoffmann, S. (2020). City-wide sanitation: the urban sustainability challenge. In (Vol. 8, pp. 585418): Frontiers Media SA.
- Makwana, D., Engineer, P., Dabhi, A., & Chudasama, H. (2023). Sampling methods in research: A review. *Int. J. Trend Sci. Res. Dev*, 7(3), 762-768.
- Mallory, A. (2018). Designing sustainable faecal sludge treatment systems for small cities in Sub-Saharan Africa. <https://era.ed.ac.uk/handle/1842/33039>
- Martínez, L. F. (2016). Using the Shit/Excreta Flow Diagrams–SFDs–for modelling future scenarios in Kumasi, Ghana (Doctoral dissertation, Loughborough University).
- Mazuze, H., Almendra, R., & Santana, P. (2023). A systematic literature review on factors of socio-environmental vulnerability associated with water-borne diseases. *The Journal of Infection in Developing Countries*, 17(12), 1658-1666.
- Mazuze, T., Nyamongo, I. K., & Okello, J. J. (2023). Poor sanitation and diarrhoeal disease prevalence in rural and peri-urban Kenya. *International Journal of Environmental Research and Public Health*, 20(5), 4127. <https://doi.org/10.3390/ijerph20054127>

- Medland, L., Cotton, A.P. and Scott, R.E. (2015). Understanding and addressing
- Ministry of Health [Kenya]. (2016). Kenya Environmental Sanitation and Hygiene Policy 2016–2030. Government of Kenya. <https://www.health.go.ke/wp-content/uploads/2020/02/National-Environmental-Sanitation-and-Hygiene-Policy-2016-2030.pdf>
- MoWSI. (2022). National Sanitation Management Policy
- Mremi, A., Kimwaga, R., Mulungu, D. M., & Izdori, F. (2025). Managing sanitation in unplanned urban areas: insights into manual emptying of onsite systems in Tandale, Dar es Salaam. *Journal of Water, Sanitation and Hygiene for Development*, 15(3), 215-231.
- Mugenda, O. M., & Mugenda, A. G. (2003). Research methods: Quantitative & qualitative approaches (Vol. 2). Acts press Nairobi.
- Mugendi, C., Kagendo, D., & Kubai, P. (2023). The influence of resource planning practices in faecal sludge management system in Embu County. *African Journal of Science, Technology and Social Sciences*, 2(2), 89-97.
- Muruganandam, M., Rajamanickam, S., Sivarethinamohan, S., Reddy, M. K., Velusamy, P., Gomathi, R., Ravindiran, G., Gurugubelli, T. R., & Munisamy, S. K. (2023). Impact of climate change and anthropogenic activities on aquatic ecosystem—A review. *Environmental Research*, 117233.
- Musaazi, I. G. (2020). Predicting Pathogen Fate and Transport Throughout The Sanitation Service Chain: Knowledge to Practice With the Global Water Pathogens Project (Master's thesis, San Diego State University).
- Musonda, K. C. (2020). Development of an excreta pathway for Kanyama peri-urban area of Lusaka using the shit flow diagram (SFD) tool [Master's thesis, University of Zambia]. <https://dspace.unza.zm/handle/123456789/8686>

- Muzioreva, H., Gumbo, T., Kavishe, N., Moyo, T., & Musonda, I. (2022). Decentralized wastewater system practices in developing countries: A systematic review. *Utilities Policy*, 79, 101442. <https://doi.org/10.1016/j.watres.2008.08.015>
- Naing, W., Harada, H., Fujii, S., & Hmwe, C. S. S. (2020). Informal emptying business in mandalay: its reasons and financial impacts. *Environmental Management*, 65, 122-130.
- Narayan, A. S. (2022). Planning citywide inclusive sanitation (Doctoral dissertation). ETH Zurich. <https://www.research-collection.ethz.ch/handle/20.500.11850/561822>
- Narayan, A. S., Marks, S. J., & Meierhofer, R. (2021). Advancements in and integration of water, sanitation, and solid waste for low-and middle-income countries. *Annual Review of Environment and Resources*, 46, 365–393. <https://doi.org/10.1146/annurev-environ-030620-042304>
- Nasim, N., El-Zein, A., & Thomas, J. (2022). A review of rural and peri-urban sanitation infrastructure in South-East Asia and the Western Pacific: Highlighting regional inequalities and limited data. *International Journal of Hygiene and Environmental Health*, 244, 113992.
- National Environment Management Authority (NEMA). (2006). Environmental Management and Coordination (Water Quality) Regulations, 2006. <https://www.nema.go.ke/>
- National Environment Management Authority (NEMA). (2019). Polluters of Nairobi River prosecuted. Retrieved 20th November from
- Ng'ang'a, D., & Mbataru, P. (2022). Effectiveness of devolution on sustainability of water supply in Kenya: A case of Athi Water Works Development Agency. *International Academic Journal of Arts and Humanities*, 1(3), 57-84. https://mail.iajournals.org/articles/iajah_v1_i3_57_84.pdf

- Ngatia, M., Kithiia, S. M., & Voda, M. (2023). Effects of anthropogenic activities on water quality within Ngong River Sub-Catchment, Nairobi, Kenya. *Water*, 15(4), 660. <https://doi.org/10.3390/w15040660>
- Nguyen, H. N., Visvanathan, C., & Jegatheesan, V. (n.d.). Performance evaluation of septic tanks as onsite sanitation system. Asian Institute of Technology & James Cook University. <https://www.fsmttoolbox.com/assets/pdf/204.pdf>
- Nicholas, H., Winrow, E., Devine, A., Robertson, I., & Mabbett, I. (2023). Faecal sludge pyrolysis as a circular economic approach to waste management and nutrient recovery. *Environment, Development and Sustainability*, 1-32.
- Nyika, J., & Dinka, M. O. (2025). Challenges Facing Wastewater Management in SSA. In *The Silent Wastewater Problem in Sub-Saharan Africa* (pp. 67-80). Springer, Cham.
- Nyika, J., & Dinka, M. O. (2025). *The Silent Wastewater Problem in Sub-Saharan Africa*. Springer. https://link.springer.com/chapter/10.1007/978-3-031-90143-0_4
- Öberg, G., Metson, G. S., Kuwayama, Y., & A. Conrad, S. (2020). Conventional sewer systems are too time-consuming, costly and inflexible to meet the challenges of the 21st century. *Sustainability*, 12(16), 6518.
- Obiewa, J. O. (2024). Investigation of Pollution Loading on Sosiani River in the Eldoret City [Master's thesis, University of Nairobi]. <https://erepository.uonbi.ac.ke/handle/11295/167682>
- Obradović, D., Šperac, M., & Marenjak, S. (2023). Challenges in sewer system maintenance. *Encyclopedia*, 3(1), 122-142.
- Ochiba, N., Abong'o, D., & Onyatta, J. (2021). The Assessment of The Effect of Proximity of Septic Tanks on The Levels of Selected Heavy Metals in Borehole Water from Ongata Rongai, Kajiado County, Kenya.

- Odeya, L. (2023). An Analysis of Sanitation in the Lake Victoria Basin in Kenya (Lake Victoria Basin Lake-wide Inclusive Sanitation (LWIS), Issue.
- Okoth, O. S., Ronoh, J. K., Dubois, A., & Mbalo, D. (2017). Scaling up Faecal Sludge Management in Kenya's Urban Areas FSM Innovation, Stockholm.
- Omina, O. L., Tao, W., Feng, W., & Kipkirui, E. (2022). Inaccessible and unaffordable? The state of water and sanitation services in Nairobi, Kenya. *International Journal of Environment and Ecology*, 4(1). <https://www.ijee.latticescipub.com/wp-content/uploads/papers/v4i1/A185204010524.pdf>
- Omohwovo, E. J. (2024). Wastewater management in Africa: challenges and recommendations. *Environmental Health Insights*, 18, 11786302241289681.
- Onyango, J., Kitaka, N., van Bruggen, J. J. A., & Irvine, K. (2024). Agricultural intensification in Lake Naivasha Catchment in Kenya and associated nutrients and pesticides pollution. *Scientific Reports*, 14, 1021. <https://doi.org/10.1038/s41598-024-67460-5>
- Othoo, C. (2021). The impact of climate extremes (floods) on sanitation infrastructure in unplanned settlements in Kisumu City, Kenya. ResearchGate. Retrieved from https://www.researchgate.net/profile/Calvince-Othoo-2/publication/379696849_The_Impact_of_Climate_Extremes_floods_on_sanitation_infrastructure_in_unplanned_settlements_in_Kisumu_City_Kenya/links/661641cf39e7641c0ba887a7/The-Impact-of-Climate-Extremes-floods-on-sanitation-infrastructure-in-unplanned-settlements-in-Kisumu-City-Kenya.
- Otieno, J. O., Obosi, J. O., & Magutu, J. M. (2023). The Effects of Coordination in Multilevel Governance System on Water Services Management in Kenya. *Journal of Public Administration and Governance*, 13(2), 3656-3656.
- Padhi, S. K. (2017). Shit Flow Diagram. www.sfd.susana.org

- 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.
- Panesar, A., Walther, D., Kauter-Eby, T., Bieker, S., Rohilla, S., Dube, R., Augustin, K., & 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.
- Patwa, A., Kumar, A., & Vijay, R. (2024). Critical review on on-site sanitation technologies: Typologies, treatment and transition towards circular economy. *Bioresource Technology*, 131954.
- Peal, A., Evans, B., Ahilan, S., Ban, R., Blackett, I., Hawkins, P., Schoebitz, L., Scott, R., Sleigh, A., & Strande, L. (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. C., Hawkins, P. M., & Heymans, C. (2014b). Fecal sludge management (FSM): analytical tools for assessing FSM in cities. *Journal of Water Sanitation and Hygiene for Development*, 4, 371-383.
- Peal, A., Evans, B., Blackett, I., Hawkins, P., & Heymans, C. (2014a). Fecal sludge management: A comparative analysis of 12 cities. *Journal of Water, Sanitation and Hygiene for Development*, 4, 563-575. <https://doi.org/10.2166/washdev.2014.026>
- Peletz, R., MacLeod, C., Kones, J., Samuel, E., Easthope-Frazer, A., Delaire, C., & Khush, R. (2020). When pits fill up: Supply and demand for safe pit-emptying services in Kisumu, Kenya. *PLoS One*, 15(9), e0238003.
- Rodrigues Mesquita, T. C., Pereira Rosa, A., de Oliveira Santos, T. F., Carraro Borges, A., Calijuri, M. L., & de Paula Souza, F. M. (2021). Decentralized management of sewage using septic tanks and anaerobic filters and its potential to comply with

- required standards in a developing country: a case study in Brazil. *Environmental Science and Pollution Research*, 28(36), 50001-50016.
- Safi, F., Furlong, C., Luthra, B., Rohilla, S., & Brdjanovic, D. (2022). Monitoring Progress in Citywide Sanitation. *Frontiers in Environmental Science*, 9. <https://doi.org/10.3389/fenvs.2021.751534>
- Sankara Narayan, A. (2022). Planning citywide inclusive sanitation (Doctoral dissertation, ETH Zurich).
- Satterthwaite, D. (2016). Missing the Millennium Development Goal targets for water and sanitation in urban areas. *Environment and Urbanization*, 28. <https://doi.org/10.1177/0956247816628435>
- Satterthwaite, D. (2017). The impact of urban development on risk in sub-Saharan Africa's cities with a focus on small and intermediate urban centres. *International Journal of Disaster Risk Reduction*, 26, 16–23. <https://doi.org/10.1016/j.ijdr.2017.09.025>
- Saxena, S., & Den, W. (2022). In situ treatment technologies for pit latrines to mitigate groundwater contamination by fecal pathogens: a review of recent technical advances. *Journal of Water, Sanitation and Hygiene for Development*, 12(1), 102-115.
- Schellenberg, T., Subramanian, V., Ganeshan, G., Tompkins, D., & Pradeep, R. (2020). Wastewater discharge standards in the evolving context of urban sustainability—The case of India. *Frontiers in Environmental Science*, 8, 30.
- Schrecongost, A., Pedi, D., Rosenboom, J. W., Shrestha, R., & Ban, R. (2020). Citywide inclusive sanitation: A public service approach for reaching the urban sanitation SDGs. *Frontiers in Environmental Science*, 8, 19. <https://doi.org/10.3389/fenvs.2020.00019>

- SFD-PI (2018). SFD Manual, Volumes 1 and 2, Version 2.0. Available online at: <https://sfd.susana.org/knowledge/the-sfd-manual> (accessed June 25, 2025)
- SFD-PI. (2018a). <https://sfd.susana.org/knowledge/how-to-make-a-sfd>
- SFD-PI. (2018b). SFD Manual Volume 1 and 2. <https://sfd.susana.org/news-events/news/96-sfd-manual-volume-1-and-2-version-2-0>
- Sharada Prasad C. S. & Ray I. 2019 When the pits fill up: (in)visible flows of waste in urban India. *Journal of Water Sanitation and Hygiene for Development* 9 (2), 338–347. <https://doi.org/10.2166/washdev.2019.153>.
- Simiyu, S., Chumo, I., & Mberu, B. (2021). Fecal sludge management in low-income settlements: Case study of Nakuru, Kenya. *Frontiers in Public Health*, 9, 750309. <https://doi.org/10.3389/fpubh.2021.750309>
- Simiyu, S., Chumo, I., & Mberu, B. (2021). Fecal sludge management in low income settlements: case study of nakuru, kenya. *Frontiers in Public Health*, 9, 750309.
- Simwambi, A., Kapembwa, M. A., & Kapanda, K. (2023). Effects of Poor Solid Waste Management on Faecal Sludge Emptying, Treatment and Disposal Services in Lusaka. *European Journal of Applied Sciences–Vol*, 11(4). <http://dx.doi.org/10.14738/aivp.114.15405>
- Singh, S., Laker, F., Bateganya, N. L., Nkurunziza, A. G., Semiyaga, S., & Brdjanovic, D. (2022). Evaluation of business models for fecal sludge emptying and transport in informal settlements of Kampala, Uganda. *Water*, 14(18), 2914.
- Sinharoy, S. S., Pittluck, R., & Clasen, T. (2019). Review of drivers and barriers of water and sanitation policies for urban informal settlements in low-income and middle-income countries. *Utilities Policy*, 60, 100957. <https://doi.org/10.1016/j.jup.2019.100957>

- Smarzewska, S., & Morawska, K. (2021). Wastewater treatment technologies. In Handbook of advanced approaches towards pollution prevention and control (pp. 3-32). Elsevier.
- SNV Netherlands Development Organisation. (2018). Kericho County sanitation situational analysis and inventory report. https://www.snv.org/assets/downloads/f/191310/21626136e0/180008_snv_kericho_county_report_lr.pdf
- SNV-Kenya. (2018). Understanding the Effects of Poor Sanitation on Public Health, the Environment and Well-being
- Soe, K. T. (2024). A Study on Knowledge and Practice of Personal Hygiene and Sanitation of Slum Dwellers (Case Study in Dagon Seik Kan Township)(Kyi Thar Soe, 2024) (Doctoral dissertation, MERAL Portal).
- Sood, B., Lokhande, S., Krishnankutty, M., & Kalbar, P. P. (2023). Economic Assessment of Centralized and Decentralized Sewerage Network Systems: A Case Study of Ludhiana, India. *Journal of Urban Planning and Development*, 149(3), 05023016.
- Spuhler, D., & Lüthi, C. (2020). Review of frameworks and tools for urban strategic sanitation planning: Considering technology innovations and sustainability. *Journal of Water, Sanitation and Hygiene for Development*, 10(4), 768–785. <https://doi.org/10.2166/washdev.2020.062>
- Ssemugabo, C., Wafula, S. T., Lubega, G. B., Ndejjo, R., Osuret, J., Halage, A. A., & Musoke, D. (2020). Status of household solid waste management and associated factors in a slum community in Kampala, Uganda. *Journal of Environmental and Public Health*, 2020.

- Strande, L., Englund, M., Andriessen, N., Carbajal, J. P., Scheidegger, A., Velkushanova, K., Ronteltap, M., Koottatep, T., & Brdjanovic, D. (2021). Estimating quantities and qualities (Q&Q) of faecal sludge at community to citywide scales. *Methods for Faecal Sludge Analysis*.
- Strande, L., Ronteltap, M., & Brdjanovic, D. (2014). *Faecal Sludge Management Systems Approach for Implementation and Operation* (M. R. Linda Strande, Damir Brdjanovic, Ed.). IWA Publishing.
- Sürücü, L., & Maslakçi, A. (2021). Kapsayıcı Liderlik Ölçeğinin Türkçeye Uyarlanması: Geçerlik Ve Güvenirlik Çalışması. *Doğuş Üniversitesi Dergisi*, 22(2), 201-215.
- SuSanA, S. S. A. (2023). SFD Promotion Initiative website. <https://sfd.susana.org/about/worldwide-projects>
- SuSanA. (2022). SFD Data. Retrieved 19th September, 2022 from <https://sfd.susana.org/about/sfd-data>
- SuSanA. (2023). Shit Flow Diagram (SFD) Reports. Sustainable Sanitation Alliance. <https://sfd.susana.org>
- Tabassum, S. (2024). An Investigation into the Efficacy of Septic Tank Systems in Removing Organics in a Subtropical Climate. *SVU-International Journal of Engineering Sciences and Applications*, 5(1), 125-135.
- Tang, T., See, L., Wada, Y., & Hofstra, N. (2022). Accelerating progress towards universal water sanitation and hygiene (WASH): Governance, technology, and data for urban settings. *Environment and Planning B: Urban Analytics and City Science*, 50(1), 21–38. <https://doi.org/10.1177/23998083221128959>
- Tariq, A., & Mushtaq, A. (2023). Untreated wastewater reasons and causes: A review of most affected areas and cities. *Int. J. Chem. Biochem. Sci*, 23(1), 121-143.

- Tay, D. A., & Ocansey, R. T. A. (2022). Impact of urbanization on health and well-being in Ghana: A rapid review. *Frontiers in Public Health*, 10, 877920. <https://doi.org/10.3389/fpubh.2022.877920>
- Tidwell, J. B., Chipungu, J., Chilengi, R., & Aunger, R. (2018). Assessing peri-urban sanitation quality using a theoretically derived composite measure in Lusaka, Zambia. *Journal of Water, Sanitation and Hygiene for Development*, 8(4), 668-678.
- Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrügg, C. (2014). *Compendium of Sanitation Systems and Technologies*.
- Tomoi, H., Ingumba, B. B., Simiyu, S., & Otteng, E. (2025). Barriers and enablers for group-based manual emptying services for onsite sanitation facilities in Nairobi, Kenya: A qualitative study. *International Journal of Hygiene and Environmental Health*. <https://doi.org/10.1016/j.ijheh.2025.114230>
- Tomoi, H., Ingumba, B. B., Simiyu, S., Ross, I., Braun, L., Moriyasu, T., & Cumming, O. (2024). Willingness-to-pay and costs for novel manual emptying services for onsite sanitation facilities in an informal settlement of Nairobi, Kenya.
- Tomoi, H., MacLeod, C., Moriyasu, T., Simiyu, S., Ross, I., Cumming, O., & Braun, L. (2023). Willingness to pay for faecal sludge management services-a scoping review.
- Too, J. K. (2023). Occurrence of Thermotolerant Escherichia Coli and Associated Risk Factors with Contamination of Source and Household Drinking Water in Kericho District, Kenya [Master's thesis, KEMRI]. <http://repository.kemri.go.ke:8080/xmlui/handle/123456789/313>
- U.S. Environmental Protection Agency. (2024, September 17). How to care for your septic system. <https://www.epa.gov/septic/how-care-your-septic-system>

- UN-Habitat. (2022). World cities report 2022: Envisioning the future of cities. United Nations Human Settlements Programme.
https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf
- UN-Habitat. (2023). Water for climate resilience: Urban water resilience for sustainable development. United Nations Human Settlements Programme (UN-Habitat).
https://unhabitat.org/sites/default/files/2023/06/water_report_web.pdf
- USAID. (2021). Kenya Water, Sanitation and Hygiene (WASH) Accounts III. Utafiti wa Afya.
https://utafitiwafya.or.ke/2406_1701690654_Publication_WASH_ACCOUNTS.pdf
- van Puijenbroek, P. J. T. M. (2023). SANITATION AND WASTEWATER TREATMENT SCENARIOS AND EFFECTS ON GLOBAL WATER QUALITY AND SDG 6.
- Velkushanova, K., Brdjanovic, D., Koottatep, T., Strande, L., Buckley, C., & Ronteltap, M. (2021). Methods for faecal sludge analysis. IWA publishing.
- Verma, R., Sengupta, S., & Anand, S. (2020). Toolkit: Managing faecal sludge in rural areas. New Delhi: Centre for Science and Environment.
- Vicario, E. F., Annis, J., Namakula, P., Kasozi, G. K., & Mihelcic, J. R. (2023). Do Sanitation Marketing Activities Increase Households' Likelihoods of Reaching Improved Sanitation or Involving Women in Decision Making?. *Environmental Science & Technology*, 57(44), 16851-16861.
- Vu, T. T. N. (2021). Understanding validity and reliability from qualitative and quantitative research traditions. *VNU Journal of Foreign Studies*, 37(3).
- Waine, T., Bari, N., Sultana, M. S., & Tyrrel, S. (2025). Sanitation Infrastructure and Faecal Flow–SanIFFlow: A Spatial Mapping Tool for Integrated Planning and

- Management of Sanitation in Unsewered Urban Areas. *Geomatica*.
<https://www.sciencedirect.com/science/article/pii/S1195103625000138>
- WASREB. (2022). A Performance Report of Kenya's Water Services Sector – 2020/21.
Nairobi
- Water and Sanitation for the Urban Poor (WSUP). (2017). SFD Report: Kampala,
Uganda. Retrieved from <https://sfd.susana.org>
- Water and Sanitation for the Urban Poor, W. (2017). Using the Excreta Flow Diagram
to Improve Sanitation in Urban Communities: Experiences from Bangladesh, Ghana,
and Uganda.
- WaterAid. (2020). Functionality of wastewater treatment plants in low- and middle-
income countries: Desk review.
https://washmatters.wateraid.org/sites/g/files/jkxoof256/files/functionality-of-wastewater-treatment-plants-in-low--and-middle-income-countries-desk-review_1
- WHO/UNICEF. (2017). Progress on Drinking Water, Sanitation and Hygiene: 2017
Update and SDG Baselines.
- WHO/UNICEF. (2017b). Progress on Drinking Water, Sanitation and Hygiene: 2017
Update and SDG Baselines.
- Willie, M. M. (2024). Population and target population in research methodology. *Golden Ratio of Social Science and Education*, 4(1), 75-79.
- World Health Organization (WHO) & United Nations Children's Fund (UNICEF).
(2021). Progress on household drinking water, sanitation and hygiene 2000–2020:
Five years into the SDGs. <https://washdata.org/reports>
- World Health Organization (WHO) & United Nations Children's Fund (UNICEF).
(2017). Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and

SDG Baselines. Geneva: WHO. Retrieved from
https://www.who.int/water_sanitation_health/publications/jmp-2017/en/

World Health Organization. (2019). Guidelines for safe recreational water environments: Volume 1 – Coastal and fresh waters (2nd ed.).
<https://www.who.int/publications/i/item/9789240020472>

World Health Organization. (2021). Progress on household drinking water, sanitation and hygiene 2000–2020: Five years into the SDGs.
<https://www.who.int/publications/i/item/9789240030848>

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

APPENDICES

Appendix A: Consent form

Title of the Study:

Assessment of Sanitation Technologies and Excreta Management in Kericho Town, Kenya

Introduction

You are invited to take part in a research study. It is important that you know why the research is being done and what your involvement is going to be prior to making your decision to take part. Please take time to read the following information carefully and ask questions if anything is unclear.

Purpose and Procedures of the Study

The purpose of this study to assess sanitation technologies, faecal sludge management and safety of excreta disposal along the sanitation chain of Kericho Town, to provide evidence-based recommendations for improvements to public health, environmental safety and service delivery. If you agree to participate in this study, we will invite you to respond to a structured set of questions in a face-to-face interview. This will take approximately 30-45 minutes. Please note that notes or voice recording may be taken with your consent, as I will want to ensure as accurate documentation as possible.

Voluntary Participation and confidentiality

Your participation in this study is completely voluntary. You can refuse to participate in any part of the study and can withdraw at any time without providing a reason and without any consequence. Refusing to participate or withdrawing will not affect your access to any services or entitlements. With respect to confidentiality, any information you provide will remain confidential and no names will be used with the data collected in this study. The data collected will be treated in anonymous form and will only be used for academic purposes. No names or identifying references will be included in either published or unpublished data.

Risks and Benefits

No significant risks are expected from participating in this study. Although you will not receive any personal benefit, you will help develop better sanitation policies and interventions in Kericho and beyond.

Compensation

No financial compensation will be provided for participating in the study. However, your contributions will be recognized and highly valued through community development services.

Consent Statement

I have read the information above and have had a chance to ask any questions I might have. I understand that my participation is voluntary, that I may withdraw at any time without explanation of any penalty, and that I give my informed consent to participate in the research study.

Participant's Name: _____

Signature: _____

Date: _____

Appendix B: Household survey questionnaire

Tick in the box or fill where appropriate.

Section A: Households Membership.

1. Please indicate your gender: Male, Female, or NA.
2. Which sublocation does your household belong to?
3. What is the highest level of education completed by the person in charge of the household?
 - No Education
 - Primary Education
 - Secondary Education
 - Tertiary Education
4. Have any children under the age of five in the household experienced diarrhoea (three or more watery stools in 24 hours) in the past two weeks (14 days)?
 - Yes
 - No
5. Have you sought advice or treatment from any source for any cases of diarrhoea among children within the past week?
 - Yes
 - No

Section B: Households Features.

1. What is the ownership status of this house/residence for a member of the household?
 - Owned
 - Rented
 - Rent-free
 - Mortgaged
 - Other (Please specify)
2. If the residence is rented, what is the monthly rental cost?

Section C: - Use of water and sanitation infrastructure

1. What is the primary source of drinking water for your household members?
 - Water piped into the dwelling
 - Water piped to the yard/plot
 - Public tap/standpipe
 - Tube well/borehole
 - Protected dug well
 - Unprotected dug well
 - Protected spring
 - Unprotected spring
 - Rainwater collection
 - Bottled water/gallon container and dispenser
 - Refilled bottled water
 - Cart with small tank/drum m) Tanker-truck
 - Surface water (river, dam, lake, pond, stream, canal, irrigation channels)
 - Others, please specify
2. On average, how much time does it take for you to travel to this water source?

3. On average, how much time does you or a household member have to wait in the queue to access water?
4. What type of toilet facility do members of your household typically use?
 - Automatic cistern flush
 - Pour/manual flush
 - Ventilated improved pit latrine
 - Pit latrine with slab
 - Composting toilet
 - Bucket or hanging toilet
 - Container-based toilet
 - No facilities or using bush or field
 - Others, please specify
5. Where does the waste from this toilet facility discharge to?
 - Piped sewer system
 - Fully-lined septic tank with soakaway
 - Fully-lined septic tank with overflow to drain/open ground/other
 - Partially-lined septic tank
 - Fully-lined pit
 - Pit with unlined bottom or sides
 - Directly to an open drain/ditch
 - Directly to the lake or river
 - Directly to open ground
 - Don't know
 - Others, please specify
6. At home, how do you dispose of wastewater from kitchen, bathing, and/or laundry?
 - Piped sewer system
 - Fully-lined septic tank with soakaway
 - Fully-lined septic tank with overflow to drain/open ground/other
 - Partially-lined septic tank
 - Fully-lined pit
 - Pit with unlined bottom or sides
 - Directly to an open drain/ditch
 - Directly to the lake or river
 - Directly to open ground
 - Don't know
 - Others, please specify
7. At home, how do you dispose of wastewater from kitchen, bathing, and/or laundry?
 - Piped sewer system
 - Fully-lined septic tank with soakaway
 - Fully-lined septic tank with overflow to drain/open ground/other
 - Partially-lined septic tank
 - Fully-lined pit
 - Pit with unlined bottom or sides
 - Directly to an open drain/ditch
 - Directly to the lake or river
 - Directly to open ground

- Don't know
 - Others, please specify
8. How are the stools of children under the age of 3 usually disposed of?
- Child used toilet/latrine
 - Put/rinsed into toilet or latrine
 - Put/rinsed into drain or ditch
 - Thrown into garbage
 - Buried
 - Left in the open
 - Others, please specify
 - No child under 3
 - Don't know

Section D: - Use of toilet

1. Regarding the toilet you mentioned earlier, do you share it with other households?
 - Yes
 - No
 - Open defecation
2. How many other households share this toilet?
3. How many people regularly use this toilet?
4. Can any member of the public use this toilet?
5. Where is this toilet located?
 - Inside
 - Outside
6. Do you have to pay to use this toilet?
 - No
 - Yes, pay per use (public)
 - Yes, weekly payment
 - Yes, monthly payment
 - Others, please specify
7. How much do you pay to use the toilet?
8. On average, how long does it take to use the toilet (including walking there, waiting in the queue, using it, and returning)?
9. How many times do you use this toilet per day?
10. Who manages this toilet?
 - This household
 - Neighbour
 - Landlord
 - NGO/CBO
 - Private provider
 - Government
 - Nobody in charge
 - Others, please specify
 - Don't know
11. Categorize the toilet into one of the following:
 - On plot (shared or private)
 - Off plot (communal or public)
12. Is the toilet currently operational/useable?
 - Yes
 - No

13. If the toilet is not operational/useable, why?
- Full/waiting to be emptied
 - Collapsed (fully or partially)
 - Blocked
 - Other
 - Don't know
14. May I see this toilet?
- Yes
 - No
15. If no, please answer the following question instead of observations. Is the toilet operational/useable?
- Yes
 - No
16. Does the toilet have a water seal?
- Yes
 - No
17. Does the toilet have a cleanable slab?
- Yes
 - No
18. What is the material of the superstructure?
- Brick or other permanent material
 - Wood/bamboo/cloth or other semi-permanent material
 - No superstructure
19. Does the toilet have a roof?
- Yes
 - No
20. Does the toilet have a curtain, door, or other materials that provide privacy? (objective 1)
- Yes
 - No
21. Is the floor or slab contaminated with faeces or urine? (objective 1)
- Faeces or faeces and urine
 - Urine only
 - No faeces and no urine
22. Can emptying equipment access the toilet?
- Poor access, only accessible to hand-carried emptying equipment
 - Reasonable access for small (manual or mechanized) emptying equipment
 - Good access for medium/large size (mechanized) emptying equipment
23. Is there an access point/hatch for emptying?
- Yes, purpose-built hatch for easy access
 - Yes, but squatting, plate must be removed
 - No, slab must be broken for access
24. Has the pit been sealed and covered?
- Yes
 - No
 - Don't know

Section E: - Satisfaction and planning

1. Please rate your satisfaction level with the quality of construction?

	Very Satisfied,	Satisfied,	Dissatisfied	Very Dissatisfied
Construction Quality				
Accessibility				
convenience				
Privacy				
Cleanliness				

Section F: Emptying.

1. Who is currently responding?
 - Same respondent
 - Neighbour
 - Landlord,
 - Caretaker of building
 - Other
2. If this toilet empties into a pit or septic tank, has it ever reached its capacity?
 - No
 - Don't know
3. In the last 5 years, how many times has it reached its capacity?
4. Has the toilet ever overflowed?
 - Yes
 - No
 - Don't know
5. If yes, what was the reason for the overflow? (Please circle all that apply)
 - Blocked
 - Flooded with rising water table (from below ground)
 - Flooded by surface water/storm water (from above ground)
 - No money to empty
 - Emptiers not available when needed
 - Other
 - Don't know
6. What action did you take when the pit or septic tank reached its capacity the last time?
 - Emptied and reused pit/tank
 - Abandoned and pit/tank unsealed
 - Abandoned with sealed cover on pit/tank
 - Covered and used alternative pit
 - Other
 - Don't know
7. On average, how many years does it take for an emptied toilet to reach its capacity again?
8. What is your intended course of action when the toilet reaches its capacity next time?
 - Empty by member of household
 - Empty by private individual or company
 - Cover and seal pit
 - Abandon toilet without covering/seal
9. Last time it was emptied, who did the emptying?

- Member of household Neighbour
 - Informal provider (individual)
 - Formal provider (company / NGO)
 - Formal provider (utility)
 - Other
10. How was it emptied? By hand, using buckets or similar
- By hand, using manual pump
 - Mechanically, using small machine
 - Mechanically, using tanker truck
11. Where was it emptied into?
- directly into drain/water body/field
 - into a pit on the compound that is then covered
 - Into a pit on the compound that is then left open
 - Directly into drum/open container
 - Directly into machine/ tanker
12. Please rate your satisfaction level with that service provider in terms of :.
- | | | | | |
|---------------------------------|--------------------|------------|------------------|----------------------|
| | Very
Satisfied, | Satisfied, | Dissatisfi
ed | Very
Dissatisfied |
| Price | | | | |
| Overall
service
quality | | | | |
| Safety | | | | |
| Ease of
obtaining
service | | | | |
13. Did you pay for the pit to be emptied?
- Yes
 - No
 - Don't know
14. How much did you pay in total?
15. How was the payment calculated?
- Flat rate
 - Cost per volume removed
16. Did you pay in instalments?
- No, paid in full amount
 - Yes, two
 - Yes, three
 - Yes, more than three
17. Was this a fair price?
- Too high
 - About fair
 - Quite cheap
18. Did the emptier face difficulties in getting their equipment to your toilet, such as lack of space, poor road conditions, etc?
- Yes
 - No
 - Don't know

19. What difficulties did they face? (circle all that apply)

Reason

Street

- Lack of space
- Poor Road conditions
- Night-time working
- Others

compound

- Entrance/gate too narrow
- Lack of space for equipment once inside
- Poor surface conditions
- Night-time working Others

toilet

- Distance too far for equipment to reach the toilet
- Access point too small to get equipment into the pit
- Had to break/dam age the slab to gain access
- Had to remove/ damaged latrine pan or seat
- Collapsed pit
- Others

Appendix C: Interview Guide

Introduction Section

Purpose: Begin the interview with an introduction to build rapport, explain the purpose of the study, and ensure informed consent.

Part A; KEWASCO Technical Manager

1. Can you describe the sanitation systems currently in place in Kericho Town, including the role of KEWASCO in managing water and sanitation services?
2. What is the scope of KEWASCO's responsibility in sanitation management, particularly in terms of wastewater treatment and faecal sludge management?
3. Can you provide more details on the specific operational challenges at the WWTP?
4. What are some of the key barriers KEWASCO faces in managing the growing sanitation demands of Kericho Town, especially as the town's population grows?
5. How would you evaluate the current capacity of the WWTP and other treatment facilities in Kericho? Do they meet the current demand?
6. From your perspective, how well-equipped are the existing facilities and infrastructure to handle future population growth in Kericho?
7. What are the main challenges associated with faecal sludge management in the town? How does KEWASCO address these challenges?
8. What is the role of KEWASCO's vacuum truck operators, and how efficient is the current sludge transport system in Kericho?
9. Can you describe the role of KEWASCO in enforcing sanitation policies and regulations within the town? Are there specific challenges in aligning local governance with national sanitation policies?
10. What is the role of private companies or non-governmental organizations (NGOs) in supporting sanitation services in Kericho?
11. What are the key infrastructure improvements that you believe are needed to enhance sanitation service delivery in Kericho?
12. As the town continues to grow, what steps is KEWASCO planning to ensure that sanitation systems will be able to handle increased demand? Are there any new projects in the pipeline to address these concerns?
13. Do you have any additional insights or recommendations for improving sanitation management in Kericho?

Part B: Wastewater Treatment Plant (WWTP) Inspector.

1. Can you describe the current operations of the WWTP in Kericho Town, including its capacity and main functions?
2. What types of wastewaters does the WWTP primarily treat? (e.g., domestic wastewater, industrial waste, faecal sludge, etc.)
3. Can you elaborate on the specific technical and operational difficulties currently experienced at the WWTP?
4. What are the most pressing issues related to equipment, maintenance, or infrastructure at the plant?

5. Are there any seasonal or capacity-related issues that affect the efficiency of the WWTP?
6. How would you evaluate the effectiveness of the WWTP in treating wastewater to meet the national water quality standards?
7. From your perspective, is the current plant capacity sufficient to meet the needs of Kericho's growing population? If not, what improvements or expansions are needed?
8. How does the WWTP handle faecal sludge, and what processes are in place to treat this waste?
9. Are there any specific challenges related to faecal sludge treatment at the WWTP, and how does the plant address these challenges?
10. Once faecal sludge is treated at the WWTP, what happens to the treated sludge? Is it reused, disposed of, or treated further?
11. What proportion of the faecal sludge from Kericho is safely treated at the WWTP compared to the amount that is not?
12. How does the public perceive the WWTP and its role in improving sanitation? Are there efforts to engage the community in wastewater treatment and sanitation awareness?
13. In your opinion, what infrastructure improvements are urgently needed to enhance the WWTP's efficiency and capacity?
14. Do you have any additional insights or recommendations for improving wastewater treatment and sanitation management in Kericho?

Part C: Kapsoit Decentralized Treatment Facility (DTF) Inspector.

1. Can you describe the role and functions of the Kapsoit Decentralized Treatment Facility (DTF) in managing faecal sludge in Kericho Town?
2. What types of waste does the DTF primarily treat? Is it exclusively faecal sludge, or does it handle other types of waste as well?
3. What are the primary operational challenges faced by the DTF?
4. How would you assess the efficiency of the DTF in treating faecal sludge? Are there any capacity constraints or technical challenges?
5. Could you clarify its daily treatment capacity and whether it is sufficient to meet the current demand?
6. What measures are being taken to expand or improve the capacity of the DTF to handle future increases in faecal sludge due to urban growth?
7. How does the Kapsoit DTF treat faecal sludge? Could you walk us through the process from intake to final treatment?
8. Are there any specific challenges in handling faecal sludge from different sources (e.g., pit latrines, septic tanks, etc.)?
9. What happens to the treated faecal sludge at the DTF? Is it disposed of safely, or is it reused in some way (e.g., for agriculture, energy generation, etc.)?
10. How much of the faecal sludge entering the DTF is safely treated and safely managed compared to the amount that is untreated?

11. Are there any gaps in coordination or communication between the DTF and other sanitation service providers in Kericho?
12. In your opinion, what infrastructure improvements are needed at the DTF to enhance its capacity and efficiency in treating faecal sludge?
13. Should the focus be on expanding the existing decentralized treatment system, or is there a need for additional treatment options in other parts of Kericho?

PART D: Vacuum Truck Operators (VTOs)

1. Can you describe your role as a vacuum truck operator (VTO) in Kericho? What types of faecal sludge or wastewater do you typically collect?
2. What are the most common types of containment systems (e.g., pit latrines, septic tanks) you empty, and how do you handle them during the process?
3. What are the main operational challenges you face during the emptying process (e.g., narrow roads, lack of equipment, time constraints)?
4. Do you encounter any specific problems with the vacuum trucks (e.g., breakdowns, insufficient capacity, lack of maintenance)?
5. Are there any communication gaps or challenges when working with local authorities or other service providers in the sanitation sector?
6. After emptying the faecal sludge, where is it transported to? Do you follow a set route to the treatment facilities (e.g., WWTP or DTF)?
7. Are there any challenges you face while transporting faecal sludge to treatment plants (e.g., road conditions, traffic, delays)?
8. What safety measures are in place to ensure the proper handling of faecal sludge during emptying and transportation?
9. Are you provided with adequate personal protective equipment (PPE), and do you face any challenges related to safety during the operation?
10. Are there any changes in policy or regulations that you believe would improve the overall faecal sludge management system in Kericho?
11. Do you have any additional insights or recommendations for improving the faecal sludge emptying and transport system in Kericho?

Appendix D: Transect Walk Observation Guide

The following shall be observed

1. Geographical Location
2. Economic status of the area: High-income Middle-income Low-income
3. Does the area face the risk of flooding? Yes No
4. Weather conditions on the day:
5. Brief overview of the community: Recent development, primary housing type, residential/commercial, main employment sectors
6. Assess the condition of the drainage system. Greywater refers to domestic wastewater excluding toilet waste and visible faecal matter.
 - a. Insufficient drainage infrastructure. Standing stormwater and/or greywater can be observed on the ground near homes or water sources.
 - b. Inadequate drainage infrastructure, evident from recent overflow of stormwater and/or greywater near homes or water sources.
 - c. Limited drainage infrastructure without signs of overflow near homes or water sources.
 - d. Poorly maintained drainage channels, diverting stormwater and/or greywater away from homes and water sources.
 - e. Well-maintained drainage channels that adequately handle water flow.
7. Provide a brief description of the observed problem.
8. Describe how humans come into contact with the contamination (e.g., washing, playing, walking, scavenging)
9. State the primary routes of contamination (e.g. hands, feet, flies, food, fields, soil).
10. Comment on the individuals or groups exposed to the contamination (e.g., all people, adults only, children only, vulnerable groups).
11. Identify the points where blackwater (wastewater containing toilet waste and visible faecal material) enters the environment.
 - a. Inadequate sewer infrastructure, with visible standing blackwater near homes or water sources.
 - b. Broken sewer pipes near homes or water sources, showing recent overflow.
 - c. Broken sewer pipes near homes or water sources, but without signs of recent overflow.
 - d. Piped sewers with signs of leakage or blockages.
 - e. Well-maintained piped sewers without signs of leakage or blockages.
12. Describe accessibility of water sources.
 - a. No piped water supply to households or public water points identified.
 - b. No piped water supply to households, but water available from public standposts, vendors, private wells, or boreholes.
 - c. Some piped water supply to households or boreholes, with additional water available from public standposts or vendors.
 - d. Intermittent piped water supply to most or all households, with water potentially available from vendors.
 - e. Continuous piped water supply to public standposts, on-plot, or in-house, with water possibly available from vendors.
13. Describe the presence of solid waste.
 - a. Accumulation of solid waste in multiple sites near residential and commercial areas, occasionally obstructing drainage or irrigation channels.

- b. Accumulation of solid waste in three or more sites near residential and commercial areas, without obstructing drainage or irrigation channels.
 - c. Accumulation of solid waste in one or two sites away from residential and commercial areas.
 - d. Provision of waste bins or enclosures, but inadequate in number, leading to overflow.
 - e. Adequate provision of waste bins or enclosures without visible overflow.
 - f. High risk associated with drainage.
14. Describe the presence of human faecal materials through open defecation.
- a. Frequent visible, widespread evidence of human faeces is seen.
 - b. Visible evidence of human faeces is seen but limited to a few locations.
 - c. Occasional evidence of human faeces in places away from the population, possibly mixed with solid waste
 - d. No visible evidence of human faeces through open defecation is seen.
 - e. High risk with drainage
15. Describe if there is any evidence of human faecal materials - through dumped faecal sludge.
- a. Frequent visible and widespread evidence of dumped faecal sludge is seen.
 - b. Visible evidence of dumped faecal sludge is seen but limited to a few locations.
 - c. Dumped faecal sludge is seen one or two times but in places away from the population.
 - d. Possible evidence of faecal sludge is seen, mixed with solid waste.
 - e. No visible evidence of dumped faecal sludge is seen.
16. Describe the coverage of household toilets (individual or shared).
- a. Less than 25% of households have access to a household toilet. The majority (more than 75%) appear to be poorly maintained.
 - b. Between 25% to 75% of households have access to a household toilet. Most (more than 50%) appear to be poorly maintained.
 - c. Between 25% to 75% of households have access to a household toilet. Most (more than 50%) appear to be well maintained.
 - d. More than 75% of households have access to a household toilet. They are in various conditions of maintenance and cleanliness. More than 75% of households have access to a household toilet. Most (more than 75%) appear to be clean and well-maintained.
17. Describe the presence of wastewater and/or faecal sludge treatment facilities inside the area.
- a. Wastewater and/or faecal sludge treatment facilities (e.g., composting of wastes) are present, poorly-maintained and insecure.
 - b. Wastewater and/or faecal sludge treatment facilities are present, poorly maintained, secure but with possible direct risks - such as from overflow.
 - c. Wastewater and/or faecal sludge treatment facilities are present and are well-maintained but with some possible indirect risks - such as from scavenging animals or waste pickers.
 - d. Wastewater and/or faecal sludge treatment facilities are present, and are well-maintained with no evident risks. No wastewater and/or faecal sludge treatment facilities present.
18. Describe housing and public space arrangement.

- a. Less well or poorly organized development, with highly restricted access for public service vehicles and no clearly defined public spaces.
 - b. Less well-organized development, with mostly temporary housing, limited access for public service vehicles and very few clearly defined public spaces.
 - c. Well organized development with semi-permanent and/or temporary properties, limited access for public service vehicles and only a few clearly defined public spaces
 - d. Well organized development with permanent and/or semi-permanent properties but restricted access for public service vehicles and public spaces, including some open spaces.
 - e. Well organized development, with permanent and/or semi-permanent properties, good access for public service vehicles and public spaces, including open spaces.
19. Describe the paths.
- a. Very narrow paths that can be used by pedestrians only (too narrow for motorbikes).
 - b. Poorly maintained dirt paths wide enough for motorbikes. Well-maintained dirt paths wide enough for motorbikes. G
 - c. gravel or paved paths, in poor condition, wide enough for motorbikes.
 - d. Gravel or paved paths, in good condition, wide enough for motorbikes.
20. Describe the roads.
- a. Unsurfaced roads, wide enough for small carts or 3-wheeler, but not for car access/
 - b. Unsurfaced roads wide enough for cars to pass.
 - c. Gravel or paved roads, wide enough for small carts or 3-wheeler, but not for car access.
 - d. Gravel or paved roads, wide enough to allow two cars to pass.
 - e. Well-maintained gravel or paved road, wide enough for two cars to pass.

Appendix F: Research Authorization by Kericho County

REPUBLIC OF KENYA



**COUNTY GOVERNMENT OF KERICHO
OFFICE OF THE GOVERNOR**

P.O. BOX 112 – 20200
KERICHO

E-mail: info@kericho.go.ke

Ref: KEC/CS/WEEF&NR/VOL.V (44)

DATE: 23rd October, 2023

TO WHOM IT MAY CONCERN

Mr. Benard Kipkemoi Kirui
Ministry of Water, Sanitation and Irrigation
P.O. Box 49720-00100
NAIROBI

REF NO: 233992

Dear *Mr. Kirui*;

**RE: AUTHORIZATION TO CARRY OUT ACADEMIC RESEARCH IN KERICHO
COUNTY- MR. BENARD KIPKEMOI KIRUI NACOSTI/P/23/26918**

The above named person has been authorized to carry out academic research at the County Government of Kericho.

His area of study is titled "Evaluation of Excreta Management Across Sanitation Service Chain Using Shit Flow Diagram in Kericho Town, Kenya" for the period ending **30th June, 2024**.

Kindly accord him any necessary assistance.

Yours

Sincerely

3 OCT 2023
P.O. Box 112-20200.
Dr. Wesley Kibon (PhD)
NYA

The County Secretary and Head of County Public Service

Appendix G: Target Population of Kericho Town (KNBS, 2019)

Location	Sub location	Total	Male	Female	Total Households	2023 Projection	Sq. Km	Persons Per Sq. Km	Sample
AINAMOI	1. Kipchिमchim	7,961	3,980	3,981	1,729	1,835	13.2	601	17
KAPSOSA	2. Kapsaos	11,034	5,548	5,486	2,315	2,457	15.8	699	23
KAPSOIT	3. Kapkitony	1,907	963	944	531	564	2.5	773	5
KAPSOIT	4. Kapsoit	3,799	1,944	1,854	956	1,015	3.4	1,106	10
KAPSUSER	5. Kakiptui	2,646	1,331	1,315	626	665	3.6	737	6
KAPSUSER	6. Kapsuser	5,717	2,891	2,826	1,616	1,715	5.8	987	16
KIPCHEBOR	7. Chebcho	3,947	1,970	1,977	1,111	1,180	10.5	376	11
KIPCHEBOR	8. Chepkolon	5,621	2,919	2,702	1,833	1,946	9.6	584	18
KIPKOIYAN	9. Borborwet	8,888	4,506	4,382	2,192	2,327	10.4	855	22
KIPKOIYAN	10. Kipkoiyan	7,695	3,827	3,868	1,747	1,854	13.2	581	17
KIPSOLU	11. Ainapko	7,096	3,500	3,596	1,720	1,826	11	669	17
KIPSOLU	12. Kipsolu,	7,152	3,527	3,625	1,566	1,662	13.5	530	16
TELANET	13. Chepkurbet	4,753	2,363	2,390	1,044	1,108	7.9	599	10
TOWNSHIP	14. Kapkugerwet	17,776	9,026	8,749	5,278	5,602	16.4	1,085	53
TOWNSHIP	15. Motobo	12,840	6,876	5,962	4,323	4,588	5.1	2,511	43
TOWNSHIP	16. Taiywet	7,526	3,911	3,615	2,512	2,666	4.9	1,530	25
TOWNSHIP	17. Township	27,725	14,404	13,319	8,797	9,336	8.2	3,377	87
Total		144,083	73,486	70,591	39,896	42,346	15.5	17,600	396

Appendix H:Shit Flow Diagram Selection Grid

List A: Where does the toilet discharge to? (i.e. what type of containment technology, if any?)	List B: What is the containment technology connected to? (i.e. where does the outlet or overflow discharge to, if anything?)									
	to centralised combined sewer	to centralised foul/separate sewer	to decentralised combined sewer	to decentralised foul/separate sewer	to soakpit	to open drain or storm sewer	to water body	to open ground	to 'don't know where'	no outlet or overflow
No onsite container. Toilet discharges directly to destination given in List B		T1A1C2			Significant risk of GW pollution Low risk of GW pollution	T1A1C5		T1A1C8	T1A1C9	Not Applicable
Septic tank					T2A2C5 T1A2C5			T1A2C8		
Fully lined tank (sealed)					Significant risk of GW pollution Low risk of GW pollution					
Lined tank with impermeable walls and open bottom	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution	Significant risk of GW pollution Low risk of GW pollution					Significant risk of GW pollution Low risk of GW pollution
Lined pit with semi-permeable walls and open bottom	Not Applicable									T2A5C10
Unlined pit										T1A5C10
Pit (all types), never emptied but abandoned when full and covered with soil										T2A5C10
										T1A5C10
Pit (all types), never emptied, abandoned when full but NOT adequately covered with soil										T2B7C10
										T1B7C10
User interface failed, damaged, collapsed or flooded										
Containment (septic tank or tank or pit latrine) failed, damaged, collapsed or flooded										
No toilet. Open defecation	Not Applicable							T1B11 C7 TO C9		Not Applicable

Appendix I: NEMA Standards for Effluent Discharge into The Environment

(r. 11)

THIRD SCHEDULE

STANDARDS FOR EFFLUENT DISCHARGE INTO THE ENVIRONMENT

Parameter	Max Allowable(Limits)
1,1,1-trichloroethane (mg/l)	3
1,1,2-trichloroethane (mg/l)	0.06
1,1-dichloroethylene	0.2
1,2-dichloroethane	0.04
1,3-dichloropropene (mg/l)	0.02
Alkyl Mercury compounds	Nd
Ammonia, ammonium compounds, NO ₂ compounds and NO ₃ compounds (Sum total of ammonia-N times 4 plus nitrate-N and Nitrite-N) (mg/l)	100
Arsenic (mg/l)	0.02
Arsenic and its compounds (mg/l)	0.1
Benzene (mg/l)	0.1
Biochemical Oxygen Demand (BOD 5days at 20 °C) (mg/l)	30
Boron (mg/l)	1.0
Boron and its compounds – non marine (mg/l)	10
Boron and its compounds –marine (mg/l)	30
Cadmium (mg/l)	0.01
Cadmium and its compounds (mg/l)	0.1
Carbon tetrachloride	0.02
Chemical Oxygen Demand (COD) (mg/l)	50
Chromium VI (mg/l)	0.05
Chloride (mg/l)	250
Chlorine free residue	0.10
Chromium total	2
cis -1,2- dichloro ethylene	0.4
Copper (mg/l)	1.0
Dichloromethane (mg/l)	0.2
Dissolved iron (mg/l)	10
Dissolved Manganese(mg/l)	10
E.coli (Counts / 100 ml)	Nil
Fluoride (mg/l)	1.5
Fluoride and its compounds (marine and non-marine) (mg/l)	8
Lead (mg/l)	0.01
Lead and its compounds (mg/l)	0.1
n-Hexane extracts (animal and vegetable fats) (mg/l)	30
n-Hexane extracts (mineral oil) (mg/l)	5
Oil and grease	Nil
Organo-Phosphorus compounds (parathion,methyl parathion,methyl demeton and Ethyl parantrophenyl phenylphosphorothroate, EPN only) (mg/l)	1.0
Polychlorinated biphenyls, PCBs (mg/l)	0.003
pH (Hydrogen ion activity---marine)	5.0-9.0
pH (Hydrogen ion activity--non marine)	6.5-8.5
Phenols (mg/l)	0.001
Selenium (mg/l)	0.01
Selenium and its compounds (mg/l)	0.1
Hexavalent Chromium VI compounds (mg/l)	0.5
Sulphide (mg/l)	0.1
Simazine (mg/l)	0.03
Total Suspended Solids, (mg/l)	30
Tetrachloroethylene (mg/l)	0.1
Thiobencarb (mg/l)	0.1
Temperature (in degrees celious) based on ambient temperature	± 3
Thiram (mg/l)	0.06
Total coliforms (counts /100 ml)	30
Total Cyanogen (mg/l)	Nd
Total Nickel (mg/l)	0.3
Total Dissolved solids (mg/l)	1200
Colour in Hazen Units (H.U)	15
Detergents (mg/l)	Nil
Total mercury (mg/l)	0.005
Trichloroethylene (mg/l)	0.3
Zinc (mg/l)	0.5
Whole effluent toxicity	
Total Phosphorus (mg/l)	2 Guideline value
Total Nitrogen	2 Guideline value

And any other parameters as may be prescribed by the Authority from time to time

Remarks

Standard values are daily/monthly average discharge values. Not detectable (nd) means that the pollution status is below the detectable level by the measurement methods established by the Authority.

Evaluation of Sanitation Technologies Across Sanitation Service Chain in Kericho Town, Kenya

Kirui Bernard^{1*}, Wandili Sarah² and Gachoka Kennedy³

¹Meru University of Science and Technology, School of Engineering and Architecture; Box 972- 60200 Meru

²Meru University of Science and Technology, School of Pure and Applied Sciences; Box 972- 60200 Meru

³Meru University of Science and Technology, School of Pure and Applied Sciences; Box 972- 60200 Meru

Corresponding Author:- Kirui Bernard^{1*}

Abstract:- In 2020, over half of the world's population resided in cities, with projections indicating that by 2050, this figure will rise to 70%. Providing adequate sanitation services in urban and peri-urban areas presents significant challenges due to the dense concentration of people, particularly in low- and middle-income countries. Poor sanitation practices in these areas can lead to the spread of diseases with high morbidity and mortality rates. The focus of the study was on Kericho town, Kenya, facing a notable sanitation challenge due to dilapidated sewer system and inadequate sanitation facilities. The aim of this study was to evaluate the safety of sanitation technologies used in Kericho Town. Descriptive study design was adopted. Data collection methods included surveys, interviews, and observations, with a sample size of 409 households. The findings revealed that 66.5% of the population relies on pit latrines with slabs, 13.69% use pour/manual flush systems, 11.49% have ventilated improved pit latrines, 8.07% employ automatic cistern flush, and a minimal 0.24% practice open defecation. 25% of population discharged waste directly into the sewerage system whereby 5% were considered safely managed. Additionally, 4% of waste from user interfaces was discharged directly into open ground or open drains. 2% of population used septic tanks connected to soak pits, whereas 6% of population used septic tanks connected to open ground. Sludge from septic tanks, comprising 20%, was delivered to the WWTP by exhausters for further treatment, of which only 20% underwent treatment, with the remainder released untreated into the environment. 49% of the population used lined pits, while 14% used unlined pits. Approximately 20% of faecal sludge from the pits was exhausted, with only 20% of it considered safely treated, and the remainder released into the environment. Notably, open defecation accounted for less than 1% based on the survey findings. Consequently, the current trend in faecal sludge management in Kericho Town posed potential health hazards to the community unless measures such as rehabilitating the existing wastewater treatment plant are implemented.

Keywords:- Safely Managed, Sanitation Technologies, Urbanization, Faecal Sludge.

I. INTRODUCTION

Access to adequate sanitation facilities is essential for public health and environmental sustainability, particularly as urbanization accelerated globally. By 2050 it's estimated that 70% of the world's population will be living in cities with majority in urban and peri-urban areas (WB, 2020). With the majority of the population living in urban and peri-urban, there is pronounced challenges in providing adequate sanitation services due to the high concentration of people (Pickford, 2016).

These challenges are particularly significant in low- and middle-income countries (LMICs), where poor sanitation practices can lead to the spread of diseases that have significant morbidity and mortality rates (WHO, 2015). In developing countries, sanitation improvement is usually neglected leading to loss of lives due to water contamination (Okurut *et al.*, 2015). With the Sustainable Development Goal (SDG) 6 emphasizing the provision of adequate and safe sanitation and hygiene for everyone, particularly focusing on the needs of women, girls, and individuals in vulnerable circumstances (UN, 2015), addressing the issue of inadequate sanitation becomes increasingly challenging. Research findings indicate that in urban areas of developing countries, a range of onsite and offsite sanitation technologies and services prevail, originating from various sources such as residents, housing investors, and governmental or mandated utility providers (Evans *et al.*, 2006). However, international targets require more advanced technologies capable of ensuring safely managed sanitation throughout the entire process, from the toilet to the point of disposal or end-use (WHO/UNICEF, 2017). Consequently, discussions surrounding various sanitation approaches, such as citywide inclusive sanitation (CWIS) (Gambrill *et al.*, 2020; Lüthi *et al.*, 2020), remain prominent in the contemporary sanitation sector.

Effluent discharge, the release of treated or untreated wastewater into the environment, poses significant challenges to ecosystem health and human well-being (Muruganandam *et al.*, 2023). To mitigate the adverse effects of effluent discharge, regulatory standards have been developed globally to establish acceptable levels of pollutants in discharged wastewater. The establishment of regulatory frameworks is a crucial step in managing effluent discharge.

Appendix K: Plagiarism Report

